

Growth and population assessment of the queen conch *Strombus gigas* (Mesogastropoda: Strombidae) by capture mark-recapture sampling in a natural protected area of the Mexican Caribbean

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Received 14-VI-2011. Corrected 02-XII-2011. Accepted 20-XII-2011.

Abstract: The Inlet of Xel-Ha is used as a park for ecotourism, representing a sanctuary for the conservation of Pink Queen Conch. Increasing fishing pressure has led to the inclusion of the species in CITES. Most knowledge about the growth of the queen conch was generated through aquaculture, ocean enclosures or obtained using estimates derived from population dynamics. In this study we estimated the growth rate of juvenile *S. gigas* in a natural protected area by direct methods, during the period of April 2009 to January 2011. Data was obtained by capture-mark-recapture sampling. 1418 individuals were tagged and growth of 714 conchs was analyzed. Population size and density was estimated using Schnabel's method. The average density was estimated at $0.1694 \pm 0.0996 \text{ ind. m}^{-2}$, while the highest density was estimated for September 2010 ($0.3074 \text{ ind. m}^{-2}$). The highest growth rate ($0.27 \pm 0.10 \text{ mm day}^{-1}$) was detected in juveniles with an initial size between 100-149mm, followed by conch <100mm, with an increase of $0.24 \pm 0.05 \text{ mm day}^{-1}$. The growth rate decreased for individuals with an initial size between 150-199mm ($0.18 \pm 0.09 \text{ mm day}^{-1}$) and for organisms > 200mm ($0.08 \pm 0.07 \text{ mm day}^{-1}$). Variability in growth rate was high in conch 100-149mm and showed seasonal differences, with the highest growth rate in May 2010. Recruitment of juveniles was highest in October 2009 and February 2010. The population of Xel-Ha has grown in size and more large and juvenile conch could be found than in previous studies, indicating that Xel-ha park is working as a sanctuary for the conservation of the queen conch in Mexico's Riviera Maya. The growth rate of juvenile conch in Xel-Ha is high and exhibits large variations in individuals, reflecting the natural conditions of foraging and aggregation. Seasonal differences in growth rate may be associated with water quality and availability of nutrients for primary production. We conclude that the direct method is useful for the assessment of growth in juvenile *S. gigas* and that growth in natural conditions may be higher than in aquaculture systems. This information may be applied to fishery management as well as rehabilitation programs and aquaculture. Rev. Biol. Trop. 60 (Suppl. 1): 127-137. Epub 2012 March 01.

Keywords: Population size, Population density, Growth, Mark-Recapture, Recruitment, Nursery, Xel-Ha.

The queen conch (*Strombus gigas* Linnaeus, 1758) is a large gastropod which represents an important food and economic resource in the Caribbean, being the second largest fishery after the spiny lobster (Appeldorn 1994) with landings of 6 000 metric tons, worth \$60 million Dollars (Chakalall & Cochrane 1997). The increasing fishing pressure caused populations to decline in the 1980's and led to the inclusion of this mollusk in the Convention on International Trade of Endangered Species (CITES)

and the list of commercially threatened species. In Mexico, on the Peninsula of Yucatan, the conch fisheries reached a peak in 1983, with landings of 1 250 tons. In the late 1980's the majority of the stocks were reported to be overexploited, especially in the state of Yucatan where a permanent fishing ban was implemented in 1988 (Baquero-Cárdenas 1997). In Quintana Roo captures reached their maximum in the early eighties and by the end of the decade catch volumes started to show signs

of overexploitation (Carta Pesquera Nacional 2006). This has led on one hand to the implementation of different management programs to protect the conch (INP-SAGARPA 2008) and on the other hand, to the development of its aquaculture (Berg 1976, Brownell 1977, Brownell & Stevely 1981, Rathier 1987, Glazer *et al.* 1997, Davis 2000, Moreno de la Torre & Aldana-Aranda 2007). The inlet of Xel-Ha is a natural marine protected area, which has been used since 1995 as a park for ecotourism. The main attraction is the observation of marine fauna in its natural environment; hence the removal of any flora or fauna is prohibited. Xel-Ha is considered a sanctuary for the conservation of the queen conch in the Mexican Riviera Maya, hosting an important number of juvenile conch (Peel *et al.* 2010).

Sound management of a resource such as *S. gigas*, as well as its rehabilitation, protection and the development of aquaculture require biological and ecological knowledge of the species, including growth rate, density and population structure. In this study we determined the rate of growth of juvenile *S. gigas* by direct methods in a natural protected area. Data was obtained through capture-mark-recapture methods, allowing the natural foraging behavior, resource selection and dispersal of the animals.

MATERIAL AND METHODS

Study Site: Xel-Ha is located on the east coast of the Yucatan Peninsula (20°19'15"-20°18'50"N and 87°21'41"-87°21'15"W). The main oceanic current is the Caribbean Current (Organismo de Cuenca Península de Yucatán Dirección Técnica 2008). The area is characterized by medium wave energy and input of fresh water by underground rivers due to karstic conditions in the Peninsula (Organismo de Cuenca Península de Yucatán Dirección Técnica 2008). Xel-Ha is a creek that consists of a mix of fresh groundwater with seawater. The Inlet is connected to the Caribbean Sea by a 100 m wide channel and has a total surface of 14 Ha with a center area and three appendices:

Bocana, North Arm and South Arm. Depth ranges from 1.75-4.0m (Organismo de Cuenca Península de Yucatán Dirección Técnica 2008). The climate in the region is warm and sub-humid, with rains during summer and winter. The average annual temperature is 26°C. Average annual rainfall is 1 079mm (Organismo de Cuenca Península de Yucatán Dirección Técnica 2008). The sampling site "Cueva" is located in the south-arm of the Inlet and includes a small bay surrounded by mangroves (*Rhizophora mangle*). Persistent upwelling of cold freshwater from underground caves, maintains a permanent thermo-and halocline (1.25m). The site has a depth 1.5-3.5m. The bottom is composed of fine mud and sand formed of fragments of calcareous algae, mixed with rocks and dense isolated patches of macroalgae (*Padina* sp., *Halimeda* sp. *Penicillus* sp. *Amphiroa* sp. *Acanthophora* sp., *Caulerpa* sp., *Dictyota* sp.), decaying mangrove leaves and inverted jellyfish (*Cassiopea* sp.) may be found.

Population Parameters: Between April 2009 and January 2011, nine surveys were conducted at the site of *Cueva* in the Inlet of Xel-Ha sampling a total area 6 000m². Three samplings were conducted during 2009, five in 2010 and one in January 2011. All organisms were collected in free-dive, by three divers during 3 hours. We used mark-recapture method, marking all individuals with a plastic Dymo® tag, bearing a consecutive number, which was fixed to the spire of the conch with a plastic cable binder. In order to evaluate the size distribution and growth rate, shell length (SL) was determined for each individual, as well as lip thickness, using a precision vernier caliper (1mm). With the abundance data of recaptured and unmarked individuals we estimated population size using Schnabel's method (Schnabel 1938):

$$N_t = \Sigma (C_t M_t) / \Sigma R_t$$

Relative density of conch in *Cueva* was derived from population size. To determine the growth rate of conch per day, we only used

the measurements of individuals which were recaptured for the first time after being marked in the previous sample (n=706).

Environmental parameters: Parameters for dissolved oxygen (O₂), water temperature (°C), salinity, total nitrogen (N total), total phosphates (P total), nitrate (NO₃⁻) and nitrite (NO₂⁻), measured at the study site between February 2009 and September 2010 were provided as a courtesy of Xel-Ha Park and were used to aid interpretation of growth rates over time. Data was obtained through the laboratory LAB-ACAMA (Laboratorio de Análisis de Calidad de Agua y Medio Ambiente S.A. de C.V) applying the procedures specified by the Mexican Normative for Water quality NMX-AA-26-SCFI-2001 for sampling and analysis.

Statistical Analysis: Using the program Infostat/S, we calculated the mean daily growth and standard deviation per size class (<100mm, 100-149mm, 150-199mm and ≥200mm) and the average growth per day in each class over time. Growth data was subjected to analysis of variance (ANOVA) to detect significant differences in growth rate over time and between classes, with a confidence level of 95%, followed by Tuckey's honestly significant difference test

(Saville 1990). Population structure was determined using histograms, with 10mm intervals for size classes from 45-245mm. We calculated the percentage of individuals with flaring lip per size class. A correlation analysis using Pearson coefficient (Pearson 1896) between average growth rates from each sample and corresponding density was executed.

RESULTS

An average of 52.83%, of a total of 1418 individuals tagged, was recaptured in each sample. The recapture success was lowest in October 2009 with 19.93% and highest in November 2010 with 74.74% (Table 1). Using the method of Schnabel, population size was estimated for each month as well as the relative density of conch in the *Cueva*. The relative average density was estimated at 0.1694 ± 0.0996 ind. m⁻², while the highest density was estimated for September 2010 with 0.3074 conches per square meter (Table 1).

Conches with SL less than 100mm were the scarcest in *Cueva* representing less than 5%, except in October 2009 and February 2010, when 11.32% and 42.81% were captured, respectively. Relative abundance was highest for the class of conch between 150

TABLE 1
Abundance, estimated abundance using Schnabel Method and density of *S. gigas* in Xel-há (Cueva)

| Sample | Ct | Rt | %Rt | Ut | Mt | Nt | Density (ind. m ⁻²) |
|---------|-----|-----|-------|-----|------|------|---------------------------------|
| Apr. 09 | 127 | 0 | | 127 | 0 | | |
| Jun. 09 | 106 | 68 | 64.15 | 38 | 127 | 198 | 0.0330 |
| Oct. 09 | 306 | 61 | 19.93 | 245 | 165 | 496 | 0.0826 |
| Feb. 10 | 406 | 193 | 47.54 | 213 | 410 | 716 | 0.1193 |
| May. 10 | 382 | 195 | 51.05 | 187 | 623 | 906 | 0.1510 |
| Jul. 10 | 566 | 305 | 53.89 | 261 | 810 | 1128 | 0.1879 |
| Sep. 10 | 545 | 319 | 58.89 | 226 | 1071 | 1844 | 0.3074 |
| Nov. 10 | 479 | 358 | 74.74 | 121 | 1297 | 1422 | 0.2370 |
| Jan. 11 | 265 | 265 | | 0 | 1418 | 1422 | 0.2369 |

1. Ct= Number of *S. gigas* caught in each sampling.
2. Rt= Number of recaptures in each sample.
3. % Rt= Percentage of recapture per sample.
4. Ut= Number of untagged conch in each sample.
5. Mt= Total of marked animals at time.
6. Nt= Estimated population size using the Schnabel method.

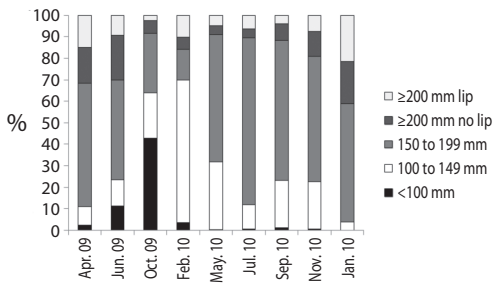


Fig. 1. Distribution of relative size class frequencies of queen conch *S. gigas*, sampled at Xel-ha, Mexico, showing the relative abundance (%) of animals which were <100mm, between 100mm and 149mm, between 150 and 199mm, ≥200mm without lip and ≥200mm with lip.

and 199mm, which made up an average of $51.18\% \pm 19.57\%$ of the population. Conch between 100 and 149mm represented on average $22.13\% \pm 18.69\%$ of the population. Their abundance was highest in February 2010 with 66.50%. Organisms with length ≥ 200 mm contributed on average $19.73\% \pm 11.80\%$ to the population. This class had the least variation in abundance compared with other classes.

$48.01\% \pm 12.90\%$ of the organisms ≥ 200 mm showed a formed lip (Fig. 1).

In April 2009, 94% of the conchs were ≥ 145 mm (Fig. 2). The size classes with highest frequency of abundance in that month were the animals with SL between 215mm and 225mm, and the animals between 185mm and 195mm, making up 26% of the population. In June 2009 a significant increase in organisms <145mm was observed, representing 24% of the organisms sampled. Throughout October 2009 and February 2010 abundance of individuals <145mm increased dramatically, recording 63.42% and 67.73%. Modal class in October was 85-95mm (16.34%) and 125-135mm (17.24%) in February. In May the number of conch <145mm captured decreased again, with 22.5% and the modal class were juveniles between 145mm and 155mm, which represented 25.65% of the population. Modal class shifted in July to the class of 155-165mm (22.79%) and the abundance of conch <145mm continued to decline, reaching 9.35%. In September of the same year, we could detect the emergence of new recruits, with 21.65% of conch <145mm and modal class was 185-195mm (16.88%). Recruits kept emerging

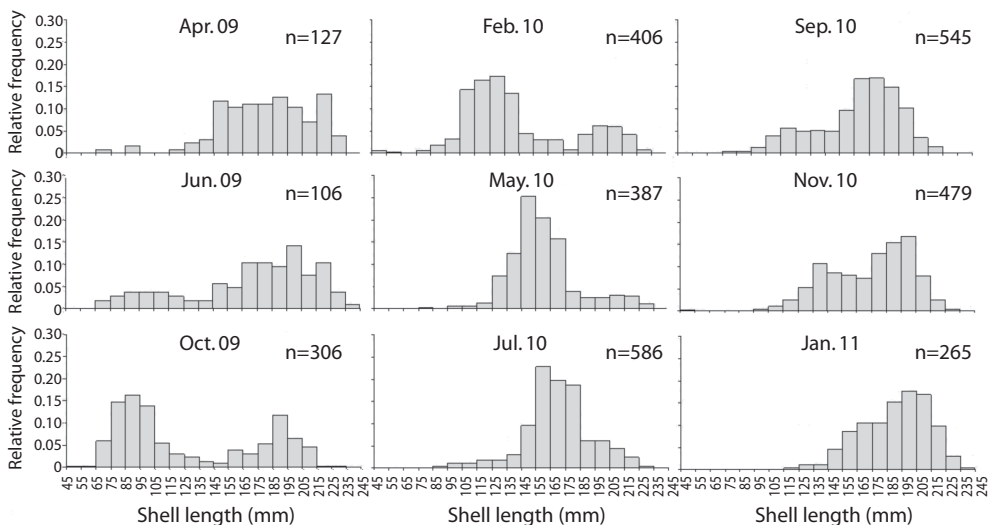


Fig. 2. Histograms showing relative frequency of abundance per size class, modal progression and recruitment patterns of queen conch *S. gigas* sampled at Xel-Ha, Mexico, between April 2004 and January 2011.

throughout November, with 20.05% of the animals <145mm and modal class shifted to 195-205mm (16.7%). In January 2011 no conchs smaller than 115mm were found and 97.37% of the sampled population had a size \geq 145mm and the class with highest frequency was 195-205mm (17.74%).

For the growth rate analysis the population was divided into 4 size classes (Fig. 3). Growth was highest in animals of 100-149mm (n=306) with an average growth of 0.27 ± 0.1 mm day⁻¹. The animals of this size class showed at the same time the greatest variation in growth rates, with values between 0.01 and 0.63 mm day⁻¹. The growth rate had normal distribution (Shapiro-Wilks p=0.0856) and the median coincided with the mean. In juvenile conch smaller than 100mm (n=96) we calculated a growth rate of 0.24 ± 0.05 mm day⁻¹. Growth rate decreased to 0.18 ± 0.08 mm day⁻¹ in the class of 150 - 199mm (n=268) and was lowest with 0.08 ± 0.07 mm day⁻¹ in conch with a size \geq 200mm (n=36) (Fig. 3). The growth rate showed significant differences between size classes (ANOVA $F_{3, 705} = 80.08$, $p < 0.0001$), but was similar between the classes <100mm and 100-149mm (Tuckey, $p < 0.05$).

The growth showed significant differences over time in classes of <100mm ($F_{5, 95} = 8.01$,

$p < 0.0001$), 100mm to 149mm ($F_{7, 305} = 36.98$, $p < 0.0001$) and 150mm to 199mm ($F_{7, 267} = 9.14$; $p < 0.0001$). There were no significant differences in the class of animals \geq 200mm ($F_{6, 35} = 1.46$; $p = 0.2262$). The highest growth rate was observed in May 2010, while the lowest growth was observed in October 2009 and November 2010 (Fig. 4 and Table 2).

No significant association was detected between growth rate and the relative density of conch ($R=0.17$; $p = 0.69$).

Xel-Ha Park occasionally carries out surveys to monitor water quality. The results corresponding to the area of *Cueva* are shown in Figure 5.

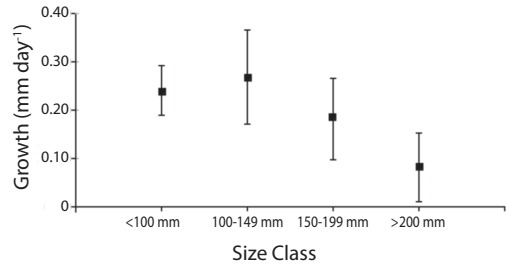


Fig. 3. Mean growth rate (mm day⁻¹) and its standard deviation (Bars) of queen conch *S.gigas* with Shell length <100mm, between 100mm and 149mm, between 150 and 199mm, and \geq 200mm, sampled at Xel-Ha, Mexico.

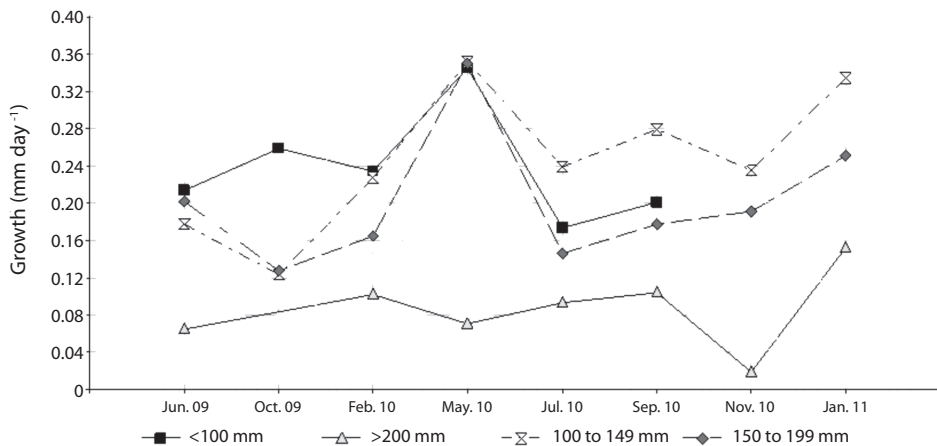


Fig. 4. Average growth rate (mm day⁻¹) over time in pink queen conch *S.gigas* with a shell length of <100mm, 100mm to 149mm, 150mm to 199mm and \geq 200mm, at *Cueva* (Xel-Ha, Mexico).

TABLE 2
Average growth (mm day⁻¹) of queen conch *S.gigas* with a shell length of <100mm, 100mm to 149mm, 150mm to 199mm and ≥ 200mm, over time, at Xel-Ha, Mexico

| Size Class / Growth | Jun. 09 | Oct. 09 | Feb. 10 | May 10 | Jul. 10 | Sep. 10 | Nov. 10 | Jan. 11 |
|---------------------|---------|---------|---------|--------|---------|---------|---------|---------|
| <100(mm) | 0.21 | 0.26 | 0.23 | 0.35 | – | 0.17 | 0.2 | – |
| 100 to 149(mm) | 0.18 | 0.12 | 0.23 | 0.35 | 0.24 | 0.24 | 0.28 | 0.33 |
| 150 to 199(mm) | 0.2 | 0.13 | 0.16 | 0.35 | 0.19 | 0.15 | 0.18 | 0.25 |
| ≥200mm | 0.06 | – | 0.1 | 0.07 | 0.02 | 0.09 | 0.1 | 0.15 |

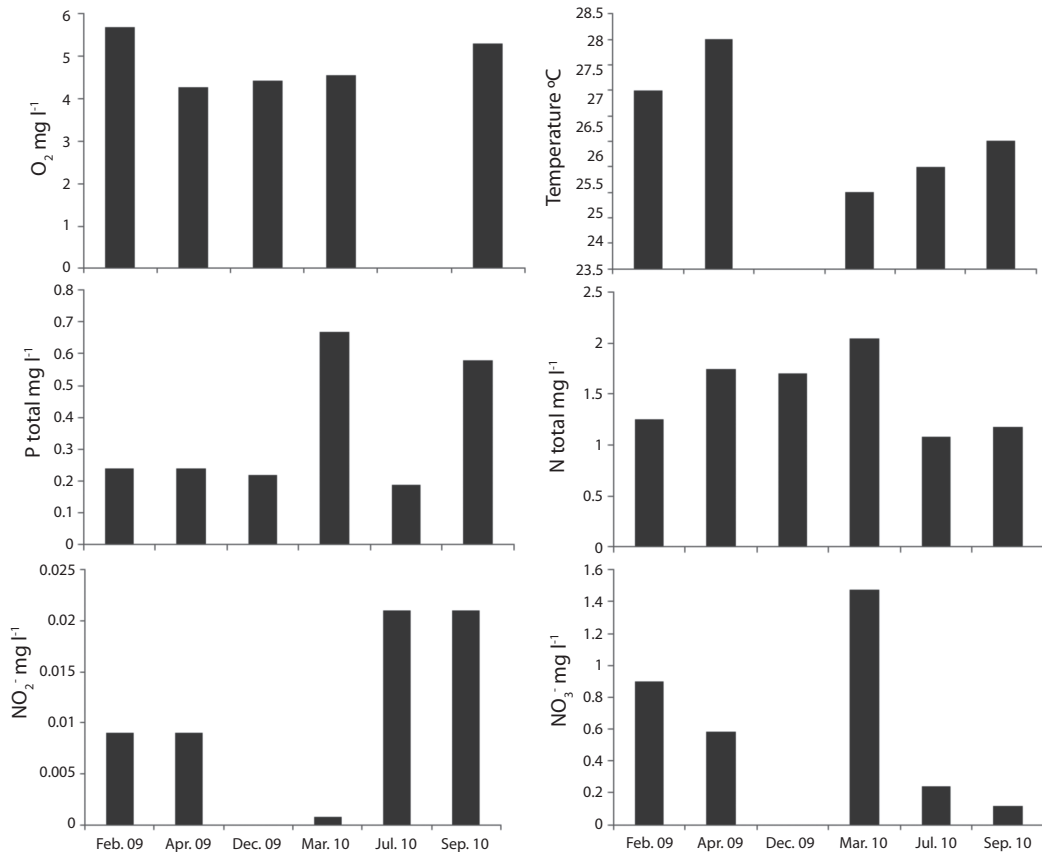


Fig. 5. Water quality parameters, showing surface temperature, dissolved oxygen at the surface, total nitrogen (N total), Nitrate (NO₃), Nitrite (NO₂) and total phosphate (total P) at Xel-Ha's *Cueva*. Data was provided by courtesy of the administration of Xel-Ha Park.

DISCUSSION

In the present work conch larger than 210mm were present in all samples and a total of 268 observations could be made, representing 8.42% of the population. Aldana-Aranda *et al.* (2005) reported the absence of animals

larger than 210mm at *Cueva* in the majority of the samples taken in a study conducted between 2001 and 2002. Xel-Ha initiated the Monitoring Program, as well as the actions for conservation and rehabilitation of the queen conch in October 2001. The conch population of Xel-Ha has grown in size and more large and

juvenile conch could be found than in previous studies, suggesting that the park of Xel-Ha is providing effective protection for the species.

Apparent recruitment was detected throughout most of the year, but was highest from June 2009 to May 2010 and September 2010 to November 2010. Aldana-Aranda *et al.* (2003) documented recruitment throughout most of the year and high recruitment during October 2001. In a subsequent study Aldana-Aranda *et al.* (2005) documented higher recruitment in October 2002, February 2002 and February 2003, consistent with recruitment peaks observed in this study, in February and October.

In the present study population structure was: <100mm = 7.0%; 100-149mm = 22.1%; 150-199mm = 51.2%; ≥200mm = 19.7%. Aldana-Aranda *et al.* (2005) reported 4.2% of the population <100mm, 23.8% in the class of 100-150mm, 51.2% conch 150-200mm and 23.4% of the population >200mm in the period from November 2001 to August 2003, applying the same methodology. It can be noted that relative proportion of adults and juveniles has remained similar in comparison with previous studies, despite the increase in numbers of

individuals, indicating the population is in an equilibrium state.

In the present study, the population was small initially; however, we observed substantial recruitment of juveniles from October 2009 onwards, reaching a maximum density of 0.3074 conches per square meter in September 2010. Aldana-Aranda *et al.* (2005) estimated a population size of 632.15 ± 49.40 individuals in the period from 2001 to 2003, using Schnabel's method. Peel *et al.* (2010) reported average catches of 82.09 conches per sample in the period from January 2004 to January 2008 at the sampling site *Cueva*. The observed population growth was attributed to increased recruitment of juveniles.

The Density at Xel-Ha's *Cueva* is high, compared to other areas in the Caribbean (Table 3). The densities documented at *Cueva* were higher than densities reported for Alacranes Reef, where conch fishery was banned in 1988 (Pérez-Pérez & Aldana-Aranda 1998, Ríos-Lara *et al.* 1998, Pérez-Pérez & Aldana-Aranda 2000, Pérez-Pérez & Aldana-Aranda 2003), ranging from 0.0047 to 0.018 conch m⁻². They were also higher than the densities reported for the two most important commercial

TABLE 3
Average densities of *S. gigas* in the Caribbean

| Author, Year | Location | Density (ind. m ⁻²) |
|---|---|---------------------------------|
| Ríos-Lara <i>et al.</i> 1998 | Alacranes Reef, Yucatán, México | 0.0047 |
| Pérez-Pérez & Aldana-Aranda 1998 | Alacranes Reef, Yucatán, México | 0.0072 |
| Pérez-Pérez & Aldana-Aranda 2000 | Alacranes Reef, Yucatán, México | 0.0084 |
| Pérez-Pérez & Aldana-Aranda 2003 | Alacranes Reef, Yucatán, México | 0.018 |
| De Jesús-Navarrete <i>et al.</i> 1992 | Punta Gavilán, Quintana Roo, México | 0.003 |
| De Jesús-Navarrete & Oliva-Riviera 1997 | Punta Gavilán, Quintana Roo, México | 0.0052 ± 0.0023 |
| INP-SAGARPA 2008 | Banco Chinchorro, Quintana Roo, México | 0.0211 ± 0.035 |
| INP-SAGARPA 2008 | Banco Cozumel, Quintana Roo, México | 0.0079 ± 0.01653 |
| Berg & Glazer 1991 | Florida Keys, Florida, USA | 0.000109-0.000298 |
| Friedlander <i>et al.</i> 1994 | Virgin Islands, USA | 0.00171 |
| Stoner & Ray 1993 | Exuma Cays, Bahamas | 0.2 |
| Stoner & Schwarte 1994 | Lee Stocking Island, Bahamas | 0.0018-0.0088 |
| Stoner 1996 | Exuma Cays (unfished zones), Bahamas | 0.0034-0.0147 |
| Stoner 1996 | Exuma Cays (fished zones), Bahamas | 0.00022-0.0088 |
| Stoner & Ray 1996 | Exuma Park, Exuma Cays, Bahamas | 0.027 |
| Posada <i>et al.</i> 1999 | Jaragua National Park, Dominican Republic | 0.0004-0.01142 |

queen conch fishery grounds in Quintana Roo, Banco Chinchorro ($0.0211 \pm 0.035 \text{ ind m}^{-2}$) and Banco Cozumel ($0.0079 \pm 0.01653 \text{ ind m}^{-2}$). In Punta Gavilán, a coastal area without commercial fishing, densities range from 0.003 to $0.0052 \text{ ind. m}^{-2}$ (De Jesús-Navarrete *et al.* 1992, De Jesús-Navarrete & Oliva-Rivera 1997). Berg & Glazer (1994) reported in the Florida Keys, USA, densities between $0.000109 \text{ ind. m}^{-2}$ and $0.000298 \text{ ind. m}^{-2}$, where a permanent fishing ban has been implemented since 1985 and sanctuaries with surveillance have been created due to the rapid depletion of stocks of Queen Conch. The density at Xel-Ha's *Cueva* is similar to the relatively natural populations in the Exuma Cays (Table 4) (Stoner & Ray 1993, Stoner 1996) and can be compared to the high-density aggregation nursery grounds (Stoner & Ray 1993, Stoner & Lally 1994) in terms of population structure and density.

The growth rate of juvenile conch in *Cueva* was high in comparison with those mentioned by other studies (Table 4). De Jesús-Navarrete (2001) obtained an average increase of $3.21 \text{ mm month}^{-1}$ ($\sim 0.1052 \text{ mm day}^{-1}$) in Punta Gavilán and $2.30 \text{ mm month}^{-1}$ ($\sim 0.075 \text{ mm day}^{-1}$) in Banco Chinchorro, maintaining conch in enclosures at density of 0.4 ind. m^{-2} . In other areas of the Caribbean similar increases were observed (Randall 1964, Alcolado 1976, Brownell 1977, Ray & Stoner 1994). Growth rates measured during this study were comparable to other studies conducted under natural conditions using mark-recapture methods. Gibson *et al.*

(1983) determined a rate of $7.2 \text{ mm month}^{-1}$ ($\sim 0.236 \text{ mm day}^{-1}$) in Belize, while in Venezuela an increase of 15 mm month^{-1} ($\sim 0.492 \text{ mm day}^{-1}$) was measured (Weil & Laughlin 1984) and in Punta Gavilán, juveniles grew an average of 10 mm month^{-1} ($\sim 0.327 \text{ mm day}^{-1}$) (De Jesús-Navarrete & Oliva-Rivera 1997). The growth rate of juvenile queen conch at Xel-Ha's *Cueva* was comparable to the growth measured by Moreno de la Torre & Aldana-Aranda (2007) under experimental conditions, using artificial diets, who obtained an increase of $0.16\text{--}0.23 \text{ mm day}^{-1}$. However, the conch used in their study had an initial size inferior to 40mm and were smaller than the organisms in the present study.

Growth rates declined in the 150-199mm size class and tended towards null in conch $\geq 200 \text{ mm}$ (Fig. 3). Conches grow in shell length only until maturation. At this time the flared shell-lip is formed. Subsequent shell growth occurs as a progressive thickening of the shell-lip (Appeldoorn 1988). Most conch reach sexual maturation when the shell lip is thicker than 5mm (Appeldoorn 1988, Aldana-Aranda & Frenkiel 2007). Shell morphology and maximum size can vary considerably (Alcolado 1976, Appeldoorn 1994) and may not represent a good indicator for maturity (Aldana-Aranda & Frenkiel 2007). The maximum SL observed at Xel-Ha in our study was 239mm and less than the half of the organisms in the $\geq 200 \text{ mm}$ class had developed a flaring lip. It may be deduced that more than half of the conch

TABLE 4
Comparative Table of mean growth rates of *S. gigas*

| Author, Year | Location | Method | Growth rate (mm month ⁻¹) | Growth rate (mm day ⁻¹) |
|---|--------------------------|--|--|--|
| Randall 1964 | Virgin Islands, USA | Enclosure | 4.16 | ~ 0.136 |
| Alcolado 1976 | Cuba | Enclosure, different environments | 3.3 | ~ 0.108 |
| Brownell 1977 | Florida Keys, USA | Enclosure | 4.5 | ~ 0.147 |
| Gibson <i>et al.</i> 1983 | Belize | Mark-Recapture | 7.2 | ~ 0.236 |
| Weil & Laughlin 1984 | Venezuela | Mark-Recapture | 15 | ~ 0.492 |
| Ray & Stoner 1994 | Exuma Cays, Bahamas | Enclosure | – | 0.058-0.139 |
| De Jesús-Navarrete & Oliva-Rivera 1997 | Punta Gavilán, México | Mark-Recapture | 10 | ~ 0.327 |
| De Jesús-Navarrete 2001 | Banco Chinchorro, México | Enclosure, different environments | 3.21 | ~ 0.1052 |
| De Jesús-Navarrete 2002 | Punta Gavilán, México | Enclosure, different environments | 2.30 | ~ 0.075 |
| Moreno de la Torre & Aldana-Aranda 2005 | México | Laboratory conditions, artificial diet | – | 0.16-0.23 |

≥200mm are still immature and may represent some considerable growth.

Growth rate of the queen conch showed large individual variations, especially in animals of the class of 100-149mm. Alcolado (1976) showed that growth may vary according to environmental variability between sites; however, the study area of the *Cueva* is a relatively small area, making it more likely that all organisms have been exposed to the same conditions. Ray & Stoner (1994) suggested that juvenile conch are vulnerable to predation and may choose lower quality habitat in terms of resources, compromising maximum ingestion and growth, by aggregating or sheltering in dense vegetation, to reduce the risk of predation and increase survival probabilities. The high growth rate of juvenile conch in Xel-Ha and the large variations in individuals likely reflects the natural conditions of foraging and aggregation.

We could detect significant variation in the rate of growth over time (Fig. 4). There was an increase in nutrients important for production of biomass (P, N and NO) in the sample of March 2010, for which it is likely that the increase in growth rate during May 2010 might be the result of higher primary productivity.

We conclude that the direct method is useful for the assessment of growth in juvenile *S. gigas* and that growth in natural conditions is higher than in enclosures and aquaculture systems. This information may be applied to fishery management as well as to rehabilitation programs and aquaculture.

ACKNOWLEDGMENTS

We gratefully acknowledge financial support by CONACYT through Grant Conacyt SEP 24210 Connectivity of the Conch in the Caribbean, CONACYT student scholarship (374674/243375) and CINVESTAV-IPN. Also we thank Xel-Ha Park's administration, Elizabeth Lugo Monjarras and Ricardo Saenz Morales for providing unlimited access and logistic support during our field work. We thank Xel-Ha staff Enrique May, Teresa Rivas, Angel Chavarria and Mario Hoil for their field support.

RESUMEN

La Ensenada de Xel-Ha es usada como parque para ecoturismo y representa un santuario para la conservación del caracol rosado. El incremento en la presión de la pesca ha llevado a la inclusión de esta especie en CITES. Mucho del conocimiento acerca del crecimiento del caracol rosado ha sido generado a través de la acuicultura, encierros oceánicos o usando estimaciones derivadas de las dinámicas poblacionales. En este estudio estimamos la tasa de crecimiento de *Strombus gigas* juvenil en un área natural protegida, por métodos directos durante el período de abril 2009 a enero 2011. Los datos fueron obtenidos por muestras de captura-marca-recaptura. Un total de 1418 individuos fueron marcados y el crecimiento de 714 caracoles fue analizado. La talla de la población y la densidad relativa fue estimada usando el método de Schnabel. La densidad promedio relativa fue estimada en $0.1694 \pm 0.0996 \text{ ind. m}^{-2}$, mientras que la densidad más alta fue estimada para septiembre 2010 con $0.3074 \text{ ind. m}^{-2}$. La tasa de crecimiento más alta ($0.27 \pm 0.10 \text{ mm día}^{-1}$) fue detectada en juveniles con una talla inicial entre 100-149mm, seguida por juveniles <100mm, con un incremento de $0.24 \pm 0.05 \text{ mm día}^{-1}$. La tasa de crecimiento disminuyó para individuos con una talla inicial entre 150-199mm ($0.18 \pm 0.09 \text{ mm día}^{-1}$) y para organismos >200mm ($0.08 \pm 0.07 \text{ mm día}^{-1}$). La variabilidad en la tasas de crecimiento fue alta en individuos entre 100-149mm y mostró diferencias estacionales; con la tasa de crecimiento más alta en mayo 2010. El reclutamiento de juveniles más alto se dio en octubre 2009 y en febrero 2010. La población de Xel-Ha ha crecido en tamaño y se pudo encontrar más adultos y juveniles que en estudios anteriores, lo que demuestra que el Parque de Xel-Ha está funcionando como un santuario para la conservación del caracol rosado del Caribe en la Riviera Maya de México. La tasa de crecimiento de juveniles en Xel-Ha es alta y presenta grandes variaciones en los individuos, lo cual refleja las condiciones naturales de la alimentación y la agregación. Las diferencias estacionales en las tasas de crecimiento pueden estar asociadas con la calidad del agua y la disponibilidad de nutrientes para la producción primaria. Concluimos que el método directo es útil para monitorear el crecimiento en juveniles de *S. gigas* y que el crecimiento en condiciones naturales es mayor que en sistemas de acuicultura. Esta información puede ser aplicada al manejo de pesquerías así como también en programas de rehabilitación y acuicultura.

Palabras clave: *Strombus gigas*, Área Marina Protegida, densidad poblacional, crecimiento, marcaje-recaptura, reclutamiento

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