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Review of bycatch in the Gulf menhaden fishery with implications for the stock assessment of red drum

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Abstract

A literature review of bycatch in the US Gulf of Mexico menhaden fishery, the second largest commercial fishery in the continental US by weight, was conducted to determine the potential bycatch of red drum (*Sciaenops ocellatus*) in the fishery. Information regarding bycatch is patchy and sparse, both temporally and spatially, with the majority of studies suggesting a negligible amount of bycatch. In this paper, we review the available literature addressing species composition and magnitude of bycatch in the Gulf menhaden fishery and use this information to generate bycatch estimates for red drum using simplistic assumptions and minimal data. This analysis emphasizes the difficulty in trying to identify whether bycatch is a substantial issue for red drum and how to quantify appropriate estimates in the absence of data. At the very least, this analysis should highlight the possibility of bycatch in the menhaden fishery and the importance of investigating the potential impact on stock dynamics.

Introduction

Gulf menhaden fishery

The Gulf menhaden (*Brevoortia patronus*) reduction fishery is the largest commercial fishery in the Gulf of Mexico (GOM) and the second largest commercial fishery in the US by weight (Geers et al. 2014; NMFS 2010; Vaughan et al. 2007), with an average of 490,000 metric tons removed each year between 2000 and 2011 (Parker and Tyedmers 2012; SEDAR 2013). Harvest of this forage fish comprised nearly 70% of all GOM landings and provided an average of $60 million dollars in landings revenue during this period (NMFS 2010; NMFS 2011). In 2012, Gulf menhaden landings ranked 19th of all global marine capture fisheries (FAO 2014), despite being confined to the GOM. The expansive, near-surface schools of menhaden make these fish relatively easy to target and, due to their high oil content, support up to 97% of US fish oil production and a variety of fish meal products (Alder et al. 2008; Hale et al. 1991).

The Gulf menhaden fishery employs purse-seines to capture individuals during the fishing season between April and October and primarily operates along the coasts of Louisiana and Mississippi (Pulver and Scott-Denton 2012). The fishery exploded following World War II as the

worldwide demand for fish meal and oil increased (Nicholson and Schaaf 1978; SEDAR 2013). The number of menhaden vessels grew from 10 in 1945 to 81 in 1956 and peaked in 1966 at 92 vessels before being reduced to 65 vessels in 1973 (Nicholson and Schaaf 1978). More recently, the fleet has stabilized to between 37 and 40 vessels (SEDAR 2013). Historically, 13 processing plants existed in the GOM, ranging from Apalachicola, FL, to Sabine Pass, TX (Nicholson and Schaaf 1978), although the number of plants stabilized at 11 by the early 1980s (SEDAR 2013; Smith 1991; See Figure 1), remained at 4 until 2013, and reduced to 4 plants in 2014 (Moss Point, Mississippi, Empire, Louisiana (LA), and Abbeville, LA (SEFSC 2015).

The issue of bycatch

The menhaden industry and many researchers have characterized bycatch in the Gulf menhaden fishery as minor in relation to other fisheries, such as the shrimp fishery (Guillory and Hutton 1982). However, emphasis is generally placed on relative bycatch quantities (e.g., <2.5% of total catch) as opposed to absolute biomass, with many earlier studies rendering conclusions based on reported bycatch in terms of percent by number (%N) of organisms (Breuer 1950; Knapp 1950; Miles and Simmons 1950; Simmons 1949). Naturally, the number of other species will be infinitesimal when landed with millions of menhaden (e.g., 5,326,000 menhaden versus 7,589 other fish; Miles and Simmons 1950). A more appropriate metric for gauging the magnitude of bycatch in the menhaden fishery would be to examine the percent by weight (%W) of the catch composition, which has been reported in more recent studies (Condrey 1994; Guillory and Hutton 1982). Although classified as a "small amount of incidental bycatch" by Guillory and Hutton (1982), 2.35% of 450,000 metric tons (the average landings) equates to 10,575 metric tons of bycatch, a substantial amount as recognized by de Silva and Condrey (1998).

Each Gulf state is tasked with regulating incidental bycatch in the menhaden fishery within state waters (Table 1), with restrictions ranging from none in Florida waters to possession limits in the remaining states (SEDAR 2013). There are limits on the amount of bycatch that can be possessed in relation to menhaden, with specific regulations regarding red drum in Mississippi territorial waters (Table 1). In the menhaden fishery, landed or retained bycatch is processed along with the menhaden in the reduction plants (Guillory and Hutton 1982). During normal fishing operations, some bycatch is released at sea, such as larger specimens of red drum (*Sciaenops ocellatus*), sharks, marine mammals, sea turtles, and other finfish (Condrey 1994). Further, some bycatch may be retained by the crew as sustenance (Condrey 1994; Dunham 1972; Stevens 1960).

In this working paper, we briefly review the various studies addressing bycatch in the Gulf menhaden fishery and summarize findings concerning red drum or similar species (i.e., other drums). The purpose of this study to highlight the need to consider the potential impact of bycatch in the Gulf menhaden fishery for economically important species such as red drum, or other species such as Spanish mackerel (*Scomberomorus maculatus*) (Harrington et al. 2005). We provide a preliminary estimate of red drum bycatch in the Gulf of Mexico menhaden fishery based on simplistic assumptions and minimal data. At the very least, this analysis should highlight the need to address the potential for bycatch in the menhaden fishery.

Methods

Total incidental bycatch in the Gulf menhaden purse seine reduction fishery

A time series of total incidental bycatch in the Gulf menhaden reduction fishery was developed based on the range of reported values in the literature (see Table 2) with the following broad assumptions:

(1) Minimum estimate of the mean total incidental bycatch by weight (0.66 %W) – from 1980 estimate in Guillory and Hutton (1982) (see Table 2 for details).
(2) Mean estimate of the mean total incidental bycatch by weight (2.06 %W) – average of estimated bycatch in weight provided from Guillory and Hutton (1982) and Condrey (1994).
(3) Maximum estimate of the mean total bycatch by weight (3.1 %W) - estimated bycatch from the processing plant in 1981 from Guillory and Hutton (1982).
(4) Condrey (1994) estimate of the mean total bycatch by weight (1.2 %W) – considered by Condrey (1994) to be a more realistic value because it accounts for the skewed distribution (many zeros). This estimate was computed as the ratio of the bycatch per set to the mean weight of the menhaden sample.

Total bycatch of red drum in the Gulf menhaden purse seine reduction fishery

A time series of red drum bycatch in the Gulf menhaden reduction fishery was developed based on the range of reported values in the literature (see Table 3) and the assumption that the respective percentages have not varied over time. In addition, this analysis required the following broad assumptions:

By weight:

(1) An estimate of "Other drum" (American star drum *Stellifer lanceolatus* and banded drum *Larimus fasciatus*) bycatch by weight (1.4 %W) was used as a proxy for red drum in the absence of better information – estimated bycatch of other drums from processing plants between 1980 and 1981 from Guillory and Hutton (1982). Note that red drum were not observed in this study, but were observed in 4 other studies (see Table 4); other drums were observed and included American star drum and banded drum.

By number:

(1) Minimum estimate of red drum bycatch by number (0.046 %N) – based on Simmons (1949) estimate for red drum.
(2) Mean estimate of red drum bycatch by number (0.63 %N) – based on all studies capturing a drum (see Table 3).
(3) Maximum estimate of red drum bycatch by number (21.6 %N * 0.654) – based on the estimate for red drum and estimated mortality (57.8% released dead + 7.6% kept) from Pulver and Scott-Denton (2012).

In the absence of consistent reporting of bycatch by weight, %N is assumed a proxy for %W, which is likely not valid. The range for %N (0.046 – 21.6%) is much larger than for %W (0.66 – 3.1).

Results

Species composition – red drum

A summary of the species composition of bycatch in the Gulf menhaden fishery is provided in Tables 4-6, with total numbers presented in Table 4, percent number presented in Table 5 (when actual numbers were not available), and percent weight presented in Table 6. Red drum were identified as bycatch at sea by Simmons (1949), Knapp (1950), Condrey (1994), de Silva and Condrey (1998) and Pulver and Scott-Denton (2012) but were not identified as bycatch in retained landings by any study. Details on sampling are provided in Appendix A.

Total incidental bycatch in the Gulf menhaden purse seine reduction fishery

The reported reduction landings of Gulf menhaden between 1948 and 2000 ranged from below 100,000 metric tons (mt) in the late 1940s to nearly 1,000,000 mt in the mid -1980s and declined there after (Figure 2A). Since 2000, landings have been variable with peak landings of 613,300 mt in 2011 and lowest landings of 379,700 mt in 2010, due to closures following the Deep-water Horizon oil spill (SEDAR 2013). The range of bycatch estimates considered in this study (minimum, mean, maximum, and Condrey 1994) produced various time series of total incidental bycatch scaled down from the menhaden landings according to their respective percentages discussed above (Figure 2B). Assuming the lowest percentage of total bycatch by weight (i.e., 0.66% of menhaden landings), total bycatch ranged from 500 mt in 1948 to 6,500 mt in 1984. In contrast, assuming the highest percentage of bycatch by weight (i.e., 3.1% of menhaden landings), total bycatch ranged from 2,300 mt in 1948 to 30,500 mt in 1984.

Total bycatch of red drum in the Gulf menhaden purse seine reduction fishery

No estimates of bycatch in terms of weight were available specifically for red drum. The range of bycatch estimates for sciaenids (Sea trout *Cynoscion* spp., Atlantic Croaker *Micropogonias undulatus*, American star drum *Stellifer lanceolatus* Southern kingfish *Menticirrhus americanus* and banded drum *Larimus fasciatus*) considered in this study (min, mean, and max) produced various time series of incidental bycatch (Figure 3). Assuming the lowest and highest percentages of weight, estimated incidental bycatch ranged from 194 mt to 2,556 mt and 911 mt to 12,000 mt, respectively.

Estimates of bycatch in terms of numbers were available for red drum. The range of bycatch estimates for drums considered in this study (min, mean, max, and Condrey 1994) produced various time series of red drum incidental bycatch (Figure 4). The highest bycatch percentage of landings (3.1 %W) combined with the highest percent by number (1.57 %N) for red drum would result in estimated red drum bycatch ranging from about 50 mt to 500 mt. No information regarding average weight of bycatch was available to convert numbers into weight.

Comparison of red drum landings with potential bycatch in the Gulf menhaden fishery

The relative magnitude of estimated red drum bycatch is minimal (<5%) compared to both commercial and recreational landings when percent by numbers are 0.046% or 0.63% (Figure 5). However, if bycatch is highest as displayed in the largest bycatch scenario (i.e., bycatch assumed 3.1% by weight of landings; 21.6% of bycatch considered red drum, with 65.4% discard), estimated red drum bycatch could comprise up to 50% total removals (Figure 5).

Discussion

This analysis provides the only estimates available for addressing bycatch in the Gulf menhaden fishery for any species; however, these estimates are extremely preliminary and are based on sporadic observations of incidental bycatch in the fishery. Red drum have not been identified within retained bycatch in any of the studies examined, although many studies admitted to less sampling of larger individuals due to either release, obstructed views, or retention as food and as a result were excluded from bycatch analyses (Condrey 1994; Dunham 1972; Miles and Simmons 1950; Stevens 1960). The most recent study which used Observers to monitor 1% of coverage, focused on larger species and identified red drum as the most common bycatch species, but did not report bycatch in terms of weight (Pulver and Scott-Denton 2012).

Although at first glance it may appear that bycatch in this fishery has been studied frequently, there are substantial limitations to previous analyses, and therefore, barriers remain in trying to provide unbiased species composition and estimates of bycatch for red drum among other species. Many of the studies are limited with sampling deficiencies, such as the exclusion of released bycatch (e.g., Guillory and Hutton 1982). Further, the majority of studies focus on numbers rather than weights, with the reliance on numbers problematic due to skewed distributions and the inflation of bycatch (by number) by setting on a non-target school (e.g., mullet, as in Christmas (1960)) (Condrey 1994). Substantial variability has been observed in the number of bycatch caught per set (e.g., 0 - 24.8%; Guillory and Hutton 1982) and among regions (e.g., 0 - 10.4%; Guillory and Hutton 1982). Rather than focus on a single metric of either number or weight, an approach similar to the compound index of relative importance in trophic ecology (Cortés 1997) may provide a better representation of bycatch. This single metric could serve to standardize the weight, number, and occurrence metrics to reduce bias, and would allow the reporting of weights, which are critical in trying to estimate the proportion of menhaden landings that are attributed to bycatch and the potential magnitude.

At present, it is difficult to assess the potential impact of bycatch in the menhaden fishery for red drum given the limited data presented herein. Red drum are likely removed from menhaden landings and released, as discussed in Condrey (1994), de Silva and Condrey (1998), and Pulver and Scott-Denton (2012). Each study classified the majority of red drum released as either dead or disoriented, as a result of hitting the deck after being deflected. Unfortunately, a federal observer program is currently lacking for the commercial fleet (Pulver and Scott-Denton 2012), potentially due to confidentiality issues as the fleet consists of 2 companies: Omega Protein and Daybrook Fisheries Inc. As a result, there is very little information available concerning the composition and potential volume of bycatch. Understandably, many previous studies acknowledged a shift from proposed sampling (i.e., at sea) versus realized sampling (e.g., at processing plant) and the lack of freedom in sampling the fishery because of the disruption of fishing operations (Dunham 1972).

Condrey (1994) found no relationship between the number of individuals in the bycatch samples (or the weight of the bycatch per sample) with volume of menhaden caught. The inclusion of released bycatch was considered negligible and would not impact the numbers or weights of bycatch substantially (Condrey 1994). However, the study acknowledged that some released fish were not observable when the fish deflector was pointed to sea, which serves the purpose of preventing the take of large fish such as large red drum. A tagging study and/or some physiological work could improve our understanding of the fate of individuals released by the menhaden fishery.

Differences in sampling implementation (e.g., retained versus released bycatch) likely complicate our attempt to compare results across studies. However, given the paucity of comprehensive analyses which quantify bycatch by weight and the findings of this review, a more frequent assessment of bycatch as in Pulver and Scott-Denton (2012) is required which samples all bycatch (both retained and released). If sampling by weight is deemed too difficult, length estimates of incidental species is a necessity to enable conversion of numbers to weights. For some species (e.g., Spanish mackerel), bycatch in the menhaden fishery may be substantial and may warrant consideration when assessing stock dynamics. Although red drum bycatch is likely larger in the menhaden fishery than estimated in this analysis, we recognize severe limitations and urge additional research to gain a better understanding of how this fishery impacts various ecosystem components, ranging from forage fish (e.g., mullet) to top predators (e.g., Spanish mackerel).

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Table 1. State restrictions for purse seine gear in inshore waters of the Gulf of Mexico.

State	Restrictions for Purse Seines
Florida	None
Alabama	May not possess >5% by number any species other than menhaden, herring, and anchovies
Mississippi	May not possess any quantity of red drum on board in MS territorial waters
	May not catch >5% by weight in any single set of the net the following species: spotted seatrout, bluefish, Spanish mackerel, king mackerel, dolphinfish, pompano, cobia, or crevalle jack
	May not possess >10% by weight of the total catch of the following species: spotted seatrout, bluefish, Spanish mackerel, king mackerel, dolphinfish, pompano, cobia, or crevalle jack
Louisiana	May not possess >5% by weight any species other than menhaden and herring-like species
Texas	May not contain >5% by volume of other edible products

Table 2. Summary of menhaden bycatch studies. At-sea studies report both releasable and landed bycatch. - indicates no data.

Study	Area	Sampled	Year	Months	Effort	Total Bycatch %W	Total Bycatch %N	Notes
Pulver and Scott-Denton (2012)	TX-MS	At-sea	2011	May – Sep	223 sets	-	-	Relative percent of bycatch not reported. Retained bycatch not observed, concentrated on large bycatch (> 50 cm) due to time constraints
de Silva and Condrey (1997)	TX-MS	At-sea	1995	Apr - Oct	257 sets	-	0.17	
de Silva et al. (1996)	TX-MS	At-sea	1994	Jun - Oct	455 sets	0.66	1.51	Also discussed in de Silva (1998) dissertation
Condrey (1994)	LA-AL	At-sea	1992	Apr - Oct	49 sets	1.20	1.00	Unable to locate original report
Guillory and Hutton (1982)	LA	Plant	1980	Apr - Oct	24 trips	1.60	2.39	Some large specimens of shark, crevalle jacks, etc. are removed from the catch during harvesting or unloading to prevent damage to the suction pumps. Some fish removed from the catch for personal consumption
	LA	Plant	1981	Apr - Oct	18 trips	3.10	2.96	
	LA	Plant	1980-81	Apr - Oct	42 trips	2.35	2.68	
Dunham (1972)	LA	Dock	1971	Jun – Oct	NA	-	0.05	Large species of fish did not normally enter the samples, but were usually removed from the catch during harvesting or unloading, since they caused damage to nets and/or unloading pumps. Edible fish were also removed from the catch by the boat crew or unloading crew; therefore, these species were not usually found in the samples.

	LA	Dock	1972	May - Jun	NA	2.00	-	
Christmas et al. (1960)	MS	At-sea	1958	Jun - Aug, Oct	62 sets	2.80	3.90	Larger species often excluded from samples (e.g., mackerel only in 5 samples but observed in 26 sets). Imperfect identification of the releasable bycatch (i.e., hard to ID fish in the net from the deck)
	MS	At-sea	1959	May	27 sets	2.80	3.90	
Stevens (1960)	TX-LA	Plant	1959-60	NA	NA	0.00	0.00	During visits to the plants, no game fish were observed in any of the catches being unloaded. The writer was informed by plant personnel that normally when game fish are taken in nets, they are used as food by the crew
Knapp (1950)	LA	At-sea	1948	Jun - Aug	17 hauls	-	0.06	Observer placed on single steamer (H. C. Dashiell)
Miles and Simmons (1950)	TX	At-sea	1949	Jun - Sep	143 sets	-	0.14	Observer placed on single steamer (Alfred E. Davies, Jr)
Simmons (1949)	LA	At-sea	1948	Jun - Aug	59 hauls	-	0.03	Observer placed on single steamer (H. C. Dashiell); discussed in Miles and Simmons (1950)

Table 3. Summary of red drum findings in bycatch studies by percent by number (%N) and percent by weight (%W). - indicates no data.

Study	Red drum identified?	Other	Notes
Pulver and Scott-Denton	Yes	Red drum = 21.6 %N	Majority (58%) of red drum were discarded dead, 29.3% released alive, 7.6% kept, and 5.3% unknown.
de Silva and Condrey (1997)	Yes	Red drum = 1.57 %N	Red drum were caught in all 5 zones and were primarily associated with being released dead or disoriented; Content also discussed in de Silva 1998 dissertation
de Silva et al. (1996)	Yes	Red drum = 1.48 %N	Red drum present in released sets, about half released dead
Condrey (1994)	Yes	Red drum = 0.53 %N; Black drum = 0.67 %N	Many of the red drum which were released dead (20%) or disoriented (80%) had hit the deck after being deflected by the large fish deflector.
Guillory and Hutton (1982)	No No No	Star drum = 1.3 %W; Banded drum = 0.1 %W	-
Dunham (1972)	No	Banded drum = 40.5 %W	-
Christmas et al. (1960)	No	Star drum = 0.046 %N	-
Stevens (1960)	No	None	-
Knapp (1950)	Yes	Red drum = 0.064 %N	-
Miles and Simmons (1950)	No	-	-
Simmons (1949)	Yes	Red drum = 0.046 %N	-

Table 4. Comparison of species composition and abundance (number) across studies quantifying bycatch in the Gulf menhaden fishery. - indicates no data.

Species	Scientific name	Simmons 1949	Knapp 1950	Breuer 1950	Christ-mas 1960	Condrey 1994 Release	de Silva and Condrey 1997	Dunham 1972	Pulver and Scott-Denton 2012
Total fish	-	2502182	2501574	5333589	55,949	NA	NA	715324	-
Menhaden	*Brevoortia* sp.	2500000	2500000	5326000	53,770	NA	NA	715000	-
Other fish	-	2,182	1,574	7,589	2,179	2,847	15,579	324	1955
UNID fish	-	-	-	-	-	-	516	-	-
Herring-like fishes	-	1,500	-	-	-	-	-	6	-
Scrawled cowfish	*Acanthostracion quadricornis*	-	-	3	0	-	-	-	-
Spotted eagle ray	*Aetobatus narinari*	-	1	1	-	-	-	-	1
Skipjack herring	*Alosa chrysochloris*	-	-	-	-	-	-	-	-
Striped anchovy	*Anchoa hepsetus*	-	-	-	1	-	-	-	-
Bay anchovy	*Anchoa mitchilli*	-	-	-	0	-	-	-	-
Oceallated flounder	*Ancylopsetta quadrocellata*	-	-	1	0	-	-	-	-
Sheepshead	*Archosargus probatocephalus*	-	-	-	0	-	-	-	5
Catfish	*Ariidae*	-	-	-	-	-	1,002	-	-
Gafftopsail catfish	*Bagre marina*	3	3	36	85	825	-	33	-
Silver perch	*Bairdiella chrysoura*	-	-	-	18	-	-	-	-
Flounder	Bothidae	-	-	-	-	-	-	-	2
Blue crab	*Callinectes sapidus*	-	-	-	-	14	-	2	-
Lesser blue crab	*Callinectes similis*	-	-	-	-	-	-	1	-
Crabs	*Callinectes* sp.	26	-	75	-	-	-		-
Blue runner	*Caranx crysos*	-	-	8	-	-	-	-	-
Crevalle jack	*Caranx hippos*	-	-	91	0	246	349	2	210
Spinner shark	*Carcharhinus brevipinna*	-	-	-	-	-	-	-	5
Finetooth shark	*Carcharhinus isodon*	-	-	-	-	-	-	-	32
Bull shark	*Carcharhinus leucas*	-	-	-	0	-	39	-	3
Blacktip shark	*Carcharhinus limbatus*	-	-	-	0	-	184	-	245

Species	Scientific name	Simmons 1949	Knapp 1950	Breuer 1950	Christ-mas 1960	Condrey 1994 Release	de Silva and Condrey 1997	Dunham 1972	Pulver and Scott-Denton 2012
Requiem shark	*Carcharhinus* sp.			-			57	-	-
Sand shark	*Carcharias littoralis*	-	-	163	-	-	-	-	-
Orange filefish	*Ceratocanthus schoepfi*	-	-	1	-	-	-	-	-
Atlantic spadefish	*Chaetodipterus faber*	-	-	14	9	-	-	-	-
Striped burrfish	*Chilomycterus schoepfi*	-	-	21	0	-	-	1	-
Atlantic bumper	*Chloroscombrus chrysurus*	-	-	3,681	1	19	2,497	-	-
Gulf Stream flounder	*Citharichthys arctifrons*	-	-	-	-	16	-	-	-
Spotted whiff	*Citharichthys macrops*	-	-	11	-	-	-	-	-
Bay whiff	*Citharichthys spilopterus*	-	-	-	3	-	-	-	-
Clupeoidei	Clupeoidei	-	1,250	-	-	-	-	-	-
Jellyfish	Cnidaria	-	-	-	-	-	61	-	-
Sand seatrout	*Cynoscion arenarius*	-	-	-	83	69	-	-	-
Spotted seatrout	*Cynoscion nebulosus*	2	2	3	7	19	-	5	-
Silver trout	*Cynoscion nothus*	-	-	242	70	29	-	-	-
Seatrout	*Cynoscion* sp.	77	77	-	-	-	3,507	11	-
Southern stinrgray	*Dasyatis americana*	-	-	-	-	-	-	-	3
Atlantic stingray	*Dasyatis sabina*	-	12	9	2	-	-	-	3
Stingrays	*Dasyatis* sp.	13	-	-	-	-	-	-	-
American gizzard shad	*Dorosoma cepedianum*	-	-	-	2	-	-	-	-
Threadfin shad	*Dorosoma petenense*	-	-	-	155	-	-	-	-
Live sharksucker	*Echeneis naucrates*	-	-	-	0	-	-	-	-
Sharks	*Elasmobranch*	63	63	-	-	201	-	7	368
Ladyfish	*Elops saurus*	-	-	-	-	5	-	-	-
Atlantic goliath grouper	*Epinephelus itajara*	-	-	-	0	-	-	-	-
Smallmouth flounder	*Etropus microstomus*	-	-	-	11	-	-	-	-
Jenny mojarra	*Eucinostomus gula*	-	-	-	-	-	-	1	-

Species	Scientific name	Simmons 1949	Knapp 1950	Breuer 1950	Christ-mas 1960	Condrey 1994 Release	de Silva and Condrey 1997	Dunham 1972	Pulver and Scott-Denton 2012
Hardhead catfish	*Galeichthys felis*	3	-	18	83	95	-	118	9
Smooth butterfly ray	*Gymnura micrura*	-	-	9	0	-	-	-	-
Scaled sardine	*Harengula pensacolae*	-	-	-	7	-	-	-	-
Lined sea horse	*Hippocampus hudsonius*	-	-	-	1	-	-	-	-
Sea horse	*Hippocampus* sp.	-	-	5	-	-	-	-	-
Common halfbeak	*Hyporhamphus unifasciatus*	-	-	5	-	-	-	-	-
Pinfish	*Lagodon rhomboides*	-	-	-	23	-	-	-	-
Banded drum	*Larimus fasciatus*	-	-	-	-	-	-	-	-
Spot	*Leiostomus xanthurus*	50	50	-	203	-	-	31	-
Tripletail	*Lobotes surinamensis*	-	-	-	-	-	-	-	1
Squid	*Loligo* sp.	1	-	6	-	-	-	-	-
Atlantic tarpon	*Megalops atlanticus*	5	5	13	0	-	-	-	1
Rough silverside	*Membras martinica*	-	-	-	0	-	-	-	-
Southern kingcroaker	*Menticirrhus americanus*	-	-	-	18	-	-	6	-
Northern kingfish	*Menticirrhus focaliger*	-	-	-	1	-	-	-	-
Gulf kingcroaker	*Menticirrhus littoralis*	-	-	-	10	-	-	-	-
Kingcroaker	*Menticirrhus* sp.	7	7	8	-	-	-	-	-
Atlantic croaker	*Micropogonias undulatus*	39	-	103	342	793	5105	5	-
Flathead grey mullet	*Mugil cephalus*	-	-	-	902	59	895	6	-
Silver mullet	*Mugil curema*	-	-	-	10	-	-	-	-
Eagle ray	Myliobatidae	-	-	-	-	-	-	-	28
Polka-dot batfish	*Ogcocephalus radiatus*	-	-	8	-	-	-	-	-
Leatherjacket	*Oligoplites saurus*	-	-	11	1	-	-	-	-
Crested cusk-eel	*Ophidion welshi*	-	-	-	-	-	-	1	-
Atlantic thread herring	*Opisthonema oglinum*	-	-	1,485	15	5	-	-	-
Gulf toadfish	*Opsanus beta*	-	-	-	1	-	-	-	-
Pigfish	*Orthopristis chrysoptera*	-	-	9	0	-	-	-	-
Southern flounder	*Paralichthys lethostigma*	-	3	-	0	-	-	-	-

Species	Scientific name	Simmons 1949	Knapp 1950	Breuer 1950	Christ-mas 1960	Condrey 1994 Release	de Silva and Condrey 1997	Dunham 1972	Pulver and Scott-Denton 2012
4-spotted flounder	*Paralichthys oblongus*	-	-	2	-	-	-	-	-
Flounder	*Paralichthys* sp.	7	-	5	-	-	-	7	-
Brown shrimp	*Penaeus aztecus*	-	-	-	-	-	65	-	-
White shrimp	*Penaeus setiferus*	-	-	-	-	-	-	3	-
Shrimp	*Penaeus* sp.	34	-	191	-	168	32	-	-
Gulf butterfish	*Peprilus burti*	-	-	-	-	16	40	-	-
American harvestfish	*Peprilus paru*	117	-	467	2	-	-	7	-
Porpoise	Phocoenidae	-	-	-	-	5	-	-	-
Portuguese man-of-war	*Physalia physalis*	-	-	1	-	-	-	-	-
Black drum	*Pogonias cromis*	3	3	-	-	19	-	3	49
Atlantic threadfin	*Polydactylus octonemus*	-	-	-	6	-	-	-	-
Bluefish	*Pomatomus saltatrix*	42	42	304	3	3	-	7	-
American butterfish	*Poronotus triacanthus*	-	-	-	73	-	-	-	-
Sea robin	*Prionotus* sp.	-	-	16	0	-	-	-	-
Bighead sea robin	*Prionotus tribulus*	-	-	-	1	-	-	-	-
Skate	Rajidae	-	-	-	-	-	-	4	7
Texas clearnose skate	*Raja texana*	-	-	-	1	-	-	-	-
Common remora	*Remora remora*	-	-	1	-	-	-	-	-
Cownose ray	*Rhinoptera bonasus*	-	-	24	0	25	70	37	176
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*	-	-	-	0	-	-	-	187
Red drum	***Sciaenops ocellatus***	**1**	**1**	**-**	**-**	**15**	**245**	**-**	**422**
Mackerel	Scombridae	-	-	-	-	-	-	-	9
King mackerel	*Scomberomorus cavalla*	-	-	1	-	4	-	-	-
Spanish mackerel	*Scomberomorus maculatus*	107	47	205	5	101	241	10	184
Lookdown	*Selene vomer*	-	-	-	2	-	-	-	-

Species	Scientific name	Simmons 1949	Knapp 1950	Breuer 1950	Christ-mas 1960	Condrey 1994 Release	de Silva and Condrey 1997	Dunham 1972	Pulver and Scott-Denton 2012
Least puffer	*Sphoeroides parvus*	-	-	-	-	2	-	-	-
Blowfish	*Sphoeroides* sp.	2	-	-	-	-	-	-	-
Bandtail puffer	*Sphoeroides spengleri*	-	-	1	-	-	-	-	-
Scalloped hammerhead	*Sphyrna lewini*	-	-	-	0	-	-	-	-
Hammerhead shark	*Sphyrna* sp.	-	-	13	-	-	-	-	-
Bonnethead shark	*Sphyrna tiburo*	-	-	26	0	-	-	-	5
American stardrum	*Stellifer lanceolatus*	-	-	-	1	-	-	-	-
Conch	Strombidae	-	-	7	-	-	-	-	-
Atlantic needlefish	*Strongylura marina*	-	-	3	-	2	-	-	-
Shoal flounder	*Syacium gunteri*	-	-	-	2	-	-	-	-
Longtail tonguefish	*Symphurus pelicanus*	-	-	-	-	4	-	-	-
Blackcheek tonguefish	*Symphurus plagiusa*	-	-	-	0	-	204	1	-
Inshore lizardfish	*Synodus foetens*	-	-	1	-	-	-	-	-
Oyster drill	*Thais haemastoma*	-	-	-	-	-	-	-	-
Florida pompano	*Trachinotus carolinus*	8	8	9	-	-	-	-	-
Largehead hairtail	*Trichiurus lepturus*	72	-	247	13	86	470	7	-
Hogchoker	*Trinectes maculatus*	-	-	12	4	2	-	2	-
Southern hake	*Urophycis floridana*	-	-	-	0	-	-	-	-
Moonfish	*Vomer setapinnis*	-	-	13	2	-	-	-	-

Table 5. Comparison of species composition and abundance (only available as a percentage) across studies addressing bycatch in the Gulf menhaden fishery. – indicates no data.

Species	Guillory and Hutton 1982	Condrey 1994 Retained	Species	Guillory and Hutton 1982	Condrey 1994 Retained
Skipjack herring	0.1%	-	Banded drum	0.1%	-
Sheepshead	0.1%	-	Spot	5.8%	0.3%
Gafftopsail catfish	1.1%	5.3%	Squid	0.3%	-
Silver perch	0.3%	-	Southern kingcroaker	0.2%	-
Blue crab	0.8%	0.3%	Atlantic croaker	25.2%	47.5%
Lesser blue crab	0.1%	-	Flathead grey mullet	0.1%	6.3%
Crevalle jack	0.2%	-	Atlantic thread herring	0.5%	0.6%
Atlantic spadefish	0.1%	-	Brown shrimp	1.0%	-
Atlantic bumper	12.6%	11.3%	White shrimp	0.3%	-
Bay whiff	0.1%	-	Shrimp	-	10.4%
Sand seatrout	-	3.1%	Gulf butterfish	0.2%	1.9%
Spotted seatrout	2.2%	-	American harvestfish	1.6%	-
Silver trout	-	6.0%	Bluefish	0.4%	0.3%
Seatrout	19.7%	-	Cownose ray	0.1%	-
Atlantic stingray	0.1%	-	King mackerel	0.1%	-
American gizzard shad	0.1%	-	Spanish mackerel	1.0%	0.9%
Threadfin shad	13.2%	-	Lookdown	0.1%	-
Sharks	0.4%	-	American stardrum	2.4%	-
Ladyfish	0.3%	-	Longtail tonguefish	-	0.3%
Hardhead catfish	8.3%	4.7%	Blackcheek tonguefish	0.1%	-
Scaled sardine	0.1%	-	Oyster drill	0.1%	-
Pinfish	0.1%	-	Florida pompano	0.1%	-
			Largehead hairtail	1.3%	0.9%

Table 6. Comparison of species composition and volume (in percent by weight) across studies addressing bycatch in the Gulf menhaden fishery. – indicates no data.

Species	Dunham 1972	Guillory and Hutton 1982	Condrey 1994
Atlantic bumper	-	8.1	17.4
Atlantic croaker	-	13.1	24.7
Atlantic cutlassfish	-	1.1	1.3
Atlantic spadefish	-	0.1	-
Atlantic stingray	-	0.2	-
Atlantic thread herring	59.5	0.6	0.6
Banded drum	40.5	0.1	-
Bay whiff	-	0.1	-
Blackcheek tonguefish	-	0.1	-
Blue crab	-	0.2	0.02
Bluefish	-	1.8	0.4
Brown shrimp	-	0.1	-
Butterfish	-	0.1	3.1
Lesser blue crab	-	0.1	-
Cownose ray	-	0.4	-
Crevalle jack	-	1.6	-
Spotted seatrout	-	0.4	-
Seatrout	-	24.2	-
Florida pompano	-	0.1	-
Gafftopsail catfish	-	7.1	7.5
Gizzard shad	-	0.1	-
Hardhead catfish	-	24.2	6.3
Harvestfish	-	1.6	-
King mackerel	-	0.3	-
Ladyfish	-	0.6	-
Longtail tonguefish	-	-	0.02
Lookdown	-	0.1	-
Oyster drill	-	0.1	-
Pinfish	-	0.1	-
Sand seatrout	-	-	5.6
Scaled sardine	-	0.1	-
Shark sp.	-	2.1	-
Sheepshead	-	0.7	-
Shrimp	-	-	12.2
Silver perch	-	0.1	-
Silver seatrout	-	-	9.4
Skipjack herring	-	0.1	-
Southern kingfish	-	0.3	-
Spanish mackerel	-	2.6	1.3
Spot	-	1.7	0.1
Squid	-	0.1	-
American stardrum	-	1.3	-

Striped mullet	-	0.1	10.1
Threadfin shad	-	4.3	-
UNID fish	-	0.1	-
White shrimp	-	0.1	-

Figure 1. Location of processing plants in the late 1980s from Smith (1991). Only Moss Point, Mississippi, Empire, Louisiana (LA), and Abbeville, LA remain active.

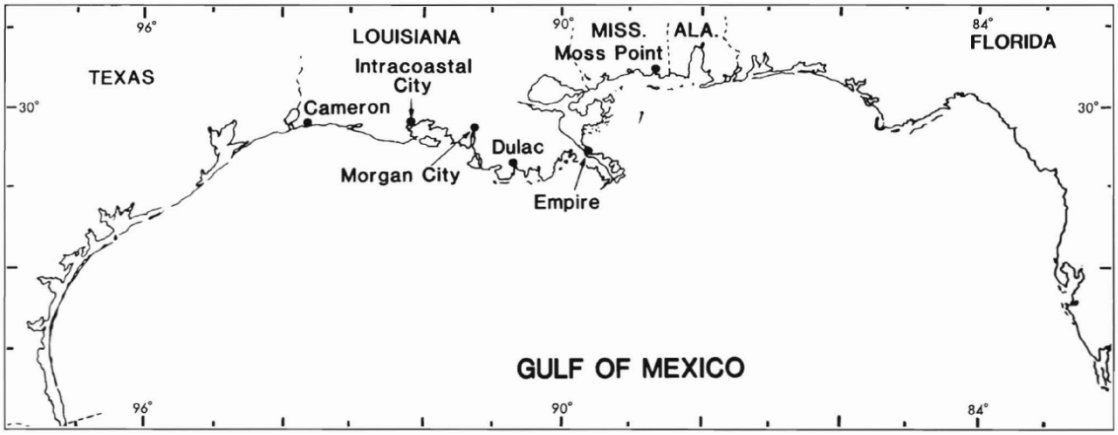


Figure 9.—Location of reduction factories for Gulf menhaden, 1989.

Figure 2. Composition of Gulf menhaden landings from the reduction fishery. (A) Total landings (in 1000s of metric tons [mt]) of the Gulf menhaden reduction fishery obtained from SEFSC (2015). (B) Estimated incidental bycatch (in 1000s of metric tons) based on percentage of bycatch by weight extracted from the literature.

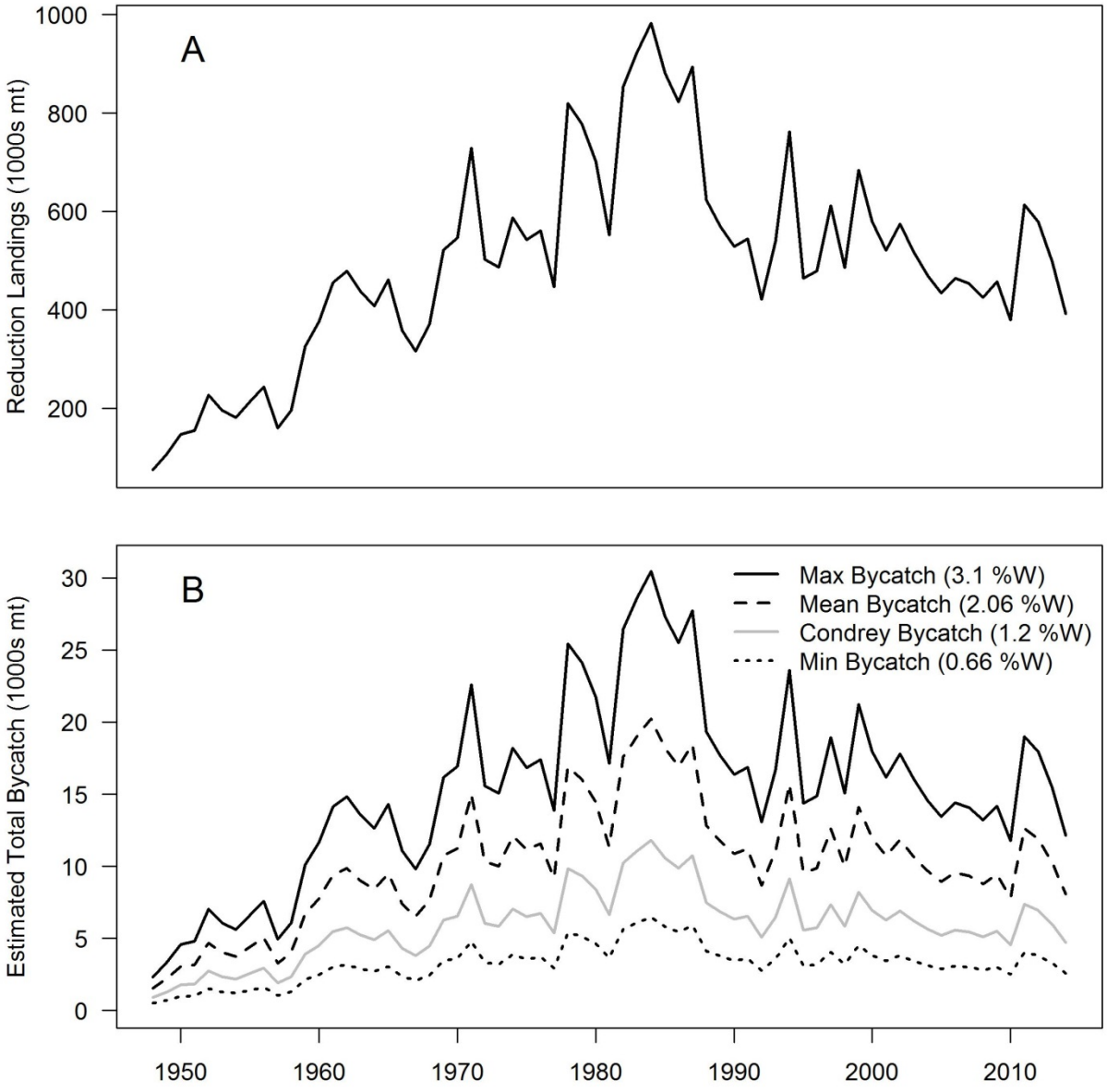


Figure 3. Estimated bycatch of Sciaenidae (Sea trout *Cynoscion* spp., Atlantic Croaker *Micropogonias undulatus*, American star drum *Stellifer lanceolatus* Southern kingfish *Menticirrhus americanus* and banded drum *Larimus fasciatus*) by weight based on the Guillory and Hutton (1982). Note that no red drum were observed in either study reporting bycatch in terms of weight.

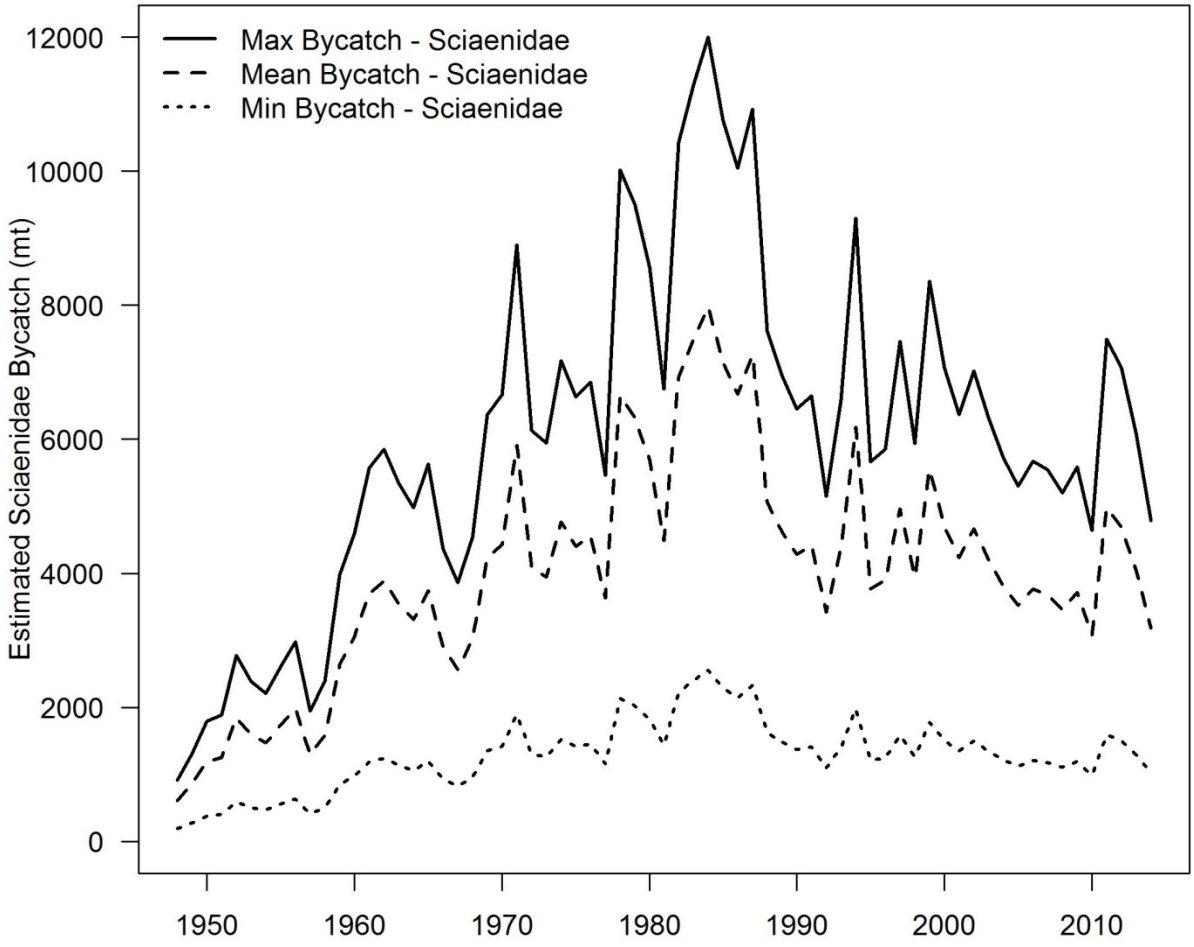


Figure 4. Estimated bycatch of red drum using percent by number as a proxy for weight based the literature.

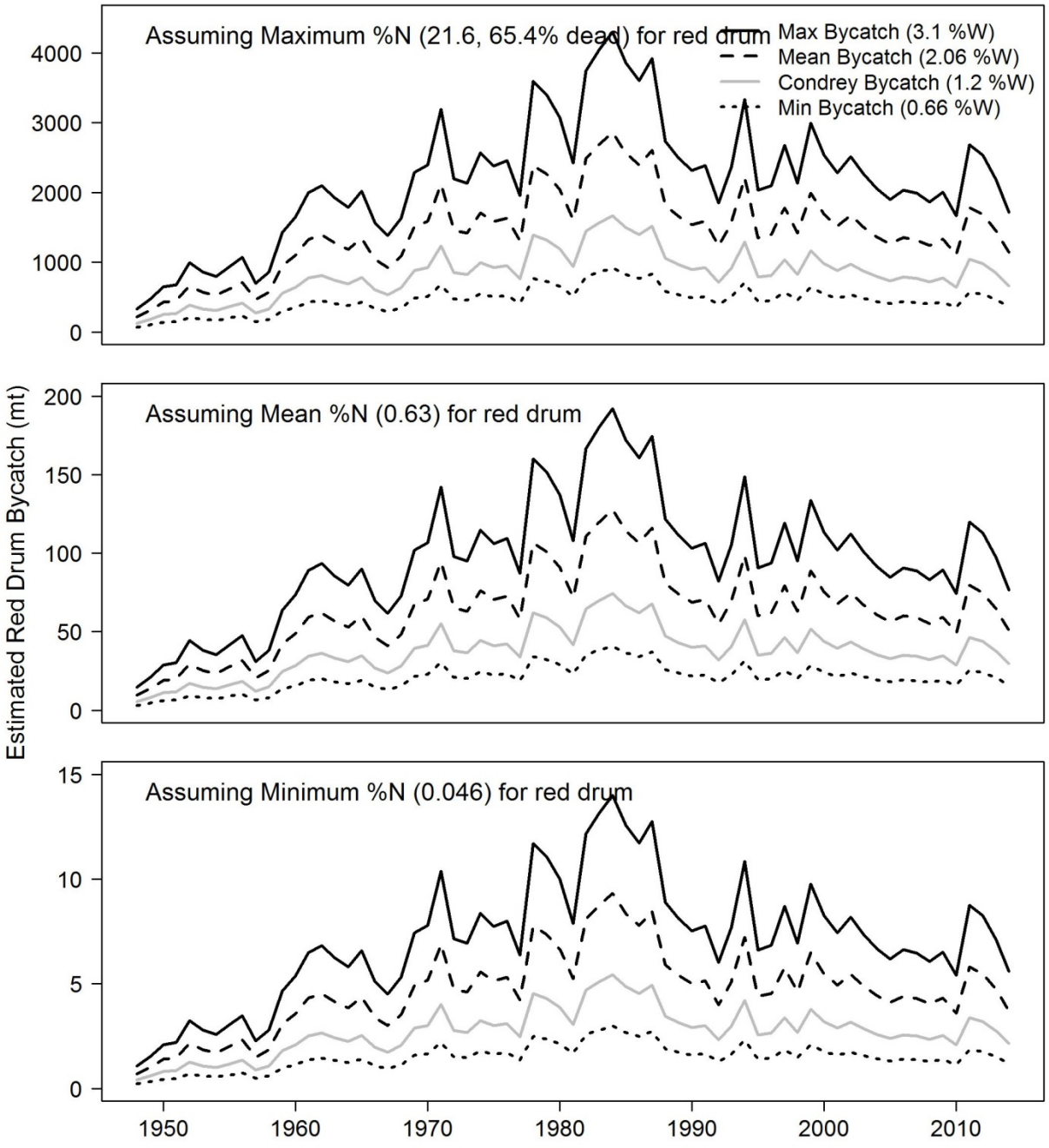
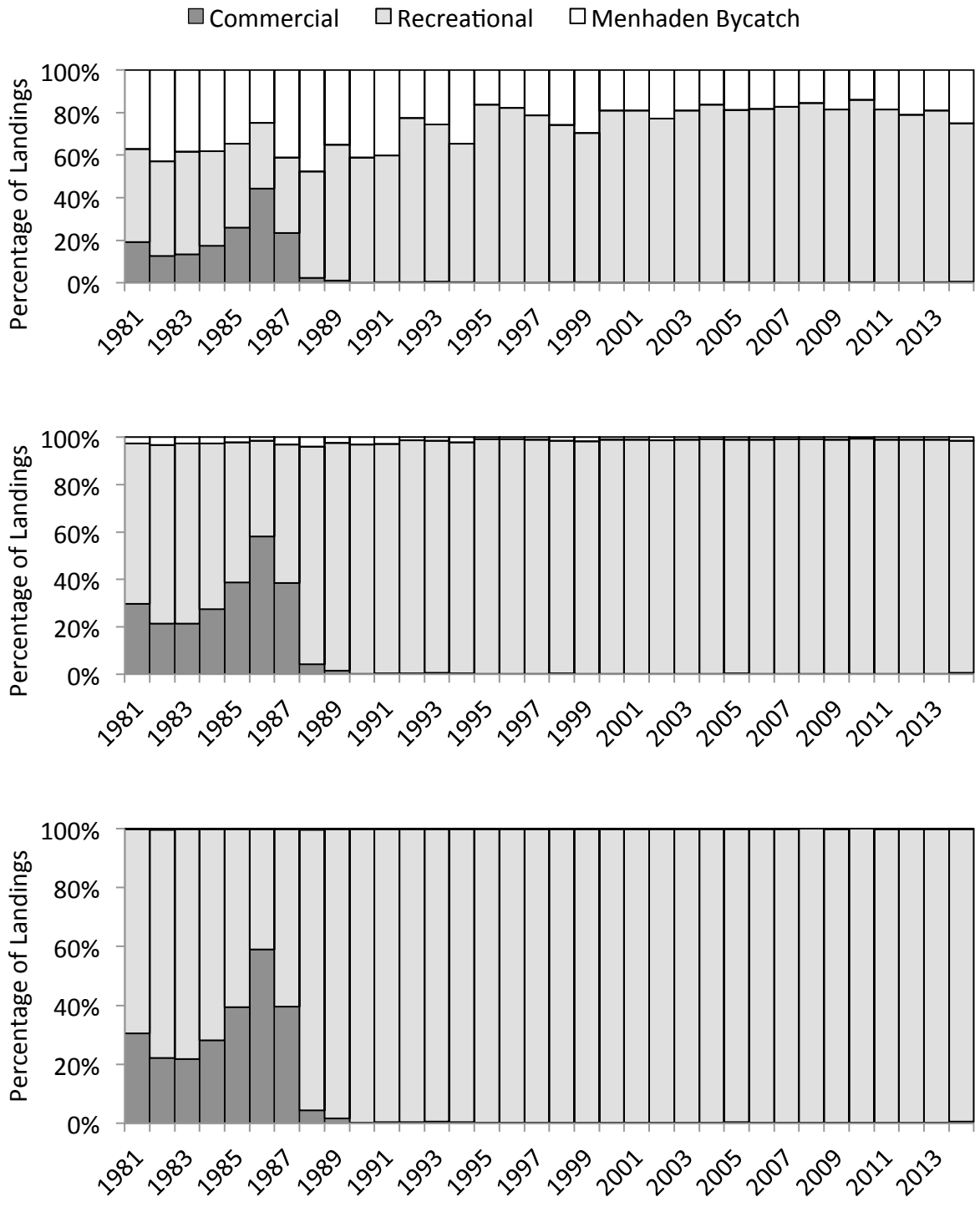


Figure 5. Comparison of commercial and recreational landings of red drum in the Gulf of Mexico (preliminary estimates from SEDAR49) with estimated bycatch in the Gulf menhaden reduction fishery. Results from top to bottom are shown for the highest estimate of total bycatch (3.1%) in conjunction with the highest (21.6 %N, of which 65.4% discarded dead), moderate (0.63 %N), and lowest percent by number for red drum (0.046 %N).



Appendix A. Brief review of studies from earliest to most recent

Breuer (1949) (as mentioned in Miles and Simmons 1950)
Objective: determine the catch of other species within purse seines from the menhaden fishery
Area and Time: Louisiana, June through September 1949
Sampled: Record kept of every fish that came aboard the Alfred E. Davies, Jr. steamer in 143 sets.
Major Findings:

- Bycatch: **0.14% by number** of total catch.
- Seasonal differences: higher bycatch during August.
- Composition: 49 species/groups, with the most prevalent species *by number* including: Atlantic bumper (48.5%), Atlantic thread herring (19.6%), harvestfish (6.15%), bluefish (4.0%), and cutlassfish (3.3%) (See Table 4 for scientific names).
- Limitations acknowledged in study: none.
- Concerns: only sampled 1 vessel.

Simmons (1949) (as mentioned in Miles and Simmons 1950)
Objective: determine the catch of other species within purse seines from the menhaden fishery
Area and Time: Louisiana, June through August 1948.
Sampled: Record kept of every fish that came aboard the H. C. Dashiell steamer in 59 hauls.
Major Findings:

- Bycatch: **0.027% by number** of total catch.
- Composition: 22 species/groups observed, with the most prevalent species *by number* including: herring-like fishes (67.7%), harvestfish (5.4%), Spanish mackerel (4.9%), sand trout (3.5%), cutlassfish (3.3%), unidentified sharks (2.9%), spot (2.3%), bluefish (1.79%), and croakers (1.87%).
- Limitations acknowledged in study: none.
- Concerns: only sampled 1 vessel.

Knapp (1950)
Objective: determine the volume of menhaden caught and the number of game/food fish captured with them in the purse seines from the menhaden fishery at Port Arthur.
Area and Time: Louisiana, June through August 1948.
Sampled: Observer stationed on menhaden steamer 'H.C. Dashiell" fishing in LA and out of Sabine, TX plant. Sampled 17 purse-seine hauls over a 2-month period.
Major Findings:

- Bycatch: **0.06% by number** of total catch.
- Composition: 15 species/groups observed, with the most prevalent *by number* including: Clupeoidei (79.4%), seatrout (4.9%), unidentified sharks (4.0%), spot (3.2%), Spanish mackerel (3.0%), and bluefish (2.7%).
- Limitations acknowledged in study: none.
- Concerns: only sampled 1 vessel.

Stevens (1960) (Job Report for Project M-1-R-1).
Objective: to study the percent of the catch made up by game fish.
Area and Time: Texas and Louisiana, 1959.

Sampled: Frequent visits to the plants to observe the unloading of the catches and to speak with plant personnel concerning catches.
Major Findings:

- Bycatch: none (qualitative)
- Limitations acknowledged in study: writer informed by plant personnel that normally when game fish are taken in nets, they are used as food by the crew.
- Concerns: only sampled at processing plant.

Christmas et al. (1960)
Objective: determine the catch composition of landings at Mississippi ports.
Area and Time: Mississippi, 1958 (May-Aug, Oct) to 1959 (May).
Sampled: fish both as they were being removed from the net (i.e., releasable bycatch) and pumped aboard (i.e., landed and processed with the menhaden catch). Biologists sampled purse seine sets in June 1958 (15 sets), July 1958 (19 sets), Aug 1958 (16 sets), Oct 1958 (12 sets), and May 1959 (27 sets). Fish were removed by suction pumps within this study.
Major Findings:

- Bycatch: **3.9% by number and 2.8% by weight** of the catches sampled overall.
- Seasonal differences: bycatch variable over seasons (higher during summer).
- Spatial differences: only sampled eastern GOM (i.e., MS).
- Composition: 80 incidental species taken, with the most abundant species *by number* in samples including: striped mullet (41.4%), croaker (15.7%), spot (9.3%), gizzard shad (7.1%), gafftopsail (3.9%), hardhead catfish (3.8%), white trout (3.8%), butterfish (3.4%), sand trout (3.2%), and pinfish (1.1%).
- Limitations acknowledged in study: Species such as mackerel were frequently observed in sets but not contained within the samples. Striped mullet considered accidental (i.e., set on wrong school) and not a typical occurrence in this fishery. Imperfect identification of the releasable bycatch (e.g., sharks; hard to ID fish in the net from the deck).
- Concerns: did not investigate species composition by weight.

Dunham (1972)
Objective: determine the catch of other species within purse seines from the menhaden fishery.
Area and Time: Louisiana, June – October, 1971, May – June, 1972.
Sampled: Dockside sampling of menhaden bycatch, sampled by number in 1971 and by weight in 1972. Sampled a minimum of one sample from each vessel's hold, but on most occasions, several samples were taken from the conveyor belt as the catch was removed from each hold. Menhaden were counted by a system incorporated at the plant for measuring fish in units of 1,000 individuals.
Major Findings:

- Bycatch: **0.05% by number** of total catch in 1971 and **2% by weight** in 1972 [author excluded thread herring from bycatch as it is also a high-oil fish].
- Composition: 29 fish species observed in both years, with the most abundance species *by number* in 1971 including: hardhead catfish (36.4%), cownose ray (11.4%), gafftopsail catfish (10.2%), and spot (9.6%). *By weight* in 1972, bycatch included Atlantic thread herring (59.4%) and banded drum (40.5%).
- Limitations acknowledged in study: unable to adhere to original sampling plan which impeded fisher operations in a timely manner.

- Concerns: sampled at dock; did not investigate species composition by weight in both years.

Guillory and Hutton (1982)
Objective: determine species composition and abundance of bycatch in the gulf menhaden fishery of Louisiana to reiterate that direct destruction of incidental species captured in purse seines is unfounded.
Area and Time: Louisiana, 1980 – 1981.
Sampled: processing plants located at Empire, Dulac, and Cameron. Number of sampling trips completed in each year and plant, respectively, are as follows: 10 and 9; 8 and 5; 6 and 4. Sampled 23 different boats.
Major Findings:

- Bycatch: **2.68% by number and 2.35% by weight** of the catches sampled overall. Variable over time (1.6% by weight in 1980, 3.1% by weight in 1981) and area (0.81 – 6.58 by weight; 1.11 – 4.6 by number).
- Spatial differences: menhaden landings from eastern LA/MS contain a greater volume of bycatch than landings from western LA/TX (attributed to enhanced primary productivity from Mississippi River outflow).
- Composition: 35 fish and 6 invertebrate incidental species taken, with the most abundance species *by number* including: Atlantic croaker (25.2%), seatrout (19.7%), threadfin shad (13.2%), Atlantic bumper (12.6%), hardhead catfish (8.3%), and spot (5.8%); and by weight including: seatrout (24.2%), hardhead catfish (24.2%), Atlantic croaker (13.1%), Atlantic bumper (8.1%), and gafftopsail catfish (7.1%).
- Limitations acknowledged in study: at-sea discards neglected; large specimens (e.g., large sharks, crevalle jacks, etc.) are removed from the catch during harvesting or unloading to prevent damage to the suction pumps. In addition, some fish may be removed for personal consumption
- Concerns: only sampled at processing plant.

Condrey (1994)
Objective: determine the species composition of retained and released bycatch in the Gulf menhaden fishery.
Area and Time: Louisiana to Alabama, 1992 fishing season.
Sampled: Sampled both 'retained bycatch' and 'released bycatch' during 10, week-long onboard sampling trips. Sampled 49 sets for retained bycatch and 127 sets for released bycatch.
Major Findings:

- Bycatch: **1% by number** and **1.2% by weight** of the total catch. Adding the released bycatch to retained bycatch would not change these numbers much.
- Composition: Most frequently observed species included Atlantic croaker (30%), Atlantic bumper (10%), silver seatrout (9%), and gafftopsail catfish (7%).
    - Retained bycatch: Most prevalent species *by weight* included: Atlantic croaker (25%), striped mullet (17%), gafftopsail catfish (12%), silver seatrout (10%), Spanish mackerel (Scomberomorus maculatus) (9%), Atlantic bumper (8%), hardhead catfish (6%), and sand seatrout (6%).
    - Released bycatch: Most frequently encountered species in the released bycatch were sharks (63%), followed by gafftopsail catfish (61%), and crevalle jack

(48%). Most prevalent species by number included: gafftopsail catfish (29%), Atlantic croaker (28%), crevalle jack (9%), sharks (7%), and shrimp (5.9%). Dead release was high [around 50% released dead] among the most abundant released bycatch species. Of 15 red drum encountered, 80% were released disoriented and 20% were released dead.

- Limitations acknowledged in study: Some released bycatch was not observable when the large fish deflector was directed directly to the sea.
- Concerns: did not investigate released species composition by weight.

De Silva et al. (1996) (also detailed in de Silva 1998 dissertation)
Objective: determine the species composition of retained and released bycatch in the Gulf menhaden fishery.
Area and Time: Gulf-wide, June through October 1994.
Sampled: by 3 onboard observers which sampled 24 week-long trips on vessels from 5 of the 6 plants operating in the Gulf. Sampled 220 and 235 sets to assess retained bycatch and released bycatch, respectively.
Major Findings:

- Bycatch: **trimmed mean of 1.1548% by number (mean = 1.508%, median = 0.388%) and trimmed mean of 0.66% by weight (mean = 0.876%, median = 0.161%)** of the catches sampled overall, where trimmed mean is calculated by removing the extreme values from each end, thus reducing the effect a rare large event might have on the value.
- Spatial differences: eastern areas of the fishery (statistical zones 11 to 14) have more bycatch than the western area of the fishery.
- Composition:
    - Retained bycatch: 39 species/groups observed, with the most prevalent species *by weight* including Atlantic croaker, sand seatrout, silver trout, striped mullet, and spot (78.5% combined).
    - Released bycatch: 58 species/groups observed, with the most prevalent species *by number* being Atlantic croaker, scaled sardine, sand seatrout, crevalle jack, gafftopsail catfish, Spanish mackerel, striped mullet, Atlantic cutlassfish, Unidentified shark, silver trout, gulf butterfish, and red drum (90% combined). Majority of sharks (70%) and red drum (50%) released dead
- Limitations acknowledged in study: Spatial analyses do not take into account seasonal differences.
- Concerns: did not investigate released species composition by weight.

de Silva and Condrey (1997) (also detailed in de Silva 1998 dissertation)
Objective: examine patchy data with bycatch from the gulf menhaden fishery.
Area and Time: Gulf-wide, April through October 1995.
Sampled: by 2 to 3 onboard observers which sampled 27 week-long trips. Samplers boarded vessels from ports in the western, central, and eastern regions in a given week as often as possible. Sampled 257 sets and observed the purse seine from the time it was brought alongside the carrier ship and throughout the pumping procedure, until the net was emptied and cleaned.
Major Findings:

- Bycatch: **mean of 0.168% by number** (median = 0.033%, sd = 0.033%) and ranged from 0% to 4% per set. Releaseable bycatch estimates range from 0.033% (median) to 0.17% (mean)
- Spatial differences: The odds of observing a set with high bycatch east of the [Mississippi] river in the early season [i.e., spring] was 11 times greater than the odds in the late season [i.e., fall]" (seasonal variability).
    - Spring: Zone 15-16 primarily associated with UNID tonguefish, red drum, crevalle jacks, blacktip shark, UNID requiem sharks, gulf butterfish, and cutlassfish.
    - Summer: Zone 17-18 associated with Spanish mackerel, Atlantic Cutlassfish, cownose ray, blacktip shark, red drum, and gafftopsail catfish.
    - Fall: Zone 17-18 associated with Atlantic croaker, red drum, bull shark, blacktip shark, gulf butterfish, and UNID shrimp.
- Composition: 62 species/groups observed, most frequently occurring species were Atlantic Cutlassfish (44% of sets), Atlantic croaker (38%), Spanish mackerel (36%), sand seatrout (35%), and gafftopsail catfish (34%).
    - Released bycatch: The most abundance species included: Atlantic croaker (32.8%), sand seatrout (22.2%), Atlantic bumper (16.0%), striped mullet (5.7%), gafftopsail catfish (5.1%), Atlantic cutlassfish (3.0%), crevalle jack (2.2%), red drum (1.6%), Spanish mackerel (1.5%), and hardhead catfish (1.3%). Species primarily associated with being released dead or disoriented were unidentified requiem sharks, red drum, crevalle jack, and bull sharks.
- Limitations acknowledged: none.
- Concerns: did not investigate released species composition by weight.

Pulver and Scott-Denton (2012)
Objective: provide quantitative biological, environmental, and gear information relative to the Gulf of Mexico menhaden fishery and characterize fishery bycatch including protected species, specifically sea turtles and bottlenose dolphins, *Tursiops truncatus*.
Area and Time: May through September 2011.
Sampled: NMFS observers were placed on menhaden vessels (one observer per trip) operating in the Gulf of Mexico on a biweekly rotational basis at each of the four plants in the region. Vessel coverage was voluntary at each location, and plant operators determined observer placement on vessels. Observations focused on viewing both bycatch reduction devices during pumping operations, and the purse-seine net after pumping ceased. Observed a total of 223 sets during 54 sea days (1% observer coverage).
Major Findings:

- Bycatch: Percent of bycatch (given by number) not related to menhaden (given in weight).
- Composition: 23 species/groups observed, with the most abundance species *by number* including: Red drum (21.6%), sharks (18.8%), blacktip shark (12.5%), crevalle jack (10.7%), Atlantic sharpnose shark (9.6%), Spanish mackerel (9.4%), and cownose ray (9.0%). The most common fate assigned was discarded dead (34%), followed by kept (31%), discarded alive (29%), and unknown (7%).
- Limitations acknowledged: Protocol concentrated on typically released large (> 50 cm total length) bycatch (sharks and finfish) due to time constraints. Estimates of smaller (≤

50 cm TL) bycatch were deemed unobservable due to the volume of catch, thus discontinued after the initial trips. Records of smaller (≤ 50 cm TL) bycatch of species, such as gafftopsail catfish, *Bagre marinus*, were not used in the analyses. Due to the speed of fishing operations, if an accurate count could not be determined, an interval range was assigned by the observer to represent the minimum and maximum number of the specimens observed for a set.

- Concerns: did not investigate bycatch by weight or retained bycatch. Observer data from a 2011 pilot program for the Gulf of Mexico menhaden fishery were not used in this update due to MSA confidentiality mandates as described in Section 402 of the MSA (i.e., only two companies constitute that fishery).