Synthesis of Scientific and Local Ecological Knowledge of Channeled and Knobbed Whelk in Rhode Island

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Final Report
URI Department of Fisheries, Animal and Veterinary Sciences

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1. Introduction

Narragansett Bay, Rhode Island is home to many types of gastropod mollusks that on the surface look very similar to each other and support important local fisheries. The largest of these is known as the whelk (or conch). There are two species that are found in high abundance: The knobbed whelk, *Busycon carica* (Gmelin, 1791), and the channeled whelk, *Busycotypus canaliculatus* (Linnaeus, 1758). The lightening whelk, *Busycon contrarium*, is also found in RI waters but in low abundance.

Over the years the whelk has been a part of the local fishery, although for different reasons. As they are considered to be predators of other important fishery species such as clams and oysters, whelk used to be treated as pests that needed to be removed (Shaw 1960; Walker 1988). However, in the 1970's, whelk became a valuable fisheries product (DeKay 1843; Davis and Sisson 1978). There is now a directed fishery for whelk as a product for local ethnic markets and export markets.

Narragansett Bay Fisherman

"Each year you get to know a little bit more about the species and you get to know the areas. It's a kind of like detective work."

During recent years (2006-2012), fishing effort directed on the Rhode Island whelk fishery resource has increased substantially in terms of both numbers of fishermen reporting whelk landings (60%) and reported whelk landings (69%). Declines in the southern New England commercial lobster fishery and dramatic increases in ex-vessel prices for whelks (187%) have resulted in shifts in fishing effort (Angell, 2013). Whelk species exhibit life history traits that make them vulnerable to overfishing that include limited larval dispersal stages, slow growth and late maturation, low fecundity, low genetic diversity, and a relatively sedentary lifestyle.

In spite of this relatively long history of exploitation, virtually nothing is known regarding the life history traits of these whelk species in the northern extent of their range, particularly for the channeled whelk, which constitutes the vast majority of annual whelk landings in Rhode Island (Angell, 2013). This synthesis combines the current state of scientific knowledge obtained by extensive literature review plus local ecological knowledge obtained through focus groups and one on one interviews with local whelk fishermen. Gaps in knowledge are identified and suggestions are made regarding future research needs. It's kind of like detective work!!

2. General Whelk Characteristics

2.1 Taxonomy- What Makes a Whelk a Whelk?

Molluscs are one of the largest of all the animal phyla with over 110,000 living species. Most molluscs have some sort of shell made from calcium carbonate with a thin organic layer (called the periostracum). There is usually a mantle cavity that houses the gills. Most possess a feeding structure known as the radula which has rows of sharp teeth. The Gastropod class is comprised of the snails and slugs. The typical snail has a visceral mass (all the internal organs) that sit atop a muscular foot. The prominent characteristic of a gastropod is that there has been a 180 degree twisting of the internal organs so that the mantle cavity lies over the head instead of in the rear (Pechenik, 1985). Shell morphology differs among species; the shells of most gastropods spiral to the right (dextral) rather than left (sinistral) (Figures 1 and 2). A rigid disc of protein called the operculum acts as a seal to the shell protecting the animal from predators and in some cases, dehydration.

Figures 1 and 2. a. Muscular foot is extended out of the shell showing the operculum. b. Channeled whelk is one of the few with a left handed twist to the shell (picture from http://njscuba.net/biology/sw_snails.php

Whelk are believed to be very old- evolving into their present day forms during the Jurassic period about 200 million years ago (Shimek, no date). They fill many different ecological niches resulting in about 50 species of whelk today around the world. Whelks are often confused with conchs which look very similar. The main difference between them is that conchs live in tropical

waters, and are herbivorous feeding on vegetation, while whelks live in more temperate waters and are carnivores.

Whelk are sub-tidal in that they live completely submerged in water below the low tidemark. Their operculum does not completely seal and they are vulnerable to dehydration when out of the water.

2.2 How do Whelks Breathe?

Whelks obtain their dissolved oxygen from the water through their gills. The gills need to transport the oxygen molecules into the body of the animal, but not let any water into it. The mantle of the whelk extends out and forms a structure called the siphon. The siphon is where water is brought in and passed over the gills. Whelks do not have to move to obtain oxygen but can retrieve it solely through their siphon (Figure 3). Diffusion occurs past the gills of whelks when the oxygen molecules are transferred to the blood. Oxygen from the water is taken in, sent to the blood, and then transferred back out of the body as carbon dioxide. Even when buried, whelk use their extended siphon to bring in oxygen. The amount of oxygen needed increases with increased activity.

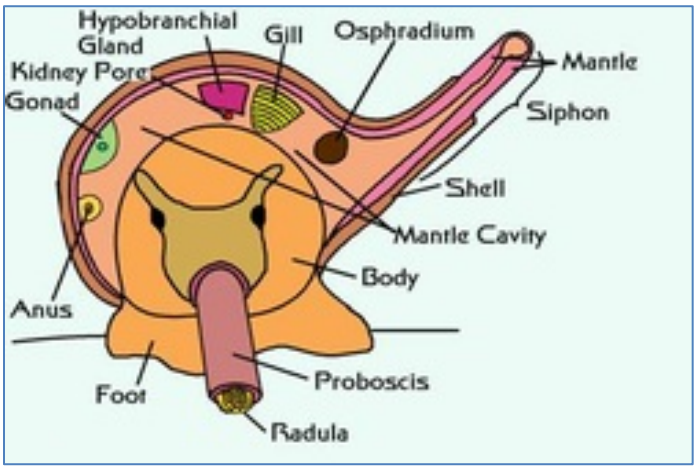


Figure 3. Characteristics of a whelk (Shimek, no date). The siphon brings in water that passes over the osphradium (the olfactory organ) and the gills to extract oxygen.

2.3 How do Whelk Eat?

Whelks get energy from the food that they eat. Whelks are active predators and scavengers. Whelk are known to track chemical cues along the seafloor to find their prey, even in turbulent flow (high currents) (Ferner, 2006). They are able to average changing chemical concentrations to locate their prey even at low odor concentrations. Whelks have several sensory organs: Bilateral tentacles contain mechanoreceptors and chemoreceptors; eyes are located at their base. The “nose” or the primary sniffer for the whelk is the osphradium. When hunting, whelk are often observed waving their siphons which directs to the osphradium. Although some species appear to zig-zag, there is no evidence that it is used to enhance odor detection (Rohrkasse and Atema, 2002).

Whelks use their shell and foot to break into a variety of clam, mussel and oyster species where they consume the soft tissue for nutrition. Depending on the shell thickness of the whelk and the prey, there are different ways to access the prey (Magalhaes, 1948; Carriker 1951). If it is a bivalve that cannot completely seal shut its valves (soft shell or razor clam) then the whelk uses its proboscis to access the soft tissue after the whelk grasps the valves of the prey with its muscular foot. If the bivalve can tightly seal its valves shut (quahog or oyster), the whelk grasps the valves with its foot and waits for the bivalve to gape slightly. As the bivalve gapes, the whelk inserts the edge of its shell into the gap, wedging the valves open. With this foothold, the whelk works the valves open by prying until it can insert its proboscis into the valves and relax the adductor muscles of the clam or oyster further. Another technique reported for the whelks is to hold the bivalve in its foot and hammer at the ventral margin of the shell to chip away the thinner edge of the shell and gain access to the soft tissue by breaking open a gap in the shell margin (Figure 4a and b). This has consequences for the predator, as that it erodes its shell lip (Castagna and Kraeuter 1994).

Figure 4 a. Whelk attacking hard clam. b. Damage to clam shell (Photos by M Hatzipetro).

2.4 How do Whelks Move?

Observations made by Magalhaes (1948) indicated that whelk show two distinct types of movement: horizontal and vertical. The horizontal movement from deep to shallow water is associated with reproduction and perhaps food supply. The vertical movement is also associated with food supply, tides, the avoidance of predators and unfavorable environmental conditions, such as excessive heat, or light, and dehydration. A third type of movement –lateral movement- was described as whelks following the contours of various shellfish beds (Shalack et al. 2011).

Laboratory observations indicated that on a hard surface such as the bottom of laboratory tank different specimens could move as fast as one centimeter per 6 to 12 seconds (Magalhaes 1948).

In general, small and medium size specimens moved faster than large ones. This would give an average rate of one meter every fifteen minutes (Magalhaes 1948). Field observations on movements of marked specimens showed that distances covered in a single day varied from fifteen to forty meters. Of those that did move, an average animal traversed about 18 meters in a day. At such a rate of speed in order to move thousand meters would require about fifty-five and a half days (Magalhaes 1948).

Many animals did not move horizontally as they merely buried themselves in the sand at the place where they were put. In June 1943, a group of 33 specimens were released and immediately buried themselves in the sand. After twenty four hours only two specimens were found above the surface of the sand. Thirty-six hours later one specimen was still in sight and a second come up out of the sand and was moving along the bottom. Shalack et al. (2011) observed that knobbed whelks in Wassaw Bay (Georgia) remains in the intertidal zone during summer where they actively prey on oyster reefs at night and possible during the day while the intertidal flats are inundated, but avoid exposure to aerial conditions during daytime low tides by burying. Burying by whelks during the summer months has previously reported by Walker et al. (2004, 2008). Knobbed whelk movement along the shore has also been previously reported (Walker et al. 2008). These observations showed that as temperatures and solar radiant heating increases, whelks are found buried during the daytime low tide in summer months.

In Wassaw Bay (Georgia), Shalack et al (2011) showed 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 (*B. carica*) and absent during hotter late spring and summer months, they remain active in the area presumably when the tide is in and at night.

2.5 Whelk Life Cycle

Whelks are either male or female (dioecious). Some species may be protandrous hermaphrodites, where individuals start as male and change to female. The sex is determined by noting the presence, or absence, of a penis, a conspicuous structure located on the side of the head within the mantle cavity (Figure 5). This organ can be seen easily only when the animal is extended, or protruding part of the way out of its shell.

Reproduction in the whelks is very different than other mollusks. Rather than broadcast spawning with free-swimming larvae, the whelks undertake internal fertilization with the larval stages contained in an egg-case manufactured by the female. Multiple paternities have been described both within and among the egg capsules on each egg string indicating multiple mating and sperm storage or selection (Walker et al, 2005; 2007).

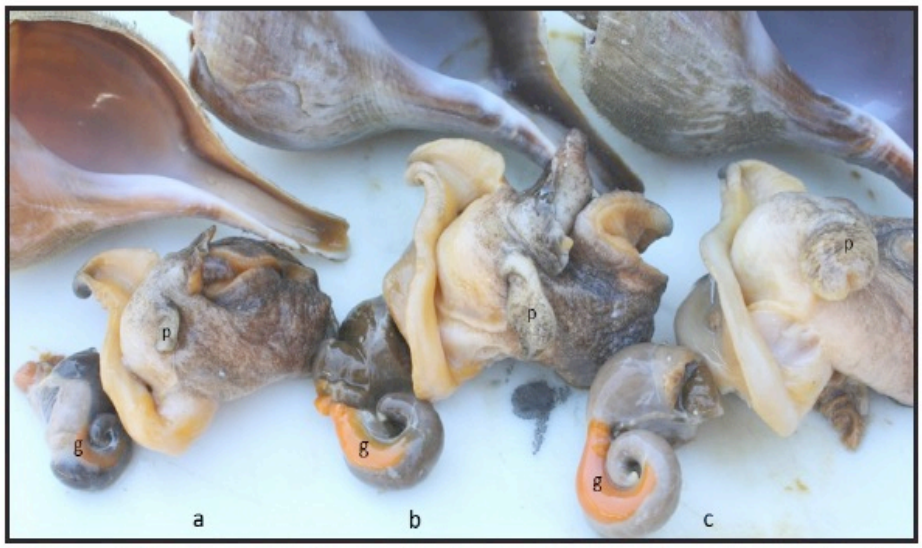


Figure 5. Increase in penis size and darkening of gonad color as maturity is reached in male *B. canaliculatus*: a. Immature, b. early mature and c. Mature. G = gonad, p = penis. (From Fisher 2015).

Figures 6 and 7. Mating in whelk and juvenile whelk in egg casing (Source:).

In some whelk species and locations, there is a seasonal pattern to mating and spawning with some whelks aggregate for several weeks during copulation and egg laying. In cold water areas, mating starts in the spring; in warm water areas, mating may occur in the fall (Figures 6 and 7). Some female whelk are known to attract the male with pheromones. In many species, egg laying occurs immediately after mating although there is evidence that whelk can store sperm for more than a year and delay spawning (Edmundson, 2016). Females may lay up to 150 eggs on various strings enclosed in capsules. The eggs in the first 5-15 capsules are not fertilized. The fertilized eggs are large (1-2 mm in diameter) and contain large amounts of yolk (Edwards and Harasewych, 1988).

Development is slow. Embryos may remain inside the egg casing for 3-13 months depending on species and water temperatures. On average, only 57% of the embryos survive to hatching. When hatched they are already well advanced juveniles (at about shell length of 3.8 mm for channeled whelk (Harding, 2011; knobbed whelk of 4-5.6 mm (Magalhaes, 1948; Kraeuter et al 1989; Power et al. 2002). Upon hatching they remain with their egg capsules feeding on the bryozoans growing on the outside surface (Harding, 2011). But shortly thereafter they move away towards more suitable habitat. Juvenile whelk were observed to crawl along the substrate but also could detach from the bottom and float at the air-water interface (in laboratory setting) possibly indicating a dispersal mechanism (Harding 2011). It is rare to find the smaller juvenile whelk in the wild (Fisher, 2015). Growth was linear for juvenile whelk in the laboratory. Whelk mortality was low after reaching shell lengths of 10-12 mm. Predation from conspecifics was the primary source of mortality in the lab setting.

2.6 What do Whelk Eggs Look Like?

Whelk species reproduce via internal fertilization followed by the production of an elongated egg mass consisting of individual capsules linked together in a string and anchored to the substrate by a series of empty capsules. Egg capsules may be different length or shapes. (Figure 8 and Figure 9)

Figure 8: Egg capsule of the channel whelk. Source:http//matthewwills.com/2011/05/17/whelk-egg-cases/

Figure 9: Egg capsule of the knobbed whelk Source :http//matthewwills.com/2011/05/17/whelk-egg-cases/

The end of the string of capsules that is laid first is buried under the surface of the sand, or the mud, about 10-20 centimeter or it can be attached to a piece of shell, or some other hard surface. The capsules are joined to one another by a strand of material similar to that from with the capsule itself is made. The juvenile whelks emerge from the egg capsules through an exit port in the side of the capsule. On average, both whelk species deposit 20 to 500 eggs per capsule with a string consisting of 20 to 150 capsules (Magalhaes 1948).

Eggs may be laid during the summer and fall and it takes an average of 6 to 8 days for a female to deposit a full string of eggs, producing about 12-14 capsules a day with egg production occurring uninterrupted until completion. In all the cases of the strings there is albuminous fluid in which segmented eggs, food eggs, and developing young in various states can be found (Magalhaes 1948). The egg capsules develop over the winter and hatch, with juvenile being released, in March through May.

2.7 How do Whelks Grow?

Whelks grow slowly. It can take up to 8-10 years to reach reproductive maturity. Whelks tend to grow non-continuously, undergoing long periods of no growth, which makes management relying upon average annual rates of growth potentially misleading (Kraeuter et al. 1989). In tagging studies, growth was irregular and, in many cases, no growth at all (or even negative growth) was recorded over intervals of hundreds of days during the regular growing season (spring through fall) (Castagna and Kraeuter 1994). The chipping of the siphonal canal from feeding , measurement error and diversion of energy from overall growth to shell repair was speculated to cause the negative growth measurements (Castagna and Kraeuter 1994).

Growth rates are generally larger for females than for males (Stevens and Peemoeller (2016; Edmundson, 2016; Angell, Wilcox 2013) and can vary by geographical area (Fisher, 2015; Wilcox, 2013). Other factors that can influence growth in whelks can be initial size, food availability, predator abundance and habitat.

The examination of marked and measured specimens of *Busycon carica* by Magahaes (1948) indicated that the process of growth in these animals is markedly irregular. Even immature specimens showed no change in size after a year, or two, in the field under apparently favorable conditions. Magalhaes (1948) assumed that there is a possibility that the period of greatest growth for whelk followed the breeding season and the rate of growth and type of shell produce by marine gastropods depends on the sort of food that is eaten.

Bourdeau (2010) reported that the frilled dogwinkle (*Nucella lamellose*), a marine snail, had thicker shells and reduce shell growth when in the presence of red rock crab (*Cancer productus*). Food-limited snails did not significantly differ from snails exposed to crab, indicating food consumption, instead of a physiological response from predation ultimately affected growth (Bourdeau, 2010).

2.8 What Eats Whelk and What do Whelk Eat?

Predators

Crabs are the commonest types of predators that were observed by Magalhaes (1948) attacking and destroying Busycons. The stone crab, *Menippe mercenaria*, is one of the crabs known to eat whelks for food. The hermit crabs are also able to kill and remove a living specimen. *Pagurus pollicaris* shows preference for empty shell of *B. canaliculatum.* It is possible that blue crab (*Callinectes sapidus*) is another important enemy of Busycons but it was never observed eating whelks in laboratory tanks (Magalhaes, 1948). Large crabs can chip away at the shell margins to gain access to the soft tissue.

Gulls according to Magalhaes (1948) can be another enemy of whelks. Gulls depend partly on mollusks for their food and Busycons are in their diet. The gulls collect the mollusks in low tide when they are exposed on the sand and mud flats, they drop the prey on a road, sidewalk or some hard surface from a considerable height and then the shell is broken and the inner parts can be eaten by the gulls.

The primary tool that the whelks use for predator avoidance is the capacity to dig in and bury in soft sediment.

Prey

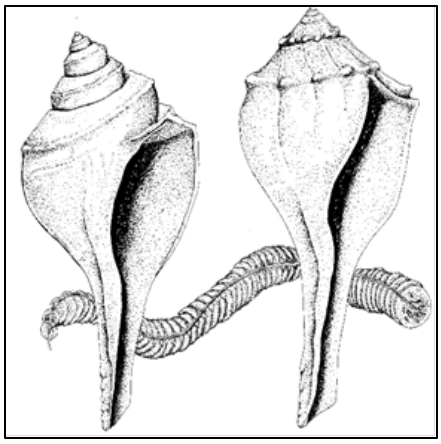
Whelk are believed to be voracious predators of other molluscs, especially bivalves such as oysters (*Crassostrea virginica)*, mussels (*Mytilus spp*) and arks (*Anadara brasiliana*). Some whelk are believed to consume large numbers of hard clam (*Mercenaria mercenaria) (Kraeuter 2001)*. They may also serve as scavengers (Magalhaes, 1948).

3. Whelk of Rhode Island

There are two species that are found in high abundance: The knobbed whelk, *Busycon carica,* (Gmelin, 1791)*,* and the channeled whelk, *Busycotypus canaliculatus* (Linnaeus, 1758)(Figure 10). The lightening whelk, *Busycon contrarium*, is also found in RI waters but in low abundance.

Channeled and knobbed whelk are found out to the continental shelf from Cape Cod to Florida. Magalhaes (1948) reported that whelk populations in the southern areas were dominated by knobbed whelk but in Woods Hole, the channeled whelk was predominant species (as reported by Sumner et al., 1917). In New England and the Middle Atlantic States, the channeled whelk is mostly targeted using baited traps (Davis and Sisson 1988; Sisson and Wood 1988; Wilcox, 2013).

In the Chesapeake Bay and southern states, the knobbed whelk dominates landings and fisheries are mostly dredge or trawl based (Walker 1988; Harding, 2011; Garcia Bruce, 2006).



	Knobbed Whelk	Channeled Whelk
Kingdom	Animalia	Animalia
Phylum	Mollusca	Mollusca
Class	Gastropoda	Gastropoda
Subclass	Caenogastropoda	Caenogastropoda
Order	Neogastropoda	Neogastropoda
Superfamily	Buccinoidea	Buccinoidea
Family	Busyconidae	Busyconidae
Genus	Busycon	Busycotypus
Species	carica	canaliculatus

Figure 10. www://savethebay.org

Table 1. Taxonomy of the whelk.

In the southern areas knobbed whelk are common on the intertidal sand/mud flats in the higher salinity areas during spring and fall, Lower whelk abundance in the summer and winter suggests movement due to reproductive events and food supply. There is very little information about the channeled whelk local movement. In the NE area, abundance and distribution of both species may be controlled by water temperatures rather than movement into shallower or deeper water. The whelk inhabits a variety of sea bottoms (sandy and muddy bottom), but appears to be most commonly found on bottoms with fine elastic sediment such as clay or silt in which bivalves, one of their main food sources, are abundant (Puffer and Emerson, 1954; Wood, 1979).

Both species of whelk in Narragansett Bay have a periodic and irregular growth. Fastest growth is observed in smallest individuals, e.g. lab reared whelks grew from 4- 36.5 mm in the first year

but it took them 10 years to grow to 144 mm and 14 years to get to 168.6 mm (reference). The bulk of their annual growth occurs during the interval of May to October, when water temperature is the warmest and food is plentiful. More information is presented for each species in the sections below.

3.1 Channeled Whelk

All of the fishermen interviewed listed channeled whelk as the most abundant catch.

The water temperature is biggest factor when catching whelk.

"*Under 42 degrees, the fishery stops. 48-70 fishery is on". Below 50 too cold. Above 75 too warm.*

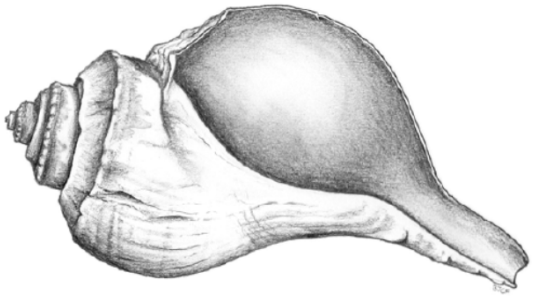


Figure 11. Channeled whelk

The Channeled whelk (*Busycon canaliculatum*) provides a locally important fishery in many areas of the Atlantic, including parts of Connecticut, Massachusetts, and Rhode Island (particularly in Narragansett Bay). The Channeled whelk free ranges over a wide variety of habitat types as it searches out prey. It is regularly observed in sand and sand-mud habitats and is often completely buried in the sediment. Channeled whelks appear to be more active in the spring and fall when water temperatures would be cool, but not extremely cold. In the Beaufort region. *B. canaliculatum* is present in larger numbers in the spring and fall. *B. canaliculatum* is considered to be a cool weather conch (Magalhaes 1948).

B. canaliculatus is nocturnal. Channeled whelk tend to bury in sediment by day, and become more active at night/or on cloudy, overcast days (Bruce, 2006). They can tolerate water temperatures between 8.5º to 31.5ºC but largest numbers of *B.canaliculatus* were found at a water temperature of 17.5º C (Magalhaes, 1948).

Can find the two species together and find them separated. Depends on the time of year

The whelk adds new shell during resting periods when it generally remains buried in the bottom (Carriker, 1951). Whelks were found to remain buried about 65 per cent of the time (Colton 1908). During daylight channeled whelks may be sufficiently buried to be invulnerable to dredge gear (Bruce 2006). The scarcity of channeled

whelks in dredge samples (Bruce 2006) is congruent with the observations of others that knobbed whelk dominate landings from dredge and trawl fisheries (Anderson et al. 1985, Davis & Sisson 1988) and channeled whelks dominate landings from pot or trap fisheries (Davis & Sisson 1988, Walker et al. 2003, Logothetis & Beresoff 2004, Bruce 2006). Channeled whelks are harvested primarily with pot or trap gear. A trap fishery exists for the channeled whelk between May and November. The nature of this fishery is very similar to the fishery for American lobster in traps that are baited and hauled at regular intervals (Davis 1988).

Channeled whelks (Figure 11) can easily be differentiated from its relative, the knobbed whelk, by the morphology of the shell. The channeled whelk is generally smaller and it has a thinner shell. The shell of *B. canaliculatum* is characteristically thinner than *B. carica.* Mature shells of channeled whelk are usually about two millimeters in thickness (Magalhaes, 1948).

The color of the shell is typically a light tan, or beige color. In many cases the shells of mature specimens are covered with a variety of attached organisms which effectively mask the color of the underlying shell (Magalhaes, 1948). The shell aperture is located on the right side, i.e. the shell of this species is almost always dextral in coiling. Left-handed or sinistral specimens occur rarely. In both whelks' species, the males are normally smaller than females of the same age.

Shells of the channeled whelk typically reach 4 to 8 inches in length. The shell is smooth and the siphonal area of the shell is narrower and more distinctly differentiated from the main portion of the shell than the observed in the knobbed. The shell has a pear-shaped shell with a large body whorl and straight siphonal canal. Between the whorls there is a wide, deep channel at the suture, and there are often weak knobs at the shoulders of the whorls. Finely sculpted lines begin at the siphonal canal and revolve around the shell surface. In *B. canaliculatum*, spines are usually absent and the shoulder region of the shell is marked by tubercles. The suture in *B. canaliculatum* is channeled, or caniculate; it is the feature of the architecture of the shell that gives rise to the specific name (Magalhaes, 1948).

Figure 12. Channeled whelk living under water

Source:http://thchanneledwhelk.weebly.com/respiratorydigestive.html

Although it is believed that whelk are scavengers, as also confirmed through the local knowledge, live prey is also a part of their diet. Differences in prey selection between the species are based on their "ability" to open a closed hinge bivalve (Magalhaes, 1948). The channeled whelk, can insert the edge of outer lip between the valves when a bivalve opens their shell slightly and force the valves apart. Peterson (1982) and Paine (1962) suggested that channeled whelk were less likely to consume hard clams than the heavier shelled species such as the knobbed whelk.

Whelk are hatched as little adults. They start out around 5 mm in length. The highest growth rate for males and females occurred in the first few years of life. Growth rate progressively decreased as channeled whelk aged. Harding (2011) reported an average size of 3.8 mm SL at hatching for channeled whelk cultured from hatch in the laboratory. At 171 days after hatching, the average SL was 48.4 mm; a linear growth model for age-at-length resulted in a growth rate of 0.20 mm/day (Harding, 2011).

Growth can vary over geographical range, sometimes very small distances. Fisher (2015) found that males grew faster and reached a smaller maximum size than females in the Mid-Atlantic. Peemoeller studied wild channeled whelk in Massachusetts waters and found that an average SL of 48.4 mm would not be achieved until the age of 3 years which indicating a much slower growth rate for whelks than Harding (2011) predicted. The von Bertalanffy growth model predicted that 3-year-old males and females would be only 41.3 mm SL and 43.5 mm SL, respectively. The discrepancy in growth rates between channeled whelk in Peemoeller (2013) study and the whelk in the Harding (2011) study possible reflects individual variation, although food availability, predator abundance, and habitat may affect shell growth as well. Peemoeller (2013) in a study on reproductive maturity and growth in channeled whelk in Buzzard Bay (Massachusetts) estimates that males reached sexual maturity$_{50}$ (SM_{50}) 2 years before females do. Females reached SM_{50} at 89.7 mm SW (SE 2.9), 20 mm greater than the minimum size limit. Male channeled whelk reached SM_{50} at 66.0 mm SW, which is below the minimum legal size limit in Massachusetts. Angell (2017) sampled whelk in Rhode Island and found that female channeled whelk had higher growth rates than males producing a SM_{50} for females of 136.3 mm SL; 78.4 SW and for males, 116.6 mm SL and 64.9 SW.

Can find small whelk in the quahog beds. Larger whelk are found in deeper

55% of fishermen interviewed believed that minimum size was important as a management tool to allow for maturity. 55% also believed in trap limits; 11% did not want any management while 11% thought limiting access was important

These maturity curves can be applied to the harvest rules to predict changes to reproduction and new recruitment as a result of changing minimum sizes. In some cases, harvesting of immature animals is occurring and needs to be considered for the future sustainability of the whelk populations. Currently, the minimum size for males is above the SL_{50} which provides ample protection for the males and sits right at the SL_{50} for females which means we are harvesting animals that have a 50% chance of not having the chance to reproduce.

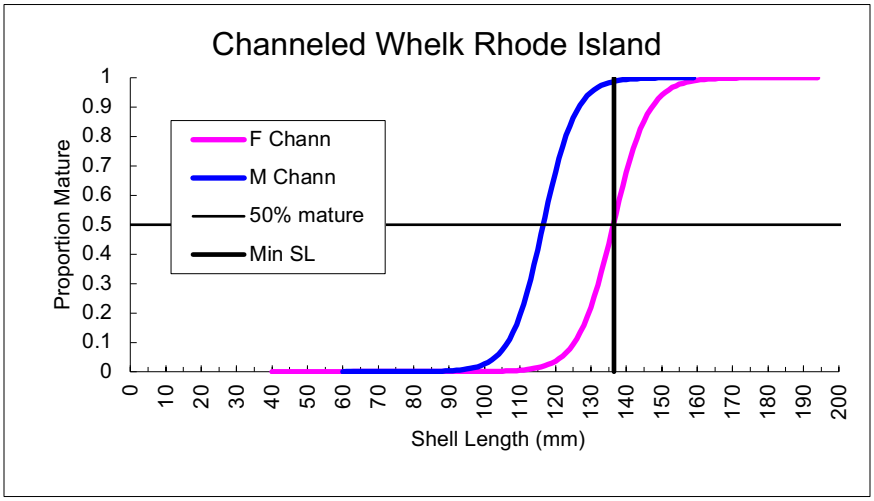


Figure 13. Maturity curves for male and female channeled whelk in RI. Angell 2017.

3.2 Knobbed Whelk

Knobbed whelks (*Busycon carica)* are generally found in shallow waters from 30 feet, down to depths of 150 feet, and are considered estuarine species (Figure 14). The knobbed whelk ranges over a variety of habitat types – Mud-sand and mussel beds. They are reported to be able to move about 15 to 40 m per day, with an average distance of 18 m per day (Magalhaes, 1948). Knobbed whelk tolerates water temperatures between 10.5º to 35º C. While channeled whelk appears to be most active when the water is cool, the knobbed whelk is very active throughout the entire

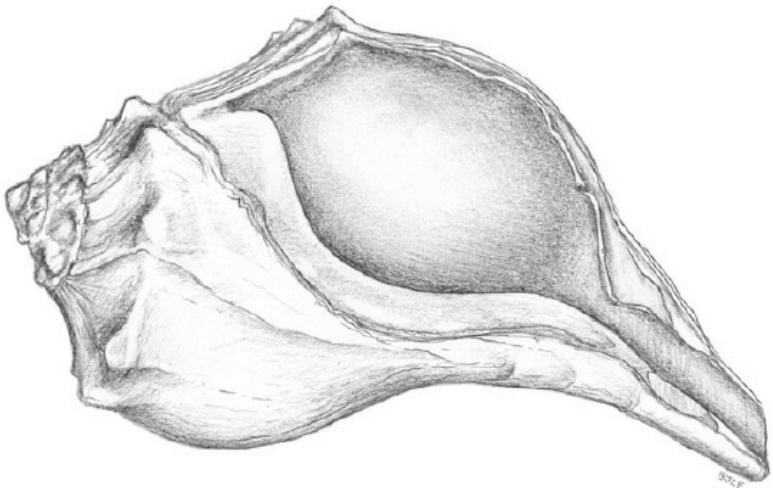


Figure 14. Knobbed whelk

summer and could be considered a warm weather conch. *B. carica* tend to be more active during the day while more mature individuals were more abundant at night. Observations made of the activity of *B. carica* indicated that it varied with the season and with the size of the individual (Magalhaes 1948). This whelk is quite active throughout the year from March until December. During the months of December, January, and February *B. carica* disappears almost completely from the sand and mud flat.

The absence of knobbed whelks in pots may be explained by a preference for live bivalves rather than bait or carrion, and potentially a reduced ability to enter traps because of a heavier shell than the thinner-shelled and more active channeled whelk (Davis 1981, Sisson & Wood 1988, Dobarro 1993, Walker et al. 2003, Logothetis & Beresoff 2004).

Data from Castro et al (2017) suggest that potential predation pressure from knobbed whelk on hard clam populations in Narragansett Bay, at least during the warmer periods, could be significant. Knobbed whelk account for up to a 13% annual loss to the hard clam population in Great South Bay New York (Greene, 1978). Carriker (1951) reported that a large *B. carica* could consume an average of 0.86 hard clams per day and that during the 5 warm months, at a density of 0.1 m^2 could consume up to 700 clams. Greene (1978) reported predation rates of *Busycon* to be 0.11-0.115 hard clams/snail/day.

Adult shells of *B. carica* are gray in color. The juvenile shells show purple-brown stripes parallel to growth lines and contrasting markedly with a cream colored background. The glazed inner surface of the shell mouth in B. carica is usually vividly colored in adult shells; the hue may vary from white, or pale yellow, to range, or even red.

Most fishermen believe knobbed whelk do not enter traps because they either are too heavy to scale the vertical wall or that they are not attracted to the bait. One fisherman thought maybe they were "vegetarian".

The Knobbed whelk shell is characterized by having a shoulder whorl that is accentuated by spines projecting of the whorls (Figure 15 and 16). The spines are highly variable in number and length but are always present on the knobbed, even as small juveniles the spines are more like knobs projecting from the whorl. The apical angle tends to be more acute in *B.carica.* The shell of most knobbed whelks is dextral, meaning that it is right-handed. The shell is thick and strong and has six clockwise coils. Knobbed whelks are generally larger than channeled whelks with the largest size of knobbed whelks reported as 22 cm in length and 11 cm in width (Pratt 1935).

The thickness of the shell varies directly with the age and size of the specimens. Shells of *B. carica* and *B. contrarium* are of similar thickness if shells of similar length and development are compared; fully grown shells of B. *carica* are usually about 4 millimeters in thickness (Magalhaes, 1948).

Figure 15. Knobbed whelk
Source: http://www.okeefes.org/Whelks/Whelks.htm

Figure 16. Knobbed whelk – Juvenile
Source: http://www.okeefes.org/Whelks/Whelks.htm

As with channeled, the males of the knobbed whelk are generally smaller than females. Magalhaes observed that the shell length for females varied from 3.5 to 21.6 cms. In males the shell length varied from 4.2 to 17.4 cms.. According with Magalhaes (1948) shells of the females according appeared to be longer and wider while shells of the males are shorter and narrower in shape.

Castagna and Kraeuter (1994) suggested that knobbed whelk may be protandrous hermaphrodites. Knobbed whelk raised in a laboratory were all males at 9 years, but, after 13 years, some males changed sex, and at the age of 14 years, produced viable offspring (Castagna and Kraeuter, 1994). Peemoeller (2013) observed that during dissections of channeled whelk there were no signs of hermaphroditism. All whelk had either penis or nidamental gland (females). No whelk were found to contain both male and female gonads. Avise, et al. (2003) confirmed that knobbed whelk are not hermaphrodites but could under some circumstances such as parasite loads, chemicals, use a form of pseudohermaphroditism to compensate, Protandry in knobbed whelk may be opportunistic.

Peemoeller found an equal sex ratio for male and female channeled whelk at early ages, but later, males dominated at ages of 7-9 years and females dominated at ages of 10-14 years. In this particular study for Buzzard Bay males did not live as long as females and there was a greater portion of males at the size range of 120-160 mm SL. Males have a lower maximum size and mature at smaller sizes than females. Because the fishery is directed at catch of large whelks, which are mostly females, fishermen do not actively target males and males may tend to accumulate.

In RI, Angell found SL_{50} maturity of both male and female to be less than the minimum size. Harvesting would not be expected to affect reproductive capacity of this species.

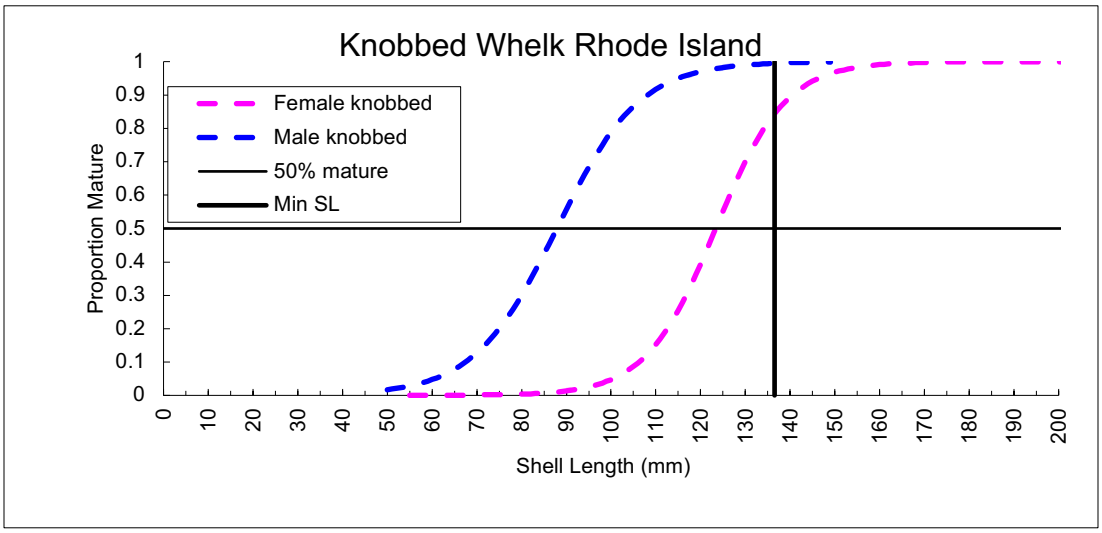


Figure 17. Proportion mature by size of knobbed whelk in Narragansett Bay (Angell 2017).

4. Narragansett Bay

4.1 Narragansett Bay- Sediments in the Bay

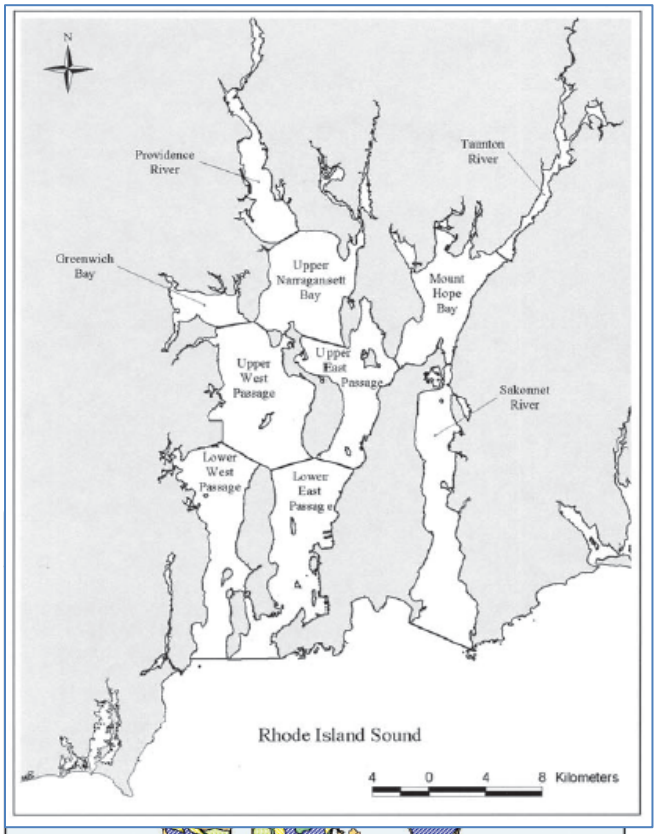


Figure 18. Commonly recognized subdivisions within Narragansett Bay. Data sources: RIGIS and Lee (2000). In Raposa K.B. Ecological Geography of Narragansett Bay. NBNERR.

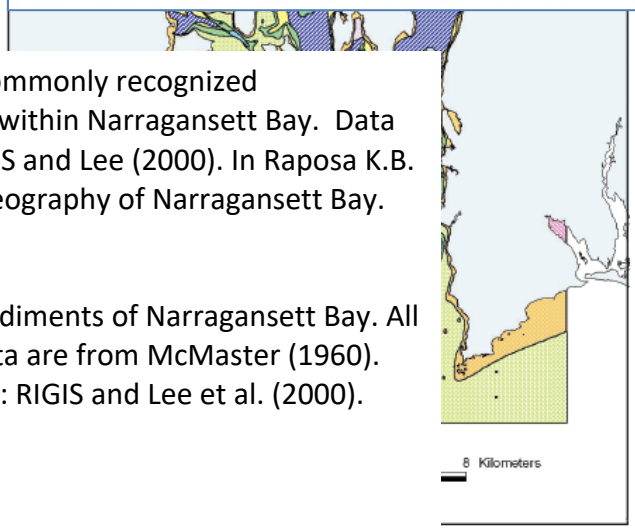


Figure 19. Sediments of Narragansett Bay. All sediment data are from McMaster (1960). Data sources: RIGIS and Lee et al. (2000).

Narragansett Bay was formed by glaciers around 9000 years ago and with increasing water level, has filled in with glacial deposits and river runoff to become a medium sized estuary (Figure 18)with three distinct areas: a) West Passage, b) East Passage and c) Sakonnet River (Hicks, 1959) which provides salt water entry into the Bay. Fresh water enters the estuary via the Blackstone, Taunton and Pawtucket Rivers.

As the glaciers retreated, the exposed bedrock was covered by drift deposits that are composed of layers of boulder, cobble, gravel, sand, silt, and clay (Figure 19). Over time, more materials have been deposited from runoff from the rivers. Total sediment depth in Narragansett Bay, including older glacial and more recent riverine deposits, varies greatly but generally ranges between 15 to over 100 m thick (McMaster, 1960). Eleven sediments types have been identified in Narragansett Bay, ranging from clayey silt to course gravel. The distribution of these sediment types largely depends on currents and circulation patterns, which generally result in finer grained materials, such as sand-silt clay and clayey silt, being located in the middle and upper portions of the Bay and in protected coves and harbors. Coarser sediments, mostly sandy, are found in the lower reaches of the Bay and in constricted areas where current velocities are greater. Overall, most of the bottom of Narragansett Bay is covered with finer grained detritus, clay-silt and sand-silt-clay sediments (McMaster, 1960). Much of the substrate in Narragansett Bay being clayed-silt or a sand-silt and clay mixture (McMaster, 1960; Wood, 1979) provides a favorable environment for the whelk (Figure 20).

The RI DEM Dredge (1993-2014) surveys indicate that more channeled whelk are found in areas of the Upper Narragansett Bay (dominance of clay-silt sediments), except for Mt Hope Bay which is dominated by knobbed whelk. Knobbed whelk also are in greater abundance in Sakonnet River and Quonset (Figure 21). However the burying behavior of channeled whelk during the day could affect these catch rates.

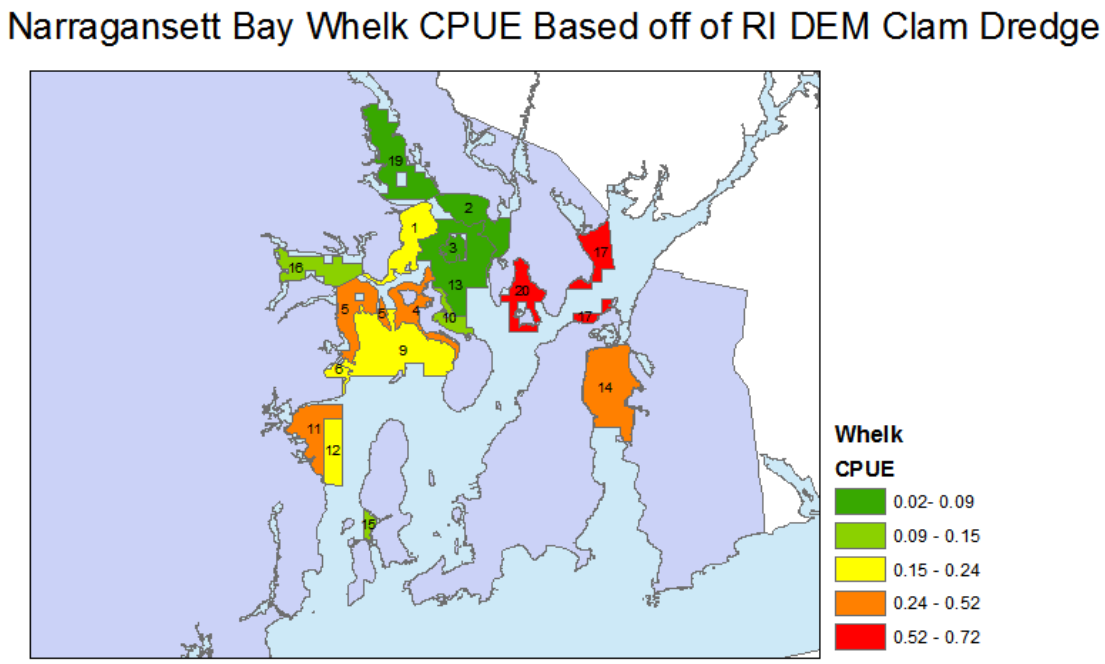


Figure 20. Catch per unit effort (CPUE) of whelk based on the Rhode Island DEM Clam dredge survey.

Where do you find whelk?

- Follow whelk between deep and shallow water as they move.
- Fish whelk on edges.
- Hard and sandy bottom. Never in the mud.
- Fish close to the coast. Look for sandy bottom and

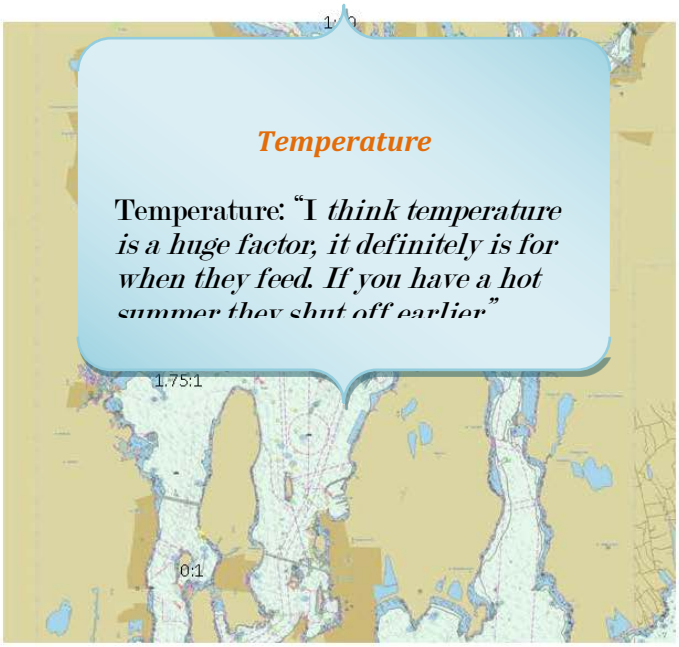


Figure 21. Proportion of channeled to knobbed whelk by location from RI DEM dredge survey 1993-2014.

4.2 Salinity and Whelk in Narragansett Bay

The most important physical characteristics of estuaries is the fluctuating salinity. There are differences due to seasonal input, tides, water depth, temperatures, and currents. The mixing of freshwater inputs with seawater results in salinities in Narragansett Bay that range between 24 ppt in the Providence River and 32 ppt at the mouth of the Bay (Kremer and Nixon, 1978). Salinities can be substantially lower in the surface waters at the head of the Bay and in landward areas of small coves, embayments, and salt marshes, especially after rain events when runoff is high. As opposed to the more pronounced horizontal salinity gradient, the vertical gradient is generally less than 2 ppt throughout the Bay (Pilson, 1985).

In general RI fishermen did not believe that whelk were affected by salinity, however one fisherman expressed a change in either feeding behavior or availability after the rain:

"I was always concerned with fishing after rain, especially rain with wind where the freshwater would sink; they really wouldn't want to eat after that."

4.3 Temperature in the Bay - Where does whelk like to live in NB?

Water temperatures in Narragansett Bay range between 0.5ºC and 24º over an annual cycle. The seasonal cycle is predictable, with highest temperatures occurring in the summer and the coldest in winter. Thermal stratification of the water column generally occurs in the upper reaches of the Bay and its associated rivers (Kremer and Nixon, 1978) and changes with the season. The surface of the water is warmer than the bottom in the summer and colder in the winter (Olsen et al., 1980

5. Rhode Island Whelk Fishery

5.1 Landings and Effort

The fishery for whelks (also commonly called conchs, snails or winkles) is a seasonal fishery (Wood, 1979). The two species are principally commercially harvested where they are used in salads, chowders, fritters and squingelli (pasta), and they are also frozen for national and international distribution (Power et al, 2009).

The fishery for whelks is both a directed and bycatch fishery in southern New England (Figure 22). In Massachusetts, Rhode Island and eastern Connecticut this fishery has traditionally provided an economic supplement to lobster and finfish fisheries, but more recently a directed fishery has developed for whelks as the economic viability of the largely ethnic market for whelks has increased (Davis and Sisson 1988).

Figure 22. Traps on a whelk boat in Rhode Island

In 1981 landings for both whelks in southern New England exceeded one million pounds (454,545 kg) of processed meats, up from about 300,000 pounds (136,364 kg) in 1979, as interest in the fishery increased (NMFS 1986). Landings peaked in 1984 at about 1.4 million pounds (636, 364 kg) as the price of processed whelk meats exceeded $1.80 /pound, but have declined since. In 1987, landings for the region totaled only 500,000 pounds (227,273 kg) (NMFS 1986).

A commercial fishery for whelks has existed in Rhode Island for many years; until September 2009 it was not regulated or the subject of a stock assessment. According to NMFS statistics, RI whelk landings were 85,000 pounds of meat weight in 1950 and increased over time to a peak in 1986 of 347,000. After several years of high landings, the fishery declined rapidly from 1994-2003, when reported landings were less than 22,000 pounds. Total reported RI whelk landings increased 110% from 368,028 pounds (Y2006) to a peak of 773,885 pounds (Y2012), followed by a 42% decrease to 446,154 pounds (Y2014) and then an 11% increase to 493,166 pounds (Y2015).

Following the reported landings trend, total ex-vessel value for whelks increased 255% from $450,137 (Y2006) to $1,599,227 (Y2012), decreased 35% to $1,036,116 (Y2014), and then increased 23% to $1,279,091 (Y2015). After an initial decrease of 24% from $1.22/pound (Y2006) to $0.93/pound (Y2007), a consistently increasing trend in the mean value ($/pound) resulted in a 179% increase over time to $2.59/pound (Y2015) (Figures 23, 24 and 25) (Angell, 2017).

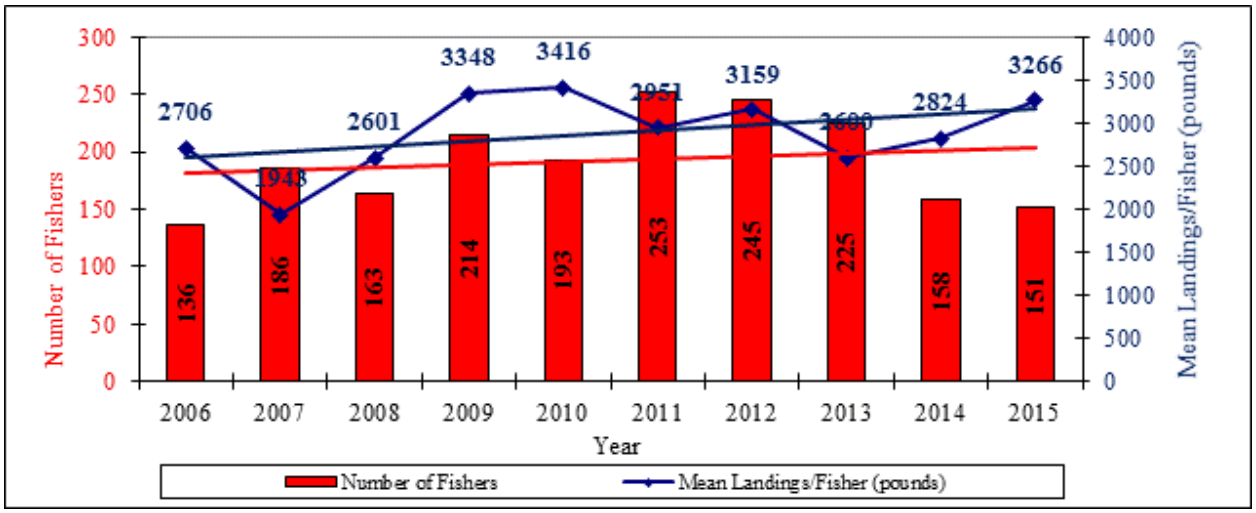


Figure 23. Fishermen reporting whelk landings in Rhode Island (Angell 2017)

Annual number of fishers reporting whelk landings during Y2006-2011 varied with an overall increasing trend and increased 86% from n=136 (Y2006) to a peak of n= 253 (Y2011), then decreased each year during Y2012-2015, resulting in a 40% decrease to n=151 (Y2015). After an initial 28% decrease from 2706 pounds/fisher (Y2006) to 1948 pounds/fisher (Y2007), mean annual whelk landings (pounds) per fisher increased 26% overall from 2706 pounds/fisher (Y2006) to a peak of 3416 pounds/fisher (Y2010), then varied without trend during Y2010-2015 while averaging 3036 pounds/fisher (range of 2600-3416 pounds/fisher). Trends in number of fishers reporting whelk landings annually follow a similar pattern as total reported RI whelk landings, with an increasing trend during Y2006-20011/2012 and a decreasing trend during Y2012-2015. For the entire time-series, the overall trend is increasing for both annual number of fishers reporting whelk landings and mean annual whelk landings (pounds) per fisher Angell, 2017).

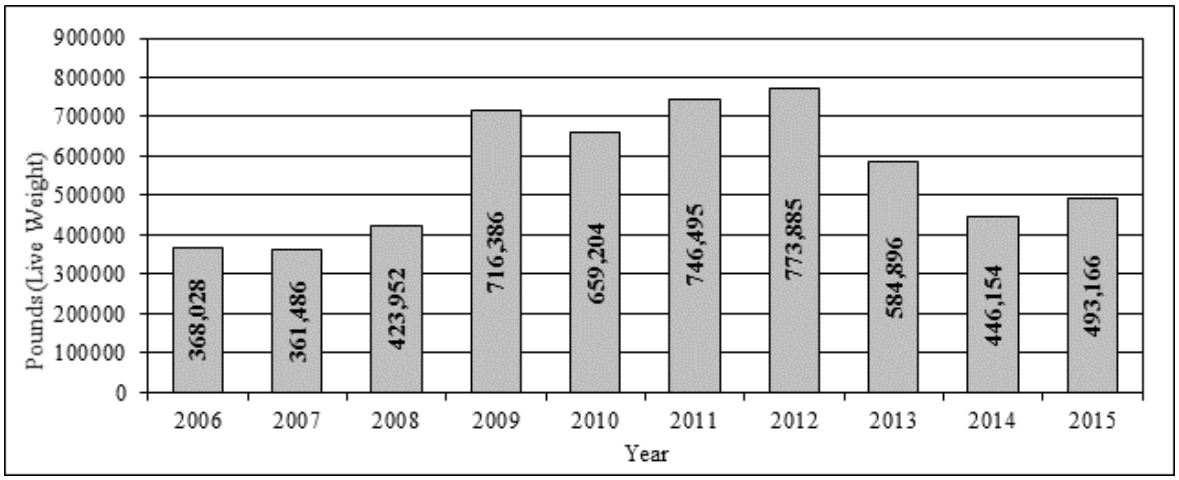


Figure 24. Total Whelk Landings in RI (Angell 2017).

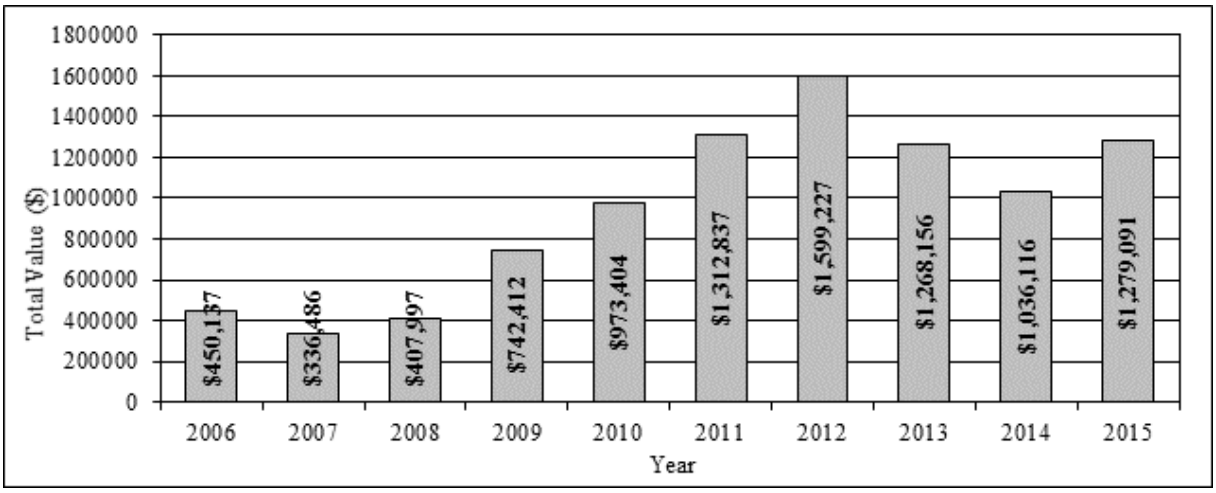


Figure 25. Total Whelk Landing Value in RI (Angell 2017).

The whelk fishery takes place from May to early December with maximum catch rates occurring in spring and fall, typically during the months of June and November with a hiatus during summer and winter. Duration of the fishing season depends mainly on water temperature. The season starts in late May to early June (first part) and starts again in late September to late November (second part). A breakdown of monthly whelk landings data (SAFIS) shows two distinct seasonal peaks and troughs. Although whelk landings occur year-round, the majority of landings occur during May-December, which account for an average of 98.6% of total annual landings. The months of January-April account for an average of 1.4% of total annual landings. The first and slightly smaller peak in whelk landings occurs in either May or June, with the second and slightly larger peak occurring in either October or November. Whelk landings decrease sharply during

August and September, presumably due to reduced catchability as a result of reproductive activity and increased water temperature (Figure 26).

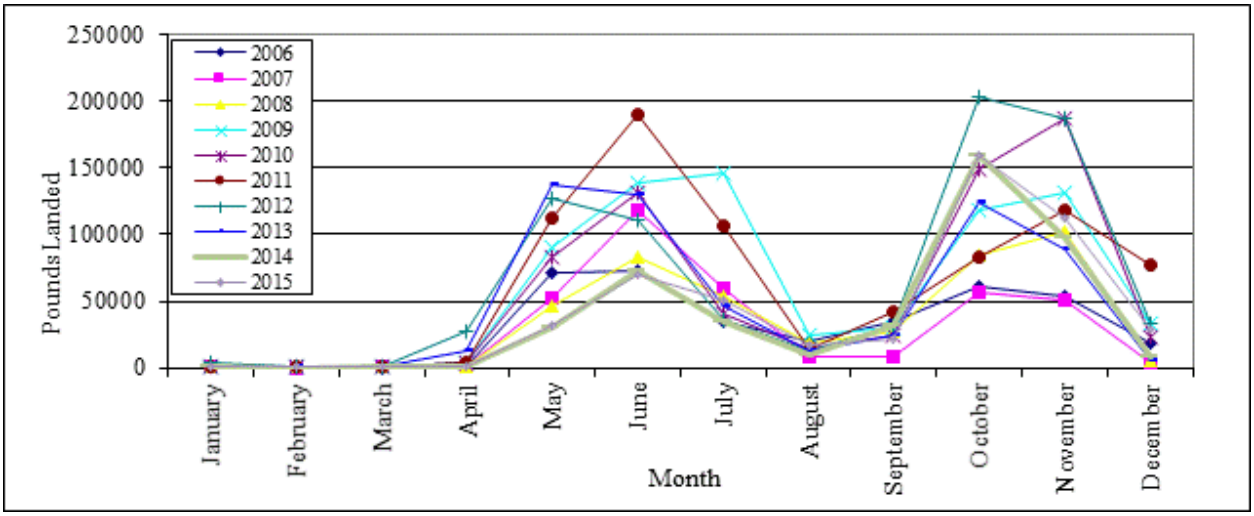


Figure 26. Whelk landings by month (Angell, 2017).

5.2 Gear Used to Harvest Whelk

Typically the channeled whelk is taken with baited traps, while the knobbed whelk is landed by trawl or quahog rake. Initial research was conducted by Shaw (1960) on wooden trap designs for the channeled whelk. Sisson (1972) and Wood (1979) examined several trap designs for use in the Narragansett Bay whelk fishery including trap efficiency, bait and bait containers. Wood was unable to effectively catch knobbed whelk, similar to results obtained by Walker et al (2003) regardless of the trap design or bait type. However, Shalack et al (2011) was successful at catching large numbers of knobbed whelk in their traps in Georgia. They attribute this high catch rate to timing in contrast to Walker et al (2003) who fished during the reproductive season for knobbed whelk. Rohrkasse and Atema (2001) report that whelk reduce feeding activities during their mating season from May-September.

May whelk fishermen believe that knobbed whelk do not trap well because they have such a heavy shell that they cannot climb up vertical trap walls.

There are several style whelk traps seen in the fishery with the following common elements:

1. Opening in the top of the trap with overhang to prevent whelk from crawling out again.
2. Some sort of material on outside to assist whelk with climbing up sides
3. Bait

4. Weight
5. Hauling bridle

The material used to construct the traps usually includes a wood or wire frame with plastic or rubber strips. Both style traps were evaluated by Castro and Marshall (2015). Results indicated no difference under lab conditions for proportions captured for channeled whelk (Figure 28). Knobbed whelk were not captured frequently although camera work showed them to be capable of climbing the sides and entering wooden traps (Figures 29 and 30).

Figure 27. Various types of whelk pots used in RI fishery (Photo: M. Hatzipetro).

Of the fishermen interviewed, 53.8% preferred wood traps; 38.5 preferred wire while 1 fisherman made his own traps from plastic.

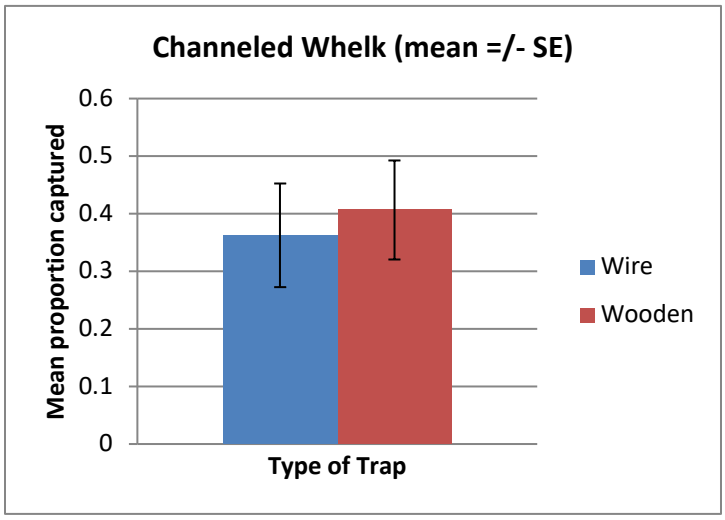


Figure 28. Research on catch rates did not find a difference between the trap style for channeled whelk (Castro and Marshall, 2015).

There is little selectivity of the whelk traps except for escapement between the wooden lathes of through the mesh. Once the whelk enters the trap it is usually unable to negotiate the climb

back up and under the overhang. Care must be taken when hauling the traps so whelk do not fall out of the open top.

Figures 29 and 30. Whelk in unable to scale the vertical wall and negotiate the overhang to escape; whelk entering the trap.

The most commonly used and most effective bait is horseshoe crab (*Limulus polyphemus*) (Figure 31). Channeled whelk responded most strongly during odor plume testing to dead *Limulus* bodies (Rohrkasse and Atema, 2002). Wood (1979) found that knobbed whelk were not attracted to any carrion as bait.

Figure 31. The horseshoe crab, *Limulus polyphemus* is the most popular bait type used in the fishery.

5.3 Vessels

Most of the vessels used in the fishery are small family owned boats that may also do other fisheries such as lobster and gillnetting. Hydraulic pot haulers are standard equipment on the vessels using traps.

"Most of the fishermen are captain and crew. They do everything

All of the fishermen interviewed fished for other species such as crab, lobster, fish, quahog, scallops and eels. 50% listed whelk as their primary fishery, 37.5 listed lobster and 12 % listed eel.

Figure 32. Typical small vessel used in the whelk fishery (Photo credit: M. Hatzipetro)

6. Local Knowledge

LEK is "the knowledge held by a group about their local ecosystem" and considers humans as parts of the ecological systems (Olsson & Folke 2001; Murray et al 2006; Boudreau and Worn, 2010). Trends from LEK interviews can be quantified on an ordinal scale and may be used to complement scientific information for resource management.

In order to fill some of the knowledge gaps for the whelk fishery in Narragansett Bay, we designed a LEK survey for the whelk fisherman of Narragansett Bay. The objective of the proposed survey was to investigate whelk fishermen's knowledge about whelk biology, whelk stocks, and local environmental problems, and to find ways to include fishermen's knowledge and experience in management. The survey was structured in two main parts: Demographic information about fishers and part two their knowledge about the whelk fishery.
A consent form and semi-structured interview were designed and approved by University of Rhode Island (Collaborative Institutional Training Initiative, CITI). The fishermen were contacted first by telephone, and arrangements were made to be interviewed in person. The interview began reading the consent form to the fisher and talking about the fishers about the confidentiality of their opinions. After agreeing with the consent form, then we proceed with an explanation of the research, leading into the interview questions.

To create an initial list of potential participants we consulted local experts for the fishery, however the majority of participants were identified by their peers through recommendations at the end of the interviews. Such referral or snowball sampling scheme are useful in situations where the information desired is perceived as 'sensitive' and finding individuals willing to participate in the survey is a challenge (Lopes et al. 1996; Boudreau et al, 2010). This non-random sampling methodology is used in the social sciences and has been used successfully in similar marine LEK studies (Boudreau et al, 2010)

A total of 9 fishermen were interviewed. There were two factors that determined the number of fishermen who could be interviewed. : 1) fishermen were not open to talk about the whelk fishery since the majority were not in agreement with the current Rhode Island regulations for whelk and the issue was very sensitive; 2) the study began just before the fishing season was starting and many did not find the time to perform the interview and 3. Consensus was reached on the major questions (Guest et al., 2006).

A qualitative analysis of their answers is explained in this section. The main questions of the fisher's interviewed are summarized in the following table 2.

Demographic Information
1. Residence, Age, Years of Experience in whelk fisheries
2. Port, crew status
3. Vessel size
4. Family fish for a living
5. Why did you choose fish for a living?
6. Other occupation
7. Other types of fishing conducted
8. Rank each fishery that participates in your livelihood
Whelk fishery
9. Whelk species that you fish
10. Where is your primary whelk fishing area
11. Nature of your involvement in the whelk fishery
12. Describe the whelk fishery
Local Ecological Knowledge
13. State of whelk populations in Rhode Island
14. Mayor changes for whelk populations in RI
15. Predators of whelk
16. What do the whelks eat naturally?
17. Bait
18. Environmental factors that affect the size quality and distribution of whelk populations
19. Threats for whelk
20. Most important knowledge than a fisher needs to have to be able to catch whelks

21. Best way to manage whelks and why
22. Best way to fisherman to participate in management
23. Size regulations passed for whelk by RIDEM

Table 2: Main questions asked in interviews

6.1 Whelk fishers in Narragansett Bay (Rhode Island) –Demographic information

Fishermen from a total of 6 ports in Rhode Island were surveyed (Newport, Sakonnet, Matunuck, Wickford, Warwick, and Point Judith). Attempts to interview fishers from Bristol were made, but it was difficult to meet with fishers there as the season started late because of the long winter. In Pt Judith, several attempts were made to interview the most experienced whelk fisherman but he was not willing to cooperate with this research.

Most of the fishermen interviewed answered questions in detailed way. They had an average of 13 years' experience fishing whelk (range 2 to 43 yr.); were on average 48-50 years old (range: 27 to 73 years) and they obtained on average 45 % of their income from the whelk fishery. In Rhode Island, multipurpose licenses are used by whelk fishers to catch whelk. This license allows participation in all fishery sectors at full harvest and allowable gear levels.

Family fish for a living, Choose to fish for a living

"A family tradition."

"I have addiction to the sea, first generation, first fool!"

"Sometimes is good, sometimes is bad: sometimes I wish to be a school teacher."

"You see and learn something new every day compared to punching a clock looking forward to a

Most fishermen engaged in the whelk fishery in Narragansett Bay perform the role of captains and crew at the same time. Usually they operate on their boats with a maximum of two people per boat, sometimes only one person. Only owners of larger vessels have differentiated assignments on their vessels. None of the respondents were fully dedicated to whelk fishery.

Most fishermen that are engaged in the whelk fishery come from families with fishing tradition (lobster, finfish, crabs, quahogs, clams). Of the nine fishermen interviewed, only three had no family connection to fisheries.

Whelk fishing is a relatively new activity for many fishermen in Narragansett Bay who are seeing this activity as a complement to other fisheries such as the lobster fishery. While all recognized that fishing for a living is very tough, they cannot give it up. Being a fisher is their job and profession and they have the passion and the skills to perform well its occupation.

For three of the respondents, most income comes from lobster fishery which is complemented with other types of fishing (clams, crabs, finfish, pot fishing and whelk). The remainder of

Fisher's about Knobbed whelk potting

"The majority of the conch in the bay are channeled."

"They (knobbed) tend to fall over crawling up. If I walk the docks in the morning, you will see them all around the docks. They like the shallow water."

"You catch the knobbies digging. You get them in the quahog rakes, and you don't get the channels, I don't know why."

"The knobbed don't really seem to

respondents (6) combines whelk fishing with finfish, crab and fish traps, quahog and clams which in combination represent the total revenues from fisheries. Only one case differs being eel fishing the main income which supplement with whelk fishing. Additionally some of them have other winter occupations such as carpentry or snowplowing.

At the time the interviews were done (April-May, 2015) only small boats were active or preparing for the whelk season. Bigger vessels size (>40 feet) were not involved in the fishery. All the fishers admitted that small vessels (15-25 feet) are more suitable for whelk fishery.

6.2 Whelk fishery: What, Where, Why

In Narragansett Bay two whelk species are targeted by fishers: channeled and knobbed. Most of the Narragansett Bay fishermen only catch channeled whelk. All fishermen agreed that knobbed whelk is very difficult to catch because the mollusk is unable to climb into the trap; its shell is too heavy and thick. In addition, interviews of fishermen documented that Knobbed is not as appreciated as channeled. Its market price is lower, so the fishermen have greater interest in targeting channeled. If they find knobbed it is usually mixed with channeled as by-catch. In many cases fishermen think that knobbed is not attracted by the smell of bait. The absence of knobbed whelks in pots was explained by a preference for live bivalves rather than bait or carrion.

Narragansett Bay and specifically the West Passage is mostly the chosen area by fishermen to target whelk. This fishing area is chosen for many of them for the convenience and proximity to home ports and since the fishermen look for an economic balance between fuel consumed and what they can catch as income in fishing whelk. Additionally many of them combined whelk fishing with other types of fishing activities in the area so that type of routine allows them to secure the profitability for the fishing day. Of the total group of respondents, only four were active whelk fishing elsewhere in Narragansett Bay or other different area of the state of Rhode Island. Two of them fish in the Salt Ponds; one of them fished both in Connecticut and Rhode Island in the Pawtucket River and another in Sakonnet River with the border with Massachusetts. Only one fisherman was fishing in East Passage because of the proximity of his port home in Newport and because he found whelk there although is very deep water. Other areas were mentioned by whelk fishers, Mount Hope Bay close to Bristol in Narragansett Bay and Block Island, but they have never tried those areas because they are too far away to make the investment. They know of other fishers that operate in those areas.

Respondents had different motivations to enter into the whelk fishery. In all cases all had a combination of reasons to trap whelk. Among other reasons that caused the conversion to the whelk fisheries were: 1) the generalized drop off of lobster fishery in Narragansett Bay, which it was the main income for many and 2) and the whelk price increase per pound.

The conversion and techniques to adapt to catch whelk were not a big investment, so easily the fishers adapted their traps for lobster to catch whelk or simply they make the investment of buying traps for whelk, which are less expensive than for lobster. For a time some fishers reoriented their work to catch whelk. Many of the fishermen set to work in the whelk fishery to cover the losses for lobster.

Nature of involvement in the whelk fishery in Narragansett Bay
No regulations
" No regulations-very independent fishery 12-15 years ago" "15 years fishing whelk in Pawcatuck river, nobody knows what I was doing, nobody fish there."
Boat size and License for it
" My boat size is perfect for whelk fishing" " Because my boat is set up to haul pots" " I have a license to fish for it"
Business aspect
" Whelk fishing is a good money" "They are worth the money!" "It went from 1$ to 2.50$ and keeps a steady price." "Whelking was being a perfect supplement, it just worked out great." "Lobstering dropped off and conchs picked up and price too" " …the more I talked to people I realized that whelk fishing was a substantial amount of income coming in."
Great feeling
"Lots of fun: the anticipation of hauling up a trap and great feeling." "Each year you get to know a little bit more about the species and you get to know the areas. It's a kind of like detective work." " When you start getting into them they are really funny animals, it'd drive you crazy, it was so funny."
Convenience and Logistic
" I could do that rather than dig clams" " You do not have to worry about swells taking your pots away" " I quahogged in the morning and then in the afternoon I would go to get my whelk" " Not directed fishery, but we do it, we do set conch pots, but never any real great amount of them."
By chance –By catch
"In my fish trap the whelk would show up and whenever I went quahogging, the whelk would be there ..so I said if I go for whelk I know where to put my pots." "I was lobstering in the Bay and I leave my pots there for the fall. Then, next year I caught a few lobster but a lot of snails."

" I quahogged and I found the animal by accident."
Lobstering drop-off
"Next year lobstering fell off but I was getting 700-800 pounds of snails a trip (2008)." " Lobstering was really falling off in the state waters and that's why I started to go for conchs." " When lobstering drop-off , we sort of converted over fish traps and conch traps for a few months" " Incidental catch fishing lobster"
Keep me working as fisher
" I was telling people 5 or 6 years ago: whelking is what keep me as a fisherman"

Table 3*:* Motivations for fishing whelk

At the same time, whelk price increased from $1.0 to $2.50 which it was a great motivation for fishermen to enter in the business. One more factor was that the whelk was entering in the lobster traps as bycatch.

For others the incentive is a combination of reasons. Some see the whelk fishery very convenient and it adapts to their own necessities as having a small boat or the license that they are entitled to use. Others see convenience in this fishery because they can combine this activity with other type of fisheries and it is less tough than for example raking for clams or quahogs in ponds.

Of all fishermen, the most experienced in the whelk fishery (10 to 15 years) entered in the activity because there was not regulations and they were able to catch whelk without any limitation. That situation compensated for the low price that the whelk had at that time.

6.3 How to Fish Whelk

Whelk fishermen from Narragansett Bay use traps, mostly because the species that they catch is channeled whelk. In other states, knobbed whelk dominates landings from dredge and trawl fisheries and channeled whelks dominate landings from pot or trap fisheries. T

Three kinds of supplies are used to build the traps: wood, plastic and metal. Only in few cases they build their own traps and respondents from all the ports reported that wood works better for this specific fishery. Traps used to be in the water for 24 hours; still some have two night's sets and that time works better for them. Regulations in Rhode Island allow them to set a maximum of 300 traps for whelk. Horseshoe crab is the most successful bait used for getting whelk and particularly horseshoe crab females. Whelk fishers used to sell their whelk in local companies and dealers from Massachusetts that comes directly to the port.

Gear

The gear is cheaper than going into lobster fishing. The traps for whelk are much cheaper. Whelk fishermen used two main types of traps: wooden traps or metal traps with plastic sides on them. Both kinds of traps are very inexpensive compared to a lobster trap. Average price for a whelk trap is $20.

Among fishermen, there are some that like to use metal or wire traps with plastic strips sides and others use wooden traps. There was only one exception case of a fisherman who manufactured their traps using bait barrels. Many respondents agreed about the effectivity of wooden traps in comparison with metal traps with plastic sides on them. A few fishermen use combination of metal and wooden traps but the majority has preference for wooden traps even though the wood pots are more difficult to maintain and last less time because of trap worms. Three respondents from three locations set to work traps individually because of their boat is small and the rest of fishermen use a trawl of traps, based on the hauling capacity of their boat, however it seems that only in few cases they set the maximum allowed by Rhode Island regulations, so they usually set under 300 pots. Some fisherman reported that other colleagues that were not interviewed go for more than 300 pots.

Soak time

Half of the fishermen leave their traps for one nights and the other half two nights. It depends on the bait that they are using ;it seems to work better or being more effective with one or two nights for soaking time. Most of the respondents reported that between 1 night set and 2 night sets the difference on average was 20% more of whelk and that for them was not worth it.

Bait

Fishermen from all the ports agreed that horseshoe crab and particularly the female horseshoe crabs works better than any bait to catch whelk. Horseshoe crabs are expensive, but the return for the investment is bigger. Others baits that they used were: spider, sand and green crabs, skate, and dogfish. Some respondents used a combination of different type of baits depending on the season. Among the respondents there was a particular situation where a fisher man was using dead lobster as bait for whelks. In this specific example, the lobster fisherman theorized about whelks going in for dead lobsters and the problem of lobster shell disease in the Bay.

Marketing and whelk price

Depending on their location, they wholesale whelks locally or to dealers that go directly to the ports. In some cases since they lived close to the border with Massachusetts they sell their whelk to dealers there. Main ports in Rhode Island where they can sell whelk are in Galilee and Wickford, although some respondents mentioned Bristol has a better price for whelk. Other fishermen sell their product to distributors who have previously agreed price of their product and port where it landed.

Figure 33: Wooden pot with horseshoe crab as a bait

6.4 Ecological knowledge

Most important knowledge a person needs to have to be able to catch whelks

The passing on of tradition and the sharing of knowledge comes with spending the time working with others. It is very difficult to just do trial and error fishing and make money that sustains you as a fisherman.

Your traps are key to good fishing. Most fishermen prefer wood traps but some narrowed that down to "new and clean".

Get to know the animal. The season (and water temperature) will dictate where they will be – in deep or shallow water. They are the most valuable from April 25th to August 10th but November 20th marks the end of season.

Bottom type is key. Sandy bottoms are more productive than muddy ones. Fish close to the coast in coves near edges.
You have to be committed and need to have a multipurpose license. It's ideal if you can catch your own bait and have a small boat

"Learn by doing and working with

State of whelk populations in Rhode Island

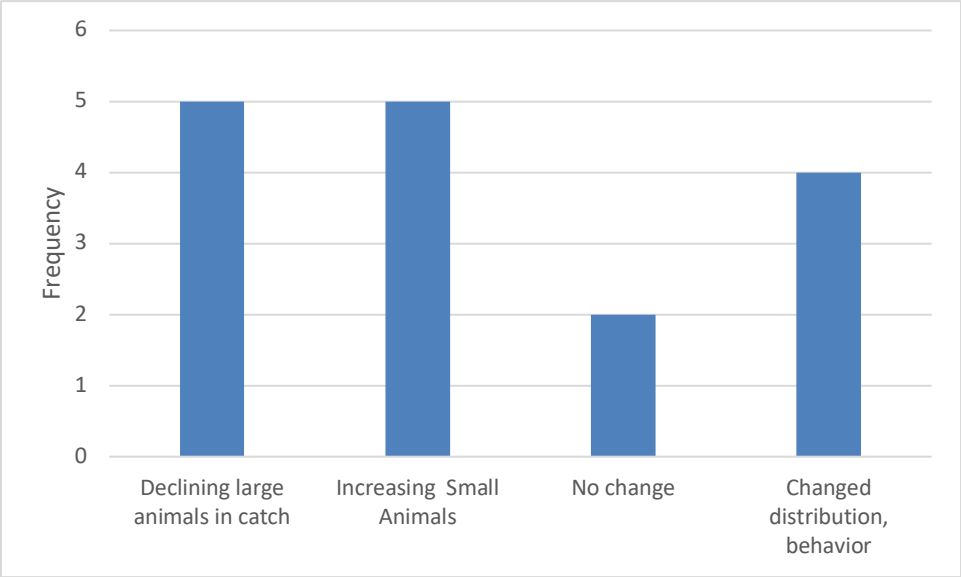


Figure 34. What is the state of the whelk population?

Why has the catch declined?

- ✓ the size increase regulations
- ✓ There are much more fisherman fishing whelk and much more pressure.
- ✓ They are just smaller
- ✓ No lobster to eat
- ✓ Change in depth
- ✓ Temperature changes

"It truly looks that we fished out the

Predators of whelk

None of the fishermen knew what predators whelk had in the environment but surmised starfish, urchins, blackfish, striped bass, seagulls, tautog, seals, other whelk, and man.




What do the whelks eat naturally?

The majority of respondents listed clams as potential prey followed by dead things and crabs. Fishermen that identified themselves as primarily whelk fishermen listed dead prey as the top choice (Figure 35).

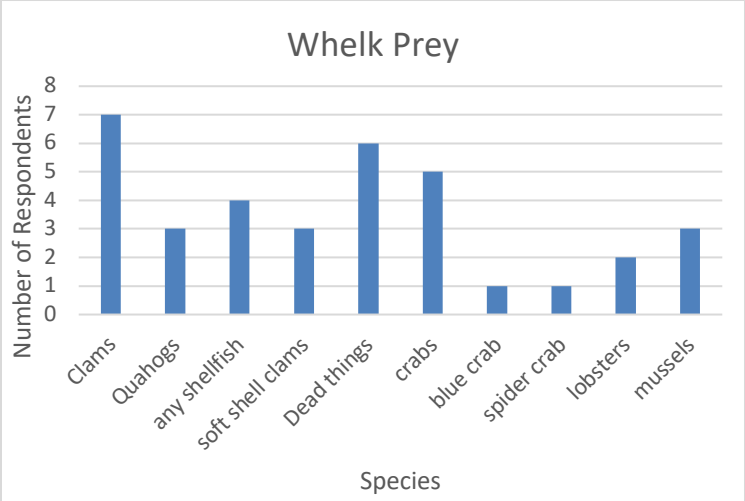


Figure 35. Free list of prey items identified by fishermen.

Narragansett Bay Fishers' about predators on whelk.

Some fishers think that whelks do not seem to have predators. Others think that seals, seagulls, starfish and fishes like tautaug can be predators of whelks.

What do they whelks eat naturally?

"Whelks eat clams, little necks, steamers, crabs, mussels-all life or dead- they are aggressive and voracious

Environmental factors that affect the size quality and distribution of whelk populations

Fishermen identified 6 factors that would affect whelk abundance. Most agreed that temperature was the most important factor affecting whelk distribution and availability, followed by salinity and sediment type. There was lack of agreement on the importance of oxygen and pollution (Figure 36). The trap fishing season for channeled whelk generally runs from late May to early

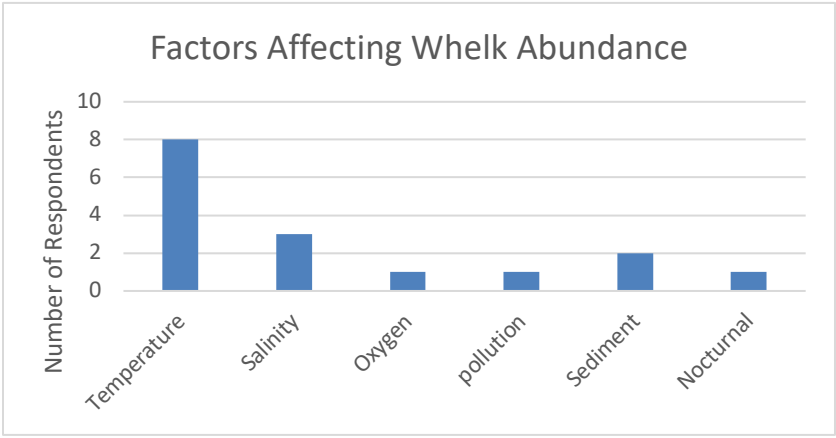


Figure 36. Factors affecting whelk abundance

June and ends in late November to early December. Fishermen believe whelk stop feeding during the hottest summer months and that they become dormant at low temperatures during the winter.

Threats for whelk

- ✓ Chemicals in the Bay, a big concern for him. He thinks Bay is much polluted.
- ✓ Fishing pressure, too much pots, and lots of fishers in the fishery. More people doing whelk fishery full time in the last years. He saw once 1350 pots.
- ✓ Human pressure
- ✓ Fishing pressure/ Humans
- ✓ Overfishing or fishing very hard or aggressively
- ✓ Overfishing, Pollution. He found (Jan-February) in the Bay; toaster, oven, microwave, three tows of trash. "Get the garbage out of the Bay". Uneducated recreational fishing. They don't realize about the size limit, they take it without thinking….Kings Charles Charter, constitution of RI-"anybody can come here and fish"
- ✓ Overfishing ***–" it is a boom and bust fishery"*** shelf limiting. Not great threat, it goes with cycles.
- ✓ Overfishing- ***" it is a gold rush, more people fishing whelk now – it needs pot limit"***
- ✓ Overfishing

"After heavy rain, whelk do not feed"

"Under 42 degrees F, this fishery is over"

"First snow, no more whelk"

6.5 Management and policy

Best way to manage whelks and why (fisherman opinion)

- ✓ Too many rules, management is not good. Minimum size for reproduction and leave economic rules to continue.
- ✓ Lower limit for pots/traps. 200-250 pots maximum. Agree with the size limit, it takes forever to grow. The current size limit is not going to help the state.
- ✓ Trap limit, size limit restrictions. Not a season, not a pound limit. He thinks people don't know when they are sexually mature. Market influences the size limits too.
- ✓ Pot limit is too much- that does not limit how much you can catch. Trap tags: name and identification of the traps. ***"There are people that fish 700 pots!"***
- ✓ He likes managing when they do not manage, so managing less. Old way was good, but with no other options whelk looks good to everyone.
- ✓ Pots/trap limit, don't go over 300 traps. He wants to expand. Meetings to educate fishermen. Let URI students through a seminar once a year on new findings and to answer questions. Mingled together can work.

- ✓ Find out what's the size are mature for sexuality. That is critical. Keeps the size above. Regulate the amount of people that goes into the fishery.
- ✓ Limit access, pot limit- 300 pots is too much.
- ✓ Size limit and Trap limit. It is too high 300 pots. Quote: "It ***is kind of high but if I have a bigger boat, I will go for them."***

Best way to fisherman to participate in management (fishermen opinion)

- ✓ Supply the whelks for studies of sexual maturity.
- ✓ Ad-hoc advisory meetings every month.
- ✓ Law enforcement, everybody has to be in the same page about what size they are keeping. Come up with an effective way to gauge them (length-diameter). Attend to meetings.
- ✓ Attend to meetings-stakeholder meetings, ad-hoc meetings, and trap tags. I want to be a fisherman for 30 years more so I should be more involved in the management.
- ✓ He used to go to meetings but he lost respect for the managers and how they approach to him. They do the opposite that they need to do and that is very damaging. Fishermen must being heard because they know more than biologist or managers ("***they do kid stuff***").
- ✓ Posted meetings-simple things
- ✓ Let's observers to go out in the boat. Cooperate. It is for our own benefit.
- ✓ Science sooner than later. Get sexual maturity. Spawning data.
- ✓ Out of the loop related with regulations; He does not participate in any kind of management or meetings; "***nothing gets accomplish in the meetings***."

Size regulations passed for whelk by RIDEM (fishermen opinion)

- ✓ No comment. They are aware of the project, too much aware.
- ✓ Worth trying right now. He wishes the price were not too high because is bad for the fishery.
- ✓ One more size increase would be good. The limit size right now, he thinks is ok.
- ✓ They went a little so far with the size limit. 5 and 8 inches were perfect. Cannot compare the snails here with the Massachusetts ones. Whelks in BI seem pretty chunky and bigger, it seems a different population than in Narragansett Bay.
- ✓ The increase in minimum size is going to bother him; they do not have in consideration the families that live from this fishery in RI. There are not consistency in what is written and the current regulations. It will affect the fishers of the Bay, he feels very sad about it.
- ✓ I only had the fall of 2014. I threw back over 5 time's juvenile channeled whelk, then keep legal size. I have 2 inches spacing on my wooden traps. Connecticut has not regulation size as of this date that I have heard or seen on the size of channeled whelk. He thinks that is going to jeopardize the whelk population. NY and MA have regulations.
- ✓ We are old fishermen and Galilei is falling apart. CT has to put regulations…
- ✓ This regulation is a big jump in size without knowing why, I do not understand.

- ✓ Insufficient data to increase size. Not increase size, limit number of pots. Need data to back it up.
- ✓ The jump is too big for the size limit without any knowledge.

7. Conclusions, research gaps and recommendations

Summary- Comments by fishermen (Size regulations passed for whelk by RIDEM)

- ✓ The jump in size limit for whelk is too big. DEM imposes a limit size without knowledge.
- ✓ Quote: " *I think this year I need to through half of the whelk because of the size, that is going to make a difference. I wish regulations wouldn't have increased size. I hope in the future will be better, but I want to pay the bills now*"
- ✓ Interviewer personal opinion. Some of the fishers' perception is that the scientists sometimes work in things because of the projects they get, but they do not think too much how they are affecting the fishers with their research.

Summary- Comments (Best way for whelk fishermen to participate in management)

- ✓ Science sooner than later. Get sexual maturity and spawning data.
- ✓ Ad-hoc advisory meeting every month.
- ✓ Cooperate, let observers to go in the boat.

Summary-Comments (Best way for whelk fishermen to manage whelks and why)

- ✓ Pot limit is too much. 300 hundred pots is too much for this fishery.
- ✓ Regulate the amount of people that go into the fishery.
- ✓ Sexually mature, nobody know.
- ✓ The current size limit does not going to help the state.
- ✓ Educate fishermen.
- ✓ Market influences the size limit too.
- ✓ Minimum size for reproduction and leave economics rules to continue.
- ✓ Quote: *" It is kind of high (numbers of pots) but if I have a bigger boat, I will go for them".*

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