BULLETIN OF MARINE SCIENCE, 73(1): 219–229, 2003

CHANGES IN THE QUEEN CONCH (*STROMBUS GIGA*S L.) POPULATION STRUCTURE AT BANCO CHINCHORRO, QUINTANA ROO, MEXICO, 1990–1997

Alberto de Jesús-Navarrete, Alejandro Medina-Quej and José Juan Oliva-Rivera

ABSTRACT

Changes in the queen conch population structure from 1990–1997 were analyzed. Density and length-frequency data were collected in four fishing sites within Banco Chinchorro, using four random sample units of 100 m^2. All conchs contained in the sample unit were measured for shell length and returned to the bottom. Von Bertalanffy's growth parameters, natural mortality, and total mortality were calculated. There was a significant decrease in conch density over the years. The highest density (2.651 conchs m^{-2}) occurred in 1992 at Cayo Norte and lowest occurred in 1994 (0.108 conchs m^{-2}) and 1997 (0.006 conchs m^{-2}) at Isla Che. There were significant differences in mean shell length (SL) between years. In 1994 mean SL was 229.30 ± 2.07 mm; in 1997 mean SL was only 128.30 ± 3.23 mm and 99.31% of conchs were lesser than 200 mm SL. No significant differences in the L_∞ were detected from 1990–1997, but K had higher values in 1997 (K = 0.45) indicating presence of a juvenile population, with a higher natural mortality (M = 1.06). Conch stock at Banco Chinchorro is overexploited and if the levels of harvesting continue the fishery is predicted to collapse in a short period. A total ban of five years is proposed and more conservative management measures are recommended in order to maintain a sustainable conch fishery.

Queen conch (S*trombus gigas* Linnaeus, 1758) is a widely distributed mollusk in the Caribbean. Their catch represents the second most important fishery, after spiny lobster (*Panulirus argus* Latreille, 1804) (Appeldoorn, 1994). A regional crisis of the resource is recognized principally due to overexploitation. The species has been considered commercially threatened since 1992 by CITES (Stoner et al., 1996). In spite of international policies in the management of the resource, such as bans, catch quotas and in many cases the close of the fishery, there has been no substantial recovery of populations (Stoner and Ray, 1996; Stoner et al., 1996a,b; Stoner, 1997).

In Quintana Roo, *S. gigas* was caught exclusively in the Costa Sur zone until 1950, to satisfy local consumption. In 1960, fisheries began commercial operations for national and international markets, principally the United States. The majority of the conch were fished in Costa Sur and Banco Chinchorro. In 1970, catches totaled 9.6 t and increased to 315 t of meat in 1975 (Miller, 1982). In 1990, after this boom, the catch practically disappeared at Costa Sur. Several management measures were imposed: a permanent ban in the coastal zone, a minimum legal size of 200 mm of shell length, and a catch quota of 30 annual t was conceded to three fishing cooperatives to extract conchs exclusively in Banco Chinchorro. Despite these management measures, the conch population continued to diminish. The ban increased illegal catches, which affected the conch population at Banco Chinchorro.

Studies conducted at Costa Sur showed that the resource has been seriously depleted (de Jesús-Navarrete and Oliva-Rivera, 1997) and at Banco Chinchorro it is considered overexploited (Chávez and Arreguín-Sánchez, 1994; Domínguez et al., 1994).

Fishing practices are known to modify the structure of populations by reducing the overall biomass (Alcalá, 1988; Roberts, 1995), decreasing age and size at sexual maturity (Harmelin et al., 1995), and altering sex ratios and genetic structure (Ryman et al., 1995).

Changes in the conch population size at Banco Chinchorro have been observed, so the goal of this study was to describe these changes and propose new strategies to manage the resource. The following hypotheses were tested: 1) the density of queen conch has diminished over time, 2) the average shell size of conchs is smaller now than in 1992, and 3) there are changes in the queen conch population parameters, the growth rate (K), and total mortality (Z).

Materials and Methods

Length-frequency data for 1990 were taken from Chávez (1990) who collected conchs at six longitudinal transects at Cayo Centro. All conchs contained in a band of 1 m on each side of the transect were counted and shell length was measured using slide calipers.

Data were collected at Banco Chinchorro Quintana Roo at four sites: Cayo Lobos (18°23′45.0″N, 87°21′20.9″W), Isla Che (18°30′12.3″N, 87°26′13.1″W), Cayo Centro (18°33′ 32.7″N, 87°18′24.5″W), and Cayo Norte (18°45′28.1″N, 87°47′01.1″W) (Fig. 1). Samples for 1992 and 1994 were collected monthly; whereas, in 1997 data were collected bimonthly.

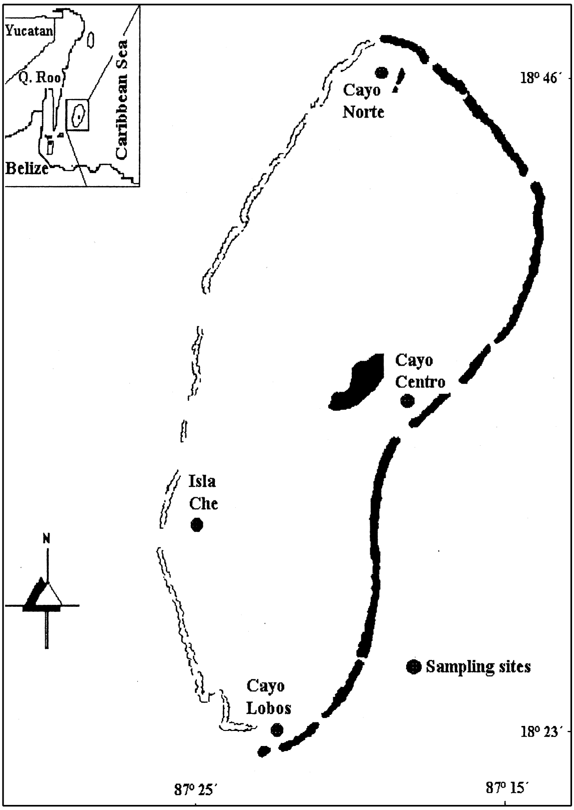

Figure 1. Sampling sites at Banco Chinchorro, Quintana Roo.

At each site, four random circular sample units of 100 m^2 were established. All conchs contained in the sample unit were collected temporarily. Shell length (SL) was measured for all conchs to the nearest millimeter using slide calipers, and then conchs were returned to the bottom. Conchs less than 200 mm SL were considered juveniles; conchs over 200 mm SL were considered adults. Length-frequency data (grouped in 1 cm intervals) and modal composition were analyzed to calculate the parameters of the Von Bertalanffy's growth model. Natural mortality was calculated with Pauly's equation, while total mortality was obtained from catch curve, using the computer package FiSAT (Gayanilo et al., 1995).

To compare conch density between years, a standardization was calculated in all cases. The total conch number, juveniles and adults by sample site was divided by the total sampled area, obtaining the mean density by site and month (conchs m^{-2}). To compare the SL, the mean length was obtained using the sizes of all conchs collected by site and sample period.

Data from 1990 were considered as reference and excluded from statistical analysis. Conch density and mean shell size for 1992, 1994, and 1997 were compared among years and sites sampled using a two-way ANOVA ($P < 0.05$) (Statgraphics, 7.0). The procedure considered independence between sites and years. To determine statistical differences between the slope and height of linearized Von Bertalanffy growth curves from each year, an analysis of covariance (ANCOVA) was applied.

Results

In August 1990, 351 conchs were collected in areas adjacent to Cayo Centro. Size varied from 62–240 mm SL. Population showed a bimodal distribution. The first peak corresponded to 81–90 mm SL, and included 51 juvenile conchs. The second peak corresponded to 131–140 mm SL, and included 31 conchs (Fig. 2A). Conch density varied from 0.122–0.905 conchs m^{-2} for juveniles (Chávez, 1990), and 1.07 conchs m^{-2} for adults (Table 1). Von Bertalanffy parameters were $L_\infty = 215$ mm, $K = 0.24$ total mortality was 1. 41 and fishing mortality 1.23 (Table 2).

In 1992, 4016 conchs were collected. Shell size varied from 50–260 mm. A peak of 1103 juveniles (27.49%) was observed at 110–120 mm SL (Fig 2B). Highest abundance occurred at Cayo Centro (1472 conchs) and Cayo Norte (2121 conchs). At Cayo Centro sizes varied from 50–260 mm SL; at Cayo Norte sizes varied from 50–220 mm SL. The largest conchs (200 mm) were observed at Cayo Lobos and Isla Che, but density was low (0.126 conchs m^{-2} and 0.075 conchs m^{-2} respectively). The highest density occurred at Cayo Norte (2.65 conchs m^{-2}) and Cayo Centro (1.84 conchs m^{-2}) (Table 1). Ninety-nine percent of the conchs (3971) were less than 220 mm SL. Von Bertalanffy parameters were $L_\infty = 385$ mm SL, $K = 0.42$ and $t_0 = -0.14$, total mortality was 1.50 and fishing mortality 0.97 (Table 2).

During 1994, 1006 conchs were registered and size distribution ranged from 60–270 mm SL**.** A bimodal distribution was observed with a high peak at 191–210 (11.68%) mm SL. A minor peak was found at 91–100 mm SL (6.05%) (Fig. 2C). The total number of conchs was one quarter of those found in 1992. The highest number of conchs were located at Cayo Centro (415 conchs) and Cayo Norte (266 conchs). In both sites, the population had a bimodal distribution with peaks at 101–110 and 151–160 mm SL at Cayo Centro and 91–100 and 181–190 mm of shell length at Cayo Norte. All conchs collected at Cayo Lobos (152) and Isla Che (172) have sizes from 160–260 mm SL. Cayo Lobos and Cayo Norte had the highest density, 0.253 conchs m^{-2} and 0.204 conchs m^{-2}, respectively (Table 1). The juvenile population was 88.96% of the total conch collected

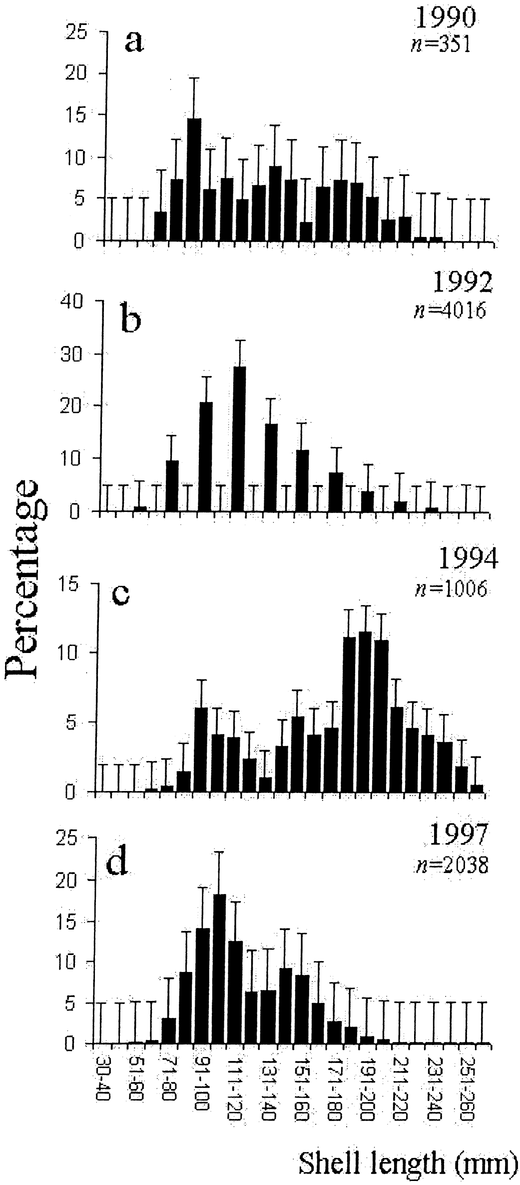

Figure 2. Frequency distribution of conchs at Banco Chinchorro.

and had shell sizes less than 220 mm SL. Conchs in 1994 had a $L_{\infty} = 306$ and K = 0.40, fishing mortality was 0.97 and total mortality 1.92 (Table 2).

Conch distribution was also bimodal in 1997. A total of 2038 conchs were collected with sizes ranging from 50–270 mm SL (Fig. 2D). The higher peak occurred at the size 101–110 SL (372 conchs; 18.25%) and the lowest peak occurred at 141–150 mm SL (186 conchs; 9.12%). Three sites contributed to the largest amount of conchs. At Cayo Norte, 1154 conchs were measured with sizes varying from 50–210 mm SL. At Cayo Lobos conch sizes varied from 30–260 mm SL while at Cayo Centro shell size varied 60–200

Table 1. Juveniles (J), adult (A) and total (T) queen conch *S. gigas* density (conchs m^{-2}) by year and site at Banco Chinchorro, Quintana Roo, Mexico.

Year/site	Cayo Lobos			Isla Che			Cayo Centro			Cayo Norte		
	J	A	T	J	A	T	J	A	T	J	A	T
1990	-	-	-	-	-	-	0.90	1.07	1.97	-	-	-
1992	0.067	0.126	0.194	0.241	0.075	0.316	1.735	0.1050	1.8400	2.620	0.0310	2.6510
1994	0.025	0.228	0.253	0.042	0.066	0.108	0.146	0.0260	0.1720	0.170	0.0340	0.2040
1997	0.183	0.007	0.190	0.002	0.004	0.006	0.171	0.0004	0.1714	0.479	0.0017	0.4807

Table 2. Von Bertalanffy growth parameters, L = asymptotic length, K = growth rate, t_0= adjust parameter, and natural (M), fishing (F) and total mortality (Z) of queen conch (*Strombus gigas*) in Banco Chinchorro, 1990–1997.

year	L_∞	K	t_0	M	F	Z
1990	215	0.24	–0.05	0.18	1.23	1.41
1992	385	0.42	–0.14	0.53	0.97	1.50
1994	306	0.40	–0.06	0.95	0.97	1.92
1997	300	0.45	–0.72	1.06	1.21	2.27

SL. Of the measured conchs, 99.31% were less than 220 mm SL. Density varied from 0.006 conchs m^{-2} at Isla Che, to 0.48 conchs m^{-2} at Cayo Norte (Table 1). Von Bertalanffy parameters were L_∞ = 300 K = 0.45, total mortality was 2.27 and fishing mortality 1.21 (Table 2).

The ANOVA showed no significant differences in conch density in 1992, 1994, and 1997 (P = 0.099). However, a post-hoc LSD analysis indicated that the lowest density occurred in 1994 (mean 0.18 conchs m^{-2}), followed by 1997 (0.21 conchs m^{-2}). In 1990 the mean density was 0.26 conchs m^{-2} and the highest density (1.25 conchs m^{-2}) occurred in 1992. No differences in density were found between sites.

The mean shell size analysis by site showed significant differences between years (P = 0.009), indicating a variation over time. In 1994 larger conchs were collected at Cayo Lobos (mean length 229.30 ± 2.07 mm) and Isla Che (206.70 ± 1.91 mm), the traditional

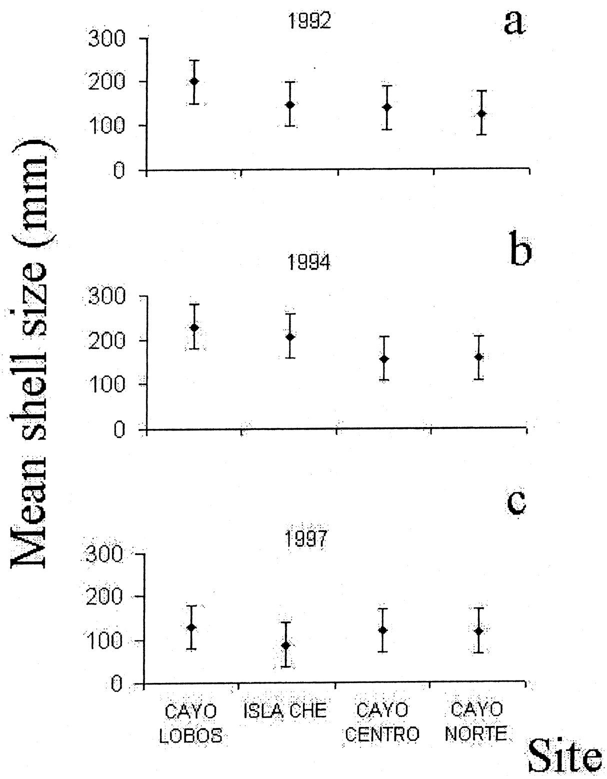

Figure 3. Mean shell size of conchs by site at Banco Chinchorro.

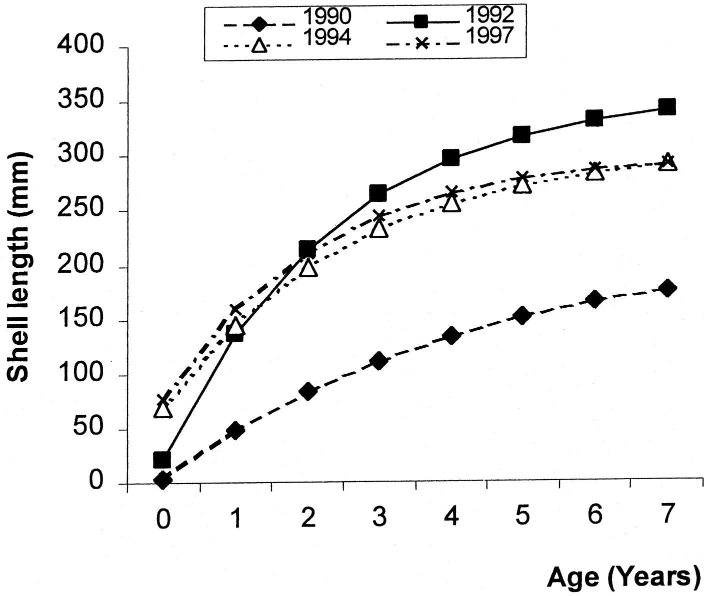

Figure 4. Von Bertalanffy's curves of conch populations at Banco Chinchorro, Quintana Roo.

fishing areas. Conchs with a smaller size have always been distributed at Cayo Centro and Cayo Norte (137.60 ± 2.55 and 122.90 ± 3.47 mm SL respectively). In 1992, larger conchs were found at Cayo Lobos (198.90 ± 3.63 mm SL) and Isla Che (146.50 ± 5.01 SL). Smaller conchs were found in 1997 at Cayo Lobos with a mean size of 128.30 ± 3.23 mm SL and 87.10 ± 3.95 mm SL at Isla Che. There were no significant differences in shell length between sites ($P = 0.914$), but smaller sizes were always found at Cayo Centro and Cayo Norte (Fig. 3A–C).

There was no significant difference between the slopes of the Von Bertalanffy linearized curves between years (ANCOVA (F 3, 23) = 0.07, ($P < 0.05$)) (Fig. 4).

Discussion

Modifications in the number of organisms and distribution of sizes has been observed within natural populations, mainly due to variations in the environmental conditions and biological interactions (Stoner et al., 1996). Changes in populations are also related to recruitment variations, many times controlled by hydrographic effects in the coastal zone and by predation on stocks (Roughgarden et al., 1988).

In sustainable fisheries, the basic premise is to harvest excess population production while leaving the reproductive capacity of the stock intact (Dugan and Davis, 1993). When this equilibrium is broken by overexploitation, fishery-induced alterations in the stock diminish the overall biomass (Alcalá, 1988; Roberts, 1995; Roberts and Polunin, 1991), decreasing size and age at sexual maturity (Harmelin et al., 1995), and altering sex ratios and genetic structure (Ryman et al., 1995). Some of these changes have been observed in the conch population at Banco Chinchorro, mainly density variations, mean length reduction, and an increase in the total mortality. At Banco Chinchorro, conch density showed a decrease over the years from a maximum density in 1992 (1.25 conchs m^{-}

^{2}) to a minimum density in 1994 (0.18 conchs m^{-2}) and 1997 (0.21 conchs m^{-2}). Even though our data are not directly comparable to Chávez (1990), who reported a density of 1.05 conch m^{-2} at Cayo Centro, they are a reference for the diminished density (0.25 conchs m^{-2}) found four years later by Domínguez et al. (1994) at Cao Norte, which consisted principally of juveniles. In Cuba, Alcolado (1976) determined a density of 0.158 conchs m^{-2}; whereas, Weil and Laughlin (1984) reported 0.188 conchs m^{-2} in a protected area at Los Roques (Venezuela); both authors included juveniles and adults in their surveys. In depleted areas such as Florida and Bermuda, an adult density of 0.0003 conchs m^{-2} and 0.00005 conchs m^{-2} were reported (Berg et al., 1989; Glazer and Berg, 1994). In the Bahamas, Stoner and Ray (1996) reported a density of 0.027 adult conchs m^{-2} within a fishery reserve and 0.0008 conchs m^{-2} in the fishing area. At Banco Chinchorro maximum density was 0.23 conchs m^{-2} in Cayo Lobos in 1994 and minimum was 0.0004 conchs m^{-2} at Cayo Centro in 1997; a decrease of three orders of magnitude in density. The Banco Chinchorro population is composed mainly of juveniles, adults represented less than 5% of the population. This confirms our hypothesis of a decrease in density and permits us to state that if density continues to decrease by fishing, a negative effect in the reproductive stock will occur in a short time.

Overfishing has been associated with conch shell decline elsewhere in the Caribbean (Appeldoorn, 1994). In the Turks and Caicos Islands the conch caught around South Caicos were smaller than they were ten years ago (Ninnes, 1994, Stager and Chen, 1996). In Belize, length declined from a mean of 191 mm SL in 1976 to 120 mm in 1979, causing a decrease in the commercial catch (Brownell and Stevely, 1981). Rodriguez-Gil (1994), noted that total landings of conch from the Yucatán Peninsula have declined and catches were composed of juveniles. In the Parque Nacional Jaragua mean length varied from 144–230 mm SL, with a high percentage of juveniles (85%) below the minimum legal size of 250 mm SL (Posada et al., 1999). Our results show a decrease in conch size at Banco Chinchorro over time. The lack of shells larger than 240 mm and a high percentage of juveniles (> 95%) confirms our second hypothesis that there has been a decline in shell length over time due to fishing pressure.

There are several ways in which fishing pressure can reduce mean SL. As fishermen collect larger individuals this reduces adult abundance, alters genetic diversity in the population, shifting the mean length downward (Dugan and Davis, 1993). The additional mortality imposed by fishing will reduce the abundance of adult organisms and change the proportion of mature individuals in the population and this may also have negative effects. Small populations resulting from overfishing have a limited capacity for reproduction (Allee effect). In the case of the queen conch, Stoner and Ray-Culp (2000) observed that mating never occurred when adult density was less than 0.0056; whereas, spawning never occurred when density was less than 0.0048 conchs m^{-2}. At Banco Chinchorro, Isla Che and Cayo Lobos are very close to those values (Table 1); these densities do not permit reproduction activities.

If the system is isolated enough from other conch populations, as apparently is the case for Banco Chinchorro (de Jesús-Navarrete and Aldana-Aranda, 2000), a limited number of juveniles and adults may enter into the population in each reproductive season and this would result in limited recruitment and a local depletion of the population.

Even trough there were no significant differences in Von Bertalanffy growth parameters between years (ANCOVA), a decrease in L_{∞} and an increase in the K values was observed. Total mortality values were high in 1994 and 1997, and this indicates that population is composed of juveniles which have a higher growth rate.

The results from this study suggest that the Banco Chinchorro conch stocks are overexploited and if the level of harvesting continues the commercial fishery will probably collapse in five or ten years. Informal conversations with conch fishermen in July 1999, revealed a widespread perception that conch catches per-man-hour had declined in the last three years, and this is supported by our data.

To curtail overfishing, additional conservation management measures to the conch fishery in Banco Chinchorro must be implemented. These should include: 1) reconsider the total ban for five years proposed by fishermen in 1997, 2) limit the catch technique to free-diving in order to protect the reproductive population—this measure has worked well in the Bahamas (Stoner and Ray, 2000), 3) restoration of a minimum legal size of 220 mm SL, 4) a reproductive ban from March to November, 5) a smaller catch quota, 6) identification of nursery and reproductive areas and their protection as areas closed to fishing, in order to ensure sufficient survival of juveniles and maintain the desired level of adult biomass, protected areas have shown increases in conch density (Weil and Laughlin, 1984; Stoner and Ray, 1996), 7) prohibit marketing at the regional level (Yucatán Peninsula) during the ban season, and 8) promote the catch of potential alternative resources in Banco Chinchorro, such as sea cucumber (*Holothuria mexicana*) (De la Fuente et al., 2001) and blue crab (*Cardisoma guanhumi*) (Oliva-Rivera and Medina Quej, 1998). It is hoped that these measures will maintain a conch fishery with sustainability criteria, and they will help the conch populations recover in Banco Chinchorro in a short time.

Acknowledgments

Surveys to Banco Chinchorro in 1992 were financed by Centro de Investigaciones de Quintana Roo. In 1994, La Secretaría de Pesca provided funds to the project “Conch Culture”, and in 1997 the work was supported by the Consejo Nacional de Ciencia y Tecnología grant 0420P-N. Field assistance of M. Domínguez, H. Hadad and V. Valencia was much appreciated. The helpful comments of G. Islebe, M. Arce, M. Davis and an anonymous reviewer improved the manuscript.

Literature Cited

Alcalá, A. C. 1988. Effects of marine reserves on coral fish abundances and yields of Philippine coral reefs. Ambio 17: 194–199.

Alcolado, P. M. 1976. Growth, morphological variations of shell and some biological data of the conch (Cobo) *Strombus gigas* L. (Molusca: Mesogastropoda). Acad. Ciencias de Cuba 34: 1–36.

Appeldoorn, R. S. 1994. Spatial variability in the morphology of queen conch and its implications for management regulations. Pages 145–158 *in* R. S. Appeldoorn and B. Rodriguez, eds. Queen conch biology, fisheries and mariculture. Fundación Científica Los Roques, Caracas, Venezuela.

Berg, C., J. Ward, B. Luckhurst, K. Nisbet and F. Couper. 1989. Observations of breeding aggregations of queen conch, *Strombus gigas* in Bermuda. Proc. Gulf and Carib. Fish. Inst. 42: 161–171.

Brownell, W. N. and J. M. Stevely. 1981. The biology, fisheries, and management of the queen conch, *Strombus gigas*. Mar. Fish. Rev. 43: 1–12.

Chávez, E. A. 1990. An assessment of the queen conch, *Strombus gigas*, stock of Chinchorro Bank, Mexico. Proc. Gulf Carib. Fish. Inst. 43: 23.

__________ and F. Arreguín-Sánchez. 1994. Simulation modeling for conch fishery management. Pages 169–189 *in* R. S. Appeldoorn and B. Rodriguez, eds. Queen conch biology, fisheries and mariculture. Fundación Científica Los Roques, Caracas, Venezuela.

de Jesús-Navarrete, A. and D. Aldana Aranda. 2000. Distribution and abundance of *Strombus gigas* veligers at six fishing sites on Banco Chinchorro, Quintana Roo, Mexico. J. Shellf. Res. 19: 891–896.

________________ and J. J. Oliva Rivera. 1997. Densidad, crecimiento y reclutamiento del caracol rosado *Strombus gigas* L. en Punta Gavilán, Quintana Roo, México. Rev. Biol. Trop. 45: 797–801.

De la Fuente Bentancourt, M. A., A. de Jesús-Navarrete, E. Sosa-Cordero and M. D. Perezrul. 2001. Assessment of the sea cucumber (Echinodermata: Holothuroidea) as potential fishery resource in Banco Chinchorro, Quintana Roo, México. Bull. Mar. Sci. 68: 51–68.

Domínguez, V. M., A. Medina Quej and A. de Jesús Navarrete. 1994. Sobrevivencia del caracol *Strombus gigas* en la región sur de Quintana Roo, México. Proc. Gulf Carib. Fish. Inst. 47th Annual Meeting. Abstract.

Dugan, J. E. and G. E. Davis. 1993. Applications of marine refugia to coastal fisheries management. Can. J. Fish. Aquat. Sci. 50: 2029–2042.

Gayanilo, F. C., P. Sparre and D. Pauly. 1995. The FAO-ICLARM Stock Assessment Tools (FiSAT). FAO Computerized Information Series (Fisheries). No. 8. FAO, Rome.

Glazer, R. A. and C. J. Berg. Jr. 1994. Queen conch research in Florida: An overview. Pages 79–96 *in* Appeldoorn, R. S. and B. Rodriguez, eds. Queen conch biology, fisheries and mariculture. Fundación Científica Los Roques, Caracas, Venezuela.

Harmelin, J. G., F. Bachet and F. Garcia. 1995**.** Mediterranean marine reserves: fish indices as a test of protection efficiency. Mar. Ecol.-Pubbliczioni Della Stazione Zool. 16: 233–250.

Miller, D. 1982. Mexico's Caribbean fishery: Recent change and current issues. Ph.D. Diss., University of Wisconsin, Milwaukee. 251 p.

Ninnes, C. 1994. A review on Turk and Caicos islands fisheries for *Strombus gigas* L. Pages 62–72 *in* R. S. Appeldoorn and B. Rodriguez, eds. Queen conch biology, fisheries and mariculture. Fundación Científica Los Roques, Caracas, Venezuela.

Oliva-Rivera, J. J. and A. Medina-Quej. 1997. El cangrejo de tierra *Cardisoma guanhumi* Latreille (Crustacea: Decapoda) como recurso pesquero potencial en Quintana Roo. AvaCient 21: 14–20.

Posada, J. M., I. R. 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. Carib. J. Sci. 35: 70–82.

Roberts, C. M. 1995. Rapid build-up of fish biomass in a Caribbean marine reserve. Cons. Biol. 9: 815–826.

______ and N. V. C. Polunin. 1991. Are marine reserves effective in management reef fisheries? Rev. Fish Biol. Fish. 1: 65–91.

Rodríguez-Gil, L. 1994. Análisis de la evolución de la pesquería del caracol en dos estados de la Península de Yucatán, México y en una cooperativa de pescadores. Pages 113–124 *in* R.S. Appeldoorn and B. Rodriguez, eds. Queen conch biology, fisheries and mariculture. Fundación Científica Los Roques, Caracas, Venezuela.

Rouhgarden, J., S. Gaines, and H. Possingaham. 1988. Recruitment dynamics in complex life cycles. Science 228: 1460–1466.

Ryman, N., F. Utter, and L. Laikre. 1995. Protection of intraspecific biodiversity of exploited fishes. Rev. Fish Biol. Fish. 5: 417–446.

Stager, J. C. and V. Chen. 1996. Fossil evidence of shell length decline in queen conch (*Strombus gigas* L.) at Middleton cay, Turks and Caicos Island, British West Indies. Carib. J. Sci. 32: 14–20.

Stoner, A. W., P. A. Pitts and R. A. Armstrong**.** 1996. Interaction of physical and biological large scale distribution of juvenile queen conch in seagrass meadows. Bull. Mar. Sci. 58: 217–233.

__________, M. Ray, R. A. Glazer and K. J. McCarthy. 1996a. Metamorphic responses to natural substrata in a gastropod larvae: decisions related to postlarval growth and habitat preference. J. Exp. Mar. Biol. Ecol. 205: 229–243.

_________, R. A. Glazer and P. J. Barile. 1996b. Larval supply to queen conch nurseries: Relationships with recruitment processes and population size in Florida, and the Bahamas. J. Shellf. Res. 15: 407–420.

__________ and M. Ray, 1996. Queen conch, *Strombus gigas*, in fished and unfished locations of the Bahamas: effects of a marine fishery reserve on adults, juveniles and larval production. Fish. Bull. 94: 551–565.

___________. 1997. The status of queen conch, *Strombus gigas*, research in the Caribbean. Mar. Fish. Rev. 59: 14–22.

__________ and M. Ray-Culp. 2000. Evidence for Allee effects in an over-harvested marine gastropod: density-dependent mating and egg production. Mar. Ecol. Prog. Ser. 202: 297–302.

Weil, M. E. and G. R. Laughlin. 1984. Biology, population dynamics, and reproduction of the queen conch *Strombus gigas* Linné in the Archipelago de Los Roques National Park. J. Shellf. Res. 4: 45–62.

Addresses: (A.deJ.-N., J.J.O-R.) *El Colegio de la Frontera Sur-Unidad Chetumal, AP 424, Chetumal, Quintana Roo, 77000 Mexico. E-mail: <alberto@ecosur-qroo.mx>*. (A.M.-Q.) *Centro de Investigación Cieníifica y de Educación Superior de Ensenada, Km 107 Carretera Tijuana-Ensenada, Ensenada 22860, B.C., Mexico.* Corresponding Author: (A.deJ.-N.).