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

La Morfología del Caracol Rosa (*Strombus gigas*) de La Plataforma de Antigua y Barbuda – Implicaciones para La Gestión de La Pesca

La Morphologie du Lambi (*Strombus gigas*) de La Plateforme de Antigua et Barbuda – Implications pour La Gestion des Pêches

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ABSTRACT

Morphometric measurements were taken from queen conch (*Strombus gigas*) from various sections of the Antigua and Barbuda shelf to: 1) ascertain if there were spatial variability regarding morphology; 2) analyse length-weight relationships for various maturation stages; 3) develop statistically valid conversion factors for different levels of processed conch meat; and 4) assess current management regimes (e.g., minimum size / weight). For both juvenile and adult conch, shell length differed significantly among the coastal groupings, $p < 0.001$. Shell lip thickness, an indicator of the age, was also significantly different among the coasts ($p < 0.001$), where conch from the north and west coast were significantly older than those from the east or south coast of Antigua ($p < 0.001$). Significant sexual dimorphism was only detected for adult conch ($p < 0.001$), with females being 4% larger than their male counterpart. The mean lip thickness for conch collected from commercial fishing trips was 25.0 mm ($N = 785$, $S.D. = 5.5$ mm) indicating that divers were targeting an old population however the sex ratio of the allowable catch (minimum weight of 225g) was favouring the harvesting of female conch, X^2 (1, $N = 711$) = 4.26, $p < 0.05$. Conversion factors differed significantly among maturation stages (juvenile, sub adult, adult and old adult), $p < 0.001$; hence the use of a single conversion factor to transform processed conch to nominal weight is problematic since conversion factor is dependent on the age structure of the population. These morphological differences require a multifaceted management approach (closed season, protected areas, etc) to ensure the long-term sustainability of the fishery.

KEY WORDS: Queen conch, Antigua and Barbuda, conversion factor, fisheries management, morphology

INTRODUCTION

The marine gastropod, queen conch (*Strombus gigas*), is one of the most important fishery resources in the Caribbean. This is due to export earnings, consumption within the tourism sector, employment, and income generated from local sales. Regional management measures include minimum size restrictions, close seasons, harvest quotas, gear restrictions, etc. Despite these measures, fear of depleted conch resource has prompted the queen conch to be listed under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Hence international trade in queen conch or parts thereof (e.g., meat, souvenir shells, jewellery) are regulated by CITES and subject to the provisions of the Convention.

Antigua and Barbuda acceded to CITES in 1997 and the subsequent review of Significant Trade in Appendix II species, resulted in a suspension of imports of specimen of queen conch from Antigua and Barbuda. This was the result of Antigua and Barbuda failing to adequately respond to the recommendations of CITES Animals Committee (basically a committee of experts that provide advice on species subject to trade controls). In 2006, CITES notified the international community that Antigua and Barbuda had implemented the recommendations and trade sanctions were lifted (CITES 2006).

The conch fishery of Antigua and Barbuda is primarily based on the island of Antigua, with much of the 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 eight part-time vessels that alternate between diving for conch and lobster. Vessels range from 4 to 14 m and include small pirogues to large fibreglass launches, equipped with global positioning systems and hydraulic haulers. Commercially, conch is harvested using SCUBA due in part to the topography of the Antigua and Barbuda shelf; the 3,400 km^2 shelf (to the 200 m contour) has a mean depth of about 27 m. In Barbuda, the conch fishery is basically subsistent to part-time commercial; the Caribbean spiny lobster (*Panulirus argus*) is the primary species of commercial interest mainly for export to the French overseas territories in the region.

In terms of conservation measures, the Fisheries Regulations, No. 10 of 1990, prohibits the harvesting of immature conch; conch with a shell smaller than 180 mm or which does not have a flared-lip shell. For conch out of the shell, the meat must not be less than 225 g, after removing the digestive gland. The Regulations also makes provision for a close season to protect spawning individuals. In 1999, Cades Bay Marine Reserve was established on the south coast of Antigua in response to fishing pressure and the need to protect critical habitats, such as sea-grass beds, that serve as nursery areas for juvenile conch. In 2005, the Northeast Marine Management Area was established to protect similar types of habitats on the north and north-eastern coasts of Antigua. While these measures have been taken, a comprehensive morphometric study of queen conch in Antigua and Barbuda waters was lacking. A pilot study conducted in 1999 indicted that conch from two sites on the western coast of Antigua were not significantly different ($p > 0.05$) in terms of morphometrics (Horsford 1999). However, anecdotal information from fishers has raised the issue of spatial variability in terms of conch morphology and "stunted" adult specimens have been collected by the fisheries department. The pilot study also indicted that as much as 23% of the sample that was legal (based on the 225 g minimum weight regulations), could be sexually immature individuals since conch become fully reproductive at a lip thickness of about 5 mm (Appeldoorn 1988). There are also no locally derived standard conversion factors to address the different levels of processed conch meat or to raise processed meat to live weight. This is essential for standard reporting of capture production and standard marketing and trading of conch meat.

In light of the fore mentioned, the specific objectives of this research were to:

i) Ascertain if there were spatial variability in terms of conch morphology for Antigua and Barbuda;
ii) Determine length-weight relationships for various stages of maturation;
iii) Develop statistically valid conversion factors for different levels of processed conch meat; and
iv) Assess the effectiveness of current management regimes (e.g., minimum size / weight).

MATERIALS AND METHODS

Conch were sampled from fourteen sites on the Antigua and Barbuda shelf and grouped according to their geographical location in reference to the island of Antigua. Sites were sampled by research personnel and commercial conch divers and included six research trips and eight commercial fishing trips. For research trips, personnel were instructed to sample all conch encountered and not to selectively sample "typical" specimen. The type of trip (i.e., commercial fishing or research), geographical coordinates, mean depth dived, and habitat characteristics were noted. Sites were predominately sampled using SCUBA; only one site was sampled by free diving.

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

i) Juvenile (J) – conch without a flared shell lip.
ii) Sub adult (SA) – conch with flared shell lip starting but not fully developed; lip thickness < 5 mm.
iii) Adult – conch with flared lip fully developed and minimal shell erosion; lip thickness ≥ 5 mm.
iv) 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:

i) Shell length – length of the shell from the apex of the spire to the end of the siphonal canal.
ii) Lip thickness – thickness of the shell lip measured in the mid-lateral region, roughly 40mm inward from the edge of the lip.
iii) Nominal weight – weight of intact animal, including shell.
iv) Tissue weight – weight of intact animal, after removal from shell.
v) Shell weight – nominal weight minus tissue weight.
vi) "Dirty" meat weight – weight after removal of shell and digestive gland (visceral mass).
vii) "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 using a knife to subsequently remove the columnar muscle from the central axis.

Statistical analyses were conducted using SPSS 15.0 for Windows. 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). Analysis of variance was used to determine if morphometric means and conversion factors for the maturation stages were significantly different. The status of the sex ratio (whether unbiased or biased) was determined by a Chi-square Goodness of Fit Test.

RESULTS

Table 1 highlights the habitat variability and depth profile of the fourteen sites sampled from February to June 2011. Rock and sand was the most common type of habitat dived during commercial fishing trips. For research trips, sand and rubble was the most common. All other sites were a combination of a number of different types of habitat. Mean depth dived ranged from 25.3 - 31.4 m for commercial trips, while research trips operated in the ranged of 6.1 - 10.7 m.

For pooled adult conch (i.e., sub adult, adult and old adult), shell length differed significantly among the coastal groups (Figure 1); Welch and Brown-Forsythe F-ratios respectively were: F (3, 84.70) = 35.27, $p < 0.001$ and F (3, 124.58) = 32.70, $p < 0.001$. There was no significant difference between conch from the south and east coast ($p = 0.907$), however they were significantly larger than those from the north or west coast ($p < 0.01$) according to Games-Howell post hoc test. Conch from the north were significantly smaller than any other coast ($p < 0.05$). In order to ensure bio-erosion (associated with the shell aging) did not impact the shell length, data was disaggregated and analysis of variance conducted only on adults with minimal shell erosion. Similar results were obtained confirming conch from the south and east were significantly larger than those from the north or west ($p < 0.05$), whilst there was no significant difference between those from south and east ($p = 0.939$, Turkey post hoc test). For juvenile conch, shell length also differed significantly among the coast [F (3, 306) = 9.53, $p < 0.001$] (Figure 2). Turkey post hoc test indicted that juveniles from the east were significantly larger than any other coast ($p < 0.05$). Whilst juveniles from the north were the smallest, they were only significantly smaller that those from the east ($p < 0.001$). No "stunted" adult conch were detected during the survey.

Shell lip thickness, an indicator of relative age since maturation, differed significantly among the coastal groups [F (3, 917) = 107.72, $p < 0.001$] (Figure 3). Conch from the north and west coast had significantly thicker shell lip and therefore older than those from the east or south coast of Antigua ($p < 0.001$, Turkey post hoc test). There was no significant difference in lip thickness between conch from the north and west ($p = 0.444$). Conch from the south had significantly thinner shell lip and therefore younger than any other coast ($p < 0.001$). The mean lip thickness of conch from the north and west coast were approximately three-times that of those from the south (25.1 mm and 24.5 mm respectively versus 9.2 mm), while the lip thickness of conch from the east were about two-times that of those from the south (17.1 mm versus 9.2 mm) (Figure 3).

In general, female conch were larger than male conch, however this was only statistically significant for adult conch [F (1, 919) = 39.13, $p < 0.001$], with females being 4% larger than their male counterpart (Figure 4). Although being statistically significant, the actual difference in mean shell length between sexes was moderately small (229 mm versus 221 mm); the effect size, calculated using eta squared was 0.04. For juveniles, the evidence of sexual dimorphism was not statistically significant; Welch and Brown-Forsythe F-ratios were both: F (1, 198.34) = 3.26, $p = 0.072$. Chi-square Goodness of Fit Test indicted that the sex ratio was 1:1 for pooled adult conch, X^2 (1, n = 921) = 2.82, $p = 0.093$. However for juveniles, the sex ratio was biased in favour of female conch, with 59.7% of the total sample being female; X^2 (1, n = 268) = 10.09, $p < 0.01$).

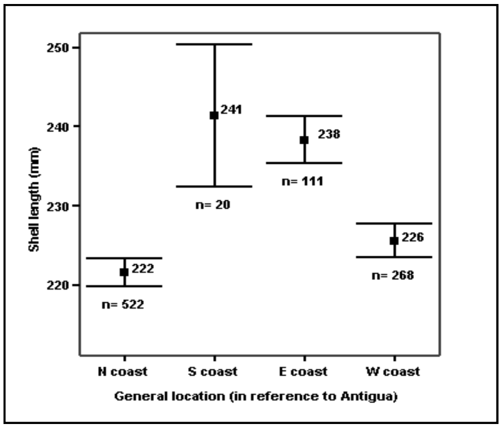

Figure 1. Mean shell length for pooled adult queen conch (i.e., sub adult, adult and old adult) sampled from the different coast of Antigua. Error bar is for the 95% confidence interval and n = sample size.

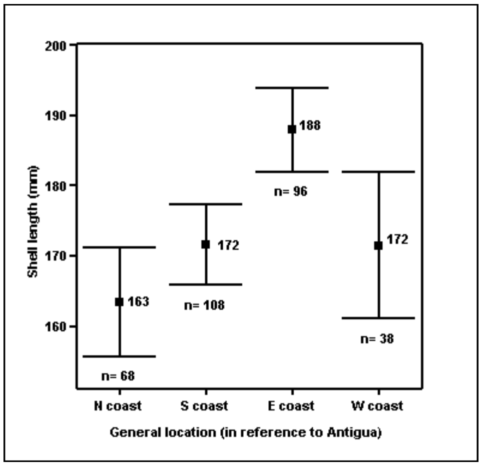

Figure 2. Mean shell length for juvenile queen conch sampled from the different coast of Antigua. Error bar is for the 95% confidence interval and
n = sample size.

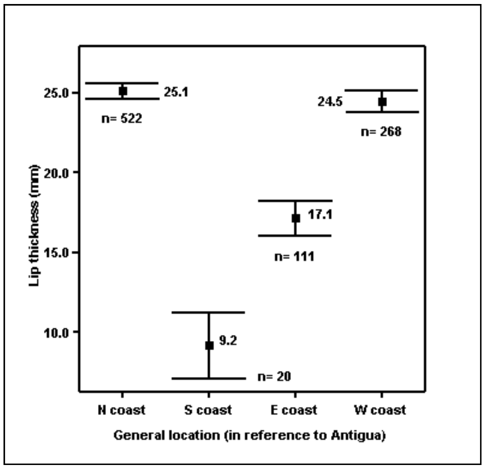

Figure 3. Mean shell lip thickness for pooled adult queen conch (i.e., sub adult, adult and old adult) sampled from the different coast of Antigua. Error bar is for the 95% confidence interval and n = sample size.

Table 1. Summary of habitat characteristics of queen conch sampling sites from Antigua and Barbuda shelf.

Site	General Location	Mean Depth (m)	Habitat Description	Type of Trip
Centre 1	North of Antigua	26.5	Rock and sand	Commercial fishing
Centre 2	North of Antigua	30.5	Sand and macroalgae	Commercial fishing
Centre 3	North of Antigua	29.3	Rock and sand	Commercial fishing
Centre 4	North of Antigua	29.0	Rock and sand	Commercial fishing
Centre 5	North of Antigua	29.6	Sand and macroalgae	Commercial fishing
Great Bird Island	North of Antigua	6.1	Sand and macroalgae	Research
North west coast	West of Antigua	25.3	Rock and sand	Commercial fishing
Cades Reef	South of Antigua	13.4	Sand and rubble	Research
Goat Head	South of Antigua	7.6	Sand and rubble	Research
South west coast 1	West of Antigua	31.4	Rock and sand	Commercial fishing
South west coast 2	West of Antigua	25.3	Sand and macroalgae	Commercial fishing
Darkwood	West of Antigua	10.1	Sand, macroalgae and sea-grass	Research
Pinching Bay	West of Antigua	6.7	Sand, rubble and sea-grass	Research
York Bank	East of Antigua	10.7	Rock, sand and macroalgae	Research

Figure 5 highlights the relationships between shell length and tissue weight for the various maturation stages for conch. These relationships differ as the regressions for old adults and sub adults and adults are shifted above that for juveniles. Regression parameters for the various comparisons are summarised in Table 2 and in all cases, regressions were significant ($p < 0.001$). For all regressions, the coefficient of determination was characteristically higher for juveniles than for any other maturation stage. Regression for juveniles accounted for as much as 71% of the variance that can be explained by the regression model; regression for sub adults and adults accounted for 27% 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 57%). For all maturation stages, the goodness of fit of the models decreased marginally with processing from tissue to “dirty” meat weight.

The relationships between nominal weight and “dirty” meat weight for the various conch maturation stages are depicted in Figure 6. Note the slopes of the regressions shifted according to the maturation stage and the goodness of fit of the models decreased with age or level of maturation. Regression for juveniles accounted for as much as 78% of the variance that can be explained by the model while regression for old adults accounted for 52%. 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 16 g; for sub adults and adults, every additional 100 g of nominal weight was associated with an increase in “dirty” meat weight of 15 g; and for old adult, every additional 100 g of nominal weight was associated with an increase in “dirty” meat weight of 12 g. Therefore, old adults yielded 20% less “dirty” meat for every 100 g increase in nominal weight when compared to sub adults and adults.

Based on the fore mentioned differences, conversion factors were estimated per maturation stage by calculating a conversion factor per sample. 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, 66.61) = 49.82, $p < 0.001$ and F (3, 523.29) = 64.61, $p < 0.001$. There was no significant difference among juvenile, sub adult and adult conch ($p > 0.05$), however the conversion factor for old adult was significantly larger than any other maturation stage ($p < 0.001$) according to Games-Howell post hoc test. Note the analysis was initially conducted on tissue weight to ensure the impact of variation in processing was minimised (i.e., animal was simply removed from shell). The means for the various conversion factors and their related parameters are presented in Table 4. Significant differences among the conversion factors for the various maturation stages were attributed primarily to the presence of old adults ($p < 0.001$), however, in the case of “clean” meat weight, the differences between sub adults and juveniles and adults and juveniles ($p < 0.01$) also attributed. Hence, the differences among the conversion factors for the various maturation stages increased with the level of processing.

In order to assess current management regime and level of compliance with respect to regulations, conch samples were disaggregated based on the type of trip (commercial fishing versus research). The mean lip thickness for conch collected from commercial fishing trips was 25.0 mm (n = 785, *S.D.* = 5.5 mm) as opposed to 15.7 mm for research (n = 136, *S.D.* = 6.5 mm). This difference was statistically significant (Figure 8); Welch and Brown-Forsythe F-ratios were both: F (1, 169.88) = 246.49, $p < 0.001$. Shell lip thickness ranged from 2.9 mm to 43.2 mm for commercial trips whilst research trips ranged from 1.8 mm to 35.1 mm. For commercial trips to a maximum depth of 31.4 m, the conch demographic was as follows: juvenile, 1.4%; sub adult, 0.9%; adult, 25.1%; and old adult, 72.6% (n = 796). Hence 98.6% of the sample had a flared-lip shell in compliance with fisheries regulations, with 97.7% classified as mature according to Appeldoorn criteria (1988). In terms of the minimum meat weight, 89.3% of the sample (n = 796) had a meat weight of 225g or greater after removal of shell and digestive gland. For research trips to a maximum depth of 10.7 m, the conch demographic was as follows: juvenile, 68.7%; sub adult, 1.6%; adult, 25.3%; and old adult, 4.4% (n = 435). Chi-square Goodness of Fit Test indicted that the sex ratio of the allowable catch (minimum meat weight of 225g) for commercial fishing trips, was favouring the harvesting of female conch [X^2 (1, n = 711) = 4.26, $p < 0.05$], with 53.9% of the sample being female. The sex ratio of the allowable catch for research trips was 1:1 [X^2 (1, n = 146) = 0.99, $p = 0.321$], however 11.6% were large juveniles and 4.1% were sub adults.

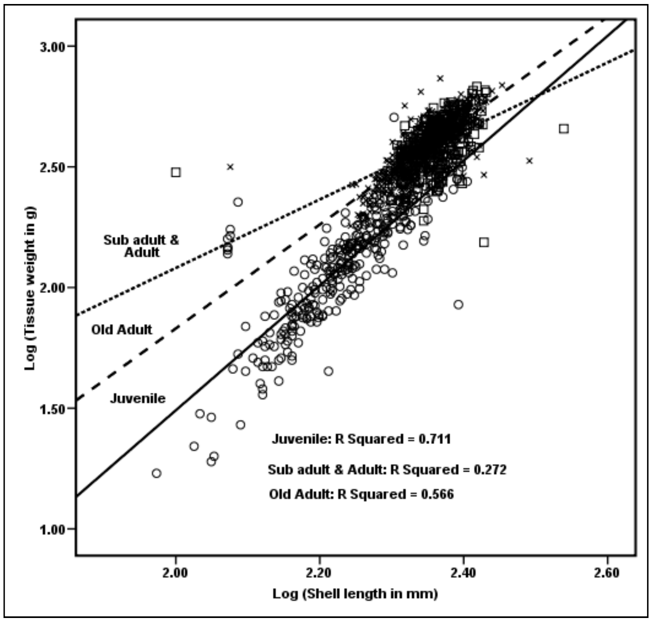

Figure 5. Shell length-tissue weight relationships for juvenile (○), sub adult and adult (□), and old adult (x) queen conch from the Antigua and Barbuda shelf.

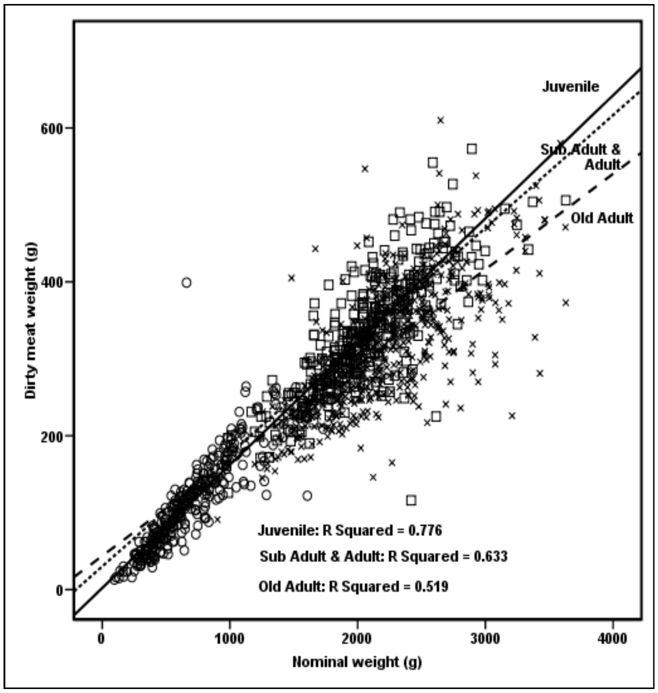

Figure 6. Nominal weight-“dirty” meat weight relationships for juvenile (○), sub adult and adult (□), and old adult (x) queen conch from the Antigua and Barbuda shelf.

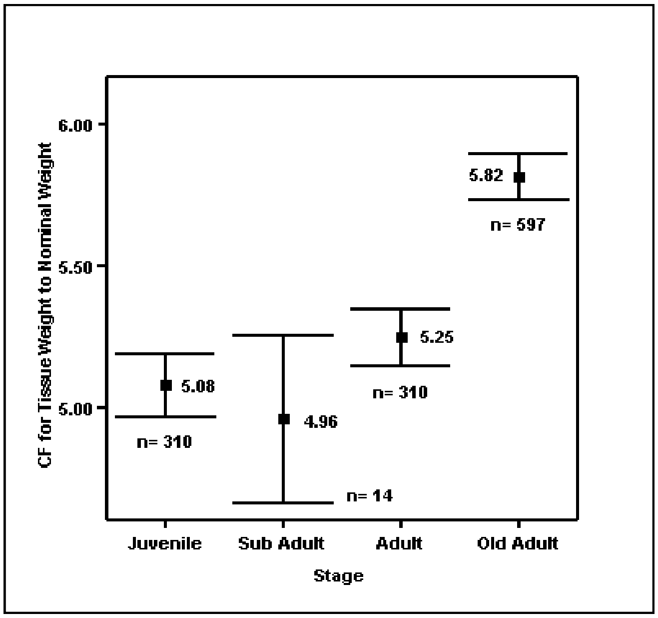

Figure 7. Mean conversion factor (CF), by maturation stage, to convert tissue weight to nominal weight for queen conch sampled from the Antigua and Barbuda shelf. Error bar is for the 95% confidence interval and n = sample size.

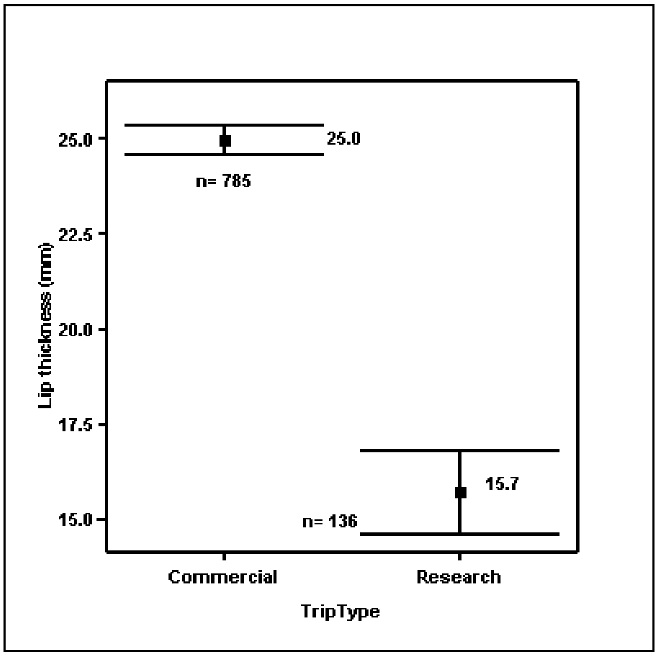

Figure 8. Mean shell lip thickness for queen conch sampled from commercial fishing trips and research trips. Error bar is for the 95% confidence interval and n = sample size.

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 Antigua and Barbuda shelf. 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) = -3.68 + 2.59Log(SL)	0.71	310	2.40	2.77
Juvenile	Log(DW) = -3.97 + 2.67Log(SL)	0.67	310	2.46	2.88
Sub adult & Adult	Log(TW) = -0.76 + 1.42Log(SL)	0.27	324	1.16	1.67
Sub adult & Adult	Log(DW) = -0.80 + 1.40Log(SL)	0.25	324	1.14	1.67
Old adult	Log(TW) = -2.47 + 2.15Log(SL)	0.57	597	2.00	2.30
Old adult	Log(DW) = -2.48 + 2.12Log(SL)	0.54	597	1.96	2.28
Pooled Adult	Log(TW) = -1.81 + 1.87Log(SL)	0.46	921	1.74	2.00
Pooled Adult	Log(DW) = -1.87 + 1.86Log(SL)	0.43	921	1.72	1.99

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, collected from Antigua and Barbuda shelf. 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 = 6.01 + 0.20NW	0.80	310	0.19	0.21
Juvenile	SW = -6.01 + 0.80NW	0.99	310	0.79	0.81
Juvenile	DW = 2.20 + 0.16NW	0.78	310	0.15	0.17
Juvenile	CW = -0.74 + 0.11NW	0.76	310	0.10	0.11
Sub adult & Adult	TW = 35.14 + 0.18NW	0.67	324	0.16	0.19
Sub adult & Adult	SW = -35.14 + 0.82NW	0.98	324	0.81	0.84
Sub adult & Adult	DW = 30.20 + 0.15NW	0.63	324	0.13	0.16
Sub adult & Adult	CW = 13.24 + 0.11NW	0.65	324	0.10	0.12
Old adult	TW = 57.21 + 0.15NW	0.53	597	0.14	0.16
Old adult	SW = -57.21 + 0.85NW	0.97	597	0.84	0.86
Old adult	DW = 43.86 + 0.12NW	0.52	597	0.11	0.13
Old adult	CW = 22.50 + 0.09NW	0.48	597	0.08	0.10

Table 4. Conversion factors to nominal weight for queen conch from the Antigua and Barbuda shelf. 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	310	5.08	0.99	4.97	5.19
	Sub adult	14	4.96	0.51	4.66	5.26
	Adult	310	5.25	0.92	5.14	5.35
	Old adult	597	5.82	0.99	5.74	5.90
	Total	1231	5.47	1.02	5.42	5.53
Shell weight	Juvenile	310	1.27	0.18	1.25	1.29
	Sub adult	14	1.26	0.03	1.24	1.28
	Adult	310	1.24	0.04	1.24	1.25
	Old adult	597	1.22	0.04	1.21	1.22
	Total	1231	1.24	0.10	1.23	1.24
"Dirty" meat weight	Juvenile	310	6.55	1.62	6.37	6.74
	Sub adult	14	6.09	0.79	5.64	6.55
	Adult	310	6.33	1.22	6.20	6.48
	Old adult	597	7.12	1.28	7.01	7.22
	Total	1231	6.77	1.40	6.69	6.85
"Clean" meat weight	Juvenile	310	9.79	2.52	9.50	10.07
	Sub adult	14	8.60	1.00	8.02	9.18
	Adult	310	9.09	1.67	8.91	9.28
	Old adult	597	10.59	2.07	10.43	10.76
	Total	1231	9.99	2.19	9.87	10.11

DISCUSSION AND CONCLUSION

The variability in shell size distribution found among the coast, confirmed anecdotal information provided by fishers, where conch from the south and east were significantly larger than those from the north or west ($p < 0.05$). With this difference, regulations based solely on a uniform minimum shell length of 180 mm would be ineffective since large juveniles particularly from the east coast would not be protected; the mean shell length for juveniles from the east coast was 188 mm (Figure 2). In terms of lip thickness, conch from the north and west coast were significantly older than those from the east or south coast of Antigua ($p < 0.001$) (Figure 3). In part, this coincides with the history of the conch fishery in Antigua and Barbuda, where the traditional area of commercial exploitation was the south-west coast of Antigua (Horsford 2007). The mean lip thickness of conch from the north and west coast were approximately three-times that of those from the south (25.1 mm and 24.5 mm respectively versus 9.2 mm). The lip thickness of conch from the east was about two-times that of those from the south (17.1 mm versus 9.2 mm) (Figure 3). This is a reflection of the relatively good health of the resources in these areas, which have been virtually unexploited at a commercial level prior to 2001. The results are consistent with the findings of earlier studies where no significant negative trends were detected with respect to the catch per unit effort, depth dived or "dirty" meat weight landed (Horsford 2004, 2008 and 2010).

Significant sexual dimorphism was only detected for adult conch ($p < 0.001$), with females being 4% larger than their male counterpart (Figure 4). One possible consequence of sexual dimorphism is that regulations governing legal minimum size may result in a differential selection between the sexes. This was confirmed in the case of commercial fishing trips, when 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. The mean lip thickness for conch collected from commercial trips was 25.0 mm (n = 785, S.D. = 5.5 mm) indicating that commercial divers were targeting an old population. The oldest conch on record collected by conch divers had a lip of 63.0 mm, for this study the maximum lip thickness was 43.2 mm. In terms of level of compliance with fisheries regulations, 98.6% of the commercial sample (n = 796) had a flared-lip shell. This validates compliance rates obtained from routine inspection conducted by the national coast guard and fisheries department as well as conch biological data collection programme; over the past decade the mean rate of compliance regarding size restrictions was 88% and in 2009, 2.1% of conch sampled (n = 144) were below the minimum meat weight of 225 g (Horsford 2010). The high level of compliance was attributed to the small, homogenous nature of the fishery (fishers came from the same community), the participatory approach taken with respect to management (including research), and the conservation awareness programme in fishers community (Horsford 2010).

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. This result primarily from tissue growth accumulated since maturation being added to tissue weight that existed at the time of maturation, and secondarily from slight decreases in shell length of adults due to erosion (Appeldoorn 1994). 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 lost with age. Hence, the reason why old adults yielded 20% less "dirty" meat for every 100 g increase in nominal weight when compared to sub adults and adults, and the goodness of fit of the regression models decreased with age.

Conch is typically landed commercially, in Antigua and Barbuda as "dirty" meat, where the shell and visceral mass are removed; "clean" meat, where shell, visceral mass, mantle collar, operculum, radula and digestive tract are removed, is landed to a less extent. The different forms of landed product emphasise the need for proper conversion factors. Antigua and Barbuda currently utilises a conversion factor of 7.5 to transform the "dirty" meat to nominal weight; this value was provided by the Food and Agriculture Organization of the United Nations. Based on this study, 7.5 is outside the range of conversion factors for Antigua and Barbuda; for "dirty" meat to nominal weight, values ranged from 6.09 to 7.12 depending on maturity. Upon examination of landings with respect to overall level of maturity, the appropriate conversion factor should be applied according to Table 4. In cases where this is not possible, a conversion factor of 7.12 should be applied if landings are from full-time commercial conch vessels based on their target population; in all other cases the pooled conversion factor of 6.77 is appropriate. Conversion factors and regression equations for shell weight according to maturation stage will also allow for proper estimates of the value and quantity of illegal conch in cases where shell middens are the only evidence.

Since conversion factors differed significantly among maturation stages ($p < 0.001$), and the differences among the conversion factors for the various maturation stages increased with the level of processing, the use of a single conversion factor to transform processed conch to nominal weight is problematic. Aspra et al. (2009) indicated that field studies conducted on conch from the Dominican Republic, Honduras and Nicaragua produced slight but significant differences between conversion factors for processing grades between countries. For example, the conversion factor for tissue weight (referred to as dirty meat in their study) to nominal weight, was as follows: Nicaragua, 5.48; Honduras, 5.83; and Dominican Republic, 6.07. Values for Antigua and Barbuda ranged from 4.96 for sub adults, to 5.82 for old adults, with the pooled value being 5.48 (Table 4), interestingly closer to the values of the Central American countries as opposed to the Caribbean. Despite differences, conversion factors can be considered to be in same order. Aspra et al. (2009) proposed the possibility of a "theoretical" conversion factor using the mean of the three national conversion factors. Their study however did not consider how conch demographics may impact national or regional conversion factors. The use of this "theoretical" conversion factor to make data series consistent throughout the years and comparable among all countries may mask important developmental changes or events in the fishery that should be recorded (e.g., changes in the age structure or demographic of conch population as the fishery evolves over time). Hence, the validity of conversion factors should be monitored over time to ensure that the reference point has not shifted due to changes in demographics, from factors such as over-fishing.

These morphological differences with respect to location, sex and maturation stage require a multifaceted management approach to ensure the long term sustainability of the conch fishery. Hence closed season, marine protected areas, harvest quotas, gear restrictions, are some of the management options needed to be combined with size restrictions; since minimum weight alone does not limit harvest to sexually matured individuals and can result in the favouring of females for harvesting. 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 shortly 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. The conch closed season would extend from 1st July to 31st August of every year and a minimum 5 mm shell lip thickness would be incorporated into the regulations. Current biological programme to monitor conch that is removed from the shell, incorporates the evaluation of the reproductive structure (i.e., verge for males and egg groove for females) for reproductive maturity based on work done by Appeldoorn (1988). A gauge for conch divers, based on the 5 mm criterion, will be incorporated into the currently gauge utilised by lobster fishers and exporters (Horsford 2010).

In terms of future research, this study should be broadened to include the Barbuda portion of the Antigua and Barbuda shelf, particularly since Brownell and Stevely (1981) documented the depletion of conch from shallow waters of western Barbuda in the early 1970s. Preliminary survey of Barbuda and anecdotal information from fishers suggest stocks may be relatively healthy. With respect to the processing and marketing of conch meat, fishers are encouraged to standardise their method of processing as well as the terminologies used to describe the different levels of processed meat. This would improve compatibility of data, harmonise trading and to a lesser extent the management of conch at the national and regional level.

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