Assessment of Queen Conch, *Lobatus gigas,* Density, Middens and Permitting Requirements, in South Eleuthera, Bahamas

by

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Abstract

Subject to subsistence and commercial harvest for decades, the queen conch, *Lobatus gigas*, has been subject to additional pressure in the Bahamas as stocks have been depleted in other countries that were historically prominent exporters. With concerns about local stocks and interest in culture of this species in the Bahamas an analysis of conch populations in south Eleuthera was executed. A survey of middens in the region to assess recent and historical fishing efforts was also performed. An area surveyed in 2003 (Clark et al., 2005) and determined to be a conch nursery ground was surveyed again in 2011 bi-monthly from July through November 2011 to assess population dynamics at nine sites in southern Eleuthera and assess any changes over time. Results suggest a decrease in density over time with no significant difference in total length over the two time periods. Middens in the area were also evaluated to quantify any change in size at harvest over time. Newer or "fresh" shells were significantly smaller than their "intermediate" and "old" counterparts. The information gathered proposes that juvenile harvest has increased substantially throughout the years, raising concerns about the sustainability of this important fishery. The permitting requirements for aquaculture of queen conch to alleviate this pressure are also discussed.

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Chapter 1: Introduction and Literature Review

An economically and socially important marine species throughout its range, the queen conch, *Lobatus gigas*, has become a species of interest not only for conservation but also for aquaculture (Stoner 1996; Stoner, 2003). It is an herbivorous large shelled gastropod that inhabits the western Atlantic Ocean with populations ranging from Bermuda to Brazil (NOAA, 2007). As a species that has been harvested and consumed as a protein source for centuries, the queen conch has only recently been considered subject to overfishing; some stocks have declined to the unsustainable densities (Brownell and Stevely, 1981). In the Bahamas, the queen conch has been protected by certain regulations throughout its time as a commercial species and populations in this country are deemed healthy but are continuously monitored.

The region's commercial fishery was developed in the 1970s, and increased fishing effort throughout its range led to a boom in total landings in the early 1990s (Fig. 1.1). Landings in the Western Atlantic increased from 1,200 metric tons in the 1970s to 16,857 metric tons by the year 2000 with exports dollars increasing from $689,000 in 1979 to $5.4 million in 1997 (Fig. 1.2). In the Bahamas, the growth in total landings increased from 100 metric tons in 1970 to over 600 metric tons by 1998 (Fig. 1.3). Notably, an export quota in the Bahamas was set for conch in the 1990s, capping external production pressures (FAO, 2005).

Other countries in its range have implemented export and harvest quotas, closed seasons, minimum meat weights and trade bans to regulate the fishery (Theile, 2001). The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) treaty also protects the trade of this species. Queen conch was one of the first organisms to be protected under Appendix II of the treaty, as "organisms that are not considered threated but may become so unless trade is controlled". Therefore export permits are required for the queen conch and importation from some countries (e.g., Haiti & Honduras) has been prohibited due to poorly managed fisheries (US Fish and Wildlife Service, 2003).

Regionally, harvest regulations are enforced by the Royal Bahamas Defense Force, prompted by the increase in demand and poaching. In the Bahamas, only adult conch, identified by the presence of a flared "lip", are allowed to be harvested legally (Fig. 1.4). Also, conch must be harvested by free-diving or through use of a hook and pole; SCUBA gear is not permitted during collection.

Despite these regulations, harvest of juvenile conch has been observed in certain areas (Clark et al., 2005). Although this is illegal in the Bahamas, this practice has been associated with fishing communities, impoverished areas, or areas where adults are unattainable due to deeper water refuges or over-exploitation of traditional fishing grounds. As juvenile habitats occur in shallower waters they are more susceptible to harvest. The illegal harvest of this crucial life stage is thought to reflect overexploitation (Appeldoorn, 1994; Mulliken, 1996; Theile, 2005). It must be noted that humans are not the only predators of conch; many other organisms also depend on them such as crabs, turtles, sharks and rays (Jory and Iversen, 1983). This natural mortality also plays a role in sustainable harvest as human-imposed decline of conch also may affect other food webs.

Previous studies (Clark et al., 2005; Danylchuk, 2005) suggest that the banks off of Cape Eleuthera (Eleuthera, Bahamas) provide habitat for juvenile queen conch. As this is not a protected area (though efforts are underway), fishing is still taking place in the area and personal observation affirms that juveniles are being harvested.

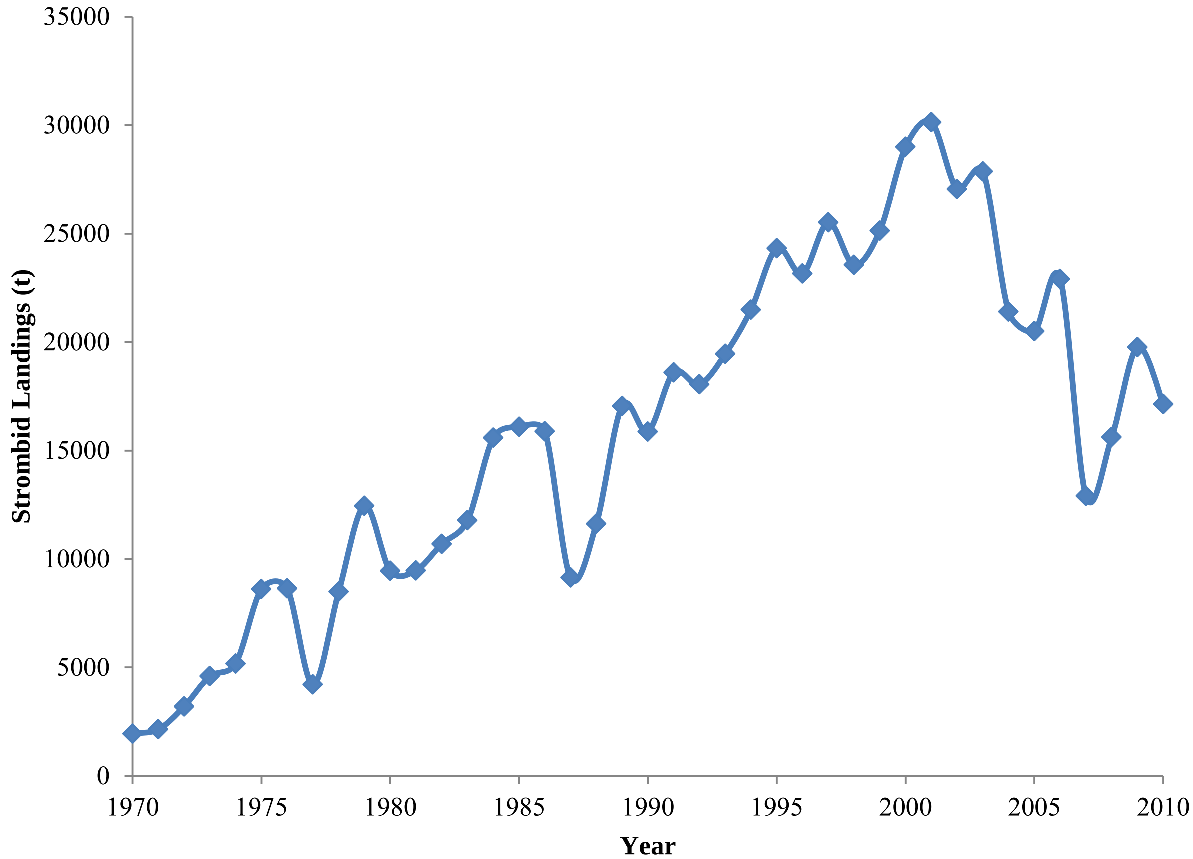

Figure 1.1. Total strombid landings in the western central Atlantic Ocean, 1970 -2010. Landings from Jamaica have been excluded as the harvested gastropod data was not separated by genre. (FAO 2012)

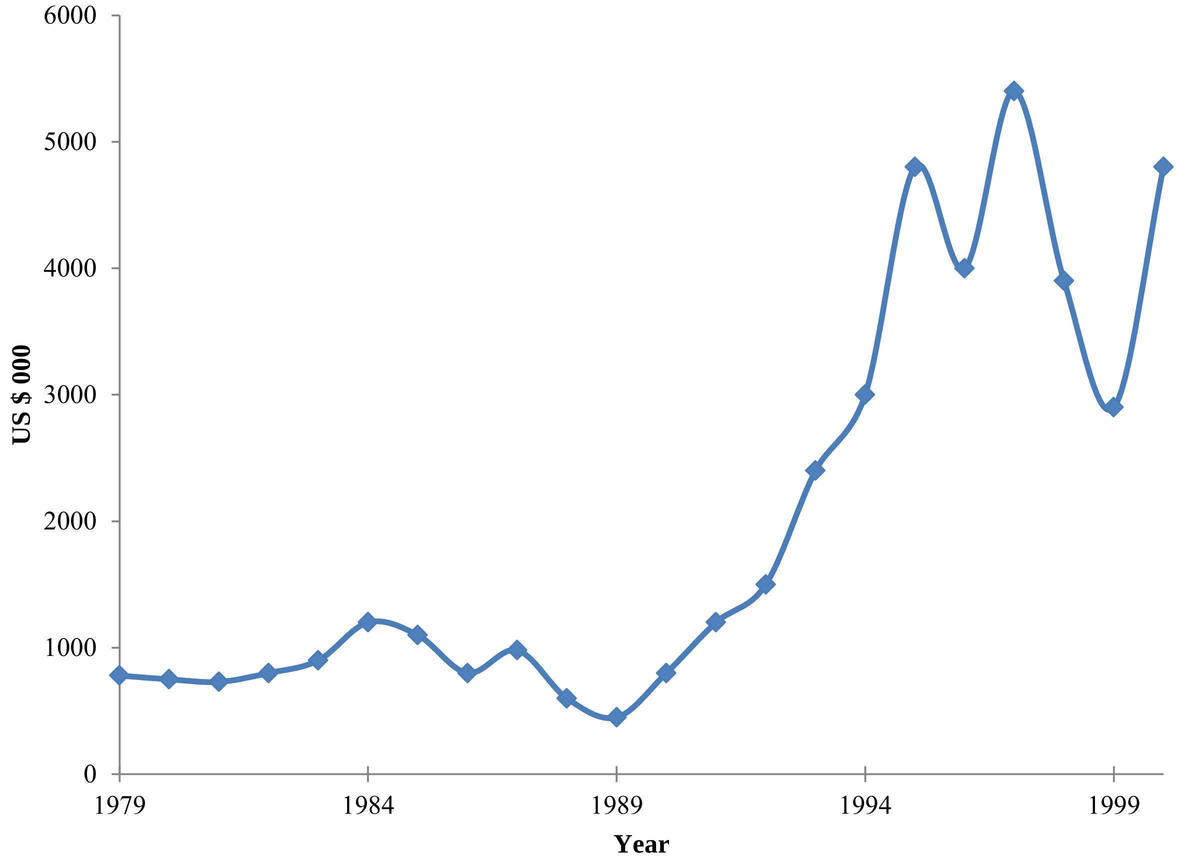

Figure 1.**2.** Exports of strombid landings from western central Atlantic countries, 1979-2000. (FAO 2012)

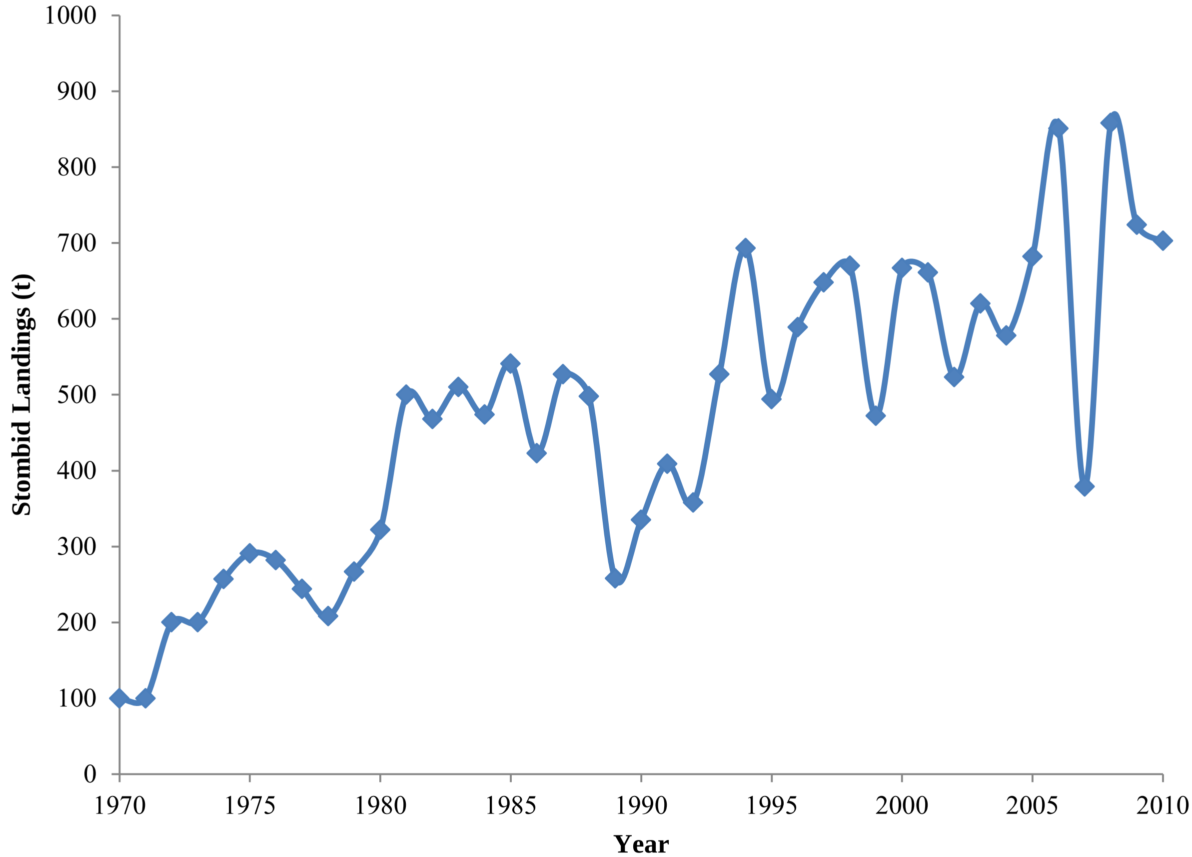

Figure 1.**3.** Strombid landings in the Bahamas, 1970-2010. (FAO 2012)

Figure 1.4. Queen conch adult and juvenile shell discarded on local beach in southern Eleuthera, Bahamas.

1.2 Biology

Queen conch reach sexual maturity at the age of three to four years of age when the flared lip is fully formed and shell growth stops (Appeldoorn, 1984; Davis, 1984). The shells can range from 15 to 23 centimeters in siphonal length but can grow to as large as 30 centimeters (Davis, 2005). The shell has a single opening which extends into the spire; this area houses and protects the soft bodied animal. The queen conch also has an operculum, which is a hardened structure used for protection and locomotion (Parker, 2005). Conchs in the strombid family are characterized by a particular type of propulsion known as the strombid leap; this technique is primarily for evasion, particularly from dart-shooting predators (Berg, 1973).

Adults can be found in waters as deep as 25 meters (Rathier, 1993; Mateo et al., 1998) and in shallow areas (Glazer and Kidney, 2004). Shallow areas tend to be the most productive nurseries for the species (Posada et al., 2000). Mature conch are also found in sandy bottom habitats, sea grass beds and patch reef areas (Glazer and Kidney, 2004). The adults migrate to deeper water during the winter (Hesse, 1979).

Queen conch migrate to shallower water to mate, typically between March and September (though this varies by location), as water temperatures increase (28 to 30 ºC) (Davis, 1984; Davis, 2005). During mating, the male inserts his verge into the groove or vaginal area of the female and releases sperm that will fertilize the female's approximately 500,000 microscopic eggs. Egg masses are laid on sandy substrate over a period of 24-36 hours following internal fertilization with hatching occurring three to five days later (Berg, 1975; Davis, 1984). Queen conch persist in temperatures ranging from 17-32°C with an optimal salinity range of 30-40 parts per thousand (Davis, 2000).

As planktonic larvae, the queen conch drift along with the currents feeding on phytoplankton until certain settling cues, particularly presence of the red algae *Laurencia poitei*,; this may take anywhere from 14-35 days (Davis et al., 1993;Boettcher and Targett, 1988; Davis, 1998). Metamorphosis and settling occur at approximately 1 mm shell length (Ray-Culp, 1997; Stoner et al., 1998). Post larval juveniles are rarely seen in the wild as they remain buried in the sand, up to 20 cm deep, until they are approximately 1-1.5 years old or 5 cm long only feeding only at night (Iversen, 1986; Danylchuk, 2003). This is thought to reduce predation, but despite these efforts up to 60% of juveniles succumb yearly to predators such as crabs, filefish and shrimps (Ray-Culp, 1997).

Benthic nursery locations for queen conch have settlement cues associated with red algae; particularly *Fosliella* sp. and *Laurencia poitei* (Boettcher and Targett, 1995). Other requirements include sea grass (30-80 g dry wt/ m^2) and a water depth of two to four feet. The veligers also seem to respond positively to strong tidal currents, where the habitats are flushed with clear oceanic water on every tide (Stoner et al., 1996; Jones, 1996; Rosada et al., 2000). It must be noted that there are areas in the queen conch's distribution that have seemingly perfect nursery habitat for these organisms but these remain unpopulated (Stoner and Ray, 1993). It is thought that the concentration of adult conch in some areas is too low to recover naturally.

Though decline has been observed throughout its region, queen conch in the United States have been limited to the Florida Keys National Marine Sanctuary. This decline, sparked in the 1980s was caused by costal development negatively impacting habitats and overfishing (Glazer and Kidney, 2004). In the Florida Keys, researchers estimated the total amount of adult conch between 1992 and 1994 was around 5,800 to 9,200 with an increase by the year 2000 of approximately 18,200 spawning adults. Studies have provided information explaining the lack of recruitment in the area. Nearshore conch in Florida were found to have underdeveloped gonads when compared to their offshore counterparts; preventing reproduction in areas when it was observed previously (McCarthy et al., 2000). Poor water quality is also thought to affect larval development. Hatchery data has shown that increased larval densities are associated with water treated against dissolved organic material (Glazer and Quintero, 1998). Though an increase has been observed recovery is still limited due to these factors following the ban on harvest (Glazer and Berg 1994; Berg and Glazer, 1995).

Though humans are a major consumer, queen conch are a prey item to many species throughout its lifecycle (Jory and Iversen, 1983; Stoner, 2003). Conch have a few techniques to avoid predation. They find safety in vegetated areas; surviving longer than their counterparts in unvegetated areas (Ray and Culp, 1997; Ray, 1995). Another tactic observed primarily in juveniles are aggregations. The conch accumulate in large numbers, up to $20/m^2$, lessening the chance of any one being consumed. Conch are nocturnal and primarily infaunal for the first year of life; they also may remain buried for up to two weeks after a storm (Davis, 1984; Danylchuk et al., 2003).

Queen conch nursery habitats have been negatively impacted by fishing and habitat destruction. Though the primary cause in queen conch decline throughout its range is thought to be due to overfishing, loss of nursery habitat may also be a contributing factor. Development in the Caribbean for tourism (hotels, marinas, piers, etc.) is also tied to eutrophication. Construction and dredging on coastal areas affects aquatic organisms, specifically those that depend directly on water clarity (Titley-O'Neal et al., 2011).

Biomarkers for ecosystems under stress are the prevalence of imposex and intersex individuals – particularly female gastropods. Imposex conch are primarily female conch with differing lengths of male reproductive organs (Linton and Warner, 2003). Pollutants such as tributyltin and dibutyltin, associated with anti-fouling paints, cause these anomalies which could affect reproduction (Titley-O'Neal et al., 2011).

1.3 Restoration

Different forms of restoration efforts have been undertaken throughout the queen conch range. These efforts have included establishment of no-take reserves or marine protected areas, banning all harvest and supplementing wild stock. Little success has been observed in terms of supplementing wild stock with juvenile conch (Appeldorn and Ballantine, 1983) though this may be attributed to and corrected when other factors such as predator prey relationships and seasonal variation in predation are taken into account (Jory and Iversen, 1983). For example, conch reared in simulated national environments in the presence of predators develop thicker shells and higher survival when tested (Delgado et al., 2002).

Marine protected areas (MPAs) have been implemented in 38 countries and territories protecting a variety of marine flora and fauna (GCFI, 2010). As conch can thrive in a variety of bottom types, specific MPAs for them can be difficult. In the Bahamas a 176 square mile marine protected area, the Exuma Cays Land and Sea Park (ECLSP), was established in 1958 and many surveys assessing conch populations have been executed over the years. However, recent studies suggest that populations have declined up to 35% in some areas despite its minimal human interaction (Stoner, 2010).

1.4 Aquaculture

Queen conch aquaculture has been studied as a means to alleviate increased market pressures on natural stocks. The limiting factor to successfully close the loop for aquaculture appears to be spawning in captivity. Harbor Branch Oceanographic Institution (HBOI) has been successful in this aspect as well as the Caicos Conch farm, a private company.

Post-fertilization (24-36 hrs.), the females produce egg masses that contain roughly 500,000 eggs (Shawl and Davis, 2005). After three to five days these eggs hatch producing planktonic lobed larvae which are reared at a relatively low density of 20 to 50/L. In culture, the newly hatched conch, called veligers, are gravity fed live algae (e.g. *Caicos isochrysis*) for the first 21-24 days. When the conch reach the proper phase they lose their lobes and metamorphose into a more recognizable form- resembling very small conch.

The addition of hydrogen peroxide has been shown to induce the metamorphosis of the six lobed veligers into benthic juveniles (Boettcher et al., 1997). The juveniles are then housed in raceways on fine micron screen trays. Thirty days after transformation, the conch are moved to systems that emulate their natural habitat with the average survival being approximately 60%. The conch then spend approximately forty-eight days in the mesocosms, which is also equipped with raceways. However, the trays used contain bottoms covered with course ground sand and the survival rate is roughly 97%.

These conch are fed another type of algae, *Chaetoceros gracilis*, but are slowly weaned off an all-algae diet to one that includes pelletized feed made from a combination of catfish chow, dried sea lettuce (*Ulva* sp.), and alginate (Shawl and Davis, 2005). The juveniles are raised at a density of 1,600/m^2. The juveniles can grow at rates of 0.3 mm/day when fed adequately and are transferred to offshore pens from the onshore pond system when they are one year old or 6 cm.

1.5 Rationale

The increase in demand for conch has led to a severe decline in the naturally occurring populations of this species. It has been deemed commercially extinct in some countries including Bermuda, Mexico and the United States (in Florida) (Lang, 1998). The price can range from $6.00 to $15.00 per pound in the U.S., and are currently sold from $2.00 to $5.00 per conch in the Bahamas (Davis, 2005). As a food it provides a low fat source of protein, vitamins E and B_{12}, magnesium, selenium, and foliate though it is relatively high in cholesterol (NOAA, 2009).

Through this study, population densities in a nursery ground off Cape Eleuthera were assessed and compared to those in 2003 to assess any changes over this relatively short time period (8 years). In addition, midden surveys were also performed in the surrounding area to characterize any changes in size and lip thickness at harvest of queen conch over longer time periods, as well as document current harvest patterns.

Based on the findings of this work, and the demonstration of the technical feasibility of conch aquaculture (Heyman et al., 1989; Spring and Davis, 2005; Woodring and Boettcher, 2005), it was determined that construction and operation of a conch aquaculture facility showed promise in the region. As a preliminary assessment of this option, an analysis was conducted of the permitting requirements for a conch hatchery and grow-out facility in the Bahamas.

Developing an economically and environmentally sustainable seafood industry to meet public demand is important. Understanding the area in which conch thrive and assessing local changes in demand are also significant in assessing the location and feasibility of an aquaculture facility.

Chapter 2: Queen Conch Density and Midden Survey

2.1 Abstract

Queen conch produce free swimming larvae during the summer months throughout its range. These larvae settle in very specific areas known as nursery grounds where they forage and thrive for the first years of life. These nursery grounds tend to be in shallow water and as the conch grow they provide sustenance for a multitude of marine organisms. Once large enough, human beings become a major predator. This study observed queen conch densities in southern Eleuthera at sites previously visited in 2003. A comparison in density and total length was performed and significant differences were observed between sites and years. Some significant difference was also observed between total lengths. Overall declines may be due to a combination of factors as source populations may have relocated or harvested but densities found at most sites are lesser than those in healthier aggregations.

2.2 Introduction

Marketed as both a staple food locally and a delicacy abroad the queen conch, *Lobatus gigas*, has come under great fishing pressure in the last century. A valuable source of protein, omega 3 fatty acids and micronutrients since the time of first inhabitance total harvest in the western Atlantic has grown from 1,200 tons in the 1970s to over 16,000 tons in the 1990s with exports increasing from $689,000 in 1979 to $5.4 million in 1997 (FAO, 2005). In the Bahamas, both subsistence and commercial markets exist with most wild caught conch consumed locally. Generally, adult conchs – those with a flared “lip”- are in highest demand due to market preferences. An adult can weigh five pounds and have a total shell length of 30 centimeters (12 inches) reaching maturity around 3.5 to 4 years of age (Stoner, 1994). Major areas of harvest in the Bahamas include the Berry Islands and Andros Island which provide the capital, Nassau, with a majority of its stock (Theile, 2001). These islands support extensive conch populations due to their proximity to queen conch habitat consisting of shallow sandy banks and algal flats. In some areas, deep-water refuges of adult conch are thought to be the source of larvae and shallow water populations (Berg and Olsen, 1989; Wicklund et al., 1991; Stoner and Sandt, 1992; Stoner, 1994). Eleuthera, another island in the archipelago is also supports a conch population. As a barrier island, there is a deep-water refuge to the east and shallow sandy banks to the west. South Eleuthera is also home to a nursery ground for the queen conch (Clark et al., 2005; this study).

Reproductive competence occurs around three to four years of age, after the lip of the shell flares and thickens for the remainder of its life (Stoner, 1992). As a sexually dimorphic species the male internally fertilizes the female and the female lays an egg mass 24- 36 hours after fertilization on sandy bottoms. A single female can lay egg masses six to nine times in the reproductive season (Davis, 1983; Stoner and Culp, 2000). These egg masses can have anywhere between 250,000 to 750,000 eggs though survival is severely limited. The planktonic larvae or veligers hatch after three to five days and remain suspended in the water column for a period of 14 to 35 days until proper metamorphic cues are met (Davis, 1994). The post larval conch then settle in the substrate and bury themselves for approximately the first year of their life (Iversen et al.; 1989; Sandt and Stoner, 2003). After a year they then emerge and continue feeding on detritus and algae though they are still at risk to be preyed upon until a shell length of approximately 75 mm.

Juvenile conch are known to amass in shallow water areas as they find safety in numbers (Ray-Culp, 1997) and are found at concentrations of 0.2 to 2.0 conch/m^2 in aggregations (Stoner, 1993). Common densities in nursery areas are reported at 1-2 conch/m^2 (Alcolado, 1976; Hesse, 1979; Wood and Olsen, 1983; Weil and Laughlin, 1984; Iversen et al., 1986). These nursery grounds are usually sandy bottoms with medium sea grass cover though algal flats and rocky bottoms also sustain populations (Torress-Rosado, 1987; Glazer and Berg, 1994; Stoner et al, 1994; Stoner, 2003).

Currently, the conch populations in the Bahamas are protected by several regulations. Possession of conch without the presence of a flared lip, deemed a juvenile, is illegal. Harvest of conch by use of SCUBA is prohibited and use of hookah rigs (air provided to a diver by a floating air compressor) is only allowed at depths greater than 30 meters. Conch must be collected by free-diving or by hooking from a vessel. Poaching and illegal harvest regulated by the policed Royal Bahamian Defense Force nationwide however, in South Eleuthera little regulation has been observed.

The local community has endured economic hardship over the last 30 years, exacerbated by the closure of a resort and subsequent job loss. Many of the locals depend on the sea for sustenance and people can be seen wading out during low tides and collecting juvenile conchs. Fishermen also use skiffs to harvest conch further off shore usually removing the meat and discarding the shell at sea; others bring their catch to land and pile the shells in middens. Assessing these middens around South Eleuthera can provide insights into any changes in size at harvest over time. As these piles are near fishing grounds, changes in distribution may also be evaluated (Stoner, 1997).

A study on nursery ground populations in southern Eleuthera (Clark, 2005) in the Bahamas was performed between March and May 2003. Densities of queen conch averaged 993 conch per hectare with a higher concentration of juveniles than adults, particularly small juveniles (<150 mm siphonal length). In the current study nine of the original 18 sites were revisited and compared in July 2011. These sites were selected as sites where conch had been found previously; all other sites had no conch at the time of collection in 2003. The sites in this study were also assessed every two months, July through November 2011 to evaluate any temporal changes.

The purpose of this study was to (a) assess changes in density and size of live conch seasonally in 2011 and between years, and (b) evaluate changes in size class at harvest over time by surveying middens in the area. It was hypothesized that:

(a) both density and size would decrease between 2003 and 2011 in field surveys;

(b) there would be a decrease in size and density throughout the bimonthly samples between July and November in the field surveys; and

(c) there would be an increase in total length and lip thickness with shell age in the shell middens.

2.3 Methods

Density survey

Nine sites off of the northeastern coast of Cape Eleuthera in south Eleuthera were sampled in July, September and November of 2011 (Fig. 2.1). To maximize comparability with a previous study of the area (Clark et al. 2005) these nine sites were based on those, and relocated using a handheld Garmin GPSmap76 system. The original study surveyed 18 sites within the area; the nine sites here were selected as they had densities greater than zero in the prior study. Each site contained a mixture of a sandy bottom and an algal plane. Water depth varied depending on the tide but it ranged between 2.1 and 1.8 meters. Tides were not taken into consideration as sample dates were confined by availability of boat support. Sites were coded from one to nine, corresponding to increasing linear distance to shore.

Following the Clark et al. (2005) procedure, each site was constrained to a 200 m x 200 m area. Within each area, three 30 meter transects were set parallel to the current, using dive weights, on the seafloor haphazardly to avoid bias (Fig. 2.2) for standard belt transects. Each transect was set by a team of two members, a leader and a follower. The leader extended the transect and was followed by the follower who collected conch along the track. With swimmers using snorkel gear, previous practice of visually estimating 1 m underwater was performed prior to data collection. All conch within 1 m on either side of each transect were collected including apparently dead shells to avoid any misjudgment. The leader then collected any unnoticed conch by reassessing the course of the transect, for a total area sampled of 60 m^2 per transect.

Each live conch was measured for total length, lip thickness and flare presence using Vernier calipers (Fig. 2.3). All data were recorded to the nearest millimeter for lip thickness and to the nearest tenth of a centimeter for total length. Lip thickness was evaluated one third of the distance from the spire (Appeldoorn, 1998; Stoner and Sandt, 1992; Stoner and Schwarte, 1994) and total length evaluated from the tip of the spire to the end of the siphonal canal. The conch were then returned to the sea bed within the sampled area.

Data Analyses

Transects and sites were considered as replicates in the course of the analysis to assess the effect of site and month on total length and lip thickness as well as year when applicable. Histograms were produced to assess changes in total length and lip thickness frequencies between 2003 and 2011. Analyses were completed using Systat Statistical Software, Microsoft Excel and XLStat. Statistical significance was determined using $\alpha = 0.05$.

Midden Survey

Conch middens in southern Eleuthera (Fig. 2.4) were surveyed assessing the size of collected individual shells in 12 middens (Fig. 2.5). The middens selected for sampling were either onshore or marginally submerged, with a minimum 50 shells/m^2 estimated visually and most were found within one kilometer of CEI; a separate midden was found in another inlet on the other side of the cape. As only the onshore middens were surveyed in this study, a complete estimation of harvest volume cannot be determined as some of the shell is discarded at sea. However, these surveys provide a model for changes in sizes and maturity at capture over time. Through this survey total lengths and lip thicknesses of shells in twelve middens around south Eleuthera were assessed. A separate statistical analysis was performed on the four middens containing all three categorical age groups ("fresh", "intermediate" and "old").

Survey techniques and apparent age estimation were derived from Schapira et al. (2009) and Stoner (2007). Based on Schapira (2009), a 1 m^2 quadrat was placed at the peak of each midden (Fig. 2.6). Each midden's area was measured for total length, width and depth. A maximum depth of approximately 1.5 m for any excavation was established for safety as middens had a tendency to start caving in at depths greater than this. Middens less than or equal to this height were excavated until the sandy substrate was reached. All shells collected within the sample area of each midden were measured for total length, lip thickness, flare presence or absence and shell condition (Fig. 2.7). Broken shells were not included in the sample. All total length measurements were collected using measuring tape and lip thickness was recorded using Vernier calipers and recorded to the nearest centimeter and millimeter, respectively. Lip thickness was measured two thirds of the distance from the anterior end (Fig. 2.8). Shell condition was divided into three groups, "fresh", "intermediate" and "old" with the type of harvest extraction being noted; more recent harvesters use a hatchet that leaves a narrow opening on the spire, while historical harvesters opened the conch using another shell, leaving a circular hole (Keegan, 1987; Stoner, 2007). The apparent age was assessed qualitatively (Stoner, 2007), specifically by the level of deterioration of the outer organic matter on the shell, periostracum, and discoloration of the typically pink inner shell. "Fresh" shells retained all of their color and more than 90% of the external organic matter was still present on the shell. "Intermediate" shells were relatively faded and retained 30-80% of their periostracum. "Old" shells were very dim in coloration and had little to no organic matter externally. This information allowed not only for a general understanding of the distribution throughout the midden but a comparison of size and lip thickness to shell age.

Data Analyses

Middens were assessed in two methods. The four of the twelve middens evaluated containing all three shell conditions (fresh, intermediate, old) were compared using ANOVA to evaluate any significant difference associated with midden, total length or lip thickness. All middens were treated as replicates to observe any significant difference between the total length and lip thickness of each of the shell conditions. Histograms were also produced to illustrate frequency distributions amongst shell condition, total length and lip thickness. Analyses were completed using Systat Statistical Software and Microsoft Excel. Statistical significance was determined using $\alpha = 0.05$.

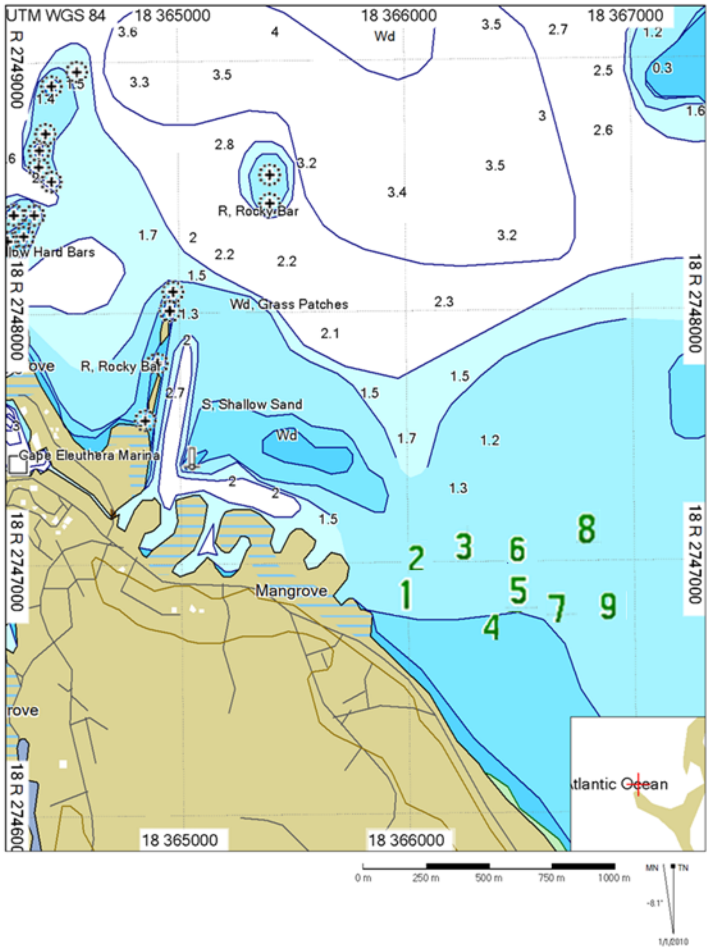

Figure 2.1**.** Map of the nine sites surveyed in both 2003 and 2011 (large numbers) in southern Eleuthera, Bahamas. Map produced using Mapsource Blue Chart Americas v2008.

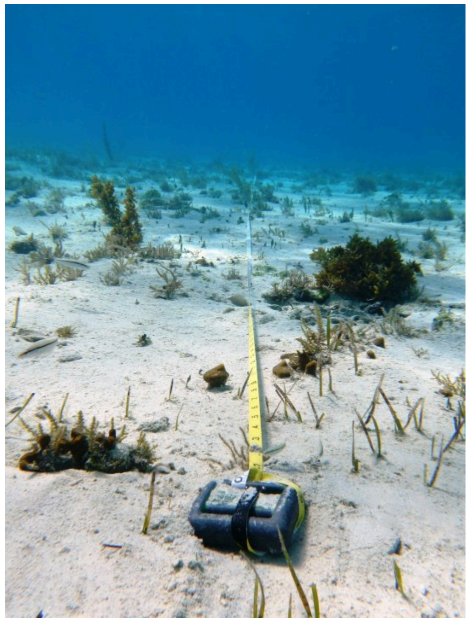

Figure 2.2**.** Transect on seafloor

Figure 2.3. Measurement of shell height using Vernier calipers

Figure 2.4. Queen conch midden in Wemyss Bight, Eleuthera.

Figure 2.5. Midden locations in southern Eleuthera. Middens containing variations on shell types (yellow) and all three shell types (red) are pictured using circles.

Figure 2.6. Quadrat placed on midden peak

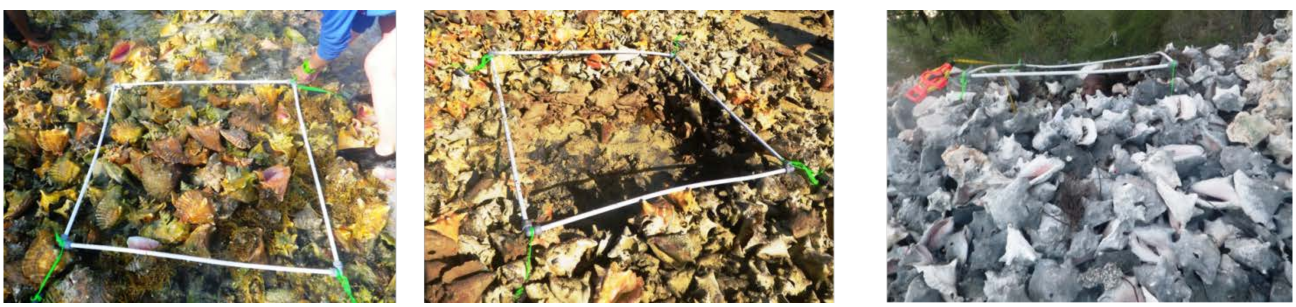

Figure 2.7. Shell conditions showing “fresh”, “intermediate” and “old” shells. Each group was determined by the amount of organic matter remained on the exterior surface.

Figure 2.8. Lip thickness measurement being taken from “old” shell

2.4 Results

Conch Abundance and Size Survey

Bimonthly Survey

A total of 417 live conch were collected within the five month period, and the density data were rank transformed to achieve a normal distribution. Using analysis of variance (ANOVA) to test differences in density as a function of month and site, significance was observed among the months ($P=0.01$), sites ($P=0.02$) and site by month ($P<0.01$) interaction. Post-hoc analysis was performed using Tukey’s honestly significant difference test to compare treatment means of the interaction. Among the means, significant differences were observed between only sites 5 and 8 in September ($P=0.05$) (Fig. 2.9).

For total length, the data were rank transformed to attain normality. Only month was a significant effect ($P<0.01$), with insignificant site ($P=0.23$) and month by site interaction ($P=0.22$). Among months, total length in July was significantly greater than total length in

November (P<0.01) but no significant differences were observed between July and September (P=0.62) and September and November (P=0.07) (Fig. 2.10).

Lip thickness, as with total length, only showed a significant effect of month (P<0.01). No significance was seen between sites (P=0.41) or month by site (P=0.09). Among months, average lip thickness of conch found in July was less than the average lip thickness observed in September and November (P=0.003 and P=0.03) but there was no difference between September and November (P=0.64) (Fig. 2.11).

Comparison between years

Unpublished data collected by Sascha Clark (Clark et al., 2005) in 2003 and the 2011 data (this study) were compared in terms of quantity (conch/m^2) and total lengths. The data, with the transects as replicates, were rank transformed to achieve normal distributions and analyzed using ANOVA testing for effects of year, site and a year by site interaction. As an additional test of differences between years, sites were treated as replicates and the data were analyzed using ANOVA testing for the effect of year. Lip thickness was not compared in either analysis as it was not assessed in the 2003 data. Additionally, any conch found over 150 mm were also not used in calculations as these were not included in the Clark et al (2005) analysis.

In the first analysis (where site was included as a factor), significant differences were found between the year (P<0.0001), site (P<0.0001) and the year by site (P<0.0001) interaction. For any given site, Site 5 was the only site where the years differed significantly, with much higher abundance in 2003 than 2011 (P<0.01) (Fig. 2.12). In the second analysis (where sites were treated as replicates), no significant difference was observed between years (P=0.26) (Fig. 2.13).

The total length data were examined using ANOVA, with sites as replicates. Sites that were without conch in either of the years were removed from analysis. Total length did not differ significantly between years ($P<0.001$) (Fig. 2.14). A two-sample Kolmogorov-Smirnov test was run on the four sites that contained more than one conch (Sites 3, 4, 7 and 9) to evaluate differences in total lengths between years within each site. The conch in 2011 at sites 3 and 4 had a greater average total length than those conch found in 2003 ($P<0.01$, $P<0.01$). The conch at site 7 were significantly larger in 2003 ($P=0.02$) and there was no difference at site 9 ($P=0.06$) (Fig. 2.15). A frequency histogram was produced to reflect overall abundance at certain lengths. Conch in 2003 were skewed to larger total lengths, while conch found in 2011 were skewed to shorter total lengths, indicating a shift in size distribution (Fig. 2.16).

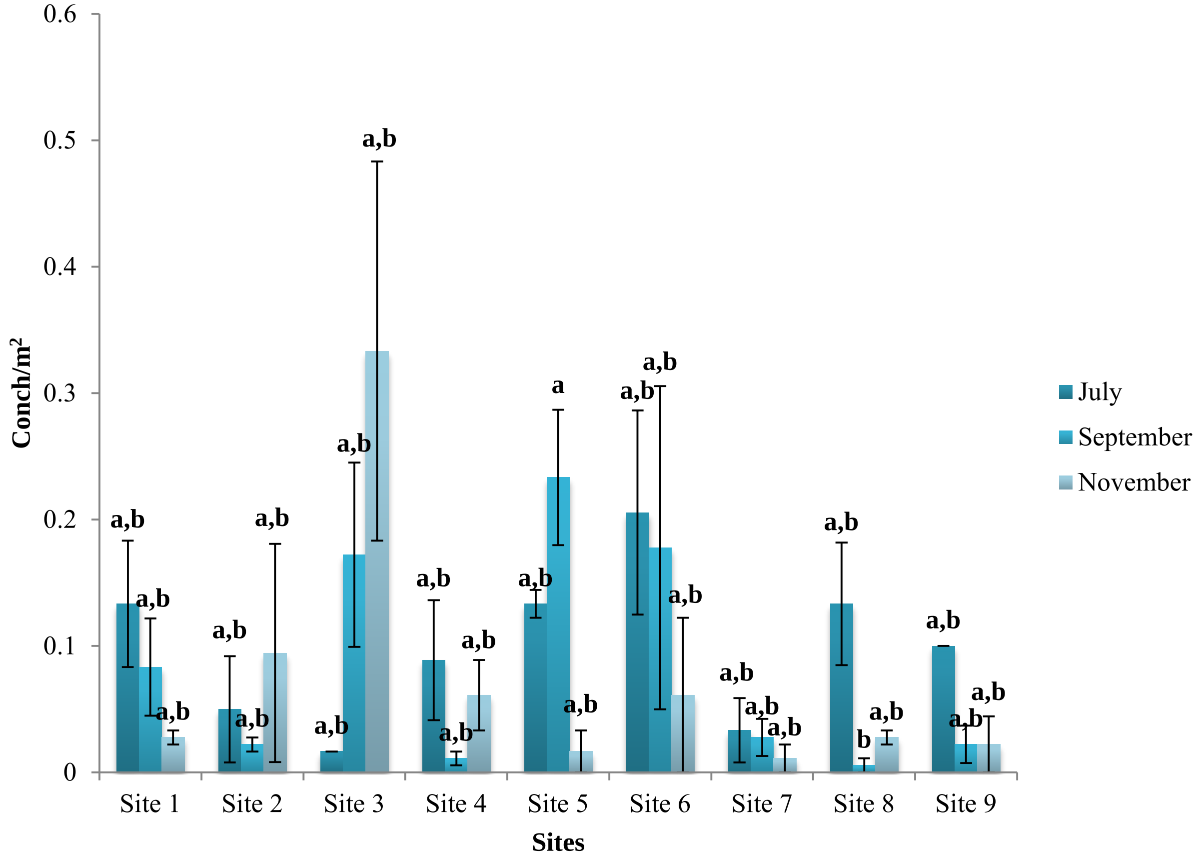

Figure 2.9. Average number of conch/ m^2 per site bimonthly (July through November, 2011) in southern Eleuthera. Error bars represent standard error of the mean.

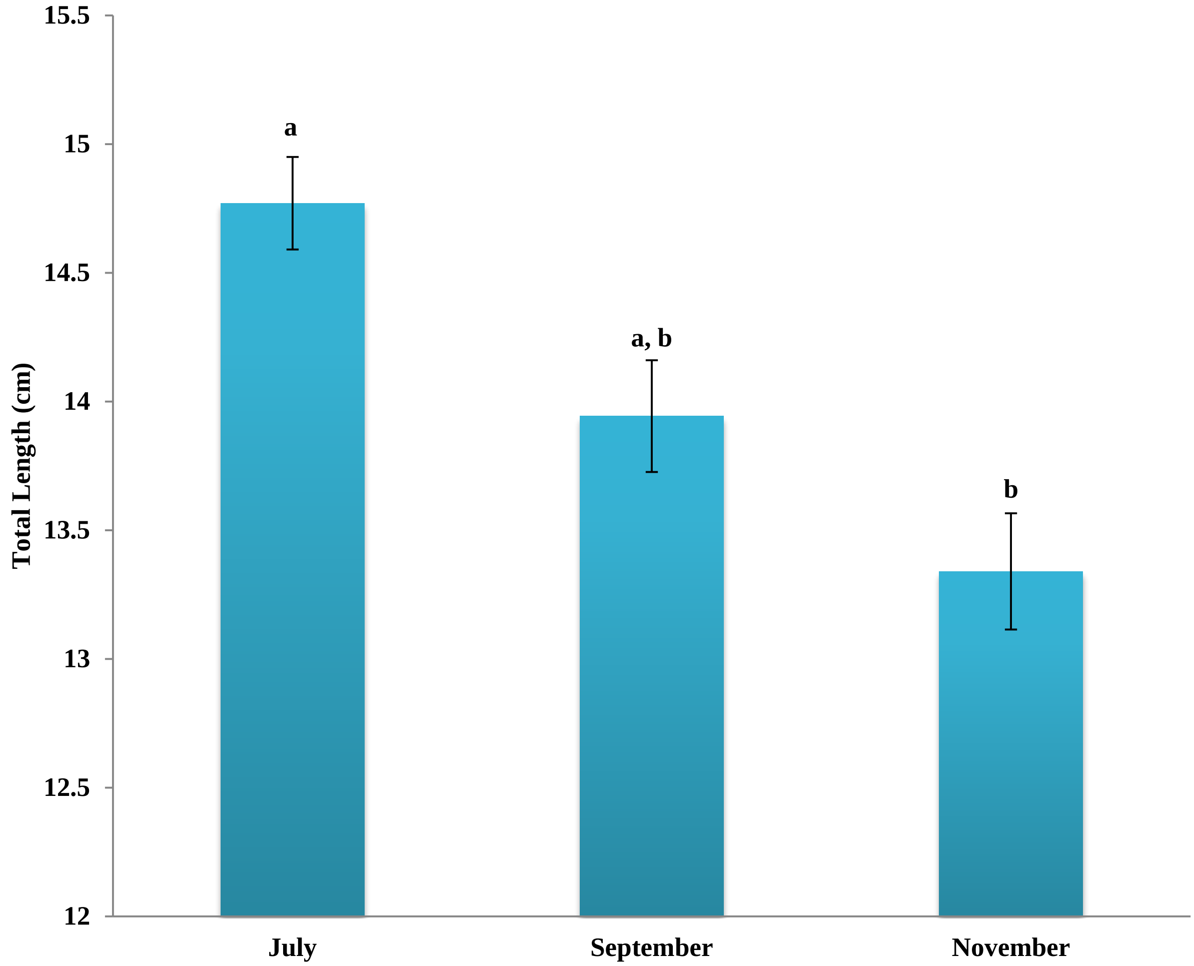

Figure 2.10. Average total length of conch collected at nine sites in south Eleuthera over a five month period. Error bars represent standard error of the mean. Significant differences among treatments are indicated by different letters.

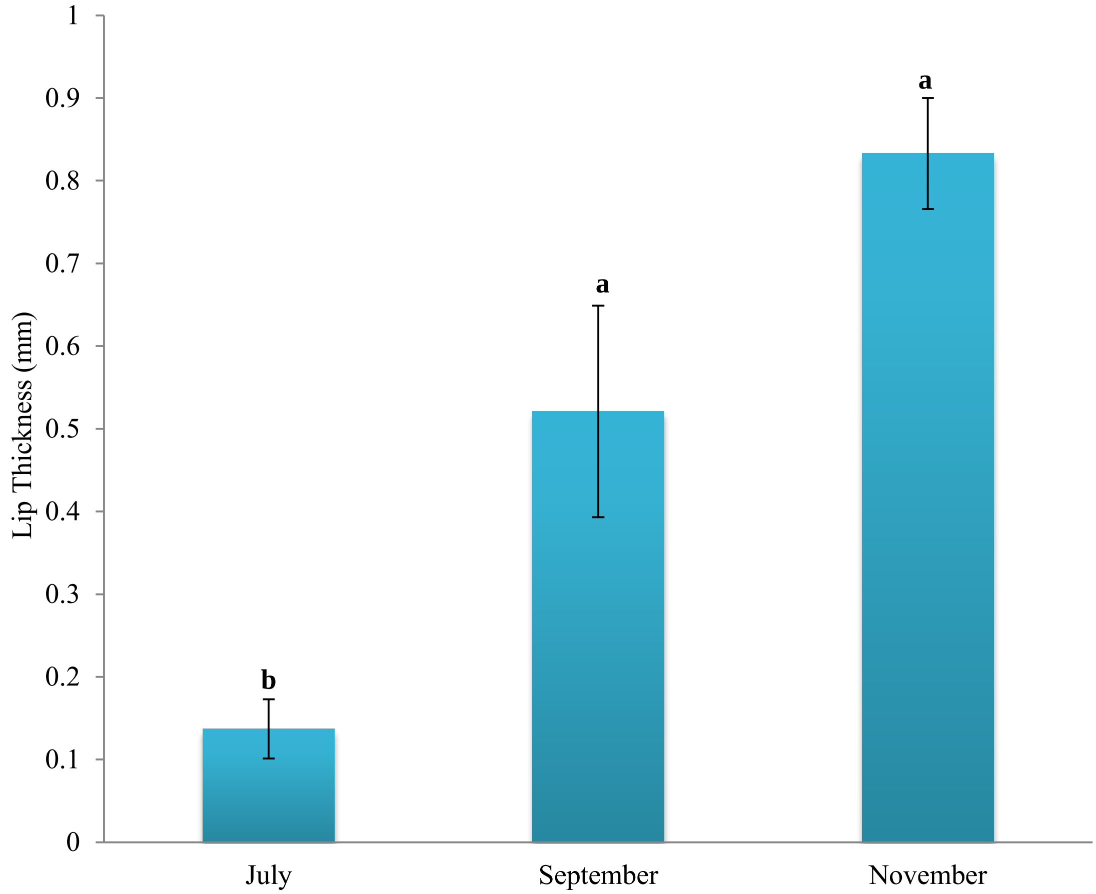

Figure 2.11. Average lip thickness of juvenile conch collected in nine sites in southern Eleuthera. Error bars represent standard error of the mean. Significant differences among treatments are indicated by different letters.

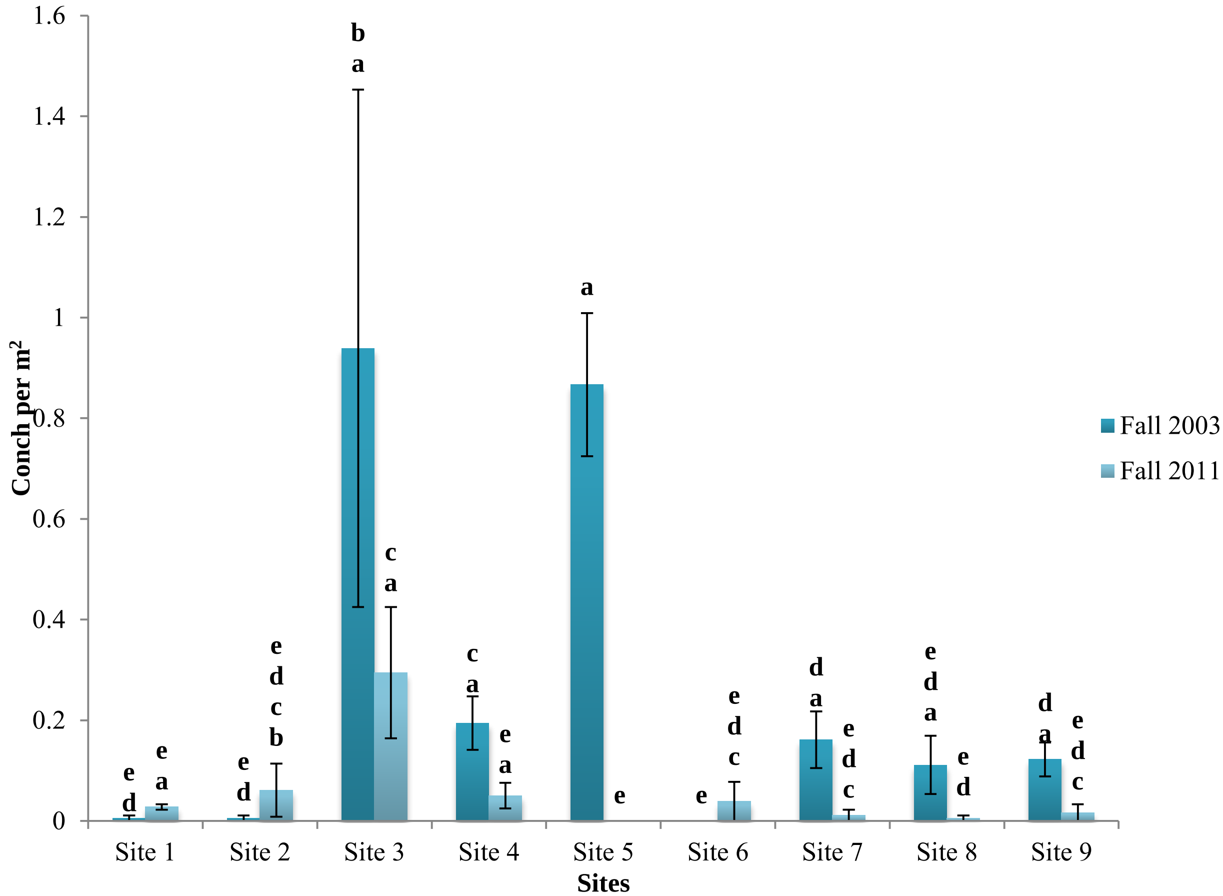

Figure 2.12. Average number of conch/ m^2 per site over two years (2003 and 2011) in southern Eleuthera. Error bars represent standard error of the mean. Significant differences among treatments are indicated by different letters.

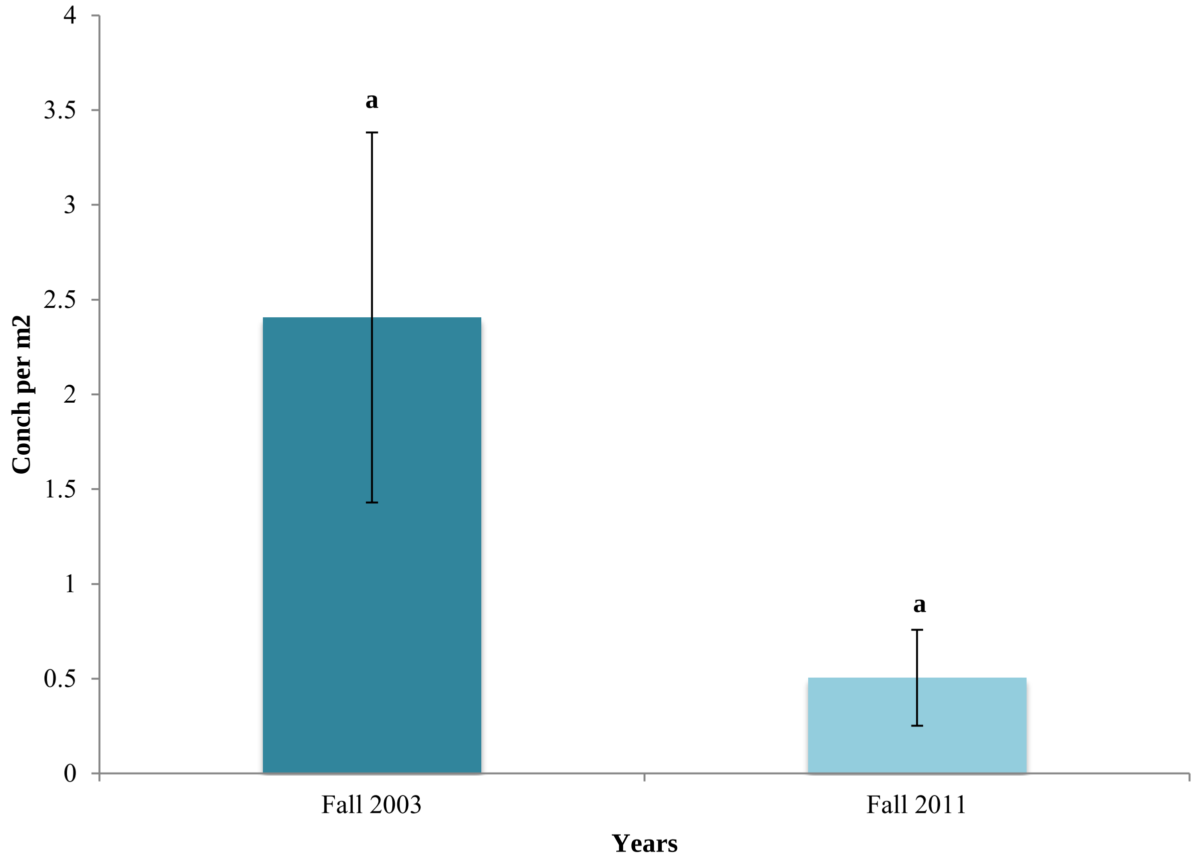

Figure 2.13. Average number of conch/m^2 over two years (2003 and 2011) in southern Eleuthera. Error bars represent standard error of the mean. Significant differences among treatments are indicated by different letters.

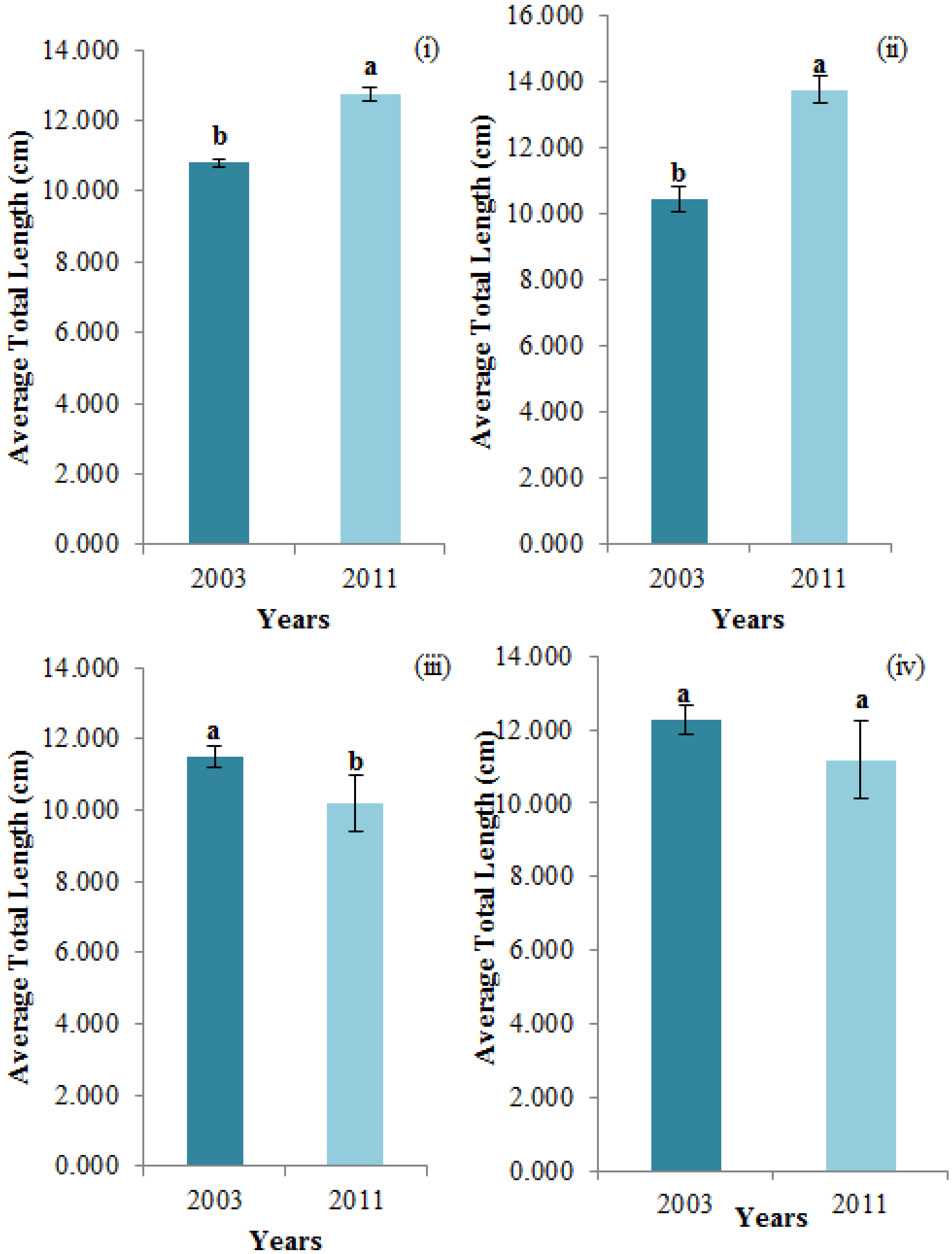

Figure 2.15. Average total length at sites 3 (i), 4 (ii), 7 (iii) and 9 (iv) in southern Eleuthera. Error bars represent standard error of the mean. Significant differences among treatments are indicated by different letters.

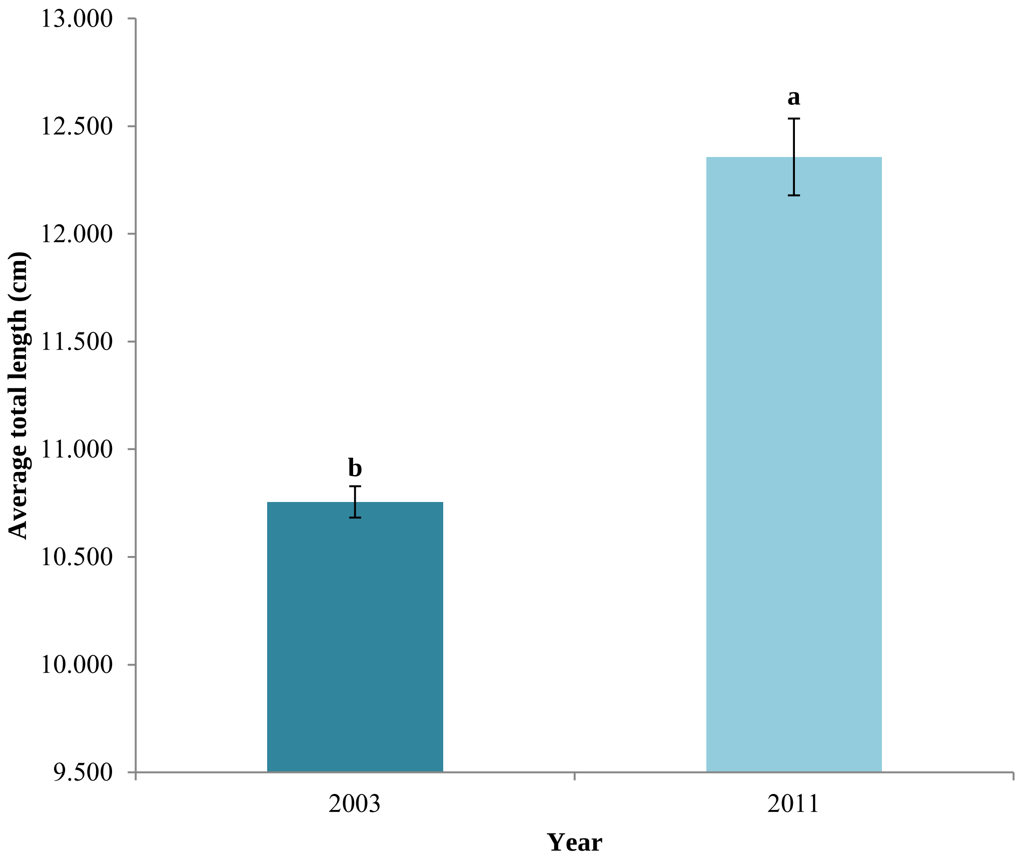

Figure 2.14. Average total length of conch collected over two years (2003 and 2011) for four sites in southern Eleuthera. Error bars represent standard error of the mean. Significant differences among treatments are indicated by different letters.

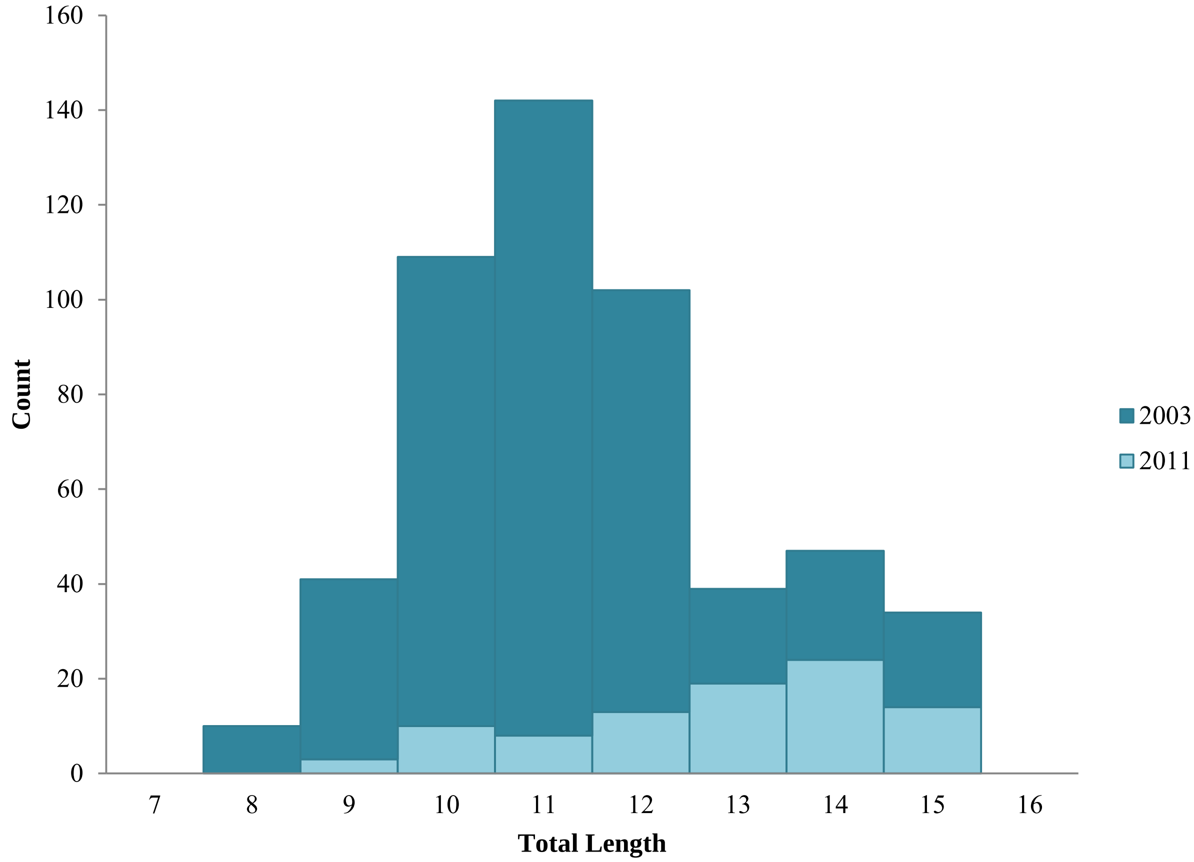

Figure 2.16. Frequency histogram showing the distribution of total length over 2003 and 2011.

Midden Survey

More than 3,000 queen conch shells were counted and measured in total from 12 separate middens in southern Eleuthera. Four of the twelve middens (~1,000 shells surveyed) contained all three shell condition types (fresh, intermediate and old) while others had a combination of two shell types. These four are: the Island School Cut Midden (IS Cut Midden), two middens in Page Creek (Page Creek A and Page Creek B) and the Wemyss Bight Midden. All analysis was performed using SYSTAT 12 (2007) (SYSTAT Software, Inc., San Jose, CA, USA) statistical software. Although the data were not normally distributed, transformations did not alter the conclusions from analysis of the raw data. Therefore ANOVA was conducted on the raw data. Statistical significance was dictated using $\alpha = 0.05$.

Among the four middens found with all three shell condition types, an ANOVA was conducted for the response variables of total length and lip thickness as a function of shell condition, midden and midden by shell condition. There was a significant effect on total length in terms of shell condition ($P=0.01$), midden ($P<0.001$) and midden by shell condition ($P<0.01$). Based on a post-hoc pairwise comparison among the interaction means, total length varied within middens and among middens (Fig. 2.17). Within a midden, the IS Cut Midden was the only midden that showed no significant differences among shell conditions. It must be noted that the fresh shells were significantly smaller than the old shells within the Wemyss Bight Midden ($P<0.001$). Frequency histograms were produced to illustrate distributions of total length within each midden in relation to shell condition. In three of the four cases (with the exception of the Page Creek B midden), the “fresh” shells were skewed toward the shorter total length (Figs. 2.18, 2.19, 2.20, 2.21).

Lip thickness also differed significantly among shell conditions ($P=0.001$), middens ($P<0.001$) and the shell condition by midden interaction ($P<0.001$). For the post-hoc pairwise comparison among the interaction means, within any midden no significant differences were observed among shell conditions in three of the four middens; the Wemyss Bight midden, one of the more active middens, showed significant differences among shell conditions (Fig. 2.22). Within the Wemyss Bight midden, “old” shell had significantly greater lip thickness than that of “fresh” shells ($P<0.001$), with no other significant pairwise difference. Frequency histograms also were produced to illustrate distributions of lip thickness within each midden in relation to shell condition. Most middens had broad overlap though the Wemyss Bight midden showed the strongest contrast between different shell conditions (Fig. 2.26).

The conch from all twelve middens were assessed collectively to test for an overall effect of shell condition, and average total length and average lip thickness significantly differed among shell condition types when analyzed in this manner ($P<0.001$). “Intermediate” shells (Figure 2.27) had a greater total length than both “old” and “fresh” shells ($P\leq0.001$), and “old” shells were, in turn, significantly greater than “fresh” shells ($P\leq0.001$).

Lip thickness (Fig. 2.29) significantly increased with shell condition with the “old” shells having generally thicker lips than both other categories ($P\leq0.0001$), and “intermediate” shells having thicker lips than “fresh” shells ($P=0.001$).

Frequency histograms also were produced to illustrate distributions of total length and lip thickness for all twelve middens combined. In terms of total length, the “fresh” shells were generally smaller with the “intermediate” shells shifting to the right suggesting larger shells. The “old” shells were relatively evenly distributed (Fig. 2.28). When observing lip thickness of conch from all the middens, the “fresh” shells accumulated on the lower end of the spectrum suggesting less developed lips at the time of harvest. The “intermediate” and “old shells” were both bi-modally distributed, with peaks at both ends of the size range though “old” shells appear to be skewed toward thicker lipped shells (Fig 2.30).

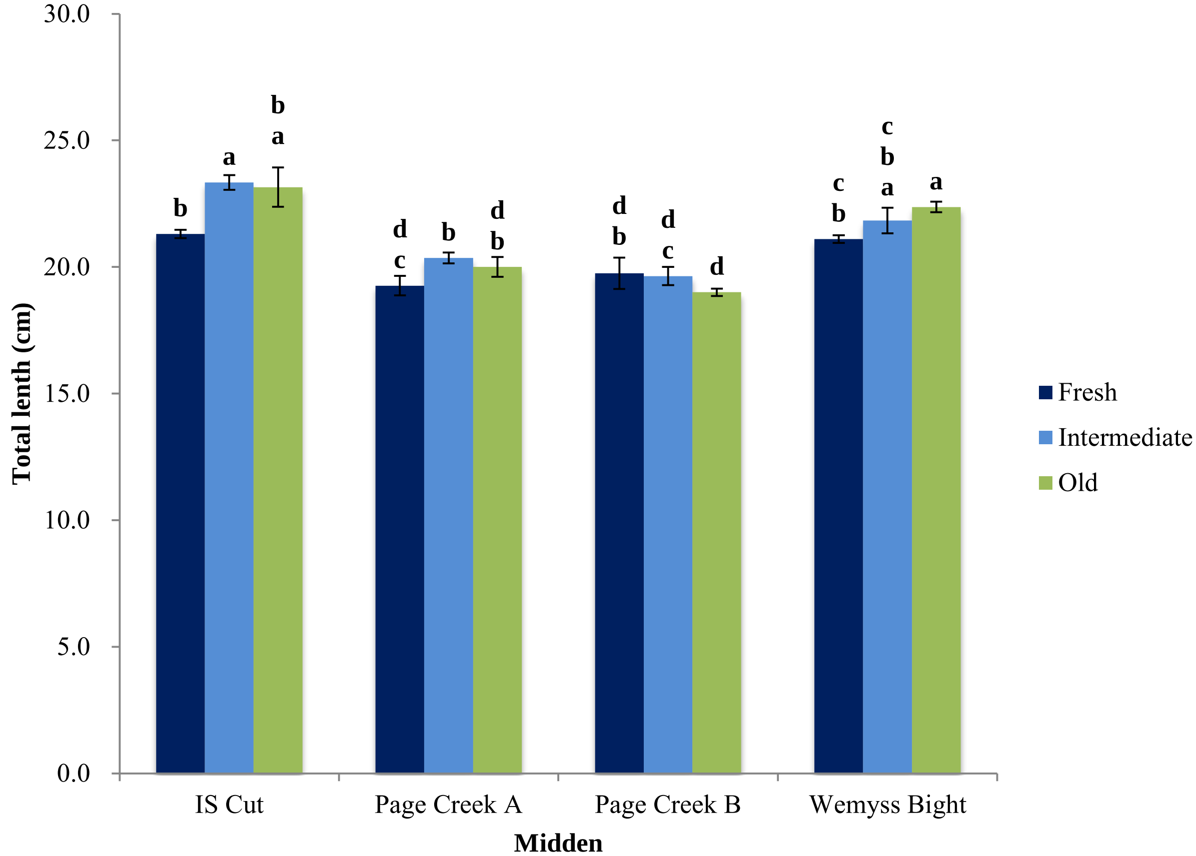

Figure 2.17. Average total length from four middens containing all three shell conditions. Error bars represent standard error of the mean. Significant differences among treatments are indicated by different letters.

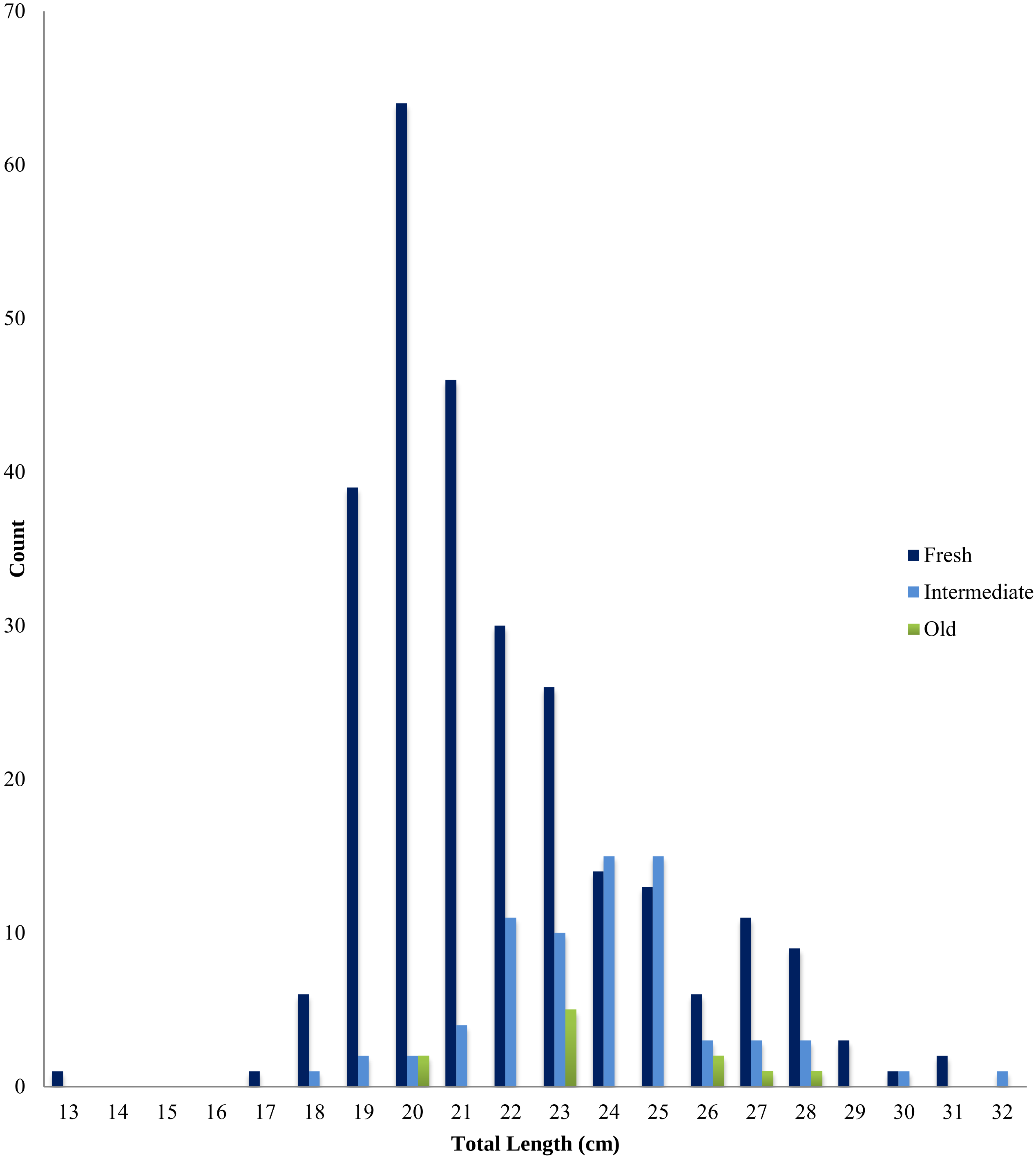

Figure 2.18. Frequency histograms showing distribution of total length of different shell conditions for the IS midden in southern Eleuthera**.**

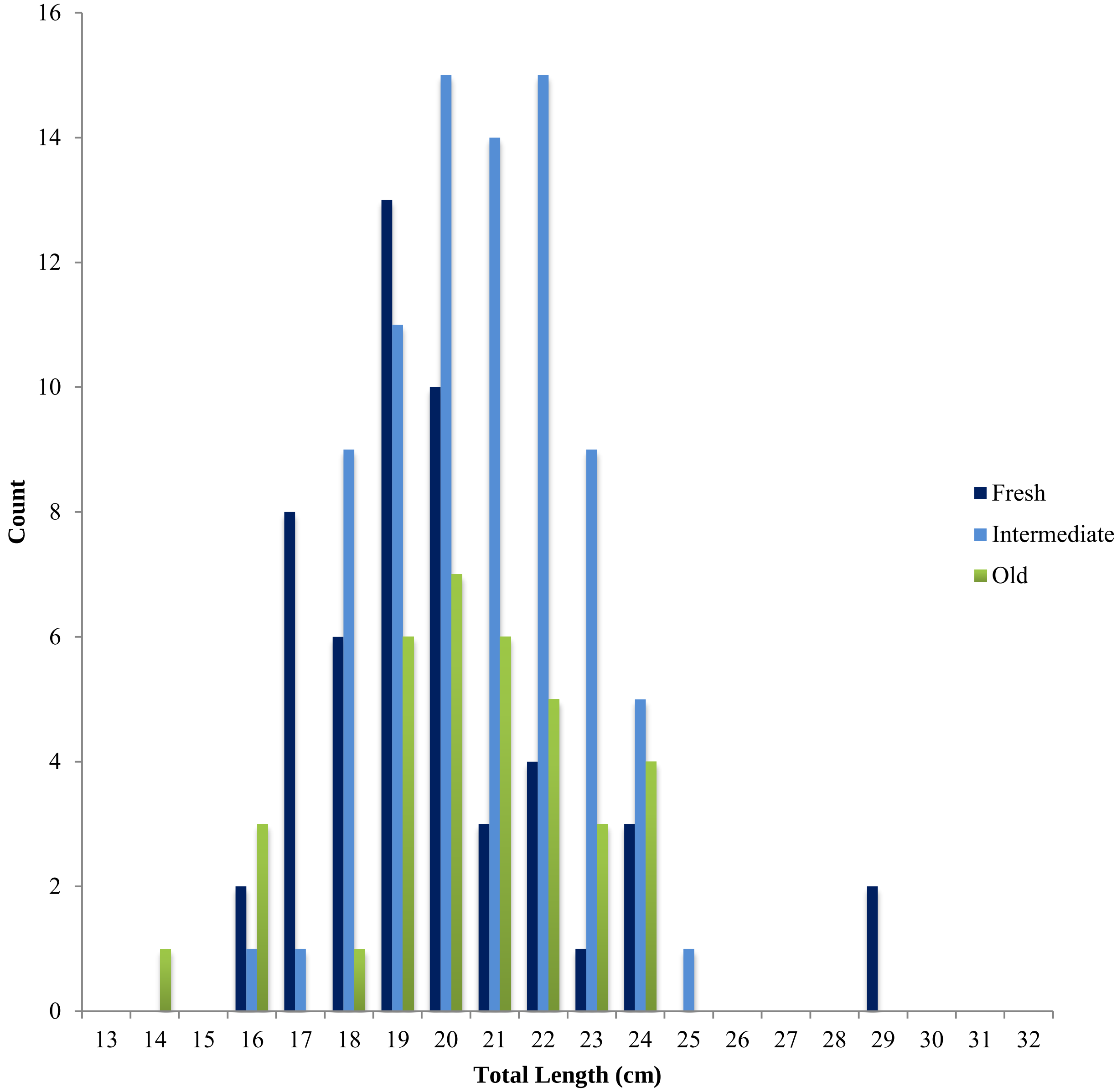

Figure 2.19. Frequency histograms showing distribution of total length of different shell conditions for the Page Creek A midden in southern Eleuthera.

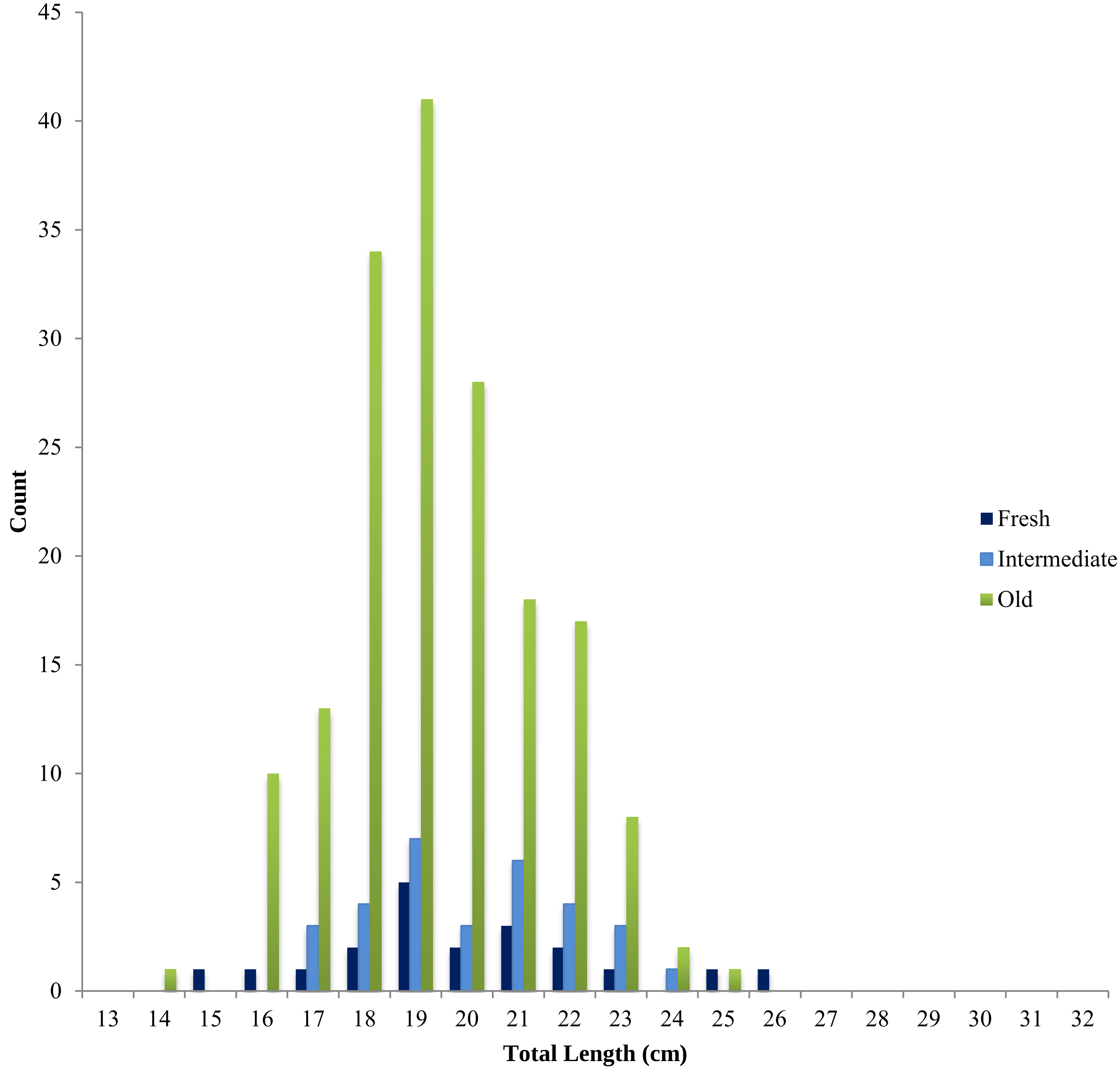

Figure 2.20. Frequency histograms showing distribution of total length of different shell conditions for Page Creek B midden in southern Eleuthera.

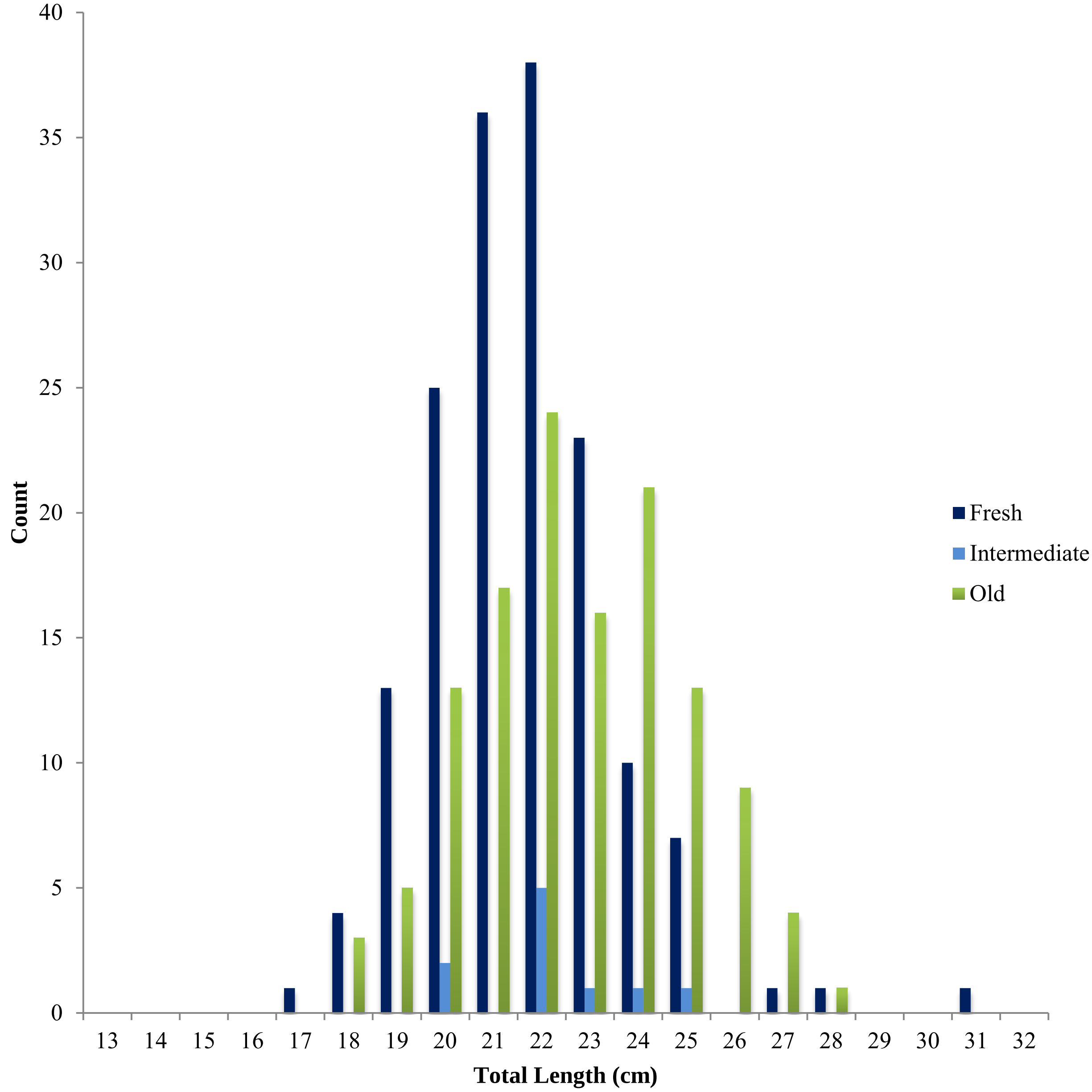

Figure 2.21. Frequency histograms showing distribution of total length of different shell conditions for the Wemyss Bight midden in southern Eleuthera.

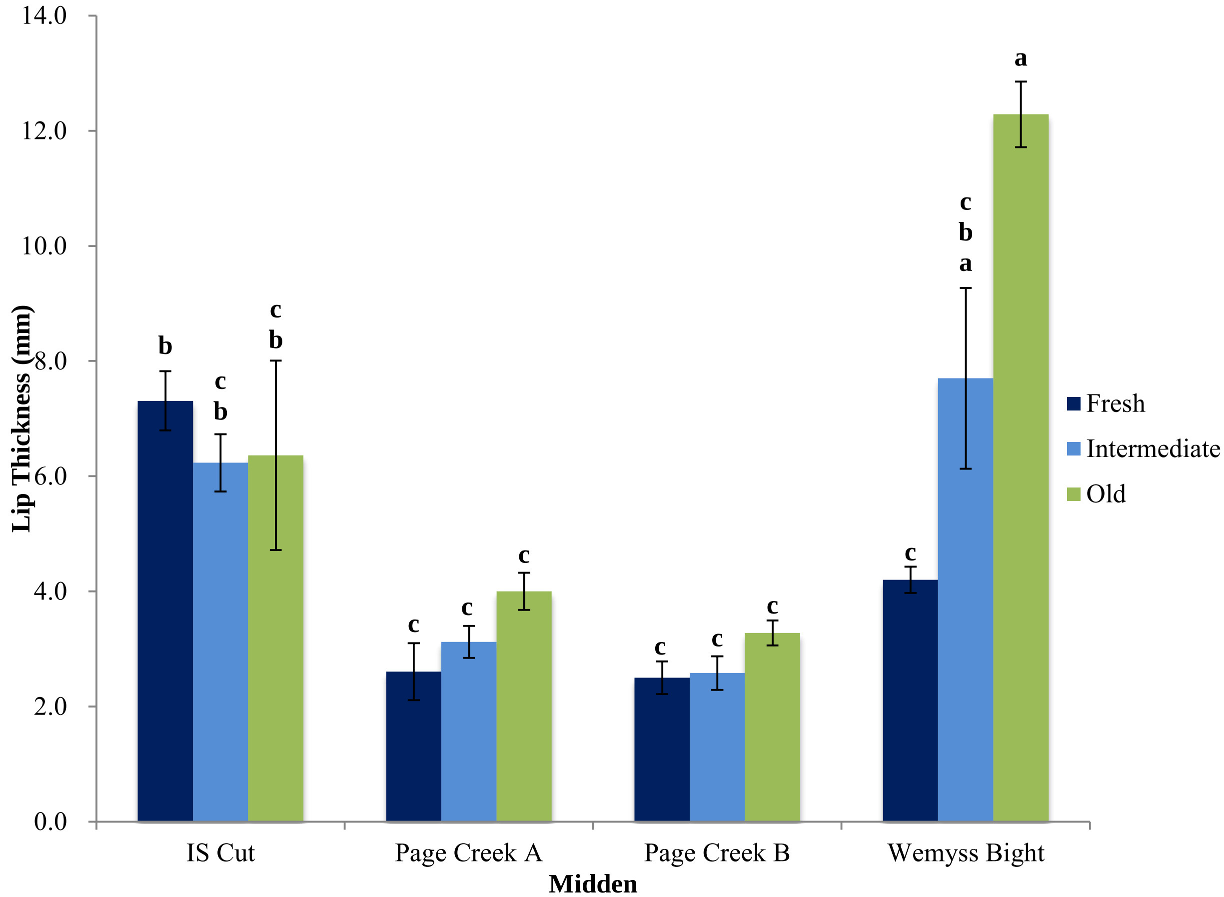

Figure 2.22. Average lip thickness from four middens containing all three shell conditions. Significant differences among treatments are indicated by different letters. Error bars represent standard error of the mean.

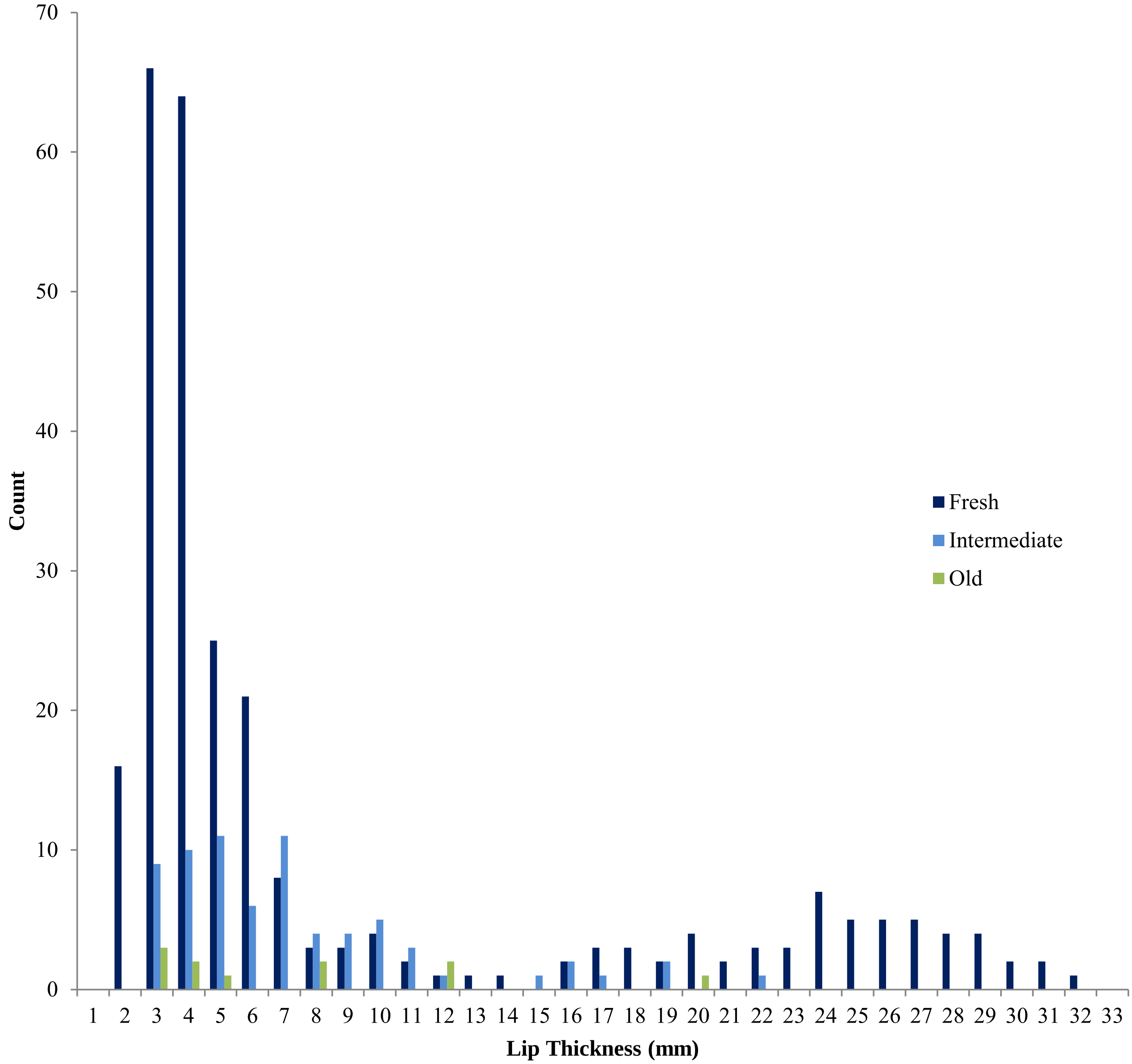

Figure 2.23. Frequency histograms showing distribution of lip thickness for the IS midden in southern Eleuthera

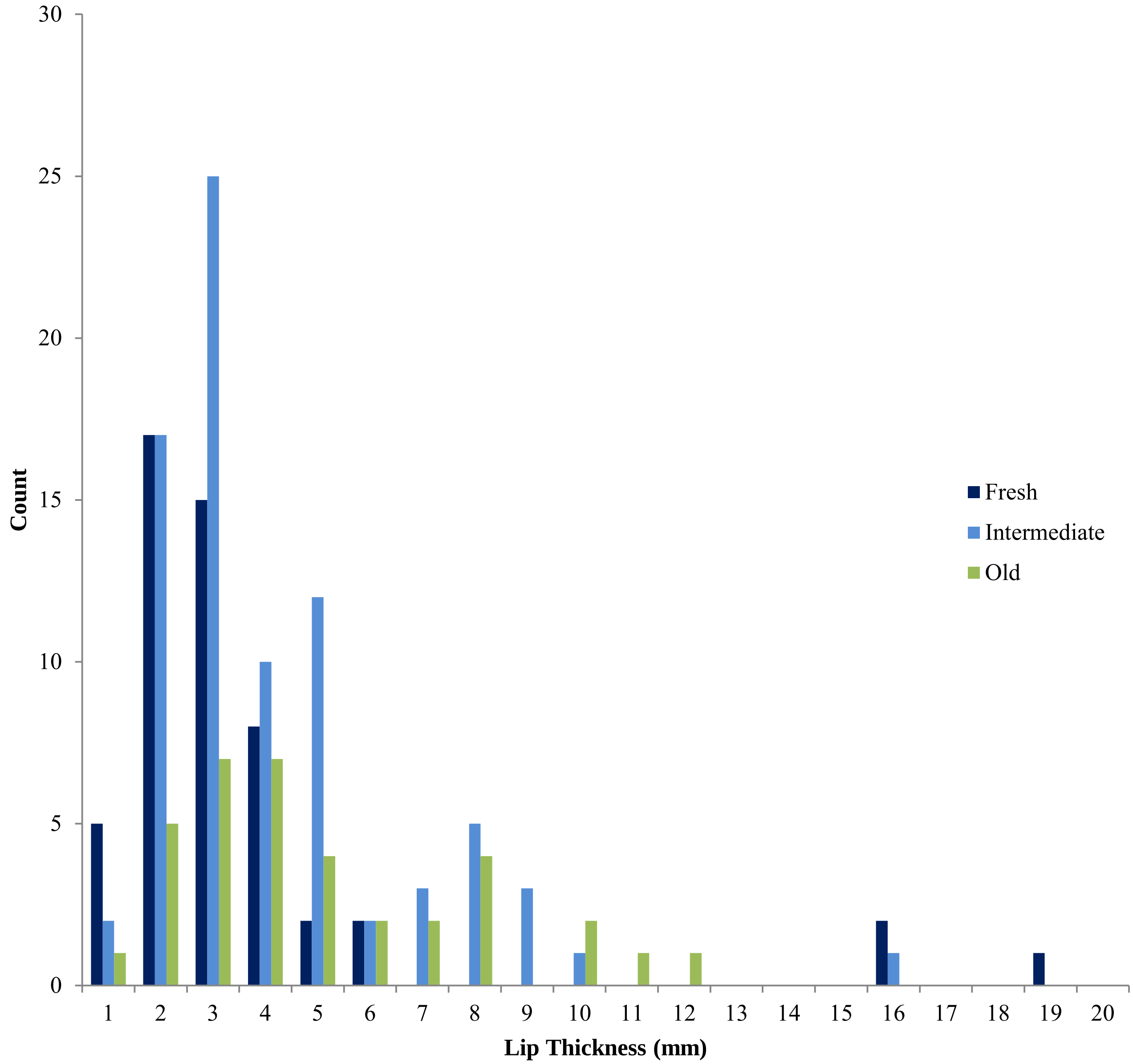

Figure 2.24. Frequency histograms showing distribution of lip thickness for the Page Creek A midden in southern Eleuthera.

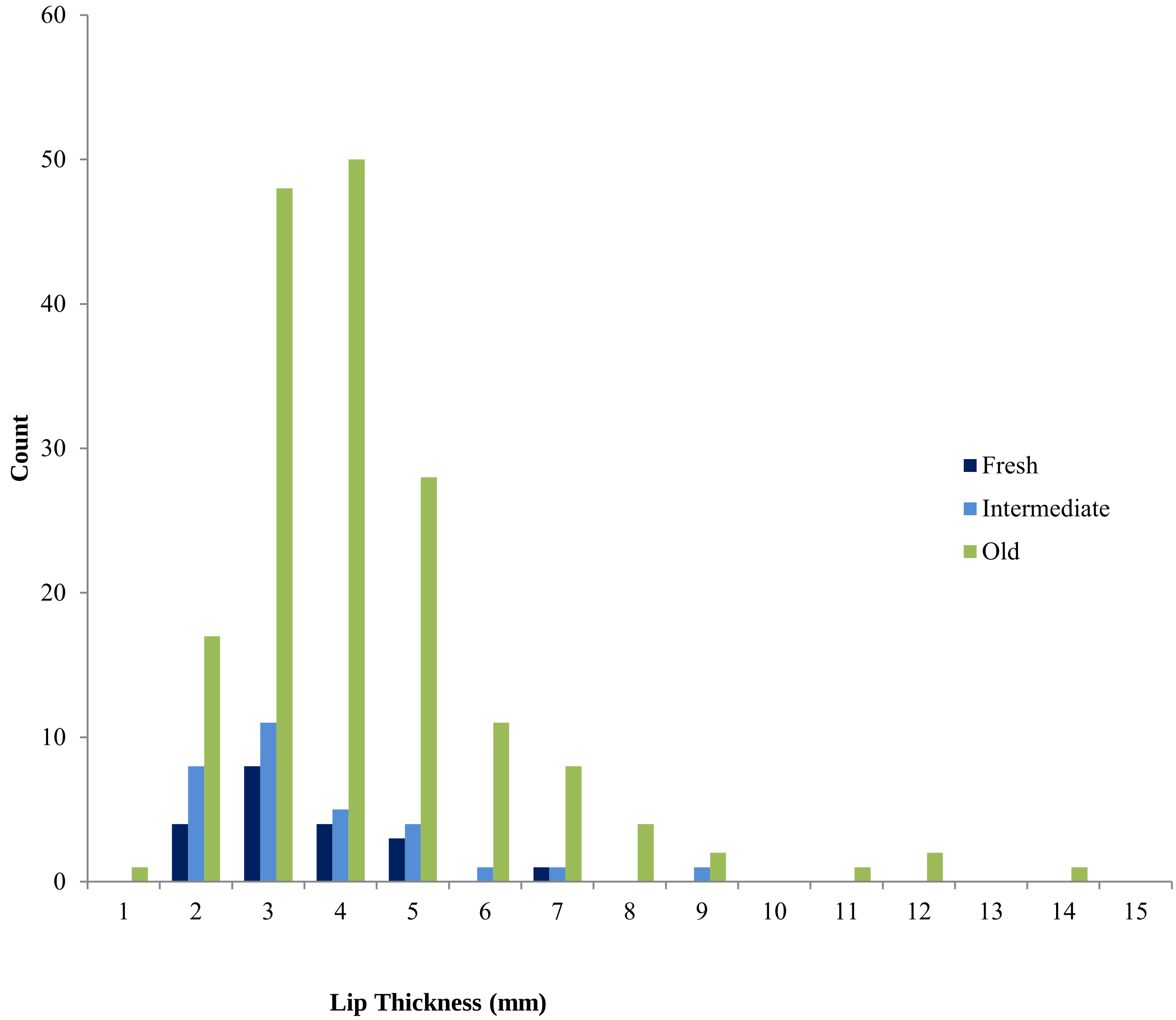

Figure 2.25. Frequency histograms showing distribution of lip thickness for the Page Creek B midden in southern Eleuthera

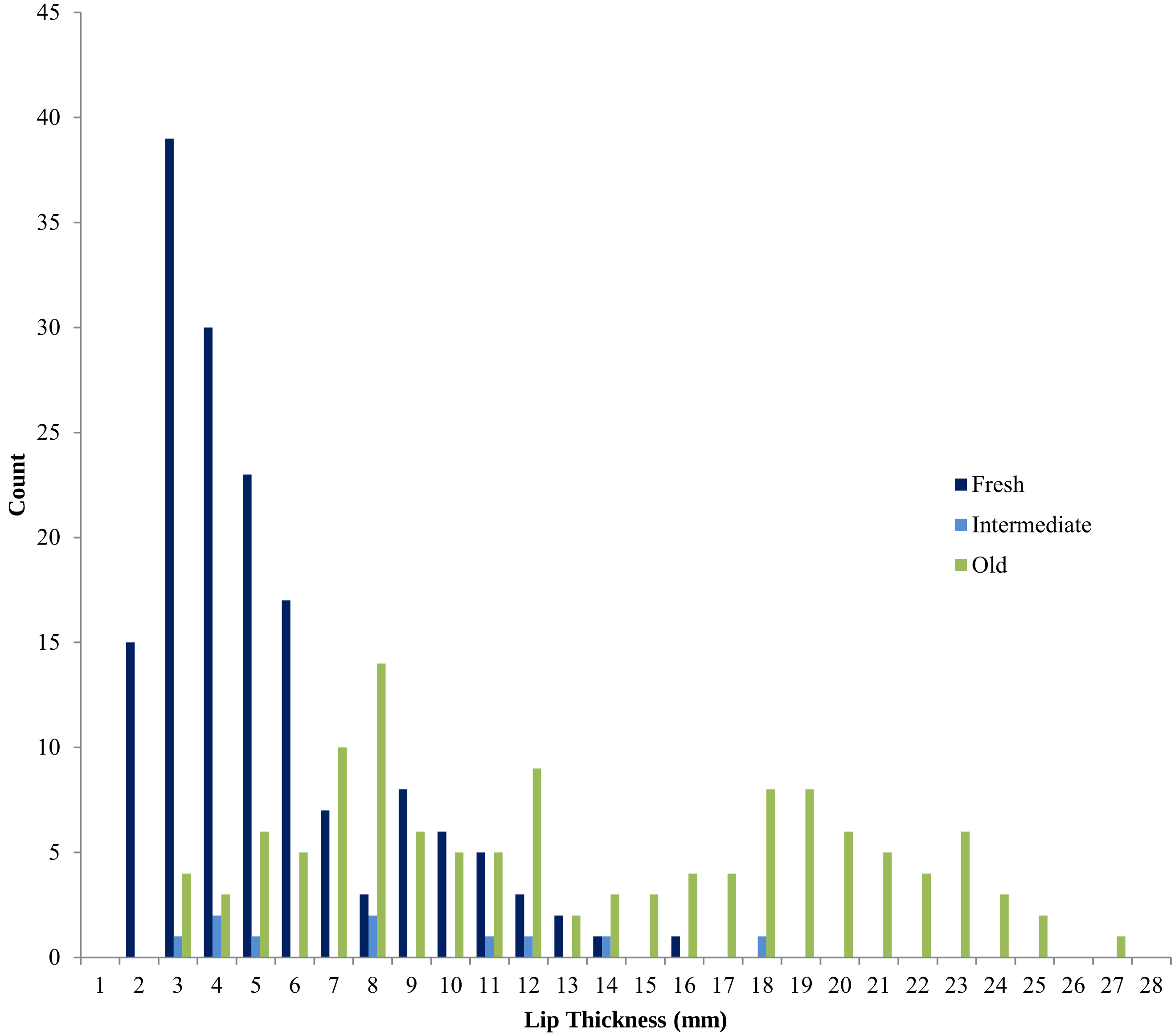

Figure **2.26.** Frequency histograms showing distribution of lip thickness for the Wemyss Bight midden in southern Eleuthera.

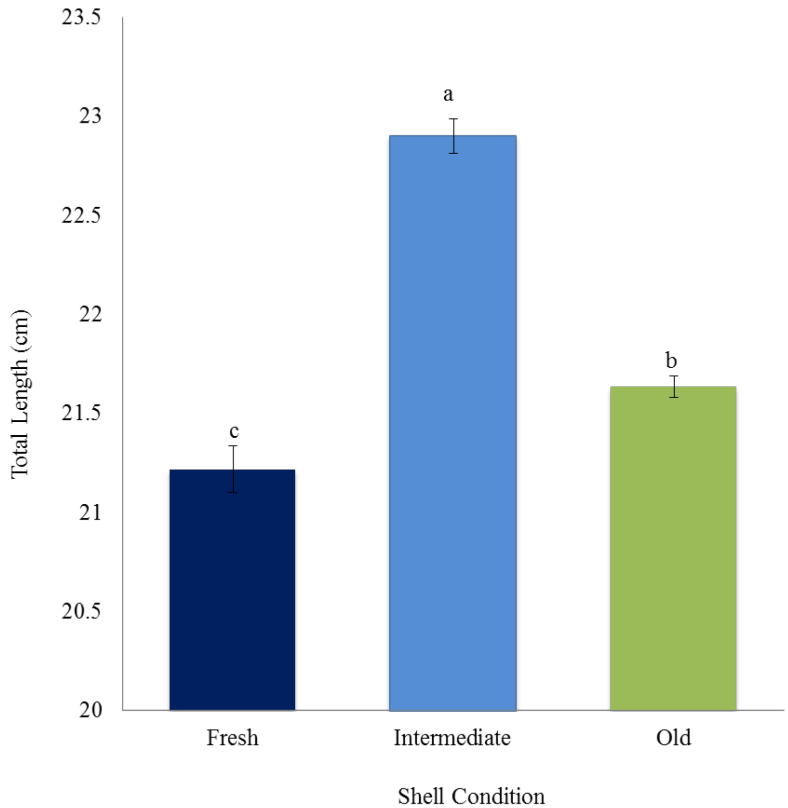

Figure 2.27. Distribution of average length found in 12 middens throughout southern Eleuthera, Bahamas. Significant differences among treatments are indicated by different letters. Error bars represent standard error of the mean.

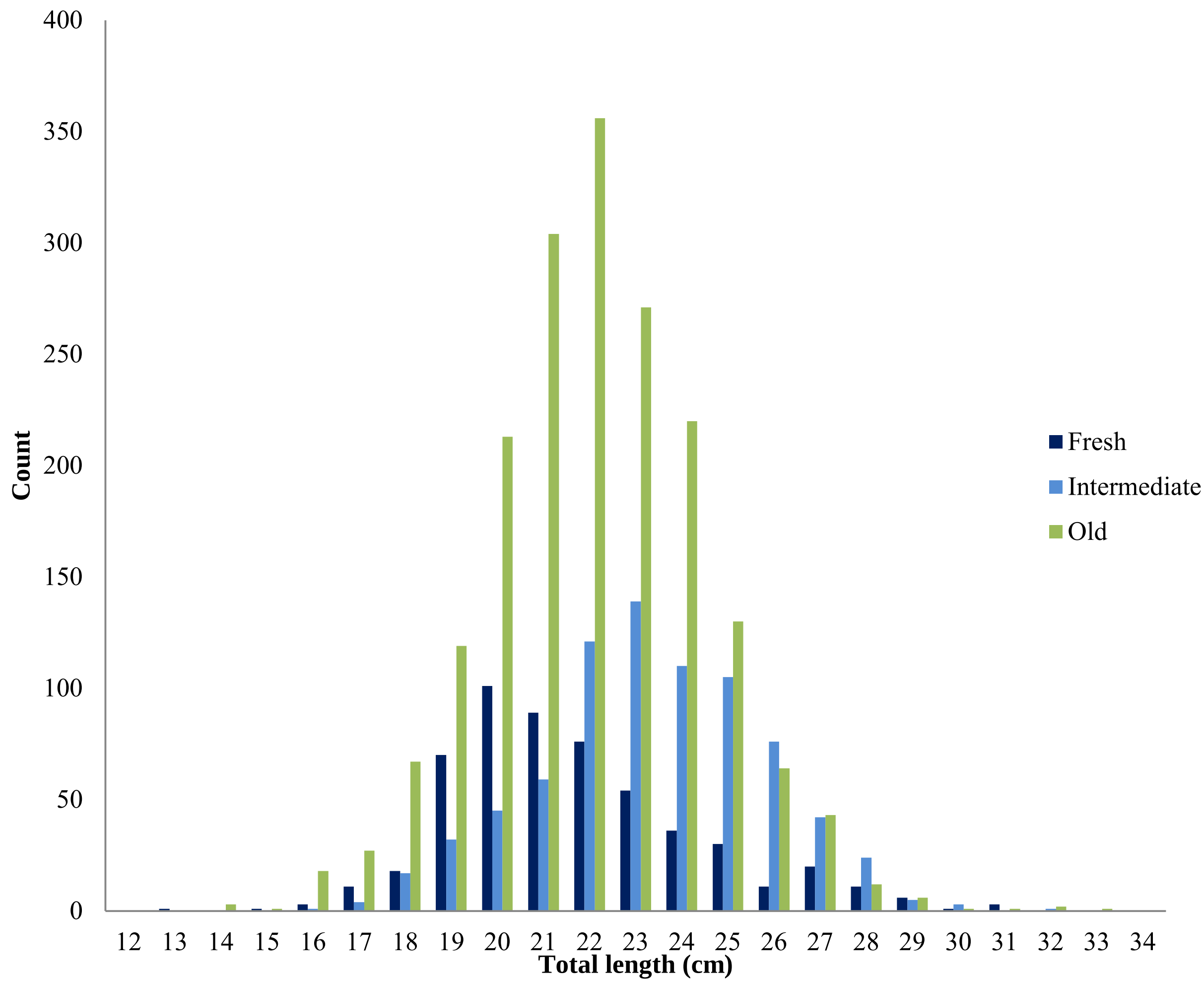

Figure **2.28**. Frequency histograms showing distribution of total length of 12 middens in southern Eleuthera.

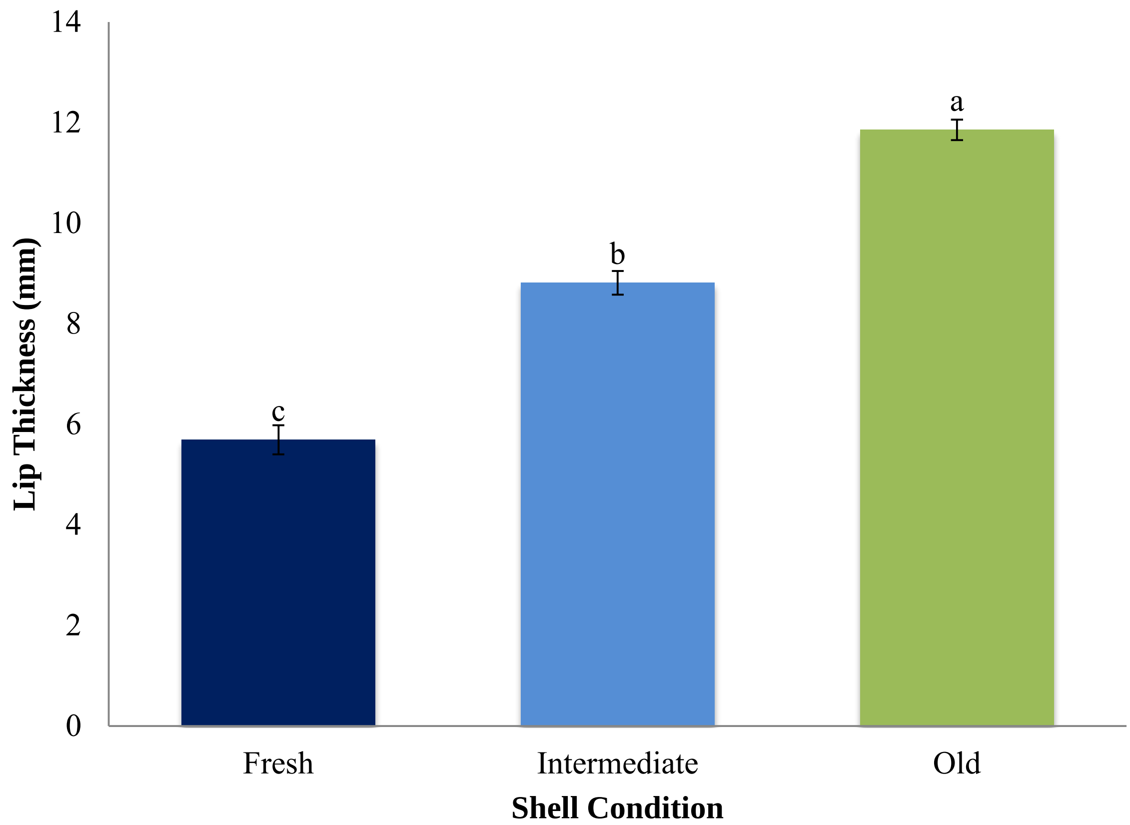

Figure 2.29. Distribution of average lip thickness found in 12 middens throughout southern Eleuthera, Bahamas. Significant differences among treatments are indicated by different letters. Error bars represent standard error of the mean.

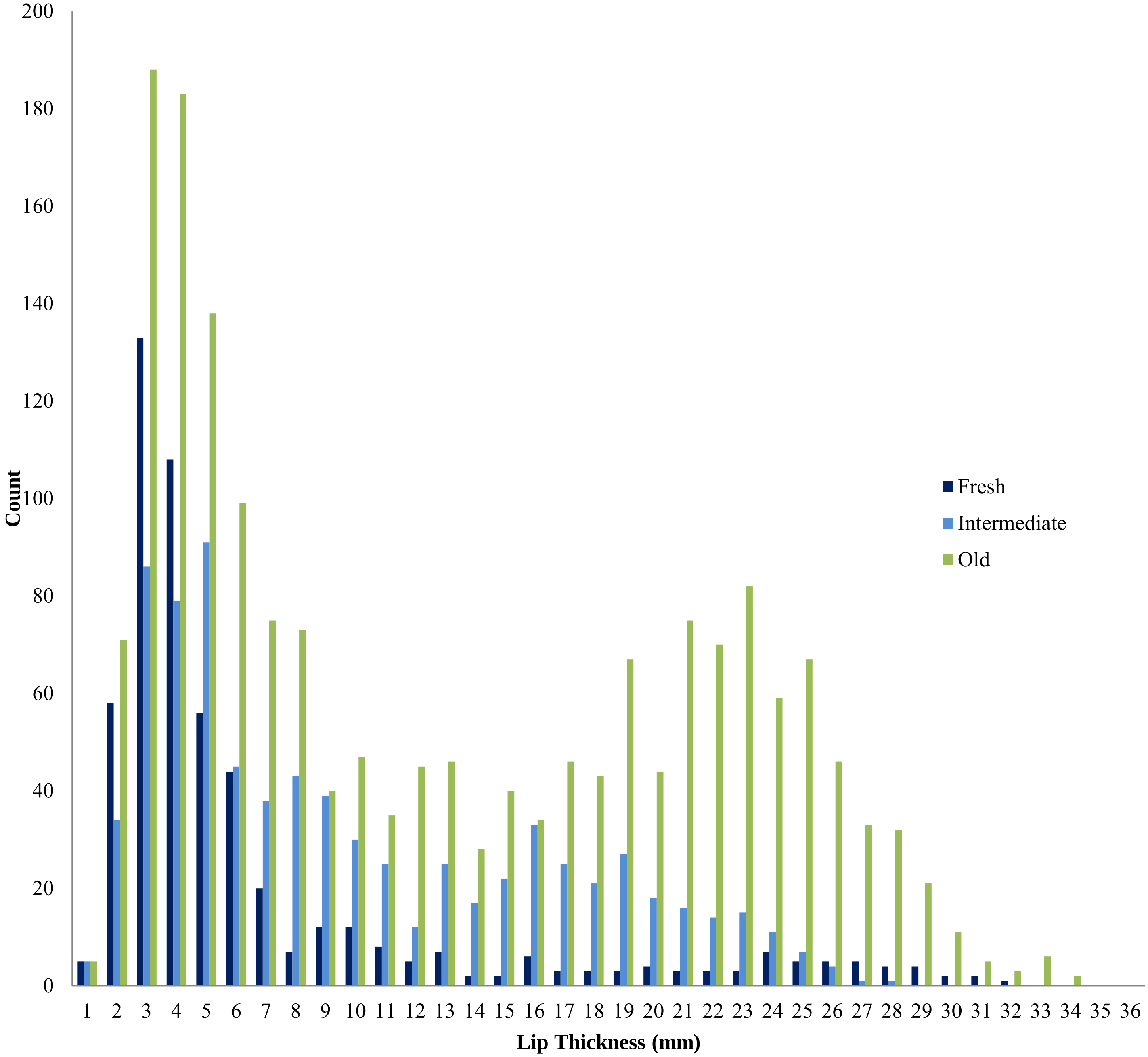

Figure **2.30**. Frequency histograms showing distribution lip thickness of 12 middens in southern Eleuthera.

2.5. Discussion

Conch Abundance and Size Survey

As suggested in the original study, this area appears to continue to support a juvenile conch population. Although a significant decrease was seen between 2003 and 2011 ($P<0.0001$) at one site, the densities did not significantly differ at any other site (Fig. 2.12). Similarly, the densities did not differ significantly between years (Fig. 2.13). In 2003 two of the nine sites observed fell within the 0.2-2.0 conch/m^2 density suggestion for a conch aggregation (Stoner and Ray, 2003. None of the sites in 2011 fell within this range. Notably, though, the one site that did differ (site 5) had been one of the two sites supporting the largest number of individuals in 2003; in 2011, none were found at the site. Furthermore, in 2003 the average density was 4-5x greater than that observed in 2011.

The lack of recruitment to the area, reflecting less of an aggregation than it had previously, may suggest that it is in danger of no longer being a worthwhile nursery ground. As these expanses are not only dictated by their substrates but a multitude of factors including density of incoming larvae that are likely to settle, currents, macroalgae, etc., a shift in either metric may have caused an effect. Impacts on source populations due to harvest, natural morality or simply migration of said population may have affected overall densities. Harvest of juveniles in the area may also be a contributing factor.

For total length of all collected conch, the average total length was greater in 2011 than 2003 ($P<0.001$, Fig. 2.14). The effect of year, however, was more complicated when the effect of site was considered (Fig. 2.15.). At the two more inshore sites, site 3 and site 4, conch were significantly larger in 2011 than in 2003. This changed at site 7 where the conch from 2003 were significantly larger. At site 9 there was no difference in total length. While this is a small sample size it may reflect changes in harvest and recruitment in the area. Furthermore, there appeared to be a sharp decrease in the number of smaller individuals in 2011 compared to 2003 (Fig. 2.4.8).These data suggest that the area is still suitable as juvenile habitat, though there was significant spatial variation.

Within the 2011 data, there was a significant effect of the site by month interaction on conch density ($P<0.03$), illustrating the importance of assessing multiple sites over an extended period.

Across 2011, total length over the five month period (Fig. 2.10) differed significantly by month ($P=0.0073$), where November had significantly smaller conch than July and September was intermediate. This suggests a possible loss of larger individuals over time to either migration (to other shallow areas or deeper water), predation or harvest. Although smaller conch tend to bury in cooler temperatures these were still more prevalent than their larger counterparts. Alternatively or in combination with these possibilities, smaller individuals may have recruited to the area, decreasing the average total length, though relatively high densities were only observed at one site (site 3) in the November sampling (Fig. 2.9).

Lip thickness was also affected by month ($P<0.01$) where July was significantly less than either other month (Fig. 2.11, $P\leq0.003$). Though November had the lowest total length, it had the greatest lip thickness (though this was still less than 1 mm). This increase in lip thickness may be attributed to growth as the juveniles develop and/or the inability to collect the very young conch which bury in the “winter” months, skewing the results upward. This study did not address movement of individual conch from one site to another; it is recommended that future studies involve a tagging aspect to evaluate this aspect.

Midden Survey

When discussing the results of the midden survey, the lack of access to all discarded shells must be taken into account. Many fishermen discard the shells overboard while harvesting conch and shells might be 'harvested' from middens; therefore, middens cannot be viewed as unbiased records of fishing effort, but have been recognized as reflecting fishing effort at least in part (Schapira et al., 2009). It was observed (pers. obs.) that those fishermen that disposed their shells at middens appeared to be dedicated to that midden. The Island School midden was particularly active; however, the presence of the school may have affected the haphazard nature of the size of shells placed in the midden. That being said, the four middens that contained the three shell condition types (of the twelve that were surveyed) were all recently visited and the "fresh" shells seemed to accurately reflect the current take in general. As total length is less of an indicator of age at harvest than is lip thickness (Appeldoorn, 1988), it is not surprising that average total length varied greatly not only within middens but among them (Fig. 2.17). The distributions of total lengths for each of these middens (Fig. 2.18) also does not reveal any clear patterns. For lip thickness, there was no significant difference among shell conditions within three of four middens, but there was within Wemyss Bight midden, the most active in the area (Fig. 2.22). At the Wemyss Bight midden, the "fresh" shells had significantly thinner lips on average than their "old" counterparts (with "intermediate" shells not differing from either). This pattern is also clear in the distribution of lip thicknesses, where none of the "fresh" shells at Wemyss Bight were above 15 mm (Fig. 2.26). As this midden is furthest away from any other activities, it may reflect harvest better than the other middens.

When all the collected conch shells from the twelve middens were analyzed collectively, total was greatest among "intermediate" shells, followed by "old" shells and finally "fresh" shells (Figs. 2.27). This unexpected result is not readily explained. In addition to conch harvest, the area has experienced development and dredging, with little data on habitat modification over time. A possible theory to explain the increase in shell length is the decrease in overall population in the area. Less competition may have allowed conch to reach a larger size before being harvested due to the increase in resources.

In terms of lip thickness, when the conch shells from the middens were analyzed collectively, there was a clear effect of shell condition on lip thickness; the "older" the shells the larger the mean lip thickness (Fig. 2.29). This result is consistent with overfishing and an increase in juvenile harvesting (Stoner, 1997; Schapira, 2009). This suggests that older conch were harvested in the past while younger conch, some of which have failed to contribute to the population, have been harvested in more recent times. It has been suggested that historical harvest of larger conch allowed the smaller phenotype to reproduce providing smaller individuals for market. These smaller or "samba" conchs have been found throughout the archipelago particularly in areas where harvest occurs (Berg et al., 1986; Mitton et al., 1989; Stoner et al., 2012).

Qualitatively, "fresh" conch shells were primarily juvenile conch. When distinctively older middens were evaluated, few to no juveniles were found. Though the argument could be made that juveniles were simply not as prevalent in earlier times, local fishermen indicated that they have always known the area to have juvenile conch (Symonette, pers.comm. June 2011). A midden in the area was previously studied where 62.5% of the total shells collected were juveniles (Clark et al., 2005).

A competing theory for the prevalence of juvenile conch is manipulation of the middens. Persons collecting larger shells for commerce or personal use may have biased the results towards smaller conch. While this was not observed, this possibility as well as a lack of true dating (carbon, historical records, etc.) were limitations of this study. The inability to reach the base of some middens, due to threat of collapse, was also a limiting factor.

Implications

Market demand in Nassau is predominately toward adult conch. The harvest of juvenile conch when their larger counterparts are demanded is said to reflect an unhealthy population as people now take only what they can find. This appears to be the case in South Eleuthera. Humans are expected to forage in such a way that the maximum quantity is collected per unit effort (MacArthur and Pianka 1966) though this has been debated (REFS). As southern Eleuthera is an area where harvest is primarily subsistence the argument can be made that the ease of harvesting juvenile conch coincides with the prevalence of juvenile shells in the local middens. However, the presence of larger and thicker lipped older shells in the same middens suggests that adult conch were once harvested in greater numbers which have since declined. An alternative to this is that the cost of fishing for legal adult conch may have increased. Most adult conch live in deeper water and boat and fuel costs in an area of economic depression may out way the costs associated with wading in shallower water and collecting juveniles from nursery grounds.

The prevalence of juvenile conch throughout the year in an area that is very accessible to the local community inspired a petition for a marine protected area (MPA). This MPA has yet to be established though surveys continue not only for the conch but other species in the range. Clark et al. (2005) suggests that protection of the conch in this area could lead to an increase in populations in the surrounding area as well as in the reserve. This possible spillover effect could provide benefits to the fishery. However with a limited adult population in the proposed area and proper understanding of the source population being unknown, likelihood of this MPA being beneficial is still in question. Further information is needed to establish such an area, especially when socioeconomic factors affecting the fishery are important (Appeldoorn, 1994).

A previous study of middens (Schapira et al., 2009) in Los Roques Archipelago National Park in Venezuela used a similar survey method though carbon dating was used to age shells within each midden. Similar to this study, older middens were comprised of larger shells and a general increase of immature shells were found as time progressed. This was also associated with a decrease in mature individuals found in modern middens. This decrease was interpreted as a depletion of the conch resource and a sign of overfishing.

As conch are density dependent spawners (>56 adults/ha are required for successful reproduction) removal of adults at an unsustainable rate may result in population depletion over time as recruitment becomes limited (Stoner and Ray-Culp, 2000; Stoner et al., 2012). Based on the results of this study, it appears that there is a trend at the study site for increased harvest of juveniles and corresponding trends of declines in conch abundance and lip thickness.

Chapter 3: Permitting Requirements

4.1 Abstract

Aquaculture in the Caribbean has been slowly developing for decades and interest in queen conch rearing followed the demand boom in the 1970s. This increase attributed to the conch becoming commercially extinct in some areas and warranted protection in others. While most of its culture methods have been deciphered, only one commercial industry has taken hold globally in the Turks and Caicos. Interest has been observed in the Bahamas though currently no hatcheries or grow out facilities exist. This section describes the permitting necessary for such a venture and some of the challenges an investor may encounter.

4.2 Introduction

Queen conch, *Lobatus gigas*, has been harvested in the western Atlantic since the time of first human settlement (Adams, 1970; Stoner, 1997). Since then, it has become a cultural cornerstone as well as an internationally recognized product. With this increase in demand, particularly high in the 1970s, population decline throughout its range have been observed (Berg, 1976; Brownell et al., 1977; Hesse and Hesse, 1977; Glazer and Delgado, 2003).

Queen conch can no longer be exported by certain countries including Haiti, the Dominican Republic and Honduras with complete harvest bans implemented in the United States. Due to severe overfishing throughout its range the conch was added to Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This distinction labels conch as an organism in peril of becoming endangered without proper regulation (Theile, 2005; Garr et al., 2011).

Through this previous research, many of the aquaculture methods have been established though husbandry and nutritional requirements are still developing (Garr et al., 2011). There has been one commercial farm to produce and export queen conch located in the Turks and Caicos, Caicos Conch Farm, but it has suspended production due to management issues.

Culture of queen conch throughout its range has been suggested and guidelines have been set in the Bahamas toward this endeavor though no aquaculture currently exists. The demand for conch locally and abroad combined with the progressively limiting wild stock creates a niche that aquaculture may be able to fill. Not only can aquaculture of this lower trophic level species alleviate pressure on naturally occurring populations but a new industry can be introduced to a country primarily focused on tourism and banking. In this chapter, the permitting requirements associated with such industry will be discussed consecutively.

4.3 Business Plan

Any individual or group interested in an aquaculture venture in the Bahamas must first provide a business plan outlining their vision for the prospective venture. This plan must be submitted along with the permit application. The business plan may include background information on the product in question, market analysis, site selection and benefits to the economy.

4.3.1 Bahamas Investment Authority (BIA)

Designated the "one stop shop" for investors, the BIA acts as a service assisting with investment policy formulation, proposal reviews and post approval monitoring and support for both Bahamian and foreign investors. These investors must apply through the BIA before using any foreign capital, government owned land or sale of property to or from foreign interests. Companies based with foreign investors, Foreign Direct Investment (FDI), require a minimum of $500,000 in start-up capital as required and approved by the National Economic Council. Outward direct investment, those made by Bahamian residents or individuals, must be approved by the Central Bank of The Bahamas.

4.3.2 Environmental Impact Assessment (EIA)

A detailed Environmental Impact Assessment based on the proposal must also be produced. Guidelines for these assessments are provided by the Bahamas Environment Science and Technology Commission (BEST Commission). Pardee and Davis (2006) suggested that aquaculture is best categorized by areas of potential impact. These include species, disease, site selection, nutritional requirements and the rearing system.

These assessments indicate the objectives of the venture, potential impacts on the environment, ways to mitigate these impacts and project benefits. Using the Caicos Conch Farm as an example for the assessment necessary preliminary information, subject to change based on site, was gathered. This information included benthic surveys, sand cores, seagrass density surveys, water quality analysis, and current/water velocity metrics. These factors are not only necessary in site determination for the facility but evaluating possible obstacles and their resolutions prior to production.

4.4 Permit Submission

An application for a permit to culture fishery resource (Form 1) must be submitted to the Department of Marine Resources detailing the applicant, method of culture, purpose and location of culture. This must be submitted with the business plan or proposal, passport(s) of the applicant(s) the EIA and approval from the National Economic Council if foreign investors are involved. Proof of access to the location of the aquaculture venture must also be provided. For commercial projects a fee of $500.00 is required for the permit.

4.5 Local Town Council

After the project has been approved by the investment agencies and the permit has been applied for, local town meetings are to be held where community members in the area can be informed of the new industry. This is also an opportunity for locals to ask questions and voice any concerns generated by the industry.

4.6 Conclusion

The Bahamian government is accepting of new ventures though proof of commitment seems to be a common theme. Support of queen conch aquaculture seems to be relatively widespread with some critics citing competition with fishermen. If a conch farm were executed as a hatchery, a new sector could be created. Fishermen could supplement their off-shore harvest with farm raised conch possibly saving them money over time in comparison to the costs associated with boat use and safety issues. If a farm is run as a grow-out facility it may provide product for an export market that is currently capped by the government. As the conch are raised in captivity, laws on harvest may be adjusted permitting for younger conch to be exported allowing for a quicker return for the farm. This product, primarily marketed toward foreign clients could fetch up to $20.00 per pound (Davis, 2005) and can be currently found in markets in the United States at approximately $9.99 per pound (Pers. Comm.). Juveniles for aquaria as well as the smaller more easily exported shells may also provide income.

However, these achievements will not be met without challenges. The export of juvenile conch is currently illegal in the Bahamas and the authorization of a farm raised export product may fuel black market demand. Proper permitting and regulation must be created and enforced throughout the Commonwealth. Backlash in fishing areas may also cause a few setbacks as local support is important not only in the accrual of a workforce but the security of the farm. Theft could be a major issue depending on the location of the facility and as with most facilities in relatively rural areas having the local community involved is vital to success. Aside from human interference, the Bahamas is situated within range of tropical storms and hurricanes annually. Proper construction must be taken into account given the locale of the facility, though this does increase costs. Through personal communication it was found that little damage has been observed during storms in the offshore cages (grow-out) as the storm usually surges over these cages and the conch bury themselves. Damage to other parts of the facility depends on construction and severity of the storm.

Currently, the Bahamian government is instituting marine protected areas throughout the 100,000 square miles of water surrounding the islands. This initiative acknowledges the necessity associated with conservation though some of these areas are being designated with little scientific support. The government's determination to develop industries outside of tourism and banking is also evident as talk of tilapia farming and hydroponics has been discussed in public forums. Finding support for a venture such as conch aquaculture may not be as harrowing as it once was though initial returns are low which may drive off some investors. This could be subsidized in theory with culture another species or another agricultural venture. Land and capital are paramount in introducing this type of business and the competent stakeholder may be able to provide not only for him or herself but for a community. Therefore the future of farm raised conch is dependent on local support, land, funding and market; if all these can unite there is little more to do than break ground.

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Appendices

Cape Eleuthera Institute

The Cape Eleuthera Institute, or CEI, (Fig. 1.31) is a research facility on the southern end of Eleuthera in the Bahamas. This organization is partnered with The Island School, an environmentally minded boarding school for high school students. It has the fortune of being placed within complex ranges of multifaceted ecosystems with the Exuma Sound, a deep water drop off, to the south, patch reefs to the west and mangrove swamps surrounding the area. At CEI a multitude of projects were underway dedicated to the understanding and preservation of the marine environment and acted as the center of operations for this study. Equipment, boats and assistance were provided by CEI and parts of the project were a part of The Island School students' curriculum. These students were trained in the scientific method and proper data collection techniques.

Figure 1.31. Cape Eleuthera Institute and The Island School, Eleuthera, Bahamas.