Abundance, Size Frequency, and Spatial Distribution of Queen Conch (*Strombus gigas*) in Southeastern Dominican Republic: A Four-year Population Study in Parque Nacional Del Este

RUBÉN E. TORRES and KATHLEEN M. SULLIVAN SEALEY
Florida and Caribbean Marine Conservation Science Center
University of Miami
P.O. Box 249118
Coral Gables, Florida 33124 USA

ABSTRACT

Since 1996, queen conch (*Strombus gigas*) density, distribution by benthic habitats, and size frequency distribution have been monitored in Parque Nacional del Este (PNE), southeastern Hispaniola. Delgado (1999) reported that queen conch are significantly more abundant in communities with sparse to moderate seagrass benthic coverage (< 30%). He also reported a marked decline in overall queen conch abundance from 1996 to 1997. As a recommendation from his findings, the government of the Dominican Republic declared Canal de Catuano as a permanent closed area for conch fishing as of 1999 and additionally implement a closed season for the fishery between 1 July and 31 October for the country.

The purpose of this study was to continue ongoing studies of annual changes in queen conch population structure in a large marine lagoon within the park, using a stratified sampling design based upon benthic community type distribution. Annual surveys have focused on the density and location of juvenile aggregations, and the presence of adults as potential spawning stock by habitat available in the lagoon. The results obtained since 1996 to 2000 are part of a database that also contains information from historical conch populations (Torres et al. in prep) that once lived in the shallow waters of PNE. Shell length, width, and lip thickness (adults only) were collected along 50m x 5m transects located in different community types of the park, to determine if there are significant differences in conch densities during the study. These estimates also provide a baseline for evaluating future changes in population abundance and size structure relative to the recent closure of the park's lagoon. An annual evaluation of conch populations in PNE will serve as performance measures for PNE's managers.

Annual surveys conducted by Delgado (1999) in 1996 and 1997 showed significant declines (orders of magnitude) in the densities of both juvenile and adult conch. Data collected during 2000 illustrate a continued decline in juvenile and adult densities, but less dramatically than in previous surveys. Conch density and size frequency distribution showed a significant difference among benthic community types in all years. There is no evidence of the effect of the closure of the lagoon from fishing or from the closed season. Continuation of annual surveys will help to evaluate the biological effects of the spatial and seasonal closures on queen conch in PNE, dependent, in part, on the ability of park managers to effectively implement the new regulations.

KEY WORDS: Benthic community, Dominican Republic, population abundance, *Strombus gigas*

INTRODUCTION

The queen conch (*Strombus gigas*) population in Parque Nacional del Este (PNE), southeastern Dominican Republic has declined dramatically, presumably due to the unregulated fishing of all sizes classes of conch in both shallow and deep water communities. The reduction in *S. gigas* abundance can have several impacts on the long-term population dynamics of the species, such as changes in growth rate (e.g. by fishery selection for larger individuals), or increased predation (e.g. as conch aggregate, predators may eat most if not all individuals in a small aggregation). The uncertainty of the effects of any reduction in population abundance makes it difficult to predict the restoration success of this important fishery. Declines in queen conch abundance are well documented throughout the tropical western Atlantic (Gibson et al. 1983, Goodwin 1983, Appeldoorn et al. 1987), particularly due to decades of commercial over-exploitation, but there is also evidence of historical depletion by traditional cultures, such as the Taino Indians (Keegan 1989, Vega 1987). Fishing practices appear to have a much more dramatic impact on local population size than environmental variability, even resulting in local extirpation, for example, in the Lesser Antilles. *S. gigas* has an enormous range dependent on dispersal via planktonic larvae. With the documented declines in density, a pertinent management issue is one concerning minimum viable population sizes, and why, having evidence of long-term intensive fishing in the area, does the local population still persist? Are such patterns due to high recruitment, sufficient optimal habitat, or asynchronous pulses in fishing pressure?

Questions concerning the viability of populations have followed two general areas of contemporary ecological research. First, community ecologists have focused on the habitat where populations occur, specifically investigating habitat change after the removal of key species (Moore 1962, Lovejoy 1980). Second, population biologists have focused on the assessment and characteristics of populations: once fishing or other anthropogenic influences have depleted populations, there may be environmental factors that prevent species recovery (Franklin 1980, Frankel and Soulé 1981, Shaffer 1981). Changes in sea level, circulation patterns, and sea surface temperature, for example, all produce changes in the distribution of benthic species and thus benthic habitats. For queen conch, long-term environmental variability may bring about changes in habitat distribution, resulting in changes in population dynamics and size. An evaluation of the population viability of queen conch, owing to its well-studied ontogeny, needs to consider habitat characteristics as well as population structure.

The queen conch population in PNE has recently shown clear signs of decline in both abundance and size of individuals, presumably due to intense fishing (Delgado 1999). The coastal zone of the park is not developed, and the marine lagoon in the eastern area of the park is some distance from coastal settlements and large human populations. The nature of the benthic habitats in the coastal lagoon may reflect more influence from natural environmental variability than anthropogenic influence. Because of rapid increases in human populations and the concurrent increases in demands for food, one can anticipate severe consequences for natural resources if appropriate management actions are not taken (Mostafa 1989). The loss of species and the degradation of habitats are difficult concepts to explain to resource users, so it may be easier to think in terms of specific indicators of change (EPA 1992). The study of a single species such as queen conch can serve as an indicator of the health of the overall coastal lagoon system.

Population size (abundance) and size-frequency distribution are determined by several measures such as fecundity, mortality, growth, emigration, and immigration (Ricklefs 1990, Krebs 1994, Begon et al. 1996). The spatial variability (i.e. patchiness) and isolation of the local population influence the immigration and emigration of individuals; thus, local dynamics play an important role in the persistence of metapopulations by making simultaneous extinction of all local populations unlikely (Hanski 1999). Requirements for the long-term persistence of an assemblage of extinction-prone populations are density dependence, high colonization rates, and some degree in asynchrony in local dynamics (Hanski 1999). There are many localities with low densities of queen conch, and, not surprisingly, many of these populations are in deeper water (> 15m depth). Therefore, only a portion of these populations is being affected by traditional fishing methods, leaving some breeding aggregations untouched and able to replenish affected areas. However, with the increased use of SCUBA and compressors (hookah) and the demise of shallow-water stocks, the deep water breeding aggregations now face the same fate

Over-exploitation of queen conch reproductive stocks may result in dramatic changes in population dynamics, as the per capita reproductive success declines at low population abundance. Ecological theory would predict that populations have multiple equilibria and may suddenly shift from one equilibrium to another (Myers et al. 1995). The temporal and spatial scale of these shifts can help resolve the definition of local populations and larger metapopulations. Understanding the dynamics of local populations and applying that information to management actions is essential for sustainable resource use.

METHODS

The methods used to assess living conch populations in PNE during this study followed that of procedures discussed in Delgado (1999). Based on the extent of habitats suspected of supporting juvenile and adult conch, a stratified, systematic survey design was used (Berg et al. 1992a). Between 160 (2000) and 350 (1996 and 1997) transects were surveyed in the marine lagoon (Canal de Catuano) of PNE. The total sample size was partitioned based upon the extent (coverage) of different benthic community types (Vega et al. 1997). Single or multiple transects measuring

50m x 5m (250m^2) were surveyed in different benthic community types in a systematic fashion, so as to increase the likelihood of sampling juvenile aggregations, if present (Figure 1). Surveys were primarily conducted within the Canal de Catuano and to the northwest of the lagoon (western shelf) in depths less than 10 m.

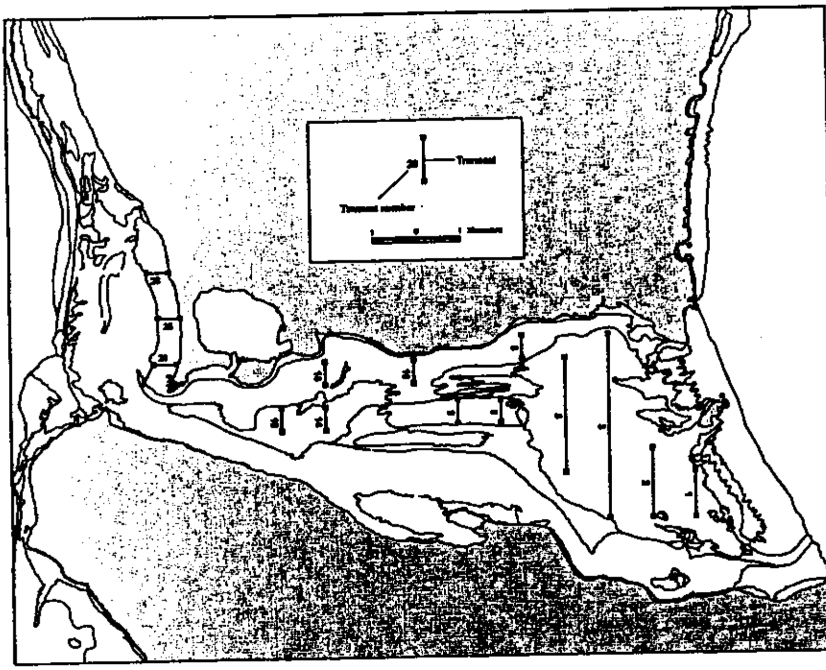


Figure 1. Map of the Canal de Catuano in Parque Nacional del Este showing the permanent queen conch stock assessment transects. Each transect is composed of many 5 m by 50 m continuous sampling units.

Queen conch were identified, counted, and measured to the nearest millimeter for total shell length and lip thickness along transects. Size measurements were taken with plastic calipers to the nearest 0.1 mm. Lip thickness was measured at the area of greatest thickness or roughly two-thirds of the distance from the end of the siphonal groove. At least three snorkelers were used to survey each transect. Observers searched 2.5 m perpendicularly from each side of the transect. It should be noted that visual estimates selectively under-sample conch less than 10 cm in shell length, because most of these individuals are buried during the day (Appeldoorn 1985a, Iversen et al. 1987).

Information collected from the transects was used to determine mean densities (no. per ha) for each community type. A Kruskal-Wallis test was used to evaluate differences in density among the community types sampled during March 2000. A Kolmogorov-Smirnov test was used to evaluate differences in the size-frequency distributions of queen conch found only in the sparse seagrass in sand (SSGS) and the sparse seagrass in sand-mud (SGSM) community types, due to very low numbers of individuals found in the other community types.

RESULTS

Conch Densities and Size Frequency Distributions

During March of 2000, only four community types in PNE were surveyed for queen conch due to the lack of SCUBA support: sparse seagrass in sand (SSGS), sparse seagrass in sand-mud (SGSM), mixed algal canopy (MAC), and seagrass patches on a matrix of soft sediment (SGP). The majority of juvenile queen conchs in the park were found in SGSM during all years (1996, 1997, and 2000). Adults were most abundant in SGSM during 1996 and 1997, but had greater densities in SSGS during 2000 (Table 1). Relative to 1996 and 1997, surveys completed in 2000 showed continued declines in both juvenile and adult densities.

Table 1. Annual estimates of mean juvenile (A) and adult (B) conch density (1 SD) in Parque Nacional del Este, Dominican Republic. SGP = seagrass patches on a matrix of soft sediment; SSGS = sparse seagrass in sand; SGSM = sparse seagrass in sand mud; MAC = Mixed algal canopy; MDSG = moderate to dense seagrass. Total number of transects were: 1996 = 350, 1997 = 350, and 2000 = 160. Data from 1996 and 1997 are as reported by Delgado (1999).

A. Juvenile Conch

Community	1996	1997	2000
SGP	0.0(0.0)	0.0(0.0)	0.0(0.0)
SSGS	2.0(2.8)	0.0(0.0)	1.0(1.9)
SGSM	707.4(2,386.1)	46.8(149.0)	26.8(25.6)
MAC	1.3(2.1)	4.0(14.2)	0.3(0.7)
MDSG	64.7(94.1)	14.2(37.4)	N/A
Total	283(1,488.1)	22.5(95.1)	14.4(4.93)

B. Adult Conch

Community	1996	1997	2000
SGP	0.0(0.0)	0.0(0.0)	0.0(0.0)
SSGS	0.0(0.0)	0.0(0.0)	1.2(2.2)
SGSM	5.9(18.5)	2.8(10.2)	0.03(0.12)
MAC	0.7(1.6)	0.7(1.6)	0.0(0.0)
MDSG	6.9(6.7)	1.5(7.5)	N/A
Total	4.5(14.3)	1.6(7.9)	0.62(1.51)

Delgado (1999) reported a significant difference in both juvenile and adult conch density among five community types from March 1996 surveys. He also reported similar results for juvenile conch, but not for adults, in 1997. During March of 2000, we observed a significant difference in juvenile conch densities among the community types sampled ($p < 0.05$). However, there was no significant difference in adult conch density among community types ($p > 0.05$) (Figure 2).

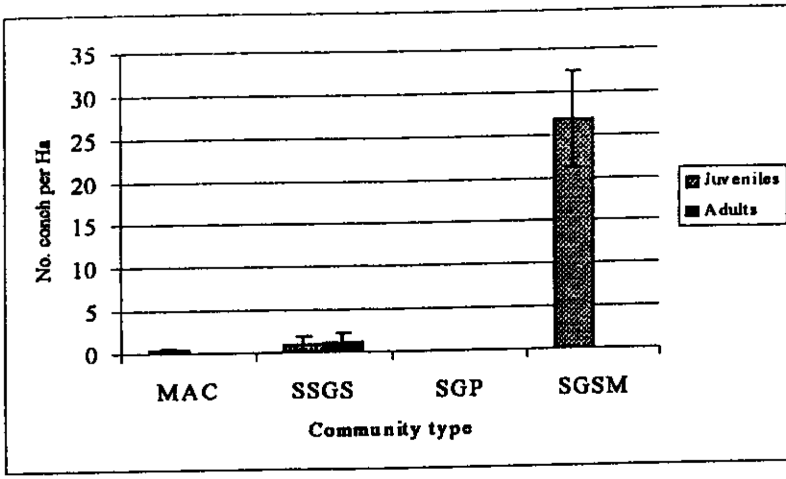
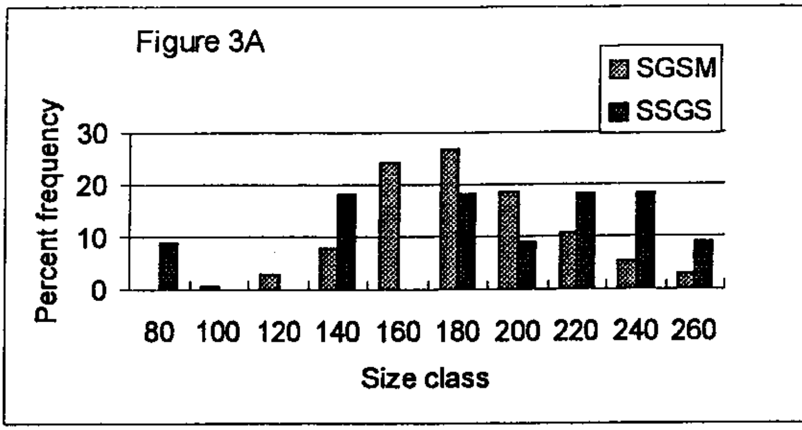


Figure 2. Mean juvenile and adults queen conch (*Strombus gigas*) densities for the community types surveyed during March 2000 in Parque Nacional del Este. (95% confidence intervals are shown as error bars). MAC = mixed algal canopy, SSGS = sparse seagrass in sand, SGP = seagrass patches on a matrix of soft sediment, SGSM = sparse seagrass in sand mud.

Size-frequency distributions for juvenile conch were significantly different in 1996 and 1997 as well, but adult size frequency distribution was not significantly different among SGSM and MDSG community types (Delgado 1999) in both 1996 and 1997. Due to depth limitations of the 2000 surveys, size-frequency distributions were compared between the communities with the greatest conch densities (SSGS and SGSM). While the size distributions of adults were found to be different ($p < 0.05$) (Figure 3A), juveniles were not significantly different ($p > 0.05$) (Figure 3B).

DISCUSSION

It is well known that seagrass beds are highly variable in attributes other than seagrass biomass or shoot count, and that many of the less obvious characteristics of seagrass habitats have a strong impact on the large-scale distribution of fishes and invertebrates (Stoner et al. 1995). From previous studies in PNE (Delgado 1999; Vega et al. 1997, Chiappone et al. in press), it is known that conch are distributed differently among several benthic community types, and that there is clear evidence of declining densities in the shallow-water areas of the park. The majority of juveniles showed a marked preference for moderate to dense seagrass habitats. This type of habitat possesses required characteristics for juvenile conch to settle and survive from natural predators, and clearly serves an important nursery function for this species.



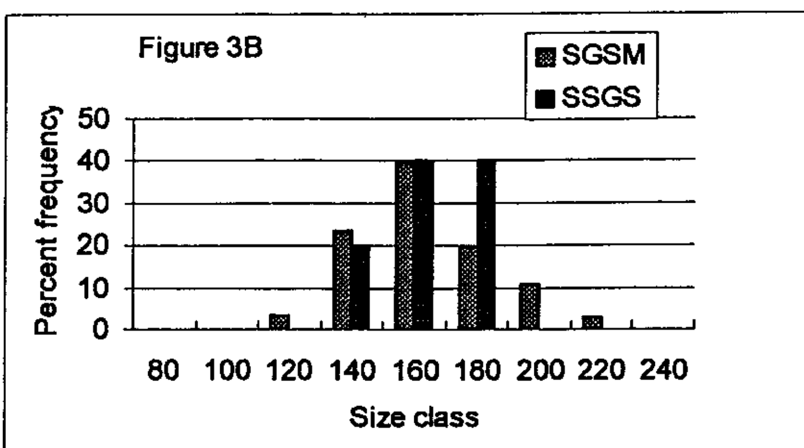


Figure 3. Size relative frequency distribution for juvenile (3A) and adult (3B) queen conch (*Strombus gigas*) for sparse seagrass in sand mud (SGSM) and sparse seagrass in sand (SSGS) during March 2000 in Parque Nacional del Este, Dominican Republic.

From a similar study of conch population in Jaragua National Park (southwestern Dominican Republic) Posada et al. (1999) estimated overall conch densities of 53.0 individuals per hectare. These results are substantially higher than estimates for PNE, possibly indicating substantial recruitment from up-current sources to the large shelf area on the southwestern Dominican coast. Although the Dominican government recently declared (1999) the Canal de Catuano as a closed area for conch fishing and implemented a countrywide, seasonal closure during the breeding season (1 July – 31 October), this has not been adequately implemented (R.E. Torres, pers. observations).

Annual surveys have been of sufficient spatial scale to detect changes in conch densities among community types. A continuation of these surveys will be necessary to evaluate possible recovery of the queen conch population PNE, or the degree to which management implementation is working. Because of the uncertainty of the effects of this reduction in densities, the restoration of this important fishery remains problematic. Fishermen have been targeting queen conch intensively for hundreds of years on the southeastern Dominican shelf. As queen conch decline from this area, there may be population changes that may prevent the recovery of the species, even if fishing pressure declines or is halted.

LITERATURE CITED

Appeldoorn, R.S. 1985a. Growth, mortality and dispersion of juvenile laboratory-reared conchs (*Strombus gigas* Linne and *S. costatus*, released at an offshore site. *Bulletin of Marine Science* 37:785-793.

Appeldoorn, R.S., G.D. Dennis, and O. Monterrosa-Lopez. 1987. Review of shared demersal resources of Puerto Rico and the Lesser Antilles region. *FAO Fisheries Report.* 383:36-106.

Begon, M., J.L. Harper and C.R. Towsend. 1996. *Ecology*. Blackwell. Oxford, England.

Berg, C.J., Jr., F. Couper, K. Nisbet, and J. Ward. 1992a. Stock assessment of queen conch, *Strombus gigas*, and harbour conch, *S. costatus*, in Bermuda. *Proceedings of the Gulf abd Caribbean Fisheries Institute* 41:433-438.

Chiappone, M. (ed.) [In press]. *Fisheries investigations and management implications in marine protected areas of the Caribbean: A case study of Parque Nacional del Este, Dominican Republic*. American Verde. Arlington, Virginia USA.

Delgado, G.A. 1999. Influence of habitat on queen conch abundance and size distribution in soft-sediment marine communities in Parque Nacional del Este, Dominican Republic. M.S. Thesis, RSMAS-University of Miami, Florida USA.

Environmental Protection Agency (EPA). 1992. *Biological Populations as Indicators of Environmental Change*. Vol 1. U.S. Environmental Protection Agency 230/R-92/011. Washington, D.C. USA. 146 pp.

Frankel, O.H. and M.E. Soulé. 1981. *Conservation and Evolution*. Cambridge University Press. Cambridge, England.

Franklin, I.A. 1980. Evolutionary change in small populations. In: M.E. Soule and B.A. Wilcox (eds.), *Conservation Biology: An Evolutionary-ecological Perspective.* Sinauer Associates. Sunderland, MA. 135 pp.

Gibson, J., S. Strasdine and K. Gonzalez. 1983. The status of the conch industry in Belize. *Proceedings of the Gulf abd Caribbean Fisheries Institute* **35**:99-107.

Goodwin, M.H. 1983. Overview of conch fishery and culture. *Proceedings of the Gulf and Caribbean Fisheries Institute* **35**:43-45.

Hanski, I. 1999. *Metapopulation Ecology*. Oxford series in ecology and evolution. Oxford University Press. NewYork, New York USA. 313 pp.

Iversen, E.S., E.S. Rutherford, S.P. Bannerot and D.E. Jory. 1987. Biological data on Berry Islands (Bahamas) queen conchs, *Strombus gigas*, with mariculture and fisheries management implications. *U.S. Fisheries Bulletin* **85**:299-310.

Keegan, W.F. 1989. The Columbus Chronicles. Pages 47-55 in:. The Sciences, January/February. Columbus, OH USA.

Krebs, C.J. 1994. *Ecology. The Experimental Analysis of Distributions and Abundance*. Harper and Row, New York, New York USA.

Lovejoy, T.E. 1980. Discontinuous wilderness: Minimum areas for conservation. *Parks* **5(2)**:13-15.

Moore, N.W. 1962. The health of Dorset and their conservation. *Journal of Ecology* **50**: 369-391.

Mostafa, T. 1989. Our biological heritage under siege. *Bioscience* **39**:725-728.

Myers, R.A., N.J. Barrowman, J.A. Hutchinson and A.A. Rosenberg. 1995. Population dynamics of exploited fish stocks at low population levels. *Science* **269**: 1106-xxxx.

Posada, J.M., I. Mateo and M. Nemeth. 1999. Occurrence, abundance and length frequency distribution of queen conch, *Strombus gigas* (Gastropoda) in shallow waters of the Jaragua National Park, Dominican Republic. *Caribbean Journal of Science* **35(1-2)**:70-82.

Ricklefs, R.E. 1990. *Ecology*. Freeman, New York, New York USA.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. *Bioscience* **31**:131-134.

Stoner, A.W., M. Ray and J.M. Waite. 1995. Effects of a large herbivorous gastropod on macrofaunal communities in tropical seagrass meadows. *Marine Ecological Progress Series* **121**:125-137.

Torres, R.E., K. M. Sullivan 2002. Shell midden surveys as source of information about fished Queen conch (*S. gigas*) populations: A case study in Parque Nacional del Este, Dominican Republic. *Proceedings of the Gulf and Caribbean Fisheries Institute* 53:144-155.

Vega, B. 1987. *Santos Shamanes y Zemies*. Fundacion Cultural Dominicana, Santo Domingo, Dominican Republic. 185 pp.

Vega, M., M. Chiappone, G. Delgado, R. Wright, K. Sullivan. 1997. Evaluacion ecological integral, Parque Nacional del Este, Republic Dominicana. Tomoe 2: Recourses marinas. The Nature Conservancy. Arlington, Virginia USA.