GROWTH, MIGRATION, POPULATION STRUCTURE AND SEX RATIO OF FOUR WHELK SPECIES (FAMILY MELONGENIDAE) WITHIN WASSAW SOUND, GEORGIA

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Table of Contents

List of Figures

List of Tables

Abstract

Growth, migrational patterns, population structure, and sex ratio of four prosobranch species of whelks (Family Melongenidae) were studied in Wassaw Sound, Georgia. Whelks (N=17,826) from offshore trawls and from inshore sites were collected, tagged, measured for shell length and width, weighed and 59% sexed prior to release at one of eight inshore intertidal oyster reefs. A total of 2,453 channeled, *Busycotypus canalicalatus*; 15,101 knobbed, *Busycon carica*; 253 lightning, *Busycon sinistrum*; and 19 pearwhelks, *Busycotypus spiratus* were tagged and released between February 2000 and April 2002. The majority (69.5%) of the channeled whelks tagged came from offshore trawls. The majority (81%) of the channeled whelks gathered inshore came from pot-trapping with only 19% found intertidally along the oyster reefs. All pearwhelks were gathered by pot-trapping at the spring-low-water mark at the Wassaw Island site. Few lightning whelks (4.3%) originated from offshore trawls. Most (95.7%) were collected at the mean-low-water mark from inshore oyster reefs. The majority (67.2%) of the knobbed whelks came from offshore trawls. The knobbed whelk was the most common whelk gathered from either offshore or inshore intertidal oyster reefs. Recapture efforts continued through spring 2004. Females of all species were larger in size than males, and in most cases females significantly outnumbered males. Channeled and knobbed whelks captured offshore exhibited a slightly higher ratio of females to males; whereas, in inshore intertidal areas near oyster reefs, females greatly outnumbered males. Channeled, knobbed, and lightning whelks occur seasonally on the intertidal flats near oyster reefs. They are common during daytime in fall and spring but are generally absent during daytime in summer and winter. Mating groups (e.g., one female and up to 9 males) of whelks occur in spring and fall from the neap low tide into subtidal regions. Egg-laying was observed in spring and fall at three sites where expansive sandflats extended well out into the sound from the intertidal oyster reef areas. Egg-laying occurred at the spring-low-water mark and into the subtidal area. Most tagged whelks (97%) were recaptured at their point of release; however, a few individuals were observed to move considerable distances. Movement of whelks is described as horizontal on and off the intertidal flat for mating and egg-laying, vertical in the substrate to escape predation and environmental extremes, and lateral following the contours of the oyster reefs in search of food. Growth rates of whelks varied between species, sexes and location. Most individuals recaptured from the intertidal flats were females: 75.3% of knobbed, 76.9% of lightning, and 56.4% of channeled whelks. Tagged whelk recovery rate was 4.7% for channeled, 6.6% for knobbed, 8.7% for lightning and 0% of pearwhelks. Mortality of recovered tagged whelks was 0.5%. Resource management implications are discussed.

Introduction

Four prosobranch species of whelks (Family *Melongenidae*) occur in the coastal waters of Georgia: the channeled whelk, *Busycotypus canalicalatus* (Linnaeus, 1758); the knobbed whelk, *Busycon carica* (Gmelin, 1791); the lightning whelk, *Busycon sinistrum* Hollister, 1958; and the pearwhelk, *Busycotypus spiratus* (Lamarck, 1816). As in other places, Georgia whelks are marketed as conchs; however, whelks are not true conchs (Family *Strombidae*). The bulk of the offshore fishery targets knobbed whelks while inshore blue crab fishermen harvest channeled whelks as a by-catch species that enter their traps. These two species dominate in terms of abundance. Fewer numbers of lightning whelks are landed, and the pearwhelk occurs infrequently (Walker 1988).

Georgia's whelk fishery is a relatively new industry. The first recorded landings totaled 84 kg of meat in 1980 (Table 1). Initially, whelks were landed as by-catch of the winter blue crab trawl fishery, and until 1997 they were managed under blue crab trawl regulations (Belcher *et al.* 2001). The recurrence of poor shrimp harvests in Georgia, coincident with favorable market conditions for whelk meat and the recognition of abundant whelk populations offshore, led to an intensification of effort and a dramatic increase in landings during the late eighties and early nineties. In the winter months after the penaeid shrimp season has closed, many shrimp boats swap gear to fish for whelks in offshore areas using nets with larger mesh and heavier chains. Lesser numbers of whelks are gathered inshore as by-catch in blue crab, *Callinectes sapidus*, Rathbun, 1896, traps (Walker *et al.* 2003) or are collected by hand from intertidal areas by clam and oyster fishers (Walker 1988). Landings peaked in 1990 with 462,197 kg of meat with a dramatic decrease occurring after 2001. At present the offshore whelk fishery appears to have entered an over-harvested phase as commercial landings have plummeted. Only 40,900 kg were landed in 2003; 1,531 kg in 2004; 1,157 kg in 2005 and 2,136 kg in 2006 (Table 1). The decline in whelk landings has caused a sharp price increases from $1.10 in 1990 at the height of the fishery to $2.68 in 2006 (Table 1). As offshore whelk and inshore blue crab fisheries have declined, interest in harvesting of inshore subtidal and intertidal stocks of whelks has increased.

As a commercial species, little is known about the life history of these various species of whelks. The best population study for whelks in North Carolina is by Magalhaes (1948). Whelks are known predators of hard clam, *Mercenaria mercenaria* (Linnaeus, 1758), and oyster, *Crassostrea virginica* (Gmelin, 1791), stocks in Georgia. They occur seasonally during the day (Walker 1988) on intertidal flats that are inhabited by oysters and clams (Harris 1980; Walker *et al.* 1980; Walker and Tenore 1984). Whelks move up into the intertidal zone in search of food during spring and fall but are not readily observed during daytime on the flats during summer and winter, presumably due to temperature extremes (Walker 1988). Knobbed whelks are more abundant and move farther up into the intertidal zone than lightning and channeled whelks. Whelks also have been observed mating and laying eggs at the spring-low-water mark in spring and fall (Walker 1988; Power *et al.* 2002). Numerous smaller-sized males, up to nine, can be found attempting to mate with a single female (Walker 1988, Power *et al.* 2002).

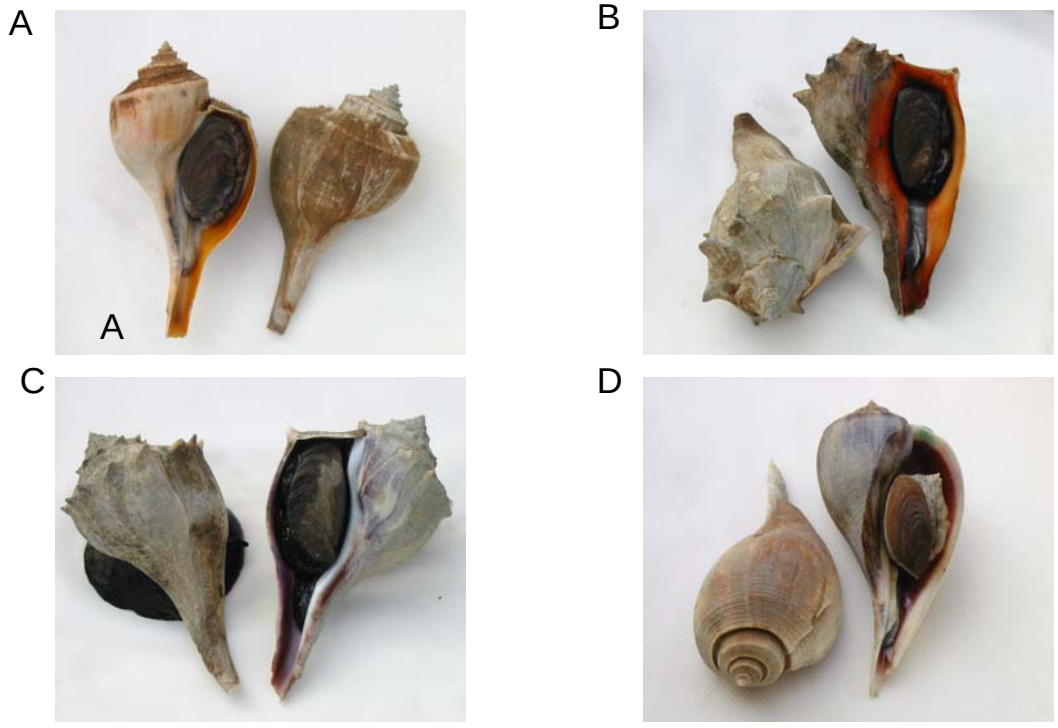

Figure 1: The four species of whelks in Georgia: A: Channeled whelk, *Busycotypus canalicalatus* B: Knobbed whelk, *Busycon carica* C: Lightning whelk, *Busycon sinistrum* and D: Pearwhelk, *Busycotypus spiratus*.

Table 1: Whelk, *Busycon* and *Busycotypus* species, production in kg of meat landed from 1979 to 2006 in Georgia. Data are from Georgia Department of Natural Resources (1979-2006).

Year	Meat (kg)	$ Value	$/kg	Year	Meat (kg)	$ Value	$/kg
1979	0	0		1993	179,656	242,049	1.35
1980	84	120	1.43	1994	305,094	377,323	1.24
1981	3,106	4,337	1.40	1995	252,710	336,654	1.33
1982	38,809	42,076	1.08	1996	193,019	254,717	1.32
1983	91,162	88,579	0.97	1997	281,785	389,437	1.38
1984	253,843	263,558	1.04	1998	264,224	406,942	1.54
1985	92,125	95,692	1.04	1999	268,148	401,195	1.50
1986	56,216	52,346	0.93	2000	191,072	277,482	1.45
1987	934,019	519,091	1.23	2001	147,762	245,330	1.66
1988	455,336	403,949	0.89	2002	28,842	49,621	1.72
1989	230,526	257,426	1.12	2003	40,900	69,393	1.70
1990	462,197	507,718	1.10	2004	1,531	3,693	2.41
1991	399,741	464,121	1.16	2005	1,157	2,544	2.20
1992	206,940	247,566	1.20	2006	2,136	5,729	2.68

The female produces viable embryos fertilized by multiple males within an egg-case string, as well as, within an individual egg capsule (Walker *et al.* 2007). Larger-sized males tend to be absent from the intertidal flats (Walker 1988). Pearwhelks were not found to occur in the intertidal zone in earlier studies (Walker *et al.* 1980; Walker 1988).

Numerous biological questions must first be answered in order to properly manage the whelk resource. Do whelks migrate and how far? Do whelks move from intertidal food sources to intertidal flats to mate and spawn and then return to the same food source? Are whelks protandric? What is the sex ratio of whelks? What is their growth rate? In order to address some of these questions, we conducted a tagging study of various species of whelks at eight sites within Wassaw

Sound, Georgia. This paper examines the growth, migrational pattern, population structure, and sex ratios of the four species of whelks found in coastal Georgia.

Study Area

Wassaw Sound is the northern-most sound in Georgia (Figure 2). It lies between the Savannah River to the north and the blackwater Ogeechee River that empties into Ossabaw Sound to the south. Neither river is part of Wassaw Sound. On the north side of the sound, Little Tybee Island, an uninhabited island of 1,600 acres, is the outer barrier island facing the Atlantic Ocean. The largely residential Wilmington Island lies just inshore of Little Tybee Island. Between these islands is Cabbage Island, a marsh island that has little land mass and supports only a few stands of trees. To the south lies Wassaw Island (2,500 acres) on the Atlantic Ocean. The residential Skidaway Island lies just inshore of Wassaw Island. Wassaw Island is uninhabited and is a United States Fish and Wildlife National Wildlife Refuge. Little Tybee and Cabbage Islands are currently protected from development and are property of the State of Georgia. Amidst all these islands are extensive areas of coastal salt marshes, *Spartina alteriflora*, which contain numerous saltwater creeks and rivers. The main river in Wassaw Sound is the Wilmington River, which connects to the Savannah River, well inland near the City of Savannah, and runs through the sound to the Atlantic Ocean. Wassaw Sound has a 2.4 m tidal amplitude and is a euhaline estuarine system.

Whelk migration was studied at eight sites within Wassaw Sound. The innermost site was at Priest Landing on the northeastern end of Skidaway Island. The site is part of the Board of Regents' state property and is under the care of the Skidaway Institue of Oceanography. The site is characterized by a large salt marsh extending down into the Wilmington River. Along the base of the marsh, a large 2-to-5 meter wide intertidal oyster reef occurs which follows the contours of the marsh. A massive mudflat lies farther down in the intertidal region. This area is characterized by a gently sloping bank that extends well out into the river.

The second site is located at Joe's Cut, which runs between the northeastern-most point of Skidaway Island and a small marsh island (approximately 1,016 m x 6 m) called Sister Island.

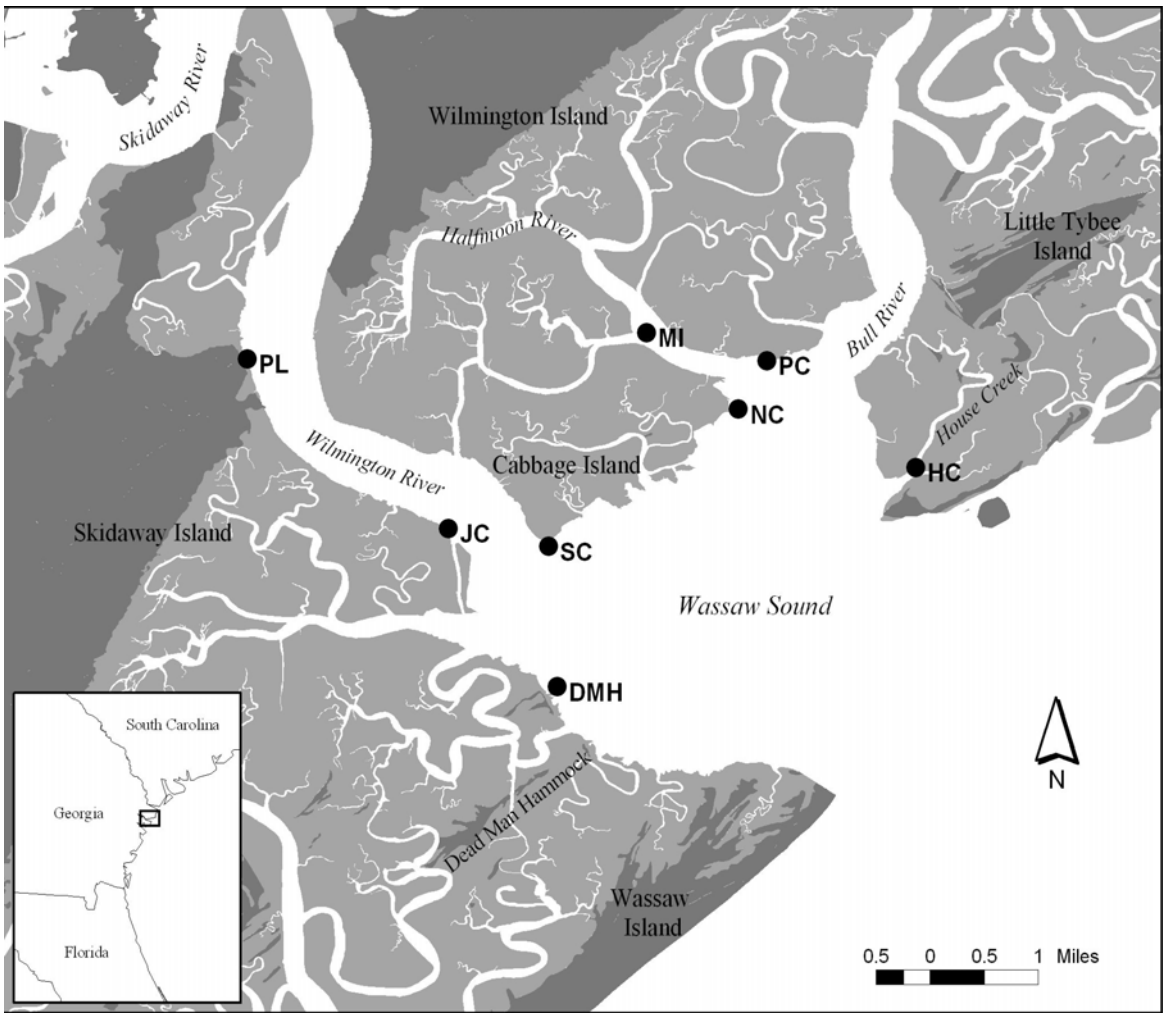

Figure 2: Map of Wassaw Sound, GA showing the eight intertidal oyster reef site where tagged whelks were captured and released. PL = Priest Landing; JC = Joe's Cut; DMH = Dead Man Hammock; SC = South Cabbage Island; NC = North Cabbage Island; PC = Pa Cooper Creek; MI = Mud Island; and HC = House Creek

Whelks were released at an oyster reef located at the eastern entrance to the cut along the Skidaway Island side. A large oyster reef extends around the bend of the island and out along the Wilmington River side of Skidaway Island. Channeled (N= 467) and knobbed (N= 1,204) whelks were released here in October and November 2001. The only recapture of whelks at this site took place in April 2004. Across from the release site is a small oyster bed along the eastern tip of Sister Island. Only a few isolated clumps of oysters occur along the steep sides of either creek bank of the cut itself. On the western end of the cut along Skidaway Island, an oyster reef starts at the tip and runs along the

shore of Romerly Marsh Creek approximately 60 meters. On the western tip of Sister Island along the cut side is a massive mound of washed oyster shells. The mound is created by storm activities coming off the ocean. A sheer drop of about 4 meters occurs on the cut side where no live oysters are present. On the northwestern end of Sister Island across from the washed oyster shell mound is a moderate oyster reef. The area between the eastern and western ends along the Wilmington River side is characterized by a long mound of washed oyster shell high in the intertidal zone that runs the length of the island. Below that is a 15-meter width of salt marsh grass below which is a clay/mud substrate down to the subtidal zone. The slope of the intertidal region here is moderate.

The third site is on the northern end of Wassaw Island near an area known as Dead Man Hammock. A small hammock containing numerous pine trees occurs within the salt marsh. A large portion of salt marsh terminates down in the intertidal zone where an extensive oyster reef occurs. Oysters run all along the length of the river bank from the creek at the northeastern end of Dead Man Hammock to Old Romerly Marsh Creek on the eastern end of the island which divides Wassaw from Skidaway Islands. Lower in the intertidal region a slight muddy-sand substrate extends about 15 meters before changing to a sandier substrate farther out into the Wilmington River. On neap tides the water falls below the oyster reef, but on spring tides, the water may be approximately 300 m farther out in the river. Lesser numbers of hard clams occur within the areas of dead oyster shells. The area is characterized by a gently sloping bank that extends well out into the river.

The fourth site is on the southeastern end of Cabbage Island, hereafter referred to as South Cabbage Island. This area is characterized by a small area of salt-marsh between the river and the upland which is composed of washed oyster shell and sand. The study area is composed mostly of a shelly-sand substrate. Several small mounds of oysters with hard clams are found within the shelly substrate. The area is characterized by its shallow depth and a large sand flat on the eastern end. This area is subject to dramatic changes due to the violence of storm activities coming off the ocean. A gently sloping bank that extends well out in the river is also characteristic of this area.

The fifth site is on the northeastern end of Cabbage Island, hereafter referred to as North Cabbage Island. Like the south side, little salt marsh occurs; however here a large massive oyster reef occurs primarily along the Halfmoon River side (northern). Behind the oyster mounds is a small area of marsh behind which is a massive mound of washed shell and sand. Behind the washed shell and sand is a massive salt marsh. On the northern corner, the bank is steep and rapidly drops off to a depth of 6-7 m about 2 meters from the base of the live oyster mound. The eastern end is characterized by a gently sloping bank that extends well out in the river. Unlike the south side, this area has an extensive shelly-sand substrate. Numerous hard clams occur within the shelly bottom areas. This area is also subjected to storm surges off the Atlantic Ocean, but is not as volatile as the southern site.

Across the Halfmoon River from the North Cabbage Island site on the eastern end of Wilmington Island is the Pa Cooper Creek site. Pa Cooper Creek is a salt marsh creek. An extensive portion of salt marsh occurs at this site, and the creek does not reach the uplands of Wilmington Island. A massive oyster reef occurs at the lower intertidal region and runs along the Half Moon River side (south side) of the river around to the mouth of Pa Cooper Creek on the eastern side of the island. Hard clams also occur among the areas of deposited dead oyster shell. At the southwestern-most side, the creek banks are very steep and drop off rapidly below the oyster boundary. As one moves closer to the bend of the island, the bank becomes more sloped with wide intertidal muddy-sand flats. At the bend of the island, a massive mudflat occurs which is not exposed at low tide. The area exposed on a spring tide is much less than at all the previous sites excluding Joe's Cut site.

The Mud Island site is located between Cabbage and Wilmington Islands along the Halfmoon River. Mud Island is a small marsh island (approximately 163 m X 5 m) that was formed when a small tip of marsh was cut off from the main marsh of Wilmington Island. Mud Island has no land mass. The salt marsh is completely encircled by live oysters occurring at the mean-low-water to 2 hours above mean-low-water mark. A 1-to-2 meter area of dead shell occurs below the live oysters after which the bank drops off steeply. A sandbar lies between Mud Island and Wilmington Island.

The last site occurs within House Creek on the western side of Little Tybee Island. House Creek is a salt marsh creek that empties directly into Wassaw Sound. At the mouth of the creek, a massive sand/mudflat occurs. In Wassaw Sound the flat is sand, while on the inside of the creek the flat has a mud substrate. Oysters occur along the creek banks. Along the entrance of the creek, the bank is gently sloping, but as one proceeds farther into the creek, the banks steepen.

Materials and Methods

Whelks from three sources were collected and tagged. Whelks were collected from offshore commercial beds by monthly trawling in the St. Simon Sound shipping channel off the northeastern end of Jekyll Island. A random sample of 30 knobbed whelks was selected for reproductive analysis (Power *et al.* in preparation). The remaining whelks from offshore were tagged and released at various intertidal sites within Wassaw Sound. Additional channeled whelks gathered from a crab pot versus conch pot experiment (Walker *et al.* 2003) and from trapping in Breads Creek for gametogenic sampling (Power *et al.* in preparation) were tagged and released at the Wassaw Island site. At each of the seven sites (excluding the Joe's Cut site where only offshore tagged whelks were released) starting February 2000, whelks were hand-gathered at low tide by visual inspection while walking the intertidal region about the oyster reefs and returned to the laboratory for tagging. Whelks were collected quarterly at seven of the eight (see below) intertidal sites during 2000 and 2001, but sampling was reduced to just spring and fall in 2002, 2003 and 2004. Whelks were generally absent from the intertidal flats in winter and summer of 2000 and 2001, as had been previously noted in earlier studies (Walker *et al.* 1980; Walker 1988). After processing for growth data, all whelks were returned to their original collection sites, with the exception of those collected at the Priest Landing site after 2001. Due to very low recapture rates, tagged whelks collected at the Priest Landings site on May 31, 2001 were released at the Wassaw Island site. The Priest Landing site was abandoned after May 2001 and was not monitored again until April/May 2004. Although recapturing of tagged whelks continued until spring 2004, after October 2002, we stopped tagging untagged whelks. If a tagged whelk was found at one of the other sites, it was measured again in the laboratory and then returned to the site where it was recently captured.

In the laboratory, whelks were kept grouped separately based on capture site, washed by hosing with fresh water, stacked in trays with the shoulder whorl exposed upward, and allowed to air dry. Whelks were initially tagged with either a round yellow (N = 573) or green (N = 442) Peterson's Floyd tag, which was cemented to the shoulder whorl with 5-minute epoxy glue. The majority of whelks (N = 16,811; 94.3%) were tagged with yellow Hallprint tags (shellfish tags type FPN, Holden Hill, Australia), which were attached with "Superglue" (Figure 3). Tagged whelks were identified by species, measured for shell length (siphonal canal to shell apex) in mm and shell width (across the shoulder) in mm and wet weighed to the nearest 0.10 gram. Notes were taken concerning attached epibenthos or damage to the shell. Starting in October 2000, tagged animals were placed in seawater containing a 7% magnesium chloride solution which serves to relax the animal. Once relaxed, animals were sexed according to the presence or absence of a penis. Recaptured tagged whelks from each site were re-measured for shell length and width and re-weighed. Recaptured tagged whelks with Peterson's tags were tagged again with a Hallprint tag.

Figure 3: A rare (1 out of 15,101: 0.007%) left-handed knobbed whelk, *Busycon carica*, tagged (L131) with a yellow shellfish tag type FPN.

Water temperature and salinity measurements were taken from the Marine Extension Service dock located on the Skidaway River off Skidaway Island at 0800 hr each working day from January 2000 until May 2004. Water temperature was taken with a standard handheld thermometer, while salinity was determined using a handheld refractometer.

Results

Mean monthly water temperatures (±SE) and salinity values (±SE) for Skidaway River are given in Figure 4. Water temperatures were cyclic with winter lows and summer highs. Mean monthly water temperatures ranged from 30.1°C in July 2002 to 8.7°C in January 2001. Salinity values remained high from January 2000 until spring 2003 due to prolonged drought conditions in Georgia. The salinity pattern of 2003 is more typical of coastal Georgia (Marine Extension Service unpublished daily work day water temperature and salinity records 1979 to 2005). Water salinity ranged from 18.4 PSU in June 2003 to 34.8 PSU in November 2001.

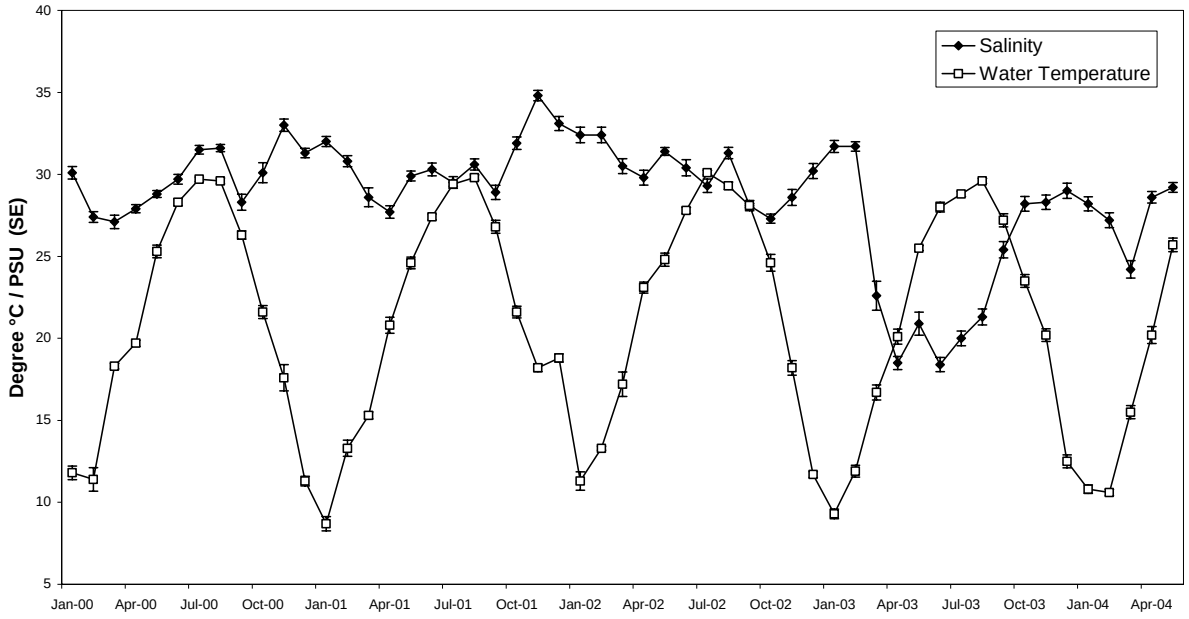

Figure 4: Mean monthly water temperature (+SE) and salinity values (+SE) for Wassaw Sound, GA from January 2000 to May 2004.

A total of 17,826 whelks were tagged and released in Wassaw Sound from February 2000 through March 2003 (Table 2). Knobbed whelks (84.7%) were the dominant species with lesser numbers of channeled (13.8%) and lightning (1.4%) whelks. Pearwhelks (N=19) accounted for only 0.1% of the whelks tagged. No pearwhelks were found at any inshore station except the Wassaw Island site. These were collected from a pot trap study at the spring-low-water mark, which was 300

meters distant from the intertidal oyster reefs where the capture/re-capture study was performed (Walker *et al.* 2003). Knobbed whelks dominated in numbers both inshore (83%) and offshore (85.5%). Channeled whelks were the second dominant species inshore (12.6%) and offshore (14.4%). Lightning whelks were rare offshore (0.11%), but were more common inshore (4.1%).

Shell length and wet weight distributions of the four species of whelks are given in Figures 5 to 8, and Table 3. For each species, females obtained larger mean sizes in shell length, shell width and weight than males. Female lightning, knobbed, channeled and pearwhelks reached maximum shell lengths of 257 mm, 228 mm, 175 mm, and 112 mm, respectively. Maximum shell lengths of male channeled, knobbed, lightning and pearwhelks were 175 mm, 190 mm, 154 mm and 104 mm, respectively. Maximum whole wet weights for female lightning, knobbed, channeled and pearwhelks were 1,441 g., 1,107 g., 513 g., and 102 g., respectively. Maximum whole wet weight for male channeled, knobbed, lightning and pearwhelks were 663.5 g., 791 g., 270 g., and 60.9 g., respectively. Although one male channeled whelk was found that was the same maximum size as the largest female (175 mm) and weighed more (664 g. vs. 513 g.), in general males were smaller than females.

The sex ratio of whelks differed between those caught offshore, those found in pots, and those captured inshore along the oyster reefs (Table 4). Overall sex ratios (M:F) of the different species of whelks were as follows: 1.00:1.39 for channeled, 1:00:2.80 for knobbed, 1:00:22.8 for lightning, and 1:00:1.33 for pearwhelks. With the exception of the sex ratio for the pearwhelk and offshore lightning whelks, significantly more females occurred than males (Table 5). Offshore knobbed whelks had a significantly different sex ratio of (M:F = 1.00:1.47), while inshore knobbed whelks from the intertidal oyster reefs had highly significantly more females (M:F = 1.00:8.33 or 8.3 females for every male). For channeled whelks, significantly more females were found in the offshore collection than were found in intertidal areas near oysters, but an equal sex ratio occurred in pot-trapped animals. Likewise an equal sex ratio occurred for pot-trapped pearwhelk. Male lightning whelks (N=9) were rare (M:F = 1.00:25.1 inshore and 1.00:4.00 offshore).

Growth rates of whelks varied between species, sexes and location (Table 6). Most individuals recaptured were females: 75.3% of knobbed, 76.9% of lightning, and 56.4% of channeled

whelks. No male lightning whelks were recaptured at any site, and only 4.1% of knobbed whelks recaptured were males. Whelks of unknown sex accounted for 20.6%, 23.1% and 2.9% of knobbed, lightning and channeled whelks, respectively. Few (N=7) channeled whelks were recovered from the oyster reefs. The exceptions were those caught in conch or crab pots that were placed lower in the intertidal zone on Wassaw Island (N=133) (Walker *et al.* 2003).

Table 2: Number and species of whelks captured from inshore and offshore areas, tagged and released at various sites in Wassaw Sound, GA.

Site	***B. canalicalatus***	***B. carica***	***B. sinistrum***	***B. spiratus***	**Total**
House Creek	43	1,774	9	0	1,826
Inshore	28	725	7	0	
Offshore	15	1,049	2	0	
Joe's Cut	467	1,204	0	0	1,671
Inshore	0	0	0	0	
Offshore	467	1,204	0	0	
Mud Island	223	1,433	1	0	1,657
Inshore	2	125	0	0	
Offshore	221	1,308	1	0	
N. Cabbage Isl.	444	4,401	101	0	4,946
Inshore	56	1,424	95	0	
Offshore	388	2,977	6	0	
Pa Cooper Creek	40	1,472	35	0	1,547
Inshore	40	1,043	33	0	
Offshore	0	429	2	0	
Priest Landing	253	592	0	0	845
Inshore	0	2	0	0	
Offshore	253	590	0	0	
S. Cabbage Isl.	93	1,948	15	0	2,056
Inshore	13	396	15	0	
Offshore	80	1,552	0	0	
Wassaw Island	890	2,277	92	19	3,278
Inshore	609	1,233	92	19	
Offshore	281	1,044	0	0	
Total	2,453	15,10	253	19	17,826
Inshore	748	4,948	242	19	
Offshore	1,705	10,153	11	0	

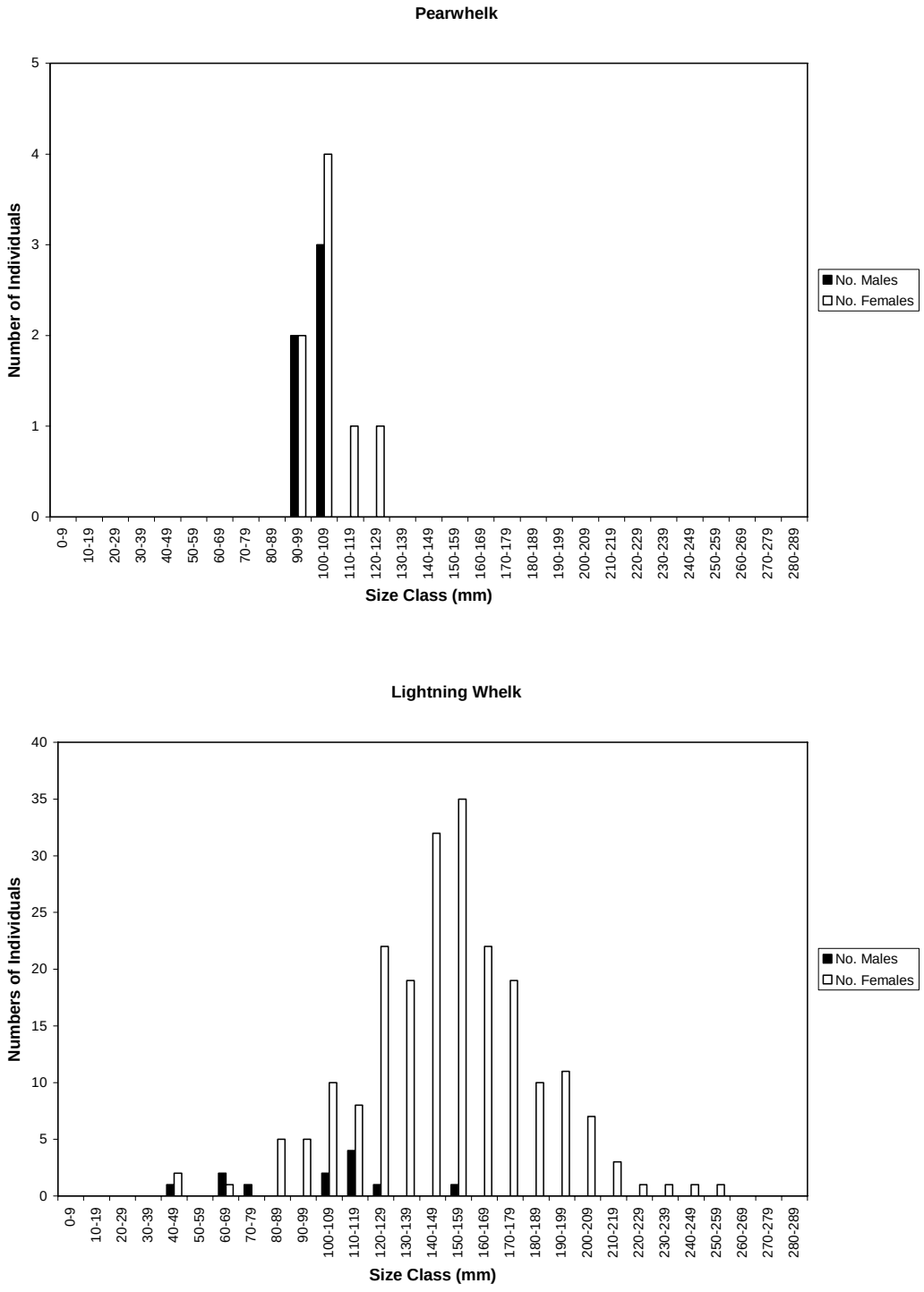

Figure 5: Shell length in mm distribution of female and male whelks for pearwhelks and lightning whelks tagged and released in Wassaw Sound, GA

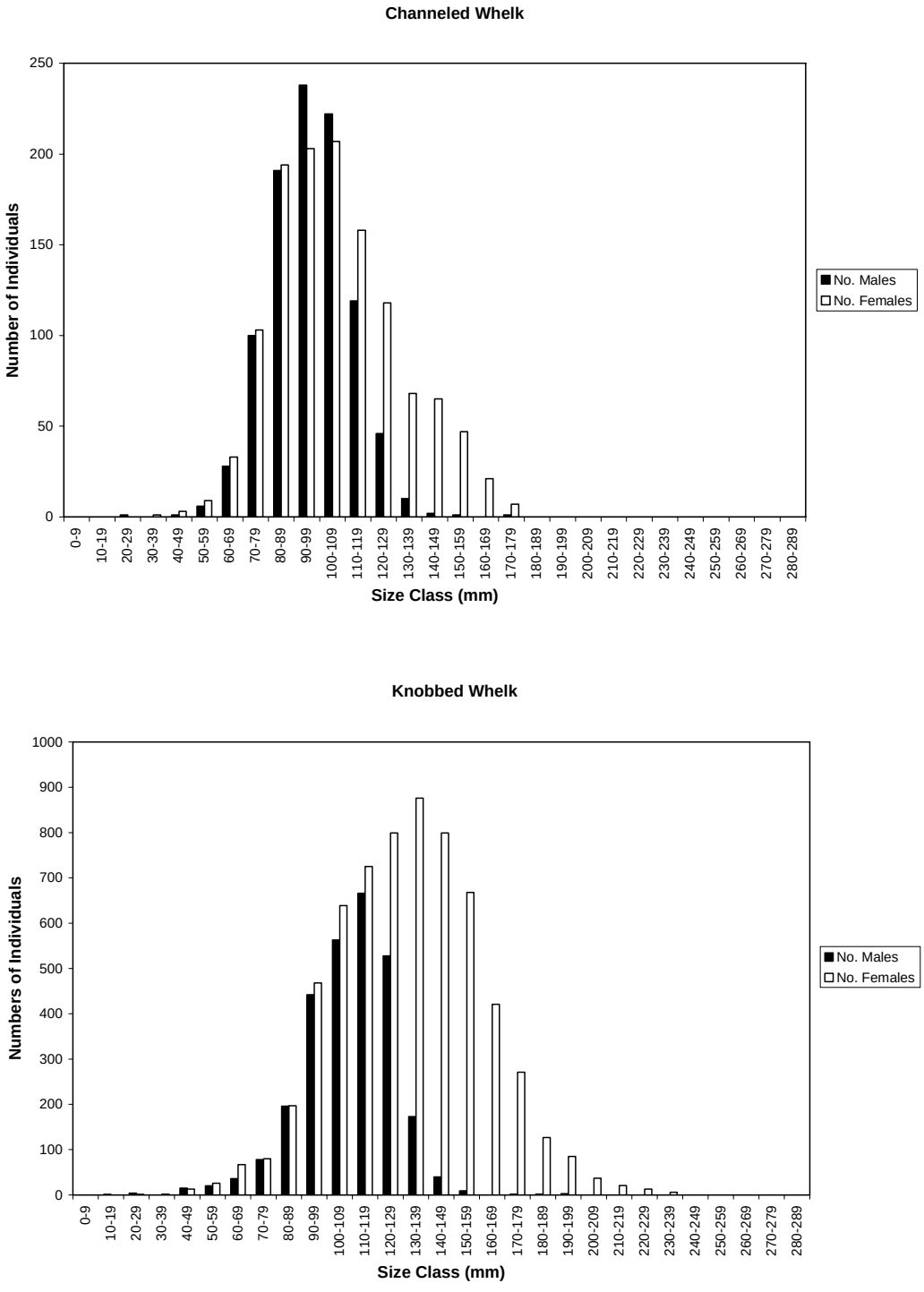

Figure 6: Shell length in mm distribution of female and male whelks for channeled and knobbed whelks tagged and released in Wassaw Sound, GA

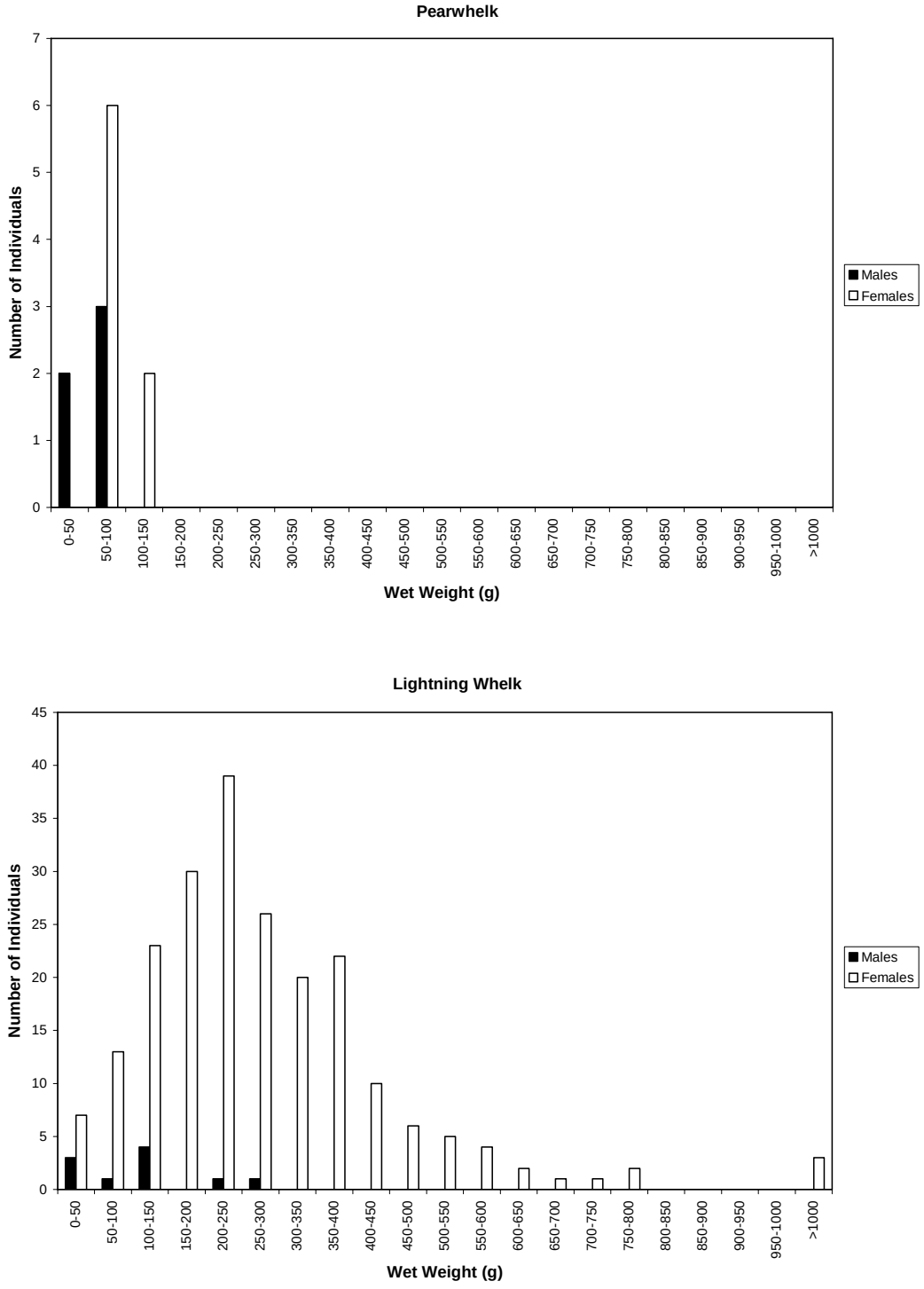

Figure 7: Wet weight in grams distribution of female and male pearwhelks and lightning whelks tagged and released in Wassaw Sound, GA

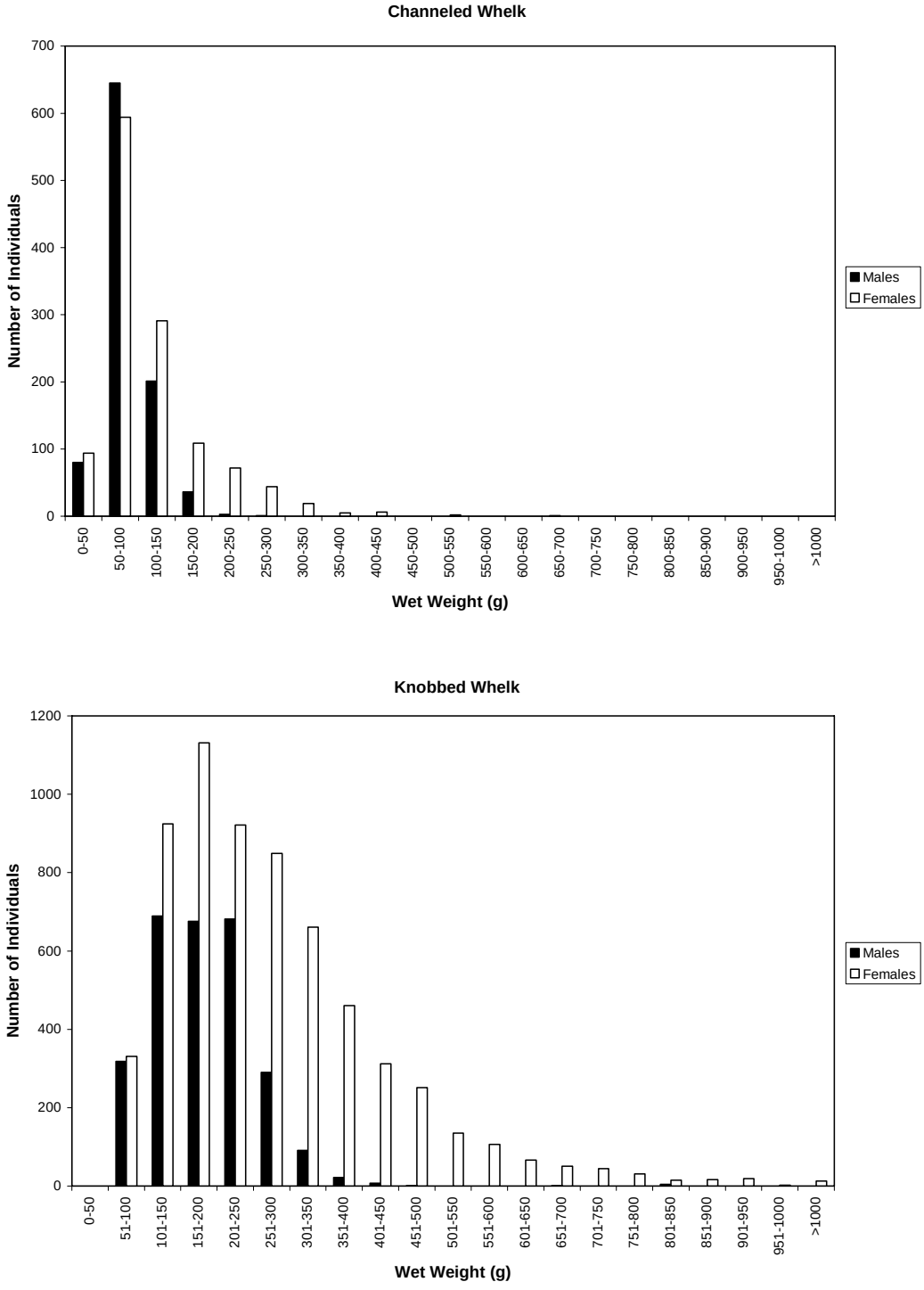

Figure 8: Wet weight in grams distribution of female and male channeled and knobbed whelks tagged and released in Wassaw Sound, GA

Table 3: The count, mean shell length, mean width, mean weight of live animal, maximum size, minimum size and median sizes of each sex per species of whelk tagged and released in Wassaw Sound, GA.

	Females			Males		
	Length (mm)	Width (mm)	Weight (g)	Length (mm)	Width (mm)	Weight (g)
Channeled Whelk						
N=	1236.00	1236.00	1236.00	967.00	967.00	967.00
Mean	105.80	56.70	89.40	96.10	50.90	60.60
STD	24.12	15.00	70.20	15.62	9.62	36.06
SE	0.69	0.43	2.00	0.50	0.31	1.16
Max	175.00	123.00	513.00	175.00	154.00	663.50
Min	39.00	18.90	3.00	28.00	26.00	7.50
Median	103.00	54.00	66.60	96.00	50.80	54.70
Knobbed Whelk						
N=	6341.00	6342.00	6338.00	2778.00	2780.00	2780.00
Mean	122.16	82.43	225.08	99.20	68.90	132.11
STD	28.80	20.86	153.21	17.90	16.10	71.85
SE	0.36	0.26	1.92	0.34	0.31	1.36
Max	228.00	193.90	1107.10	190.00	176.60	790.60
Min	17.00	14.20	2.10	10.00	14.90	2.20
Median	122.00	83.00	192.90	101.00	71.60	129.40
Lightning Whelk						
N=	215.00	215.00	214.00	10.00	10.00	10.00
Mean	150.00	86.80	280.50	103.40	58.50	113.30
STD	32.61	20.50	188.10	27.45	16.93	78.63
SE	2.22	1.40	12.86	8.68	5.35	24.86
Max	257.00	160.00	1440.90	154.00	85.00	270.20
Min	42.30	24.50	8.40	63.00	32.00	17.80
Median	151.40	85.90	240.40	110.50	62.00	108.50
Pearwhelk						
N=	8.00	8.00	8.00	5.00	5.00	5.00
Mean	106.50	53.90	78.50	97.60	47.30	53.10
STD	7.31	4.58	19.76	4.71	2.66	6.74
SE	2.58	1.62	6.98	2.11	1.19	3.01
Max	111.60	61.80	101.50	104.10	52.00	60.90
Min	98.40	47.80	54.40	90.70	44.00	42.70
Median	105.00	54.70	68.40	99.10	47.20	53.10

Table 4: Sex of the various species of whelks tagged and released at various sites in Wassaw Sound, GA.

Site	*B. canalicalatus*		*B. carica*		*B. sinistrum*	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
House Creek	3	8	52	282	1	5
Inshore	3	8	52	282	1	5
Offshore	0	0	0	0	0	0
Joe's Cut	206	259	326	817	0	0
Inshore	0	0	0	0	0	0
Offshore	206	259	326	817	0	0
Mud Island	81	112	178	261	0	0
Inshore	0	0	0	0	0	0
Offshore	81	112	178	261	0	0
N. Cabbage Isl.	19	177	580	1838	5	77
Inshore	9	38	127	1014	4	74
Offshore	10	139	453	824	1	3
Pa Cooper Creek	10	29	339	1049	0	39
Inshore	7	23	60	952	0	38
Offshore	3	6	279	97	0	1
Priest Landing	111	139	316	268	0	0
Inshore	0	0	0	0	0	0
Offshore	111	139	316	268	0	0
S. Cabbage Isl.	30	30	209	455	2	9
Inshore	3	14	48	211	2	9
Offshore	27	16	161	244	0	0
Wassaw Island	123	197	144	1,055	1	75
Inshore	24	31	120	1,015	1	75
Offshore	99	166	24	40	0	0
Pot Trapped*	285	255	12	18	0	0
Total	868	1,206	2,156	6,043	9	205
Inshore	311	369	419	3,492	8	201
Offshore	537	837	1,737	2,551	1	4

*Six male and 8 female *B. spiratus* were caught during a trapping study at the Wassaw Island site.

Table 5: Chi-square test statistic for sex ratios of the four species of whelks for combined, inshore and offshore data sets (P>0.05). N.S. = not significantly different

	B. canalicalatus	***B. carica***	***B. sinistrum***	***B. spiratus***
Overall	55.10	1842.8	179.5	0.29 N.S.
Inshore	4.95	2414.6	178.2	0.29 N.S.
Offshore	65.50	154.5	1.8 N.S.	
Potted	1.66 N.S.			
Intertidal	63.1			

At Wassaw Island most channeled whelks were recaptured in pots near the spring-low-water mark. The negative growth rate of channeled whelks at Wassaw Island (Table 6) is probably due to handling affects. These whelks were captured during a pot trap study, taken to the laboratory for measurements, tagged, returned two days later, and released higher in the intertidal zone at the base of the oyster reef. Released channeled whelks subsequently migrated back to the spring-low-water mark, where once again they were recaptured in the pots (Walker *et al.* 2003).

Due to the small number of recaptured lightning and channeled whelks, growth estimates are not as strong as those for knobbed whelks (Table 6). Negative shell length growth was observed for channeled whelks of both sexes at Wassaw Island and Priest Landing sites, while positive growth was recorded for a female at House Creek, a whelk of unknown sex at North Cabbage Island, and three females at Pa Cooper Creek. Female lightning whelks exhibited positive mean growth at North Cabbage Island (N=11), Pa Cooper Creek (N=5), South Cabbage Island (N=1), and Wassaw Island (N=7) sites, although some individuals showed negative growth at both North Cabbage Island and Wassaw Island sites. Shell length growth rates for female and male knobbed whelks varied from negative growth for both sexes at Priest Landing to negative growth for males, but positive growth for females at Wassaw Island to positive growth for both sexes at all other sites. Whole wet weight increased for both sexes of each species at all sites with the exception of female channeled whelks (N=6) at Priest Landing and male knobbed whelks (N= 8) at Pa Cooper Creek.

Table 6: Growth in shell length (SL cm/day ± SE) and wet weight (g/day ± SE) of whelks recaptured in Wassaw Sound, GA.

*No pearwhelks were recaptured

Location	All	Males	Females
House Creek			
Busycon carica			
Numbers	51	3	34
Mean Shell Length	0.0204 ± 0.005	0.0701 ± 0.0574	0.0201 ± 0.0044
Range	0.0022 to 0.0995	0.0574 to 0.0995	-0.0245 to 0.0991
Numbers	48	2	34
Mean Wet Weight	0.1434 ± 0.0161	0.0436 ± 0.0022	0.1744 ± 0.0196
Range	-0.141 to 0.4577	0.0022 to 0.0436	-0.141 to 0.4577
Busycotypus canalicalatus			
Numbers	1	0	1
Mean Shell Length	0.0357	0	0.0357
Range			
Numbers	1	0	1
Mean Wet Weight	0.1424	0	0.1424
Range			
Joe's Cut			
Busycon carica			
Numbers	24	0	24
Mean Shell Length	0.0036 ± 0.001	0	0.0036 ± 0.001
Range	-0.003 to 0.0158		-0.003 to 0.0158
Numbers	24	0	24
Mean Wet Weight	0.0359 ± 0.007		0.0359 ± 0.007
Range	-0.02 to 0.1019		-0.02 to 0.1019
Mud Island			
Busycon carica			
Numbers	20	3	16
Mean Shell Length	0.0220 ± 0.0112	0.0827 ± 0.0569	0.0125 ± 0.0053
Range	-0.035 to 0.22	-0.007 to 0.22	-0.035 to 0.049
Numbers	20	3	16
Mean Wet Weight	0.1629 ± 0.0286	0.0893 ± 0.0481	0.1863 ± 0.0318
Range	-0.011 to 0.408	-0.011 to 0.086	0.019 to 0.408
Priest Landing			
Busycon carica			
Numbers	9	3	6
Mean Shell Length	-0.00322 ± 0.0046	-0.0053 ± 0.0021	-0.0022 ± 0.0067
Range	-0.026 to 0.023	-0.01 to -0.001	–0.026 to 0.023
Numbers	9	3	6
Mean Wet Weight	-0.0119 ± 0.0623	0.132 ± 0.0457	-0.0838 ± 0.075
Range	-0.379 to 0.244	0.075 to 0.244	-0.379 to 0.106

Busycotypus canalicalatus			
Numbers	2	1	1
Mean Shell Length	-0.0097 ± 0.0218	-0.002	-0.0174
Range	-0.0174 to -0.002		
Numbers	2	1	1
Mean Wet Weight	0.0908 ± 0.1668	-0.076	0.2579
Range	-0.076 to 0.2579		
North Cabbage Island			
Busycon carica			
Numbers	395	10	245
Mean Shell Length	0.0311 ± 0.0023	0.0285 ± 0.0216	0.0241 ± 0.0017
Range	-0.0846 to 0.2733	-0.0085 to 0.232	-0.0586 to 0.0959
Numbers	305	9	262
Mean Wet Weight	0.1509 ± 0.008	0.0308 ± 0.011	0.1621 ± 0.0090
Range	-0.3355 to 0.7976	-0.0265 to 0.081	-0.3355 to 0.7976
Busycon sinistrum			
Numbers	11	1	8
Mean Shell Length	0.0339 ± 0.0197	0.0307	0.0136 ± 0.0064
Range	-0.0121 to 0.234		-0.0121 to 0.0431
Numbers	8	1	6
Mean Wet Weight	0.1252 ± 0.0453	0.062	0.1551 ± 0.0549
Range	-0.099 to 0.329		-0.099 to 0.329
Busycotypus canalicatulus			
Numbers	1	0	0
Mean Shell Length	0.3449		
Range			
Numbers	0	0	0
Mean Wet Weight	ND		
Range			
Pa Cooper Creek			
Busycon carica			
Numbers	225	8	199
Mean Shell Length	0.0211 ± 0.003	-0.0038 ± 0.0024	0.0236 ± 0.0034
Range	-0.0491 to 0.51	-0.0194 to 0.005	-0.0491 to 0.51
Numbers	220	8	195
Mean Wet Weight	0.1452 ± 0.0096	-0.0408 ± 0.0522	0.1622 ± 0.0010
Range	-0.422 to 0.8827	-0.422 to 0.0761	-0.1086 to 0.8827
Busycon sinistrum			
Numbers	5	0	5
Mean Shell Length	0.0731 ± 0.0132		0.0731 ± 0.0132
Range	0.041 to 0.123		0.041 to 0.123
Numbers	4	0	4
Mean Wet Weight	0.3063 ± 0.0356		0.3063 ± 0.0356
Range	0.248 to 0.428		0.248 to 0.428

Busycotypus canalicatulus			
Numbers	3	0	3
Mean Shell Length	0.0407 ± 0.0143		0.0407 ± 0.0143
Range	0.0123 to 0.0727		0.0123 to 0.0727
Numbers	3	0	3
Mean Wet Weight	0.1583 ± 0.0387		0.1583 ± 0.0387
Range	0.0931 to 0.2505		0.0931 to 0.2505
South Cabbage Island			
Busycon carica			
Numbers	85	6	64
Mean Shell Length	0.0255 ± 0.003	0.0017 ± 0.0023	0.0258 ± 0.003
Range	-0.049 to 0.0905	-0.008 to 0.012	-0.049 to 0.0905
Numbers	85	6	64
Mean Wet Weight	0.1242 ± 0.0152	0.0138 ± 0.0023	0.1297 ± 0.0191
Range	-0.407 to 0.5913	0.0062 to 0.0192	-0.4069 to 0.5913
Busycon sinistrum			
Numbers	1	0	1
Mean Shell Length	0.0272		0.0272
Range			
Numbers	1	0	1
Mean Wet Weight	0.1052		0.0272
Range			
Wassaw Island (Dead Man Hammock)			
Busycon carica			
Numbers	317	13	260
Mean Shell Length	0.0212 ± 0.0016	-0.007 ± 0.0101	0.0230 ± 0.0019
Range	-0.125 to 0.3343	-0.125 to 0.0268	-0.0667 to 0.3343
Numbers	316	13	259
Mean Wet Weight	0.1787 ± 0.088	0.0777 ± 0.0305	0.1999 ± 0.0102
Range	-0.481 to 0.7591	-0.089 to 0.3323	-0.481 to 0.7591
Busycon sinistrum			
Numbers	7	0	4
Mean Shell Length	0.001 ± 0.01		0.0137 ± 0.0146
Range	-0.0229 to 0.0584		-0.0229 to 0.0584
Numbers	7	0	4
Mean Wet Weight	0.1183 ± 0.0579		0.1325 ± 0.0966
Range	-0.1771 to 0.3556		-0.1771 to 0.556
Busycotypus canalicatulus			
Numbers	133	56	74
Mean Shell Length	-0.014 ± 0.0046	-0.0229 ± 0.0045	-0.0089 ± 0.0074
Range	-0.151 to 0.3529	-0.1509 to 0.0594	-0.1326 to 0.3529
Numbers	133	56	74
Mean Wet Weight	0.0463 ± 0.0102	0.034 ± 0.0095	0.0553 ± 0.0167
Range	-0.713 to 0.5864	-0.1604 to 0.2408	-0.7129 to 0.5864

A total of 1,135 tagged live whelks (Table 7) and 97 tagged shells (Table 8) were recaptured. Of the 1,135 live whelks recaptured, 1.9% were lightning whelks all of which were recaptured only once. No live male lightning whelks were recaptured. Channeled whelks accounted for 10.2% of the live recaptures. Most of the live channeled whelks (95%) were recaptured during the conch pot trials at Wassaw Island (Walker *et al.* 2003). In addition 11 males and 11 females were recaptured a second time and one male caught a third time in conch pots or crab traps at the Wassaw Island site. Excluding channeled whelks caught at Wassaw Island, five females, one male and one channeled whelk of unknown sex were recaptured. One female channeled whelk was caught a second time at Pa Cooper Creek. Female knobbed whelks consisted of 87.8% of all recaptured tagged whelks, many of which were caught several times. One female was caught four times at North Cabbage Island and another four times at Wassaw Island. Male knobbed whelks consist of only 3.6% of the live tagged knobbed whelks that were recaptured. Overall combined recovery rate was 6.9%. According to the number of tagged whelks per species released, recovery rate was 4.7% for channeled, 6.6% for knobbed, 8.7% for lightning and 0% of pearwhelks (Table 8).

Mortality of recovered tagged whelks was low. Only 97 (0.5%) dead tagged shells were found (Table 8). Slightly more dead knobbed whelks (0.57%) occurred than for channeled (0.4%) or lightning (0.4%). Of these, six were male channeled, three female channeled, one female lightning, four male knobbed, 37 female knobbed and 39 knobbed whelks of unknown sexed. In general dead whelks were found at their site of release; however, 10 (10.3%) were recovered at other sites. Most were found with hermit crabs inhabiting the shell, thus it is unknown rather the whelk traveled to the site and died or if the hermit crab carried the shell to the new site. Thus, these individuals were eliminated from the migration results. It is also known that some whelks were commercially harvested, since tagged whelks appeared in a local seafood market.

In general, female tagged whelks remained in the same area in which they were released, while male whelks of all species were recaptured infrequently at all sites. Of the 1,135 live and 97 dead recovered tagged whelks, 96.9% were found at their release site. A notable exception to this was at Joe's Cut where whelks moved from the small oyster

Table 7: Number of times an individual tagged whelk was recaptured per site.

	1	2	3	4	Total
House Creek					
Busycon carica					
Female	30	4	0	0	34
Male	3	0	0	0	3
Unknown	13	1	0	0	14
Busycotypus canalicalatus					
Female	1	0	0	0	1
Male	0	0	0	0	0
Unknown	0	0	0	0	0
Joe's Cut					
Busycon carica					
Female	24	0	0	0	24
Male	0	0	0	0	0
Unknown	0	0	0	0	0
Mud Island					
Busycon carica					
Female	16	0	0	0	16
Male	3	0	0	0	3
Unknown	1	0	0	0	1
Priest Landings					
Busycon carica					
Female	6	0	0	0	6
Male	3	0	0	0	3
Unknown	0	0	0	0	0
Busycotypus canalicalatus					
Female	1	0	0	0	1
Male	1	0	0	0	1
Unknown	0	0	0	0	0
North Cabbage Island					
Busycon carica					
Female	208	29	7	1	245
Male	7	1	0	0	8
Unknown	135	4	1	0	140
Busycon sinistrum					
Female	6	0	0	0	6
Male	1	0	0	0	1
Unknown	1	0	0	0	1

Busycotypus canalicalatus					
Female	0	0	0	0	0
Male	0	0	0	0	0
Unknown	1	0	0	0	1
Pa Cooper					
Busycon carica					
Female	176	19	4	0	199
Male	8	0	0	0	8
Unknown	18	1	0	0	19
Busycon sinistrum					
Female	5	0	0	0	5
Male	0	0	0	0	0
Unknown	1	0	0	0	1
Busycotypus canalicalatus					
Female	2	1	0	0	3
Male	0	0	0	0	0
Unknown	0	0	0	0	0
South Cabbage Island					
Busycon carica					
Female	59	5	0	0	64
Male	6	0	0	0	6
Unknown	13	2	0	0	15
Busycon sinistrum					
Female	1	0	0	0	1
Male	0	0	0	0	0
Unknown	0	0	0	0	0
Wassaw Island					
Busycon carica					
Female	217	36	6	1	260
Male	11	2	0	0	13
Unknown	40	4	0	0	44
Busycon sinistrum					
Female	4	0	0	0	4
Male	0	0	0	0	0
Unknown	3	0	0	0	3
Busycotypus canalicalatus					
Female	63	11	0	0	74
Male	44	11	1	0	56
Unknown	3	0	0	0	3
Total	1,135	131	19	2	1,287

Table 8: Known dead tagged whelks found at the eight study sites from 2000 to 2004.

	B. canalicalatus	*B. carica*	*B. sinistrum*
House Creek			
Released	43	1,774	9
Dead	0	5	0
Joe's Cut			
Released	467	1,204	0
Dead	0	1	0
Mud Island			
Released	223	1,433	0
Dead	0	8	0
North Cabbage Island			
Released	444	4,401	101
Dead	3	27	0
Pa Cooper Creek			
Released	40	1,472	35
Dead	1	22	0
Priest Landing			
Released	253	592	0
Dead	1	6	0
South Cabbage Island			
Released	93	1,948	15
Dead	0	8	0
Wassaw Island*			
Released	890	2,277	92
Dead	5	9	1
Total	2,453	15,101	252
Dead	10	86	1
% Mortality	0.4	0.57	0.4

* No dead *Busycotypus spiratum* were found among the 19 tagged. reef at the southeastern end of the cut on the Skidaway Island side to a larger oyster reef at the northwestern end of Sister Island.

Overall, little movement was observed between sites. One female lightning whelk, 14 female knobbed, and eight knobbed whelks of unknown sex moved across the Halfmoon River from the North Cabbage Island site to the Pa Cooper Creek site - a distance of 732 meters (Table 9). Two female knobbed and two knobbed whelks of unknown sexed made the transit in 222 days (3.3 m/d). The mean time required for the 22 knobbed whelks to cross the river was 709 days (range 222 to 1,426 days). The female lightning whelk was found after 340 days (2.15 m/d). Two knobbed whelks of unknown sex and four female knobbed whelks moved from Pa Cooper to North Cabbage Island. The mean time was 545.5 days (range 218 to 1,449 days). A single female knobbed whelk was found to have moved from Pa Cooper Creek to Wassaw Island - a distance of approximately 5,283 meters in 513 days (10.3 m/d). Two female knobbed whelks moved from South Cabbage Island to Pa Cooper Creek - an approximate distance of 3,983 meters in 756 days (5.3 m/d) and 1150 days (3.5 m/d). Nine female knobbed whelks and one of unknown sex moved from House Creek to South Cabbage Island - a distance of 4,064 meters in 384 (N=6; 10.6 m/d) to 902 days (N=1; 4.5 m/d).

Table 9: Relative straight line distance in meters between the eight intertidal whelk sampling sites in Wassaw Sound, GA.

	House Creek	Joes Cut	Mud Island	North Cabbage	Pa Cooper	Priest Landing	South Cabbage	Wassaw Island
Joes Cut							1,219	2,845
Mud Island				1,626	1,422			
N. Cabbage	2,032		1,626		732		3,251	4,552
Pa Cooper	2,438			732			3,983	5,283
Priests Landing							4,674	
S. Cabbage	4,064	1,219		3,251	3,983	4,674		1,829
Wassaw Island	5,080	2,845		4,552	5,283	6,096	1,829	

In general, whelks of all species were more numerous in areas around oyster reefs with gently sloping sand or sandy/mud intertidal flats. They occurred less frequently on steeper creek or river banks with oyster reefs. In areas with steep banks and oysters like Mud Island, House Creek, the northern end of North Cabbage Island, and the western end of the Pa Cooper site, tagged whelks were less common. In areas with gently sloping sand or sandy-mud banks that extended well out beyond the oyster beds into the sound, whelks were common. Whelks were uncommon in muddy substrates such as the Priest Landing site regardless of the slope of the bank or intertidal flat.

Few tagged (11 alive/6 dead) whelks were recovered at the Priest Landing site which had a massive mud flat occurring below the oyster beds. No tagged whelks from Priest Landing were collected from other study sites nor were any tagged whelks from those sites found at Priest Landing. On November 22, 2000, six dead whelks (five female knobbed whelks and one male channeled whelk) were recovered. On March 12, 2001, ten live whelks (eight knobbed and two channeled whelks) were recaptured, while one knobbed whelk was recaptured on May 31, 2001. Due to the low recapture rate at this site, these tagged whelks were released at the Wassaw Island site and this site was not monitored again until spring 2004. Fifteen knobbed whelks were found in May 2004, none of which were tagged.

Female knobbed whelks at Joe's Cut had the lowest mean positive shell length growth rate. No male knobbed whelks or other species were recaptured at this site which was only sampled once in April 2004. The greatest amount of detectable whelk movement occurred at this site. Tagged whelks were originally released at the eastern end of Joe's Cut on the Skidaway Island side. In April 2004, only two tagged knobbed whelks were found here out of 82 whelks collected. During the last sampling date, an attempt was made to locate whelks eastward and westward of the release sites. One additional tagged knobbed whelk out of 40 was found at the western end of the cut on the Skidaway Island side. No tagged whelks were found among the six knobbed whelks found along either intertidal mud bank of the cut. However along the northern side of Sister Island, two tagged knobbed whelks were found at the small oyster bar on the eastern tip of the island, while 17 tagged knobbed whelks out of 437 were found at the largest oyster bar in the area on the northwestern tip of Sister Island. Tagged knobbed whelks had apparently moved in a seaward direction from a small

oyster reef to a larger oyster reef, a distance of approximately 1,200 meters. No tagged whelks were found along the Wilmington River bank inshore of the release site. The low growth rate (Table 6) may be attributed in part to the relatively small amount of oysters available as food and distance traveled.

A total of 385 tagged whelks were recaptured in the Dead Man Hammock area of Wassaw Island. Of the 268 knobbed whelks, 217 were females, 11 were males and 40 were of unknown sex. Thirty-six of the females, two males and four of unknown sex were caught twice. Six females were caught three times, and one female was caught four times. Four female lightning and 3 lightning whelks of unknown sex were recaptured once. Of the 110 channeled whelks that were caught, 63 were females, 44 males and 3 were of unknown sex. Most were caught in the conch pots and crab traps. Of these, 11 males and 11 females were recaptured a second time, and one male was captured a third time. Two attempts were made to find tagged whelks across the creek on the easternmost part of the Dead Man Hammock area. No tagged whelks were found to have crossed the creek. Oysters are much less abundant in this intertidal area. Two attempts were made to locate tagged whelks westward of the release site. Massive oyster reefs follow the contour of the marsh all the way to Romerly Marsh Creek, which separates Wassaw and Skidaway Islands. Tagged whelks were found to have moved laterally in a westward direction but only over a small portion of the distance. No tagged whelks were found near the Romerly Marsh Creek area.

A total of 75 tagged whelks were recaptured at southern end of Cabbage Island. Of these, 5 were captured a second time. Of these 75 whelks, one was a female lightning whelk, six were male knobbed whelks, 54 were female knobbed whelks, and 14 were knobbed whelks of unknown sex. Six female knobbed whelks were found dead: three on 7 June 2001 and three on 1 June 2001. Nine females, one of unknown sex and one male knobbed whelk originally tagged and released from House Creek were found at this site: six females and one of unknown sex on 4 November 2002 and three females and one male on 18 March 2003. The male was dead. One attempt was made to locate tagged whelks westward of the release site. Oyster reefs occur intermittently along the marsh near the release site to Tybee Cut, the creek that separates Cabbage and Wilmington Islands. No tagged whelks were found in this area.

At North Cabbage a total of 359 tagged whelks were recaptured. Of the 350 knobbed whelks recaptured, 208 were females, seven males and 135 were of unknown sex. Twenty-nine females were gathered twice, seven were collected a third time and one was found a fourth time. Only one male was captured a second time. Six females, one male and one tagged lightning whelk of unknown sex were captured once. Only one channeled whelk of unknown sex was recaptured at this site. Twenty-nine dead shells were collected at North Cabbage. One dead knobbed whelk of unknown sex originally from Pa Cooper was found here. Eleven knobbed whelks of unknown sex, 13 females and one male knobbed whelk were located here. One female and two male channeled whelks were found dead.

Some whelks at the Pa Cooper Creek site tended to move laterally along the shore -line. Whelks were released along the Halfmoon River. Most recovered tagged whelks occurred in a gently sloping sandy/mud intertidal flat near the area of release; however over time a few whelks were recovered near the mouth of Pa Cooper Creek along the Bull River. A total of 210 tagged whelks were recaptured at the Pa Cooper site: 202 knobbed, six lightning and two channeled. Nineteen of the knobbed females (N=176) were captured a second time and four of these a third time. Of the 18 knobbed whelks of unknown sex, one was caught a second time. The six lightning whelks were recaptured only once. One of the two channeled whelks was recaptured a second time. Seventeen dead tagged shells were recovered: two male knobbed, ten female knobbed, four knobbed of unknown sex and one female knobbed whelk originally released at North Cabbage Island.

Few tagged whelks were recovered at the Mud Island site. Out of the 1,167 tagged whelks released, two knobbed whelks released on 25 May 2000 were found dead - one on 28 October 2000 and one on 28 March 2002. Both whelk shells were inhabited by hermit crabs, and were found on Wilmington Island across the sand bar from Mud Island. No tagged whelks were gathered along the steep banks of Mud Island. Twenty tagged knobbed whelks were recaptured on Wilmington Island in an area of gently sloping banks. One of these was captured twice, once on 6 February 2001 and again on 28 March 2002. All were gathered along Wilmington Island except one which was collected from a small oyster reef across the Halfmoon River on Cabbage Island. No tagged whelks

from Mud Island were collected from other study sites, nor were any tagged whelks from those sites found at Mud Island.

At House Creek, a total of 47 tagged whelks were recovered. Thirty females, three males and 13 knobbed whelks of unknown sex were recaptured. Of the females, four were recaptured a second time, while only one knobbed whelks of unknown sexed was gathered a second time. Only one tagged female channeled whelk was recaptured. Four dead knobbed whelks of unknown sex were found, and one dead knobbed male originally from South Cabbage Island was located at this site. Searches for tagged whelks outside of the release area turned up one tagged knobbed whelk at an oyster reef located directly across the Bull River from the Pa Cooper Creek site. This individual had crossed over the mud and sand flat at the mouth of the creek and was in the sound.

Discussion

Knobbed whelks are the dominant species by numbers in both inshore (Walker 1988) and offshore stocks in Georgia and South Carolina (Anderson *et al.* 1985). The prevalence of the second dominant species, channeled whelks is dependant upon tidal location. At three offshore sites (two in SC and one in GA), nine knobbed whelks occurred for every channeled whelk (Anderson *et al.* 1989). This is in agreement with the species composition of whelks gathered offshore in Georgia (Table 2) and in earlier intertidal whelk studies in Georgia (Walker *et al.* 1980; Walker 1988). In inshore intertidal areas in Georgia, lightning whelks were gathered more often than channeled whelks (Walker *et al.* 1980; Walker 1988). In this study, however, more channeled whelks were gathered than lightning whelks. The explanation is that more lightning whelks were gathered at the base of the oyster reefs than channeled whelks in this study. The discrepancy is due to the large number of channeled whelks gathered at the Wassaw Island site (81% of all inshore channeled whelks), which were gathered by either conch pot or crab trap very low in the intertidal zone approximately 300 meters away from the actual tagging capture/recapture site. Channeled whelks captured in conch pots or crab traps at the spring-low-water mark and tagged and released at the base of the oyster reef moved back to the spring-low-water mark and were caught again (Walker *et al.* 2003). Channeled whelks are, however, probably more numerous inshore than lightning

whelks. Channeled whelks are nocturnal, whereas lightning and knobbed whelks may feed during day and night (Magalhaes 1948). We only collected whelks during the daytime in this study. Shalack *et al.* (in preparation) working at the Dead Man Hammock area found significantly more channeled and knobbed whelks at night than during the day; whereas, more lightning whelks were collected in daytime. Shalack found approximately 20 times more knobbed whelks (N=1,663) than either lightning (N=74) or channeled whelks (N=86).

Whelks in Georgia are similar in size to those reported from other locations (Table 10). Lightning whelks appear to be smaller in shell length than those reported from the Gulf Coast of Florida, but are similar in size to that reported by Magalhaes (1948) in North Carolina. Berlocher (2000) found large genetic differences between lightning whelks found on the South Atlantic coast as compared to those from Florida in the Gulf of Mexico. He suggests that there is strong genetic evidence to suggest the existence of either highly distinct subspecies or unresolved species status between stocks (Berlocher 2000). Among whelks from South Carolina (Anderson *et al.* 1985), North Carolina (Magalhaes 1948), and Delaware (Bruce *et al.* 2006), knobbed and channeled whelks in Massachusetts (Davis and Matthiessen 1978), and for lightning, knobbed and channeled whelks in Georgia (Walker 1988), males are smaller in size than females.

Females of each species dominated in numbers at all seven intertidal sites (the Joe's Cut site was excluded, since no local whelks were tagged from this site) in Wassaw Sound. This is in agreement with an earlier whelk study which found that females occurred more often at the North Cabbage, South Cabbage and Wassaw Islands sites studied (Walker 1988). Female knobbed whelks were nine times as frequent as males on the intertidal oyster beds in the 1978-1980 study. This is comparable to the overall 8.3 figure observed in the present study (Table 4). In a recent study of whelks at Dead Man Hammock, 1,170 female knobbed whelks were gathered versus 275 males (Shalack *et al.* in preparation). For lightning whelks only one male out of 56 was found, while a statistically equal number of females (N=30) versus males (N=22)occurred for the channeled whelk. As in Georgia, female knobbed whelks were observed nine times more often than males in intertidal areas in Virginia (Castagna and Kraeuter 1994). In offshore areas of Georgia, the ratio of male to

female knobbed whelks was much closer to parity. In offshore South Carolina, three female knobbed whelks were found for each male (Anderson *et al.* 1985). Commercial gear used for offshore collections target larger-sized individuals, thus smaller-sized males may have been missed.

An unequal sex ratio for knobbed whelks occur in offshore and intertidal inshore areas above mean-low water where oysters occur. In offshore areas, a higher percentage of male knobbed whelks (43.5%) occurred than in the inshore stock (10.7%). It is possible that the sampling gear used offshore was selecting for females, since females grow to a larger size than males. Smaller males may have passed through the webbing of the conch trawl nets. Anderson *et al.* (1985) also found that female knobbed whelks occurred three times more frequently as males in offshore areas of South Carolina and remarked that gear selectively could possibly be responsible for the unequal sex ratio. Males are found intertidally primarily during mating and egg-laying seasons (Fall and Spring). Yet even then, they occur in low numbers. Apparently, males prefer to stay in the subtidal regions or possibly remain buried during daylight hours. There are two reasons for assuming this. Large numbers of offshore knobbed whelks where 43% were males were released at the various sites in Wassaw Sound. If an almost equal number of each sex was released, then one would expect to recapture an almost equal number of males and females. However most recaptured tagged whelks were female. In a tag and release study (Shalack 2007) at the Wassaw site where a piece of metal was attached to the shell for detection by a metal detector, male knobbed whelks remained in the area but were consistently found buried. In Rhode Island, Wood (1979) found a higher percentage of male knobbed whelks (64%) occurring in the shallow waters of Narrangansett Bay. Channeled whelks gathered inshore in Georgia, exhibited no significant differences in sex ratio; however when one examines just the whelks collected near the oysters, significantly more were females. Furthermore, when one examines the pot-trapped channeled whelks from either Bread Creek (subtidal) or Wassaw Island at the spring-low-water mark approximately 300 meters out in the sound from the oyster reef, an equal sex ratio occurred. Most males occurring intertidally were found during mating season. Since males are smaller than females, it is possible that they remain buried during daylight hours to avoid predation. Channeled whelks are reported to be basically nocturnal (Magalhaes 1948) in North Carolina, however, Shalack *et al.* (in preparation) found no significant

difference in capture rates of channeled whelks between day and night in Georgia nor between the sex ratios gathered in day or night.

Male knobbed whelks were generally found intertidally during spring or fall mating seasons. It was not uncommon to find one-to-nine smaller-sized males attempting to mate with a larger female (Power *et al.* 2002, Walker 1988). Generally the female was observed on the surface with one male present, but when one dug around the female, several other males could be found. In North Carolina, knobbed whelks were observed to move to areas of shallow waters from areas of no water on spring tides to spawn (Coues 1871). Magalhaes (1948) also observed 2, 3 or 4 smaller males attempting to mate with a single female during breeding time in North Carolina. We know now that numerous males can contribute their gametes to the progeny produced by a single female knobbed whelk (Avise *et al.* 2004, Walker *et al.* 2007).

Knobbed whelks are not protandric. Avise *et al.* (2004) determined that the juveniles within the egg capsules of the egg-case string occur at an equal sex ratio. Castagna and Kraeuter (1994) and Power *et al.* (in progress) have shown that females grow to a larger size than males. Several field studies have also reported that females occurred at a larger size than males (Magalhaes 1948; Davis and Matthiessen 1978; Anderson *et al.* 1985; Walker 1988; this study). Thus, the higher female ratio of whelks in the intertidal zone is not due to protandry. Males may prefer to stay in the subtidal areas for some behavioral reason, have a higher juvenile mortality rate, or remain buried during the daylight hours (Shalack 2007). The greater occurrence of females in the intertidal zone may be at attributable to the fact they are large enough to escape predation. Females may move into the intertidal zone in search of plentiful supplies of clams and oysters. Hard clam and oysters are important food sources for knobbed whelks (Colton 1908; Warren 1916; Magalhaes 1948; Carriker 1951; Menzel and Nichy 1958; Peterson 1982; Walker 1988; Kreauter 2001), and these resources occur primarily intertidally in Georgia (Harris 1980; Walker *et al.* 1980; Walker and Tenore 1984; Walker and Rawson 1985; Walker and Cotton 2001).

Growth rates of whelks varied between species, sexes and location (Table 10). Best growth data occurred for female knobbed whelks since they comprised the majority of tagged whelks

recaptured. Mean female knobbed growth rates ranged from -0.0022 mm/d at Priest Landing to 0.0258 mm/day at South Cabbage Island. Overall growth for all species and sexes was poorest at Priest Landing, where negative shell length and wet weight growth were recorded for females and males of both the channeled and knobbed whelk. The exception is for the single female channeled whelk which displayed positive weight, but negative shell length growth. Female growth rates were also low for those knobbed whelks recaptured at Joe's Cut (0.0036 mm/d and 0.0359 g/d). Shell length growth rates for female knobbed whelks were intermediate at Mud Island (0.0125 mm/d) and ranged from 0.02 mm/d at House Creek to 0.0258 mm/d at South Cabbage Island. Greatest shell length growth rates occurred for knobbed whelk males at House Creek (0.07 mm/d) and at Mud Island (0.0827 mm/d). Anderson *et al.* (1985) reported no growth for most knobbed whelks tagged and released offshore of South Carolina. In Virginia, Kreauter *et al.* (1989) reported growth rates of tagged knobbed whelks of 1.8 mm/yr (0.005 mm/d) and 0.7 mm/yr (0.002 mm/d). They also reported negative growth for many individuals and reported growth rates of 3.2 mm/yr (0.009 mm/d) and 1.9 mm/yr (0.005 mm/d) if the negative growth values were eliminated. Magalhaes (1948) reported negative growth in most tagged knobbed whelks in North Carolina. For 19 knobbed whelks exhibiting positive growth over an average of 438 days, a growth rate of 0.028 mm/d (10.2 mm/y) was observed. Eversole *et al.* (2008) reported a mean growth rate of <0.001 mm/d with negative growth in 47% of knobbed whelks recaptured from offshore South Carolina. In assuming a zero value for the 47% with negative growth, they calculated a mean growth rate of 0.022 mm/d. The greatest growth rate reported was 0.042 mm/d for an individual recaptured after 377 days. Annual mean shell length growth rates in Georgia for females ranged from -0.8 mm/yr (-0.002 mm/d) at Priest Landing to 9.4 mm/yr (0.026 mm/d) at South Cabbage Island and for males ranged from -2.5 mm/yr (-0.007 mm/d) at Wassaw Island to 29.2 mm/yr (0.08 mm/d) at Mud Island. Sisson (1972) reported a growth rate of 1.4 mm/m (0.047 mm/d) for channeled whelks occurring subtidally in Rhode Island. In Florida growth rates of 0.04 mm/d were reported for the pearwhelk (Kent 1983). Growth rates for small and large sized lightning whelks from Florida were 0.06 and 0.019 mm/d, respectively. Mean growth rates for female lightning whelks in Georgia ranged from 0.0136 mm/d at North Cabbage Island to 0.073 mm/d at Pa Cooper Creek.

Table 10: Shell lengths in cm of various species of whelks from different geographical regions.

	B. canalicalatus	*B. carica*	*B. sinistrum*	*B. spiratus*
North Carolina (Magalhaes 1948)	16.3	24.0	26.0	
South Carolina (Anderson *et al.* 1985)	18.8	21.0		
Georgia (Walker 1988)	16.0	22.0	21.8	
Georgia (This study)	17.5	22.8	25.7	11.2
Florida (Gulf) (Kent 1983)			34.5	13.5
Florida (Gulf) (Menzel and Nichy 1958)			31.8	
California (Stohler 1961)	18.5			

Growth rates of whelks in Georgia are faster than those reported in more northern areas (Kreauter *et al.* 1989, Sisson 1972). In general growth rates of mollusks increase with decreases in latitude and higher water temperatures (Ansell 1968, Gosling 2003). Anderson *et al.* (1989) report that fishermen in South Carolina believe that whelks stay buried until water temperatures reach 12°C. At 14°C whelks were actively searching for food. This was observed in a separate whelk study in Georgia. Tagged whelks (N=100) as in this study were further tagged with a piece of metal, released on January 9, 2003 at the Wassaw Island site at the center of a 15 X 15 m grid, and their movements followed with the aid of a metal detector (Walker *et al.* 2004). The water temperature

was 9°C, and the animals immediately dug beneath the sand. On January 30, whelk movement was minimal with the greatest distanced moved was 1.9 m. By mid-February, whelks had remained in place with the greatest movement of 3 m, but by March 2 after the water temperature reached 13°C, a third of the recovered tagged whelks had moved out of the grid area completely and were moving and forging along the oyster reef. Few whelks are found during winter months on intertidal flats in Georgia (Walker 1988 and this study) as was the case for knobbed whelks in North Carolina (Magalhaes 1948). In Virginia little-to-no growth was recorded in knobbed whelks from early November to the end of March (Kraeuter *et al.* 1989). In New England, knobbed whelks showed seasonal growth in width of 0.0486 mm/d for males and 0.0624 mm/d for females. However these growth rates were for an eighteen week period starting in spring (Davis and Matthiessen 1978). The authors report no growth in whelks over winter.

The differences in growth rates between sites in Georgia may be explained by the number of recaptures or availability of food per site. Many of the growth rates determined for channeled or lightning whelks are based on a single or relatively few recaptured individuals. Given the extreme variability in growth among individuals of knobbed whelks at a particular site, the value of a single or even a few growth measurement(s) is questionable. However certain trends were noticeable. Negative growth occurred for both knobbed and channeled whelks at the Priest Landing site. This site had the muddiest substrate and probably the second fewest live oysters of all sites. Recaptures were so low that we quit monitoring this site in 2001 and did not re-sample again until May 2004. Relatively speaking it had the highest mortality rate of 0.8%. No tagged whelks were found among the 15 knobbed whelks found at the final sampling in May 2004. Low growth rate of knobbed whelks occurred at Joe Cuts in an area with the fewest oysters. The greatest migration rate occurred here as whelks left the southeastern end of Joe's Cut and moved to the northwestern tip of Sister Island where a larger bed of oysters occurs.

Knobbed whelk growth was most interesting at Mud Island. Shell length growth was only moderate at 0.0125 mm/d; while growth in wet weight was the greatest among all sites (0.1863 g/d). No tagged whelks were recovered at their release sites. Few untagged whelks were recovered here as well. It is believed that the bank around the island is too steep. All recaptured tagged whelks were

found on a more gently sloping bank on Wilmington Island or across the river at a small oyster reef along a gently sloping bank of Cabbage Island.

Female knobbed whelks at the remaining four sites all had shell length growth rates between 0.020 mm/d to 0.026 mm/d. These sites all had plentiful oyster resources. With the exception of House Creek, the oyster reefs were adjacent to large gently sloping sand/mud intertidal flats. It appears that large oyster reefs with gently sloping intertidal flats are the preferred habitat for female knobbed whelks. This is further supported by observations at Pa Cooper Creek site where few whelks are found along the steeper banks of the sampling site. Most whelks occur in the areas where numerous oysters occur along a gently sloping intertidal flat.

Movement of all species of whelks tends to be limited (Sisson 1972; Shaw 1960; Menzel and Nichy 1958; Anderson *et al.* 1985; Walker 1988). The majority of the whelks recaptured in this study were recaptured at their release sites. While there is considerable movement laterally about the oyster reefs (Walker 1988; Walker *et al.* 2003; Walker *et al.* 2004), little migration from site-to-site occurs. Whelks in Georgia tend to move laterally following the contours of the oyster reefs in search of food (Shalack 2007, this study). Females moved horizontally from the intertidal oyster reefs to the spring-low-water mark or into subtidal areas to deposit their egg case strings during spawning in fall and spring, but return to the oyster reefs (Walker 1988; this study). Whelks tend to be absent from the intertidal flats in winter and summer, but whether they bury (vertical movement) or move off the flats into subtidal areas is unknown. Shalack (2007) found that a higher percentage of knobbed whelks remained buried during daytime in summer as opposed to springtime when more are found on the surface. He also observed that knobbed whelks would be on the surface in summer feeding on oysters only during the neap tides when oyster reefs are barely exposed. If placed high in the intertidal zone during winter females will bury and remain stationary until the water temperature increases (Walker *et al.* 2004). However, it is not known whether they bury naturally with decline in water temperature or move off the intertidal flats to escape the seasonal temperature extremes. Little is known about movements of male whelks in Georgia. Males do appear during mating season when up to nine males may be found attempting to mate with a single female (Power *et al.* 2003). Shalack found that knobbed whelk males prefer to remain buried. In

the shallow waters of North Carolina, 57% of the knobbed whelks recaptured were males (Magalhaes 1948).

Magalhaes (1948) described two types of migration for whelks in North Carolina: vertical and horizontal. Horizontal migration from shallow-to-deep waters was believed to be associated with food supply and reproduction. Vertical migration in the substrate is associated with food supply, predator avoidance and unfavorable environmental conditions such as excessive heat, light and dehydration (Magalhaes 1948). Both types of movement were seen in this Georgia study. Knobbed whelk mating may occur near the base of oyster bars in Georgia, but egg-case string laying generally occurs low in the intertidal zone near the spring-low-water mark and into subtidal areas. Pearwhelks in Georgia do not occur near the oysters but remain at the spring-low-water mark to subtidal areas. Pearwhelks at Wassaw Island also deposited egg-case strings at the spring-low-water mark as were knobbed whelks. In House Creek whelks moved from the oyster beds along the creek banks across the creek to lay eggs either on the mud or sand side of the intertidal flat at the mouth of the creek. Coues (1871) noted that knobbed whelks in North Carolina moved to shallow areas of sandy shoals at the spring-low-water mark to a depth of 0.3 meters prior to laying eggs. With increases in the extremes of weather, whelks are less frequently observed in the intertidal zone. Whether they bury for the winter and summer months or move to subtidal areas is not known. Shalack's (2007) study indicates that whelks simply bury during summer days, but they may remain active during neap tides or at night. Fishermen claim that whelks in offshore areas bury for the winter (Anderson *et al.* 1985).

Recapture rates for tagged whelks in this study are similar to those reported elsewhere. A 7.8% recapture of tagged whelks occurred for all species in Georgia. In Florida, South Carolina, North Carolina, Virginia and Rhode Island, recovery rates of 6.8% for lightning whelks (Paine 1962), 4% for channeled and knobbed whelks (Anderson *et al.* 1985), 10.3% for knobbed whelks (Magalhaes 1948), 8.7% and 18.8% for knobbed whelks (Kraeuter *et al.* 1989), and 11% for channeled whelks (Sisson 1972), respectively were reported. Paine (1962) released 117 tagged lightning whelks only to recover 8 (6.8%) a week later.

Mortality estimates of whelks in Georgia are similar to those reported elsewhere. Dead shell recovery of channeled, knobbed and lightning whelks in Georgia was 0.4%, 0.57% and 0.5%, respectively. In Florida 12% recovery of dead tagged lightning and pearwhelks occurred (Menzel and Nichy 1958). Offshore South Carolina 115 dead shells (1.2%) were found of which 95% were knobbed whelks and 5% channeled whelks (Anderson *et al.* 1985). Magalhaes (1948) recovered only 1.4% dead tagged knobbed whelks in North Carolina. Shalack (2007) tracked tagged knobbed whelks with a metal detector and confirmed that 9 of 50 (18%) whelks were killed by predation during his four- month study.

In general whelks remain in areas where food supplies are plentiful. Relatively few whelks migrated between sites in Georgia. The greatest migration event occurred at Joe's Cut, where whelks moved from an area of low oyster abundance to a larger oyster bed at the other end of a small marsh island. Most whelks were recaptured at their original release sites. Anderson *et al.* (1985) report no migration of whelks released in an offshore area of South Carolina. Menzel and Nichy (1958) also reported that lightning whelks remained in their release areas. Sisson (1972) recaptured 57% of his tagged channeled whelks at their original release sites. For those that moved, the movement was described as random along the bay bottom. The greatest distance moved was 4,211 m in 308 days (Sisson 1972).

Resource Management Implications for Inshore Whelk Stocks

Georgia's offshore whelk fishery is in an over-harvested stage as landings have plummeted. With the collapse of the offshore fishery, interest has shifted to inshore stocks of whelks. Fortunately, commercial shrimp (June through December/January) and whelk (January through March) trawling is prohibited within Georgia's inshore waters. This prevents trawling from inadvertently pulling whelk egg-case strings from their anchors in inshore subtidal and spring-low-water areas during spring and fall mating and egg-laying seasons. Georgia has a closed whelk season during spring in the offshore areas of Georgia. Due to the commercial importance of the penaeid shrimp industry in Georgia, it is unlikely that shrimp fishers will be prevented from fishing in offshore areas during fall. Shrimp nets do not harvest that many whelks since they skim just above the bottom, but they do gather egg-case strings, which are thrown back overboard and eventually

wash up on the beaches to dessicate. With the collapse of the offshore whelk fishery, closing the spring season was not enough to protect the resource. Trawling in inshore areas for whelks should not be allowed at all.

There is commercial interest in establishing a conch pot-trap fishery for the channeled whelk in the inshore waters of Georgia. Channeled whelks already are caught as a by-product of the blue crab fishery. Knobbed and lightning whelks generally do not enter crab traps or conch pots (Walker *et al.* 2003). Pot-trapping of channeled whelks at the Wassaw Island site showed that channeled whelk stocks were depleted within a two-week period (Walker *et al.* 2003). Shalack (2007) also showed that whelk stocks were depleted within a few weeks of pot-trapping at two sites in Georgia. In Massachusetts a trapping experiment showed that 1,122 channeled whelks were pot-trapped, 80% within the first two weeks in 1957 and 80% of 1,052 in four weeks in 1958 (Shaw 1960). These studies tend to illustrate how easily it is to impact a localized channeled whelk stock. A closed season during egg-case string laying periods or just prior to those events should be investigated for the channeled whelk. If female whelks do not feed during egg-laying and mating events, then they may not enter the pot traps. Thus a closed season during that time period may not protect the stock. On the other hand, if females seek out an easy food source just prior to mating and egg-laying that meets their energy requirements for spawning, then perhaps that period of time should be closed to prevent the removal of females from the stock prior to mating and egg laying periods. More studies on the timing and feeding behavior of females during spawning and mating are needed, as well as, a complete understanding of their gametogenic cycle.

Important biological information concerning the life history of knobbed whelks is revealed by this study. Knobbed whelks tend to stay within areas of plentiful food sources, and females migrate on and off the intertidal flats seasonally to lay eggs. This allows them to be easily harvested at low tides during fall and spring. Unfortunately, spring and fall are the season when whelks are mating and the females are laying their egg-case strings. Most of the whelks present on the intertidal flats are knobbed whelk females. The females are larger sized and thus more easily harvested than males. Any fishery that targets females during their reproductive period will eventually collapse. Establishing a closed season for harvesting whelks from the inshore oyster reefs during mating and egg-laying periods should be considered. Perhaps during the three-to-four months each spring and

fall period that whelks are present on the intertidal flats, the first six weeks should be closed to allow mating and spawning, then harvesting allowed afterwards.

Sexual maturity in the knobbed whelk in Georgia is indicated in both sexes by a rapid increase in relative gonadal weight at 85 to 90 mm in shell length for males and at 100 mm for females (Power *et al.* in preparation). Knobbed whelks in Georgia grow slowly and reach sexual maturity in 4 years for males and in 6 years for females. Castagna and Kreauter (1989) report that knobbed whelks in Virginia lived to 21 years. Female whelks in Georgia grow to a larger size than males and thus are more easily harvested by commercial fishers and recreational harvesters. Presently, all sizes of whelks are being harvested which could result in overfishing for this species. In Virginia, laboratory-reared knobbed whelks sexuality matured as males at 9 years of age (Castagna and Kraeuter 1994) and at an average size of 130 mm in shell length (Kreauter *et al.* 1989). Female whelks were not observed until year 12 at a shell length of 172 mm (Castagna and Kraeuter 1994). Field collections of mating whelks in March 2003 support our findings that whelks in Georgia reach sexual maturity at a smaller size than those from Virginia. The Georgia offshore fishery is selectively catching more females, since the smaller males may pass through the nets. No size limits currently are in place to protect whelk species. A minimum-size limit for the commercial harvesting of knobbed whelks should be established. In South Carolina a minimal size limit of 127 mm was first established for knobbed whelk, only to be lowered to 102 mm at the request of fishermen (Eversole *et al.* 2008). It is suggested that a size limit of 130 mm in length be established for Georgia. Reproductive studies on the channeled and lightning whelk need to be performed to determine a minium size for harvesting of these species. Presently, whelks are not culled at sea and do to so would require a lot of effort by the fishers. Regulations for doing so should be enacted.

It is the opinion of the authors that lightning and pearwhelks should not be harvested as they are relatively uncommon in abundance compared to the channeled and knobbed whelks. Commercial fishers should be instructed in how to identify each species and taught conservation measures that explain why a species of limited numbers should be returned to the sea.

As the offshore whelk fishery continues to decline in Georgia, increased interest by commercial fishermen is aimed at developing an inshore whelk fishery. Most of the present interest

in is developing a conch-pot fishery for the channeled whelk (Shalack 2007; Walker *et al.* 2003). With the development of an inshore pot fishery, an increase in hand- gathering of intertidal whelks in Georgia will occur. This study provides data that should help resource managers make wise decisions about managing this natural resource. Resource management regulation should be put in place now to protect the inshore stocks of whelks before they disappear as the offshore stocks have.

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