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ARTICLE

Characterization of the Bycatch in the Commercial Blue Crab Pot Fishery in Georgia, November 2003–December 2006

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Abstract
Bycatch studies have been conducted in many fisheries in Georgia, but none has focused on the commercial pot fishery for blue crab *Callinectes sapidus*. The purpose of this study was to identify abundance and seasonality of finfish and invertebrate bycatch species in the commercial blue crab fishery in Georgia. Between November 2003 and December 2006, observers accompanied volunteer commercial blue crab fishers randomly selected from a list of willing participants. A total of 91 trips were observed, with 5,707 commercial blue crab pots sampled. Soak times, or fishing effort, ranged from 24 to 168 h, averaging 55.8 h/trap for each trip. The number of traps sampled each trip ranged from 5 to 163, with a mean of 62.7 traps per trip. We collected 306 finfish and 4,972 invertebrates in this study period. The most numerous finfish were Southern Flounder *Paralichthys lethostigma* (n = 52), Atlantic Spadefish *Chaetodipterus faber* (n = 50), Oyster Toadfish *Opsanus tau* (n = 50), Hardhead Catfish *Ariopsis felis* (n = 46), and Southern Kingfish *Menticirrhus americanus* (n = 37). The most numerous invertebrates species were hermit crabs *Pagurus* spp. (n = 2,341), spider crabs *Libinia* spp. (n = 532), stone crabs *Menippe mercenaria* (n = 438), channeled whelk *Busycon canaliculatum* (n = 1,570), and knobbed whelk *Busycon carica* (n = 25). The similarity of bycatch by season was compared using a Morisita similarity index, and results were that Southern Flounder, Atlantic Spadefish, Oyster Toadfish, spider crabs, channeled whelk, and stone crabs varied seasonally. Of all species observed, we conclude that channeled whelk populations may be impacted by this fishery.

The blue crab *Callinectes sapidus*, a member of the Portunidae family, is a common swimming crab commercially and recreationally targeted in several states along the eastern U.S. seaboard, including Georgia. A popular food item, the species is often sold live to various restaurants, processing facilities, or individual consumers. Fishermen may employ any of several gear types to harvest the species, though most commercial crabbers in Georgia utilize pots to harvest blue crabs. While the number of commercial crabbers in Georgia has declined in recent years (totaling < 150 annually), the blue crab fishery remains extremely

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important, currently serving as Georgia's largest commercial fishery in terms of volume (kg) landed and second-largest fishery in terms of economic value behind the penaeid food shrimp fishery. In addition to catching blue crabs, crabbers have reported capturing nontarget species in their pots, including multiple whelk species, which may be retained for personal consumption or offered for commercial sale. The reporting of these nontargeted species, termed "bycatch," has raised questions as to what other bycatch species are encountered in blue crab pots.

Bycatch has been an issue of concern for many fisheries throughout the world, including the southeastern USA (Rogers et al. 1997; Crowder and Murawski 1998). Virtually all fisheries conducted in the South Atlantic Bight produce unwanted catch to some degree, and the volume and composition of bycatch varies by fishery. The ecological and economic implications resulting from such nontargeted catch also vary by fishery. The ecological implications of harvesting bycatch include the potential of negatively impacting finfish and invertebrate species, some of which may be protected. The economic implications of bycatch include increased expenses for adequate species protection, additional costs for modifying gear to reduce unwanted catch, and lost fishing time sorting the catch.

Bycatch studies have been conducted in many fisheries throughout the world, including those utilizing various nets (trawl, gill, seine, etc.) and traps. For example, Favaro et al. (2010) studied bycatch in the trap fishery for spot prawn *Pandalus platyceros* in British Columbia. With regards to bycatch studies in the southeastern USA, perhaps no other fishery has been studied more than the commercial shrimp trawl fishery. The effects and composition of bycatch from large shrimp trawls have been studied in detail (Wallace and Robinson 1994; Ortiz et al. 2000; Baum et al. 2003; Diamond 2003); alternatively, the bycatch of the commercial blue crab pot fishery in Georgia has not. While these two fisheries utilize different gears, the marine waters in which they often fish 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 commercial blue crab pot fishery is minimal and consists primarily of invertebrates, though characterization and quantification of such bycatch has yet to be conducted. Work has been conducted in multiple states, including Georgia, on the bycatch of diamondback terrapins *Malaclemys terrapin* in commercial blue crab traps, primarily through investigating gear modifications to reduce their capture (Bishop 1983; Seigel and Gibbons 1995; Guillory and Prejean 1998; Belcher and Sheirling 2004).

Seasonal residence time is a critical factor to consider when determining the species composition of bycatch in a fishery. Many marine species, such as migratory sharks, inhabit an area only seasonally and are not available for harvest outside that migratory period (Carlson and Brusher 1999). Therefore, the impact on these animals may be narrowed to a specific window of time. Annual residence periods may be determined with the use of long-term monthly surveys designed to examine species presence and abundance, such as the monthly trawl survey conducted by the Georgia Department of Natural Resources (GADNR; Page et al. 2004). Southern Flounder *Paralichthys lethostigma* were observed in GADNR trawl data in each of the four seasons, though Wenner and Archambault (2005) concluded that seasonal movements for this species did occur and were directly related to life stage. Southern Flounder occurred in nearshore shallow coastal waters during warm months and migrated offshore in colder months. Oyster Toadfish *Opsanus tau* were also observed year-round by Mensinger et al. (2001) and in GADNR trawl data. Atlantic Spadefish *Chaetodipterus faber* were determined to occur year-round by Robins (1992), though they did not occur in GADNR trawls in the winter months. Southern Kingfish *Menticirrhus americanus* have been observed to occur during all four seasons by GADNR trawl data and by Hildebrand and Cable (1934) and Shealy et al. (1974). Hardhead Catfish *Ariopsis felis* migrate to offshore waters in winter with decreasing water temperatures (Muncy and Wingo 1983), although GADNR recorded the species in trawls in shallow coastal waters during the summer, fall, and winter. Residence time within a fished area will affect the potential period during which species will be collected as 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 commercial and recreational fisheries (Nance 1998). These mandates include pursuing the reduction of bycatch in fisheries known to have large volumes of bycatch (e.g., shrimp fishery) and determining the level of bycatch in historically unsurveyed fisheries (e.g., blue crab fishery). An observer program was initiated in 2003 in response to these mandates to collect fishery-dependent data on bycatch in the commercial blue crab pot fishery from willing participants. Data from this fishery-dependent observer program will be presented in this manuscript. The purpose of this study was to identify bycatch species composition in the commercial blue crab pot fishery in Georgia and to determine if seasonal differences in species composition exist.

METHODS

Between November 2003 and December 2006, observers accompanied volunteer commercial blue crab fishers randomly selected from a list of willing participants. The fishery is open year-round in Georgia, and, when possible, at least 1 trip/month was conducted (Table 1). Unless restricted by law, all salt waters in Georgia are open for the harvest of blue crabs. Consequently, efforts were made to conduct trips in each of the six coastal Georgia counties (Chatham, Bryan, Liberty, McIntosh, Glynn, and Camden) in many of the waters associated with Wassaw, Ossabaw, St. Catherines, Sapelo, Altamaha, St. Simons, St. Andrews, and Cumberland sounds (Figure 1). While crabbers in Georgia are not assigned leased grounds or fishing areas, most choose and claim their fishing area on a "first-come, first-served" basis, remaining in that area until decreased catches warrant

TABLE 1. Total number of trips conducted in Georgia onboard commercial blue crab vessels between November 2003 and December 2006 ($n = 91$); blanks represent months without sampling.

	Year			
Month	2003	2004	2005	2006
Jan				
Feb		3		2
Mar		1		
Apr		4		1
May		5	1	8
Jun		2		7
Jul		7	2	8
Aug			1	8
Sep				6
Oct		2	1	6
Nov	1		1	5
Dec		1	1	7
Total	1	25	7	58

relocation to a new site. Because crabbers stay in one location and observer trips typically occurred within 24 h of contacting participating crabbers, opportunities for bias by crabbers altering fishing habits when observers were onboard were minimized.

Standard blue crab pots—defined as being constructed of wire material with a minimum 2.54-cm mesh, having a single float attached to them, and not exceeding 0.6096 × 0.6096 m in dimension—were used in this study. Each trap had four openings, or funnels, by which animals could enter the pot. A single funnel (width measuring approximately 12.7 cm) was located on each side of the pot. Pots were baited, Atlantic Menhaden *Brevoortia tyrannus* being the preferred bait of most commercial crabbers. Most fishing activity occurred during daylight hours, though some crabbers opted to fish at nighttime in the summer months when the potential for excessive daytime heat threatened to increase mortality on harvested crabs.

Soak times or fishing effort, defined as the amount of time traps fished prior to the final check, were obtained from each crabber. Though Georgia law does not stipulate the amount of time blue crab pots may fish, or soak, most crabbers allow pots to soak for 24–48 h. Global Positioning System coordinates (latitude–longitude) for each trap fished were recorded from each trip. Though efforts were made by observers to record information from all traps fished by crabbers, time constraints prevented this from being feasible in every scenario. In some instances, observers were continuing to work up information from a previous trap when the next trap was being hauled in. Because some traps were in areas heavily influenced by tide and time was of the essence in getting traps checked as quickly as possible, it was not always feasible to record information from every trap. However, information on bycatch was recorded from over 90% of all traps fished. Finfish and whelk bycatch were identified to the species level, and total numbers of individuals were recorded for each trap. For other species (e.g., crabs), individuals were identified to the species level when possible and total numbers were recorded for each trap. Although disposition of bycatch not kept for commercial harvest was not quantified, observers noted that the majority of bycatch was returned to the water alive. A daily CPUE ± SD was calculated and defined as the total number of individuals of a species harvested per trap hour, determined by soak times. Surface hydrographic data (surface water temperature, salinity, and dissolved oxygen) were recorded using a YSI 85 meter (Yellow Springs, Yellow Springs, Ohio) for a random sample of traps during each observed trip. Participating commercial fishers were compensated US$75 for daily costs of each completed trip with observers onboard. This fee is comparable to other observer programs currently operating in the South Atlantic Bight.

Seasons were defined according to the celestial calendar, specifically utilizing dates associated with the two solstice and two equinox periods. The similarity of bycatch by season was compared using a Morisita similarity index. The computation of a season matrix containing similarity indices provides insight into the overall similarity of seasons while incorporating all species observed. Of the various similarity measures available, the Morisita index was chosen because it is not dependant on sample size (Krebs 1989). Specifically, this index measures the probability that an individual drawn from two different seasons will belong to the same species divided by the probability that two individuals drawn from either season will belong to the same species (Krebs 1989). The Morisita index varies from 0 to 1, values close to 0 indicating no similarity and values close to 1 indicating strong similarity. This index provides information regarding insight into seasonal differences for multiple species collectively but does not provide results for individual species; statistical results are not generated by this index.

Daily CPUE calculations were made to determine variability within species by season. Data were examined for normality and, when applicable, examined for homogeneity of variance. Summary statistics of these calculations were examined to determine if the data were normal or nonnormal. Data were considered to be nonnormal based on high values of skewness and kurtosis; thus, data transformations (e.g., $\log_{10}$ transformations, inverse transformations, square-root transformations) were attempted to correct the issue. The resulting skewness and kurtosis values for the transforms still failed to indicate normality, so rank transformations were applied. In addition, small sample sizes and violations of homogeneity of variance lead to the application of rank transformations to the data. Rank transformations allow for nonparametric analysis of the data, which releases the assumption of normality. Ranks were determined by first sorting the data and then ranking observations from lowest to highest. If observations were found to be equal (i.e., tied), an average rank was applied to those values. Spearman correlation coefficients were calculated

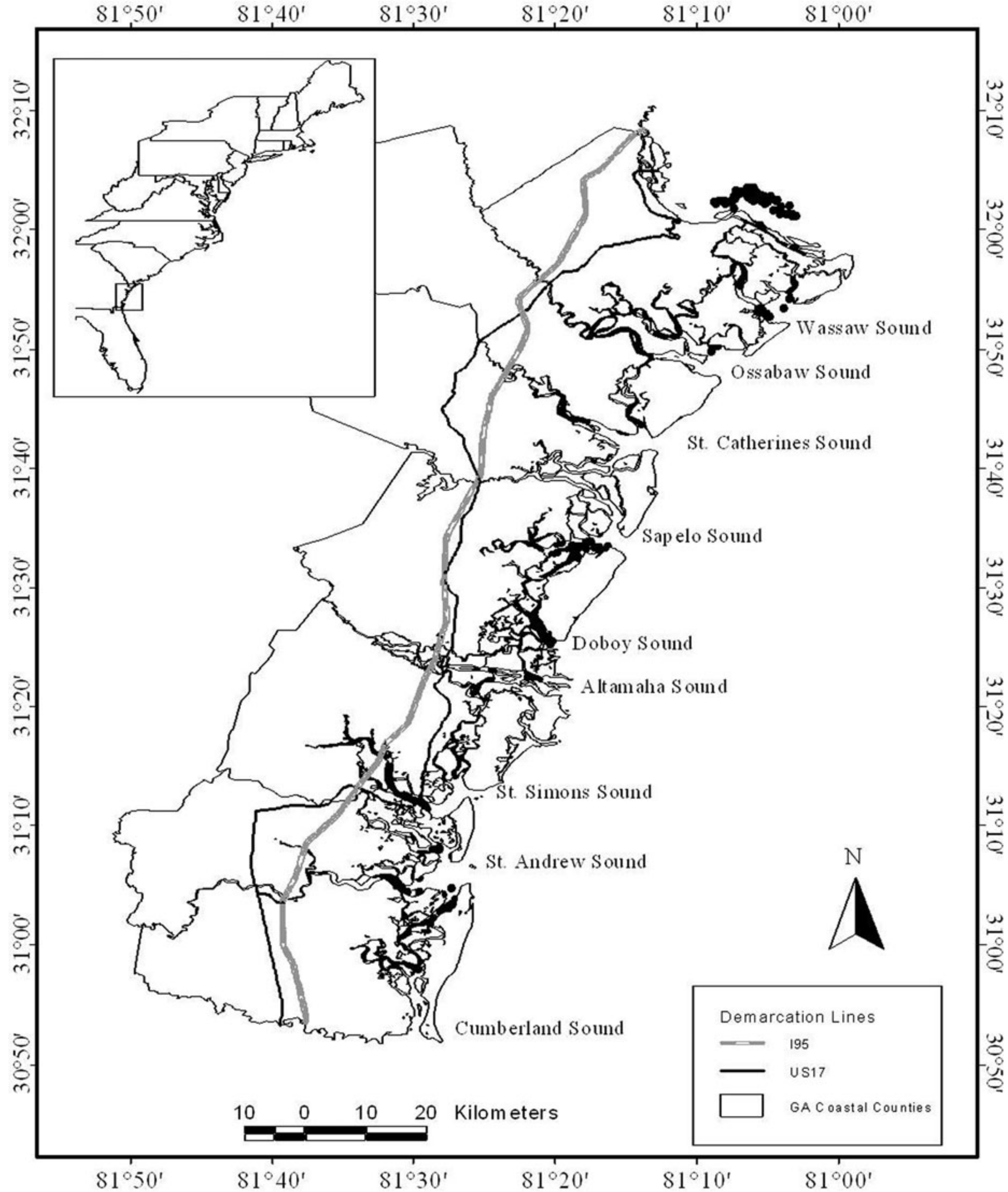

FIGURE 1. The coast of Georgia indicating the county lines for the six coastal counties and the location of all of Georgia's sounds.

between species and indicated if MANOVA or ANOVA should be utilized. An ANOVA ($\alpha = 0.05$) was chosen and performed in SAS on rank-transformed data due to a small number of significant and strong correlations, defined as Rho $\geq$0.75 (Zar 1999). The ANOVA was performed to support or reject the occurrence of seasonal variation for these species. Results of *p*-values ($P < 0.05$) generated from the ANOVA supported or rejected significance of seasonality by species, seasonal variation occurring for *P*-values < 0.05. For those species with seasonal variation, a Student–Newman–Keuls (SNK) multiple-comparison test was conducted to determine specifically which seasons varied. Of the various multiple-comparison tests, including Duncan's and

TABLE 2. Finfish composition of bycatch (combined and by season) in the commercial blue crab pot fishery in Georgia between November 2003 and December 2006.

Species	Number of individuals (all seasons)	Number of individuals (spring)	Number of individuals (summer)	Number of individuals (fall)	Number of individuals (winter)
Southern Flounder *Paralichthys lethostigma*	52	20	28	4	0
Atlantic Spadefish *Chaetodipterus faber*	50	20	23	7	0
Oyster Toadfish *Opsanus tau*	50	25	17	8	0
Hardhead Catfish *Ariopsis felis*	46	7	39	0	0
Southern Kingfish *Menticirrhus americanus*	37	14	15	8	0
Channel Catfish *Ictalurus punctatus*	18	0	18	0	0
Sheepshead *Archosargus probatocephalus*	9	2	3	4	0
Spotted Hake *Urophycis regia*	8	8	0	0	0
White Catfish *I. catus*	8	0	0	8	0
Hogchoker *Trinectes maculatus*	4	2	2	0	0
Summer Flounder *P. dentatus*	4	4	0	0	0
Atlantic Stingray *Dasyatis sabina*	3	2	1	0	0
Blennies *Hypleurochilus* spp.	2	2	0	0	0
Crevalle Jack *Caranx hippos*	2	0	2	0	0
Spot *Leiostomus xanthurus*	2	1	1	0	0
Atlantic Sharpnose Shark *Rhizoprionodon terraenovae*	1	1	0	0	0
Bank Sea Bass *Centropristis ocyurus*	1	0	0	1	0
Blackedge Cusk-eel *Lepophidium brevibarbe*	1	0	1	0	0
Black Sea Bass *Centropristis striatus*	1	0	0	1	0
Fringed Flounder *Etropus crossotus*	1	0	1	0	0
Pinfish *Lagodon rhomboides*	1	0	1	0	0
Silver Perch *Bairdiella chrysoura*	1	1	0	0	0
Skilletfish *Gobiesox strumosus*	1	0	0	1	0
Southern Hake *U. floridana*	1	1	0	0	0
Southern Stingray *D. americana*	1	0	1	0	0
Striped Burrfish *Chilomycterus schoepfi*	1	1	0	0	0
Total	306	111	153	42	0

Tukey's, the SNK was chosen because of its average ranking for both power and type I error rate (Dowdy and Wearden 1983).

RESULTS

We logged 91 trips during this study, resulting in 5,707 sampled traps representing 5,077 h of fishing effort. Soak times ranged from 24 to 168 h, averaging 55.8 h per trap for each trip. The number of traps sampled each trip ranged from 5 to 163, with a mean of 62.7 traps per trip.

We observed 306 finfish from 26 species in crab traps over the 3-year study as outlined in Table 2. Southern Flounder was the most commonly observed species, accounting for 17% in number (Figure 2) of all finfish observed, and had a daily mean CPUE of 0.0075 ± 0.0308 fish/trap-hour. Atlantic Spadefish and Oyster Toadfish were the next most-abundant fish species, with a CPUE of 0.0057 ± 0.0151 and 0.0061 ± 0.0127 fish/trap-hour,

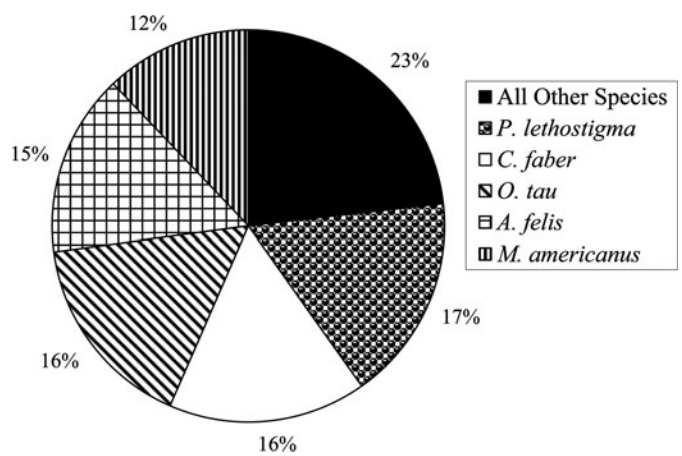

FIGURE 2. Percent contribution of the five most commonly observed finfish species in commercial blue crab traps in Georgia between November 2003 and December 2006 ($n = 306$).

TABLE 3. Species composition by season of invertebrate bycatch species observed in the commercial blue crab pot fishery from November 2003 to December 2006.

Species	Number of individuals (all seasons)	Number of individuals (spring)	Number of individuals (summer)	Number of individuals (fall)	Number of individuals (winter)
Hermit crabs *Pagurus* spp.	2,341	822	637	822	60
Channeled whelk *Busycon canaliculatum*	1,570	228	7	575	760
Spider crabs *Libinia* spp.	532	56	4	12	460
Stone crabs *Menippe mercenaria*	438	184	164	88	2
Knobbed whelk *B. carica*	25	12	1	7	5
Diamondback terrapins *Malaclemys terrapin*	24	20	2	2	0
Lesser blue crabs *Callinectes similis*	14	13	0	0	1
Atlantic mud crab *Panopeus herbstii*	14	9	4	1	0
Lightning whelk *B. sinistrum*	8	8	0	0	0
Cannonball jellyfish *Stomolophus meleagris*	1	1	0	0	0
Horseshoe crab *Limulus polyphemus*	1	0	0	0	1
Iridescent swimming crab *Portunus gibbesii*	1	0	0	1	0
Jellyfishes *Chrysaora* spp.	1	0	1	0	0
Starfishes *Luidia* spp.	1	0	0	1	0
White shrimp *Litopenaeus setiferus*	1	0	0	1	0
Total	4,972	1,353	820	1,510	1,289

respectively. Hardhead Catfish, the fourth most-common species, had a CPUE of 0.0036 ± 0.0213 fish/trap-hour. Southern Kingfish had a CPUE of 0.0037 ± 0.0083 fish/trap-hour.

We observed 4,972 invertebrates (Table 3). Of these, hermit crabs *Pagurus* spp. ($n = 2{,}341$) were the dominant invertebrate recorded and represented 47% in number of all invertebrates logged (Figure 3). The number of hermit crabs observed in traps ranged from 0 to 43, and collectively the species had a CPUE of 0.2852 ± 0.0813 crabs/trap-hour. Channeled whelks *Busycon canaliculatum* ($n = 1{,}570$) had a CPUE of 0.1933 ± 0.0637 individuals/trap-hour, while spider crabs *Libinia* spp. ($n = 532$) had a CPUE of 0.1002 ± 0.0618 individuals/trap-hour. A total of 438 stone crabs *Menippe mercenaria* were observed for a CPUE of 0.0493 ± 0.0077 crabs/trap-hour. The knobbed whelk *Busycon carica* ($n = 25$) accounted for only 1% in number of all invertebrates logged and had a CPUE of 0.0036 ± 0.0016 whelks/trap-hour. Compared with finfish, invertebrate CPUE calculations were higher for four of the top five invertebrate species than for any of the finfish species, though none exceeded one individual per trap.

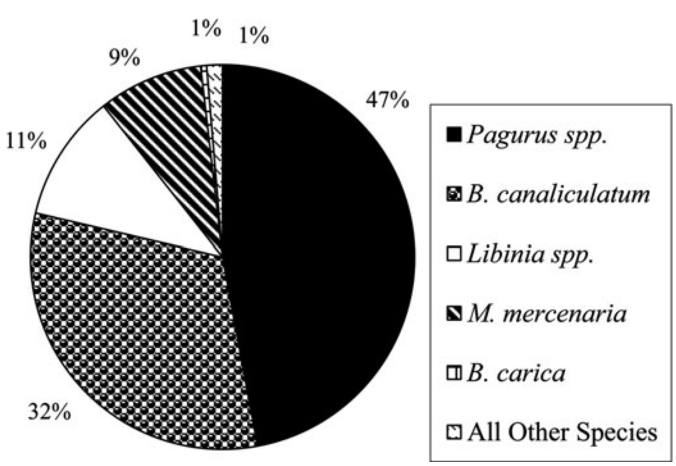

FIGURE 3. Percent contribution of the five most commonly observed invertebrate species in commercial blue crab traps in Georgia between November 2003 and December 2006 ($n = 4{,}972$).

Results of the Morisita index analyses (Table 4) were that the highest similarity between all species was observed in the spring and summer (0.9560), while the least similarity occurred between winter and summer (0.0777). Some differences in CPUE, with respect to season, were observed for the most numerous finfish and invertebrate species (Figures 4, 5). Seasonal variation existed for Southern Flounder, Atlantic Spadefish, Oyster Toadfish, channeled whelk, spider crabs, and stone crabs. For these species, an SNK multiple-comparison test was performed to determine specific seasonal differences for each species. For

TABLE 4. Results of Morisita indices for all finfish and invertebrate species combined comparing similarity of seasons for bycatch observed in commercial blue crab traps between November 2003 and December 2006 (0 = not similar; 1 = similar).

	Spring	Winter	Summer
Fall	0.9312	0.5476	0.8147
Spring		0.3157	0.9569
Winter			0.0777

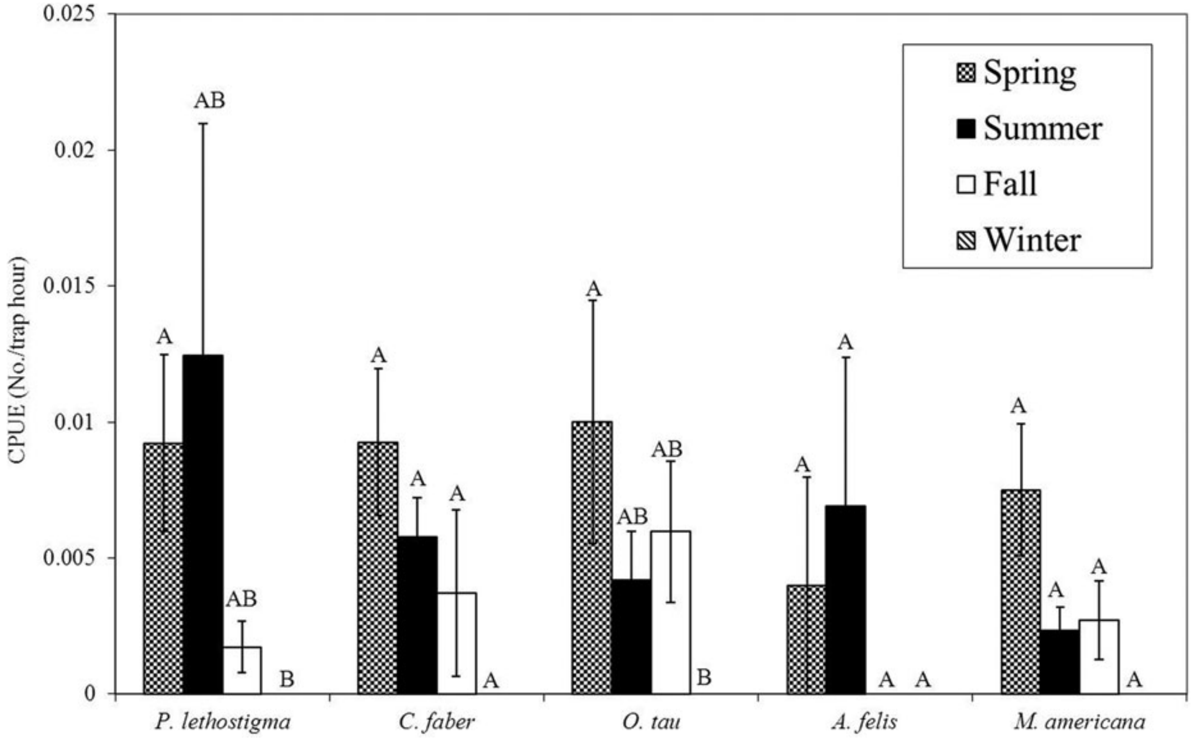

FIGURE 4. Seasonal CPUE (defined as number of individuals/trap-hour) by season for the top five finfish species observed in commercial blue crab pots in Georgia between November 2003 and December 2006. Letters represent results of SNK multiple-comparison test using species CPUE to determine specific seasonal variation. Any seasons not sharing the same letter are significantly different; trips observed in spring (24), summer (33), fall (29), and winter (5).

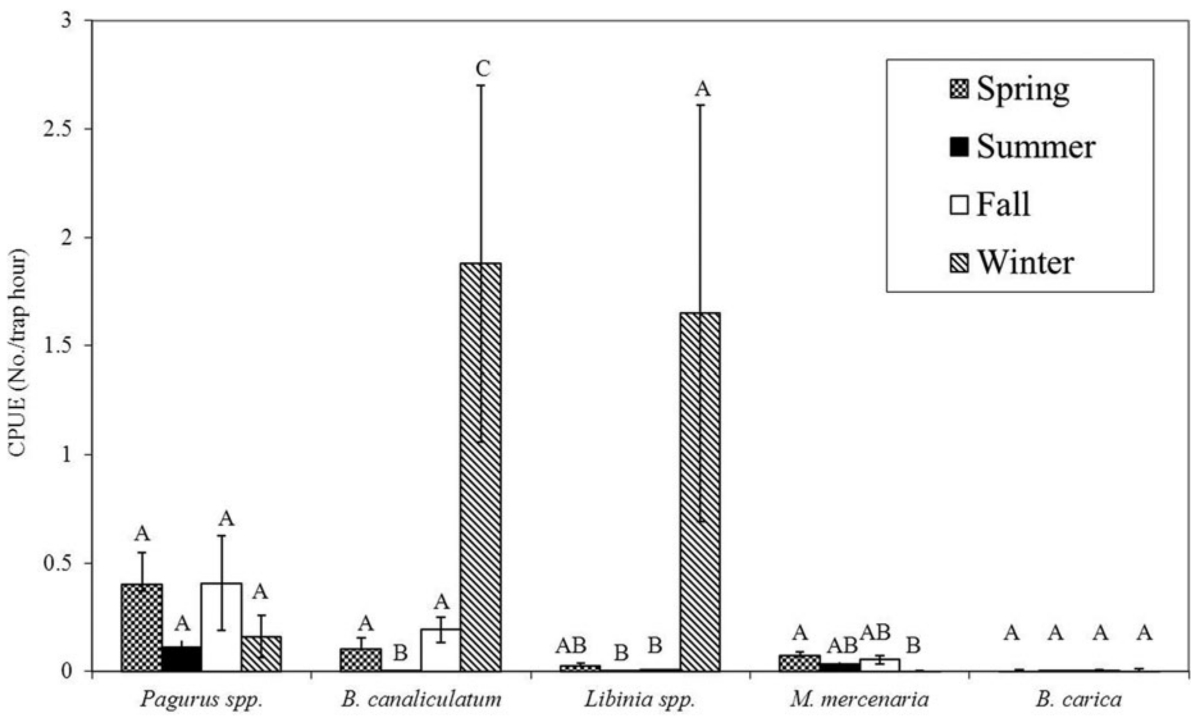

FIGURE 5. Seasonal CPUE (defined as number of individuals/trap-hour) by season for the top five invertebrate species observed in commercial blue crab pots in Georgia between November 2003 and December 2006. Letters represent results of SNK multiple-comparison test using species CPUE to determine specific seasonal variation. Any seasons not sharing the same letter are significantly different; trips observed in spring (24), summer (33), fall (29), and winter (5).

finfish, specifically Southern Flounder and Oyster Toadfish, differences were divided into three categories: spring, summer, and fall, which were similar to each other; summer, fall, and winter, which were similar to each other; and spring and winter, which were significantly different ($P < 0.05$) from each other. Hardhead Catfish and Southern Kingfish were recorded in multiple seasons, but there was no variation by season.

For the invertebrates, there was seasonal variation for channeled whelks, spider crabs, and stone crabs (Figure 5). For channeled whelk, differences were divided into three categories: spring and fall, which were similar to each other; summer; and winter. For spider crabs, winter catches differed significantly from summer and fall catches, but were similar to catch rates in spring. For stone crabs, significant differences were found between spring and winter catch rates. Differences in summer and fall catches cannot be differentiated for this species due to the variability within the catch rates (i.e., AB as seen in Figure 5).

DISCUSSION

The 91 trips and 5,707 traps observed during this study represented 0.3% and 0.2%, respectively, of the total number of trips and traps reported by commercial crabbers over that same period of time. While the number of observed trips conducted annually ranged from 1 (2003) to 58 (2007), the total number per season collectively ranged from 5 (winter) to 33 (summer). The fewest number of observed trips were conducted in the winter when fishing effort is lowest. It is interesting to note that, regardless of fishing effort, statistical differences were observed for some species due to the abundance of that species during a particular season. For instance, there was a statistically significant ($P < 0.05$) seasonal variation in winter for channeled whelk and spider crabs. For these invertebrates, their increased abundance in winter (channeled whelk = 760 individuals; spider crabs = 460 individuals) probably contributed to the strong seasonal variation (winter and summer were most dissimilar) observed in the Morisita's index results, as this index utilizes total numbers of individuals. The drastic differences in numbers of individuals of channeled whelk and spider crabs in winter and summer likely resulted in the strong seasonal difference (least similarity) observed in the Morisita index results (Tables 3, 4).

The most numerous finfish species observed in the commercial blue crab pot fishery were Southern Flounder, Atlantic Spadefish, Oyster Toadfish, Hardhead Catfish, and Southern Kingfish. Three of the finfish species (Southern Flounder, Atlantic Spadefish, and Oyster Toadfish) varied by season ($P < 0.05$). Seasonal variability was only observed for two species (Southern Flounder and Oyster Toadfish) based on SNK multiple-comparison tests. The differences between the ANOVA results and the SNK multiple-comparison tests are primarily due to the fact that the ANOVA is a more powerful test than the multiple-comparison tests (Zar 1999). Additionally, smaller sample sizes also contribute to the fluctuating differences in seasonal variation (Zar 1999).

The occurrence of these abundant finfish species (Southern Flounder, Atlantic Spadefish, Oyster Toadfish, Hardhead Catfish, and Southern Kingfish) can be attributed in part to their ecology, or life history characteristics. All of these species are benthic except the Atlantic Spadefish. Therefore, species composition of finfish bycatch in commercial blue crab traps appears to be directly related to the ecology of a fish species, which is expected given that the traps were situated on the river or sound bottom. Species abundance was predicted to be a major factor in what finfish would occur as bycatch. Not surprisingly, each of the five species observed are common in Georgia. Results of fishery-independent trawl data collected by the GADNR were that other benthic finfish are equally or more common (Page et al. 2004), yet have minimal or no occurrence in the commercial blue crab pot fishery. For example, benthic species such as the Hogchoker *Trinectes maculatus* and Blackcheek Tonguefish *Symphurus plagiusa* have both been commonly observed in trawl sampling in Georgia (Page et al. 2004), but were rarely found in commercial blue crab pots. Though these species are benthic, they do have ecological traits that differ from many of the common species captured as bycatch in this study. For instance, Hogchokers and Blackcheek Tonguefish are not shelter seekers like the Oyster Toadfish, which was commonly observed in crab pots. Consequently, the shelter-seeking may encourage some species to enter into crab pots and subsequently be captured. Dietary habits may also influence catch rates of bycatch in crab pots. Unlike Hogchokers and Blackcheek tonguefish, Southern Flounder and Southern Kingfish are known to frequently feed on small fish, which are commonly found seeking shelter around crab pots. Therefore, the absence of Hogchokers and Blackcheek Tonguefish in observer-collected data in this fishery is not surprising. Furthermore, the body shape of the tonguefish (elongated, flexible body), combined with the mesh size (3.81 cm hexagonal) of commercial blue crab pots, probably prevent capture. The flexible body and smaller size (typically < 150 mm) of the Hogchoker may also enable them to escape the traps. Therefore, species abundance is not always directly related to the composition of bycatch in commercial blue crab pots. Collectively, ecological traits and physical characteristics probably play the greatest role in what fish species are retained as bycatch in blue crab pots.

Similarly, each of the top five invertebrate species was benthic. The three most commonly observed species of crabs observed in traps (hermit crab, spider crab, and stone crab) are all bottom-dwelling species that have been noted in monthly trawl data collected by the GADNR (Page et al. 2004). The remaining two species (channeled whelk and knobbed whelk) are also bottom dwellers that occur in GADNR trawls. The appearance of channeled and knobbed whelk in crab pots is not surprising, as both of these species have been observed to enter whelk pots utilized by commercial fishermen in the Northeast and in Georgia (Davis and Matthiessen 1978; Page et al. 2004). Results of observer data collected by the GADNR from an experimental whelk pot fishery in Georgia were that channeled whelk occurred in 97% of whelk pots sampled, while knobbed whelk occurred in 1.5% of recorded pots (Page et al. 2004). Channeled whelk, more than the knobbed whelk, enter whelk pots extensively to feed on the horseshoe crabs used as bait within (Shaw 1960). This attraction to bait may explain why the channeled whelk is commonly observed in blue crab traps.

The composition of bycatch species in the commercial blue crab pot fishery in Georgia appears to be dominated by a few recurring species. The top five finfish species combined (n = 235) comprised over 76% of all finfish recorded ($n = 306$) during this study. As a result, the remaining 21 species comprised the rest. The top four invertebrate species (n = 4,881) accounted for 98% of all invertebrates observed (n = 4,972).

From a fisheries management perspective, at least two conclusions can be drawn from the results of this study. First, bycatch associated with the commercial blue crab pot fishery in Georgia is nominal as compared with another important fishery in this state, namely the commercial shrimp trawl fishery. Calculations of CPUE for the top five finfish species observed as bycatch in the commercial shrimp trawl fishery of Georgia ranged from 25 to 557 individuals/trawl-hour (Page et al. 2004), as compared with a range of 0.0036–0.0075 individuals/trap-hour for the top five finfish bycatch species in the blue crab fishery found in this study. Though CPUE is relatively low for finfish and invertebrate bycatch species in the commercial blue crab fishery, the potential for at least some of these species to be harvested in large quantities may exist. Under current Georgia law, no more than 100 commercial crabbers may be licensed at any time, each licensee being allowed to purchase up to 200 crab pots, collectively totaling a daily maximum of 20,000 traps that can potentially fish on any given day year-round (Evans 1997). Though the number of commercial blue crab licenses sold declined slightly throughout this study (150 in 2004; 148 in 2005; 146 in 2006), the number of purchased pots increased each year (15,700 in 2004; 16,850 in 2005; 17,850 in 2006). In examining the five most numerous finfish and invertebrate species as observed in the commercial blue crab pot fishery, at least three of these species (Southern Flounder, Southern Kingfish, and channeled whelk) are recreationally or commercially important in Georgia. Each of these are commonly targeted by recreationally licensed hook-and-line fishermen along the coast of Georgia, and their common occurrence as bycatch in the commercial blue crab pot fishery could be of concern based upon the total number of crab pots that could potentially fish along the Georgia coast. However, based upon the CPUE of Southern Flounder (0.0075 fish/trap-hour) and Southern Kingfish (0.0037 fish/trap-hour) as observed in this study, the number of these animals projected to be harvested by 20,000 traps in a single day would be would be 3,600 and 1,776, respectively. With a maximum number of crabbers fishing in a single day being 100 individuals, the average number of Southern Flounder (3,600 flounder ÷ 100 crabbers) and Southern Kingfish (1,776 kingfish ÷ 100 crabbers) caught per crabber per day would be 36 and 18, respectively. The recreational creel, or possession, limit for hook-and-line anglers targeting Southern Flounder is 15/person/d and for Southern Kingfish, unlimited; however, the bycatch estimates include all observed specimens regardless of size, including undersized fish. The legal size limit is 30.48 cm TL for Southern Flounder, while Southern Kingfish have no size limit. Due to size and creel regulations, incidental catches of these fish would probably not be detrimental to the overall coastwide populations of Southern Flounder and Southern Kingfish, even under these absolute maximum conditions.

For channeled whelk, the potential exists to harvest large quantities of this species, especially in the winter season. When expanded with the CPUE of this species in winter (1.8795 individuals/trap-hour), the 20,000 traps potentially fishing on any given day could result in the harvest of 902,160 channeled whelk/d, with an average of 9,022 channeled whelk caught per day per crabber. Though it is extremely unlikely all whelks would be harvested, this potential and the common occurrence of channeled whelk in commercial blue crab pots could have a localized effect on channeled whelk populations. Much of this potential effect on populations would, however, be directly correlated with demand by local whelk meat processors and size of whelk harvested. Depending on their size and marketability, whelks have and continue to be harvested commercially by crabbers in Georgia. Whelks that are too small in size, too few in number, or not profitable due to declining demand are returned to the water alive and not harvested. When demand for whelk meat is high, whelk size is large, and whelk capture in pots is abundant, negative implications may occur. These potential implications would need to be examined and verified through fishery-independent population surveys on channeled whelk performed by fishery managers.

A second conclusion to be drawn is that abundance does vary seasonally for some of the top vertebrate and invertebrate bycatch species in the blue crab fishery. For instance, Southern Flounder and Atlantic Spadefish were most abundant as bycatch in the commercial blue crab fishery during the summer and were not observed at all in the winter (Table 2). Spider crabs were most abundant in winter, and fewer were noted in each of the other seasons (Table 3). Seasonal differences also appear to occur for diamondback terrapins and lesser blue crabs *Callinectes similis* (Table 3). Though these species were not in the top five species for all seasons combined, their abundance was high enough in one season to place them in the top five species within a season. Statistically, these species had ANOVA p-values of 0.0067 and 0.0006, respectively. However, results of SNK multiple-comparison tests for these species were that no seasonal difference exists for either of these species. This again is probably due to the strength of the ANOVA versus the SNK and the smaller numbers of individuals observed for both of these species (Zar 1999). Nonetheless, a fishery management concern would be the implications for those species during times of highest abundance or periods of extreme vulnerability (e.g., spawning, mating). Of those species observed to have seasonal variation, spider crabs, oyster toadfish, and Atlantic Spadefish are typically not harvested by commercial crabbers and are returned to the water alive. Therefore, unless harvest, incidental mortality, or reproductive interruption of these species occurs, the impacts to these species, even during seasons of peak abundance, would be minimal.

In summary, the major findings of this research were that, regarding bycatch in the commercial blue crab pot fishery, the abundance of invertebrates (4,972 individuals) is greater than that of finfish (306 individuals), a few recurring species dominate the catch, and seasonal variation does exist for some nontargeted species in this fishery. Of the invertebrates, collectively 98% were hermit crabs, channeled whelk, spider crabs, or stone crabs, while 76% of the finfish were Southern Flounder, Atlantic Spadefish, Oyster Toadfish, Hardhead Catfish, or Southern Kingfish. Seasonal variation does occur for some of the most numerous finfish and invertebrate species, including Southern Flounder, Oyster Toadfish, channeled whelk, spider crabs, and stone crabs. It is important to note that long-term concerns may arise for the channeled whelk, a species that occurs seasonally and is harvested commercially. Its occurrence in crab pots and its potential commercial value may result in an increased harvest to the point of negatively impacting species abundance. While the number of observed trips conducted during this study was relatively low compared with the overall number of reported trips during the same period (<1%), the information collected in this study does provide resource managers with foundational knowledge to better understand the occurrence and seasonality of some commonly occurring bycatch species encountered in Georgia's commercial blue crab pot fishery. The information gained in this study supports the need for continued and expanded examination of bycatch associated with this fishery to assess long-term potential impacts on species occurring seasonally and ensure sustainability of populations.

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