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NOTE

Characterization of Bycatch in the Cannonball Jellyfish Fishery in the Coastal Waters off Georgia

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Abstract
Studies have been conducted in Georgia to examine bycatch in many fisheries, but none has focused on the trawl fishery for cannonball jellyfish *Stomolophus meleagris*. Although this fishery is relatively new, it presently ranks in the top three by weight (kg) in Georgia, along with the food shrimp and blue crab *Callinectes sapidus* fisheries. The purpose of this study was to characterize and quantify the finfish and invertebrate bycatch species in the cannonball jellyfish trawl fishery in Georgia. Between December 2005 and December 2012, observers accompanied commercial fishers utilizing trawl gear to target cannonball jellyfish in the coastal waters off Georgia; a total of 133 tows were sampled. Observed tow duration ranged from 0.15 to 1.22 h, averaging 0.55 h/tow. During the study period, 1,488 finfish and 150 invertebrates were collected, and 13 individuals representing four species of concern were present in the bycatch. The most numerous species were the Harvestfish *Peprilus paru* (n = 677), Cownose Ray *Rhinoptera bonasus* (n = 185), Atlantic Bumper *Chloroscombrus chrysurus* (n = 179), Butterfish *Peprilus triacanthus* (n = 175), and blue crab (n = 114). The estimated numbers of captured cannonball jellyfish and bycatch varied monthly and yielded an overall cannonball jellyfish : bycatch ratio of 291:1. Results suggest that bycatch in the cannonball jellyfish fishery is nominal in comparison with other Georgia trawl fisheries (e.g., shrimp trawl fishery) and is dominated by a few species that are known to associate with jellyfish. Information gained in the present study provides fishery managers with the knowledge necessary to better understand the impacts of Georgia's commercial cannonball jellyfish trawl fishery on other species.

The cannonball jellyfish *Stomolophus meleagris* (often referred to as the "cabbagehead" or "jellyball") is a member of the Stomolophidae family and is a common jellyfish species occurring throughout the Atlantic waters off the southeastern U.S. coast (Calder 1982). Often found aggregating in large schools or "swarms," cannonball jellyfish are desirable prey for several species of marine biota. They are a dominant prey species for Atlantic Spadefish *Chaetodipterus faber* (Hayse 1989) and butterfishes *Peprilus* spp. (Phillips et. al 1969). Jellyfish also serve as an important food source for sea turtles, particularly the leatherback sea turtle *Dermochelys coriacea* (Griffin and Murphy 2005). Murphy et al. (2006) noted that leatherback sea turtle movements are often influenced by the distribution and abundance of their preferred food items, including cannonball jellyfish.

In addition to being targeted by marine biota, jellyfish are also targeted by humans. Cannonball jellyfish historically occurred as bycatch in multiple commercial fisheries in Georgia and were considered a "pest" species by food shrimp trawl fishers due to their abundance and ability to clog shrimp trawl nets. However, in recent years, cannonball jellyfish have increasingly become targeted by commercial fishers in federal waters of the South Atlantic Bight, including those waters adjacent to Georgia. A popular food item in Asia, cannonball jellyfish are partially processed locally and are shipped overseas, where additional processing occurs prior to human consumption (Huang 1988; Rudloe 1996; Hsieh et al. 2001). Although fishers that target cannonball jellyfish in the coastal waters off Georgia may employ any of several gear types to harvest the species (e.g., cast nets, seines, etc.), trawling is the preferred and most common harvest method. First opened as an experimental fishery in 1998, the cannonball jellyfish fishery has grown in popularity and has recently developed into

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one of Georgia's top-three fisheries. Although the number of fishers targeting cannonball jellyfish in Georgia has remained stable over the years (averaging 6–12 fishers), the fishery in coastal Georgia has evolved and expanded, currently serving as the state's third-largest commercial fishery in terms of weight (kg). As with any trawl fishery, concerns exist about the potential impacts on nontargeted species (i.e., bycatch) that are encountered.

Fisheries for jellyfish exist all over the world. Kingsford et al. (2000) reported that the majority of jellyfish are harvested in the western and northwestern Pacific and the East Indian Ocean, with the countries of Indonesia, China, and Thailand having the longest history of fishing. Other countries with jellyfish fisheries include Australia (FVD-DPI 2006), southern British Columbia (Sloan and Gunn 1985), Malaysia, and the Philippines (Kingsford et al. 2000). Rudloe (1996) reported that in 1995, imports of jellyfish were valued at $25 million in Japan, $20 million in Taiwan, and $17 million in Korea.

Various fishing methods and gear have been employed to catch jellyfish. Kingsford et al. (2000) indicated that dip nets, seines, and trawls are the most commonly used gears, although jellyfish in Southeast Asia have been captured by using set nets, drift nets, and hooks (Omori and Nakano 2001). Concerns exist over the implications of using these differing gear types to harvest jellyfish. Kingsford et al. (2000) suggested that the relative merits and demerits of the various techniques and gears can be summarized in terms of (1) damage to the targeted and undersized jellyfish; (2) quantity of and impacts to bycatch species; (3) efficiency of the fishing method; (4) abundance of the targeted species; and (5) cost of the operation. Few scientific studies have been conducted to examine these issues in various jellyfish fisheries. Limited data from a brief comparison of two methods (dipnetting and beach seining) used in Australia indicated that seines collected undersized jellyfish along with nontargeted (bycatch) benthic and pelagic fish species (Kingsford et al. 2000). Rudloe (1996) observed that the paired seines used to harvest cannonball jellyfish in Florida contained "almost no bycatch." However, there have been no previous scientific studies examining the bycatch encountered by trawl fishers targeting jellyfish.

The issue of bycatch has been a concern for many fisheries throughout the world, including those in the southeastern USA (Rogers et al. 1997; Crowder and Murawski 1998). In the southeastern USA, the bycatch associated with the commercial food shrimp trawl fishery has received more attention than the bycatch of most other fisheries, primarily due to the indiscriminate ability of trawl nets to capture multiple species of organisms beyond the targeted species. In an effort to better understand the potential impacts that trawl gear may have on nontargeted species, the effects and composition of bycatch associated with large food shrimp trawls have been studied in detail (Wallace and Robinson 1994; Ortiz et al. 2000; Baum et al. 2003; Diamond 2003). Similarly, efforts have been conducted to examine the bycatch associated with the whelk trawl fishery in the southeastern USA (Gaddis et al. 2001). To date, no studies have examined the bycatch associated with the cannonball jellyfish trawl fishery in Georgia. Although these fisheries utilize different trawl gears and fishing methods, the marine waters where fishing occurs share many of the same species. Consequently, information on any targeted or incidental takes of marine organisms by any of these gears is needed by fishery managers overseeing the management of these populations. Anecdotal information suggests that the bycatch in the cannonball jellyfish trawl fishery is minimal.

Several pieces of federal legislation have been enacted in recent years to address the issue of bycatch. The Endangered Species Act, the Marine Mammal Protection Act, and the Magnuson–Stevens Fishery Conservation and Management Act all have mandates requiring both users and managers to limit bycatch from recreational and commercial fisheries (Nance 1998). These mandates include reducing bycatch in fisheries that are known to have large volumes of bycatch and determining the level of bycatch in historically unsurveyed fisheries. Although the cannonball jellyfish trawl fishery in Georgia was not a bona fide fishery until 2013, an observer program was initiated during the experimental phase of the fishery. The purpose of this study was to identify the characteristics and composition of targeted and bycatch species in the commercial cannonball jellyfish trawl fishery along the Georgia coast.

METHODS

Data collection.—Between December 2005 and December 2012, fishery observers accompanied commercial fishers involved in the cannonball jellyfish trawl fishery; the fishers were randomly selected from a list of willing participants. All vessels in this study fished a paired configuration of nets, with one net on each side of the vessel. Observers recorded specific information on each net fished, including the length of the headrope (m), mesh size (cm), size of the trawl doors (cm), and the number of floats on the headrope and trawl doors. Most of the fishing activity occurred during daylight hours, although some fishers opted to continue fishing at nighttime if the expected amount of jellyfish had not been caught.

Tow duration was recorded for each trawl and was defined as the amount of time occurring between (1) the moment when the net was fully deployed into the water and the winch was "dogged off"; and (2) the moment when the winch was reengaged and net retrieval began. The GPS coordinates (latitude, longitude) for the beginning and ending of each tow were recorded. The tow speed (km/h) was recorded for each trawl.

Although efforts were made by observers to record information from all tows, this was not always feasible. In some instances, the observers continued to collect information from a previous tow while the next tow was being hauled in.

Depending on the available abundance of jellyfish in the area, the time needed to fill a net to capacity varied. Information on bycatch was recorded from over 90% of all observed tows conducted while the observers were onboard.

All individuals in the bycatch (excluding spider crabs *Libinia* spp.) were identified to the species level, and the total numbers of individuals were recorded for each tow. Initially, attempts were made to quantify the bycatch of spider crabs; however, it was not feasible to accurately quantify all individuals because of the symbiotic relationship between spider crabs and cannonball jellyfish. The total weight of each species in the bycatch was recorded along with individual lengths of up to 30 individuals per species. In the event that protected species were captured, observers (1) evaluated the condition of the animal; (2) attained the necessary measurements for that species; and (3) released the animal back into the water as soon as it appeared physically ready.

For each tow, a subsample of up to 30 cannonball jellyfish was randomly selected for weighing (kg) and for the measurement of individual length (mm). Due to the volume of jellyfish captured during tows, it was not feasible for observers to process total weights of all cannonball jellyfish; therefore, estimates of weight per tow were provided by the fishers.

Fishing methods.—The cannonball jellyfish fishery typically opens in late fall (October–November) in Georgia's territorial waters (0–5.6 km [0–3 nautical miles] offshore) and remains open until late spring (May–June), although minimal fishing effort actually occurs in Georgia waters. The majority of fishing effort takes place in the federal waters adjacent to Georgia (5.6–370.4 km [3–200 nautical miles] offshore), where fishing is allowed year-round. Unless restricted by law, all salt waters in Georgia east of sound demarcation lines and all federal waters adjacent to Georgia are open for the harvest of cannonball jellyfish. Not all offshore waters are conducive to trawling, and jellyfish are not equally distributed among all areas. Consequently, fishers often fished for jellyfish in the same general areas (Figure 1). Furthermore, fishers opted to minimize their traveling distance by fishing in waters nearest to cannonball jellyfish processing or unloading facilities. Because fishers tried to maximize their catches (and subsequent profits) as quickly as possible, opportunities for bias by trawlers altering fishing habits when observers were onboard were minimized.

In accordance with Georgia law, all trawl nets observed in this study were constructed of 10.16-cm (4-in) or larger stretched mesh (OCGA 2014). Nets were constructed of varying materials and headrope lengths, with each net being uniquely rigged (e.g., number of floats on the headrope; number and size of floats on the trawl doors) depending on the vessel. All nets were equipped with several floats on the headrope and doors, which allowed the nets to fish at or near the surface of the ocean; however, fishers did sometimes modify these float configurations to change the fishing location of the net in the water column. Such modifications were made based upon the fishers' observations of cannonball jellyfish while fishing.

Georgia law stipulates that tow duration cannot exceed 30 min in state waters, but there are no restrictions on tow duration in adjacent federal waters. Nonetheless, most of the tows conducted by jellyfish trawl fishers in federal waters do not exceed 45 min. Specific tow durations are dependent upon the abundance of jellyfish in an area and can be less than 5 min if jellyfish are highly abundant.

RESULTS

Observed fishing effort occurred annually during November–May; this is the period when larger jellyfish are most abundant in the coastal waters off Georgia and when over 98% of reported fishing effort occurred during the study. In total, 133 tows were sampled, representing less than 5% of all tows reported by fishers during the study period. Sampled tows were conducted in November ($n = 6$), December ($n = 21$), January ($n = 8$), February ($n = 6$), March ($n = 42$), April ($n = 31$), and May ($n = 19$). Collectively, the observed tows totaled 45.4 h of fishing effort. The number of tows sampled during each trip ranged from 6 to 16 (average = 9.5 tows/trip). Observed tow durations ranged from 0.15 to 1.22 h and averaged 0.55 h. Tow speeds ranged from 3.7 to 7.4 km/h (2 to 4 knots).

Overall, 1,488 individuals from 38 species of finfish and 150 individuals from three species of invertebrates (not including spider crabs) were observed during the study period (Table 1). The Harvestfish was the most commonly observed bycatch species, occurring in 43 of the 133 observed tows and accounting for 41% of the number of individuals across all species observed (Figure 2). The Cownose Ray, Atlantic Bumper, and Butterfish were the next most abundant fish species, each accounting for 11% of individuals across all species observed (Figure 2). Excluding spider crabs, the most abundant invertebrate recorded was the blue crab ($n = 114$ individuals), which occurred in 29 of the 133 tows and represented 7% of individuals across all bycatch species observed (Figure 2). Four protected species ($n = 13$ individuals) were captured during fishing efforts: the bottlenose dolphin, green sea turtle, Kemp's ridley sea turtle, and loggerhead sea turtle (Table 1). Data on size, condition, and other necessary information were recorded for each of these animals.

Of the 677 Harvestfish captured in this study, over 94% were captured during April ($n = 353$) and May ($n = 288$; Table 2). All Atlantic Bumpers captured in this study were observed during April and May (Table 2). Blue crabs were captured during the winter (December) through early spring (March–April), coinciding with the period of blue crab migration to the coastal waters off Georgia for spawning (Table 2).

The total numbers of cannonball jellyfish in each tow were calculated from the sample number collected by observers and expanded to the total weight provided by commercial fishers;

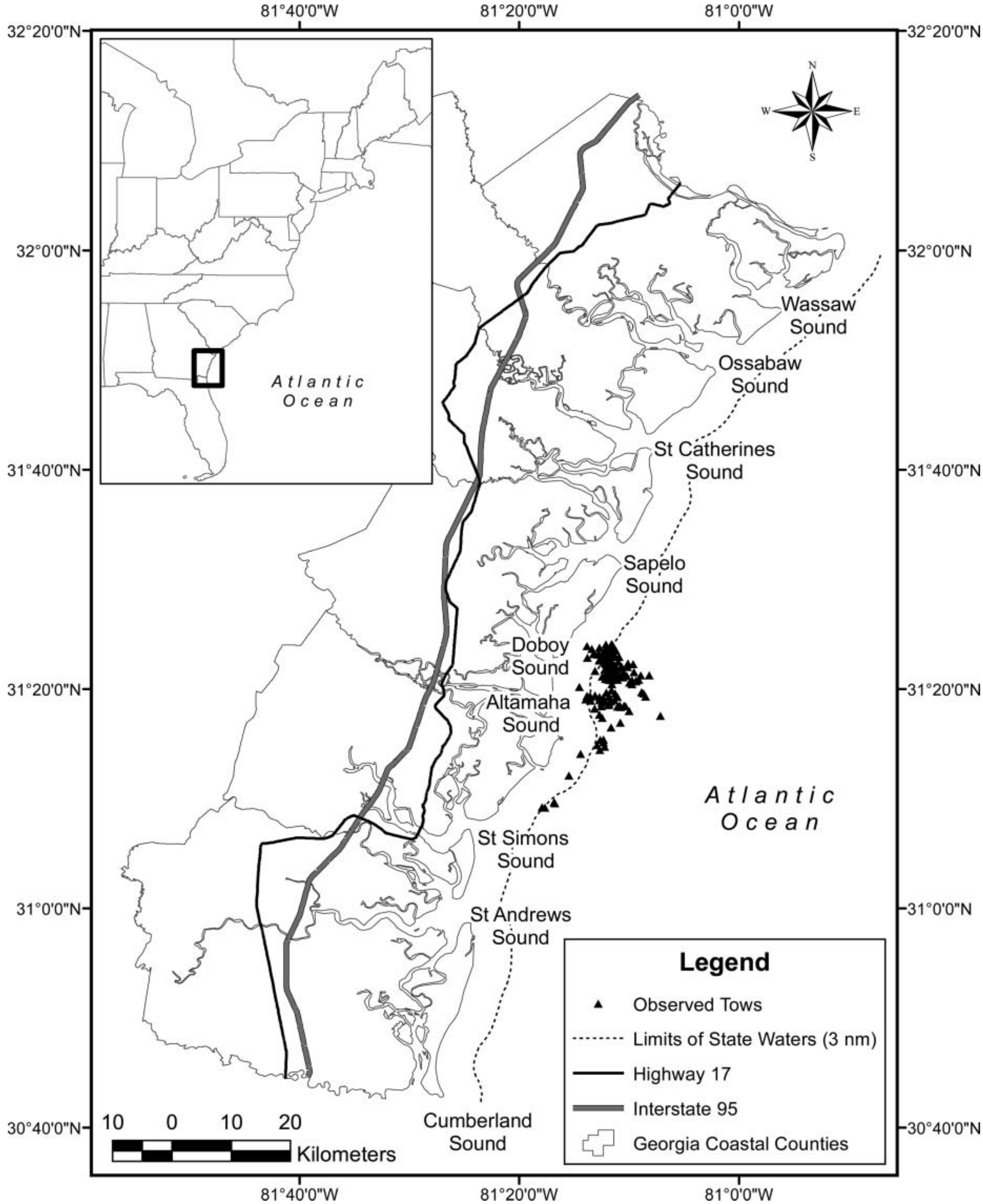

FIGURE 1. Locations of observed trawl tows conducted by commercial cannonball jellyfish vessels along the coast of Georgia.

these estimates were compared with the total number of individuals in the bycatch (all species except spider crabs) recorded for each tow. The jellyfish : bycatch ratio varied by month, with the highest ratios being observed in February (75:1), May (93:1), and November (96:1). A jellyfish : bycatch ratio of 291:1 was calculated for the study period. This ratio suggests that bycatch in the cannonball jellyfish trawl fishery is minimal. Observer notes indicated that 32 of the 133 tows had zero bycatch (excluding spider crabs), further supporting this finding.

TABLE 1. Composition of bycatch (number of individuals) in the commercial cannonball jellyfish trawl fishery in the coastal waters off Georgia between December 2005 and December 2012 (n = 133 tows). Frequency is the number of tows in which the given species was observed. Spider crabs were present but are excluded from the bycatch data. Measurements for nonray fish species are TL or FL, crab species and sea turtles are carapace width (CW), ray species are disc width (DW); no. = number.

Species	Total no. observed	CPUE (no. per tow)	Frequency	Average size (mm)	Maximum size (mm)	Minimum size (mm)	Measurement type
Harvestfish *Peprilus paru*	677	5.09	43	132.11	211	76	FL
Cownose Ray *Rhinoptera bonasus*	185	1.39	20	660.68	1,090	245	DW
Atlantic Bumper *Chloroscombrus chrysurus*	179	1.35	15	152.26	189	83	FL
Butterfish *Peprilus triacanthus*	175	1.32	37	123.72	180	30	FL
Blue crab *Callinectes sapidus*	114	0.86	29	149.15	191	0	CW
Atlantic Moonfish *Selene setapinnis*	56	0.42	12	146.94	193	52	FL
Horseshoe crab *Limulus polyphemus*	34	0.26	11	212.38	305	117	CW
Spanish Mackerel *Scomberomorus maculatus*	30	0.23	11	282.56	426	225	FL
Atlantic Cutlassfish *Trichiurus lepturus*	16	0.12	7	315.70	434	210	TL
Bluefish *Pomatomus saltatrix*	14	0.11	8	266.20	345	155	FL
Atlantic Thread Herring *Opisthonema oglinum*	13	0.10	9	117.38	166	85	FL
Spot *Leiostomus xanthurus*	12	0.09	4	152.45	172	138	TL
Star Drum *Stellifer lanceolatus*	12	0.09	5	98.00	138	68	TL
Atlantic Spadefish *Chaetodipterus faber*	11	0.08	4	116.89	137	105	TL
Bonnethead *Sphyrna tiburo*	11	0.08	5	1,036.00	1,219	759	TL
Atlantic Menhaden *Brevoortia tyrannus*	10	0.08	6	156.75	191	117	FL
Bullnose Ray *Myliobatis freminvillei*	10	0.08	8	644.25	1,185	325	DW
Striped Anchovy *Anchoa hepsetus*	10	0.08	5	83.17	114	53	FL
Atlantic Sharpnose Shark *Rhizoprionodon terraenovae*	9	0.07	4	891.78	946	820	TL
Loggerhead sea turtle *Caretta caretta*	7	0.05	4	592.50	820	480	CW
Bluntnose Stingray *Dasyatis say*	6	0.05	4	274.00	300	248	DW
Bay Anchovy *Anchoa mitchilli*	5	0.04	2	51.00	57	42	FL
Silver Seatrout *Cynoscion nothus*	5	0.04	2	237.80	258	208	TL
Atlantic Silverside *Menidia menidia*	5	0.04	3	77.67	80	75	FL
Atlantic Tripletail *Lobotes surinamensis*	5	0.04	4	356.60	565	244	TL
Southern Eagle Ray *Myliobatis goodei*	4	0.03	3	318.50	340	304	DW
Striped Burrfish *Chilomycterus schoepfi*	4	0.03	2	120.00	128	112	TL
Blacktip Shark *Carcharhinus limbatus*	3	0.02	2	1,875.00	1,930	1,820	TL
Kemp's ridley sea turtle *Lepidochelys kempi*	3	0.02	3	297.33	362	227	CW
Scalloped Hammerhead *Sphyrna lewini*	3	0.02	2	957.50	1,040	875	TL
Common bottlenose dolphin *Tursiops truncatus*	2	0.02	2	N/A	N/A	N/A	TL
Filefishes (Monacanthidae)	2	0.02	1	299.00	299	299	TL
Florida Pompano *Trachinotus carolinus*	2	0.02	1	185.00	185	185	FL
Sandbar Shark *Carcharhinus plumbeus*	2	0.02	1	910.00	910	910	TL
Silver Perch *Bairdiella chrysoura*	2	0.02	2	126.00	126	126	TL
Smooth Butterfly Ray *Gymnura micrura*	2	0.02	2	650.00	650	650	DW
Spotted Eagle Ray *Aetobatus narinari*	2	0.02	1	1,475.00	1,730	1,220	DW
White shrimp *Litopenaeus setiferus*	2	0.02	1	154.00	160	150	TL
Atlantic Stingray *Dasyatis sabina*	1	0.01	1	178.00	178	178	DW
Finetooth Shark *Carcharhinus isodon*	1	0.01	1	1,395.00	1,395	1,395	TL
Green sea turtle *Chelonia mydas mydas*	1	0.01	1	310.00	310	310	CW
Red Drum *Sciaenops ocellatus*	1	0.01	1	905.00	905	905	TL
Sharksucker *Echeneis naucrates*	1	0.01	1	266.00	266	266	TL
Southern Kingfish *Menticirrhus americanus*	1	0.01	1	287.00	287	287	TL
Southern Stingray *Dasyatis americana*	1	0.01	1	156.00	156	156	DW

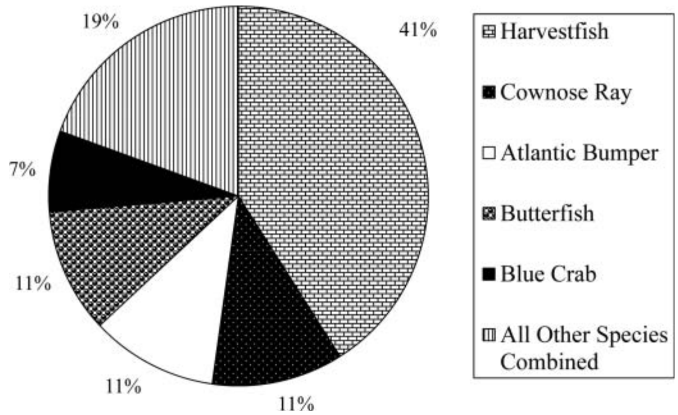

FIGURE 2. Percent contributions of the five most commonly observed bycatch species (by number) in commercial cannonball jellyfish trawls conducted off the coast of Georgia between December 2005 and December 2012 (n = 1,651 individuals): Harvestfish *Peprilus paru*, Cownose Ray *Rhinoptera bonasus*, Atlantic Bumper *Chloroscombrus chrysurus*, Butterfish *Peprilus triacanthus*, and blue crab *Callinectes sapidus*.

Excluding spider crabs, the majority of bycatch encountered in fishing efforts were returned to the sea. For protected species that were encountered during fishing activities (e.g., sea turtles), necessary steps were taken to ensure that the animals were viable prior to their release. The mortality or survival rate of bycatch species after they were returned to the water was not quantified during this study.

DISCUSSION

The seasonality exhibited by cannonball jellyfish dictated when fishing efforts occurred, thus influencing the composition of bycatch associated with the fishery. Krauter and Setzler (1975) and Rountree (1983) studied and described the seasonal movements of cannonball jellyfish. Those authors reported that juvenile cannonball jellyfish are typically found in greatest abundance during summer (July) within creeks and rivers and then move toward larger water bodies during late summer as they grow. Large numbers of medium-sized cannonball jellyfish move offshore into traditional shrimp trawling grounds in the nearshore waters off Georgia by late October to early November (Krauter and Setzler 1975). By December, minimal numbers of jellyfish were found in either study, although Krauter and Setzler (1975) reported that large concentrations of jellyfish were observed in the offshore waters of Florida. Krauter and Setzler (1975) did not determine whether these large concentrations were the result of southward movement by Georgia populations or offshore movement by Florida populations; however, Rountree (1983) observed similar southerly migrations in the fall. Krauter and Setzler (1975) and Rountree (1983) found that populations of large cannonball jellyfish occurred in offshore waters during spring (March), remaining there until they moved nearer to estuarine waters during late spring or early summer (May–June). The seasonal abundance and occurrence of cannonball jellyfish in offshore fishing grounds during late fall to spring cause all fishing effort to occur at that time, including the trawl tows examined in this study. Consequently, the characterization of bycatch observed in the cannonball jellyfish trawl fishery may also be impacted by the abundance of bycatch species available during late fall to spring.

The most common species observed in this commercial fishery were the Harvestfish, Cownose Ray, Atlantic Bumper, Butterfish, and blue crab. The occurrence of these species can be attributed in part to their ecology or life history characteristics. Harvestfish, Atlantic Bumpers, and Butterfish are pelagic as juveniles, whereas Cownose Rays and blue crabs are not. However, Cownose Rays frequent oceanic waters, particularly when engaged in schooling activities. Similarly, blue crabs swim and spawn in oceanic waters (Van Den Avyle and Fowler 1984) where fishing is occurring. During cannonball jellyfish trawling efforts, most nets are towed at or near the ocean's surface. Consequently, species such as these are potentially more susceptible to capture due to their position in the water column.

In addition to being pelagic, juveniles of the Harvestfish, Atlantic Bumper, and Butterfish are known to associate with jellyfish (Rountree 1983). Rountree (1983) found that these species, along with other finfishes (e.g., Planehead Filefish *Stephanolepis hispidus* and Crevalle Jack *Caranx hippos*), were commonly observed with cannonball jellyfish. Mansueti (1963) suggested that Harvestfish may use jellyfish medusae for protection from various predators, but Rountree (1983) found that Harvestfish gradually become ectoparasites and eventually begin consuming their jellyfish hosts. Purcell and Arai (2001) reported that as the juvenile Harvestfish grow, they begin to consume parts of the medusae, potentially even stealing food from the jellyfish. Similarly, Atlantic Bumpers (Phillips et al. 1969) and Butterfish (Duffy 1988) also appear to have a commensal relationship with jellyfish, as juvenile fish utilize the jellyfish for shelter and protection from predators. Shanks and Graham (1988) concluded that Atlantic Bumpers consume prey that are stunned by cannonball jellyfish, whereas Rountree (1983) suggested that the association of Atlantic Bumpers with this jellyfish species may be the result of jellyfish movement and location during certain times of the year. Rountree (1989) also revealed that many of these pelagic species associate not only with jellyfish but with other forms of marine biota, including *Sargassum*, drifting seaweeds, and various floating materials. As a result of these known symbiotic relationships, it is not surprising that Harvestfish, Atlantic Bumpers, and Butterfish were more commonly encountered than other finfish species as bycatch during jellyfish trawling activities.

Species abundance was predicted to be a major factor in which species would occur as bycatch. Not surprisingly, each of the top-five bycatch species observed are common in Georgia, particularly during the time of year when trawling occurs (late

TABLE 2. Composition of the bycatch (number of individuals by month) in the commercial cannonball jellyfish trawl fishery in the coastal waters off Georgia between December 2005 and December 2012. Spider crabs were present but are excluded from the bycatch data.

Species	Total number of individuals (all months)	Number of individuals by month						
		Jan	Feb	Mar	Apr	May	Nov	Dec
Harvestfish	677			16	353	288	12	8
Cownose Ray	185			73	54	10	46	2
Atlantic Bumper	179				117	62		
Butterfish	175			11	32	80		52
Blue crab	114			48	4			62
Atlantic Moonfish	56				13	40	2	1
Horseshoe crab	34			2			2	30
Spanish Mackerel	30			5	15	10		
Atlantic Cutlassfish	16		2	1		10		3
Bluefish	14		2		10	2		
Atlantic Thread Herring	13			1	8	2		2
Spot	12					10		2
Star Drum	12				10	2		
Atlantic Spadefish	11				11			
Bonnethead	11				5	6		
Atlantic Menhaden	10	4			4	2		
Bullnose Ray	10			6	2		2	
Striped Anchovy	10				5			5
Atlantic Sharpnose Shark	9				1	8		
Loggerhead sea turtle	7			3	2	2		
Bluntnose Stingray	6				2	4		
Bay Anchovy	5			1	4			
Silver Seatrout	5				5			
Atlantic Silverside	5		4	1				
Atlantic Tripletail	5			5				
Southern Eagle Ray	4			4				
Striped Burrfish	4						4	
Blacktip Shark	3			1		2		
Kemp's ridley sea turtle	3			1	2			
Scalloped Hammerhead	3			1		2		
Common bottlenose dolphin	2			1	1			
Filefishes	2				2			
Florida Pompano	2					2		
Sandbar Shark	2					2		
Silver Perch	2				1			1
Smooth Butterfly Ray	2			1	1			
Spotted Eagle Ray	2			2				
White Shrimp	2						2	
Atlantic Stingray	1							1
Finetooth Shark	1			1				
Green sea turtle	1			1				
Red Drum	1				1			
Sharksucker	1			1				
Southern Kingfish	1				1			
Southern Stingray	1							1

fall to spring). Such findings suggest that seasonality also impacts the species composition of the bycatch in this fishery. Other pelagic species are equally as common or perhaps more common in the waters off Georgia, but they are not frequently captured in this fishery. For example, Rountree (1983) and Kondo et al. (2014) reported that many juvenile carangids associate with jellyfish. Several members of the Carangidae family (e.g., Florida Pompano, Crevalle Jack, Horse-eye Jack *Caranx latus*, etc.) are known to commonly inhabit the open waters off Georgia but are rarely, if ever, captured as bycatch in the cannonball jellyfish trawl fishery. The absence of some carangids from the bycatch during this study may be attributable to their ability to escape the net, as most are strong swimmers; factors such as seasonal abundance and availability may also have an effect. Fishery-independent data collected by the Georgia Department of Natural Resources suggest that most juvenile jacks and pompanoes occur in Georgia waters during the late-spring through summer months, near the end of or outside of the normal jellyfish fishing season. Thus, their occurrence as bycatch in the fishery could increase if the fishery were to operate later in the spring, summer, or early fall months.

Although it was not feasible to quantify the number of spider crabs occurring in each tow, observer notes indicated that spider crabs were undoubtedly the most common bycatch species captured in this fishery. The frequent and common occurrence of spider crabs is unsurprising, however, as these species have a well-documented symbiotic relationship with cannonball jellyfish. Moyano et al. (2012) described the relationship between spider crabs and jellyfish in South America. In North America, juvenile spider crabs are known to use the cannonball jellyfish as a host for both shelter and food (Rountree 1983). Although early observations by Corrington (1927) and Gutsell (1928) suggested a commensal relationship in which spider crabs do not negatively impact cannonball jellyfish, studies by Shanks and Graham (1988) demonstrated that a spider crab does indeed consume its host, as evidenced by examination of cardiac stomach contents from sampled spider crabs. Shanks and Graham (1988) further noted that 20–80% of observed cannonball jellyfish had spider crabs inside their bells, suggesting that spider crabs are fairly tolerant of the chemical defenses employed by the jellyfish. Rountree (1983) found that 63% of cannonball jellyfish harbored spider crabs, although the association was highly seasonal (ranging from 0% in October to 95% in July). Rountree (1983) further concluded that the number of crabs per medusa declined as the jellyfish population increased in the fall.

From a fisheries management perspective, at least two conclusions can be drawn from the results of this study. First, bycatch associated with the commercial cannonball jellyfish trawl fishery in Georgia is dominated by a few recurring species and is minimal relative to the bycatch associated with another important trawl fishery in the state—namely the commercial food shrimp trawl fishery. The top-five bycatch species combined (n = 1,330) comprised 80.5% of all individuals recorded (n = 1,651; across species, excluding spider crabs) during this study. As a result, the remaining 33 species comprised only 19.5% of the overall bycatch observed. The CPUEs calculated for the top-five species observed as bycatch in Georgia's commercial shrimp trawl fishery ranged from 25 to 557 individuals per trawl-hour (Page et al. 2004), whereas the CPUEs for the top-five bycatch species in the cannonball jellyfish trawl fishery ranged from 0.86 to 5.09 individuals per trawl-hour (present study; Table 1).

Although CPUEs are relatively low for bycatch species in the jellyfish trawl fishery, the potential still exists for at least some of these species to be harvested in large quantities. Three of the most common bycatch species observed in this study (the Harvestfish, Butterfish, and blue crab) are commercially harvested along the Atlantic coast. Of these, only blue crabs are commercially harvested in Georgia. Harvestfish are commercially harvested in the inshore waters of eastern Florida and are then exported to Japan for human consumption (Haedrich 2010). Similarly, Butterfish are harvested for human consumption, with most fishing effort occurring north of Cape Hatteras, North Carolina (MAFMC 1978). Consequently, the common occurrence of these species, particularly Harvestfish and Butterfish, as bycatch in the fishery could be of concern. However, although both species are known to exhibit migratory patterns, most of their migration involves movement from offshore to inshore; thus, it is unlikely that individuals captured in the marine waters off Georgia would be migrating to the commercial fishing grounds off Florida or Cape Hatteras. Furthermore, annual harvest totals in 2012 along the Atlantic coast exceeded 110,223 kg (243,000 lb) for Harvestfish and 725,747 kg (1.6 million lb) for Butterfish (NMFS 2014), and thus the incidental take of these species by the few vessels (currently $\leq$ 12) engaged in cannonball jellyfish trawling off Georgia would likely result in minimal impact to the populations of either species.

Efforts to fully quantify the amount of spider crabs captured during this study proved to be impracticable. However, observer notes suggested that a large quantity of spider crabs was captured during fishing activities; therefore, the common occurrence of these species in the bycatch could be of concern. Spider crabs are not considered to be commercially or recreationally important in Georgia, but they are ecologically important, serving as prey for multiple marine animals. Stachowicz and Hay (1999) observed that juvenile spider crabs were preyed upon by larger fishes, including Pinfish *Lagodon rhomboides*, juvenile Gags *Mycteroperca microlepis*, and Oyster Toadfish *Opsanus tau*. Kemp's ridley sea turtles have also been observed to eat spider crabs (GADNR 1999). Consequently, the frequent capture of spider crabs during jellyfish trawling activities could negatively impact those species that rely upon spider crabs as a food source. However, it is believed that such impacts to these species would be minimal, as spider crabs are known to constitute a small portion of their diets. Perhaps the greatest potential impact of the incidental harvest of spider crabs would be on the species' own populations. Currently, no information exists on the stock status of spider crabs in the South Atlantic; thus, the potential effects of jellyfish harvest on spider crab populations in this area are unknown. These implications would need to be examined and verified through fishery-independent spider crab population surveys performed by fishery managers.

A second conclusion is that current and additional management strategies, including the continued use of fishery observers and the monitoring of protected species encountered as bycatch in this fishery, should occur. Currently, the majority of cannonball jellyfish trawl fishing effort occurs in federal waters eastward of Georgia's territorial waters. This is due to differing gear requirements in state waters versus federal waters. In Georgia's territorial waters, fishery managers took pro-active measures to require the use of turtle excluder devices (TEDs) approved by the National Marine Fisheries Service to provide protection for threatened or endangered species should they be encountered during fishing activities. Fishers have long expressed concerns and frustrations over the negative impacts of the TED, which has a maximum bar spacing of 10.16 cm (4 in), on the retention of jellyfish; fishers contend that such TEDs reduce both the quantity and size of cannonball jellyfish harvested. Such reductions are not surprising, however, since the "Georgia Jumper" TED was originally invented in the late 1960s to exclude cannonball jellyfish from shrimp nets (Murphy et al. 2006). Because larger-sized jellyfish are typically more marketable, valuable, and desired in the Asian market, their exclusion can have significant financial consequences. Therefore, most fishers opt to exclusively fish in the federal waters adjacent to Georgia, where TEDs are not required. All species of concern captured during this study were encountered in federal waters. In an effort to address the concerns of fishers and to curtail their continued reluctance to use TEDs, fishery managers in Georgia are working with fishers to design, evaluate, and potentially certify new or modified TED designs that could increase cannonball jellyfish retention in nets while adequately excluding sea turtles and other species of concern. The ongoing evaluation of this and other regulations by fishery managers is critical for pursuing a balance between the desires and needs of fishers and the sustainability of fishery and natural resources.

Additionally, fishery managers must continue to seek management strategies that ensure the sustainability of the cannonball jellyfish population. Such strategies include (1) developing and enhancing existing surveys to monitor the abundance of cannonball jellyfish in the coastal waters of Georgia and (2) monitoring the levels of exploitation incurred by the cannonball jellyfish population. Although cannonball jellyfish are often considered a nuisance by beachgoers and shrimp fishers alike, they do have important roles in planktonic and benthic assemblages, and significant cascade effects may result if exploitation levels are not properly managed (Kingsford et al. 2000). Current levels of exploitation do not appear to have a negative impact on the jellyfish population, but continued growth of the fishery is certainly plausible. Therefore, the potential exists for unsustainable exploitation of cannonball jellyfish to eventually occur if the fishery is not given proper oversight.

The demand for jellyfish does not appear to be waning, and because jellyfish have been exploited along the coasts of China for over 1,000 years (Omori and Nakano 2001), it is likely that the fishery will continue and perhaps expand in the near future. Such growth could include expansion of fishing efforts into other states along the Atlantic coast. Thus, the use of fishery observers and the continued examination of management strategies employed in this fishery are needed to ensure adequate data collection.

In summary, the major findings of this research are as follows. In the commercial cannonball jellyfish trawl fishery, a few recurring species dominate the bycatch. Most of these species are pelagic in nature and are known to associate with cannonball jellyfish, and many are abundant during the late-fall–spring period when fishing is occurring. Although the number of observed tows conducted during this study was low relative to the overall number of reported trips during the same period ($<5\%$ of tows were observed), the information collected in this study does provide resource managers with foundational knowledge to better understand the occurrence of some common bycatch species encountered in Georgia's commercial cannonball jellyfish trawl fishery. The information gained here supports the need for continued and expanded examination of the species captured in this fishery (i.e., target and bycatch species) to assess the long-term potential impacts on these species and ensure the sustainability of their populations.

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