Size Related Distribution and Mobility of the Queen Conch *Strombus gigas* in the Xel-Há Park, Mexican Caribbean

Distribución y Movilidad del Caracol Rosa *Strombus gigas* en Función de la Talla, en el Parque de Xel-Há, Caribe Mexicano

Distribution et Mobilité du Lambi *Strombus gigas* Corrélée à sa Taille au Parc du Xel-Há, Caraïbe Mexicaine

JOANNE REBECCA PEEL* and DALILA ALDANA ARANDA
Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional (CINVESTAV), Km 6 Antigua Carretera a Progreso, Mérida, Yucatán, México. *jrpeel@gmx.de.

ABSTRACT

The queen conch *Strombus gigas* is a large herbivorous gastropod which represents one of the most important fishery resources of the Caribbean. High fishing pressure and destruction of its natural habitat have caused severe depletion of stocks throughout the region and many of the populations haven't recovered despite of management and rehabilitation efforts. The conch's life cycle is highly complex, implying various ontogenic habitat shifts and migrations. The distribution of juveniles generally is restricted to certain areas and the majority of the previous studies are either biased towards aspects of juvenile ecology or adult ecology, but few studies have addressed connectivity between nurseries and reproductive aggregations. The inlet of Xel-Há is a natural protected area under private administration, hosting a population of *S. gigas*. In the present study we assessed size distribution and mobility throughout the inlet using a stratified mark-recapture scheme at four sites (*Cueva*, *Centro*, *Bocana* and *Brazo N*) in order to determine how *S. gigas* uses its habitat and how the different stages of its life cycle connect in it. A total of 8,292 conch was tagged between 2005 and 2011. The population was composed of 70% juveniles. At *Cueva*, *Centro* and *Brazo N* mainly juveniles were captured, while at Bocana mostly adults were encountered. Mobility increased in adult and sub-adult conch and during summer months. Spatial distribution and mobility could be associated to length and lip thickness, suggesting that conch might undergo ontogenetic niche shift as they reach sexual maturity.

KEY WORDS: Migration, connectivity, ontogenic niche, population structure, spatial distribution

INTRODUCTION

Strombus gigas is a large herbivorous gastropod, endemic to the Caribbean region (Abbott 1974). This species represents one of the most important fishery resources to the area, being the second largest fishery after the spiny lobster (Brownell and Stevely 1981, Chakalall and Cochrane 1996). Increasing fishing pressure and destruction of its natural habitat have lead to the depletion of stocks throughout the Caribbean (Stevely 1979, Berg and Glazer 1994, Stoner 1996, Delgado et al. 2004) and many populations have not recovered despite of ongoing management efforts (Glazer and Berg 1994. Berg and Glazer 1995, Stoner and Ray-Culp 2000). In the 1990s, *S. gigas* was included into CITES Appendix 2 and classified by IUCN as commercially threatened (Acosta 2006).

The conch's life cycle is highly complex, with a pelagic larval stage, infaunal juvenile stage, epibentonic juvenile stage and epibentonic adult stage, implying various ontogenic habitat shifts and migrations. Up to the date, at least two types of migration have been described: juvenile migrations (Stoner et al. 1988, De Jesús-Navarrete and Valencia-Beltrán 2003, Danylchuck et al. 2003) and seasonal adult migration (Robertson 1959, Alcolado 1976, Hesse 1979, Appeldoorn 1997).

The distribution of juveniles is generally restricted to certain areas, while adult distribution may be more extensive (Alcolado 1976, Appeldoorn 1987). Many of the previous studies on this species are either biased towards aspects of juvenile ecology or adult ecology (Appeldoorn 1987), but few studies have addressed connectivity between nurseries and reproductive aggregations.

The inlet of Xel-Há is a natural protected area under private administration, hosting an important population of juveniles and old adult conches (Baqueiro-Cárdenas and Aldana Aranda 2010), allowing us to study the complete life cycle of this species in a semi-enclosed natural environment. In the present study, we assessed size distribution and mobility throughout the Inlet, using a stratified mark-recapture scheme at four sites (*Cueva*, *Centro*, *Brazo N* and *Bocana*), with the objective to determine how *S. gigas* uses its habitat and how the different stages of its life cycle connect in it.

MATERIAL AND METHODS

Study Site

Xel-Há is located on the east coast of the Yucatan Peninsula (20°19'15"-20°18'50"N and 87°21'41"-87°21'15"W) (Figure 1). The area is characterized by input of freshwater from underground rivers due to karstic conditions in the Peninsula. Xel-Há is a highly stratified coastal lagoon that consists of a mix of fresh groundwater with seawater. The Inlet is connected to the Caribbean Sea by a 100 m wide channel and has a total surface of 14 ha, with a center area and three appendices: Bocana, North Arm and South Arm. Its depth ranges from 0.5 – 4.5 m. (Organismo de Cuenca Península de Yucatán Dirección Técnica, 2008). Within the Inlet we sampled four sites: *Cueva* (6,000 m²), *Brazo N* (6,000 m²), *Centro* (23,000 m²) and *Bocana* (10,000 m²).

Population Parameters

From January 2005 to January 2008 samplings were carried out monthly, and from April 2009 to September 2011 every two months. All organisms were collected in free-dive by three divers during 3 hours at each of the sites. We used mark-recapture method, marking all individuals with a plastic Dymo® tag, bearing a consecutive number, which was fixed to the spire of the conch with a plastic cable binder. A total of 8,292 individuals were tagged throughout the whole study. In order to evaluate population structure and size distribution, shell length and lip thickness were determined for each individual, using a precision caliper accurate to ± 1 mm. All animals were released at the same location they were found.

Statistical Analysis

Population structure was determined calculating the relative abundance of juveniles (organisms without lip), subadults (organisms with lip < 5 mm) and adults (organisms with lip ≥ 5 mm (Appeldoorn 1988, Aldana Aranda and Frenkiel 2007)) within the whole Inlet and within each of the four sampling sites. Pie charts were employed to visualize results.

Tag recovery was used to determine the number of animals that emigrated from their original tagging site. Then we calculated the percentage of juveniles, subadults and adults participating in these migrations, applying the same method as mentioned before.

Mean shell length of migrating conch and its standard deviation was calculated using the program Infostat/S. In order to determine significant differences between shell length and destiny of migrations, we applied analysis of variance (ANOVA), using 95% confidence level. The same treatment of data was employed concerning lip thickness data.

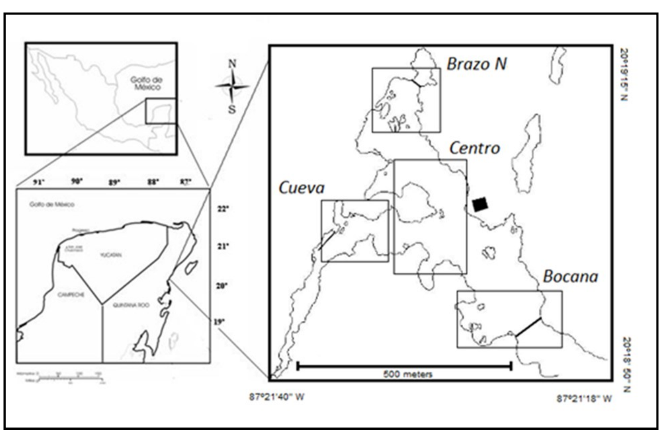

Figure 1. Location of marine protected area Xel-Há Park, Quintana Roo, Mexico and sampling sites within the Inlet: *Cueva*, *Brazo N*, *Centro* and *Bocana*.

RESULTS

The population found in the Xel-Há Inlet is mainly composed of juvenile organisms, representing 69% of the sampled population (Figure 2). Only 31% of the sampled animals had developed a flaring lip, of which 18% could be considered adults (Figure 2).

Conch distribution showed differences throughout space. More than 70% of the conch found at *Brazo N*, *Centro* and *Cueva* were juveniles, while at *Bocana* only 32% of the conches sampled were juveniles (Figure 3). Subadult abundance was lowest at *Cueva* (Figure 3). There was a strong gradient in the distribution of adults throughout the lagoon, encountering less than 10% adults at *Cueva* and *Brazo N*, 12% at *Centro* and 58% at *Bocana*, the site that connects the lagoon to the Caribbean Sea (Figure 3).

Figure 4 shows the origin of queen conch captured at each sampling site. At *Cueva* (Figure 4A) and *Brazo N* (Figure 4B), the majority of animals encountered were conches either tagged at those sites or animals without tag.

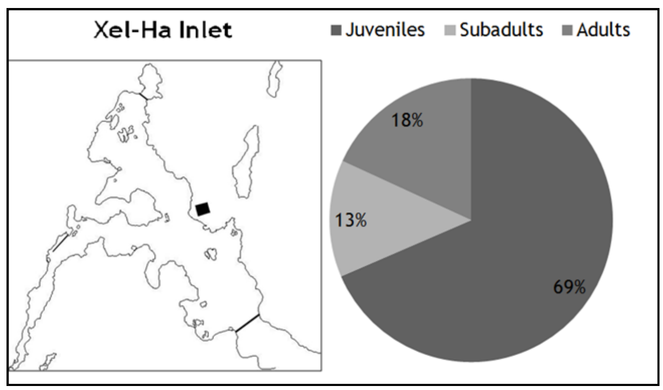

Figure 2. Relative abundance (%) of juvenile (no lip), subadult (lip < 5 mm) and adult (with lip ≥ 5 mm) queen conch *S. gigas*, in the Xel-Há Inlet.

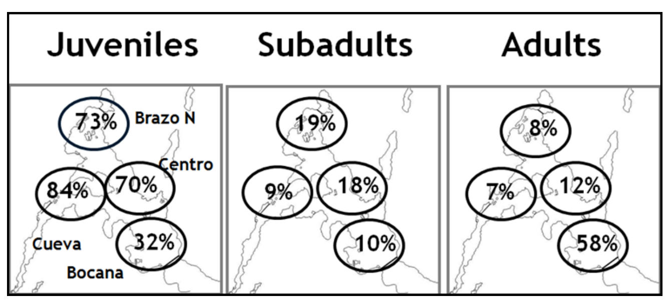

Figure 3. Relative abundance (%) of juvenile (no lip), subadult (lip < 5 mm) and adult (with lip ≥ 5 mm) queen conch, *S. gigas,* at the four sampling sites (*Cueva, Brazo N, Centro* and *Bocana*), of the Xel-Há Inlet.

Less than 5 % of conches captured at those two sites had immigrated from *Centro* or *Bocana*. At *Centro* (Figure 4C), also, most of the animals encountered, were animals without tag or tagged there. Nevertheless, up to 20% of the animals recovered had been originally tagged at *Cueva* or *Brazo N*, suggesting that animals had moved from the interior of the Inlet to *Centro*, but less than 3% of the animals were conches tagged at *Bocana*. At *Bocana* we found the highest proportion of tagged animals, most of which had been originally tagged there, but up to 30% of the recaptured animals had been marked in the first place at *Cueva*, *Brazo N* or *Centro*, indicating that animals had moved from the interior of the lagoon to the mouth.

Conch mobility varied in frequency throughout the study period (Figure 5). Frequency of emigration from *Cueva* (Figure 5A), *Brazo N* (Figure 5B) and *Centro* (Figure 5C) increased over the sampled period and in the months from March to November, being generally highest in July and September.

Most of the conches emigrating from their original tagging sites were adults (Figure 6).

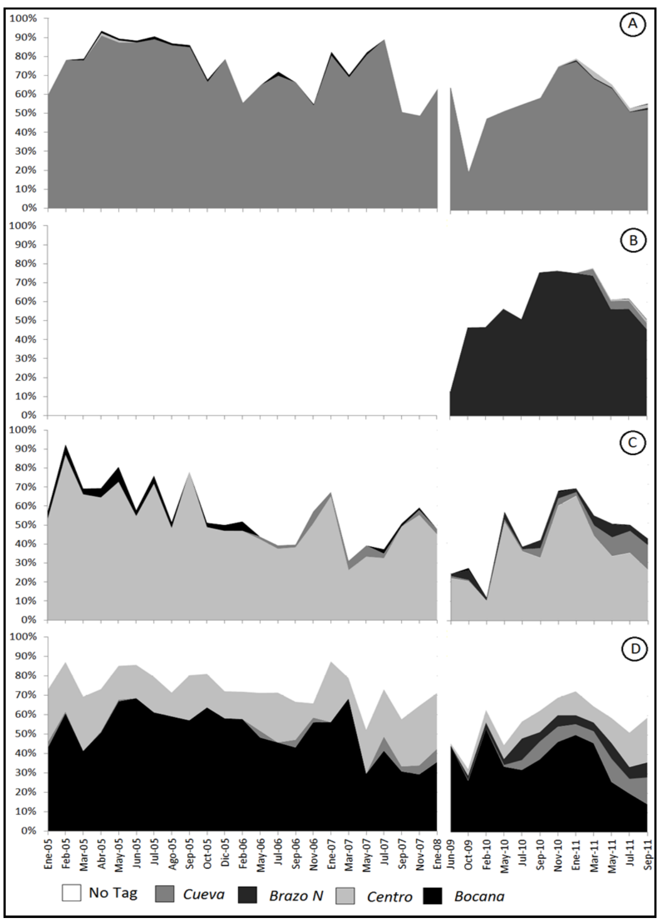

Figure 4. Sampling site tag composition, showing queen conch *S. gigas* captured at (A) *Cueva*, (B) *Brazo N*, (C) *Centro* and (D) *Bocana*, and origin of conch within the Xel-Há Inlet (*Cueva*, *Brazo N*, *Centro*, *Bocana* or no tag).

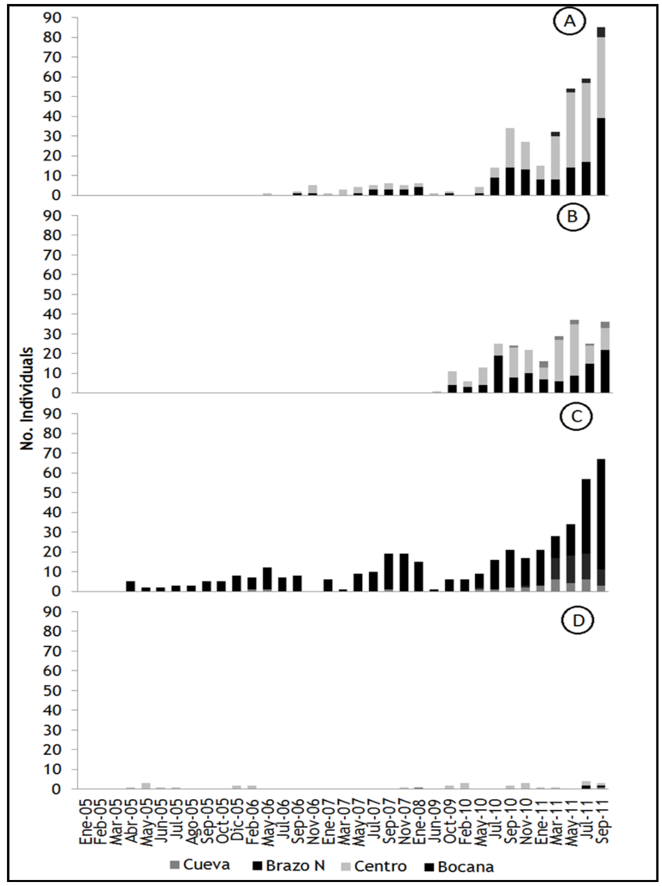

Figure 5. Frequency of emigration of the queen conch *S. gigas* from the four sampling sites (A) *Cueva*, (B) *Brazo N*, (C) *Centro* and (D) *Bocana*, of the Xel-Há Inlet.

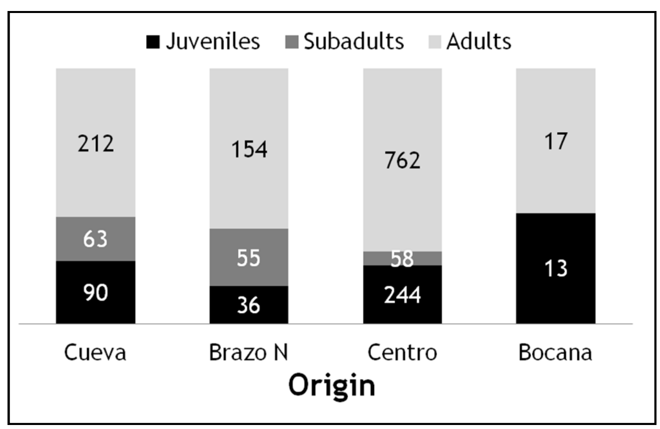

Figure 6. Number of juvenile (no lip), subadult (lip < 5 mm) and adult (with lip ≥ 5 mm) queen conch, *S. gigas*, which participated in the emigration from each of the four sampling sites (*Cueva*, *Brazo N*, *Centro* and *Bocana*), of the Xel -Há Inlet.

Figure 7 shows average shell length of those conches which emigrated from their original tagging site. In the case of conches emigrating from *Cueva*, *Brazo N* and *Centro,* the average size ranged from 205 to 215 mm. There were no significant differences between shell length and the destiny of movements. In the case of conches emigrating from *Bocana*, shell length was much more variable.

Nevertheless, concerning lip thickness (Figure 8), we detected significant differences depending on the destination of migrations. Conch with thicker lips generally tended to migrate towards *Bocana*.

DISCUSSION

The conch population found at Xel-Há was mainly composed of juveniles. This result was consistent with findings of Aldana Aranda et al. (2005), who reported 79.2% juveniles and subadults in the Inlet in the sampling period from 2001 – 2003. Tewfik and Bené (2000) and De Jesús-Navarrete et al. (2003) reported populations composed mainly of juveniles, but both research teams attribute low adult abundance to fishing impact. On the other hand, Hesse (1979) described populations with a juvenile adult ratio of 3:1, which she could attribute to increased mobility of adults. Fishing is prohibited in Xel-Há, suggesting that the population composition found in this study is natural and can be ascribed to other factors, such as emigration, as this study suggests.

We observed spatial segregation of juveniles and adults. This was consistent with findings of Aldana Aranda et al. (2005), who reported 76% juveniles in *Cueva* and 82% adults in *Bocana* in a study conducted between 2001 and 2003. Alcolado (1976) and Stoner and Ray (1996) determined that nurseries are usually restricted to certain sites, with special environmental features. Corporal size of an organism is a key aspect of its ecology, determining its

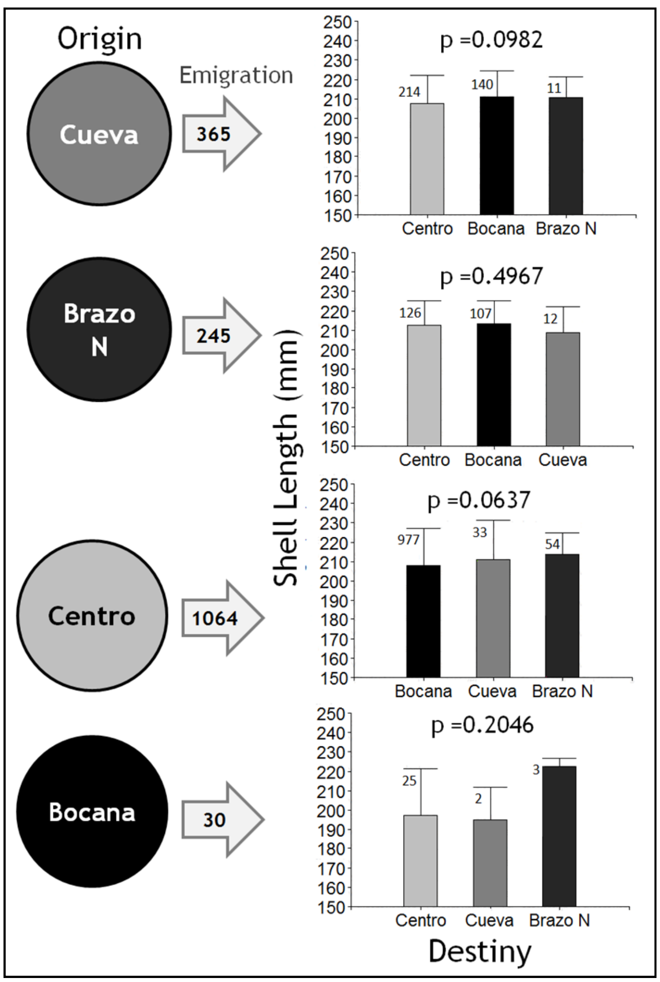

Figure 7. Average shell length and its standard deviation of queen conch *S. gigas* that emigrated from their original tagging site (Origin: *Cueva, Brazo N, Centro* and *Bocana*) to another sampling site (Destiny: *Cueva, Brazo N, Centro* and *Bocana*) of the Inlet of Xel-Há.

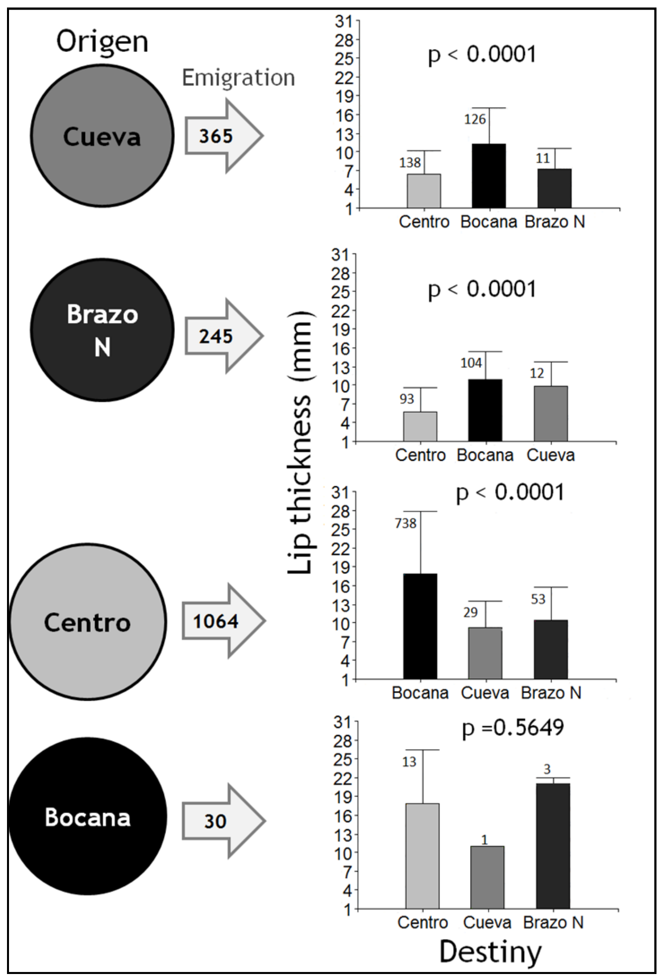

Figure 8. Average lip thickness and its standard deviation of queen conch *S. gigas* that emigrated from their original tagging site (Origin: *Cueva, Brazo N, Centro* and *Bocana*) to another sampling site (Destiny: *Cueva, Brazo N, Centro* and *Bocana*) of the Inlet of Xel-Há.

ability to exploit resources and susceptibility to predation (Werner and Gilliam 1984). Many species undergo extensive ontogenic shifts in food or habitat use, known as *ontogenic niche shifts*, as they increase in size. This phenomenon is especially well documented in aquatic communities (Werner and Gilliam 1984). We suggest that the sites in the interior of the Inlet probably function as nurseries while *Bocana* may be associated to reproductive activity.

Mobility and redistribution of conches in the Inlet appeared to be related to size. This result was consistent with observations made by Hesse (1979), reporting that mobility increases in conches > 170 mm. in the case of Xel-Há conch, average size of mobile conch was ~210 mm. Redistribution in the Inlet was related to lip thickness, encountering mainly older adult conch in *Bocana*.

Mobility of *S. gigas* in the Xel-Há Inlet increased between May and November. Hesse (1979), Glazer et al. (2003) and Doerr and Hill (2007) all report increased mobility during the summer months. Furthermore, conch reproductive season has been associated to increasing temperatures (Stoner et al. 1992, Pérez-Pérez and Aldana Aranda 2002, Pérez-Pérez and Aldana Aranda 2003, Appeldoorn 1990), so we conclude that the observed niche shift may be related to the first reproduction of these conches.

CONCLUSION

There is evidence that conch population segregate spatially in function of size, which is a key aspect of the existence ontogenic niche in this species. Most of the Xel-Há Inlet seems to function as a nursery, while the channel that connects it to the Caribbean Sea hosts mainly adults, suggesting that it is a reproductive site. Mobility and range of conch increase with size and spatial distribution could be attributed to lip thickness. Mobility increases during the summer months which may be related to reproductive behavior.

ACKNOWLEDGEMENTS

We thank CINVESTAV-Merida and CONACYT for the financial support. Special thanks go to Xel-Ha's Executive Director Elizabeth Lugo and Manager for Sustainable Management Ricardo Saenz for the unconditional support and unlimited access during our work. This work was supported by Xel-Ha's staff Enrique May, Angel Chavarría, Mario Hoil, Teresa Rivas and Rafael Benítes, without whom this work wouldn't have been possible.

LITERATURE CITED

Abott, R.T. 1974. *American Seashells; The Marine Molluska of the Atlantic and Pacific Coasts of North America*, *2nd Edition*. Van Nostrand Reinhold Company, New York, New York USA. 663 pp.

Acosta, C.A. 2006. Impending trade suspensions of Caribbean Queen Conch under CITES: A case study on fishery impacts and potential for stock recovery. *Fisheries* **31**:601-606.

Alcolado, P.M. 1976. Crecimiento, variaciones morfológicas de la concha y algunos datos biológicos del cobo *Strombus gigas* L. (Mollusca, Mesogastropoda). *Acad. Cienc. Cub Ser. Oceanol.* **34**:1-36.

Aldana Aranda, D. and L. Frenkiel. 2007. Lip thickness of *Strombus gigas*, Mollusca Gastropoda versus maturity: a management measure. *Proceedings of the Gulf and Caribbean Fisheries Institute* **58**:431-442.

Aldana Aranda, D., M. Sánchez-Crespo, P. Reynaga Alvarez, V. Patiño-Suárez, A. George-Zamora, and E.R. Baqueiro-Cárdenas. 2005. Crecimiento y temporada reproductiva del caracol rosa *Strombus gigas* en el parque Xel-Há, México. *Proceedings of the Gulf and Caribbean Fisheries Institute* **56:** 741-754**.**

Appeldoorn, R.S. 1987. Practical considerations in the assesment of queen conch fisheries and population dynamics. *Proceedings of the Gulf and Caribbean Fisheries Institute* **38**: 307-324.

Appeldoorn, R.S. 1988. Age determination, growth, mortality and age of first reproduction in adult queen conch, *Strombus gigas* L., off Puerto Rico. *Fisheries Research* **6**: 363-378

Appeldorn, R.S. 1990. Growth of juvenile queen conch, *Strombus gigas*, L., off La Parguera, Puerto Rico. *Journal of Shellfish Research* **9**:59-62.

Appeldoorn, R.S. 1997. Deep water spatial variability in the morphology of the queen conch and its implication for management regulations. In: CFRAMP (eds.) *Lobster and Conch Subproject Specification and Training Workshop Proceedings*, 9-12 October, Kingston, Jamaica. CARICOM Fishery Research Document No. 19.

Baqueiro-Cárdenas, E. and D. Aldana Aranda. 2010. Histories of success for the conservation of populations of queen conch (*Strombus gigas*). *Proceedings of the Gulf and Caribbean Fisheries Institute* **62**: 306-312.

Berg, C.J., and R.A. Glazer. 1995. Stock assessment of a large marine gastropod (*Strombus gigas*) using randomized and stratified towed-diver censusing. *ICES Marine Science Symposium* **199**:247- 258.

Brownell, W.N. and J.M. Stevely. 1981. The biology, fisheries and management of the Queen conch *Strombus gigas*. *Marine Fisheries Review* **43**(7):1-12.

Chakalall, B. and K.L. Cochrane. 1996. The queen conch fisheries in the Caribbean – An approach to responsible fisheries management. Pages 60-76 in: J.M. Posada, and G. Garcia-Moliner (eds.) *Proceedings of the First International Queen Conch Conference*. Caribbean Fisheries Management Council, San Juan, Puerto Rico.

Danylchuk, A., R.A. Mudd, G. Ingelise, and K. Baldwin. 2003. Size-dependent habitat use of juvenile queen conch (*Strombus gigas*) in East Harbour Lobster and Conch Reserve, Turks and Caicos Islands, BWI. *Proceedings of the Gulf and Caribbean Fisheries Institute* **54**:241-249.

De Jesús-Navarrete, A. and V. Valencia-Beltrán. 2003. Abundance of *Strombus gigas* zero-year class juveniles at Banco Chinchorro Biosphere Reserve, Quintana Roo, Mexico. *Bulletin of Marine Science* **73**: 232-240.

De Jesús-Navarrete, A., M. Domínguez-Viveros, A. Medina-Quej, and J.J. Oliva-Rivera. 2003. Crecimiento, mortalidad y reclutamiento del caracol *Strombus gigas* en Punta Gavilán, Q. Roó, México. *Ciencia Pesquera* **4**:1-4.

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

Doerr, J. C. & R. L. Hill. 2007. A Preliminary Analysis of Habitat Use, Movement, and Migration Patterns of Queen Conch, *Strombus gigas*, in St. John, USVI, Using Acoustic Tagging Techniques. *Proceedings of the Gulf and Caribbean Fisheries Institute* **60**:509-515.

Glazer, R.A. and C.J. Berg, Jr. 1994. Queen conch research in Florida: an overview. Pages 79-96 in: R.S. Appeldoorn and B. Rodríguez (eds.) *Queen Conch Biology, Fisheries, and Mariculture.* Fundación Científica Los Roques, Venezuela.

Glazer, R.A., G.A. Delgado, and J.A. Kidney. 2003. Estimating queen conch (*Strombus gigas*) home ranges using acoustic telemetry: implications for the design of marine fishery reserves. *Gulf and Caribbean Research* **14**(2):79-89.

Hesse, K.O. 1979. Movement and migration of the queen conch, *Strombus gigas*, in the Turks and Caicos Islands. *Bulletin of Marine Science* **29**:303-311.

Pérez-Pérez, M. and D. Aldana Aranda. 2002. Distribución, abundancia, densidad y morfometría de *Strombus gigas* (Mesogastropoda: Strombidae) en el Arrecife Alacranes Yucatán, México. *Revista de Biologia Tropicale* **48**:51-57.

Pérez-Pérez, M. and D. Aldana Aranda. 2003. Actividad de *Strombus gigas* (Mesogastropoda: Strombidae) en diferentes hábitats del arrecife Alacranes, Yucatán. *Revista de Biologia Tropicale* **51**:119-126.

Robertson, R. 1959. Observations on the spawn and veligers of conchs (Strombus) in the Bahamas. *Proceedings of the Malacological Society of London* **33**:164-171.

Stevely, J.M. 1979. The biology and fishery of the queen conch (*Strombus gigas*): a review. *Proceedings of the Tropical and Subtropical Fisheries Technology Conference of the Americas* **4**:203-210.

Stoner, A.W., R,N. Lipcius, L.S. Marshall, A.T. Bardales. 1988. Synchronous emergence and mass migration in juvenile queen conch. *Marine Ecology Progress Ser*ies **49**:51-55.

Stoner, A.W., V.J. Sandt, and I.F. Boidron-Metairon. 1992. Seasonality of reprodutucive activity and abundance of veligers in queen conch, *Strombus gigas*. *Fisheries Bulletin* **90**:161-170.

Stoner, A.W., P.L. Pitts, and R.A. Armstrong. 1996. The interaction of physical and biological factors in the large-scale distribution of juvenile queen conch in seagrass meadows. *Bulletin of Marine Science* **58**:217-233.

Stoner, A.W. and M. Ray-Culp. 2000. Evidence for Allee effects in an over-harvested marine gastropod: density-dependent mating and egg production. *Marine Ecology Progress Ser*ies **202**:297-302.

Tewfik. A. and C. Bené. 2000. Densities and age structure of fished versus protected populations of queen conch (Strombus gigas L.) in the Turks & Caicos Islands. *Proceedings of the Gulf and Caribbean Fisheries Institute* **51**:60-79.

Werner, E.E. and J.F. Gilliam. 1984. The ontogenetic niche and species interactions in size-structured populations. *Annual Review of Ecology and Systematics* **15**:393-425.