

Queen Conch (*Strombus gigas*): Endangered Species Status Review 2014-2019

Bibliography

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Background & Scope

In 2013, a status review on the queen conch was conducted to present biological information covering the queen conch, *Strombus gigas*. In 2019, there is a need to update this review to cover the last five years of research on the queen conch. This bibliography focuses on any relevant queen conch literature, from peer-reviewed scientific material to government reports. It is organized into three sections: fisheries management and regulations; life history; and threats.

Section I – Fisheries Management and Regulations

Section one is intended to provide an overview of new information since 2014 on the fisheries management and current regulations covering the queen conch. The research in this area covers management plans, stock assessments, ecosystem assessments, population status, and conservation plans.

Section II – Life History

Section two is intended to provide an overview of new information since 2014 on the biology and life history of the queen conch. The research in this area includes a compilation of diet, lifespan, habitat conditions, migration patterns, behavior, feeding, social ecology, and reproduction.

Section III – Threats

Section three is intended to provide an overview of new information since 2014 on the threats to queen conch's recovery. In this case, it is only a few articles, covering environmental contaminants and pollution as well as the sociological response to conservation that may threaten the queen conch's conservation plans.

Sources Reviewed

The following databases were used to identify sources: Clarivate Analytics' Web of Science: Science Citation Index Expanded and Social Science Index; Lexis Advance; ProQuest's Science and Technology including Aquatic Science Fisheries Abstracts; Elsevier's Science Direct ;JSTOR; EBSCO's Academic Search Complete and Environment Complete; NOAA's Institutional Repository; the Biodiversity Heritage Library; BioOneComplete; and Google Scholar.

Section I: Fisheries Management and Regulations

Acosta, C., Frank, A., Howard, K., & Robertson, D. (2019). Comparisons of Caribbean Spiny Lobster and Queen Conch Populations in Coastal Marine Reserves of Belize over 15 Years. *Gulf and Caribbean Research*, 30(1), 1-9 <https://doi.org/10.18785/gcr.3001.02>

Many coastal fisheries are increasingly reliant on marine protected areas (MPAs) as a fishery management strategy. However, the efficacy of any particular MPA depends on a complex suite of factors. This study investigates whether Caribbean spiny lobster *Panulirus argus* and queen conch *Lobatus gigas* abundance, mean size, and fishery productivity changed in MPAs over 15 years of increasing effective enforcement. A before-after control-impact design was used to analyze differences between years in the same protected and fished sampling sites. Catch-per-unit-effort was higher for both species in protected than fished zones, but there were no significant changes between 2001 and 2016. Mean conch size declined in most protected and fished areas between years, whereas mean lobster size was consistently higher in most protected areas. The proportions of fishery legal-sized animals were also higher overall in most protected areas but varied in the different reserves. A number of factors may operate to produce these results, including differences in MPA size and habitat area, differences in recruitment dynamics, and density dependence at habitat limits.

Baker, N. (2014). *Effectiveness of Management Regulations and Updated Analysis of Population Health and Trends of Queen Conch, Strombus Gigas, in Puerto Rico*. (Master of Science), University of Puerto Rico, Mayaguez, Puerto Rico. Retrieved from <https://scholar.uprm.edu/handle/20.500.11801/1121>

The queen conch resource continues to support a commercial fishery in Puerto Rico, despite a history of overfishing and low conch densities. The primary goal of this study was to generate density estimates for queen conch off western Puerto Rico using diver-based visual surveys and to assess trends and evaluate hypotheses of management interest using generalized linear mixed models. Density data were supplemented by size/age data. The spawning stock was also calculated and compared to a population (Abrir La Sierra) recently discovered at depths of 38-44m. Forty-six sites were surveyed and data on habitat, depth, estimated length, age class and reproduction were collected. Total density was 14.05/ha (adults = 7.32/ha; juveniles = 6.63/ha). Year (current and past surveys), depth and location were all significant factors influencing adult density. Lower densities of both juvenile and adult conch were observed in 1997 compared to 2006 and 2013. This result alone indicates some level of improvement in the population, though not recently. A location effect compared sites within the US EEZ (greater than 9NM from Puerto Rico) which is closed to fishing versus local waters which are open to fishing. Adult density was higher in shallower water; and regardless of depth or year, adult densities were higher in the EEZ than in local waters, though a greater proportional increase occurred in the EEZ. This suggests that though not statistically significant, the closure of the EEZ is having a positive effect on conch density. Length-frequency diagrams showed an increase in the proportion of adults within the 16-20 cm size class in 2006-2013 pooled relative to 1997. This suggests an effect of the 9inch minimum size limit implemented in 2004. In 1997, juveniles comprised 70% of the population, and no very old adults were found. In 2013, 50% of the population was juveniles, and adults were found in all the age classes, including very old adult. This suggests an overall decrease in fishing mortality. The spawning stock on the broad, shallow shelf was estimated at 172,705 individuals, significantly greater than the 29,092 individuals reported at Abrir La Sierra. Changes in survey methodology are recommended, including but

not limited to shortening the transects, not utilizing scooters, standardizing area surveyed, stratifying between depth and habitats, and increasing sites in the EEZ area.

Baker, N., Appeldoorn, R. S., & Torres-Saavedra, P. A. (2016). Fishery-Independent Surveys of the Queen Conch Stock in Western Puerto Rico, with an Assessment of Historical Trends and Management Effectiveness. *Marine and Coastal Fisheries*, 8(1), 567-579
<https://doi.org/10.1080/19425120.2016.1223232>

The queen conch *Lobatus gigas* continues to support a commercial fishery in Puerto Rico despite a history of overfishing and low population densities. The goals of this study were to generate density estimates for the queen conch, to assess temporal trends, and to evaluate hypotheses of management interest using generalized linear models. Density data were supplemented by size-and age-class data. Total mean density was 14.1/ha (adults = 7.3/ha; juveniles = 6.6/ha). Year plus habitat and depth (associated effects) were significant factors influencing adult and juvenile density. Lower densities of both juvenile and adult queen conchs were observed in 1997 and 2001 than in 2013, but there have been no differences since 2006. This indicates an improvement in the population, though not recently. A location effect compared sites within the U.S. Exclusive Economic Zone (EEZ), which is closed to fishing, with those in local waters, which are open to fishing. The location term was significant for adults, with lower densities inshore regardless of year. For juveniles, both the location and year x location terms were significant; the EEZ had a higher juvenile density and a proportionally greater density increase (from 2.3/h to 10.0/ha) from 1997 to 2013. Length-frequency diagrams showed an increase in the proportion of adult conchs of 16-20-cm shell length in 2013 relative to 1997. This suggests an effect of the 22.86-cm minimum size limit implemented in 2004. Juveniles comprised 50% of the population in 2013, compared with 70% in 1997, and adults were found in the oldest age-class during the 2013 survey. This suggests an overall decrease in fishing mortality since 1997. Changes in survey methodology are recommended, including but not limited to shortening transects to increase the number of sites, utilizing a two-stage design, not utilizing scooters, standardizing the areas surveyed, and stratifying by depth and habitat.

Bomhauer-Beins, L., de Guttery, C., & Ratter, B. M. W. (2019). When Culture Materializes: Societal Dynamics in Resilience of Social-Ecological Systems in the Case of Conch Management on Abaco, the Bahamas. *Sustainability*, 11(4), 17 <https://doi.org/10.3390/su11041080>

The concept of resilience has greatly contributed to the scientific discussion on human-nature interactions by analysing the dynamics, relationships and feedbacks between society and the natural environment at different levels. In this paper, we analyse how culture and societal dynamics influence those connections and, at the same time, have the potential to eventually hinder or foster social-ecological resilience. In order to do so, we take the example of a natural element which is also a cultural icon: the Conch (pronounced 'konk'). Conch is a marine mollusc with significant social and cultural value for the islands' society of The Bahamas. In the last decade, a decline in several Conch stocks has been documented, calling for an urgent sustainable management strategy. Nevertheless, only little efforts are happening. This case study offers an innovative understanding of resilience by introducing an aspect which is too often overseen: the role of culture in shaping social-ecological resilience. In this case study, the role of culture proved to be crucial as the cultural significance and embeddedness of Conch has made the management process challenging. But at the same time, culture can be used as a positive impulse towards adaptive management and as a starting point for sustainability. When culture

materializes, it affects not only societal dynamics but also the vulnerability and the resilience process of the entire social-ecological system.

Carrillo, L., Lamkin, J. T., Johns, E. M., Vasquez-Yeomans, L., Sosa-Cordero, F., Malca, E., . . . Gerard, T. (2017). Linking Oceanographic Processes and Marine Resources in the Western Caribbean Sea Large Marine Ecosystem Subarea. *Environmental Development*, 22, 84-96
<https://doi.org/10.1016/j.envdev.2017.01.004>

The western Caribbean, a subarea of the Caribbean Sea Large Marine Ecosystem, includes the Mesoamerican Barrier Reef System, the Yucatan Basin, the Cayman Basin and the Yucatan Channel. Here we discuss the main oceanographic features of the western Caribbean Sea and present some examples of marine resources distributed throughout the western Caribbean Sea LME subarea along different spatial scales. Particular attention is given to their planktonic stages when physical oceanographic features (such as eddies and gyres, or current systems) can operate either as forces that promote larval dispersal or as barriers enhancing larval retention, as this determines their connectivity. Bluefin tuna, the early life stages (eggs and larvae) of reef fish, the Caribbean Spiny lobster, and the Queen conch are presented as examples. Dispersal distances depend on the oceanographic phenomena, with larger dispersals expected where intense currents occur, such as in the Yucatan Current. Conversely, retention can be expected in the presence of gyres such as the Honduras Gyre and Yucatan Basin eddies. There is a growing body of evidence supporting the need for a multi-scale approach in order to understand the complexity of LMEs. Moreover, the connectivity between regions in the western Caribbean Sea LME subarea, as shown by the exchange of marine resources and physical oceanographic processes, requires an international policy that supports collaborative efforts to monitor the dynamics of coastal and oceanic habitats together with marine resources.

Chan, I., Tseng, L. C., Dahms, H. U., & Hwang, J. S. (2013). Population and Growth of Queen Conch (*Lobatus Gigas* Linnaeus, 1758) in the Sapodilla Cayes Marine Reserve of Belize. *Zoological Studies*, 52, 8 <https://doi.org/10.1186/1810-522x-52-46>

Background: The conservation effectiveness of marine protected areas is of substantial dispute. In the Belize Barrier Reef, there are several zones with increasing human activity and harvesting of overexploited species. Marine protected areas are designed to protect endangered species and increase the population size of exploited species. The present study investigated the population and morphological characteristics of *Lobatus gigas* (Linnaeus, 1758) in the Sapodilla Cayes Marine Reserve (SCMR) at the southernmost tip of the Belize Barrier Reef to estimate the effectiveness of the marine protected area. Results: A total of 693 *L. gigas* conches were counted over the 7,200 m² from 36 transect lines. The densities of juveniles and adult conches in the conservation zone were substantially higher (20.13 and 2.88 individuals/100 m², respectively) than in the general use zone (5.29 juveniles and 0.58 adults individuals/100 m²). The shell length of adult individuals ranged from 14.4 to 18.5 cm in the conservation zone and from 14.6 to 18.1 cm in the general use zone. A comparison of shell length of juveniles and adults showed no significant differences between the conservation zone (11.39 +/- 1.46 cm) and general use zone (11.62 +/- 1.24 cm). There was a significant positive correlation for shell length with lip thickness in the conservation zone (Pearson's correlation, $r = 0.729$, $p < 0.001$) and general use zone (Pearson's correlation, $r = 0.613$, $p = 0.02$). Conclusions: The function and effectiveness of marine protected areas are discussed using the results of the present study that identifies the primary objective which is to ensure a continuous recruitment of valuable targeted species by the protection of spawning

stock biomass that is important for the management of marine protected areas in an environmentally sensitive ecosystem.

CRFM. (2013). *Underwater Fisheries Independent Approaches for Queen Conch Population Estimation – a Review*. Caribbean Regional Fisheries Mechanism Secretariat Belize and St. Vincent and the Grenadines. Retrieved from http://mail.crfm.net/~uwohxjxf/images/Final_Report_-_Underwater_Fish_Independent_Approaches_for_Queen_Conch_Online_copy.pdf

This review is meant to provide an overview of how fisheries-independent approaches have been used for conch surveys, the types of survey approaches that have been used, the advantages of each method, and the difficulties or deficiencies provided by each methodology. The various methods are presented with a brief overview of their use. The specific studies and countries where the approaches were used, along with the advantages and disadvantages are them detailed in more depth in the associated table. It has been our intent to be as comprehensive as possible but it is likely that we may have missed one or more studies due to the extensive literature based in peer-reviewed, gray, and unpublished literature. The data was collected through an extensive literature review as well as in-person contacts during conch workshops conducted in St. Vincent and the Grenadines in June 2013. Additional literature was collected from personal contacts. Finally, we present an extensive bibliography of references that are cited in the text and the table.

De Jesus Navarrete, A. (2014). Proposal for Conservation of Queen Conch (*Strombus Gigas*) in the Alacranes Reef. Retrieved from <https://repository.library.noaa.gov/view/noaa/12915>

Coral reefs are highly complex and high diversity systems that are distributed in tropical and subtropical areas of the Planet (Ault et al., 2005). From the economic point of view, are highly productive in terms of tourism and production of fishery resources, and other supplies for human consumption. One of the fishery resources reefs Mexico is the queen conch (*Strombus gigas* L.) that is widely distributed from the Mexican Caribbean to the Gulf of Mexico in the state of Veracruz, but is currently limited to some reefs of the Gulf of Mexico and Caribbean sea (Baqueiro, et al. 1999). This conch represented the second fishery resource, surpassed only by the spiny lobster (*Panulirus argus*) (Jesus-Navarrete et al., 1992). Despite the different management strategies that include catch quotas, bans reproductive, and protected natural areas, as the Alacranes reef itself, resource recovery in Mexico and elsewhere in the Caribbean, has not been visible.

Doerr, J. C., & Hill, R. L. (2018). Spatial Distribution, Density, and Habitat Associations of Queen Conch *Strombus Gigas* in St. Croix, Us Virgin Islands. *Marine Ecology Progress Series*, 594, 119-133 <https://doi.org/10.3354/meps12547>

Conventional stock assessment methods have been ineffective for determining the status of queen conch throughout the Caribbean, mainly due to a lack of available fishery-independent data. We examined queen conch populations on the northeastern coast of St. Croix, US Virgin Islands, using a 10 m radial survey sampling technique with sample sites stratified by water depth, habitat type, and management regime, encompassing both open and closed fishing areas. We completed 503 radial surveys and located 4773 queen conch, representing an overall density of 302 conch ha⁻¹. Densities of juvenile and adult queen conch were higher within Buck Island Reef National Monument (BIRNM) boundaries compared to open fishing areas. Densities of juvenile and adult queen conch were highest in habitats characterized as 50-90 and 10-50% patchy seagrass, respectively. Shell length data suggest that

the seagrass beds south of Buck Island are functioning as valuable nursery habitat for juvenile conch, and the presence of multiple juvenile cohorts indicates that larval recruitment in the area has been successful in recent years. Comparisons of data from this and previous studies indicate that the queen conch population in St. Croix is potentially stable under the current management approach and that BIRNM is providing the spatial protection required for the population to continue to recover. Given the spatial and temporal patchiness of queen conch distributions, standardized fishery-independent monitoring surveys should be repeated regularly to provide data sufficient to assess stock conditions and the efficacy of management measures.

Foley, J. R., & Takahashi, M. (2017). Shell Lip Thickness Is the Most Reliable Proxy to Sexual Maturity in Queen Conch (*Lobatus Gigas*) of Port Honduras Marine Reserve, Belize; Informing Management to Reduce the Risk of Growth Overfishing. *Frontiers in Marine Science*, 4, 17
<https://doi.org/10.3389/fmars.2017.00179>

Queen conch (*Lobatus gigas*) is an important food source and export product for Belize, where extraction is regulated by shell length (SL) and market clean weight (MCW) limits. However, lip thickness (LT) limits are used to manage juvenile mortality and reduce risk of growth overfishing in other countries. Empirical studies suggest relationships between LT and sexual maturity vary spatially and need to be determined locally. This study was conducted to determine the most reliable, easily measurable proxy indicator(s) of maturity and associated target size limits in *L. gigas* that can effectively restrict harvest of juveniles. Morphological measures (SL, LT, lip width, unprocessed meat weight, MCW, operculum dimensions), gonadosomatic index (GSI) and histological evaluations were recorded from *L. gigas* collected in PHMR before, during, and after the *L. gigas* closed season. Upon determining Period 2 (during closed season) as the peak reproductive period, relationships between these variables in Period 2 were examined. No relationship was found in males between SL and maturity, and was weak in females, whereas there were significant curvilinear relationships between LT and GSI for both sexes, suggesting urgent need to base size limits on LT not SL. LT at which 50% of the population was mature (LT50) was 15.51 mm for females and 12.33 mm for males, therefore a 16 mm LT limit is recommended. MCW of female *L. gigas* was also significantly related to GSI, indicating MCW may be an appropriate management tool in conjunction with LT as it can be measured at landing sites whereas shells are usually discarded at sea. However, MCW at which 50% of females were mature (MCW50) was 199g and many individuals exceeding LT50 had MCW <199 g, suggesting the current 85g MCW limit is too low to protect juveniles yet 199 g MCW limit would be too high to substitute the recommended LT limit at landing sites. To minimize short-term impacts yet maximize long-term benefits to fishers' livelihoods, multi-stage adaptive management is recommended that integrates initial catch reductions, followed by introduction of size limits of 16 mm LT, and 150g MCW. Adjustable LT and MCW limits determined by fishery simulation could later be introduced.

de Graaf, M., Meijer zu Schlochtern, M., Boman, E. (2014) Non-Detriment Finding Regarding the Export of Queen Conch (*Lobatus gigas*) from St Eustatius (Caribbean Netherlands). IMARES Report C173/14. Retrieved from <http://edepot.wur.nl/328935>

Queen conch (*Lobatus gigas* (Strombidae; Gastropoda)) is a large, long-lived marine gastropod that is widely distributed throughout the coastal zones of the Wider Caribbean region. Because of concern for its future the species was listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in 1992. This non-detriment finding was written following the most recent checklist for CITES non-detriment findings. The suggested annual (export) quota for the

small scale, artisanal queen conch fishery on St Eustatius is based on recent scientific data on the status of the wild population and follows the recommendations of the first CMFC/OSPESCA/WECAFC/CRFM/CITES Working Group on Queen Conch (QCWG) to ensure a sustainable harvest and trade.

Harford, W. J., Gedamke, T., Babcock, E. A., Carcamo, R., McDonald, G., & Wilson, J. R. (2016). Management Strategy Evaluation of a Multi-Indicator Adaptive Framework for Data-Limited Fisheries Management. *Bulletin of Marine Science*, 92(4), 423-445
<https://doi.org/10.5343/bms.2016.1025>

In data-limited fisheries, making informed management decisions based on scientific advice is challenging. Here, we evaluate a multi-indicator adaptive management framework (AMF) that allows dynamic responses to changing environmental, socioeconomic, and fishing conditions. Using stakeholder-defined goals as a foundation for specifying performance metrics, we employ management strategy evaluation (MSE) to explore the performance of the AMF relative to prescriptive alternatives that are sometimes used in data-limited situations. We conduct simulations involving the two most economically important fisheries in Belize, spiny lobster, *Panulirus argus* (Latreille, 1804), and queen conch, *Strombus gigas* (Linnaeus, 1758). Spiny lobster fishery simulations demonstrate that when relatively stable catches have historically persisted, an AMF can help to ensure that stable catches continue to persist into the foreseeable future when faced with factors such as increased entry to the fishery or environmentally induced recruitment fluctuations. The queen conch fishery simulations demonstrate that optimizing economic performance is complicated without stock status indicators and depends greatly upon the current, yet typically unknown, state of the resource. Since our indicator-based approach could not provide direct information about resource status in relation to management reference points such as maximum sustainable yield, economic objectives could not be achieved. Nevertheless, implementing the AMF served as a beneficial control against stock collapse and could function well as an interim fishery policy during which sufficient fishery data could be collected to inform population modeling and quantitative stock assessment.

Kitson-Walters, K. A., Candy, A. S., Truelov, N. K., Roye, M. E., Webber, M. K., Aiken, K. A., & Box, S. J. (2018). Fine-Scale Population Structure of *Lobatus Gigas* in Jamaica's Exclusive Economic Zone Considering Hydrodynamic Influences. *Fisheries Research*, 199, 53-62
<https://doi.org/10.1016/j.fishres.2017.11.010>

Jamaica is one of the few remaining countries in the Caribbean region with an abundant population of *Lobatus gigas* (queen conch) able to sustain a lucrative fishery. Efforts to understand and maintain queen conch populations must involve an investigation into genetic connectivity. This connectivity facilitates population replenishment and continuity via the transport of veliger larvae by ocean currents. Due to the lack of knowledge in this regard to queen conch populations in Jamaica, the fine-scale population structure of *Lobatus gigas* populations in the country's Exclusive Economic Zone (EEZ) has been analysed by comparing the allele frequencies of nine microsatellite loci on a total of 459 individuals collected across twelve sites encompassing nearshore and offshore locations. Samples were grouped into five broad scale geographic clusters for statistical analysis. Our findings indicate that a weak but significant population structure exists (Global $F_{st} = 0.004$, $p = 0.01$) suggesting that mainland Jamaica acts as a weak divide between populations north and south of the island. Greater levels of connectivity are suggested between north coast populations and those present at the Formigas Bank, an offshore site northeast of the island. The island's primary conch fishing ground located offshore on Pedro Bank,

receives limited gene flow from the other sampled populations and may be heavily dependent on local recuitment or receive recruits from sources external to Jamaica's EEZ. An analysis of surface ocean currents strongly supports these three findings and further that conch populations on Pedro Bank very likely receive recruits from sources distinct to those that supply nearshore populations. Further genetic studies into the recuitment patterns and sources for the community on Pedro Bank are therefore critical to ensure sustainable management of this commercially threatened population. Decades of intense fishing pressure has resulted in the establishment of the Allee effect on the island shelf, significantly hampering reproduction and consequently recruitment. If the question of recruitment on Pedro Bank is not addressed, further development of the Allee effect there and eventual population exhaustion are inevitable. These findings, their implications and recommendations for the management of the queen conch fishery in Jamaica are discussed.

Kough, A. S., Cronin, H., Skubel, R., Belak, C. A., & Stoner, A. W. (2017). Efficacy of an Established Marine Protected Area at Sustaining a Queen Conch *Lobatus Gigas* Population During Three Decades of Monitoring. *Marine Ecology Progress Series*, 573, 177-189 <https://doi.org/10.3354/meps12163>

Marine Protected Areas (MPAs) are designed to conserve and preserve the ecosystems and cultural resources of the ocean. In theory, protected populations flourish, replenish adjacent regions, and are self-sustaining. However, describing the efficacy of MPAs requires long-term monitoring. Queen conch *Lobatus gigas* are iconic Caribbean denizens with populations that have been decimated by overfishing and are slow to rebound due to density-dependent breeding. The Exuma Cays Land and Sea Park (ECLSP) is a well-enforced, no-take, old, and large MPA. Surveys in 1994, 2011, and 2016 were used to track changes in the abundance, size, and age structure of conch within the park. Statistical models suggested that abundances of adults in 50 km of repeated towed-observer surveys had declined by 71% in 2016 relative to 2011. Further, the remaining conch populations were associated with tidal channels, and these model results agreed with independent observations in 40 km of expanded survey area. Measurements of shell lip thickness, an estimator of relative age, showed an increase relative to 1994 with the greatest effect in 2016, indicating senescence. The ECLSP population appears to be slowly dying of old age, and an early life history process has been altered. Upstream populations have been heavily fished while habitats within the park remain productive, suggesting that low local retention and a lack of exogenous larval sources are driving the decline. A network of MPAs encompassing the entire life cycle and dispersal envelope of targeted organisms is needed for proper conch conservation. Surveys focused on tidal channels could locate candidate upstream populations of conch.

Lugo, M. A., Crabtree, R. E., Arnold, B., García-Moliner, G., Herndon, A., Levy, M., . . . del López, M. a. (2014). Development of Island-Based Fishery Management Plans (FMPs) in the U.S. Caribbean : Transition from Species-Based FMPs to Island-Based FMPs. Retrieved from <https://repository.library.noaa.gov/view/noaa/10213>

The Caribbean Fishery Management Council (Council) is proposing to transition management of federal fisheries in the U.S. Caribbean from the current species-based fishery management plans (FMPs) to island-based FMPs. Current regulations under the Spiny Lobster FMP, Reef Fish FMP, Queen Conch FMP, and the Corals and Reef Associated Plants and Invertebrates FMP will be reorganized into FMPs for Puerto Rico, St. Thomas/St. John, and St. Croix.

Omori, K. L., Hoenig, J. M., Luehring, M. A., & Baier-Lockhart, K. (2016). Effects of Underestimating Catch and Effort on Surplus Production Models. *Fisheries Research*, 183, 138-145
<https://doi.org/10.1016/j.fishres.2016.05.021>

Fisheries can be managed based on surplus production models when only catch and effort data are available. However, reported catch and effort may not equal the true values. We studied the effects of jointly underestimated catch and effort on surplus production model parameter estimates (e.g., MSY, B-msy and F-msy) as well as estimates of key ratios (e.g., F/F-msy). We used ASPIC to examine various scenarios of underreporting for three example fisheries, North Atlantic swordfish, northern pike in Minnesota and queen conch in the Turks and Caicos Islands. With constant underestimation of catch and effort throughout time, MSY, B-msy and B-next are all underestimated by the same percentage, while F-last and the ratios, F/F-msy and B/B-msy, are not affected. As a result, harvest regulations can be set based on fishing mortality and the ratios. That is, when one thinks the harvest is MSY with $F=F\text{-msy}$, one is achieving MSY and F-msy even though the catch is actually larger than it is thought to be. However, increasing or decreasing trends in underreporting of catch and effort over time lead to errors in the parameter and ratio estimates whose direction is case-specific and whose magnitude can be high or low. Each fishery model responded differently to the simulated scenarios, which may be a result of different exploitation histories or the quality of the fit of the production model to the data. The wide range of outcomes observed may be due to the fact that underestimation of catch and effort can lead to a gain or reduction in data contrast. Simulations of a variety of possible scenarios similar to the methods in this study should be conducted if catch and effort are believed to be underestimated to determine how the surplus production model responds.

Peel, J. R., & Mandujano, M. D. (2014). Impact of Minimum Catch Size on the Population Viability of *Strombus Gigas* (Mesogastropoda: Strombidae) in Quintana Roo, Mexico. *Revista De Biologia Tropical*, 62(4), 1343-1352 <https://doi.org/10.15517/rbt.v62i4.13389>

The queen conch *Strombus gigas* represents one of the most important fishery resources of the Caribbean but heavy fishing pressure has led to the depletion of stocks throughout the region, causing the inclusion of this species into CITES Appendix II and IUCN's Red-List. In Mexico, the queen conch is managed through a minimum fishing size of 200mm shell length and a fishing quota which usually represents 50% of the adult biomass. The objectives of this study were to determine the intrinsic population growth rate of the queen conch population of Xel-Ha, Quintana Roo, Mexico, and to assess the effects of a regulated fishing impact, simulating the extraction of 50% adult biomass on the population density. We used three different minimum size criteria to demonstrate the effects of minimum catch size on the population density and discuss biological implications. Demographic data was obtained through capture-mark-recapture sampling, collecting all animals encountered during three hours, by three divers, at four different sampling sites of the Xel-Ha inlet. The conch population was sampled each month between 2005 and 2006, and bimonthly between 2006 and 2011, tagging a total of 8 292 animals. Shell length and lip thickness were determined for each individual. The average shell length for conch with formed lip in Xel-Ha was 209.39 +/- 14.18mm and the median 210mm. Half of the sampled conch with lip ranged between 200mm and 219mm shell length. Assuming that the presence of the lip is an indicator for sexual maturity, it can be concluded that many animals may form their lip at greater shell lengths than 200mm and ought to be considered immature. Estimation of relative adult abundance and densities varied greatly depending on the criteria employed for adult classification. When using a minimum fishing size of 200mm shell length, between 26.2% and up to 54.8% of the population qualified as adults, which represented a simulated fishing impact of almost one third of the population. When conch extraction was simulated using a classification criteria based on lip thickness, it

had a much smaller impact on the population density. We concluded that the best management strategy for *S. gigas* is a minimum fishing size based on a lip thickness, since it has lower impact on the population density, and given that selective fishing pressure based on size may lead to the appearance of small adult individuals with reduced fecundity. Furthermore, based on the reproductive biology and the results of the simulated fishing, we suggest a minimum lip thickness of ≥ 15 mm, which ensures the protection of reproductive stages, reduces the risk of overfishing, leading to non-viable density reduction.

Regional Queen Conch Fisheries Management and Conservation Plan. (2017). Rome. Retrieved from <http://www.fao.org/3/a-i7818e.pdf>

The overall objective of this 10-year Regional Queen Conch Fishery Management and Conservation Plan is to guide the implementation of a set of identified management measures that can be applied at the regional or sub-regional level for the sustainability of queen conch populations and for the maintenance of a healthy fishery and livelihood of the people involved in the fishery. The ecosystem approach forms the basis of this Regional Queen Conch Fishery Management and Conservation Plan, enhancing partnerships and collaboration throughout the Wider Caribbean region to improve the long-term governance of queen conch fisheries. This regional plan has been adopted by the 16th session of WECAFC, Guadeloupe, France, 20-24 June 2016, and the 17th meeting of the Conference of the Parties to CITES, Johannesburg, South Africa, 24 September - 5 October 2016.

Report of the Second Meeting of the CFMC/OSPESCA/WECAFC/CRFM Working Group on Queen Conch. (2016). FAO, United Nations. Retrieved from <http://www.fao.org/documents/card/en/c/2caf490d-5783-4a54-b77d-3dde06c1109f/>

The second meeting of the CFMC/OSPESCA/WECAFC/CRFM Working Group on Queen Conch was held in Panama City, Panama, from 18 to 20 November 2014. The meeting followed up on decisions by the sixteenth meeting of the Conference of Parties of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and a recommendation from the fifteenth session of the Western Central Atlantic Fishery Commission (WECAFC). The meeting reviewed a draft Regional Queen Conch Management and Conservation Plan with 26 potential fisheries management measures, and determined which measures will contribute most to the sustainability of the stocks and livelihoods of those involved in queen conch fisheries in the region. The meeting reached expert agreement on the use of regional harmonized conversion factors for the various degrees of processing of conch meat and on a format for non-detriment findings (NDFs) assessments. The meeting also updated the Terms of Reference of the Working Group and prepared a new work plan. The conclusions and draft recommendation from the Working Group will be reviewed by the Scientific Advisory Group and forwarded to the sixteenth session of WECAFC and important meetings of partner agencies for their endorsement. The working group meeting was attended by 55 fisheries and CITES authority delegates from 22 countries and territories. The meeting was facilitated by the Caribbean Fisheries Management Council, CITES and FAO.

Rodriguez-Zaragoza, F. A., Ortiz, M., Berrios, F., Campos, L., de Jesus-Navarrete, A., Castro-Perez, J., . . . Gallegos-Aguilar, E. (2016). Trophic Models and Short-Term Dynamic Simulations for Benthic-Pelagic Communities at Banco Chinchorro Biosphere Reserve (Mexican Caribbean): A Conservation Case. *Community Ecology*, 17(1), 48-60 <https://doi.org/10.1556/168.2016.17.1.7>

Banco Chinchorro is the largest reef in the Mexican Caribbean. Historically, spiny lobster, queen conch and over 20 other reef species have been exploited here. Multispecies intervention management from an ecosystem perspective has been developed in this area; however, an assessment of the effects of such practices on ecosystem health is required. Five quantitative trophic models were constructed using Ecopath with Ecosim. The results show that, in terms of biomass, benthic autotrophs are the dominant group in all communities. Ecosystem Network Analysis indices showed that Cueva de Tiburones was the most mature, developed, complex and healthy subsystem, but, El Colorado and La Baliza were the subsystems most resistant to disturbances. The fisheries mainly concentrate on primary (La Baliza and Cueva de Tiburones sites) and secondary consumers (La Caldera, Chancay, and El Colorado). The greatest propagation of direct and indirect effects, estimated by Mixed Trophic Impacts and Ecosim simulations, were generated by the benthic autotrophs, small benthic epifauna, benthic-pelagic carnivorous fish and benthic carnivorous fish, among others. In contrast, the System Recovery Time showed different patterns among subsystems, indicating several compartments that reduce resilience. Considering the structure, dynamics, trophic functioning and ecosystem health of Banco Chinchorro, its ecological heterogeneity highlights the need for the design of a specific (by subsystem) management strategy, particularly because different species or functional groups present greater sensitivity to human interventions in each community.

Rodriguez, A. G., & Fanning, L. M. (2018). Queen Conch (*Lobatus Gigas*) in the Grenadine Islands: A Preliminary Assessment on Its Abundance and Current Management Needs. *Ocean & Coastal Management*, 165, 109-116 <https://doi.org/10.1016/j.ocecoaman.2018.08.020>

Due to its cultural and economic value, one of the most important fisheries resources in the Caribbean Sea is the marine gastropod *Lobatus gigas*, commonly known as queen conch, (Appeldoorn et al., 2011). This species has been harvested as a food source in the region for approximately 5000 years, but the increase in its consumption during the past decades has contributed to its overexploitation (Lawrence and Phillips, 2013). Currently, many Caribbean countries lack adequate information about their queen conch stocks, which could jeopardize the conservation and sustainable use of this species.

Rolón, M. A., McGovern, J., López, M. d. M., & Crabtree, R. E. (2015). Comprehensive Amendment to the U.S. Caribbean Fishery Management Plans: Application of Accountability Measures. Retrieved from <https://repository.library.noaa.gov/view/noaa/18380>

The Comprehensive Amendment to the U.S. Caribbean Fishery Management Plans (FMPs): Application of Accountability Measures (AMs) would resolve an existing inconsistency between language in the Caribbean Fishery Management Council (Council) FMPs and the implementing regulations describing the application of AMs in the U.S. Caribbean exclusive economic zone (EEZ). The regulations describing AM application in the EEZ specify that AM-based closures are to remain in effect only during the particular fishing year in which they are implemented. However, the FMPs that implemented the AM closure regulatory language state that any AM-based closure will remain in effect until modified by the Council, thereby carrying these closures over from year to year unless, or until revised by subsequent Council action. This amendment would correct this inconsistency by revising the text within the four FMPs describing how AMs are to be applied to be consistent with the language in the regulations. Specifically, the phrase in the four FMPs that states “The needed changes will remain in effect until modified by the Council”, which describes how AMs are to be applied, will be removed from the four FMPs. The result of this proposed change would be that within both the FMPs and AM-based closure regulatory language, any AM closure would only apply for the fishing year in which it was implemented, which is consistent

with the intent and implementing regulations used by NMFS and the Council to apply AMs in the U.S. Caribbean EEZ.

Ruttenberg, B., Caselle, J. E., Estep, A. J., Johnson, A. E., Marhaver, K. L., Richter, L. J., . . . Cannon, A. (2018). Ecological Assessment of the Marine Ecosystems of Barbuda, West Indies: Using Rapid Scientific Assessment to Inform Ocean Zoning and Fisheries Management. *Plos One*, 13(1), 20 <https://doi.org/10.1371/journal.pone.0189355>

To inform a community-based ocean zoning initiative, we conducted an intensive ecological assessment of the marine ecosystems of Barbuda, West Indies. We conducted 116 fish and 108 benthic surveys around the island, and measured the abundance and size structure of lobsters and conch at 52 and 35 sites, respectively. We found that both coral cover and fish biomass were similar to or lower than levels observed across the greater Caribbean; live coral cover and abundance of fishery target species, such as large snappers and groupers, was generally low. However, Barbuda lacks many of the high-relief forereef areas where similar work has been conducted in other Caribbean locations. The distribution of lobsters was patchy, making it difficult to quantify density at the island scale. However, the maximum size of lobsters was generally larger than in other locations in the Caribbean and similar to the maximum size reported 40 years ago. While the lobster population has clearly been heavily exploited, our data suggest that it is not as overexploited as in much of the rest of the Caribbean. Surveys of Barbuda's Codrington Lagoon revealed many juvenile lobsters, but none of legal size (95 mm carapace length), suggesting that the lagoon functions primarily as nursery habitat. Conch abundance and size on Barbuda were similar to that of other Caribbean islands. Our data suggest that many of the regional threats observed on other Caribbean islands are present on Barbuda, but some resources—particularly lobster and conch—may be less overexploited than on other Caribbean islands. Local management has the potential to provide sustainability for at least some of the island's marine resources. We show that a rapid, thorough ecological assessment can reveal clear conservation opportunities and facilitate rapid conservation action by providing the foundation for a community-driven policymaking process at the island scale.

Sherman, K. D., Shultz, A. D., Dahlgren, C. P., Thomas, C., Brooks, E., Brooks, A., . . . Murchie, K. J. (2018). Contemporary and Emerging Fisheries in the Bahamas: Conservation and Management Challenges, Achievements and Future Directions. *Fisheries Management and Ecology*, 25(5), 319-331 <https://doi.org/10.1111/fme.12299>

The harvest of marine resources has long-standing cultural and economic importance to The Bahamas and other small island developing states. Tourists and residents place a demand on local marine resources, particularly Caribbean spiny lobster, *Panulirus argus* (Latreille), queen conch, *Lobatus gigas* (Linnaeus) and Nassau grouper, *Epinephelus striatus* (Bloch), and many fishery products are also sold on the global market. Illegal, unreported and unregulated fishing coupled with inadequate regulations and enforcement are the main factors contributing to the decline of Bahamian fisheries along with other anthropogenic impacts. This article reviews the status of fisheries management in The Bahamas using economically and ecologically important species as case studies to highlight conservation successes, knowledge gaps and deficiencies in existing management approaches. The review concludes with an examination of how emerging fisheries and improved conservation management strategies have the potential to improve economic and food security throughout the archipelago.

Stieglitz, T. C., & Dujon, A. M. (2017). A Groundwater-Fed Coastal Inlet as Habitat for the Caribbean Queen Conch *Lobatus Gigas*-an Acoustic Telemetry and Space Use Analysis. *Marine Ecology Progress Series*, 571, 139-152 <https://doi.org/10.3354/meps12123>

The queen conch *Lobatus (Strombus) gigas*, a marine snail, is among the most important fisheries resources of the Caribbean region. To provide effective protection in marine reserves, a good understanding of its habitat usage is essential. Queen conches commonly inhabit marine habitats. In this study, its activity space in a marginal estuarine-like habitat, the groundwater-fed inlet of Xel-Ha (Mexico) was determined using high-resolution acoustic telemetry (VEMCO Positioning System). Thirty-eight animals with siphonal lengths ranging from 80 to 200 mm were tagged, 1 of them with an accelerometer tag. Their trajectories were recorded for 20 mo at 5 m resolution in a closely spaced array of 12 receivers. Space-time kernel home ranges ranged from 1000 to 18 500 m² with an ontogenetically increasing trend. Juveniles, subadults and most adults displayed continuous, non-patchy home ranges consistent with the typical intensive feeding activity by this fast-growing gastropod. In some adults, Levy flight-like fragmentation of home ranges was observed that may be related to feeding range expansion or other ecological drivers such as the breeding cycle. The observed small home ranges indicate that the space use of queen conch in this estuarine-like habitat is not conditioned by food availability, and despite environmental stress due to daily low-oxygen conditions, space use is comparable to that observed in more typical marine habitats. In a marine reserve context, the groundwater-fed inlet provides adequate protection of this inshore queen conch population. Such marginal habitats may play an increasingly important role in conservation management as pressure on populations increase.

Stoner, A. W. (2019). Forty Years of Field and Laboratory Experiments with Hatchery-Reared Queen Conch: The Case for Conserving Natural Stocks. *Reviews in Fisheries Science & Aquaculture*, 27(4), 490-516 <https://doi.org/10.1080/23308249.2019.1628705>

Rehabilitating overfished species through releases of cultured juveniles depends upon growth and survival of those animals in the field. Releasing cultured queen conch (*Strombus gigas*) was proposed 40 years ago to rebuild over-harvested populations. Hatchery culture has been perfected and thousands of juveniles can be produced with meticulous husbandry. Many field experiments have been conducted with hatchery-raised queen conch since the early 1980s, but the results cast doubt regarding stock enhancement. Queen conch demonstrates high natural mortality rates, and cultured conch can have morphological and behavioral deficiencies that diminish survival. Deficiencies can be reduced with perfect culture conditions and prerelease field conditioning; and survival can be improved by releasing large juveniles, but all of these measures add to cost of seed stock. Also, release requirements are problematic. Habitat selection, release timing, and release patterns are all critical for reducing predation losses. While all of these challenges have been considered, no field release has resulted in survival rates that are encouraging. The cost of stock restoration through release of cultured queen conch will be enormously expensive, if successful at all, and every effort should be made to conserve wild populations. Hatchery production for stock restoration should be considered a last resort.

Stoner, A. W., Davis, M. H., & Kough, A. S. (2019). Relationships between Fishing Pressure and Stock Structure in Queen Conch (*Lobatus Gigas*) Populations: Synthesis of Long-Term Surveys and Evidence for Overfishing in the Bahamas. *Reviews in Fisheries Science & Aquaculture*, 27(1), 51-71 <https://doi.org/10.1080/23308249.2018.1480008>

Broad-scale surveys for the economically valuable gastropod queen conch in historically important fishing grounds of the Bahamian archipelago provide opportunity to explore the impact of variable fishing intensity on population structures. Visual surveys spanning two decades showed that densities of mature individuals had a significant negative relationship with an index of fishing pressure (FP). Average shell length in a population was not related to FP, but shell lip thickness (an index of conch age) declined significantly with FP. Repeated surveys in three fishing grounds revealed that densities of mature conch have declined in all of those locations and the populations have become younger with time. Densities have also declined significantly in three repeated surveys (over 22 years) conducted in a large no-take fishery reserve. Unlike fished populations, the protected population has aged and appears to be declining for lack of recruitment. In all fishing grounds except those most lightly fished, densities of adult conch are now below that needed for successful mating and reproduction. It is clear that queen conch populations in The Bahamas have undergone serial depletion, nearing fishery collapse, and a wide range of recommendations aimed at stock recovery are offered including a broader network of no-take reserves.

Tewfik, A., Babcock, E. A., Gibson, J., Perez, V. R. B., & Strindberg, S. (2017). Benefits of a Replenishment Zone Revealed through Trends in Focal Species at Glover's Atoll, Belize. *Marine Ecology Progress Series*, 580, 37-56 <https://doi.org/10.3354/meps12290>

Marine protected areas or replenishment zones have become one of the more popular tools within an ecosystem-based management approach aimed at balancing environmental health with socio-economic needs. We examined changes in populations of an ecologically representative suite of focal species, including ones important to local small-scale fisheries, over a 7 yr period using both independent visual surveys and fisheries-dependent data. Most small-scale fisheries targets showed increases in density, biomass, or size within the replenishment zone and stable or increasing catch rates beyond replenishment zone boundaries. Lower trophic level, high recruiting species of more limited movement such as parrotfish, conch, and lobster appeared to respond most clearly to protection, while higher trophic level, late maturing, and more widely dispersing snappers and groupers generally displayed more limited recovery. Patterns of mid-trophic level hogfish and queen triggerfish appeared to be linked to the availability of appropriate prey, i.e. conch and urchins respectively, with increasing angelfish catch per unit effort appearing to replace large parrotfish since the ban on harvesting herbivorous fish in 2009. Patterns of triggerfish and angelfish may also be linked to benthic cover, given their preferences for urchins and sponges, respectively. These results address the core management objectives for Glover's Reef Marine Reserve, Belize, to ensure sustainability of its resources and enhance economic benefits from fisheries. Our study highlights the importance of using other fisheries conservation strategies (size limits, closed seasons) in conjunction with replenishment zones, as well as direct consultation with resource users in order to maximize benefits.

Truelove, N. K., Box, S. J., Aiken, K. A., Blythe-Mallett, A., Boman, E. M., Booker, C. J., . . . Stoner, A. W. (2017). Isolation by Oceanic Distance and Spatial Genetic Structure in an Overharvested International Fishery. *Diversity and Distributions*, 23(11), 1292-1300 <https://doi.org/10.1111/ddi.12626>

AimA detailed understanding of spatial genetic structure (SGS) and the factors driving contemporary patterns of gene flow and genetic diversity are fundamental for developing conservation and management plans for marine fisheries. We performed a detailed study of SGS and genetic diversity throughout the overharvested queen conch (*Lobatus gigas*) fishery. Caribbean countries were presented

as major populations to examine transboundary patterns of population differentiation.

Location Nineteen locations in the greater Caribbean from Anguilla, the Bahamas, Belize, Caribbean Netherlands, Honduras, Jamaica, Mexico, Turks and Caicos, and the USA. Methods We genotyped 643 individuals with nine microsatellites. Population genetic and multivariate analyses characterized SGS. We tested the alternate hypotheses: (1) SGS is randomly distributed in space or (2) pairwise genetic structure among sites is correlated with oceanic distance (IBOD). Results Our study found that *L.gigas* does not form a single panmictic population in the greater Caribbean. Significant levels of genetic differentiation were identified between Caribbean countries ($F_{CT}=0.011$; $p=.0001$), within Caribbean countries ($F_{SC}=0.003$; $p=.001$), and among sites irrespective of geographic location ($F_{ST}=0.013$; $p=.0001$). Gene flow across the greater Caribbean was constrained by oceanic distance ($p=.0009$; Mantel $r=.40$), which acted to isolate populations. Main conclusions: Gene flow over the spatial scale of the entire Caribbean basin is constrained by oceanic distance, which may impede the natural recovery of overfished *L.gigas* populations. Our results suggest a careful blend of local and international management will be required to ensure long-term sustainability for the species.

Ulman, A., Burke, L., Hind, E., Ramdeen, R., & Zeller, D. (2016). Conched Out: Total Reconstructed Fisheries Catches for the Turks and Caicos Islands Uncover Unsustainable Resource Usage. *Frontiers in Marine Science*, 3(71) <https://doi.org/10.3389/fmars.2016.00071>

The Turks and Caicos Islands' total marine fisheries catches were estimated for 1950–2012 using a catch reconstruction approach, estimating all removals, including reported catch destined for export, and unreported domestic artisanal and subsistence catches. Total reconstructed catch for the period is approximately 2.8 times that reported by the Turks and Caicos to the FAO, and 86% higher than the export-adjusted national reported baseline. The pattern of total catches (strong decline to 1970, followed by gradual increase) differs distinctly from that shown by data reported to FAO. Reported landings show a steady increase from less than 1000 t·year⁻¹ in the 1950s to around 6000 t·year⁻¹ in the 2000s. In contrast, the total reconstructed catches suggest declines in total catches from around 20,000 t in 1950 to a low of about 5000 t in 1970, before gradual increases to about 12,500 t·year⁻¹ in the late 2000s. Major discrepancies between reported and reconstructed data are under-reported artisanal catches in the early decades (accounting for 86% of total catches), and the absence of subsistence catches (14% of total catches) in reported data. Queen conch (*Strombus gigas*) and Caribbean spiny lobster (*Panulirus argus*) dominate reconstructed catches. No discards were estimated as fishing has been highly selective, carried out by hand collection (conch), trap or hook (lobster), or hook and line (finfish). New data published here from local seafood consumption surveys demonstrates that the total local consumption of conch equates to almost the entire total allowable catch, before exported amounts are even factored. Policy-makers in the Turks and Caicos need to act if the sustainability of the fisheries stock and fishing industry is to be ensured.

Update of Annual Catch Limit Landings for Caribbean Reef Fishes and Projected Season Lengths. (2015-07). (2015). St. Petersburg, FL. Retrieved from <https://repository.library.noaa.gov/view/noaa/18721>

The U.S. Caribbean is composed of the Commonwealth of Puerto Rico and the Territory of the U.S. Virgin Islands. Federal waters of this region are managed by the Caribbean Fishery Management Council (Caribbean Council). In January 2012, NOAA Fisheries implemented Annual Catch Limit (ACL) Amendments for federally managed species in the Caribbean. The Caribbean Council established ACLs for all federally managed species included in the Reef Fish, Queen Conch, Spiny Lobster, and Corals and

Reef Associated Plants and Invertebrates Fishery Management Plans (FMPs). Accountability measures (AMs) were also established requiring NOAA Fisheries to reduce the length of the fishing season if it has been determined that landings in the prior year(s) exceeded the ACL for that species and/or species group. For purposes of ACL monitoring, a 3-average of landings is used.

Section II: Life History

Aldana Aranda, D., Oxenford, H. A., Bissada, C., Enriquez Díaz, M., Brulé, T., Delgado, G. A., . . . Frenkiel, L. (2014). Reproductive Patterns of Queen Conch, *Strombus Gigas* (Mollusca, Gastropoda), across the Wider Caribbean Region. *Bulletin of Marine Science*, 90(3), 813-831
<https://doi.org/10.5343/bms.2013.1072>

Queen conch, *Strombus gigas* (Linnaeus, 1758), is a species of significant economic importance in the Caribbean Sea, exploited mainly for consumption by a ravenous export market in the USA and French West Indies. Because populations have been depleted throughout the Caribbean region by overfishing, present conservation efforts are focused on regional harmonization of conch management to improve its sustainability. In the present study, we compare the reproductive cycle of *S. gigas* from eight sites (Florida Keys, Alacranes Reef, Chinchorro Bank, San Pedro, San Andrés Archipelago, Guadeloupe, Martinique, and Barbados) to consider the biological rationale for a harmonized closed fishing season. A framework recognizing four reproductive stages for males and females is proposed for use in future studies. Significant differences were found in the timing and intensity of reproductively active stages between conch from western and eastern sites in the Wider Caribbean Region. Two distinct reproductive strategies were observed: (1) continuous and low level of reproduction throughout the year (Alacranes Reef, San Pedro, and San Andrés Archipelago); and (2) a discrete and intense reproductive period with rapid gametogenesis (Guadeloupe, Martinique, and Barbados). Queen conch required a temperature of ≥ 27.7 °C to initiate gametogenesis; and were found in the resting stage below 27.5 °C. Based on a comparison of spawning seasons across the reproductive strategies observed, we suggest that the most "biologically meaningful" period for a closed season for the entire western central Atlantic would need to incorporate the months of June to September, at a minimum, to offer regional protection for spawners.

Aranda, D. A., Diaz, M. E., & Paris-Limouzy, C. (2015). Effect of Tide and Photoperiod on Abundance and Distribution of Larvae of Queen Conch, *Strombus Gigas*. *Journal of Shellfish Research*, 34(2), 603-603 <https://doi.org/10.2983/035.034.0243>

Larval abundance and distribution of queen conch, *Strombus gigas*, is regulated by currents (Jesus Navarrete, 1999), temperature (Stoner et al., 1992), photoperiod (Barile et al., 1994) and depth (Stoner & Davis, 1997). Daigle et al. (2014) studied the effect of tides on abundance of gastropods larvae. The goals of this study were to determine the effects of tides and photoperiods on vertical abundance of queen conch larvae. We carried out plankton tows at Puerto Morelos, Quintana Roo, Mexico (2054'34" N-8650'13" W) in June 2014. Plankton samples were made at surface and -3.0 m covering two high and two low tides per day (n = 40). The highest abundance of larvae was recorded during a Full moon with 0.72 ± 0.66 larvae.10m-3, and at high tide (0.87 ± 0.62 larvae10 m-3). Significant variation was recorded between abundance of larvae and depth, tidal coefficient and moon phases ($p = 0.0034$, $p = 0.0015$, and p

#0.0001, respectively). The highest abundances of larvae were recorded during the full moon, at high tide near the surface (1.16 ± 0.80 larvae.10 m⁻³). Regardless of the value of the coefficients of tide, larval abundance was more homogeneous at 3 m depth. On the surface, larval density showed variations; being greater at higher tidal coefficient. With respect to photoperiod, samples taken during the day had higher larval abundance as those conducted at night. Significant variation was recorded between abundance of larvae and depth and tidal coefficients ($p = 0.0034$, $p = 0.0015$, respectively), indicative of tidal stream transport.

Aranda, D. A., & Manzano, N. B. (2017). Effects of near-Future-Predicted Ocean Temperatures on Early Development and Calcification of the Queen Conch *Strombus Gigas*. *Aquaculture International*, 25(5), 1869-1881 <https://doi.org/10.1007/s10499-017-0153-y>

The queen conch, *Strombus (Lobatus) gigas*, is one of six species of conch distributed throughout the Caribbean of significant commercial importance. The Caribbean region is adversely impacted by climate change, which affects the marine ecosystems and the calcification process of organisms with calcareous structures, such as mollusks. We tested the influence of global warming predicted in 2100 on queen conch, *Strombus gigas* larval development, growth, survival rate, and calcification by exposing egg masses and larvae to increased temperatures (28, 28.5, 29, 29.5, and 30 A degrees C) for 30 days. For analysis of calcification, imaging and chemical mapping (proportion, wt) were performed on 30-day-old larvae using a high-resolution scanning electron microscopy (HR-SEM) and X-ray photoelectron spectroscopy (XPS). A temperature of 30 A degrees C resulted in the highest larval growth rate (mean +/- SD 27.33 +/- 2.96 μ m day⁻¹), significantly among treatments ($p < 0.05$). Development was fastest at 30 A degrees C, where the first larvae settled by day 27 (49%) and the mortality rate was 76%. At 28 A degrees C, day 29 was the first day where settlement was observed for 20% of the larvae. There are significant differences among treatments on larval growth and development. The calcification process of *S. gigas* larvae was not affected by the experimental temperatures tested. Percent Ca content of shelled larvae showed no significant differences among treatments (mean +/- SD 25.44 +/- 4.74 and 24.99 +/- 0.74% w for larvae grown at 30 and 28 A degrees C, respectively).

Aranda, D. A., Oxenford, H. A., Bissada, C., Diaz, M. E., Brule, T., Delgado, G. A., . . . Frenkiel, L. (2014). Reproductive Patterns of Queen Conch, *Strombus Gigas* (Mollusca, Gastropoda), across the Wider Caribbean Region. *Bulletin of Marine Science*, 90(3), 813-831 <https://doi.org/10.5343/bms.2013.1072>

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required a temperature of ≥ 27.7 degrees C to initiate gametogenesis; and were found in the resting stage below 27.5 degrees C. Based on a comparison of spawning seasons across the reproductive strategies observed, we suggest that the most "biologically meaningful" period for a closed season for the entire western central Atlantic would need to incorporate the months of June to September, at a minimum, to offer regional protection for spawners.

Aranda, D. A., Villegas, J. F. C., & Crespo, M. S. (2014). Is the Queen Conch *Strombus Gigas* (Mesogastropoda: Strombidae) a Species with Allee Effect? *Revista De Biología Tropical*, 62, 207-213 Retrieved from https://www.scielo.sa.cr/scielo.php?script=sci_abstract&pid=S0034-77442014000700021&lng=en&nrm=iso&tlng=en

The marine park of Xel-Ha has a population of *Strombus gigas* which breeds in the area. We determined the relationship between reproductive activity, conch density and environmental parameters. Samples were collected from February to December 2012, using the transect method, at four sites of Marine Park Xel-Ha, Quintana Roo, Mexico. Sediment samples were analyzed and classified using Folk & Ward's method. Temperature, salinity and dissolved oxygen were also recorded. Density had a small correlation with sediment (Pearson $r=0.29$ with very coarse and $r=0.26$ with coarse sand), while mating and spawning had a correlation of $r=0.54$ and 0.62 with medium sand, respectively. Density was high in the four sites and was not associated with mating and spawning ($r=0.08$ and 0.03 , respectively). For reproduction, *S. gigas* requires specific substrate conditions (sandy effect) and not just a density of 56 Conch Ha(-1) (Allee effect).

Banaszak, A. T., Ramos, M. G., & Goulet, T. L. (2013). The Symbiosis between the Gastropod *Strombus Gigas* and the Dinoflagellate *Symbiodinium*: An Ontogenic Journey from Mutualism to Parasitism. *Journal of Experimental Marine Biology and Ecology*, 449, 358-365 <https://doi.org/10.1016/j.jembe.2013.10.027>

Dinoflagellates in the genus *Symbiodinium* form mutualistic symbioses not only with corals and other cnidarians but also with sponges, bivalves, and gastropods, including the commercially important queen conch, *Strombus gigas* (Linnaeus 1758). The eggs of *S. gigas* are aposymbiotic, but acquisition of *Symbiodinium* at the larval stage significantly enhances survival and growth, demonstrating the mutualistic nature of this symbiosis at the larval stage. The objective of the present study was to investigate the symbiotic association between adult *S. gigas* and *Symbiodinium*. *S. gigas* were collected along the Mexican Caribbean coast. *Symbiodinium* did not occur in the muscle tissue or gonads, the latter supporting the lack of symbionts in *S. gigas*' eggs. *Symbiodinium* cells were morphologically intact in all of the anatomical structures in which they were found that included, in order of abundance, the digestive gland and other parts of the digestive tract, gills, in connective tissue surrounding the mantle and foot, as well as in the nephridium and proboscis. The symbionts underwent mitosis in the mantle, stomach and digestive gland. The healthy condition of the *Symbiodinium*, evident in their morphology and mitotic index, was surprising given the low light habitat in which they were found in adult *S. gigas*. The shell of *S. gigas* is a strong light attenuator; a maximum of 21% of incident radiation passed through the conch shell and decreased exponentially with increasing shell length to a low of 0.1%. The maximal photochemical efficiencies (F_v/F_m) of the symbionts were low, suggesting that their photosynthetic activity would be suboptimal in the reduced light environment in which they are found. The large population of *Symbiodinium* may be maintained by the symbionts acquiring nutrients heterotrophically from the host. Consequently, in *S. gigas*, a mutualistic symbiont at the larval life stage may confer a net cost at the adult life stage.

Banks, M. A., Minch, J. D., & Stoner, A. W. (2014). *Preliminary Report on Population Genetic Structuring among Queen Conch (Strombus Gigas) from the Bahamas*. Retrieved from <http://www.communityconch.org/wp-content/uploads/2014/03/Banks-Minch-Stoner-final.pdf>

This study was conducted to evaluate whether polymorphic DNA microsatellite markers isolated in queen conch by Zamora-Bustillos et al. (2007) can be used to differentiate geographically distant populations of conch in The Bahamas. We concluded that if this preliminary screening revealed genetic distinction in populations separated by 500 kilometers then microsatellite markers can be used for stock identification over the broader Caribbean region and within large nations such as The Bahamas, Cuba, and Venezuela where important fisheries for queen conch are prosecuted.

Berry, C., Hill, R. L., & Walker, B. K. (2016). Demographics of a Nearshore Mating Queen Conch (*Lobatus Gigas*) Aggregation on the Southeast Florida Reef Tract. *Bulletin of Marine Science*, 92(1), 59-73 <https://doi.org/10.5343/bms.2015.1047>

The queen conch, *Lobatus gigas* (Linnaeus, 1758), is a large gastropod found throughout the Caribbean region, including off Florida. The extent, habitat association, and population demographics of an aggregation were investigated off southeast Florida near a major shipping port. Population surveys were conducted over 4 km² of hard-bottom habitats to document benthic cover, conch distribution, and size data within 2 km north and south of the shipping inlet. In total, 122 conch were recorded for the entire surveyed area, equating to 70.6 conch ha⁻¹. Mean density was highest south of the inlet. Juvenile and subadult conch were found throughout the study area, but mostly in the westernmost, shallowest hard-bottom habitats. The highest density of adult conch was found in the CPW south of the inlet. Analyses showed that CPW south has a unique community composition dominated by macroalgae and sand. This area was surveyed further using cross-shelf transects measuring conch extent and demographics. Five-hundred and twenty-five conch were found, resulting in a density of 495 ha⁻¹. Confirmed mating sightings, females with eggs, and solitary egg masses were found indicating reproduction in this nearshore habitat is successful. The ratio of females with eggs to those without indicated that, although 21.2% of the females with eggs had a thinner lip, the majority had a lip thickness >12 mm. Nearshore mating conch should be a consideration in beach construction projects. Future research should include reconnaissance for other aggregations, monitoring, and comparisons among other nearshore populations.

Boman, E. M., Bervoets, T., de Graaf, M., Dewenter, J., Maitz, A., Zu Schlochtern, M. P. M., . . . Nagelkerke, L. A. J. (2019). Diet and Growth of Juvenile Queen Conch *Lobatus Gigas* (Gastropoda: Strombidae) in Native, Mixed and Invasive Seagrass Habitats. *Marine Ecology Progress Series*, 621, 143-154 <https://doi.org/10.3354/meps12990>

Juvenile queen conch are primarily associated with native seagrass such as *Thalassia testudinum* in large parts of their range in the Caribbean and the southern Gulf of Mexico. Here, a number of non-native seagrass species have been introduced including *Halophila stipulacea*, which is natural to the Red Sea and the Indo-Pacific. In the Caribbean, *H. stipulacea* often creates dense continuous mats with little or no sediment exposed, compared to native seagrass, which grows much less dense. We examined the diet and growth of juvenile conch in both native, mixed, and invasive seagrass beds using stable isotope analysis and an in situ growth enclosure experiment. Organic material in the sediment (i.e. benthic diatoms and particulate organic matter) was found to be the most important source of carbon and nitrogen for juvenile queen conch in all 3 habitats investigated, and there was a significantly higher probability of positive growth in the native seagrass compared to the invasive seagrass. Due to the

importance of the organic material in the sediment as a source of nutrition for juvenile conch, limited access to the sediment in the invasive seagrass can potentially cause inadequate nutritional conditions to sustain high growth rates. Thus, it is likely that there is a negative effect on juvenile queen conch growth currently inhabiting invasive seagrass beds, compared to native seagrass beds, when other potential sources of nutrition are not available.

Boman, E. M., de Graaf, M., Nagelkerke, L. A. J., Stoner, A. W., Bissada, C. E., Avila-Poveda, O. H., . . . Smaal, A. C. (2018). Variability in Size at Maturity and Reproductive Season of Queen Conch *Lobatus Gigas* (Gastropoda: Strombidae) in the Wider Caribbean Region. *Fisheries Research*, 201, 18-25 <https://doi.org/10.1016/j.fishres.2017.12.016>

Queen conch (*Lobatus gigas*), is an economically and culturally important marine gastropod. The species is subject to extensive exploitation throughout large parts of the Caribbean which has led to a decrease in population densities across much of the species' distribution range. Hence, there is a need for protective measures to safeguard the reproductive stock. This requires a better estimation of its size at maturity, which is best quantified as the thickness of the lip that the shell develops after reaching its maximum length. The lip thickness at 50% maturity (LT50) was determined using a logistic and an accumulation model, from seven representative location of distribution of this species in the Wider Caribbean Region. LT50 of both females (7-14 mm) and males (4-11.5 mm) varied between different locations in the Caribbean, although it did not correspond with variation in water temperature. In most cases females had a larger LT50 than males indicating sexual dimorphism. LT50 values estimated with the logistic model were smaller (7-14 mm for females, 4-11.5 mm for males) than values estimated with the accumulation model (13-26 mm for females, 16-24 mm for males), showing an overestimation of LT50 in queen conch in previous studies which used the accumulation model to estimate LT50. Locations with a relatively high variation in water temperature had a significantly shorter reproductive season. The implementation of adequate minimum size regulation based on lip thickness (ca. 15 mm) and a Caribbean wide seasonal closure (May September) using the most recent biological information from this study, taking into consideration the local differences in LT50 and reproductive season, will assist in developing a long term sustainable queen conch fishery in the Caribbean.

Boman, E. M., De Graaf, M., Nagelkerke, L. A. J., Van Rijn, J., Schlochtern, M. M. Z., & Smaal, A. (2016). Underwater Towed Video: A Novel Method to Estimate Densities of Queen Conch (*Lobatus Gigas*; Strombidae) across Its Depth Range. *Journal of Shellfish Research*, 35(2), 493-498 <https://doi.org/10.2983/035.035.0222>

Queen conch (*Lobatus gigas*) populations living deeper than 20 m are rarely studied, because of the limitations of conventional survey methods using divers [i.e., belt transect (BT), towed-diver]. A crucial management goal for conch populations is to maintain adult densities at adequate levels to ensure reproduction, which is highly density dependent. Therefore, accurate estimates of adult conch densities, both in shallow and deep areas, are essential. The rapid technical progress of video systems has made it possible to develop new cost-effective ecological sampling tools, which can be used to survey areas previously hardly accessible. A lightweight towed video array was used, which was able to survey adult conch throughout the species entire depth range (ca. 0-60 m depth), in a safe and efficient manner. The towed video method (TVM) was compared with a conventional BT method using scuba divers, in its ability to identify adult live and dead conch. A series of intercalibration transects was conducted in a high-complexity (HC) and in a low-complexity (LC) habitat by having the towed video followed by a diver conducting a concurrent standard BT, covering the exact same surface area as the towed video. In both the HC and LC habitat, adult live queen conch had similar counts with both methods. Adult dead conch

were not mistaken for live conch but were significantly underestimated with the towed video compared with the BT. The results validate the use of TVM as a reliable sampling tool to estimate densities of live adult conch in both HC and LC habitats throughout the species depth range.

Brownscombe, J. W., Wilson, A. D. M., Samson, E., Nowell, L., Cooke, S. J., & Danylchuk, A. J. (2015). Individual Differences in Activity and Habitat Selection of Juvenile Queen Conch Evaluated Using Acceleration Biologgers. *Endangered Species Research*, 27(2), 181-188
<https://doi.org/10.3354/esr00664>

Fine-scale differences in behaviour and habitat use have important ecological implications, but have rarely been examined in marine gastropods. We used tri-axial accelerometer loggers to estimate activity levels and movement patterns of the juvenile queen conch *Lobatus gigas* (n = 11) in 2 habitat types in Eleuthera, The Bahamas. In 2 manipulations in nearshore areas, queen conchs were equipped with accelerometers and released in adjacent coral rubble or seagrass habitats. Queen conchs were located approximately every 6 h during daylight by snorkeling, to measure individual differences in linear distance moved, and after 24 h they were relocated to an alternate habitat (24 h in each habitat). We found significant inter-individual variability in activity levels, but more consistent levels of activity between the 2 habitat types within individual queen conchs. Four (36%) of the individuals placed in seagrass moved back to the adjacent coral rubble habitat, suggesting selectivity for coral rubble. Individuals showed variable behavioural responses when relocated to the less preferable seagrass habitat, which may be related to differing stress-coping styles. Our results suggest that behavioural variability between individuals may be an important factor driving movement and habitat use in queen conch and, potentially, their susceptibility to human stressors. This study provides evidence of diverse behavioural (activity) patterns and habitat selectivity in a marine gastropod and highlights the utility of accelerometer biologgers for continuously monitoring animal behaviour in the wild.

Cala, Y. R., de Jesus-Navarrete, A., Ocana, F. A., & Oliva-Rivera, J. (2013). Density and Reproduction of the Queen Conch *Eustrombus Gigas* (Mesogastropoda: Strombidae) at Cabo Cruz, Desembarco Del Granma National Park, Cuba. *Revista De Biología Tropical*, 61(2), 645-655 Retrieved from
https://www.scielo.sa.cr/scielo.php?script=sci_arttext&pid=S0034-77442013000300013

The queen conch *Eustrombus gigas* is an important fisheries resource in the Caribbean region. In Cuba Island the studies about this resource are very scarce and particularly in the Southeastern regions of the country. With the aim to get important fishery information about this gastropod, adult Queen Conch density and frequency of reproductive activity were evaluated in Cabo Cruz, Cuba, during 2009-2010. Data from three seasons were obtained (rainy, dry and cold fronts periods) from three different areas: Farito, Guafe and Laguna. The highest density was observed in cold fronts season (468.5ind./ha) and the lowest occurred during the dry season (268.5ind./ha). The highest density was reported at Laguna (520.4ind./ha) and the lowest at Farito (290.9ind./ha). In total, 158 reproductive events were observed. The highest frequency was reported in rainy season (36%), followed by dry (9%) and cold fronts (5%) seasons. Reproductive behavior (mating and egg laying) was related to temperature and photoperiod. Reproductive activity was observed during the whole year, which suggests the existence of an important Queen Conch reserve in the Southeastern region of Cuba and an apparently self-sufficient population for recruitment. From our results we may conclude that, the population's sustainable exploitation is viable if the following management measures are observed: functional zoning within the area, rotation of fishing areas and a closed season. We recommend that the Laguna site should be protected as a reproduction zone and banned for fishing activities.

Cala, Y. R., de Jesus-Navarrete, A., Ocana, F. A., & Oliva-Rivera, J. J. (2013). Density and Structure of a Queen Conch *Strombus Gigas* (Mollusca: Strombidae) Population at Desembarco Del Granma National Park, Cabo Cruz, Cuba. *Caribbean Journal of Science*, 47(2-3), 242-250
<https://doi.org/10.18475/cjos.v47i3.a12>

Cabo Cruz, Southeastern coast of Cuba, is an important site for queen conch development. Within the Desembarco del Granma National Park, a conch fishery is practically non-existent. Research was carried out in 2010 during three climatic periods (rainy, dry and cold front) at three zones (Farito, Guafe, and Laguna) in order to determine density and population structure of the queen conch. Population density varied from 247 ind.ha(-1) at Guafe in the rainy period, to 1767 ind. ha(-1) at Farito in the dry one. Conch population displayed an aggregated distribution in all zones and seasons. The highest density was detected during the dry season (1395 ind. ha-1) and the lowest in the rainy season (647 ind. ha-1). Siphonal lengths (SL) and the lip thickness (LT) of 1836 conchs were measured; the SL varied from 87 to 286 mm. An analysis of LT showed that 73% of conchs had a completely formed lip, but they measured less than 200 mm SL, which represents the minimal fishing size in Cuba. Apparently, the conch population at Cabo Cruz is made up by small conchs, with a gradual increase in weight and lip thickness, as they develop into "dwarf" conchs. The dwarf population is probably related to density dependence. A revision of the protected area management plan is suggested, focused on conchs and its sustainable use.

Cardenas, E. B., & Aranda, D. A. (2014). Growth Parameters and Density Variation of a Queen Conch, *Strombus Gigas* (Neotaenioglossa: Strombidae), Population from Xel-Ha Park, a Marine Protected Area. *Revista De Biología Tropical*, 62(1), 45-57
<https://doi.org/10.15517/rbt.v62i1.7561>

The queen conch, *Strombus gigas*, is a gastropod of commercial importance in the Caribbean. Population studies are based on size frequency analysis, using either length or weight parameters for the whole live organism. This contribution used mark-recapture data to estimate the Von Bertalanffy equation parameters and population number variation within a non harvest population from a protected area, to clarify the biometric parameters that better suit for the whole population, or for the juvenile and adult fractions. Conchs from Xel-Ha Park were monthly sampled from November 2001 to August 2005. Every conch found was measured and marked with a numbered tag that identified month and locality; and monthly abundance was estimated with Jolly's method. Length, lip thickness and weight increments were used to estimate the Von Bertalanffy growth equation parameters with Appeldoorn's subroutine of FISAT program. The population number varied through the study, with a minimum of 49 in April 2003 and maximum of 9 848 during June 2005. Conchs make only temporary use of Xel-Ha cove. Shell length gave the best fit for the juvenile fraction: $L_{\infty}=251$, $K=0.3$, $C=0.8$ $W_p=0.3$; and lip thickness for adults: $L_{\infty}=47.78$, $K=0.17$, $C=0.1$, $W_p=0.86$, while, the whole population was better represented by weight: $L_{\infty}=3850$, $K=0.36$, $C=0.8$, $W_p=0.3$. A maximum age of 19 years was estimated from the population. Natural mortality was 0.49/year for juveniles and 0.29/year for adults. There were two pulses of recruitment: fall-winter and summer. It is concluded that population studies from length frequency data, should be analyzed independently in two groups, shell for the juvenile fraction and lip thickness for the adult fraction, or if it is not possible to analyze the population fractions separately, weight should be used to avoid miss calculation of the age structure.

Carrascal, O. M. P., Elorza, M. P., Restrepo, G. E. C., & Herrera, C. X. M. (2014). Assessment of the Bacterial Community Diversity Associated with the Queen Conch *Strombus Gigas* (Linnaeus, 1758) from the Caribbean Coast of Colombia Using Denaturing Gradient Gel Electrophoresis and Culturing. *Aquaculture Research*, 45(5), 773-786 <https://doi.org/10.1111/are.12016>

The biotic diversity of *Strombus gigas* has not been thoroughly studied despite the status of the queen conch as an important ecological resource. The bacteria associated with the conch influence their host in several ways, including through the metabolism of nutrients, protection against invasive bacteria and the regulation of the physical conditions. In this study, conventional microbiological methods and molecular tools such as denaturing gradient gel electrophoresis (DGGE) were used to assess the composition of the bacterial communities associated with the queen conch (*S. gigas*) in wild and captive habitats in Colombia. A genetic analysis of the bacterial communities revealed a high level of diversity based on the large number of bands detected using DGGE. In addition, differences in bacterial community structure were found between the conchs in captivity and the wild populations. The dominant phylogenetic affiliations of the bacteria, as determined using 16S rRNA gene sequencing, were grouped into four classes, namely, Betaproteobacteria (16%), Gammaproteobacteria (70%), Firmicutes (7%) and Actinobacteria (2%). These groups are related to host defence processes and the decomposition of organic matter. The 16S rDNA sequence analysis of the cultured bacteria and the resulting DGGE profiles are useful tools for characterizing the diversity of the bacteria associated with the analyzed conchs.

Chávez Villegas, J. F., Enríquez Díaz, M., & Aldana Aranda, D. (2017). Efecto De La Temperatura Y La Acidificación En Larvas De *Strombus Gigas* (Mesogastropoda: Strombidae). [Effect of temperature and acidification in *Strombus gigas* (Mesogastropoda: Strombidae) larvae.]. *Revista De Biología Tropical*, 65(2), 505-515 <https://doi.org/10.15517/rbt.v65i2.25504>

The increase in CO₂ emissions produces heating and reduced pH in the oceans, which may have negative effects on many marine organisms. This is particularly important for those with calcified structures such as the molluscs and their larval stages. We studied *Strombus gigas* larvae, a gastropod of commercial importance in the Caribbean Sea, in order to know the effect of water temperature and acidification on their development, growth, mortality and calcification during the larval period. A larval culture with triplicate samples was carried out employing four treatments of temperature and pH (Control = 28 °C - pH 8.1, T1 = 28 °C - pH 7.6, T2 = 31 °C - pH 8.1 and T3 = 31 °C - pH 7.6) in August 2015. We registered hatching (No. of eggs - No. of larvae hatched) and organs development, while shell growth and mortality ratio were evaluated over time. Shell calcification was studied in 30 days old larvae using EDX and RAMAN analysis. Our results showed that organs development and shell growth were higher at 31 °C treatments (initial size of 230 ± 4.12 to 313.27 ± 11.34 µm, and final size from 829.50 ± 11.33 to 1 054.50 ± 11.13 µm; from T1 to T2 respectively), and the same pattern was recorded for hatching time (18 hr) and mortality rate (~ 57 %). The Calcium proportion (% wt) was similar between treatments (34.37 ± 10.05 to 37.29 ± 16.81 % wt). Shell Raman analysis showed aragonite in all experimental treatments, with the highest values in the control (1 039.54 ± 780.26 a.u.). Calcite was detected only in 31 °C treatments (174.56 ± 127.19 a.u.), while less intensity of aragonite and calcite were registered at pH 7.6. In conclusion, *S. gigas* could be adapted to ocean future predictions, however, shell biomineralization processes can be affected.

Cigliano, J. A., & Kliman, R. M. (2014). Density, Age Structure, and Length of Queen Conch (*Strombus Gigas*) in Shallow-Water Aggregations in the Sapodilla Cayes Marine Reserve, Belize. *Caribbean Journal of Science*, 48(1), 18-30 <https://doi.org/10.18475/cjos.v48i1.a4>

The Sapodilla Cayes Marine Reserve (SCMR) was established in 1996 to protect the queen conch (*Strombus gigas*) fishery in southern Belize. However, no systematic survey of queen conch populations in the SCMR had been conducted. To determine the state of the queen conch population and to provide a baseline to measure management effectiveness, we conducted shallow-water surveys of historical conch fishing areas from 2006-2008 during July and August. We collected data on habitat, depth, maturity, length, and density. We sampled 1,778 conch at eight sites throughout the reserve. Conch were found primarily in seagrass meadows (88.6%) in an average depth of 1.7 +/- 0.01 m (range: 0.3-4.9 m). 93% of conch were juveniles and the percentage of juveniles in aggregations averaged 85.0 +/- 3.8 (range 28.6 - 100.00%). Average shell length was 14.6 +/- 0.1 cm (range: 6.5-25.0 cm) and varied among aggregations and among years within aggregations. 85% of conch were below the legal harvestable size for Belize. Average density (all age classes) ranged from 0.00 +/- 0.00 to 4014.29 +/- 741.12 conch/ha and varied among sites and year. Average adult density ranged from 0.00 +/- 0.00 to 75.00 +/- 41.19 conch/ha, subadult density ranged from 0.00 +/- 0.00 to 214.29 +/- 67.01 conch/ha, and juvenile density ranged from 0.00 +/- 0.00 conch/ha to 3785.00 +/- 737.57. Only twice was an aggregation above the density threshold required for reproduction (50 conch/ha). The SCMR appears to be an important nursery area for queen conch.

Cuartas, J. H., Alzate, J. F., Moreno-Herrera, C. X., & Marquez, E. J. (2018). Metagenomic Analysis of Orange Colored Protrusions from the Muscle of Queen Conch *Lobatus Gigas* (Linnaeus, 1758). *PeerJ*, 6, 20 <https://doi.org/10.7717/peerj.4307>

The endangered marine gastropod, *Lobatus gigas*, is an important fishery resource in the Caribbean region. Microbiological and parasitological research of this species have been poorly addressed despite its role in ecological fitness, conservation status and prevention of potential pathogenic infections. This study identified taxonomic groups associated with orange colored protrusions in the muscle of queen conchs using histological analysis, 454 pyrosequencing, and a combination of PCR amplification and automated Sanger sequencing. The molecular approaches indicate that the etiological agent of the muscle protrusions is a parasite belonging to the subclass Digenea. Additionally, the scope of the molecular technique allowed the detection of bacterial and fungi clades in the assignment analysis. This is the first evidence of a digenean infection in the muscle of this valuable Caribbean resource.

De Jesus-Navarrete, A., & Valencia-Hernandez, A. (2013). Declining Densities and Reproductive Activities of the Queen Conch *Strombus Gigas* (Mesogastropoda: Strombidae) in Banco Chinchorro, Eastern Caribbean, Mexico. *Revista De Biología Tropical*, 61(4), 1671-1679 Retrieved from https://www.scielo.sa.cr/scielo.php?script=sci_arttext&pid=S0034-77442013000500011

Queen conch is a gastropod inhabiting the Caribbean Sea, it represents the second largest fishery after the Spiny lobster, but it has been extensively captured in the area. In order to know its population status in Chinchorro Bank, we determined conch density changes and its effects on reproductive activities, between July and November 2009. For this, data on conch density, morphology and reproductive activities were obtained from 15 sites within three fishing zones, and compared with previously collected data (1990, 1992, 1994, and 1997). Data showed that adult density decreased with time, from 10700ind./ha in 1990, to 198ind./ha in 2009. Neither egg masses nor spawns were found and mating was only observed once in July 2009. In July, adult (lip>4mm) density in the Southern zone was 23ind./ha whereas in the Northern zone and Central zone densities were 15 and 9ind./ha respectively. In November, density was somewhat higher: Southern zone 96ind./ha; Central zone 39ind./ha and Northern zone had 38ind./ha. In July, mean shell length was 170.80 +/- 46.28mm, with a higher median

abundance at 180-189mm. In November, higher frequency was 187.63 +/- 45.14mm, maximum at 210-219mm interval. For the last 10 years period, mean adult conch densities have diminished in each zone, which might be the main cause of decreased reproductive activities of the conch at Banco Chinchorro. It is therefore an immediate need to analyse the management plan for this species in this Reserve and perhaps to promote a re-population of queen conch and culture activities.

De Jesus Navarrete, A. (2014). Population Evaluation of Queen Conch (*Strombus Gigas*), Alacranes Reef National Park, Yucatan, Mexico : Final Report. Retrieved from <https://repository.library.noaa.gov/view/noaa/12916>

This final report describes the effort to determine the population density of Queen Conch (*Strombus gigas*) in the Alacranes Reef National Park.

Dellagnola, F. A., Vega, I. A., & Castro-Vazquez, A. (2017). Evidence for a Prokaryotic Origin of Intracellular Corpuscles in the Digestive Gland of the Queen Conch *Lobatus Gigas* (Linnaeus, 1758) (Gastropoda: Strombidae). *Journal of Molluscan Studies*, 83, 186-193
<https://doi.org/10.1093/mollus/eyx003>

Two types of pigmented intracellular bodies have been reported in the digestive glands of several caenogastropods, particularly in the families Ampullariidae (Architaenioglossa: Ampullarioidea), Strombidae and Struthiolariidae (Littorinimorpha: Stromboidea). Rounded corpuscles, which are usually light brown, are identified here as C corpuscles, while corpuscles that are oval, darker and larger are identified as K corpuscles. We studied both corpuscular types in *Lobatus gigas* (Strombidae) using (1) differential-interference contrast microscopy, (2) transmission electron microscopy, (3) in situ hybridization with a generalized cyanobacterial 16S rRNA probe and (4) autofluorescence before and after lysozyme digestion. Results indicated that C corpuscles were located in the basal regions of columnar cells and the intensity of their pigmentation and alcianophilicity (indicative of glycosaminoglycans) was variable. They showed an electron-dense wall and contained abundant electron-dense clumps and irregularly arranged membranes, but no thylakoids or nuclei. Hybridization with the 16S rRNA probe varied from none to intense in C corpuscles, indicative of variations in the rRNA content during their life cycles. Their walls were sensitive to lysozyme digestion, which strongly suggests that peptidoglycans are an integral part of this structure. K corpuscles were located within pyramidal cells and were uniformly dark brown but variably alcianophilic. They showed multiple lamellae of moderate electron density, organized around one to three cores, each one containing one or several small spherical bodies. All K corpuscles hybridized with the 16S rRNA probe and were partly digested by lysozyme. Both C and K corpuscles showed red autofluorescence, which suggests the presence of chlorophyll-like pigments. It is concluded that C and K corpuscles in the digestive gland of *L. gigas* may be forms of a prokaryotic symbiont related to the Cyanobacteria.

DiPette, S., Ural, A., & Santhanam, S. (2015). Analysis of Toughening Mechanisms in the *Strombus Gigas* Shell. *Journal of the Mechanical Behavior of Biomedical Materials*, 48, 200-209
<https://doi.org/https://doi.org/10.1016/j.jmbbm.2015.04.011>

A finite element analysis of the fracture mechanisms in the *Strombus gigas* conch shell is presented in this work. The *S. gigas* shell has a complex microarchitecture that consists of three main macroscopic layers of calcium carbonate: the inner, middle, and outer layers. Each layer is composed of lamellae of calcium carbonate, held together by a cohesive organic protein. As a result of this elaborate architecture, the *S. gigas* shell exhibits a much greater damage tolerance than the calcium carbonate by

itself, with a work of fracture reported to be three magnitudes of order greater. The two main energy dissipating factors that contribute to this are multiple, parallel cracking along first-order interfaces in the inner and outer layers and crack bridging through the second-order interfaces of the middle layer. Finite element analysis was conducted to simulate and replicate flexural strength and work-of-fracture results obtained in the literature for both dry and wet physical bend test specimens. Several parameters were varied including protein strength and fracture toughness, initial protein damage, and the relative heights of macroscopic layers in order to create a model that predicted published, experimental results. The simulations indicate that having some initially weakened protein interfaces is key to matching the parallel cracking in the inner layer of the physical specimens. The wet models exhibit significantly higher work of fracture compared to the dry specimens in large part due to a crack growth resistance behavior in the middle layer, which was successfully modeled. The parametric studies that have been performed on the finite element models provide guidelines for manufacturing the ideal *S. gigas*-inspired, biomimetic composite.

Doerr, J. C., & Hill, R. L. (2013). Home Range, Movement Rates, and Habitat Use of Queen Conch, *Strombus Gigas*, in St. John, US Virgin Islands. *Caribbean Journal of Science*, 47(2-3), 251-259
<https://doi.org/10.18475/cjos.v47i3.a13>

The queen conch, *Strombus gigas*, is a highly valued fishery resource in the Caribbean basin, historically second only to the spiny lobster. Currently listed in Appendix II of CITES, historical surveys from the U.S. Virgin Islands have documented wide-spread reductions in population densities. Habitat use and movement patterns of queen conch differ by size and maturity status, making it important to identify areas and habitat types that can play a role in the recovery of this species. We tracked long-term movements and spatial distributions of conch in St. John, USVI, using visual surveys coupled with mark-and-recapture techniques. Juvenile conch exhibited the smallest mean home range (95% contour) and core area (50% contour) at 8470 m² and 2083 m², respectively, but had the largest aggregate home range (115,410 m²) and aggregate core area (55,055 m²). Transitional conch had the largest mean home range and core area at 18,203 m² and 4944 m², respectively, with an aggregate home range and core area of 113,147 m² and 59,067 m². Adults had an aggregate home range and core area of 65,045 m² and 29,178 m², with a mean home range and core area of 14,987 m² and 3929 m². Adults exhibited the highest daily movement rate at 11.36 m per day, with juvenile and transitional conch having similar rates of 4.66 m per day and 3.44 m per day, respectively. Multiple recapture events of tagged conch showed an ontogenetic shift in habitat use as maturing individuals moved from shallow seagrass habitats into deeper-water macroalgae plains.

Doerr, J. C., & Hill, R. L. (2018). Spatial Distribution, Density, and Habitat Associations of Queen Conch *Strombus Gigas* in St. Croix, US Virgin Islands. *Marine Ecology Progress Series*, 594, 119-133
<https://doi.org/10.3354/meps12547>

Conventional stock assessment methods have been ineffective for determining the status of queen conch throughout the Caribbean, mainly due to a lack of available fishery-independent data. We examined queen conch populations on the northeastern coast of St. Croix, US Virgin Islands, using a 10 m radial survey sampling technique with sample sites stratified by water depth, habitat type, and management regime, encompassing both open and closed fishing areas. We completed 503 radial surveys and located 4773 queen conch, representing an overall density of 302 conch ha⁻¹. Densities of juvenile and adult queen conch were higher within Buck Island Reef National Monument (BIRNM) boundaries compared to open fishing areas. Densities of juvenile and adult queen conch were highest in habitats characterized as 50-90 and 10-50% patchy seagrass, respectively. Shell length data

suggest that the seagrass beds south of Buck Island are functioning as valuable nursery habitat for juvenile conch, and the presence of multiple juvenile cohorts indicates that larval recruitment in the area has been successful in recent years. Comparisons of data from this and previous studies indicate that the queen conch population in St. Croix is potentially stable under the current management approach and that BIRNM is providing the spatial protection required for the population to continue to recover. Given the spatial and temporal patchiness of queen conch distributions, standardized fishery-independent monitoring surveys should be repeated regularly to provide data sufficient to assess stock conditions and the efficacy of management measures.

Domínguez-Pérez, D., Lippolis, J., Dennis, M., Miller, B., Tiley, K., Vasconcelos, V., . . . Campos, A. (2019). The Queen Conch (*Lobatus Gigas*) Proteome: A Valuable Tool for Biological Studies in Marine Gastropods. *The Protein Journal* <https://doi.org/10.1007/s10930-019-09857-0>

Queen conch (*Lobatus gigas*) is a marine gastropod endemic to the Caribbean. This species is a cultural symbol, being a significant local food source and the second largest commercial fishery in the region. However, over-exploitation and natural habitat degradation have exerted high survival pressure on this species. This work aims to provide novel proteomic data to highlight the metabolism of the species and to provide an important tool for the understanding of queen conch biology and physiology. Herein, we profiled the whole proteome from 3 organs (gills, digestive gland and muscle) of *L. gigas* combining gel-free and gel-based techniques. Overall 420 clusters of proteins were identified corresponding to the minimum identification requirement of protein sequence redundancy. Gene ontology and KEGG analysis highlighted 59 metabolic pathways between identified proteins. The most relevant routes according to the number of sequences found per pathway were purine and thiamine metabolism, closely related to nucleotide and carbohydrate metabolism. We also emphasize the high number of proteins associated to the biosynthesis of antibiotics (93 proteins and a total of 28 enzymes), which were among the top-twenty pathways identified by KEGG analysis. The proteomics approach allowed the identification and description of putative markers of oxidative stress, xenobiotic metabolism, heat shock response and respiratory chain for the first time in the species, which could be extremely useful in future investigations for diagnosing and monitoring *L. gigas* population health.

Dujon, A. M., Stieglitz, T. C., Amice, E., & Webber, D. M. (2019). Snail Leaps and Bounds: Drivers of the Diel Movement Pattern of a Large Invertebrate, the Caribbean Queen Conch (*Lobatus Gigas*), in a Marginal Inshore Habitat. *Canadian Journal of Zoology*, 97(5), 436-445
<https://doi.org/10.1139/cjz-2018-0106>

Understanding the relationship between the movements of animals and their environment is crucial for fisheries and species management. There is currently a lack of detailed information about the movement of slow-moving benthic species, especially for species of ecological or commercial importance. Here we document the relationship between diel movement and environmental parameters in a groundwater-fed coastal inlet for the queen conch (*Lobatus gigas* (Linnaeus, 1758)), an important fishery resource of the Caribbean region, using three-dimensional accelerometers and video cameras. Our results show immature queen conch ($n = 9$) spend most of their active time grazing, exhibiting two main distinct movements that we characterize as a leap and a drift that are mostly used to access new foraging resources. When overturned, they flip, producing a movement with the highest acceleration recorded to limit exposure and restore normal position. Movement patterns appear to be significantly affected by the oxygen concentration of the bottom water, with lower activity during low-oxygen levels in the morning (probability of 0.75 of observing 0 movement per hour) and maximum activity during the afternoon when oxygen concentration is at its maximum (probability of 0.80 of

observing >10 movements per hour). Salinity and temperature had little effect on movement patterns. Our results confirm that highly variable marginal habitats like groundwater-fed inlets are suitable for juvenile conch growth and should be included in efficient conservation plans.

Enriquez-Diaz, M. R., Volland, J. M., Chavez-Villegas, J. F., Aldana-Aranda, D., & Gros, O. (2015). Development of the Planktotrophic Veligers and Plantigrades of *Strombus Pugilis* (Gastropoda). *Journal of Molluscan Studies*, 81, 335-344 <https://doi.org/10.1093/mollus/eyv011>

The organogenesis, histogenesis and growth of larvae of the fighting conch *Strombus pugilis* (Linne, 1758) were studied over a period of 30 d after hatching in laboratory culture. Early development of *S. pugilis* was examined by light and scanning electron microscopy. Rearing was conducted at 27 +/- 1 degrees C. Veligers were reared at 200 larvae l(-1) in 4-l containers. Larvae were fed with the microalgae *Isochrysis galbana* and *Nanochloropsis oculata* at a concentration of 1,000 cell l(-1). The protoconch at hatching measured 212 +/- 12.14 mu m in length and the shell reached 1,100 +/- 29.11 mu m 29 d after hatching. Development characteristics are described from hatching to settlement. Newly hatched veligers possess two velar lobes, a larval shell consisting of 1.5 whorls, eyespots and a single right tentacle. Late veligers (5-d old larvae) have four velar lobes and two shell whorls and the left tentacle appears. Pediveligers show a functional adult heart at 11 d. Crawling behaviour and settlement were observed from 27 to 31 d. Plantigrades were observed after 29 d, when a functioning proboscis is observed and the velar lobes are lost. This study will facilitate the identification of gastropod larval shells in the plankton and of juveniles in the meiobenthos and will aid aquaculture of *Strombus* species.

García Ramos, M., & Banaszak, A. T. (2014). Symbiotic Association between *Symbiodinium* and the Gastropod *Strombus Gigas*: Larval Acquisition of Symbionts. *Marine Biotechnology*, 16(2), 193-201 <https://doi.org/10.1007/s10126-013-9536-x>

The importance of the dinoflagellate *Symbiodinium* sp. was studied in the early life stages of the gastropod *Strombus gigas*. This dinoflagellate was not found in the eggs or the gelatinous mass surrounding the eggs of the mollusk; therefore, *Symbiodinium* is not inherited directly. To determine whether the planktonic veligers can acquire these algae from the environment, they were exposed to freshly isolated *Symbiodinium* from adult *S. gigas* (homologous). The optimal stage for *Symbiodinium* inoculation was found at 48 h post-hatching. Survival and growth rates of veligers and juveniles were higher when inoculated with freshly isolated *Symbiodinium* in conjunction with daily feeding of *Isochrysis* spp. Veligers inoculated with *Symbiodinium* freshly isolated from three host species elicited distinct responses: (1) veligers did not take up *Symbiodinium* isolated from the hydrozoan *Millepora alcicornis* suggesting that there is discrimination on contact prior to ingestion, (2) veligers did take up *Symbiodinium* isolated from the anemone *Bartholomea annulata*, but the algae did not persist in the host tissue suggesting that selection against this type took place after ingestion or that the algae did not divide in the host, and (3) veligers did take up *Symbiodinium* isolated from *Pterogorgia anceps* where it persisted and was associated with metamorphosis of the larvae. In contrast, the *Symbiodinium* freshly isolated from *S. gigas* were not associated with metamorphosis and required an inducer such as the red alga *Laurencia poitei*. These data present a significant advancement for the establishment of a new approach in the aquaculture of this important but declining Caribbean species.

Hadden, C. S., & Cherkinsky, A. (2015). C-14 Variations in Pre-Bomb Nearshore Habitats of the Florida Panhandle, USA. *Radiocarbon*, 57(3), 469-U152 https://doi.org/10.2458/azu_rc.57.18353

This article presents radiocarbon data for known-age, pre-bomb marine gastropods, *Busycon sinistrum* and *Strombus alatus*, collected between AD 1924 and 1946 from nearshore environments of the Florida Panhandle, on the northern Gulf of Mexico. Delta C-14 was measured in whole crushed juvenile specimens (n = 7) and terminal edges of adult specimens (n = 6). A subsample of adult specimens (n = 3) was subjected to additional, intrashell sampling to observe short-term variability in C-14 conditions. Delta C-14 values were consistent within and among *B. sinistrum* specimens, and we propose a reservoir age offset (Delta R) of -9 ± 25 C-14 yr for *B. sinistrum* from the northwest coast of Florida. *S. alatus* shells exhibited significant variability from one individual to another, and also within individual specimens. Delta R values for *S. alatus* range from -3 ± 30 to 659 ± 30 C-14 yr. These differences may result from a combination of factors, including subregional variability in inputs of C-14 depleted waters and life-history factors including mobility, mode of feeding, and ontogenetic niche shifts.

Higueta-Valencia, M. M., Montoya-Campuzano, O. I., Márquez-Fernández, E. J., & Moreno-Herrera, C. X. (2018). Estructura De La Comunidad Bacteriana En Diferentes Tejidos De *Lobatus Gigas* Silvestres (Linnaeus, 1758) De La Reserva De Biosfera Seaflower Del Caribe. [Bacterial community structure in different tissues of the wild *Lobatus gigas* (Linnaeus, 1758) from the Caribbean Seaflower Biosphere Reserve]. *Boletín de Investigaciones Marinas y Costeras - INVEMAR*, 47(2), 37-62 <https://doi.org/10.25268/bimc.invemar.2018.47.2.746>

The microbial diversity of *Lobatus gigas* has not been thoroughly studied despite of them is a specie endangered. Knowledge of microbiota may help to improve the conservation and cultivation of this species. The objective of this study was to evaluate the bacterial populations associated with the gonad and the gut compartments of the wild endangered *L. gigas* from the Caribbean Seaflower Biosphere Reserve, using microbiological methods and culture-independent molecular tools. The genetic profiles of the bacterial populations were generated and Temporal Temperature Gradient Electrophoresis (TTGE) was used to compare them with total DNA. A genetic and statistical analysis of the bacterial communities revealed a low level of diversity in gonad tissue based on the number of bands detected using TTGE. In addition, statistical differences in bacterial community structure were found between the foregut and hindgut tissue of *L. gigas*. The dominant phylogenetic affiliations of the gonad bacteria, as determined using 16S rRNA gene sequencing, belong to *Ralstonia* (50%). The possible involvement of this genus in the reproduction and development of the conch is discussed. On the other hand, the bacterial phylotypes from foregut and hindgut included members of Alphaproteobacteria (12.5%), Betaproteobacteria (12.5%), Gammaproteobacteria (12.5%), Bacilli (31.25%), Clostridia (6.25%), Actinobacteria (6.25%), Mollicutes (6.25%) and Deinococci (6.25%) classes. Knowing the composition of the gonad and foregut and hindgut bacteria of *L. gigas* is the first step toward exploring the proper management of this species, as well as provides useful information to future researches that allow a better understanding of the role of these bacterial populations in the health and reproductive rate of *L. gigas*.

Hollyman, P. R., Laptikhovsky, V. V., & Richardson, C. A. (2018). Techniques for Estimating the Age and Growth of Molluscs: Gastropoda. *Journal of Shellfish Research*, 37(4), 773-782, 710 <https://doi.org/10.2983/035.037.0408>

Gastropoda is a large and diverse group of the Mollusca found almost ubiquitously throughout freshwater, terrestrial, and marine habitats. Marine gastropods often support large commercially important fisheries, many of which are facing concerns over sustainability as landings have increased and populations have dwindled over recent decades. For effective fishery management, the inclusion of an age estimation technique is vital to understand growth rates and population structures to feed into

analytical stock assessments. Unlike many bivalve species, gastropods are often difficult to age, especially those which exhibit planispiral coiling of their shells, as no single growth axis can be easily uncovered via sectioning. This review covers a range of techniques that can be used to estimate age and growth rates for many marine gastropod species. Although there is no universal aging technique to cover all species, individual techniques have varying success levels for different species groups.

Landro, S. M., Teso, V., & Arrighetti, F. (2019). Morphology of the Digestive Gland of the Marine Panpulmonate Limpet *Siphonaria Lessonii*: A Cytological, Histochemical, and Ultrastructural Description. *Journal of Morphology*, 280(10), 1475-1484 <https://doi.org/10.1002/jmor.21043>

The molluscan digestive gland has been widely studied and its structural and ultrastructural descriptions have allowed the understanding of its several functions. Despite siphonarids are broadly distributed around the world, morphological studies on their digestive system are poorly represented. The panpulmonate limpet *Siphonaria lessonii* is the most abundant gastropod and the dominant herbivore in the rocky intertidal coast of Buenos Aires. The aim of this study was to describe the morphology, histology, ultrastructure, and histochemistry of the digestive gland of this gastropod as well as the cycle of activity of digestion. For that, different histochemical techniques along with light microscopy, transmission electron microscopy, and scanning electron microscopy were employed. This study revealed a complex epithelium, composed of a simple layer with five cell types. Digestive cells and vacuolated cells are responsible for intracellular digestion and energy accumulation; basophilic cells, secrete substances that would be involved in extracellular digestion; pigmented cells might have an excretory function and thin cells would correspond to undifferentiated cells. In addition, the tubules present a changing morphology according to the digestive activity that they undergo. As *S. lessonii* is a grazer that feeds continuously, the cycle of activity of the digestive gland seems to be daily.

Machkour-M'Rabet, S., Cruz-Medina, J., Garcia-De Leon, F. J., De Jesus-Navarrete, A., & Henaut, Y. (2017). Connectivity and Genetic Structure of the Queen Conch on the Mesoamerican Reef. *Coral Reefs*, 36(2), 535-548 <https://doi.org/10.1007/s00338-017-1551-3>

The queen conch (*Strombus gigas*) is a commercially important marine invertebrate that is widely distributed throughout the western Atlantic, from Bermuda to Brazil. Intense exploitation has resulted in a decrease in population numbers of this species, which is listed as protected from commercial exploitation under IUCN and CITES. Previous studies on population genetics have demonstrated contrasting results in terms of the population structure of *S. gigas*. This research analyzed the genetic connectivity of the queen conch over a wide area of the Mesoamerican Reef System to determine whether *S. gigas* presents one panmictic population or a more complex structure. Furthermore, we evaluated the risk of local extinction by establishing the genetic diversity of the studied populations. High resolution was obtained for the five ISSR markers used for a total of 190 individuals, from seven localities along the Mesoamerican Reef. Our results reject the panmictic structure hypothesis for the queen conch in the study area and demonstrate genetic patchiness, indicating general homogeneity among localities that present an isolation-by-distance pattern. However, some genetic temporal variation was confirmed for the Cozumel locality. Furthermore, our results reveal self-recruitment for the Alacranes Reef aggregation and suggest sufficient connectivity with localities on the Caribbean coast to maintain high genetic diversity. With regard to genetic diversity, the results demonstrate that the queen conch is not genetically threatened in the study area. This is probably due to high annual recruitment within Caribbean queen conch aggregations, and suggests that *S. gigas* is a highly resilient organism. We advocate that the appropriate management of *S. gigas* (fishing quota and/or closed season) must be followed to attain a rapid recovery of queen conch populations. This study represents a

fundamental step in the understanding of the dynamic population structure of *S. gigas* in the Mesoamerican Reef and is an important contribution toward improving the future management of this commercially protected species.

Marquez, E. J., Castro, E. R., & Alzate, J. F. (2016). Mitochondrial Genome of the Endangered Marine Gastropod *Strombus Gigas* Linnaeus, 1758 (Mollusca: Gastropoda). *Mitochondrial DNA Part A*, 27(2), 1516-1517 <https://doi.org/10.3109/19401736.2014.953118>

The queen conch *Strombus gigas* is an endangered marine gastropod of significant economic importance across the Greater Caribbean region. This work reports for the first time the complete mitochondrial genome of *S. gigas*, obtained by FLX 454 pyrosequencing. The mtDNA genome encodes for 13 proteins, 22 tRNAs and 2 ribosomal RNAs. In addition, the coding sequences and gene synteny were similar to other previously reported mitogenomes of gastropods.

Marquez, E. J., Restrepo-Escobar, N., & Montoya-Herrera, F. L. (2016). Shell Shape Variation of Queen Conch *Strombus Gigas* (Mesogastropoda: Strombidae) from Southwest Caribbean. *Revista De Biología Tropical*, 64(4), 1585-1595 <https://doi.org/10.15517/RBT.V64I4.21468>

The endangered species *Strombus gigas* is a marine gastropod of significant economic importance through the Greater Caribbean region. In contrast to phenotypic plasticity, the role of genetics on shell variations in *S. gigas* has not been addressed so far, despite its importance in evolution, management and conservation of this species. This work used geometric morphometrics to investigate the phenotypic variation of 219 shells of *S. gigas* from eight sites of the Colombian Southwest Caribbean. Differences in mean size between sexes and among sites were contrasted by analysis of variance. Allometry was tested by multivariate regression and the hypothesis of common slope was contrasted by covariance multivariate analysis. Differences in the shell shape among sites were analyzed by principal component analysis. Sexual size dimorphism was not significant, whereas sexual shape dimorphism was significant and variable across sites. Differences in the shell shape among sites were concordant with genetic differences based on microsatellite data, supporting its genetic background. Besides, differences in the shell shape between populations genetically similar suggest a role of phenotypic plasticity in the morphometric variation of the shell shape. These outcomes evidence the role of genetic background and phenotypic plasticity in the shell shape of *S. gigas*. Thus, geometric morphometrics of shell shape may constitute a complementary tool to explore the genetic diversity of this species.

Martínez Coello, D., Lopeztegui Castillo, A., & Amador Marrero, U. (2015). Diferencias Entre Sexos En La Composición De La Dieta Natural De La Langosta *Panulirus Argus*(Decapoda: Palinuridae) Al Este Del Golfo De Batabanó, Cuba. *Cuadernos de Investigación UNED*, 7(2), 269-277 Retrieved from https://www.scielo.sa.cr/scielo.php?script=sci_abstract&pid=S1659-42662015000200269&lng=en&nrm=iso

Sex differences in the composition of the natural diet of *Panulirus argus* (Decapoda: Palinuridae) in the eastern of the Gulf of Batabano, Cuba. The spiny lobster *Panulirus argus* is one of the most valuable fishery resources in the Caribbean Sea. This is the only species of lobster that has commercial importance in Cuba. This study was aimed to identify the organisms that conform the natural diet for both sexes of *P. argus* and to determine the importance of each prey in the diet of each sex. A total of 30 stomachs of commercial lobsters (≥ 76 mm of carapace length) was analyzed. The identified content was grouping by items and classified for species if it was possible. The total weight of each item was determined and the gravimetric method was applied to estimate the relative weight of the principal diet

components. The most frequently consumed prey was also determined. Items with high, middle or low importance were established by the relative importance index (IIR). Similarities between both sexes diet were estimated by similarity index (ISe). Stomachs were extracted of lobsters captured in a fishing zones from eastern of the gulf of Batabano. The predation pressure (P) on the mollusks species found in the stomach content was calculated based on the respective opercula. It was possible to identified 15 feeding entities (12 in females and 14 in the males) being the preferences: crustacean rests (100%), shell rests (80%), vegetable rests (70%), opercula (63%) and mineral rests (53%). Those preference entities were the same between sexes although in the males the foraminifera and the mineral rest were included. The IIR showed crustaceans as a single group of high importance. The gravimetric analysis showed crustaceans as the most consumed prey (62.3% in females and 40% in males). The opercula of *Lobatus gigas*, *Turbo castanea*, *Fasciolaria tulipa*, *Nassarius antillarum*, *Cerithium* sp and *Tegula fasciata* were found. *Tegula fasciata* showed the highest predation pressure (2.25 in females and 2.14 in males) and together *Cerithium* sp. they were the most abundant species (60.5% and 33.9% respectively). Respect to the weight of stomach contents the Mann-Whitney test showed no significant difference between females and males. The diet of both sexes of *P. argus* in the assessed area was similar (ISe=96.75%) and it was constituted mainly of crustaceans and mollusks.

Morris, R. A. (2016). *Distribution of Queen Conch (Strombus Gigas) on the Pedro Bank, Jamaica: Descriptive and Predictive Distribution Models*. (Master of Science), University of Iceland, Reykjavik, Iceland. Retrieved from <http://hdl.handle.net/1946/23971>

Species distribution models (SDM) are useful tools for describing and predicting species ecological role within its community or ecosystem. They are increasingly becoming important in the context of marine resource management and conservation in light of the the relative difficulty and expense of obtaining quality marine biological and environmental data. SDM have been applied to the marine realm in areas such as marine spatial planning (MSP), prioritizing for the establishment of protected areas, predicting and planning for the impact of non-native species and climate change mitigation. There is an on-going effort by private and public stakeholders to further develop and implement ecosystem based management approaches to Jamaica's marine resources, in particular on socio-economically important species and habitats. In this context descriptive and predictive distribution models were developed for different size and age groups of the commercially important gastropod mollusc, Queen conch (*Strombus gigas*), on the Pedro Bank Jamaica. Species occurrence data from four abundance surveys (2002, 2007, 2011 and 2015) were modelled against the environmental variables; depth, substrate and primary production using generalized additive models (GAM) and Maxent. Descriptive results revealed that for both juveniles and adults there is a higher tendency toward shallower depths and substrates with relatively high amounts of their marcoalgal food. However, it is substrate complexity rather than specific substrate types that may be most important. Predictive models showed that not all supposedly suitable areas were being occupied by the species, but importantly also suggest priority areas for management of the species and its habitat in the context of the Pedro Banks' increasingly multi-use nature.

Mueller, K. W., & Stoner, A. W. (2013). Proxy Measures for Queen Conch (*Strombus Gigas* Linne, 1758) Age and Maturity: Relationships between Shell Lip Thickness and Operculum Dimensions. *Journal of Shellfish Research*, 32(3), 739-744 <https://doi.org/10.2983/035.032.0316>

Estimating age and maturity of the commercially harvested queen conch (*Strombus gigas*) offers fishery managers a unique challenge: How can these variables be determined if only the soft, edible parts of the marine gastropod are landed in port whereas the shells used for aging purposes are discarded at sea? Throughout the greater Caribbean region, including The Bahamas, the age and maturity of *S. gigas* are

estimated by measuring the thickness of the flared lip of the shell. Given the traditional fishery practices for queen conch, including at-sea processing, developing proxy measures for *S. gigas* age and maturity would greatly benefit fishery managers. To this end, we used traditional morphometric analysis to find a significant inverse relationship between the ratio of operculum length to operculum width and shell lip thickness. A logistic regression model using the same operculum metric and a breakpoint of 15 mm for shell lip thickness as an indication of *S. gigas* maturity predicted correctly the maturity level for 86% of queen conch sampled in The Bahamas. This study provides the proof of principle for relationships between operculum measures and queen conch age and maturity that can be applied by fishery managers throughout the geographical range of the species.

Nieto-Bernal, R., Chasqui, L., Rodriguez, A. M., Castro, E., & Gil-Agudelo, D. L. (2013). Composition, Abundance and Distribution of Populations of Commercially Important Gastropods in La Guajira, Colombian Caribbean. *Revista De Biología Tropical*, 61(2), 683-700
<https://doi.org/10.15517/RBT.V61I2.11168>

In the continental Colombian Caribbean the conch resource exploitation and the status of snails populations has been poorly studied, which are reflected in the lack of fisheries management. This study assesses composition, population density and distribution of the gastropods species that make conch resource in La Guajira region. Underwater visual censuses for snails were performed between September-November 2009 in 145 100x4m (400m(2)) transects, spanning a total area of 56 920m(2) between Riohacha and Cabo de la Vela. The study was complemented with the evaluation of composition, abundance and size of gastropods conch found in the discarded-by-fishermen shell mounds in 13 beaches. In October 2010 another 40 transects were evaluated (16 000m(2)) from the Southern of Riohacha to the Camarones village (La Guajira). We found a total of 9 911 snails belonging to 12 species, the most abundant being *Strombus pugilis* with 8 912 individuals and an average density of 1 538.4 +/- 3 662.6 ind./ha, followed by *Vasum muricatum* with 374 individuals and an average density of 51.8 +/- 91.2 ind./ha. Calculating the importance value index (IVI) for both living organisms as the empty shells on beaches, shows that *Turbinella angulata* is the most used species by artisanal fishermen in the region. *Cassis madagascariensis* and *Cassis tuberosa* are also important snail resources in the region (as suggested by the number of empty shells found in beaches), but its densities were low. *Strombus gigas*, with only three living organisms found in the area, presented the lowest abundance ever found in the Colombian Caribbean (0.52 +/- 3.6 ind./ha), showing that queen conch population in La Guajira cannot support commercial exploitation. The abundance of discarded *S. gigas* shells on beaches suggests resource exploitation in the recent past. Results remarks the urgency of implementing management plans for snail fisheries in the region.

Nunez, M. N., & Aranda, D. A. (2014). Basic Eco-Ethology of the Queen Conch, *Strombus Gigas* (Mesogastropoda: Strombidae) in Xel-Ha, Yucatan, Mexican Caribbean. *Revista De Biología Tropical*, 62, 215-222 Retrieved from
https://www.scielo.sa.cr/scielo.php?script=sci_abstract&pid=S0034-77442014000700022&lng=en&nrm=iso

The queen conch *Strombus gigas* is an important fishery in the Caribbean, whose populations are currently overexploited. Since the decade of 1980 there have been several studies on aquaculture, resource management and area rehabilitation. However, little is known about its behavior in a natural environment and the influence of environmental parameters. Monthly surveys, from January to November 2012 were conducted in in Xel Ha, to observe and quantify six behaviors of *S. gigas*: rest, feeding, movement, burying, copulation and spawning. The observations were made every hour from 8h

to 17h by free diving through three transects with three replicates each. Each behavior was observed 90 times each month. Salinity, temperature and dissolved oxygen were registered at the bottom. We found the highest number of snails at rest in July and the lowest in March and September. Feeding and movements had a peak in August. Most buried in October and November. Copulation was first observed on March with a peak in June and July to October's spawning. In daytime observations resting had a peak at 8h; feeding and moving at 12 to 17h. Copulation and spawning did not have a clear pattern. Variations between months and hours (resting, feeding, moving and buried) were significant ($p < 0.05$). Resting correlated with temperature and being buried with oxygen level ($r = -0.5803$; $p = 0.0536$). Feeding and moving correlated with temperature and salinity. These results should be useful for the conservation, restoration and aquaculture programs.

Osuna-Mascardo, A., Cruz-Bustos, T., Benhamada, S., Guichard, N., Marie, B., Plasseraud, L., . . . Mann, F. (2014). The Shell Organic Matrix of the Crossed Lamellar Queen Conch Shell (*Strombus Gigas*). *Comparative Biochemistry and Physiology B-Biochemistry & Molecular Biology*, 168, 76-85 <https://doi.org/10.1016/j.cbpb.2013.11.009>

In molluscs, the shell organic matrix comprises a large set of biomineral-occluded proteins, glycoproteins and polysaccharides that are secreted by the calcifying mantle epithelium, and are supposed to display several functions related to the synthesis of the shell. In the present paper, we have characterized biochemically the shell matrix associated to the crossed-lamellar structure of the giant queen conch *Strombus gigas*. The acid-soluble (ASM) and acid-insoluble (AIM) matrices represent an extremely minor fraction of the shell. Both are constituted of polydisperse and of few discrete proteins among which three fractions, obtained by preparative SDS-PAGE and named 1P3, 2P3 and 3P3, are dominant and were further characterized. Compared to other matrices, the acid-soluble matrix is weakly glycosylated (3%) and among the discrete components, only 3P3 seems noticeably glycosylated. The monosaccharide composition of the ASM shows that mannose represents the main monosaccharide. To our knowledge, this is the first report of a high ratio of this sugar in a skeletal matrix. Furthermore, the ASM interacts with the in vitro crystallization of calcium carbonate, but this interaction is moderate. It differs from that of the isolated 1P3 fraction but is similar to that of the 2P3 and 3P3 fractions. At last, antibodies developed from the 3P3 fraction were used to localize this fraction within the shell by immunogold. This study is the first one aiming at characterizing the organic matrix associated to the crossed-lamellar structure of the queen conch shell.

Padilla, D. K., Charifson, D., Liguori, A., McCarty-Glenn, M., Rosa, M., & Rugila, A. (2018). Factors Affecting Gastropod Larval Development and Performance: A Systematic Review. *Journal of Shellfish Research*, 37(4), 851-867 <https://doi.org/10.2983/035.037.0414>

The goal of this article was to use a systematic review of studies on the larval stages of gastropods reared to metamorphosis to determine whether there are general patterns for the effects of temperature, rearing density, and food availability on larval development and performance among species, major taxa, and modes of development. Most studies did not include sufficient metadata to be included in many of the analyses. For all analyses, there were differences among major groups of taxa in terms of response to the considered variables. Increased temperature was frequently correlated with decreased development time and increased growth but often not for the same taxa. Increased larval density was generally correlated with increased development time, but again, the patterns were not consistent across taxa. The most consistent pattern was the positive correlation between per capita food availability and larval growth. In all but two cases, patterns for the most studied species, *Crepidula fornicata*, were opposite those of other caenogastropods. This indicates that caution should be used

when drawing general patterns among species based on studies of *C. fornicata*. Among lecithotrophs, the vetigastropod *Haliotis rufescens* was the most studied. In this case, patterns found for this species were similar to those for all other vetigastropods; however, few species outside the genus *Haliotis* have been studied. Increased temperature was associated with reduced survivorship and, in the most studied clade, the Vetigastropoda, reduced time to metamorphosis, which suggests that there may be an energetic cost to more rapid development or physiological mechanisms for coping with heat stress. Curiously, increased larval density was associated with increased survivorship for lecithotrophs. In several cases, however, there were too few studies, or the studies that were found did not provide enough metadata to be included in analyses. Although some patterns emerged from existing research on gastropod larvae, studies on a more diverse set of species that report all metadata are required for cross-study comparisons, which are crucial for drawing robust general conclusions.

National Marine Fisheries Service. *Queen Conch, Strombus Gigas (Linnaeus 1758) Status Report*. (2014). Retrieved from <https://repository.library.noaa.gov/view/noaa/17710>

This document summarizes and synthesizes biological information covering queen conch, *Strombus gigas*, throughout its natural distribution. It seeks to present the best available information from published and unpublished sources (e.g., literature searches, interviews). This document does not represent a decision by NMFS on whether this taxon should be proposed for listing as threatened or endangered under the Endangered Species Act.

Ramos, M. G., & Banaszak, A. T. (2014). Symbiotic Association between Symbiodinium and the Gastropod *Strombus Gigas*: Larval Acquisition of Symbionts. *Marine Biotechnology*, 16(2), 193-201 <https://doi.org/10.1007/s10126-013-9536-x>

The importance of the dinoflagellate *Symbiodinium* sp. was studied in the early life stages of the gastropod *Strombus gigas*. This dinoflagellate was not found in the eggs or the gelatinous mass surrounding the eggs of the mollusk; therefore, *Symbiodinium* is not inherited directly. To determine whether the planktonic veligers can acquire these algae from the environment, they were exposed to freshly isolated *Symbiodinium* from adult *S. gigas* (homologous). The optimal stage for *Symbiodinium* inoculation was found at 48 h post-hatching. Survival and growth rates of veligers and juveniles were higher when inoculated with freshly isolated *Symbiodinium* in conjunction with daily feeding of *Isochrysis* spp. Veligers inoculated with *Symbiodinium* freshly isolated from three host species elicited distinct responses: (1) veligers did not take up *Symbiodinium* isolated from the hydrozoan *Millepora alcicornis* suggesting that there is discrimination on contact prior to ingestion, (2) veligers did take up *Symbiodinium* isolated from the anemone *Bartholomea annulata*, but the algae did not persist in the host tissue suggesting that selection against this type took place after ingestion or that the algae did not divide in the host, and (3) veligers did take up *Symbiodinium* isolated from *Pterogorgia anceps* where it persisted and was associated with metamorphosis of the larvae. In contrast, the *Symbiodinium* freshly isolated from *S. gigas* were not associated with metamorphosis and required an inducer such as the red alga *Laurencia poitei*. These data present a significant advancement for the establishment of a new approach in the aquaculture of this important but declining Caribbean species.

Ruga, M. R., Meyer, D. L., & Huntley, J. W. (2019). Conch Fritters through Time: Human Predation and Population Demographics of *Lobatus Gigas* on San Salvador Island, the Bahamas. *Palaios*, 34(8), 383-392 <https://doi.org/10.2110/palo.2018.054>

Lobatus gigas, the queen conch, is a central component of Caribbean cuisine but over-fishing of juveniles has threatened the stability of wild populations. Strombid gastropods, upon reaching sexual maturity, cease growing along the shell length axis and continue growing in width via a flared and thickened shell lip. This morphology serves as a useful indicator of an individual's sexual maturity. Here we examine temporal trends in population demographics, size, and morphology of harvested *L. gigas* individuals over the last 1000 years, similar to 1 ky from San Salvador island, the Bahamas to quantify the dynamics of human-induced stress on the local queen conch fishery. We collected 284 human-harvested individuals from shell middens at seven localities, measured seven morphological variables, and classified the specimens as either adult or juvenile. We randomly selected 64 of these shells for rapid AMS radiocarbon dating in order to establish three geochronological bins: Lucayan (Pre-European invasion, 1492 CE), Modern (similar to 10(2) y), and Global (similar to 10(1) y). The proportion of juveniles harvested increased significantly from 47% (Lucayan) to 61% (Modern) to 68% (Global) suggesting increasing pressure on the fishery through time. Patterns in body size and morphology diverge between adults and juveniles and are likely the result of an increase in the proportion of harvested juveniles, the selection of smaller juveniles through time, and possibly changes in fishing methods. This size selective predation did not result in the suppression of adult body size as found in other studies. Geohistorical data, such as these, are vital for providing long term ecological context for addressing anthropogenic ecological degradation and are central to the conservation paleobiology approach.

Sanchez-Barranco, V. (2017). *Diet and Maximum Size of Queen Conch (Lobatus Gigas) around the Island of Curaçao*. (Master of Science), Utrecht University, Utrecht, Netherlands. Retrieved from <https://dspace.library.uu.nl/handle/1874/356831>

The main focus of this study was to gather more information about the diet and ecology of the Queen conch (*Lobatus gigas*) in the island of Curaçao and provide background knowledge for future restoration and mariculture programs. The presence of conchs in the Sea Aquarium of Curaçao, where there is practically no poaching or predation, offered a good opportunity to study the diet and length distribution of the conchs under various semi-natural conditions. For this study, samples of conchs and possible items of their diet were collected from 5 natural sites and 6 basins of the Sea Aquarium. The presence of various species of sea mammals (i.e. dolphins, sea lions) in these basins was thought to influence diet composition and therefore the growth rate of the conchs. Stable isotope analysis of nitrogen ($\delta^{15}\text{N}$) and carbon ($\delta^{13}\text{C}$) was used to test this hypothesis and to determine the main diets of the conchs in every site. This method allows identifying the composition of consumers and estimating the contribution of the different elements of a consumer's diet. The results showed that in the basins of the Sea Aquarium and in the natural sites where there was human influence, the $\delta^{15}\text{N}$ of the conchs and the algae sampled were high compared to the more pristine natural sites. The reason for that might be that the sewage of resorts and the Sea Aquarium discharge close to where the conchs were found. In the Sea Aquarium, the presence of the sea mammals inhabiting the basins could also be the reason for the high levels of $\delta^{15}\text{N}$. The second main goal was to assess if the maximum sizes reached in the Sea Aquarium were larger compared to the wild and, if that was the case, try to relate it to the different diets. The length of this study did not allow for growth measurements. Therefore, the maximum length of the shell and the thickness of the flared lip were used as proxies for local growth conditions. Within the basins of the Sea Aquarium, the largest specimen found had a shell length of 33cm and a lip thickness of 1.2cm. Moreover, adults with flared lips were found in all the basins of the Sea Aquarium, but juveniles were mostly lacking. At most natural sites, however, only juveniles were found and only at Playa Grandi, some specimens with a shell length of more than 28cm and complete developed flared lip were found. The presence of these large specimens suggests that the large sizes reached in the Sea Aquarium are related to the lack of predation (including fisheries) rather than to the diet. This study

underlines that adult Queen conchs in the waters surrounding Curaçao are very rare and appear to occur only in restricted places where there is no poaching of large specimens. Even though specimens of Queen conch were larger and had a different diet in the basins of the Sea Aquarium than those living within more natural waters of Curacao, a causal relationship between growth and diet could not be established. The contrasting size-frequency distributions, finding mostly adults in the Sea Aquarium and juveniles in natural sites, suggest that the high mortality of Queen conch at accessible locations strongly influences the survival and subsequent the length that can be reached. Future restoration of wild populations appears only feasible if juveniles are allowed to reach adult size at which they can reproduce.

Sanchez, F. C., Diaz, M. E., & Aranda, D. A. (2019). Quantification of 17 Beta - Estradiol and Progesterone Hormones in the Pink Snail *Lobatus Gigas* (Mollusca, Gastropoda). *Revista De Biología Tropical*, 67(4), 708-715 [no URL available]

Quantification of steroid hormones in molluscs is performed with different techniques, using the hemolymph or gonads. *Lobatus gigas* is a Caribbean gastropod of commercial interest indexed in CITES as a protected species. Hormonal studies of this species are as yet unavailable. The objective of this study is to determine the presence of the steroid hormones 17 beta - estradiol and progesterone in *L. gigas* using a non-invasive method, and to compare two techniques for their quantification. Every two months over the course of one year, the feces of ten organisms were collected in Xel-Ha park Quintana Roo, Mexico. The samples were analyzed with High resolution liquid chromatography and Enzyme-linked immunosorbent assays. The values of both hormones were highest during the months of March to September then decreased during November and January. Comparison of the concentrations obtained with HPLC and EIA, presented similar results for 17 beta-estradiol (Passing - Bablock $r = 0.673$; mean differences -0.17 ng / ml). In contrast, the progesterone results with both techniques showed no adjustment (Passing - Bablock $r = 0.389$; mean differences -1.43 ng / ml). Our results suggest that the enzyme-linked immunosorbent assay is suitable for the study of hormones in *L. gigas*. The knowledge generated will allow the monitoring and selection of breeding organisms that are conditioned in laboratories and thus will not affect the collection of wild egg masses.

Sanchez, F. C., Diaz, M. E., Rodriguez, E. M., & Aranda, D. A. (2019). First Use of a Non-Invasive Technique for Determination of Sex Hormones in the Queen Conch *Lobatus Gigas*, Mollusca Gastropoda. *Aquaculture International*, 27(2), 437-448 <https://doi.org/10.1007/s10499-018-0336-1>

Profiles were generated of the sex hormones estrogen, progesterone, and testosterone in the marine snail *Lobatus gigas* every 2 months for 1 year. A non-invasive technique involving feces collection was used. Hormones were extracted from the feces with 80% methanol. After filtering, hormone concentrations were measured by high-performance liquid chromatography and a UV detector. All three sex hormones were present in *L. gigas* feces, and their concentrations increased contemporaneously with the conch reproductive period. Males and females showed the highest concentration of testosterone in May (1.8 ± 0.3 and 2.1 ± 0.8 ng/ml, respectively). Both sexes presented a maximum estrogen concentration in May (1.2 ± 0.7 and 1.0 ± 0.3 ng/ml). Progesterone in females remained constant from March to July. Pearson correlation between estrogen and spawning activity were $r=0.66$ ($p=0.03$) and for testosterone ($r=0.5216$) and progesterone ($r=0.437$). This study constitutes the first use of this technique in this species. Results show that sex hormones may be controlling this species' reproductive events, as occurs in other gastropods. The understanding of the *L. gigas* reproductive

process, this is one of several steps that will allow in the future improve aquaculture systems and supporting conservation of wild populations.

Shin, Y. A., Yin, S., Li, X. Y., Lee, S. B., Moon, S. M., Jeong, J. W., . . . Oh, S. H. (2016). Nanotwin-Governed Toughening Mechanism in Hierarchically Structured Biological Materials. *Nature Communications*, 7, 10 <https://doi.org/10.1038/ncomms10772>

As a natural biocomposite, *Strombus gigas*, commonly known as the giant pink queen conch shell, exhibits outstanding mechanical properties, especially a high fracture toughness. It is known that the basic building block of conch shell contains a high density of growth twins with average thickness of several nanometres, but their effects on the mechanical properties of the shell remain mysterious. Here we reveal a toughening mechanism governed by nanoscale twins in the conch shell. A combination of in situ fracture experiments inside a transmission electron microscope, large-scale atomistic simulations and finite element modelling show that the twin boundaries can effectively block crack propagation by inducing phase transformation and delocalization of deformation around the crack tip. This mechanism leads to an increase in fracture energy of the basic building block by one order of magnitude, and contributes significantly to that of the overall structure via structural hierarchy.

Thomas, C., Auscavitch, S., Brooks, A., & Stoner, A. W. (2015). *Assessing Essential Queen Conch (Strombus Gigas) Habitat in Eleuthera, the Bahamas: Population Declines Suggest the Urgent Need for Changes in Management*. Paper presented at the Proceedings of the Gulf and Caribbean Fisheries Institute, Christ Church, Barbados. [no URL available]

Queen conch (*Strombus gigas*) are economically and culturally important throughout the greater Caribbean region. However, recent surveys have shown declines throughout their range. In The Bahamas, there exists one of the last viable conch fisheries, but overfishing and illegal juvenile harvest is observed throughout the family islands. In Eleuthera, many local residents rely on marine resources, particularly conch, for subsistence. Population declines may have devastating effects on an already impoverished part of the country. A marine protected area has been suggested for South Eleuthera, but without current information on conch populations and identification of essential habitat, ideal placement and effectiveness cannot be assessed. To determine the health of the local conch population, we performed surveys in two crucial habitats: shallow water habitat and deep water breeding grounds. Utilizing towed snorkel surveys, we obtained necessary baseline data in nearshore habitat with moderate fishing pressure; preliminary results show low numbers of conch, with a mean density of 18 conch/ha. The deep water surveys (performed on SCUBA) were compared to surveys from the 1990s, to determine if local waters are still used by conch for reproduction. Although mating and egg masses were identified in the deep water, the mean density of 11 adults/ha is significantly lower than previous population estimates, and below the threshold identified for a healthy breeding population. Coupled with midden surveys that show only 14% of locally harvested conch are adult, the data suggest a drastic decrease in the South Eleutheran conch population, a potential early sign of population collapse.

Tiley, K., Dennis, M. M., Lewin-Smith, M. R., Jenkins, H. M., Kristmundsson, A., & Freeman, M. A. (2018). Digestive Gland Inclusion Bodies in Queen Conch (*Lobatus Gigas*) Are Non-Parasitic. *Journal of Invertebrate Pathology*, 157, 4-8 <https://doi.org/10.1016/j.jip.2018.07.004>

Unusual inclusion bodies occur within the epithelial cells of the digestive gland of queen conch, *Lobatus gigas*, and have previously been described as apicomplexan parasites. The aim of this study was to investigate the parasitic features of these inclusion bodies in queen conch. *L. gigas* from St. Kitts

(Caribbean Sea) consistently (100% of n = 61) showed large numbers of ovoid to tri-bulbous dark brown inclusion bodies (15 x 30 μ m) within vacuolar cells. Histochemical stains demonstrated iron, melanin, and glycoprotein and/or mucopolysaccharide within the inclusion bodies. Microscopic features indicative of a host response to injury were lacking in every case, as were consistent morphological forms to indicate distinct parasitic stages. Transmission electron microscopy failed to reveal cellular organelles of parasitic organisms and DNA extractions of purified inclusion bodies did not yield sufficient concentrations for successful PCR amplification. Scanning electron microscopy with energy dispersive X-ray analysis revealed a number of elements, particularly iron, within the inclusion bodies. We conclude that the inclusion bodies are not an infectious agent, and hypothesize that they represent a storage form for iron, and potentially other elements, within a protein matrix. Similar structures have been described in the digestive glands of other invertebrates, including prosobranchs.

Tiley, K., Freeman, M. A., & Dennis, M. M. (2018). Pathology and Reproductive Health of Queen Conch (*Lobatus Gigas*) in St. Kitts. *Journal of Invertebrate Pathology*, 155, 32-37
<https://doi.org/10.1016/j.jip.2018.04.007>

Queen conch, *Lobatus gigas*, are one of the largest commercial fisheries in the Caribbean and are severely depleted due to overharvesting. Dwindling and fragmented populations are at high risk to stochastic events such as disease epidemics; however, there is a paucity of literature regarding queen conch disease. A histopathological survey was conducted to assess the disease status of St. Kitts' queen conch populations, and contribute to the little information known about *L. gigas* pathology. Using a standard dissection and sampling protocol, pathology status was assessed in 61 *L. gigas* sampled opportunistically from fishermen in St. Kitts from October 2015 to November 2016. Pathology was observed in 13.1% (8/61) of the study population, mostly comprising internal parasitism (n = 5), especially encysted metazoan parasites (likely digenean metacercaria), observed in the gill, mantle, digestive gland and large intestine. Parasitism appeared incidental, having little impact on the host's health and minimal host response to the infection. Additionally, aspects of *L. gigas* reproductive health were analyzed: reproductive season in St. Kitts was confirmed from May to September; lip thickness is suggested as a better regulation measure for protecting juvenile populations compared to shell length; and variation in gonad color is found to be an unreliable predictor of reproductive activity. We conclude that disease appears to be uncommon in fisherman-caught *L. gigas* from St. Kitts. Pathologies observed elsewhere, including imposex and apicomplexan infection of the digestive gland, could not be substantiated in the study population. The cryptic nature of sick gastropods, as well as high predation rate and selection pressure for diseased queen conch may yield underrepresentation of pathology in such surveys. Future disease surveys could benefit from targeting stunted individuals, those showing unusual behavior, or those grown in an aquaculture environment.

Tiley, K., Freeman, M. A., Yen, I., & Dennis, M. M. (2019). Histology Atlas and Systematic Approach to Postmortem Examination of the Queen Conch *Lobatus Gigas*. *Journal of Shellfish Research*, 38(1), 131-148 <https://doi.org/10.2983/035.038.0113>

The queen conch *Lobatus gigas* is the second largest commercial fishery in the Caribbean, and overharvesting has resulted in significant population declines. Depleted populations are at greater risk of stochastic events, including disease epidemics; however, disease diagnosis in *L. gigas* has been limited by the lack of standard procedure and histological reference material. This manual outlines a systematic technique for postmortem examination and compiles a comprehensive histology atlas to facilitate research regarding the pathology of *L. gigas*. Methods for euthanasia, dissection, sampling, and fixation are described, which produced optimal presentation and preservation of tissues. The recommended

approach includes anesthesia with magnesium sulphate, extraction from shell, and euthanasia by incision through ganglia posterior to the buccal mass, followed by exposure of all tissues using four incisions. Anatomy is described for both sexes and standard sample locations are established. Tissue fixation is optimal using Davidson's formula. A histological reference for 16 tissues, nine of which were described for the first time in this species, is presented, including the anus, columellar muscle, digestive gland, esophagus, foot, ganglia and nerves, gill, gonad, heart, hypobranchial gland, kidney, mantle, nephridial gland, osphradium, small intestine and rectum. This manual is the first necropsy guide and histology atlas for *L. gigas*, a baseline resource for researchers monitoring health and disease in the species.

Titley-O'Neal, C. P., Spade, D. J., Zhang, Y. P., Kan, R., Martyniuk, C. J., Denslow, N. D., & MacDonald, B. A. (2013). Gene Expression Profiling in the Ovary of Queen Conch (*Strombus Gigas*) Exposed to Environments with High Tributyltin in the British Virgin Islands. *Science of the Total Environment*, 449, 52-62 <https://doi.org/10.1016/j.scitotenv.2013.01.028>

Queen conch (*Strombus gigas*) are listed in CITES Appendix II. Populations may be declining due to anthropogenic inputs that include pollutants from boating activity. In the British Virgin Islands (BVI), some conch exhibit imposex, a condition in which male external genitalia are present in female conch. Previous studies suggest that tributyltin (TBT), an antifouling chemical used in boat paint, is correlated to increased incidence of imposex although the mechanisms leading to imposex are not known. The present study utilized a Queen conch microarray to measure the response of the ovarian transcriptome in conch inhabiting polluted environments with high TBT levels in the BVI. The polluted sites, Road Harbour (RH) and Trellis Bay (TB), are areas with high boating activity while the reference sites, Guana Island (GI) and Anegada (AN), are areas with low boating activity. There were 754 and 898 probes differentially expressed in the ovary of conch collected at RH and TB respectively compared to conch collected at GI. Of the genes that were differentially expressed at both sites, >10% were shared suggesting that these sites have additional environmental factors influencing gene expression patterns. Functional enrichment analysis showed that the biological processes of cell proliferation, translation, and oxidative stress were over-represented in the polluted sites. Gene set enrichment analysis revealed that transcripts involved in the biological processes of general metabolism, immune, lipid metabolism, and stress were affected in conch from polluted environments. Interestingly, altered stress genes appeared to be more prevalent in conch collected from RH than TB, corresponding to the higher TBT load at RH compared to TB. Our study shows that stress pathways are affected in conch ovary in environments that experience heavy boating activity in the BVIs, although we are unable to directly link changes at the transcriptomics level to high TBT levels.

Truelove, N. K., Fai Ho, L., Preziosi, R. F., & Box, S. J. (2016). Validation and Characterization of Thirteen Microsatellite Markers for Queen Conch, *Lobatus Gigas*. *PeerJ Preprints*, 4(e2559v1) <https://doi.org/10.7287/peerj.preprints.2559v1>

We report the development and characterization of 13 novel microsatellite loci for the Caribbean queen conch, *Lobatus gigas*, an ecologically and commercially important marine gastropod. Paired-end sequencing was carried out on genomic DNA from a single queen conch using half a flow cell lane of an Illumina MiSeq. A total of 48 potentially amplifiable loci containing microsatellites were tested on 45 individuals from the Florida Keys and Bahamas. In total, 13 consistently amplifying and polymorphic microsatellite loci were identified. The number of alleles ranged from 4 to 26 and observed heterozygosities ranged from 0.340 to 1.00. There was no evidence of scoring error, large allele dropout, or evidence of linkage disequilibrium at any locus. Four loci deviated from Hardy-Weinberg equilibrium

due to moderate levels of null alleles (null allele frequencies ranged from 0.081 to 0.230). Although null alleles were detected at four microsatellite loci, the high levels of polymorphism and moderate null allele frequencies suggest that these 13 novel microsatellite markers will be useful for researchers carrying out conservation genetic studies of *L. gigas*.

Villanueva-Gutiérrez, E., Enríquez-Ocaña, L. F., López-Elias, J. A., Garza-Aguirre, M. d. C., Mazón-Suástegui, J. M., & Martínez-Córdova, L. R. (2019). Gonadic Conditioning and Maturation of the Queen Conch (*Dosinia Ponderosa*) Fed Three Microalgae at Three Temperatures. *Aquaculture Nutrition*, 25(1), 88-96 <https://doi.org/10.1111/anu.12832>

Gonadic conditioning and maturation of queen clam *Dosinia ponderosa* fed three microalgae (*Isochrysis galbana*, *Tetraselmis suecica* and *Chaetoceros calcitrans*) at three temperatures (20, 25 and 30°C) were assessed. Histological analysis showed six gonadic stages, indicators of maturity. The evaluation included sex proportion, oocyte diameter and frequency of gonadic stages after 22 (middle of trial) and 44 days (end of trial). At day 22, around 60% of females conditioned at 20°C, reached stage III (advances grade of maturation) when fed *T. suecica*. At day 44, around 50% of females were on stage III, conditioned at 20 and 25°C and fed *T. suecica* and *C. calcitrans*. For males, the best combination was *C. calcitrans* at 20 and 25°C. The temperature of 30°C resulted inadequate for maturation, especially when fed the diatom *Isochrysis galbana*. High mortalities occurred at that temperature with the three microalgal diets, especially in females. The results permits conclude that *T. suecica* and *C. calcitrans* are good sources of feed for *D. ponderosa* and that the best range of temperature for gonadic development is 22-25°C. These results may be basic for a best management and culture of this clam.

Section III: Threats

Apeti, D. A., Mason, A. L., Hartwell, S. I., Pait, A. S., Bauer, L. J., Jeffrey, C. F., . . . Galdo, F. R. (2014). An Assessment of Contaminant Body Burdens in the Coral (*Porites Astreoides*) and Queen Conch (*Strombus Gigas*) from the St. Thomas East End Reserves (STEER). Retrieved from <https://repository.library.noaa.gov/view/noaa/798>

As part of the joint effort between the US Virgin Islands Department of Planning and Natural Resources and the NOAA Centers for Coastal and Ocean Science (NCCOS), to conduct a Reserves-wide impact assessment of land-based sources of pollution and effects in the St. Thomas East End Reserves (STEER), contaminant body burdens in coral (*Porites astreoides*) and conch (*Strombus gigas*) were assessed. Samples of coral and conch were collected from five previously identified strata and analyzed for more than 150 chemical contaminants including heavy metals (e.g. cadmium, copper, mercury and zinc) and organic contaminants (e.g. polycyclic aromatic hydrocarbons, polychlorinated biphenyls and pesticides). Conch from the STEER had lower contaminant body burdens relative to published data on conch from south Florida and some other areas of the Caribbean. Where available, contaminant body burdens in conch were compared to FDA maximum permissible action levels for molluscan shellfish consumption. The conch samples from the STEER had contaminant body burdens lower than their available respective FDA action levels. A significant correlation between higher concentrations of butyltins closer to shore existed for conch, despite relatively low overall concentrations as compared to previous results from the region.

Delgado, G. A., Glazer, R. A., & Wetzel, D. (2013). Effects of Mosquito Control Pesticides on Competent Queen Conch (*Strombus Gigas*) Larvae. *Biological Bulletin*, 225(2), 79-84
<https://doi.org/10.1086/BBLv225n2p79>

Pesticides are applied seasonally in the Florida Keys to control nuisance populations of mosquitoes that pose a health threat to humans. There is, however, a need to investigate the effects of these pesticides on non-target marine organisms. We tested naled and permethrin, two mosquito adulticides used in the Keys, on a critical early life-history stage of queen conch (*Strombus gigas*). We conducted 12-h exposure experiments on competent (i. e., capable of undergoing metamorphosis) queen conch larvae using environmentally relevant pesticide concentrations. We found that there was little to no mortality and that the pesticides did not induce or interfere with metamorphosis. However, after introduction of a natural metamorphic cue (extract of the red alga *Laurencia potei*), a significantly greater proportion of larvae underwent metamorphosis in the pesticide treatments than in those with the alga alone. In addition to the morphogenetic pathway that induces metamorphosis when stimulated, there thus appears to be a regulatory pathway that enhances the response to metamorphic triggers, as suggested by the increased sensitivity of the queen conch larvae to the algal cue after pesticide exposure (i. e., the pesticides stimulated the regulatory pathway). The regulatory pathway probably plays a role in the identification of high-quality habitat for metamorphosis, as the increased response to the algal cue suggests. Aerial drift and runoff can carry these pesticides into nearshore waters, where they may act as a false signal of favorable conditions and facilitate metamorphosis in suboptimal habitat, thus adversely affecting recruitment in nearshore queen conch populations.

Hoffman, D. M. (2014). Conch, Cooperatives, and Conflict: Conservation and Resistance in the Banco Chinchorro Biosphere Reserve. *Conservation & Society*, 12(2), 120-132
<https://doi.org/10.4103/0972-4923.138408>

In theory, biosphere reserves link biodiversity conservation with development, primarily through sustainable resource utilisation, and alternative, conservation-compatible economies in the buffer and transition zones outside the core area. Successful management should reduce pressure on natural resources within its core area as well as enable local communities to participate in the management of buffer zone resources in a sustainable manner. The Banco Chinchorro Biosphere Reserve was declared in 1996 to protect coral reefs and marine biodiversity, while also enabling fishing cooperatives to maintain their livelihoods based upon the sustainable extraction of lobster, conch, and scalefish. In 2004, eight years after the Reserve's declaration, Mexican authorities struggled to control marine resource use in the reserve, especially the extraction of queen conch (*Strombus gigas*). This article provides an overview of the long struggle to conserve queen conch populations in the area. Particular attention is paid to describing the various forms of resistance fishermen employed to counter the increasing regulation and vigilance that accompanied the creation of the Banco Chinchorro Biosphere Reserve. This case chronicles the resistance to regulation and interpersonal violence that erupts when entrenched attitudes and practices are confronted with increasing surveillance. Thus, what was observed in the Banco Chinchorro Biosphere Reserve parallels other research that depicts the forms of resistance to conservation that local people enact when confronted with conservation interventions. Finally, the plight of queen conch in the Banco Chinchorro Biosphere Reserve clearly reflects the conflicts and difficulties found across Mexico in the implementation of the biosphere reserve model.

Whitall, D., Ramos, A., Wehner, D., Fulton, M., Mason, A., Wirth, E., . . . Reed, L. A. (2016). Contaminants in Queen Conch (*Strombus Gigas*) in Vieques, Puerto Rico. *Regional Studies in Marine Science*, 5, 80-86 <https://doi.org/10.1016/j.rsma.2016.02.003>

Pollution has the potential to negatively alter coastal ecosystem health, including fisheries species, through direct impacts, food web effects and habitat degradation. Vieques is an island municipality of the Commonwealth of Puerto Rico, which lies off the east coast of the main island. In addition to normal pollution stressors associated with human activities, Vieques was also the site of a military bombing range from the 1940s until 2003. There is significant local concern about potential negative impacts of pollution from these and other activities on fisheries stocks, as well as seafood as a vector for toxic contaminants to enter the human food supply. In this study, queen conch (*Strombus gigas*) tissues were analyzed for a suite of contaminants: metals, the pesticide DDT (and its degradation products), and energetic compounds (associated with munitions) from three areas around the island. The magnitude of contamination found in queen conch was within the range of values reported in other studies in the Caribbean, suggesting that the levels of these selected contaminants present in conch in Vieques are not unusual for the region.

Whitall, D. R., Mason, A. L., Fulton, M. H., Wirth, E. F., Wehner, D., Ramos, A., . . . Reed, L. A. (2016). Chemical Contaminants in the Marine Resources of Vieques, Puerto Rico. <https://doi.org/10.7289/V5/TM-NOS-NCCOS-223>

Pollution in the marine environment has the potential to negatively impact ecosystem health, including adverse effects on fisheries species. This can occur through direct impacts, food web effects and habitat degradation. Vieques is an island municipality of the Commonwealth of Puerto Rico, located 11 km off the east coast of the main island. In addition to normal pollution stressors associated with human activities, Vieques was also the site of a military bombing range from the 1940s until 2003. Local concern exists about potential impacts of pollution from these and other activities on fisheries stocks, as well as potential seafood safety issues. In this study, queen conch (*Strombus gigas*) and spiny lobster (*Panulirus argus*) tissues were analyzed for a suite of contaminants: metals, the pesticide DDT (and its degradation products), and energetic compounds (associated with munitions) from three areas around the island. Concentrations of pollutants in queen conch were compared to other published values for the region, and compared with conservative seafood safety guidelines.