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OBSERVATIONS ON THE EARLY LIFE HISTORY AND GROWTH RATES OF JUVENILE CHANNEL WHELKS *BUSYCOTYPUS CANALICULATUS* (LINNAEUS, 1758)

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ABSTRACT Channel whelks (*Busycotypus canaliculatus*) were cultured from hatch through 171 days to describe the early life history and growth rates of juveniles. Whelks began to hatch at water temperatures of 15–18°C. Channel whelks grew quickly from average shell lengths (SL) at hatch of 3.8 mm (SE = 0.1) to an average of 48.4 mm SL (SE = 1.3, n = 42 individuals) at 171 days post-hatch. The largest individual reached 53.2 mm SL, a gain of ~49.4 mm SL in 171 days, with a growth rate of 0.29 mm/day. Juvenile whelks readily consumed oyster (*Crassostrea virginica*) and mussel (*Geukensia demissa*) prey. A linear growth model (SL = 0.21 × [Age (days post-hatch)] + 1.6068) was used to describe the channel whelk age-at-length relationship. This is the first published growth curve for juvenile channel whelks. The observed juvenile growth rates for *B. canaliculatus* (0.21 mm/day) are higher than those previously described for *Busycon carica*. Whelk mortality was very low (<2%) after whelks reached SLs of ~10–12 mm.

KEY WORDS: Channel whelk, *Busycotypus canaliculatus*, *Busycon*, Melongenidae, age-at-length, growth rate, conch

INTRODUCTION

Channel whelks, *Busycotypus canaliculatus* (Linnaeus 1758), are large marine gastropods that occupy littoral and subtidal habitats along the western Atlantic coast from Cape Cod, MA, to Cape Canaveral, FL (Abbott 1974, Edwards & Harasewych 1988). *B. canaliculatus* are members of the Melongenidae, with the closely related knobbed whelk *Busycon carica* (Gmelin 1791). They are important bivalve predators in nearshore coastal communities (Magalhaes 1948, Carriker 1951, Paine 1962, Peterson 1982). Channel whelks are typically less abundant than knobbed whelks in habitats south of Cape May, NJ (Wood & Wood 1927, Magalhaes 1948, Paine 1962, DiCosimo 1988, Walker 1988).

Channel whelks are the focus of commercial fisheries throughout their range (e.g., Davis & Sisson 1988, DiCosimo 1988, Bruce 2006, Eversole et al. 2008). These neogastropods mature slowly (3–5 y (Edwards & Harasewych 1988) 9–12 y (Castagna & Kraeuter 1994), have relatively low annual fecundity (Edwards & Harasewych 1988), and are thought to be at least as long lived as *B. carica* (20–30 y, Kraeuter et al. 1989). These life history characteristics combined with size selectivity by the fishery for larger whelks that are typically female (e.g., Walker 1988, Castagna & Kraeuter 1994, Eversole et al. 2008) make channel whelk populations vulnerable to harvest pressure as well as disruptions in coastal habitats where egg strings are deposited.

In Virginia, adult channel whelks typically lay egg capsule strings on intertidal and shallow subtidal mudflats during the fall (mid August to November, Castagna & Kraeuter 1994). Egg capsule strings are secured to the bottom by the parent (Magalhaes 1948), and then develop, with hatching occurring early the following spring (Castagna & Kraeuter 1994). Freshly hatched juveniles are thought to occupy infaunal nursery habitats in inshore areas with older, larger juveniles shifting habitat use ontogenetically to deeper nearshore and coastal waters. Juvenile channel and knobbed whelks have been rarely observed, even in the habitats in which their egg strings have been found (Kraeuter et al. 1989, Castagna & Kraeuter 1994, Power et al. 2002). The biology of channel whelks from hatching through recruitment to the fishery at shell lengths (SL) of ~100–120 mm, including growth rates, feeding ecology, and seasonal or ontogenetic habitat use, is poorly described. This study describes the growth rates and behavior of cultured channel whelks for the first 6 mo after hatching.

MATERIALS AND METHODS

A channel whelk egg string (*n* = ~50 capsules) was collected on approximately March 1, 2010, on intertidal sand flats adjacent to a natural oyster reef (36°37′36″ N, 75°37′34″ W) behind Cedar Island, VA. The egg string was maintained at the Virginia Institute of Marine Science (VIMS) Eastern Shore Laboratory in Wachapreague, VA, until April 8, 2010, at ambient conditions (March 1, 4.5°C; April 8, 20°C; ~30 ppt; data from NOAA Tides and Currents, station ID: 8631044, Wachapreague, VA; http://tidesandcurrents.noaa.gov), when it was transported to the VIMS Seawater Research Laboratory at Gloucester Point, VA, for culture.

At Gloucester Point, the egg string was cultured at ambient temperature conditions and salinities of 25–30 ppt in a 38-L aquarium. Instant Ocean was added to filtered (10 μm) York River water to maintain a stock of culture water for egg string and juvenile whelk culture.

Juvenile whelks were transferred to 38-L aquaria (58 × 28 × 30 cm) within 24–48 h post-hatch, and were maintained at densities of 20–30 whelks per aquarium. Aquaria were established for whelks that hatched within a 3–4-day interval so that whelks of similar age (day of hatch) were cultured together. Juveniles were held at the same temperature and salinity conditions as the egg string (ambient temperature, salinities of 25–30 ppt, a natural photoperiod, recirculating water with filtration) until ambient temperatures were more than 28°C. Static culture aquaria with recirculating water were submerged up to three-quarters of their height in a flow-through flume that acted as a water bath to maintain ambient temperatures.

At SLs of approximately 15–20 mm, whelks were transferred to flow-through containers (7-L buckets with holes drilled in the sides) that were maintained in a 1,500-L flume at salinities of 25–30 ppt under natural photoperiod and filtration. Water

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temperatures in the 1,500-L flume were maintained at either 28°C (maximum) or ambient York River temperatures. Whelk densities in the 6 flow-through containers were between 6 and 10 individuals per container, and whelks of approximately the same SL were kept together.

Whelks were fed fresh mussels (*Geukensia demissa*, Dwillyn) or oysters (*Crassostrea virginica*, Gmelin) at least once daily. Bivalve shells were cracked before prey were offered to the juvenile whelks. Prey densities were approximately 1 prey per 10 whelks (day 0–day 30 post-hatch) and then 2 or 3 prey per 6–10 whelks (day 30–day 171 post-hatch). The maximum dimension of the bivalve prey was at least equal to the SLs of the whelk predators.

SL and shell shoulder width measurements (in mm) were made on at least 12 whelks selected randomly across all tanks or containers at hatch, and at approximately 30-day intervals post-hatch. SL was the maximum dimension from spire to siphonal canal (in mm). Shell shoulder width (SSW) was the maximum dimension perpendicular to SL. Linear models ($y = m \times (x) + b$) were used to describe channel whelk age-at-length and SSW-at-SL relationships.

RESULTS AND DISCUSSION

Ambient York River water temperatures ranged from 14.5–29°C from April 8, 2010 through October 7, 2010 (Fig. 1). Temperatures in the whelk culture tanks did not exceed 28°C, but mirrored ambient temperatures when ambient temperatures were less than 28°C.

Whelks began to hatch (emerge) from the egg capsules on April 18, 2010, and continued hatching through April 30, 2010, at water temperatures of 15–18°C. Channel whelk juveniles emerged from their egg capsules at an average SL of 3.84 ± 0.13 mm (SE). These SLs at hatch are similar to those described for knobbed whelks. Freshly hatched knobbed whelks observed by Magalhaes (1948, North Carolina) and Kraeuter et al. (1989, Virginia) had SLs of 4 mm. Knobbed whelks cultured by Power et al. (2002) near Wassaw Sound, GA, had an average SL of 5.6 ± 0.02 mm at hatch.

Juvenile whelks walked on their egg capsule and egg string immediately after emerging and appeared to graze on the bryozoans (*Membranipora* sp.) that were growing on the exterior of the egg capsules and string. Whelks were transferred out of the egg string aquaria after they had moved off the egg string onto the sides or bottom of the aquarium. After transfer to the culture aquaria, whelks were often found in the low-flow zone directly underneath the filter inflow, within the right angles formed by the intersection of the aquarium walls and the bottom or the air–water interface.

When food was placed in the center of the aquarium, whelks quickly moved toward the food and began feeding. Juvenile whelks crawled with their feet in contact with the substrate, but were also observed floating at the water–air interface with their feet inflated and their shell–body toward the substrate. This floating behavior was common in channel whelks with SLs less than 25 mm. It was often observed after food was added to the aquaria when whelks detached from the walls, floated to the center of the aquarium and then sank, landing in proximity to the recently added food. Similar foot inflation and floating behaviors have been observed in juvenile *Urosalpinx cinerea* Say, *Stramonita haemastoma* Conrad, and *Rapana venosa* Valenciennes (Harding, unpubl. data) under culture conditions, and may be a dispersal mechanism for postsettlement gastropods in the wild.

Juvenile whelks were voracious consumers of both mussels and oysters. After making contact with the bivalve, whelks crawled in or on to the shell, extended their proboscis, and began consuming the bivalve tissue. Bivalve tissue, including the adductor muscles, was completely consumed within 6–12 h, and the clean valve was removed when whelks had crawled away from the valve.

Channel whelks grew quickly from SLs at hatch (Fig. 2; average, 3.8 mm; SE = 0.1) to an average of 48.4 mm (SE = 1.3) at 171 days post-hatch. The largest individual reached an

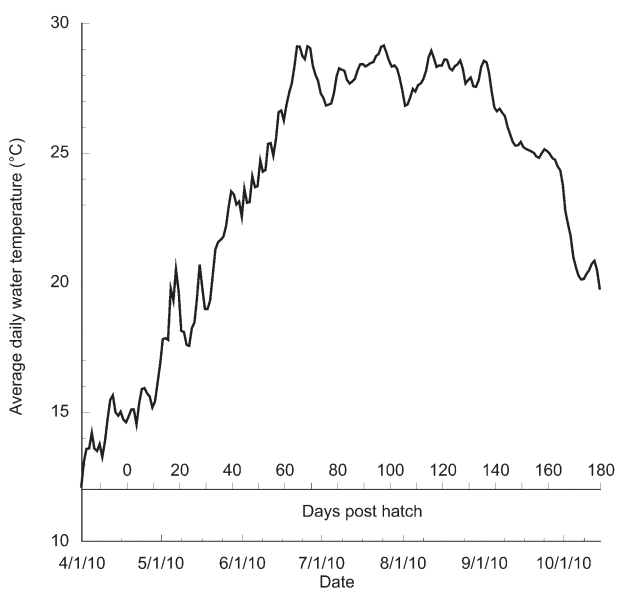

Figure 1. Ambient daily average York River water temperature (in °C) measured at Gloucester Point, VA (37°14′51″ N, 76°29′58″ W) from April through October 2010. The secondary x-axis (days post-hatch) corresponds to the age of the cultured whelks (Fig. 2).

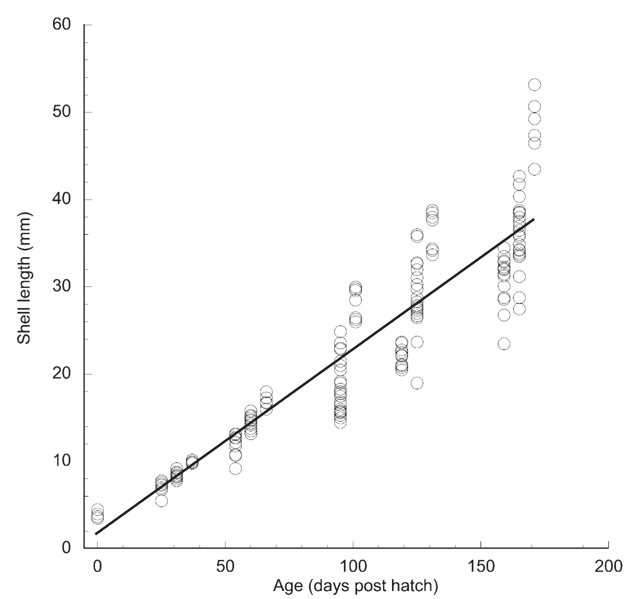

Figure 2. Relationship between channel whelk age (days post-hatch) and shell length (in mm) for individual channel whelks cultured in 2010 at 25–30 ppt and 14–28°C (*n* = 192 measurements of individual whelks). Day 0 on the x-axis is the date of hatching or emergence from the egg capsule. The fitted linear regression model is described in the text.

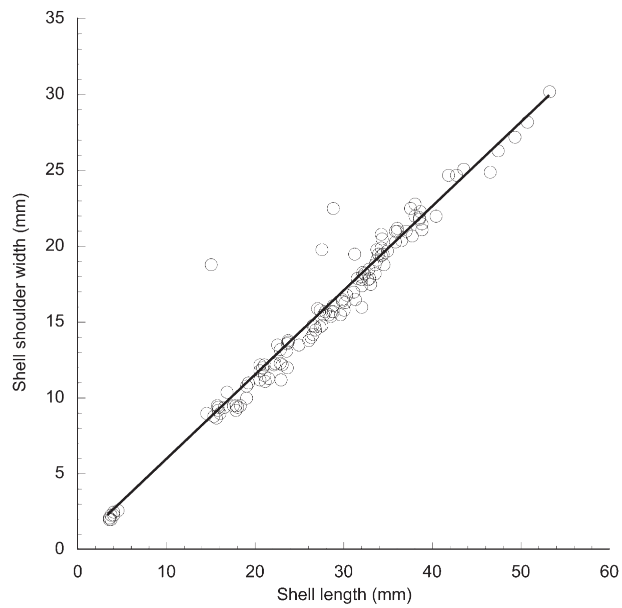

Figure 3. Relationship between shell length and shell shoulder width for cultured channel whelks ($n = 122$ measurements of individual whelks). The fitted linear regression model is described in the text.

SL of 53.2 mm, a gain of approximately 49 mm SL in 171 days, with a growth rate of 0.29 mm/day. SL was a good predictor of SSW for all channel whelk ages examined (Fig. 3; $SSW = 0.55 \times (SL) + 0.33$; $R^2 = 0.97$, 122 whelk measurements).

A linear growth model ($SL = 0.21 \times$ [age (days post-hatch)] + 1.6068) was used to describe the channel whelk age-at-length relationship ($R^2 = 0.94$, 192 whelk measurements). In the absence of other published growth curves for juvenile channel whelks, growth models for cultured juvenile knobbed whelks offer data for comparisons. The observed juvenile growth rates for *B. canaliculatus* (0.21 mm/day) are higher than those described for *B. carica*. Kraeuter et al. (1989) observed knobbed whelk growth rates of approximately 32 mm/y (0.09 mm/day) during the first year whereas Power et al. (2002) describe knobbed whelk growth rates of 7–8 mm in the 8 wk immediately after hatching (~0.13 mm/day).

These channel whelks were cultured at lower densities than the knobbed whelks raised by Kraeuter et al. (1989, initial density approximately 2,000 whelks/container) or Power et al. (2002, 50 whelks/container). Although food was supplied to excess in both *B. carica* studies, the lower densities used here may be more representative of the natural densities maintained by juvenile channel or knobbed whelks. Although the culture densities used in the current study for channel whelks are likely higher than natural densities, these relatively lower culture densities may be more representative of natural densities, resulting in the observed growth rate of 0.21 mm/day.

Whelk mortality was very low (<2%) after whelks reached SLs of approximately 10–12 mm. The primary source of mortality for juvenile whelks from hatch through SLs of 10 mm was predation by larger conspecifics. No mortality was observed for channel whelks with a SL larger than 25 mm ($n = 42$ individual whelks).

These data provide a baseline from which to evaluate field demographics observed in wild channel whelk populations. Field-based studies of channel whelk age and growth, as well as ontogenetic migrations and shifts in habitat use are needed to describe and define habitat areas that could be important nursery and feeding grounds. A quantitative understanding of age and growth in the context of natural whelk population demographics is necessary to evaluate the periodicity and intensity of recruitment events for this species, particularly in the context of active commercial fisheries focused on these whelks and *B. carica*.

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