Shell Midden Surveys as Source of Information about Fished Queen Conch (*Strombus gigas*) Populations: A Case Study in Parque Nacional Del Este, Dominican Republic

RUBÉN E. TORRES and KATHLEEN M. SULLIVAN-SEALEY
University of Miami, Department of Biology
P.O. Box 249118
Coral Gables, Florida 33124-0421 USA

ABSTRACT

Queen conch (*Strombus gigas*) populations are in decline throughout their range in the tropical western Atlantic, due to a combination of intense fishing, habitat loss and water quality degradation. The dramatic decline in abundance of queen conch has led to commercial extinction throughout much of its range. Life history features such as their slow movements, aggregational behavior, and dependence on shallow-water habitats make them vulnerable to over-exploitation by humans. A better understanding of how population dynamics have reacted to long-term fishing pressure is critical for future restoration and management efforts. From the beginning of conch fishing in the area, fishermen have left evidence of past fishing efforts in the form of shell middens. It is our objective to determine the characteristics of fished populations by surveying undisturbed middens that have been found on the shores of a marine lagoon in Parque Nacional del Este (PNE), Dominican Republic. Some of the middens date to pre-Columbian fishing times and provide a historical context for evaluating recent fishing intensity.

Two conch shell middens were thoroughly surveyed by excavating a 2m x 2m area from top to ground level during March and April 2000. Nearly 10,000 queen conch shells were mapped within the middens and measured for shell length, shell width, spine length, and lip thickness when a flared lip was present. The type of opening used to extract the animal was also recorded. One of the middens dates approximately to 1400 ± 70 years, suggested first by Taino artifacts found with the shells and later confirmed by carbon-14 isotopic analysis. The second midden was presumed to be modern based on anecdotal accounts, the pink coloration of shells, and the modern artifacts found at the base of the midden. Results from these excavations revealed that there is a long history of conch fishing in PNE. Shells from the older midden were found to be dominated by smaller shells than the modern midden (probably suggesting different fishing practices or target preferences by Tainos). As we excavated from the top to the bottom of the recent midden, a significant increase in mean shell length of queen conch shells was apparent. The further analysis and dating of these shell middens may help to reconstruct the history of *S. gigas* fishing and better understand how such activities have affected population dynamics in terms of size frequency distribution and shell morphology.

KEY WORDS: Carbon dating, Parque Nacional del Este, shell midden, *Strombus gigas*.

INTRODUCTION

The status of queen conch (*Strombus gigas*) populations is well documented throughout the wider Caribbean, but historical population abundance and size frequency distribution patterns are known only from anecdotal accounts and shell midden records. Queen conch fishermen left evidence of fishing practices in the form of shell middens that probably date back to pre-Columbian occupation of the Caribbean, especially in remote areas where only the meat was transported to a distant market. A marine lagoon in Parque Nacional del Este (PNE), in the southeastern corner of the island of Hispaniola, has been an area of conch fishing over the centuries of human occupation in the Caribbean Basin. The analysis and dating of these shell middens may help us to elucidate the structure of fished populations once present in the lagoon. Long-term population dynamics of a tropical marine invertebrate are influenced both by climatic factors and biological factors such as high fishing mortality. Queen conch have been utilized as a food and shell source in the Caribbean Basin for well over 1,500 years. Through this time, climatic cycles and changes have impacted growth, reproduction and recruitment of populations. Changes in population dynamics related to climate are only now possible to study with the construction of new climate records for the past 1,000 years. Segregating the impacts of climate from intensive fishing pressure requires a study site with a long-term fishing history.

Queen conch have persisted in many coastal systems, because the fishing techniques exploited only part of the depth range of adults breeding aggregation. Commercial fisheries were once important in the southeastern Dominican Republic (DR). The southeastern coast has the largest platform area (722 km^2) in the country (Secretaría de Estado de Agricultura 1995). Historically, important fisheries ports were located in San Rafael de Yuma (northeast of PNE) and La Romana (west of PNE) (Bonnelly de Calventi 1975). These fisheries supported a relatively large export market to the U.S., Virgin Islands, and Puerto Rico. More recently, however, small-scale artisanal fisheries exist for local consumption. Presently, fishermen are allowed to fish in the areas surrounding the park, with the exception of Canal de Catuano. The degree to which the Canal de Catuano has been protected from poaching is unknown.

PNE was designated as a national park by the Dominican government on 16 September 1975 (Act No. 1311) and it is the second largest in the country (Figure 1). A large, mostly shallow (< 10 m depth) marine lagoon (Canal de Catuano) separates Isla Saona from the mainland. Because of the lagoon's nursery function for queen conch, it was declared a no-fishing zone for conch in 1999. Additionally, a seasonal closure has been implemented from 1 July to 31 October throughout the country. PNE is located in an area where one of five major Taino provinces occurred. Just north of San Rafael de Yuma (northeast of PNE) was located Villa Salvaleon, where Ponce de Leon once lived. This area was governed by the Cacique Cayacoa, who was one of the last to be killed by the Spaniards, leaving Caizcimu as the last area of Hispaniola where Taino people ever lived. Taino fished queen conch for food and used the shells for tools (Vega 1990).

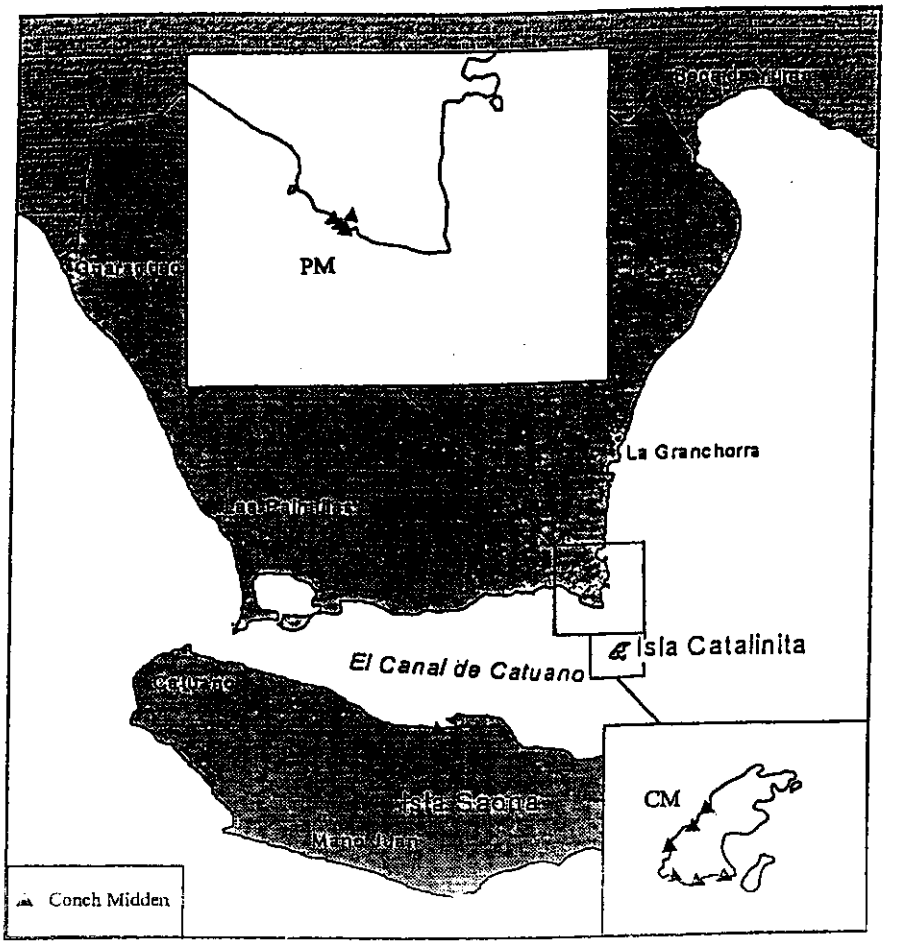

Figure 1. Map of Parque Nacional del Este, southeastern Dominican Republic. Midden sites: Peninsula Middens (PM) and Catalinita Middens (CM) are indicated.

An evaluation of historical queen conch populations in PNE will be an important issue in the DR, as PNE plays an important role in conservation efforts in the country's protected areas system. Although most of the marine habitats around the park are not legally protected, they have the potential to serve as a source of replenishment for many marine organisms. Nursery grounds for many marine organisms are located within the park and these areas may be a potential source of larvae that could seed adjacent coastal habitats of the Dominican Republic and other countries in the wider Caribbean.

METHODS

Previous expeditions to Parque Nacional del Este (PNE) led to the discovery of several shell middens. From these, two were selected based on how undisturbed they were and by their estimated age. Catalinita Midden #1 (CM1), an ancient midden, is located on the western shore of Isla Catalinita, while a modern midden, Peninsula Midden #5 (PM5), is located on the southeastern extent of the PNE peninsula (Figure 1). Shells were also collected from other middens (CM2, CM3, CM4 and CM5) for carbon-14 dating to identify possible future excavation sites. Volunteers from Earthwatch were used in the midden excavation work, all staff and volunteers received training in shell measurement. An exercise measuring a set of 35 conch shells was performed prior to the excavations to test for differences in error in shell measuring between surveyors prior to the midden survey. A Kendall's coefficient of concordance was obtained from this exercise to compare how surveyors ranked by size the 35 conch shells and to determine if there was any association between them or if there was any similarity or difference in the measurements that each surveyor was obtaining.

At the midden sites, we first mapped the middens by laying parallel measuring tapes with a meter of separation between them over the midden to record the elevation of every meter increment within these grid lines using an electronic builder's level (Compulevel by Stanley Tools). This provided a three-dimensional profile of the midden and an estimate of the volume of shells per cubic meter. The grid lines later served for placement of 2 m x 2 m PVC quadrants at the highest point of the midden (Figure 2).

At the site of what was believed to be an intensive commercial fishery between 1955 and 1970, a serives of nine middens were mapped and the total volume of shells estimated. The mapping was accomplished by placing a central survey line parallel to shore and making distance and altitude measurements off that line (Figure 3). The PM5 was in the center of this midden line. Total volume of the middens was estimated by calculating the volume of an elipsoid cut in half by the slope of the shoreline.

Within quadrants, information on the location and measurement of every other queen conch shell was recorded as follows. Using string, each quadrant was equally divided into sixteen 50cm x 50 cm areas. These areas represent the horizontal location of the shells within the midden, as the sides of the unit (X and Y axes) are divided into four segments (0 = 0-49cm, 1 = 50-99cm, 2 = 100-149cm, and 3 = 150-200cm). This was used to record X and Y coordinates. The third coordinate was recorded from the relative altitude of the shell within the midden. For this an electronic engineer level was used to measure the difference in elevation from a previously set reference point, in this case, ground level on one side of the midden. Also within the units (and only in PM5), several layers were pre-determined to later look for differences in shell sizes between layer or through time (based on the superposition effect). Layers were chosen to be as a 50-cm difference in elevation starting from the lowest corner of the unit, and later from the base of each previous layer. Shell samples were collected from the different middens and layers for

carbon-14 isotope analysis.

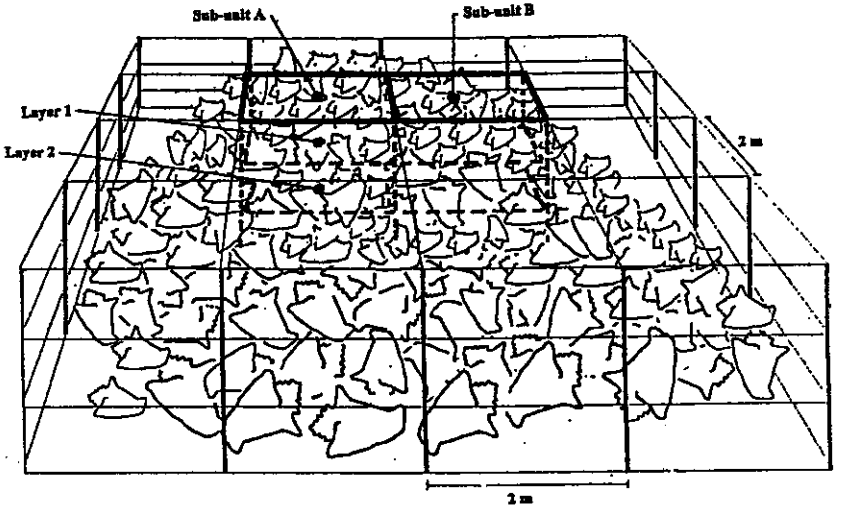

Figure 2. Midden excavation grid used to map and later excavate the middens. Sub-units are 2 m x 2 m areas, Layers are determined to be a 50 cm vertical difference in elevation.

Every other shell was mapped (X,Y, Z coordinates) and then measured in mm by tossing one shell and selecting another as randomly as possible for shell length, body whorl width, lip thickness, and length of the shell spines. When a flared lip was present in a shell, lip thickness was measured about two-thirds of the distance from the end of the siphonal groove. Information on the shape of the opening used to extract the animal out of the shell was also recorded. A standard fish board was used to measure the shell length, while body whorl, lip thickness and spine length was measured using plastic calipers. While the midden surveys yielded a wealth of information, we limit our discussion herein to patterns of species composition, proportion of juvenile to adults and shell length. Further excavations and analyses will be carried out during 2001.

A Kolmogorov-Smirnoff test was used to test for differences in shell length frequency distribution between the CM1 and PM5 middens. Due to the heterogeneity of variances of shell lengths found using Bartlett's test between the

different layers of PM5, a Kruskall-Wallis test was perfomed in lieu of a one-way ANOVA to test for differences in mean shell length between the layers. Both these tests as well as the Kendall's coefficient of concordance for the volunteer practice were performed as described in Zar (1999) and Sokal and Rolf (1995).

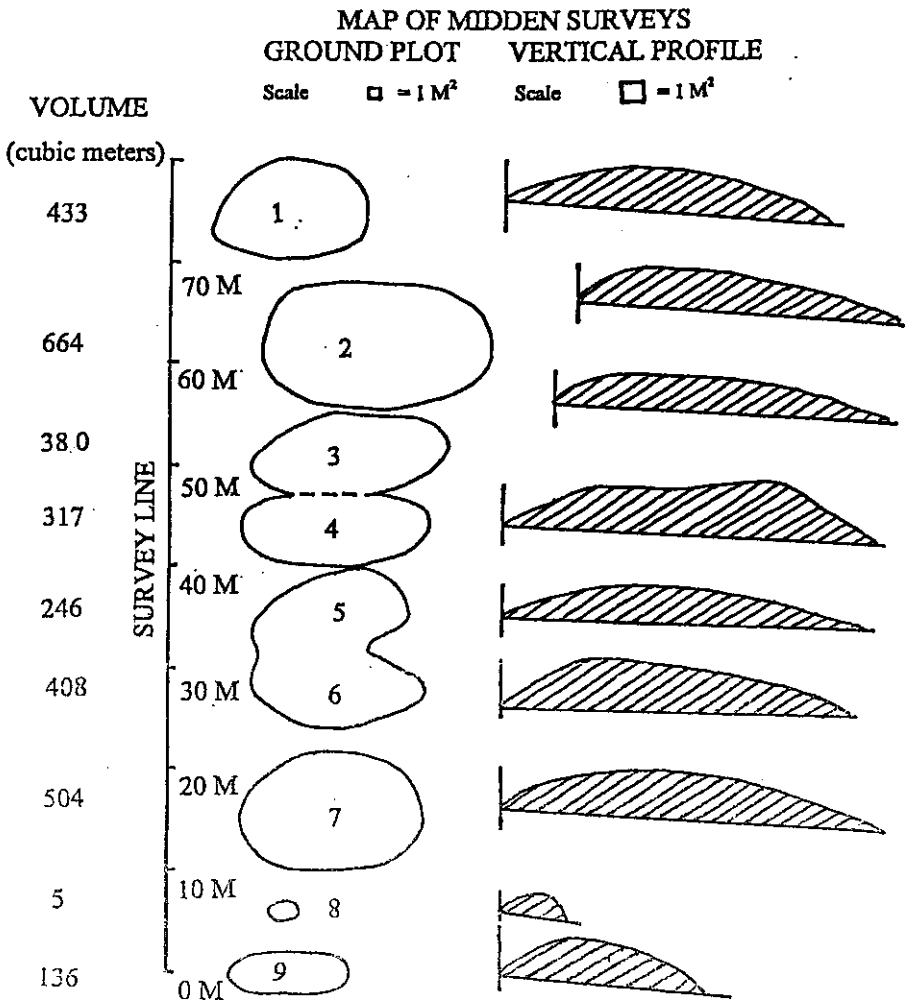

Figure 3. Map of the nine shell middens found at the Peninsula site. This graphs shows each middens' area and elevation along the survey line. Also the volume (in cubic meters) is indicated for each.

RESULTS

Shell Measuring Error

Results from the Kendall's coefficient of concordance from the shell length data produced by 14 different surveyors measuring 35 known shells, showed that there was an association on the way the surveyors ranked the shells from smallest to largest. This result indicates that these 14 surveyors would measure conch shells with very similar results.

Older Conch Shell Midden (CM1)

Detailed information on the middens can be found in Table 1. CM1 is located on the northwestern side of Isla Catalinita (Figure 1). Radiocarbon dating analysis performed with samples taken from CM1 indicated that this midden was formed with shells approximately 1,400 years old (± 70 years). This later date (year 600 or so) was also suggested by the finding of several pieces of Taino pottery found within the midden. In CM1, 2,175 conch shells were mapped and measured, yielding a mean (SD) shell length of 121.8 (26.0) mm. Most shells (98%) were *Strombus gigas*, less than 2% were *Cittarium pica*, and less than 1% from other species (*Cassiss sp.*, *Murex sp.*, and *S. pugilis)*. We determined that 99% of the *S. gigas* shells were juveniles.

Table 1. Information on the volume of shells, mean shell length (SD in parenthesis), species composition and proportion of juveniles to adults of middens CM1 and PM5 (Top, middle and bottom layers from PM5 are also described).

	Density (shells/m³)	Shell Length (mm)	Species proportions	% Juveniles
CM1	1391	121.80 (26)	98% *S. gigas* <2% *C. pica* <1% other	99%
PM5				
Total	1139	147.99 (33.08)	98% *S. gigas* <2% *S. costatus* <1% other	85%
Layer 1	1298	131.49 (26.97)		
Layer 2	1079	154.30 (25.92)		
Layer 3	860	177.12 (30.51)		

Recent Conch Shell Midden (PM5)

PM5 is located on Punta Algibe, and it is presumed to have been formed in recent decades due to several modern artifacts (e.g. broken bottles and piece of sandal) found at the base of this midden. Several local fishermen indicated that this midden, along with others in the same general locale, were a product of commercial fishery in the 1960s and 1970s. PM5 is larger than CM1, and it forms part of a group of middens with similar sizes and shapes. In total, we mapped and measured 4,868 *S. gigas* shells that had a mean (SD) shell length of 147.99 (33.08) mm, with a range of 45 mm to 267 mm. The species composition of PM5 was similar to CM1

in terms of the predominance (98%) of *S. gigas*. Less abundant species were represented by *S. costatus* (2%), *S. pugilis* < 1%) and *C. pica* (< 1%). A larger proportion of adult queen conch (15%) were found at PM5.

Figure 4 shows a relative shell length frequency distribution for both CM1 and PM5. Results indicate that there is some difference in the size structure (shell length) between the middens. PM5 has a larger mean shell length when compared to CM1, and frequency distributions were found to differ ($p < 0.001$), as determined by a Kolmogorov-Smirnoff test.

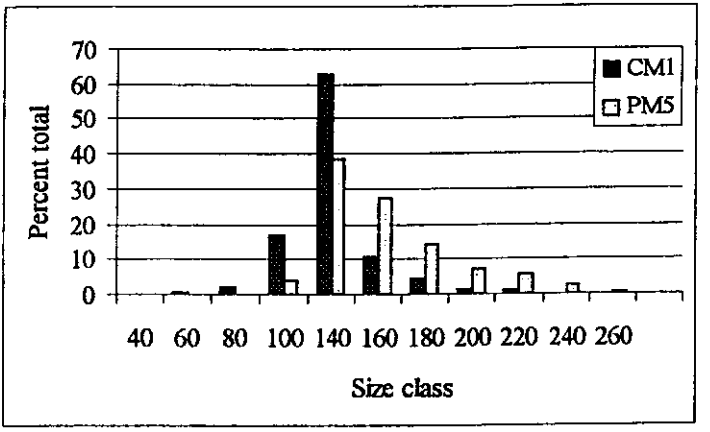

Figure 4. Shell length frequency distribution of CM1 and PM5 middens.

Stratigraphy Within PM5

Given the large size of PM5 compared to CM1, it was possible to subdivide PM5 into three different layers to determine if there was any significant difference in shell length of conchs deposited at the bottom of the midden (ealier in time) than from the top (later in time). Figure 5 shows a relative shell length frequency distribution of layers 1 (top), 2 (middle), and 3 (bottom) for midden PM5. Mean shell length increases from the top to the bottom of the midden. Mean length from layers 1, 2 and 3 was 131.49 (26.97) mm, 154.30 (25.92) mm, and 177.14 (30.51) mm, respectively (Table 1). A Kruskall-Wallis test showed that there was a significant difference ($p < 0.001$) in mean shell length among the three layers.

Midden Ages

Queen conch shells shells from the two excavated middens and other locations in the vicinity of CM1 were dated using radiocarbon isotope analysis. These data will help to determine the approximate time when the middens were formed (and hence when

fishing occurred). Radiocarbon data will also be used to locate future excavation sites that will target different periods of time in conch fishery history in the area. Table 2 summarizes the dates from these middens.

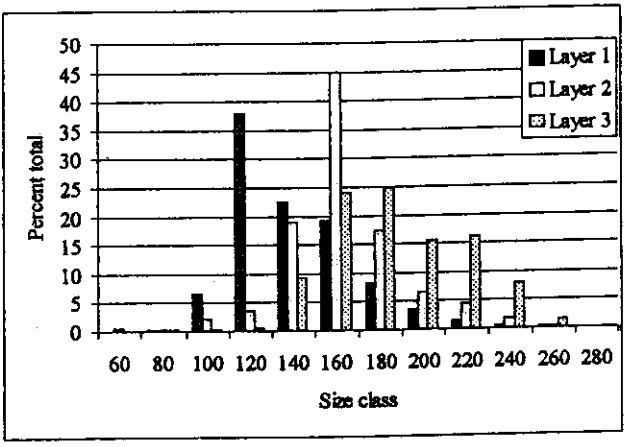

Figure 5. Shell length frequency distribution of the top, middle and bottom layers within PM5.

Table 2. Radiocarbon dating analysis performed on several shell samples collected from different middens in Parque Nacional del Este. PM5 is located at the southeastern tip of the mainland peninsula while CM1-5 middens are located on Isla Catalinita (Figure 1).

Sample	Material	Age (years)	Date (year AD)
CM1	*S. gigas* shell	1,400 (± 70)	600 (± 70)
CM2	*S. gigas* shell	1,390 (±60)	1,800 (±70)
CM3	*S. gigas* shell	1,010 (±60)	1,420 (±60)
CM4	*S. gigas* shell	460 (±60)	870 (±60)
CM5	*S. gigas* shell	1,170(±70)	1,590 (±70)
PM5	*S. gigas* shell	Recent	1960's ??

From this range of dates found at other middens, future midden surveys will be conducted at middens CM2, CM3 and CM5. This will give us an adequate range to compare to collected data from the year 600 (± 70) and recent decades.

DISCUSSION

Stoner and Ray (1996) concluded that shell remains provide useful information about marine mollusks over ecologically relevant time scales, and that important insights about the long-term distribution and exploitation of some species can be drawn from shell middens. Besides being a very labor-intensive exercise (excavating shell middens), this study has shown that many ancient (and fished) and recent conch shell parameters can be accessed from shell middens.

Older middens (CM1-5) in Parque Nacional del Este are definitively a product of a conch fishing activities that occurred hundreds of years ago when the area was first inhabited by the Taino people. Not having the most appropriate fishing gear (mask, fins, scuba, etc), they seemed to have targeted mostly juvenile conch in very shallow water and other species found on the rocky inter tidal coasts of Isla Catalinita (Table 1). Vega (1987) found large piles of shells on the shores of Isla Catalinita and Isla Saona, indicating the importance of conch in the diet of early inhabitants.

Stoner (1997) found that shell middens at several sites in the Bahamas probably indicate a historically significant abundance of conch in that area. Many shell middens have been reported by Vega (1987) and this study on Isla Catalinita island that appear (and now confimed by carbon dating) to have been formed in pre-Columbian time. These findings indicate that there is a long-term occurrence of conch, possibly indicative of a steady or high recruitment rate. This latter assumption is based upon the long history of fishing pressure. Conch aggregations still occur in shallow-water habitats on the southeastern coast, albeit at reduced densities (Delgado 1999, Torres and Sullivan Sealey, in prep.).

Shell midden analysis has to be conducted with a good knowledge of resource use by human populations. Fishermen, ancient or contemporary, may target specific sizes of conch given the relative access to the resource, and by their personal preference for a type of conch. The smaller mean shell length found in the older midden (CM1) can be viewed from different perspectives. The fact that the Taino people were limited in their fishing gear when compared to modern fishermen may indicate that they only had access to juvenile conch in shallower water. It is also possible that Tainos had a preference for conch that were easier to "open" (i.e. thinner shells), or perhaps the meat from juveniles was more tender.

The recent midden (PM5) showed a larger proportion of adult conch shells, mostly found at the base of the midden. There are several possible conclusion that can be drawn from this pattern. Given more advanced fishing gear (SCUBA or hookah), modern fishermen are able to reach adult conch aggregations in deeper water. This midden was part of a large group of 9 middens with a total shell volume of over 3,095 cubic meters, representing an estimated 3.2 million shells. These middens are very similar in size, shape and apparent age. Mangroves trees growing in between most of these recent middens may indicate that this site was a beach used by fishermen only targeting queen conch that beached their boats on shore and cleaned the shells on-site, throwing empty shells to either side and forming the middens we see today.

The midden information combined with local interviews allow us to make some important observations of the commercial fishery:

i) the fishery was intensive, and at least 3 million conch shells were deposited over a relatively short period of time, (2 to 3 conch generations),

ii) the fishery preferentially exploited adult conch first, as evidenced by the large conch at the bottom of the midden, then proceeded to fish sub-adults then smaller and smaller juveniles.

Towel (1973) reported that by the early 1970s, the creation of PNE was not controversial because the commercial fisheries in the area had already collapsed. Presumably it was no longer profitable – the density and size of conch available making it more expensive to collect conch meat than it would sell for in the export market. It is unlikely that this 1955 - 1970 commercial fishery used hookah. The operation of the commercial fishery was intensive and not intended to be sustainable. This high mortality over such a short period of time would likely require a long (tens of years) recover time, but the depth range and habitats not accessible to this earlier fishery are now open to present-day fishers.

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