Size-maturity Indicators in Queen Conch (*Lobatus gigas*) of Port Honduras Marine Reserve, Belize: Strengthening Management for Improved Fisheries Sustainability

Indicadores de Talla Versus Madurez en Caracol Rosado (*Lobatus gigas*) de la Reserva Marina de Port Honduras, Belice : Fortaleciendo la Gestión para Mejorar la Sostenibilidad de la Pesquería

Indicateurs Taille-maturité dans Lambi (*Lobatus gigas*) de Réserve Marine Port Honduras, Belize : Renforcement de la Gestion pour L'amélioration de la Durabilité de la Pêche

JAMES FOLEY
Toledo Institute for Development and Environment, Punta Gorda, Belize. Jfoley@Tidebelize.Org

EXTENDED ABSTRACT

Introduction

Queen conch (*Lobatus gigas*) is an important food source and export product for Belize. Overfished in many parts of the Caribbean, international trade of *L. gigas* is regulated by CITES. Extraction in Belize is regulated by a 17.8 cm (7 inch) national shell length limit or 85 g (3 oz) market-clean meat weight limit, 3-month closed season, and full protection in Replenishment Zones. However, PHMR fisheries-independent surveys between 2009 - 2015 indicate population decline to below the 88 conch/ha minimum density threshold recommended by the Belize Fisheries Department with apparent recruitment failure since 2013. Fisheries-dependent surveys between 2009 - 2012 revealed that while fishers are largely adhering to the shell length limit, the proportion of catch with shell lip thickness < 9 mm (males) and < 12 mm (females) - minimum maturity thresholds in other studies - increased from ~30% in 2009 to ~90% in 2012. Other studies show lip thickness is a more reliable indicator of maturity, but varies on local and regional scales and needs to be determined locally. Relationships were compared between gonad development and shell length, lip thickness, meat weight and operculum dimensions to determine the most reliable, easily measured proxy indicator(s) of maturity in *L. gigas* of PHMR that can be feasibly implemented to ensure immature individuals are protected from harvest. No relationship was found between shell length and maturity at any time. Lip thickness-maturity relationships were strong and most significant during the closed, reproductive season (Period 2) ($p < 0.01$), likely due to peak gonad development during this time, and indicated 80% probability of being sexually mature with good fecundity at lip thicknesses 18 mm for males and 20 mm for females. An non-linear management approach that integrates initial catch reductions, temporary closures, Replenishment Zone expansion and adaptive lip thickness limits could achieve long-term sustainability of *L. gigas* in PHMR, and minimize short-term impacts yet maximize long-term benefits on fishers' livelihoods.

Methodologies

To understand seasonal dynamics in conch maturity, sample collection was divided into three seasonal periods.

i) Period 1 (late open season) February - March 2015,
ii) Period 2 (closed & reproductive season) July - August 2015, and
iii) Period 3 (early open season) November - December 2015.

Samples were obtained from sites in PHMR known as good conch fishing grounds, recording sex, shell length, lip thickness, lip width, operculum length & width, unprocessed weight and market clean weight. Gonadosomatic Index (GSI) was calculated as the ratio between gonad weight and total unprocessed meat weight. For histology analysis, each sample was scanned on a compound light microscope to classify samples by sex and maturity stages using a gonadal maturity phase scale (ranging between no germ tissue, immature, early developing, late developing, spawning capable and regressing), and % germ tissue cover scale (ranging between 0 - < 25%, 25 - < 50%, 50 - < 75% and > 75% germ tissue coverage) (Stoner et al. 2012, Delgado et al. 2004). Maturity derived using GSI, phase scale and % cover scale methods was compared with physical metrics for males and females. Polynomial regression was used to determine statistical significance for GSI relationships. Binomial logistic regressions were used to determine significance of histology-derived relationships. For management, size-maturity thresholds were only recommended when both phase scale and % cover scale relationships were significant ($p < 0.01$) with relationships reaching 95% probability of being mature (spawning capable, regressing or spent) and having > 50% germ tissue cover, as well as achieving a minimum probability of < 20%.

Results

514 specimens were examined; 221 males, 293 females. GSI analysis yielded clear relationships between GSI and LT for both sexes during all periods (males - Period 1: $r^2 = 0.42$; Period 2: $r^2 = 0.44$; Period 3 $r^2 = 0.11$; females - Period 1: $r^2 = 0.26$, Period 2: $r^2 = 0.26$, Period 3: $r^2 = 0.26$). No relationship was observed between SL and GSI (males - Period 1: $r^2 = 0.02$; Period 2: $r^2 < 0.01$; Period 3 $r^2 < 0.01$; females - Period 1: $r^2 < 0.01$; Period 2: $r^2 = 0.13$; Period 3: $r^2 = 0.05$). Histolo-

gy-derived size-maturity relationships were strongest in Period 2 (reproductive season), with a significant relationship between LT and probability of maturity derived using the phase scale for both males and females (both $p < 0.05$) (Figure 1-A); males exhibited 80% probability of maturity (spawning capable/regressing/spent) at 13.7 mm LT, females at 16.4 mm LT, and a 95% probability of maturity at 20.1 mm LT (males), 19.2 mm LT (females). Period 2 % cover scale analysis also yielded significant LT-maturity relationships for males and females (both $p < 0.05$) (Figure 1-B); males exhibited 80% probability of maturity (spawning capable/regressing/spent) at 17.8mm LT, females at 19.8 mm LT, and a 95% probability of maturity at 24.0 mm LT (males), 24.8 mm LT (females). No relationships between SL and maturity were significant using both phase scale and % cover scale analysis for either sex during any Period. There were also significant market clean weight-maturity relationships for females only in Period 2 ($p < 0.05$) with phase scale analysis yielding 80% probability of maturity at 273 g, 95% probability of maturity at 355 g, and only 10.5% probability of maturity at the current legal market clean weight limit of 85 g. Market clean weight-maturity relationships were unclear for males.

Conclusions

There was an 80% probability of both maturity (spawning capable/regressing) and good fecundity (> 50% germ tissue cover) by 17.8 mm LT for males and 19.8 mm LT for females. There was a 95% probability of both maturity and good fecundity by 24.0 mm LT for males and 24.6 mm LT for females. There was an 80% probability of maturity females only by 273 g market clean weight, although this relationship did not reach 95% probability of > 50% germ tissue cover. There was a 10.5% probability of maturity at the current 85 g legal market clean weight limit in females. Market clean weight relationships were unclear for males. No relationships between SL and maturity were significant for either sex during any Period. All Periods combined, 35.5% of males, and 67.0% of females of legal size were not mature using phase scale analysis. Therefore many legal sized conch that are in fact immature are vulnerable to harvest because they reach legal SL limit before maturity. This could explain the stock decline in recent years. Shell length regulation alone is therefore not achieving its intended management objective of protecting all immature conch from being harvested during the open season (Avila-Poveda and Baqueiro-Cárdenas 2006), posing a threat to sustainability of conch in PHMR.

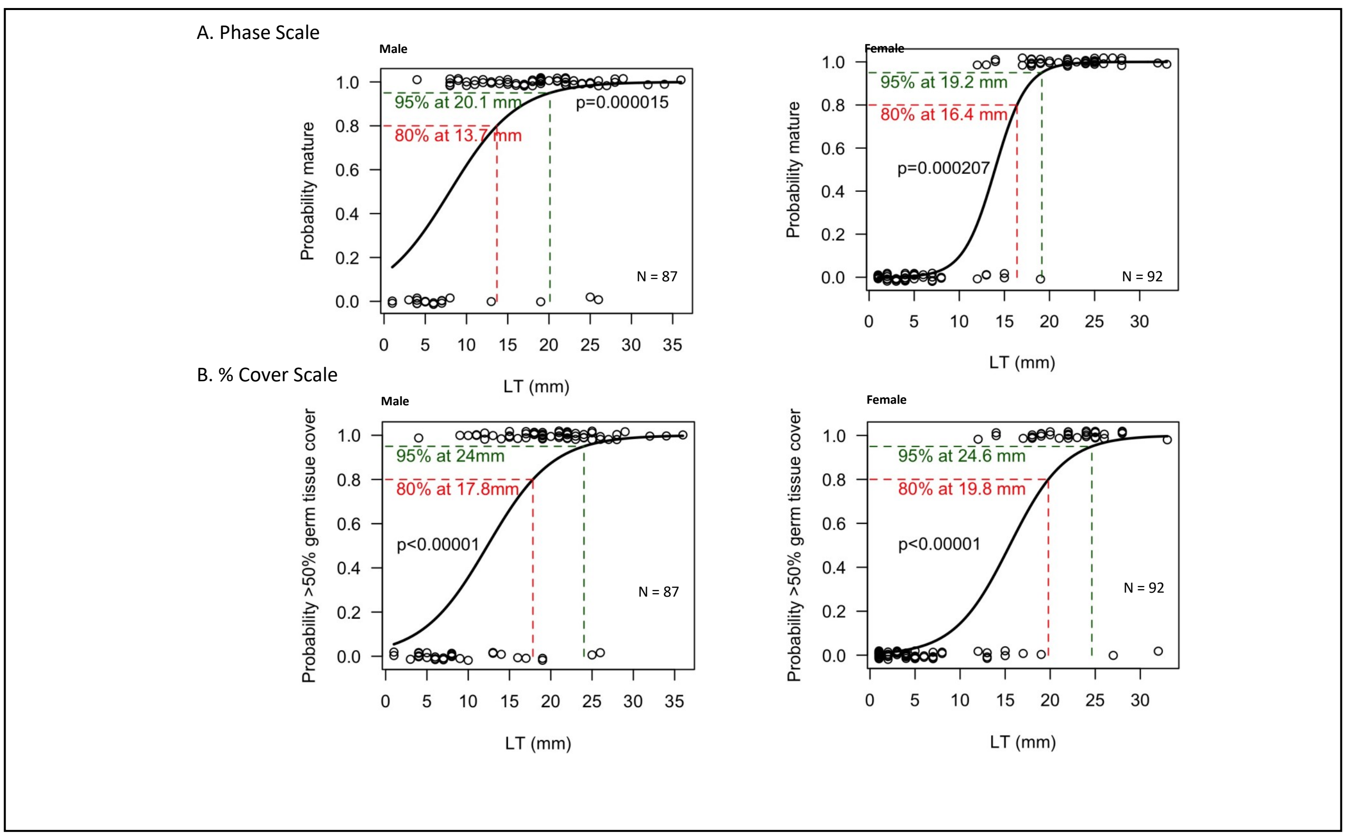

Figure 1. Period 2 - logistic regressions of lip thickness (LT) vs probability mature, males (left); females (right). (A) Phase Scale - spawning capable & regressing specimens considered mature; no germ tissue, immature, early developing, late developing and no germ tissue considered not mature. (B) % Germ Tissue Cover Scale - $\geq$ 50% cover considered mature; < 50% considered not mature.

Recommendations

A non-linear adaptive management approach is proposed, whereby either a quota reduction or moratorium is introduced for at least two years, followed by reopening of a spatially restricted fishery comprising temporary closures in some areas of PHMR alongside expansion of permanent Replenishment Zones. This could preserve older adult spawners capable of producing many times more eggs than younger adults, thereby promoting stock recovery in minimal time, creating pockets of high density populations to reproduce and replenish more impacted areas to above the 88 conch/ha threshold. Once mean density returns to > 88 conch/ha, an adaptive LT limit could be introduced, assessed annually through TIDE's fisheries-independent and fisheries-dependent surveys. A modeling approach may determine recovery timescales under different adaptive LT limit options to be implemented in future seasons. Fishers would then be empowered to make informed decisions over how they would like the fishery to be managed, striking the optimal balance between achieving stock recovery in the quickest time and minimizing short-term economic impacts to within limits acceptable to fishers.

KEYWORDS: Conch, maturity, size, fisheries, sustainability

ACKNOWLEDGEMENTS

Research Staff: Miwa Takahashi, Tom Irvine, Marty Alvarez, Tanya Barona, TIDE Community Researchers; Managed Access fishers; Belize Fisheries Department; Belize Coastguard. *Funding:* Protected Areas Conservation Trust (PACT).

LITERATURE CITED

Avila-Poveda, O.H. and E.R. Baqueiro-Cárdenas. 2006. Size at sexual maturity in the queen conch *Stombus gigas* from Colombia. *Boletín de Investigaciones Marinas y Costeras* **35**(1):223-233.

Delgado, G.A., C.T. Bartels, R.A. Glazer, N.J. Brown-Peterson, and K.J. McCarthy. 2004. Translocation as a strategy to rehabilitate the queen conch (*Strombus gigas*) population in the Florida Keys. *Fishery Bulletin* **102**(2):278-288.

Stoner, A.W., K.W. Meuller, N.J. Brown-Peterson, M.H. Davis, and C.J. Booker. 2012. Maturation and age in queen conch (*Strombus gigas*): urgent need for changes in harvest criteria. *Fisheries Research* **131-133**:76-84.