The Morphology of the Queen Conch (*Strombus gigas*) from the Island of Barbuda – Implications for Fisheries Management

La Morfología del Caracol Rosa (*Strombus gigas*) de la isla de Barbuda – Implicaciones para La Gestión de La Pesca

La Morphologie du Lambi (*Strombus gigas*) de l'île de Barbuda – Implications pour La Gestion des Pêches

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ABSTRACT

A morphometric study was conducted on queen conch (*Strombus gigas*) taken from the Barbuda portion of the Antigua and Barbuda Shelf. The objectives were to: 1) ascertain if there were habitat preference based on maturation stages (juvenile, sub adult, adult and old adult); 2) determine if there were spatial variability in regards to morphology; 3) examine length-weight relationships for various maturation stages; 4) improve national-derived conversion factors for different levels of processed conch meat; and 5) appraise current management regimes (e.g., minimum size / weight). Juveniles tended to prefer sand and seagrass strongly, whilst pooled adults tended to prefer habitats that were a combination of sand and macroalgae, rock or coral rubble ($p < 0.001$). Shell length and shell lip thickness (an indicator of the age of conch) both differed significantly ($p < 0.01$) along the coast of Barbuda. Differences in lip thickness or conch age were attributed to variation in the level of exploitation (i.e., traditional fishing areas versus recent fishing areas), proximity to fishing grounds and type of habitat (seagrass, rock, coral rubble, etc.). In terms of size, sexual dimorphism was detected, with females being significantly larger than males ($p < 0.001$). Conversion factors differed significantly among maturation stages ($p < 0.01$); this was consistent with conversion factors derived from conch collected from the Antigua portion of the Antigua and Barbuda shelf. These results reaffirm an earlier study that a multifaceted management approach (minimum size, limited access, close season, protected areas, etc.) was required to ensure that the conch fishery was sustainable, given the variation in morphology.

KEY WORDS: queen conch, Barbuda, fisheries management, conversion factor, morphology

INTRODUCTION

The queen conch (*Strombus gigas*) fishery of the twin-island nation of Antigua and Barbuda is based primarily on the island of Antigua, with some 72 fishers residing in the southern villages of Urlings and Old Road. The fleet in Antigua is comprised of 11 full-time conch vessels and an additional 8 part-time vessels that alternate between diving for conch and lobster. Barbuda, in contrast, has only one full-time and 10 part-time to occasional conch vessels. In Barbuda, conch is generally harvested upon request from local restaurants, seasonal hotels or its estimated resident population of 1,800. Vessels range from small fibreglass pirogues to large launches, equipped with global positioning systems and hydraulic haulers. Commercially conch is harvested using SCUBA due in part to the mean depth of the Antigua and Barbuda Shelf (about 27 metres). The Antigua and Barbuda Shelf is one of the largest in the Eastern Caribbean (3,400 km^2) and is the main area of exploitation for conch and spiny lobster due to its ideal topography for demersal species.

The principal fishery species of commercial interest on the island of Barbuda is the Caribbean spiny lobster (*Panulirus argus*). This is due to its high retail value as a "luxury goods" as well as its strong demand for export to neighbouring French overseas territories in the Eastern Caribbean. In contrast, the queen conch is considered locally as a "normal goods", retailing at the same ex-vessel price as mixed reef fish (US$7.41 / kg); although conch has been listed as an endangered species under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES).

In terms of conservation measures, the Fisheries Regulations, No. 10 of 1990, prohibits: harvest of conch with shell less than180 mm or no flared-lip shell; or conch whose meat weight is less than 225 g without digestive gland. There are provisions for closed season, prohibited gears (e.g., hookah compressor diving rig) and protected areas. The Cades Bay Marine Reserve was established in 1999 (approx. size: 19.43 km^2) primarily to protect conch nursery areas (e.g., seagrass meadows). The Northeast Marine Management Area was established in 2005 to protect similar habitats on the north-eastern coasts of Antigua. Whilst the Fisheries Division is the primary management authority for Antigua and Barbuda, the Barbuda Local Government Act (1976), gives the local governing council of the island of Barbuda, authority to manage its fisheries up to one maritime league (3 nautical miles or 5.56 km) from the shores of Barbuda according to the Barbuda Shooting and Fishing By-Law of 1959. By-laws gazetted by the Council have the full force and effect in Barbuda however they shall only operate in addition to and not in derogation of any other law of Antigua and Barbuda.

The most recent research (Horsford *et al.* [In press]) with respect to conch from the Antigua and Barbuda Shelf was a comprehensive morphometric study, in 2011, which was funded by Fisheries Division and Japan International Cooperation Agency (JICA), in collaboration with conch fishers. Spatial variability in the growth and morphology was observed for both juvenile and adult conch, with shell length differed significantly around the coast of Antigua, $p < 0.001$. Shell lip thickness, an indicator of the age, was also significantly different around the coast of Antigua ($p < 0.001$), where conch from the north (25.1 mm) and west coast (24.5 mm) were significantly older than those from the east (17.1 mm) or south coast (9.2 mm) of Antigua ($p < 0.001$). Conversion factors, essential for standard reporting of capture production in nominal weight and standard trading of conch meat, differed significantly among maturation stages (particularly for adult and old adult) $p < 0.001$; hence the use of a single conversion factor to transform processed meat time-series to nominal weight is problematic (i.e., the issue of a shifting baseline with changing demographics). The study concluded that a "multifaceted" management approach (limited entry, closed season, protected areas, lip thickness, etc.) was required to address morphological variances. This research aims to validate earlier results specifically in reference to the island of Barbuda as well as explore the importance of habitat to conch conservation.

In light of the fore mentioned, the specific objectives of this research were to: 1) ascertain if there were habitat preference based on maturation stages (juvenile, sub adult, adult and old adult); 2) determine if there were spatial variability with regards to morphology; 3) examine length-weight relationships for various maturation stages; 4) improve national-derived conversion factors for different levels of processed conch meat; and 5) appraise current management regimes (e.g., minimum size / weight).

MATERIALS AND METHODS

Conch were sampled from four sites from the Barbuda portion of the Antigua and Barbuda Shelf and grouped according to their geographical location in reference to the island of Barbuda. Traditional fishing grounds as well as relatively new areas were sampled by research personnel and commercial conch divers. The type of trip (i.e., commercial fishing or research), geographical coordinates, mean depth dived, and habitat characteristics were noted. For research trips, personnel were instructed to sample all conch encountered and not to selectively sample "typical" specimen.

Conch were sexed, where possible, and their maturation stage determined according to the following criteria derived from Appeldoorn (1988):

1) Juvenile (J) – conch without a flared shell lip.
2) Sub adult (SA) – conch with flared shell lip starting but not fully developed; lip thickness < 5 mm.
3) Adult – conch with flared lip fully developed and minimal shell erosion; lip thickness ≥ 5 mm.
4) Old adult (OA) – conch with shell characterised by thick lip (> 5 mm), heavy erosion and fouling.

From each sample, the following morphometric data were collected:

1) Shell length – length of the shell from the apex of the spire to the end of the siphonal canal.
2) Lip thickness – thickness of the shell lip measured in the mid-lateral region, roughly 40 mm inward from the edge of the lip.
3) Nominal weight – weight of intact animal, including shell.
4) Tissue weight – weight of intact animal, after removal from shell.
5) Shell weight – nominal weight minus tissue weight.
6) "Dirty" meat weight – weight after removal of shell and digestive gland (visceral mass).
7) "Clean" meat weight – weight after removal of shell, digestive gland (visceral mass), mantle collar, operculum, radula and digestive tract.

All weights were to the nearest 1 g. Lip thickness was measured to the nearest 0.1 mm while shell length was measured to the nearest 1 mm using calipers. Conch meat were extracted from the shell by making a small hole in the fourth whirl of the spire and removing the columnar muscle from the central axis using a knife.

Statistical analyses were conducted using SPSS 15.0 for Windows. Chi-square Test of Independence was used to determine habitat preference based on maturation stages. Simple linear regression was used to investigate the relationships between nominal weight and different levels of processed conch meat. To determine the relationships between shell dimensions and weights, simple linear regression was used on common log transformed data. Separate analyses were made for the various maturation stages, where possible; maturation stages were only grouped to address statistical issues in certain cases (e.g., sub-adults grouped with adults due to small sample size). Conversion factors were estimated per maturation stage by calculating a conversion factor per sample for each processing grade or level. Analysis of variance was used to determine if morphometric means and conversion factors for the maturation stages were significantly different.

RESULTS

The habitat variability and depth profile of sites sampled are summarised in Table 1. Sites ranged in depth from 4.6 - 30.5 m and comprised of various combinations of sand and other materials (macroalgae, rock, seagrass or coral rubble). Based on the maturation stage, conch had a preference for certain types of habitat. Juveniles tended to prefer sand and seagrass strongly (Figure 1), whereas pooled adults tended to prefer habitats that were a combination of sand and macroalgae, rock or coral rubble [X^2 (3, N = 477) = 230.95, $p < 0.001$].

For pooled adult conch (i.e., sub adult, adult and old adult), shell length differed significantly among the coast (Figure 2), F (1, 330) = 9.29, $p < 0.01$. The mean shell length for pooled adult conch from the west coast of Barbuda was significantly larger than that for the south coast (223 mm versus 218 mm). Analysis of variance was also conducted on the disaggregated data for sub adult and adult conch and the results were the same, indicating that bio-erosion of shell with age did not impact the fore mentioned morphometric variation ($p < 0.01$). For juvenile conch, there was no significant difference between the west and south coast with respect to shell length ($p > 0.05$).

The age of conch with a flared shell lip can be estimated with some degree of accuracy by measurement of lip thickness (Appeldoorn 1988). Lip thickness, as an indicator of relative age since maturation, differed significantly among the coasts [F (1, 330) = 1247.14, $p < 0.001$], where conch from the south coast were significantly older than those from the west of Barbuda (Figure 3). The lip thickness of conch from the south was three-times that of those from the west (24.5 mm versus 7.5 mm).

Adult female conch were significantly larger than their male counterparts [F (1, 330) = 26.56, $p < 0.001$]; females were 4% larger than males (Figure 4). Although being statistically significant, the actual difference in mean shell length between sexes was moderate (224 mm versus 215 mm); the effect size, calculated using eta squared was 0.07, indicating that 7% of the variation in shell length is explained by sex. For juveniles, the difference between the sexes with respect to shell length was not statistically significant, $p > 0.05$ (Figure 5), however most conch were larger than the 180 mm statute and weighted more than 225 g.

The relationship between shell length and tissue weight differed across maturation stage, with the regressions for the sub adult and adult group and old adults shifting above that for juveniles (Figure 6). Table 2 summarises the regression parameters for the various comparisons across maturation stages and in all cases regressions were significant ($p < 0.001$). For all regressions, juveniles had a higher adjusted coefficient of determination than any other maturation stage. Regression for juveniles accounted for as much as 88% of the variance that can be explained by the regression model; regression for sub adults and adults accounted for 35% of the variance at best. For old adults, the regression models accounted for more of the variance than for sub adults and adults (at much as 73%). In general, processing from tissue to “dirty” meat weight for all maturation stages did not considerably impact the goodness of fit of the length-weight models.

Table 3 summarises the regression parameters for the various weight-weight comparisons and in all cases, regressions were significant ($p < 0.001$). The weight-weight relationships changed according to the level of maturation: for juveniles, every additional 100 g of nominal weight was associated with an increase in “dirty” meat weight of 18 g; whilst for sub adults, adults and old adults, every additional 100 g of nominal weight was associated with an increase in “dirty” meat weight of 14 g. Therefore, sub adults, adults and old adults yielded 22% less “dirty” meat for every 100 g increase in nominal weight when compared to juveniles. Note the slopes of the regressions shifted according to the maturation stage and the goodness of fit of the models decreased with age (level of maturation) and well as with increase processing of conch meat. For example, regression for juveniles regarding “dirty” meat accounted for as much as 93% of the variance that can be explained by the model while regression for old adults accounted for 58%.

Analysis of variance indicated that the conversion factor to convert tissue weight to nominal weight differed significantly among maturation stages (Figure 7); Welch and Brown-Forsythe F-ratios respectively were: F (3, 135.93) = 21.49, $p < 0.001$ and F (3, 275.66) = 27.99, $p < 0.001$. No significant difference existed between juvenile and sub adult conch ($p > 0.05$), however the conversion factor for adult and old adult were significantly different from any other maturation stage ($p < 0.05$) according to Games-Howell post hoc test. The conversion factors for the various processing grades and their related parameters are summarised in Table 4. The presence of old adults contributed most significantly to the differences among conversion factors for the various maturation stages ($p < 0.001$). In the case of “dirty” meat weight, the differences between juveniles and adults and sub adults and adults ($p < 0.01$) also attributed.

DISCUSSION AND CONCLUSION

Juvenile conch strong preference for seagrass relative to other habitats ($p < 0.001$) highlights the ecological role of seagrass meadows for both food and shelter. Roughly 97% of all juveniles sampled came from habitats that had seagrass as one of its primary component (Figure 1). Robertson (1961) observed conch feeding on the epiphytic algae on turtlegrass (*Thalassia* sp.) but found no turtlegrass leaves in the gut; instead four species of algae were ingested (an unidentified blue-green, *Cladophora* sp., *Hypnea cervicornis*, and *Polysiphonia* sp.). Stoner *et al*. (1994) postulated that nursery locations appear to be related to production of certain macroalgal species that provide food for juveniles as oppose to standing crops of seagrass. This was due to the fact that seagrass meadows of moderate shoot density have served as primary nursery habitats in central Bahamas, despite large expanses of seagrasses elsewhere. Hence, the issue is not only about having standing crops of seagrass, but having them located in the ecologically “ideal” position to maximise production of certain macroalgae. Stoner (2003) concluded that habitat management must be designed to conserve habitat function and not just form, and that key nurseries may represent distinctive or even anomalous conditions. For these unique areas to be preserved and managed effectively, a better understanding of what constitutes an essential nursery habitat for conch is required.

The shift in preference to other types of habitat with age (macroalgae, rock or coral rubble), possibly represents a shifting or widening of diet. Hence, sub adults, adults and old adults may be less selective of their habitat and thus found over a wider range as in this study. Serviere-Zaragosa *et al.* (2009) observed qualitative differences in the stomach content in their preliminary study about the natural feed of queen conch in juveniles and adults stages; they detected a total of 22 items in the stomach contents, of which 15 were in adults and 12 in juveniles.

Pooled adult conch from the west coast of Barbuda were significantly larger than those from the south coast ($p < 0.01$). Variation in conch size with respect to location is consistent with earlier findings from Antigua, where conch from the south and east coast were significantly larger than those from the north or west ($p < 0.05$) (Horsford *et al.* [In press]). In terms of lip thickness, conch from the south coast of Barbuda were significantly older than those from the west coast ($p < 0.001$) (Figure 3). The lip thickness of conch from the south was three-times that of those from the west (24.5 mm versus 7.5 mm). These results in part reflect the relative good health of conch in recent fishing areas (south) versus traditional area of exploitation (west). Brownell and Stevely (1981) documented the depletion of conch in shallow waters, west of Barbuda in the late 1970s, when conch was exported to Puerto Rico. Other factors such as the close proximity of traditional fishing area to the home port (Codrington) and the type of habitat being exploited (shallow, seagrass meadows) impacted the results. The presence of extensive deep-water conch resources on the south coast of Barbuda, or the central portion of the Antigua and Barbuda Shelf, is consistent with the findings on the overall status of the resource; earlier studies had concluded that conch resources overall were relatively healthy given no significant negative trends were detected with respect to the catch per unit effort, depth dived or "dirty" meat landed from random sampling of commercial trips and routine inspection at sea (Horsford 2004, 2008 and 2010).

Adult conch exhibited sexual dimorphism, with females being 4% larger than their male counterpart, $p < 0.001$. This difference between the sexes has implications for the size at sexual maturity (i.e., females maturing at a larger shell length). Whilst the difference between the sexes for juveniles was not statistically significant ($p > 0.05$), most conch whose sex were determined were larger than the 180 mm statute and weighted more than 225 g (Figure 5). One of the implications of having regulations based solely on a standard minimum size (i.e., a standard shell length and a corresponding standard meat weight), is that this approach would not afford proper protection for large juveniles in situations where there are morphological differences with respect to location. While setting specific size limits for specific areas could address the problem, this option is not viable given there are no designated fishing zones and fishers do not limit their effort to specific areas.

There is no "silver bullet" management solution to address the complexities associated with conch morphological variances. For example, increasing minimum shell length regulations from 180 mm could result in a differential selection between the sexes since conch exhibited sexual dimorphism. Under the current management regime, Horsford *et al.* [In press] confirmed that in the case of commercial fishing trips, the sex ratio of the allowable catch (minimum meat weight of 225g), was favouring the harvesting of females [X^2 (1, $N = 711$) = 4.26, $p < 0.05$], with 53.9% of the sample being female. Hence, increasing the shell length to exclude the landing of meat from large juveniles (without shell) would further skew the sex ratio of the catch. For Antigua and Barbuda, conch is normally landed as "dirty" meat, where the shell and visceral mass are removed.

Morphological differences also extend to shell lip thickness with respect to the size at sexual maturity. A recent histological study of conch gonads from Colombia (Avila-Poveda and Baqueiro-Cárdenas 2006) showed that the lip thickness at sexual maturity (based on 50% of sampled population) was 17.5 mm for females and 13.0 mm for males. Avila-Poveda and Baqueiro-Cárdenas (2006) proposed a lip thickness of 13.5 mm or greater to be a better maturity criterion for management as opposed to the lip thickness at the onset of maturity (5 mm) (Appeldoorn 1988).

In terms of the length-weight relationships (Table 2), shell length and tissue weight differed across maturation stage, with the regressions for the sub adult and adult group and old adults shifting above that for juveniles. The steeper slope for juveniles (when compared with other maturation stages) is an indication of the greater weight gain per unit increase in length, at this stage. With the cessation of shell length growth at maturity (Appeldoorn 1988) and bio-erosion of the shell with age, old adults growth are geared towards thickening the lip and shell, while soft tissue mass is being lost with age (Horsford *et al.* [In press]). The cessation of shell length growth at maturity is responsible for the decrease in the goodness of fit of the regression models from juvenile to sub adult to adult. For weight-weight relationships (Table 3), the dynamics are also driven by the level of maturity. For example, sub adults and adults yielded 22% less "dirty" meat for every 100 g increase in nominal weight when compared to juveniles. This was due to the fore mentioned greater weight gain at the juvenile stage.

Conversion factors differed significantly among maturation stages ($p < 0.001$); this was consistent with results obtained from Antigua (Horsford *et al.* [In press]). Conversion factors were also not statistically different ($p > 0.05$) from those derived from Antigua, indicating that both samples could be pooled to improve the national conversion factors for the various processing grades. While the establishment of statistically valid conversion factors is essential for transforming all processed conch into nominal weight, making data series consistent throughout the years and comparable among all countries of the region (Aspra *et al.* 2009), the use of a single conversion factor for the species is problematic due to the significant differences among maturation stages (Figure 7). In the case of Antigua and Barbuda, the significant presence of an older demographic (old adults) prevented the pooling of data for the various maturation stages. Since the conversion factor applied is dependent on the demographics of the population, they should be monitored over time to ensure that the reference point has not shifted due to factors such as over-fishing (i.e., the issue of a shifting baseline with changing demographics).

Taking the morphological variances with respect to location, sex and maturation stage into consideration as well as the ecological role of certain habitats (e.g., seagrass meadows), the only viable option for management is a multifaceted approach. These results reaffirm earlier study (Horsford *et al.* [In press]) that a multifaceted management approach is required to ensure the long term sustainability of the conch fishery. Fisheries managers in Antigua and Barbuda, have opted for a combination of minimum size restrictions, protected areas, closed season, prohibited gears (e.g., hookah compressor diving rig), and "limited entry" through the use of special permits. The latter three options are expected to be implemented in 2013 with the gazetting of the draft amended fisheries regulations; the substantive legislation, the Fisheries Act, No. 22 of 2006, has being passed by Parliament and is currently awaiting a date of enactment, which would coincide with the gazetting of the regulations in 2013. The conch closed season would extend from 1st July to 31st August of every year and a minimum 5 mm shell lip thickness would also be implemented. Based on the works of Avila-Poveda and Baqueiro-Cárdenas (2006), future research should focus on lip thickness and sexual maturity with respect to conch from Antigua and Barbuda waters.

For Barbuda, the local fisheries management authority, the Barbuda Council, should consider diverting fishing effort away from shallow, nursery areas (seagrass meadows), given extensive adult conch resource in deeper waters; this would reduce the likelihood of growth over-fishing due to SCUBA. If this is not feasible given the subsistence to artisanal nature of certain sections of the fishery, Council should consider limiting the harvest of conch to free diving within these areas coupled with environmental awareness and strict enforcement. *Antigua and Barbuda's plan of action to prevent, deter and eliminate illegal, unreported and unregulated fishing*, highlights a number of key measures that has enhance fisheries governance with respect to conch as well as new measures (Horsford 2010). Given Barbuda's long history of community-based natural resource management dating back to the communal land rights of the Barbuda Act of 1904 (i.e., land in Barbuda is held in trust by the Council and individuals may not hold title to any land), approval for such measures should be actively sought at the community level to ensure this form of delegated co-management is effective.

ACKNOWLEDGEMENTS

This study was funded by the Japan International Cooperation Agency (JICA) and the Fisheries Division, Ministry of Agriculture, Lands, Housing & the Environment, in collaboration with Barbuda Fisheries, the local fisheries management agency of the Barbuda Council. Special thanks to the conch fishers of "Round South" particularly: Leonard "Decade" Jackson, Clive Pelle, Jameson "Kublai" Mannix, Adrian "Ivan" Pryce, Alexander Lewis, Selvyn Francis, "Rudolph", Beresford Rodgers and Clifton "Shamback" Roberts, for their invaluable support.

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Table 1. Summary of habitat characteristics of queen conch sampling sites from the coast of Barbuda.

Portion of the Antigua and Barbuda Shelf	General Location	Mean Depth (m)	Habitat Description	Type of Trip
Central	South of Barbuda	30.5	Sand and macroalgae	Commercial fishing
Central	South of Barbuda	29.3	Rock and sand	Commercial fishing
North western	West of Barbuda	4.6	Sand and seagrass	Research
North western	West of Barbuda	4.9	Sand, coral rubble and seagrass	Research

Table 2. Regression equations for tissue weight (TW) and "dirty" meat weight (DW) as a function of shell length (SL), for various maturation stages for queen conch, collected from the coast of Barbuda. Lengths are in mm; weights are in g; A is the *Y* intercept; *B* is the slope of the estimated regression line; and CI is the confidence interval.

Group	Regression Equation $Y = A + B(x)$	Adjusted Coefficient of Determination, R^2	Sample Size, *N*	Lower Bound for the 95% CI for *B*	Upper Bound for the 95% CI for *B*
Juvenile	Log(TW) = -4.62 + 2.98Log(SL)	0.88	145	2.80	3.16
Juvenile	Log(DW) = -4.87 + 3.07Log(SL)	0.87	145	2.87	3.26
Sub adult & Adult	Log(TW) = -2.14 + 1.97Log(SL)	0.31	181	1.54	2.40
Sub adult & Adult	Log(DW) = -2.17 + 1.95Log(SL)	0.35	181	1.56	2.34
Old adult	Log(TW) = -3.73 + 2.69Log(SL)	0.70	151	2.41	2.97
Old adult	Log(DW) = -3.79 + 2.67Log(SL)	0.73	151	2.41	2.94
Pooled Adult	Log(TW) = -2.35 + 2.08Log(SL)	0.36	332	1.78	2.38
Pooled Adult	Log(DW) = -2.54 + 2.12Log(SL)	0.43	332	1.86	2.39

Table 3. Regression equations for tissue weight (TW), shell weight (SW), "dirty" meat weight (DW) and "clean" meat weight (CW) as a function of nominal weight (NW), for various maturation stages for queen conch, sampled from the coast of Barbuda. Weights are in g; A is the *Y* intercept; *B* is the slope of the estimated regression line; and CI is the confidence interval.

Group	Regression Equation $Y = A + B(x)$	Adjusted Coefficient of Determination, R^2	Sample Size, *N*	Lower Bound for the 95% CI for *B*	Upper Bound for the 95% CI for *B*
Juvenile	TW = -3.47 + 0.21NW	0.94	145	0.20	0.21
Juvenile	SW = 3.47 + 0.80NW	0.99	145	0.79	0.80
Juvenile	DW = -5.29 + 0.18NW	0.93	145	0.17	0.19
Juvenile	CW = -3.32 + 0.11NW	0.92	145	0.10	0.12
Sub adult & Adult	TW = 26.26 + 0.17NW	0.80	181	0.16	0.18
Sub adult & Adult	SW = -26.26 + 0.83NW	0.99	181	0.81	0.84
Sub adult & Adult	DW = 40.95 + 0.14NW	0.76	181	0.13	0.15
Sub adult & Adult	CW = 11.54 + 0.10NW	0.81	181	0.09	0.11
Old adult	TW = 2.88 + 0.18NW	0.57	151	0.15	0.20
Old adult	SW = -2.88 + 0.83NW	0.97	151	0.80	0.85
Old adult	DW = -0.36 + 0.14NW	0.58	151	0.12	0.16
Old adult	CW = 4.90 + 0.10NW	0.57	151	0.08	0.11

Table 4. Conversion factors to nominal weight for queen conch sampled from the coast of Barbuda. CI is the confidence interval.

Level of Processing	Group	Sample Size, *N*	Mean Conversion Factor	Standard Deviation, *S.D.*	Lower Bound for the 95% CI for the Mean	Upper Bound for the 95% CI for the Mean
Tissue weight	Juvenile	145	5.07	0.68	4.96	5.19
	Sub adult	33	5.01	0.69	4.76	5.25
	Adult	148	5.36	0.61	5.26	5.46
	Old adult	151	5.81	0.99	5.66	5.98
Shell weight	Juvenile	145	1.25	0.05	1.24	1.26
	Sub adult	33	1.26	0.04	1.24	1.27
	Adult	148	1.23	0.03	1.23	1.24
	Old adult	151	1.22	0.04	1.21	1.22
"Dirty" meat weight	Juvenile	145	5.96	1.01	5.80	6.13
	Sub adult	33	5.77	0.75	5.51	6.04
	Adult	148	6.35	0.76	6.23	6.47
	Old adult	151	7.24	1.21	7.04	7.43
"Clean" meat weight	Juvenile	145	9.44	1.47	9.20	9.69
	Sub adult	33	9.22	1.35	8.74	9.70
	Adult	148	9.44	1.14	9.25	9.62
	Old adult	151	10.17	1.63	9.91	10.43

Figure 1. Habitat preference within maturation stages for queen conch sampled from the coast of Barbuda.

Figure 2. Mean shell length for pooled adult queen conch (i.e., sub adult, adult and old adult) sampled from the different coast of Barbuda. Error bar is for the 95% confidence interval and n = sample size.

Figure 3. Mean shell lip thickness for pooled adult queen conch (i.e., sub adult, adult and old adult) sampled from the different coast of Barbuda. Error bar is for the 95% confidence interval and n = sample size.

Figure 4. Mean shell length by sex for pooled adult queen conch (i.e., sub adult, adult and old adult) sampled from the coast of Barbuda. Error bar is for the 95% confidence interval and n = sample size.

Figure 5. Mean shell length by sex for juvenile queen conch sampled from the coast of Barbuda. Error bar is for the 95% confidence interval and n = sample size.

Figure 6. Shell length-tissue weight relationships for juvenile (○), sub adult and adult (□), and old adult (x) queen conch from the coast of Barbuda.

Figure 7. Mean conversion factor (CF), by maturation stage, to convert tissue weight to nominal weight for queen conch sampled from the coast of Barbuda. Error bar is for the 95% confidence interval and n = sample size.

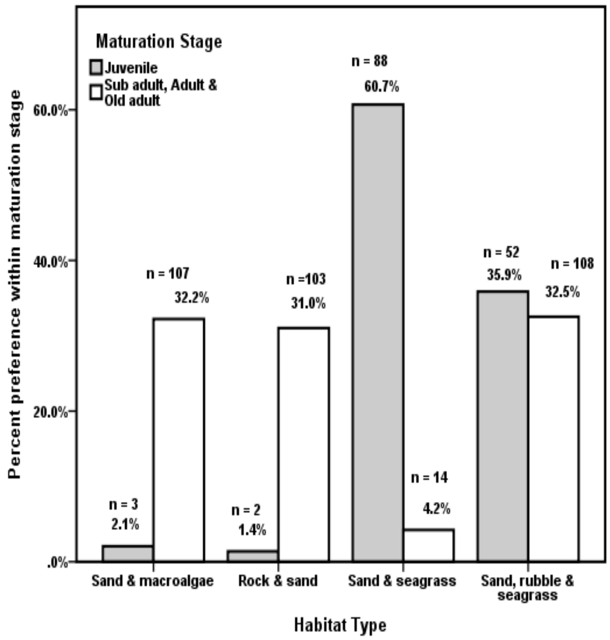

Figure 1. Habitat preference within maturation stages for queen conch sampled from the coast of Barbuda.

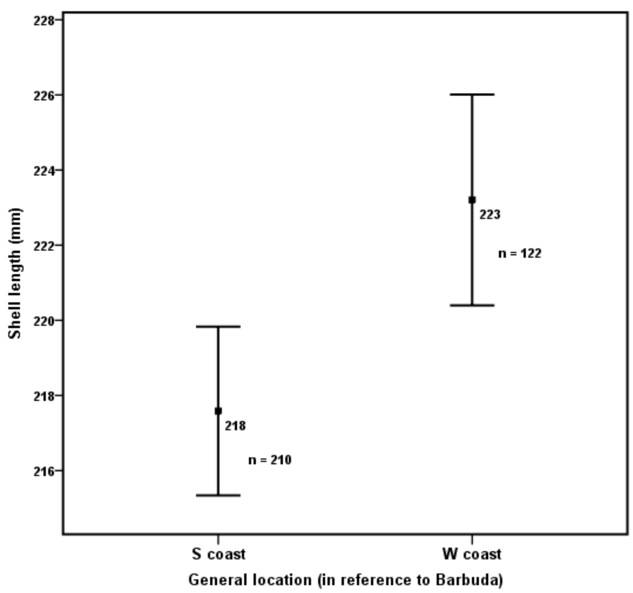

Figure 2. Mean shell length for pooled adult queen conch (i.e., sub adult, adult and old adult) sampled from the different coast of Barbuda. Error bar is for the 95% confidence interval and n = sample size.

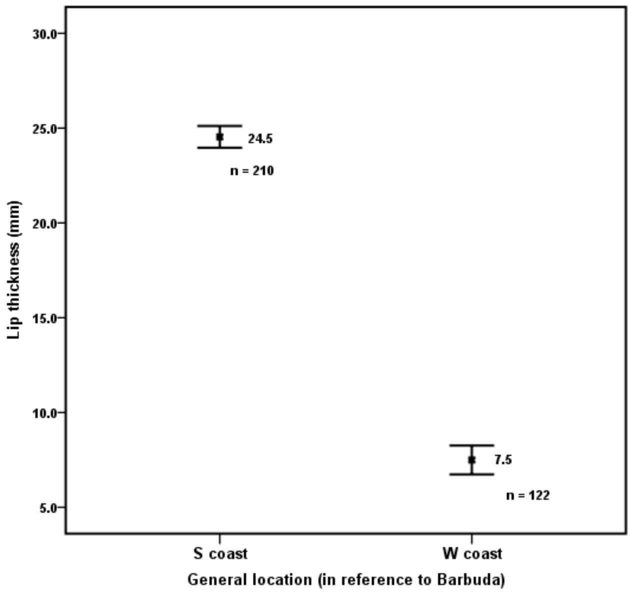

Figure 3. Mean shell lip thickness for pooled adult queen conch (i.e., sub adult, adult and old adult) sampled from the different coast of Barbuda. Error bar is for the 95% confidence interval and n = sample size.

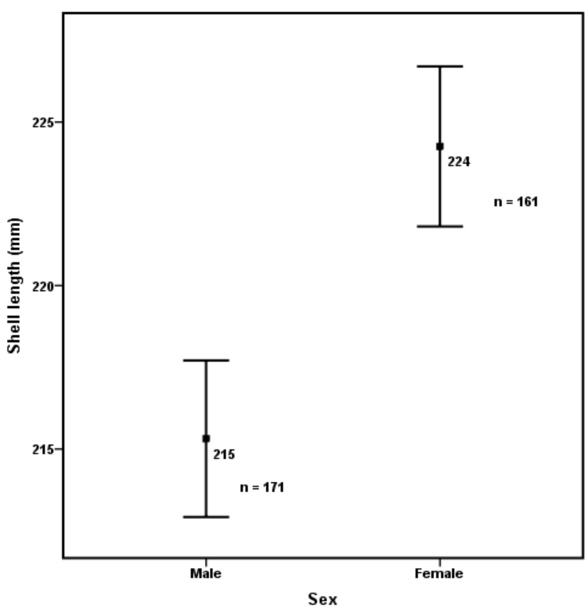

Figure 4. Mean shell length by sex for pooled adult queen conch (i.e., sub adult, adult and old adult) sampled from the coast of Barbuda. Error bar is for the 95% confidence interval and n = sample size.

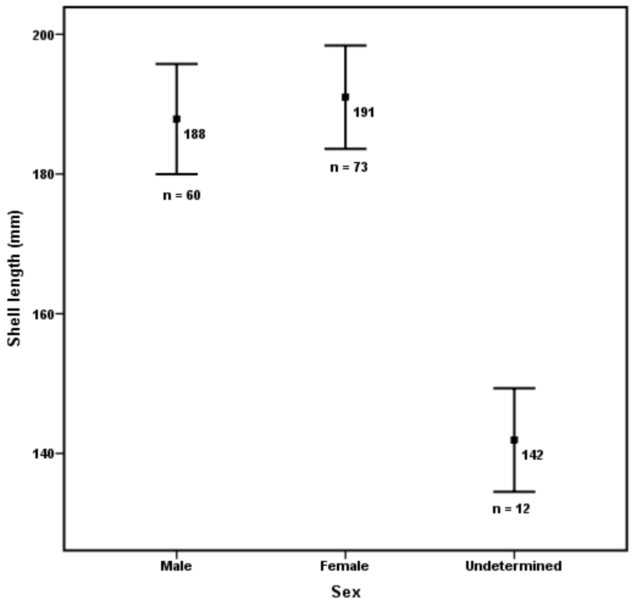

Figure 5. Mean shell length by sex for juvenile queen conch sampled from the coast of Barbuda. Error bar is for the 95% confidence interval and n = sample size.

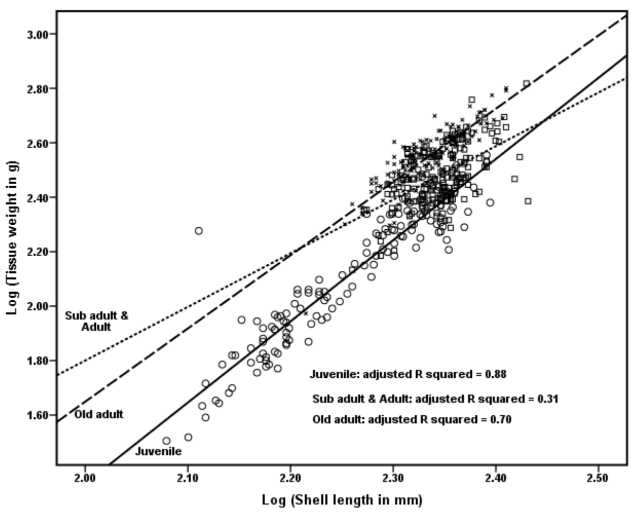

Figure 6. Shell length-tissue weight relationships for juvenile (○), sub adult and adult (□), and old adult (x) queen conch from the coast of Barbuda.

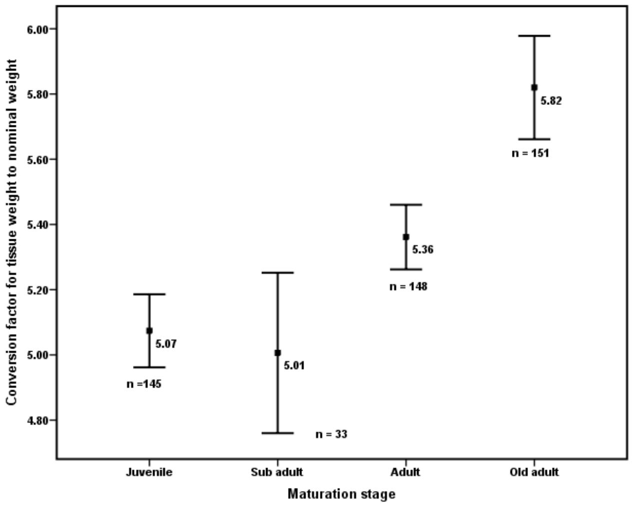

Figure 7. Mean conversion factor (CF), by maturation stage, to convert tissue weight to nominal weight for queen conch sampled from the coast of Barbuda. Error bar is for the 95% confidence interval and n = sample size.