Seasonal Movement and Behavior of the Knobbed Whelk, *Busycon carica* (Gmelin, 1791), on intertidal Flats in Wassaw Sound, Georgia

Occasional Papers of the
University of Georgia Marine Extension Service
Vol. 11, 2011

By Jacob Shalack, Alan Power and R.L. Walker

Marine Extension Service, University of Georgia, Shellfish Research Laboratory,
20 Ocean Science Circle, Savannah, GA 31411-1011
Acknowledgment

ArcView GIS assistance was provided by Douglas Atkinson, Thomas Bliss, and Dr. Karen Payne and may have never been completed without assistance from Taylor Johnson, all of the Marine Extension Service. Aerial photography assistance was provided by Dr. Clark Alexander and Mr. Mike Robinson of the Skidaway Institute of Oceanography. Field assistance was provided by Jason Brown and Ellie Covington. Editing assistance provided by Dr. Merryl Alber of the Department of Marine Sciences, University of Georgia. A special thanks to Mary Lauren Shalack who provided extensive field and laboratory support.
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Abstract

The temporal and spatial movement and behavior of the knobbed whelk, *Busycon carica* (Gmelin, 1791) (Family Melongenidae), was examined on an intertidal sand/mud flat adjacent to an oyster, *Crassostrea virginica* (Gmelin, 1791), reef in Wassaw Sound, GA between April and August 2006. Our objective was to determine whether snails migrate off intertidal flats during summer into subtidal waters or remain in the intertidal zone and bury during daytime aerial exposure at low tide. Fifty whelks (25 males, 25 females) were tagged with Hallprint shellfish tags for identification and a 2x3 cm piece of galvanized aluminum flashing was attached for location by metal detector. After release in April, whelks typically concentrated on and near live oyster reefs and moved along the reef contour following the shoreline. The average individual minimum daily movement rate was significantly different (ANOVA α = 0.05) for males (mean 1.61 m d⁻¹) and females (mean 2.57 m d⁻¹) over the four month period. In April, chi-squared tests showed significantly more whelks were observed on the surface or partially exposed at low tide; but in May through August significantly more whelks were found buried during daytime. At completion of tracking, one whelk had never been located, nine were still in the tracking area and nine were confirmed dead. Of the remaining 31, 24 had previously been located at the edge of the search area and were following the contours of the oyster reef and shoreline out of the test area. The other seven were lost in the search area. Knobbed whelks remain in the intertidal zone during summer where they actively prey on oyster reefs at night and possibly during the day while the intertidal flats are inundated, but avoid exposure to aerial conditions during daytime low tides by burying.
Introduction

The knobbed whelk, *Busycon carica* (Gmelin, 1791) (Family Melongenidae), supports a fishery in coastal Georgia. The main fishery is an offshore trawl fishery that operates in winter after the close of the penaeid shrimp fishery. Commercial shrimp trawlers at the end of the season (December to January) change gear to a heavier net in which the bottom edge is weighted in order for the nets to dig into the substrate to catch whelks (Belcher et al. 2001). The offshore whelk fishery has collapsed. The fishery peaked in 1990 with 462,204 kg of meats landed valued at $507,718. From 2004 to 2010, annual landings have averaged 3,127 kg (Table 1). Fishers have expressed an interest in increasing harvesting of whelks from inshore areas (Walker et al. 2008; Shalack et al. 2011a). Knobbed whelks are common on intertidal sand/mud flats in the higher saline areas in the southeastern United States during spring and fall. Whelks may be hand harvested by hard clam, *Mercenaria mercenaria* (Linnaeus, 1758), and oyster, *Crassostrea virginica* (Gmelin, 1971), fishers (Walker 1988). Georgia has a 2.4 m tide which exposes vast intertidal areas at low tide. Lower whelk abundances on the intertidal flats during the winter and summer suggest that movement between intertidal and subtidal waters may be associated with reproductive events and food supply in the southeastern United States (Magalhaes 1948, Walker 1988, Walker et al. 2004, Walker et al. 2008). Female knobbed whelks move from the intertidal oyster beds in spring and fall to more subtidal areas in order to lay their egg-case strings (Walker 1988, Power et al. 2002, Walker et al. 2008).

During spring and fall, multiple whelk matings are frequently observed during low tide on exposed sand/mud flats (Magalhaes 1948, Walker 1988, Castagna and Kraeuter 1994, Power et al. 2002, Walker et al. 2008). Egg laying from April to early June has been studied in Georgia (Power et al. 2002). Individual egg-case strings containing the genetic contributions of several sires are subsequently anchored into the sediment by oviparous females (Walker et al. 2007).
Table 1. Whelks, *Busycon* and *Busycotypus* species, production in pounds of meat landed from 1880 to 1999 in Georgia. Data are from Georgia Department of Natural Resources (1979-2010) and National Marine Fisheries Service (1880-1978).

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<th>Year</th>
<th>kg of meat</th>
<th>$ value</th>
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* 2010 Data are preliminary and therefore subject to change

Egg-case strings contain on average 90 capsules which hold on average 46 embryos per capsule (Power et al. 2002).

In the southeastern United States oysters and hard clams are important prey items for *Busycon carica* and both predominantly occur in the intertidal zones of creeks, rivers and sounds (Harris 1980, Walker and Tenore 1984, respectively). Whelks locate these bivalve species by tracking odor plumes (Ferner and Weissburg 2005) and preys upon them by chipping and wedging valves apart using the relatively thick edge of their own shell aperture lip (Colton 1908, Warren 1916, Magalhaes 1948, Carriker 1951, Menzel and Nichy 1958, Paine 1962, Peterson 1982, Walker 1988).
Previous manipulative experiments in Georgia have indicated that *Busycon carica* will bury in place when released on the intertidal sand/mud flats during winter and do not become active again until water temperatures reach a minimum of 14°C (Walker *et al.* 2004). This poses the alternative theory that the knobbed whelk remains in the intertidal zone year round and bury down into the sediment to escape daytime temperature extremes when exposed at low tide during winter and summer. This study’s objective was to document individual whelk movement and behavior on an intertidal sand/mud flat in Georgia between spring and summer to determine whether they participate in a subtidal migration, remain present and active, or remains present and buried until environmental conditions become more favorable. The information provided by this study has relevance for the development of a sustainable fisheries management plan for the species.

**MATERIALS AND METHODS**

**Study Area**

The study was conducted off Dead Man Hammock on Wassaw Island in Wassaw Sound, GA (Figure 1). An extensive oyster reef runs along the length of the shoreline from the northeastern end of Dead Man Hammock to Old Romerly Marsh Creek. Below the oyster reef, a mud/sand flat substrate extending approximately 300 meters out into the sound is exposed at spring low tide.
Figure 1. Dead Man Hammock study site in Wassaw Sound, GA.

Study Design

Whelks were collected by hand at low tide from the Dead Man Hammock area in March 2006. The shell length (apex to siphon canal) in mm, shell width (across shoulder) in mm, and wet weight (0.10 g) were recorded for each animal. The whelks were relaxed in seawater containing 7% magnesium chloride to relax the organism and sex was determined by the presence or absence of a penis. Each organism was then individually tagged with Hallprint tags (type FPN, Holden Hill, Australia) for identification. A 2x3 cm piece of galvanized aluminum flashing was also attached to the dorsal area of the shell, with J-B Weld Kwik, to allow detection by a metal detector (Minelab Excalibur 800) (adapted from Walker et al. 2004).

Tagged *Busycon carica* (25 males and 25 females) were released on the intertidal sand/mud flat April 11, 2006, during low tide, at a vertical PVC pole placed at the rear middle of
an oyster reef inlet (Figure 2). Tracking occurred daily for the first 14 days and then every other day until August 7, 2006 when the tide recession permitted. Most (94%) tracking of movement occurred during daylight low tides (3 nighttime). When a whelk was located, its distance (by measuring tape) and compass direction (by handheld magnetic compass) to the release point was determined. The whelks position in relation to the substrate was recorded as on the surface, partially buried (if any portion of the shell was visible), or completely buried. Any activity (mating, feeding, etc.) that the whelk was engaged in was also noted.

Over time, whelks became increasingly more buried, so on July 2, 2007 a separate counting method of all visible (not buried) whelks was started. All visible whelks (including untagged resident whelks) were counted along a 55 meter contoured length of the oyster reef out to 5 meters from the edge of the oyster reef on the sand/mud substrate on the right side of the study inlet.

Water and air temperature was recorded each sample period with a thermometer.

Data Analyses

The release point UTM coordinates were determined using the averaging function on 1200 readings from a Garmin GPS 72, which provided an estimated error of less than one meter. Whelk compass locations were corrected $6^\circ$ W for magnetic declination from true north according to calculations by the National Geophysical Data Center. Whelk location distances and directions from the release point were converted into UTM coordinates using ESRI ArcView GIS 3.2 with the extension Bearing Maker v1.1. The coordinates were then used to create a
Figure 2. Dead Man Hammock study inlet with release point denoted by a star.

shapefile of all whelk locations during the study. The point shapefile was layered on a georeferenced aerial photograph from the Savannah Chatham County Metropolitan Planning Commission (January 2004). Minimum average daily movement was calculated between every two consecutive whelk locations. The minimum distance between the points was divided by the number of days between the locations providing an average minimum daily movement rate for the segment. SAS/STAT 9.1 was used for statistical analysis of minimum daily movement.
RESULTS

Tracking Totals

Fifty whelks (25 males, 25 females) were released on April 11, 2006 and their movement followed until August 7, 2006. The males ranged in length from 78 mm to 118 mm (mean 96.4 ± 12.1 mm (S.D.)) and females from 121 mm to 222 mm (mean 160.1 ± 21.5 mm). Tracking occurred during daylight hours on 48 days and during three nights (total = 51 days). Water temperatures ranged from a low of 20.5ºC to a high of 31ºC and air temperatures from 18ºC to 34ºC during the tracking (Figure 3).

Figure 3. Air and water temperatures (ºC) at Dead Man Hammock.
Figure 4. Whelk positions on day 1-6, 8, and 9 respectively, after release. Release point denoted by a star.
A total of 680 whelk locations were recorded (261 male, 419 female). The number of sightings for individual whelks ranged from 0 to 42 locations (mean 13.6 ± 9.1, median 11). Movement paths and the minimum convex polygon shapefiles were created by the extension Animal Movement v2. A minimum convex polygon around all of the located whelk positions encompassed an area of 7064.3 m². In 356 instances, the whelks were completely buried (52%), 253 partially buried (37%), 69 on the surface (10%) and two unknown (not recorded). Whelks were found mating on four and feeding on 17 occasions. After release, whelks randomly dispersed from the release point over the intertidal sand/mud flat. Eight days after release, whelks began concentrating on and near live oyster reefs (Figure 4). Over the entire study, the majority of whelk sightings were made on or near live oyster reefs (Figure 5).

Figure 5. All whelk locations at study site, Dead Man Hammock.
As the study progressed, fewer whelks were being located. In May, 38 (76%) individuals were identified as still present in the study inlet. By June, 32 (64%) of the whelks could be accounted for; and by July the number had declined to 23 (46%). By completion of the tracking in August, one whelk had never been located, nine (18%) were still within the tracking area, and nine were confirmed dead (4 males, 5 females). Twenty-four of the remaining whelks had been within 30 meters of the edge of the search area when last located: four males were tracked at near center of inlet and presumably heading for open water (Figure 6); five within 10 meters of the left side oyster reef; and 15 within 10 meters of the right side oyster reef (Figure 7). The remaining seven whelks were greater than 50 meters from the search area perimeter when last observed and are less likely to have moved out of the surveyed area but may have been preyed upon or lost their metal flashing tag.

Figure 6. Four male whelk’s last known location, presumably heading for open water.
Figure 7. Whelks moving around oyster reefs leading to last known location

Movement and Positions

The mean individual minimum (assumes straight movement path) daily movement rate was not significantly different (Tukey’s studentized range α = 0.05) for 41 of the 49 located whelks. Six of the 49 whelks were significantly faster than the group of 41. One female whelk movement (52.9 m d⁻¹) was significantly greater than all others, but was based on only one movement segment. The grouping of the 41 whelks that did not display significant differences in movement had mean individual minimum daily movement rates that ranged from 0.66 to 6.05 m d⁻¹. The minimum daily movement was significantly lower (ANOVA p<0.0001) for males (ranged from 0.0 m d⁻¹ to 42.2 m d⁻¹ mean 1.61 m d⁻¹) than females (ranged from 0.0 m d⁻¹ to 52.9 m d⁻¹ mean 2.57 m d⁻¹).

Early in the study, whelks tended to be on the surface or only partially buried (exposed), but later in the study most of the whelks located were found completely buried (not exposed)
(Figure 8). In April, significantly more (Chi squared $\alpha = 0.05$) whelks were partially or completely exposed when located on seven of the 16 tracking days versus one of the 16 that significantly favored completely buried. From May to August, significantly more whelks were found buried on 12 of the 32 tracking days (Figure 9). Significantly more (Chi squared $\alpha = 0.05$) female whelks’ locations were made than male whelks’ locations for each of the periods. Exposed females outnumbered males 2.51:1 during April and 2.55:1 from May to August.

Of the 680 whelk locations, 27 were made during the night. For two of the nights, there was no difference in the nighttime versus daytime activity. However, for the daytime and nighttime samples on July 9; three out of eight located whelks were observed on the surface and feeding at night whereas none of the nine located whelk during the day were observed on the surface.

![Figure 8](image.png)

Figure 8. Percent of whelks found buried, partially buried or on the surface.
Figure 9. Chi squared significant differences in exposed whelks versus buried whelks.

Separate counts of all visible whelks (not just the whelks being tracked) on the right side of the oyster reef supports the idea of active feeding while submerged during the summer months. Many knobbed whelks could be found on the oyster reefs immediately following a series of neap tides in which the reefs were submerged for several days. However, within one or two days following the submerged period, when the low tide levels began to fall, very few if any whelks were still visible on the reefs (Figure 10).
DISCUSSION

After release, knobbed whelks randomly dispersed from the release point on the intertidal sand/mud flat. However, by day 8 after release and thereafter, whelks concentrated on and near live oyster reefs (Figure 4). At this time, many naturally occurring whelks were observed on and around other oyster reefs in the area; however few natural or tagged whelks occurred away from the reefs in the intertidal muddy-sand flats. The center oyster reef and the right reef in the study inlet had higher live oyster densities than the left side oyster reef. Greater observations of tagged
whelks occurred about the central and right reefs (Figure 5) where greater prey abundances occurred. This is consistent with previous reports of *B. carica* behavior. Knobbed whelks are known to feed heavily on bivalves (Colton 1908, Warren 1916, Magalhaes 1948, Carriker 1951, Menzel and Nichy 1958, Peterson 1982, Walker 1988) and occur in great numbers during the spring around oyster reefs in Georgia waters (Walker 1988, Walker *et al.* 2008).

Once whelks concentrated on and near the oyster reefs, future movement followed the contours (within 10 meters) of the oyster reefs. For movement pattern of 20 whelks that presumably left the tracking area by August; five whelks migrated around the contours of the left side and 15 around the right side of oyster reef when they were last located. Of these 20 whelks, only one whelk was located outside of the study inlet, it is presumed that the 20 whelks that were moving along the contours of the oyster reefs, continued to do so, as there is no evidence of them moving out onto the intertidal flat towards open water. Four male whelks (Figure 6) were observed heading for open water. A whelk trapping study (Shalack 2007; Shalack *et al.* 2011b) conducted 320 meters directly out from the study inlet in Wassaw Sound was conducted from May 10 and June 27, 2006. Although knobbed whelks were trapped, no tagged knobbed whelks from this study were caught.

Knobbed whelk movement along the shore has been previously reported (Walker *et al.* 2008). Horizontal movement from shallow to deeper waters has been associated with reproduction and food supply and vertical movement in the substrate with food supply, predator avoidance and unfavorable environmental conditions such as excessive heat, light, and dehydration (Magalhaes 1948). In Walker *et al.* (2008) tagging study on whelks in Georgia, where 17,826 whelks were tagged and released at seven sites in Wassaw Sound, a third type of movement was described. Lateral movement was described as whelks following the contours of
various shellfish beds, as was observed in this study. The oyster reefs beyond the study inlet were not as well organized as the ones inside the tracking area, so it is possible that a greater dispersion of the whelks occurred beyond the study inlet. The poorly defined oyster reefs outside the study area may explain why attempts to locate whelks outside of the search inlet, along the shore as well as directly out from, proved mostly unsuccessful.

*Busycon carica* movement varies greatly. In a tagging study of 17,826 whelks, most tagged whelks (97%) were recaptured at their point of release; however a few individual were observed to move considerable distances (Walker *et al.* 2008). One knobbed whelk traveled across Wassaw Sound 5,283 meters in 513 days. Walker (1988) reported movements of 400 and 600 meters by knobbed whelks moving from one shellfish bed to another in Georgia. Magalhaes (1948) reported movement of 1,000 meters along a shore in North Carolina. They may be active for several days and then inactive for a longer period of time (Magalhaes 1948). Magalhaes (1948) reported single day movements of fifteen to forty meters. She also reported laboratory movement rates varying from 0.83 mm s$^{-1}$ to 1.67 mm s$^{-1}$. Ferner (2006) reported a speed of 0.5 mm s$^{-1}$ while tracking prey odor plumes in a laboratory flume.

Individual daily whelk movement ranged from no movement to a high of 52.9 m d$^{-1}$. Assuming movement only when submerged (approximately 18 hr d$^{-1}$), a speed of 52.9 m d$^{-1}$ is equal to 0.82 mm s$^{-1}$, which is close to previously reported laboratory speeds of 0.83 mm s$^{-1}$ to 1.67 mm s$^{-1}$ (Magalhaes 1948). The actual speed may have even been greater as our calculation assumes the whelk proceeded in a straight line. In field observations, Magalhaes (1948) reported movements of 15 m d$^{-1}$ to 40 m d$^{-1}$ with an average movement of 18 m d$^{-1}$. Walker *et al.* (2004) reported speeds of 2.5 m d$^{-1}$. 

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Although individual minimum daily movement rates were not significantly different for most of the whelks, movement rates between males and females as groups were significantly different (ANOVA p<0.0001). Females as a group had a calculated mean minimum daily movement of 2.57 m d⁻¹ which was almost a meter greater than the males mean of 1.61 m d⁻¹. The significance was not due to an extreme skewing of the mean by the female with only one calculation mentioned previously. Exclusion of that female still resulted in a significant difference between male and female movement. It is unlikely that this is simply a difference in body size as well. No correlation was found between the movements of the whelks and their body lengths. *Busycon spp.* generally crawls by means of cilia (Gainey 1976). Of the many types of locomotion by gastropods, ciliary movers show the least correlation between size and speed (Linsley 1978). However, it is possible that the greater movement is a result of the greater energy demand by female whelks in the production of eggs and egg cases. Females of the commercial species *Buccinum undatum* (Linnaeus, 1758), use six to 16 times more energy for reproduction than males of the same species (Martel *et al.* 1986, Kideys *et al.* 1993). Although no females in this study were observed laying eggs, females have been readily observed on lower intertidal sand/mud flats laying egg cases in the spring months in Georgia (Power *et al.* 2002).

Of the 49 located whelks, only the movements of four male whelks may have displayed evidence of direct movement across the intertidal flat towards subtidal areas (Figure 6). They were all males and all not located after one week of release. The four males were representative of all males (mean size of the four was 94 mm vs 96 mm for all males). Mating can occur near the oyster reefs, but generally occurs lower in the intertidal zone. Multiple males can be observed mating or trying to mate with a single female even while egg laying is occurring (Walker 1988, Power *et al.* 2002, Walker *et al.* 2008). Walker *et al.* (2007) showed that multiple sires can
contribute to the fertilization of embryos in not only an egg-case string, but within the individual embryos in a capsule attached to the egg-case string. It is interesting that no females were observing moving towards the lower intertidal areas during the start of this work. Egg laying occurs April to June (Power et al. 2002) and generally occurs low in the intertidal zone to subtidal areas. Perhaps since whelks were initially gathered and tagged just after the start of the egg-laying season, females capable of spawning had already left the shallow water areas for lower intertidal areas, while those captured for tagging required food.

Mortality of the tagged whelks in this study was high. Nine of the 50 whelks released were confirmed dead. Several different possible sources of mortality were identified. One whelk was observed on an oyster reef upside down (aperture up) on an extremely hot and sunny day. The whelk was found deceased the next day presumably due to the exposure from the previous day. Another whelk was observed with numerous hermit crabs, *Clibanarius vittatus* (Bosc, 1802), picking at the operculum before being found as an empty shell the following day. However, it is unclear whether the health of the whelk was somehow already compromised before the hermit crab attack. Finally, for five of the whelks, only shell fragments were located. Stone crabs [*Menippe mercenaria* (Say, 1818)] are common in the area and are known to prey upon small and medium size *B. carica* (Magalhaes 1948). Three of the five whelks could be considered rather large (162 mm, 171 mm, and 176 mm total length); therefore it is possible that other predators possibly including loggerhead sea turtles, *Caretta caretta* (Linnaeus, 1758), may be responsible for some whelk predation as well (Youngkin and Wyneken, 2005; Seney and Musick 2007; Wallace et al. 2008).

The positions of the whelks varied from on the surface to completely buried (Figure 8). Of the 680 recorded locations of whelks, in 322 instances the whelk was at least partly exposed
and in 356 instances, the whelk was found completely buried. Although the positions seem relatively evenly split, the position of the whelks shifted from significantly more on the surface or partially buried (exposed) in April through the first week of May to significantly more buried (not exposed) for the rest of the study. This is presumably a response to increasing air and water temperatures (Figure 3) and solar radiant heating. Burying by whelks during the summer months has previously been reported by Walker et al. (2004, 2008). These results showed that as temperatures and solar radiant heating increases, whelks are found buried during the daytime low tide in summer months.

By the end of May, untagged whelks became noticeably less abundant on the oyster reefs as well. The tracked whelks were still quite abundant in the intertidal area, just not readily visible in daytime, during the summer months. The whelks continued to move around the inlet during May through August when significantly more were found buried. Ferner and Weissburg (2005) observed knobbed whelks on the surface at night feeding on clams and oysters on Georgia intertidal oyster reefs in August 2003, but whelks were absent during day. Therefore, it is likely the whelks are continuing to actively pursue prey or mates during high tide and at night and then bury during day time low tide to escape environmental extremes.

Presumably submersion of the oyster reef on higher neap tides during daytime provided an opportunity for the whelk to feed on live oysters while not being exposed to the intense summer heat. When the tide level began to drop and expose the reef, the whelks moved off the reef into the lower, muddier areas to escape daytime heat exposure by burying during low tide. Metal tagged whelks were located below the oyster reef buried on the intertidal flat during low tide levels in July and August when few whelks naturally occur on the oyster reef.
By completion of the tracking in August, only nine of the 50 released whelks could still be found inhabiting the inlet. In the last month of tracking, several of the pieces of aluminum flashing that were used to locate the whelk by metal detector were found. It is possible that more of the tagged whelks were still in the inlet but not located due to the loss of the attached metal. Additionally, Walker et al. (2004) reported knobbed whelks buried from 1 to 14.4 cm deep in intertidal areas. It was determined that the pieces of metal flashing used in this study could only be detected up to a depth of 8 cm. Whelks burying to the depths reported by Walker et al. (2004) would most likely go undetected by the metal detector being used to locate the whelks. This may have also contributed to the assumption that many of the whelks had left the study inlet.

This study shows that whelks tend to concentrate on or near intertidal oyster reefs from April to August. Most whelk movement was laterally along the contours of oyster reefs. This study also shows that although whelks may be visually more abundant on the surface during early spring and absent during the hotter late spring and summer months, they remain active in the area presumably when the tide is in and at night. They bury during summer daytime low tide, presumably to avoid exposure to the higher aerial temperatures and direct exposure to solar radiation, yet remain quite active during high tide.


Shalack, J.D. 2007. Movement and behavior of whelks (Family Melongenidae) in Georgia coastal waters. Master Thesis, School of Marine Programs, University of Georgia, Athens


