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SIZE AT SEXUAL MATURITY IN THE QUEEN CONCH *STROMBUS GIGAS* FROM COLOMBIA

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ABSTRACT

Size at sexual maturity was investigated in 346 queen conch, *Strombus gigas,* collected from the Archipelago of San Andres, Providencia and Santa Catalina (SAI), Colombia. Size at sexual maturity is defined as the size (based on total shell length and lip thickness) at which 50 % of the population of queen conch sampled had mature and emission gonad developmental stages, based on microscopic examination (samples of gonads were processed by standardized histological methods). Only 12.14% of whole samples had mature and emission gonad developmental stages. The size at sexual maturity based on total shell length (ST_{mat}) was estimated to be ST_{mat}=249 mm for females (n=14), ST_{mat}=234 mm for males (n=28) and ST_{mat}=241 mm for both sexes (n=42). Lip thickness (LT_{mat}) at sexual maturity was estimated to be LT_{mat}=17.5 mm for females, LT_{mat}=13 mm for males and LT_{mat}=13.5 mm for both sexes. ST_{mat} and LT_{mat} for females were greater than those estimated for males, according to plot of the cumulative size frequencies. The maximum sizes that had mature gonad stage were 285 mm ST and 24 mm LT for males (n=2) and 280 mm ST and 30 mm LT for females (n=2). The present size restrictions adopted by some countries with queen conch fisheries is 5 mm LT and/or 180-250 mm ST, which is not adequate to protect conch stocks. A lip thickness of 13.5 mm or greater appears from this study as to be a better maturity criterion. Therefore, this criterion should be adopted by Caribbean countries as a fisheries management tool in order to protect the queen conch fishery and ensure sustainability of the fishery.

KEY WORDS: Fishery management, Lip thickness, Shell length, Sexual maturity, *Strombus gigas*.

RESUMEN

Talla en madurez sexual del caracol pala *Strombus gigas* de Colombia. La talla en madurez sexual fue investigada en 346 caracoles pala *Strombus gigas*, colectados del archipiélago de San Andrés, Providencia y Santa Catalina (SAI), Colombia. La talla en madurez sexual es definida como la talla (basada en longitud total de la concha y grosor del labio) en la cual el 50 por ciento de la población de *Strombus gigas* muestreada tenía estados de desarrollo gonádico de madurez y emisión, basado en examen microscópico (Las muestras de gónadas fueron procesadas por métodos histológicos estándares). Sólo 12.14% de todas las muestras presentó

estado de desarrollo gonádico en madurez y emisión. La talla en madurez sexual basada en longitud total de la concha (ST_{mat}) fue estimada en ST_{mat}=249 mm para hembras (n=14), ST_{mat}=234 mm para machos (n=28) y ST_{mat}=241 mm para ambos sexos (n=42). El grosor del labio (LT_{mat}) en madurez sexual fue estimada en LT_{mat}=17.5 mm para hembras, LT_{mat}=13 mm para machos y LT_{mat}=13.5 mm para ambos sexos. ST_{mat} y LT_{mat} para las hembras fue mayor que el estimado para machos, según el gráfico de las frecuencias acumuladas. Las tallas máximas que presentaron estado gonádico de madurez fueron de 285 mm en ST y 24 mm en LT para machos (n=2) y de 280 mm en ST y 30 mm en LT para hembras (n=2). La actual restricción de talla adoptada por algunos países con pesquerías de caracol pala es de 5 mm de LT y/o 180-250 mm de ST; la cual no es adecuada para proteger el stock. Un grosor del labio de 13.5 mm o mayor surge de éste estudio como un mejor criterio de madurez. Por lo tanto, este criterio debería ser adoptado por los países del Caribe como una herramienta de manejo pesquero para proteger el Caracol Pala y garantizar la sustentabilidad de la pesquería.

PALABRAS CLAVE: Manejo pesquero, Grosor del labio, Longitud de la concha, Madurez sexual, *Strombus gigas*.

INTRODUCTION

The queen conch fishery has a long tradition in the Caribbean region; however the commercial fishery has only been expanding since the mid to late seventies, due to the relatively recent increase in demand for *Strombus* meat, both within the Caribbean and in foreign markets, and also by the growing tourism industry that increased the demand for shells and jewelry. Most stocks are heavily exploited (Catarci, 2004). The ultimate aim is to establish a regional conservation and management strategy (CITES, 2002).

CITES (2003) indicated that, since the 1980's, several countries started to impose species-specific regulations and management measures for their conch fisheries and most have now implemented some form of fisheries management. The most common management tools include minimum size restrictions (shell length or meat weight). However, the effectiveness of these measures is largely dependent on adequate knowledge of the stock status, other biological and morphometric criteria (shell growth and size at maturity) and country-specific characteristics of the fishery. For example, the imposition of a minimum shell length restriction for *Strombus gigas* does not prevent the harvest of immature individuals, unless it is implemented in combination with a lip thickness requirement.

According to Medley (2005), the minimum size for queen conch should be related to size at sexual maturity. In general, unless the shell is landed, minimum size is difficult to apply. The meat size composition may indicate violations of a flared lip rule (only mature conch allowed), but only gross violations may be detectable. Hence, minimum size may prove less useful for direct enforcement, but remains a useful indicator of the performance of other controls. A restriction requiring fishers to take only those conchs with a flared lip would require cooperation from the fishers by preventing immature conch from being landed.

The size at sexual maturity is an important biological characteristic for fisheries management (Wenner *et al*., 1974; Annala *et al*., 1980; Conand, 1981; 1990; Appeldoorn, 1988). Several studies have included observations on the size at the onset of maturity in queen conch (Randall, 1964; Alcolado, 1976; Weil and Laughlin, 1984; Wilkins *et al*., 1987; Wicklund *et al*., 1991; Berg *et al*., 1992; Stoner *et al*., 1992; Appeldoorn, 1994). However, those studies commonly used only external macroscopic characteristics of the gonad, reproductive behavior, or growth models as criteria for assessing maturity. Consequently, sexual maturity in queen conch is considered to occur after the shell lip has started to flare and has reached a thickness of approximately 5 mm.

More precision is needed in determining sexual maturity. Knowledge of which animals are capable of reproduction is required. Quantitative numbers, such as the size at which 50% of the population is sexually mature, are desirable. The purpose of this study was to assess the size (based on total shell length and lip thickness) at sexual maturity for both sexes of *Strombus gigas* in Colombian waters using microscopic gonadal characteristics.

MATERIAL AND METHODS

Strombus gigas, equal to or greater than 20 cm of total shell length, with and without a flared lip were collected from the artisanal fishing site in the south cays of the Archipelago of San Andres, Providencia and Santa Catalina (SAI), Colombia: San Andres island (12°32'N, 81°42'W), Bolivar "Courtown" cays (12°24'N, 81°28'W) and Alburquerque cays (12°10'N, 81°51'W). Sampling was conducted monthly using local fishermen between February 2003 and January 2004. Total shell length (ST, measured as the length from the tip of the siphonal canal to the apex of the spire) and lip thickness (LT, measured in the mid-lateral region in a spot unaffected by plaits, and at a distance of 35-45 mm from the edge of the lip) of whole conch were recorded, as well as the sex, according to the methodology of Appeldoorn (1988).

Samples of the visceral mass (a 1 cm^3 cross-section taken along the mid-length of the gonad and digestive glands) were dissected out and pre-fixed for 12 to 15 days in 10% buffer formalin prepared in seawater with sodium borate. Because the samples would not be processed immediately, they were preserved in 70% commercial alcohol with 0.1% glycerine for air transport purposes. Histological processing was done according to the dehydration, clearing, and embedding technique used by Avila-Poveda *et al*. (2005, 2006).

The maturity stage, as well as verification of sex, was assigned based on microscopic examination of the histological sections made from the gonads using the criteria in Table 1. Size at 50 % sexual maturity (ST_{mat} and LT_{mat}) was determined by plotting the cumulative size frequencies of individuals with mature and emission gonad

Table 1. *Strombus gigas*. Histological criteria used in classifying gonads into sex and maturity stages (Avila-Poveda, 2004)

Gonad developmental stage	Histological description
Rest "undifferentiated"	In cross section, the gonad display less 10% with respect to the area of the digestive gland. Gonad composed in 90% up to 100% of connective tissue and not more than 10% to follicular tissue. Few empty follicles can be detected. There are no gametes. It is not possible to determine sex histologically. Some phagocytes and amoebocytes can be detected.
Gametogenesis	Follicular tissue can occupy from 10% up to 80% of the gonad area. Follicles expanded with circular form. Follicular lumen remains empty (female) or with some atypical spermatozoa (male). There are oogonias grouped in four to five cells and oocytes with and without vitelline (female) or spermatogonias, spermatocytes, and isolated groups of spermatozoa (male) towards the follicular wall. Only in male, there is vas deferens empty with a columnar epithelium wall.
Mature	Follicular tissue occupy until 90% of the gonad area. Follicles are anastomosed with enlarged form. There is dominion of mature gametes. There are eggs with abundant vitelline grains filling the follicles and some oogonias and oocytes towards the follicular wall (female) or follicular lumen partial or totally full of typical and atypical spermatozoa with spermatogonias and spermatocytes toward the follicular wall (male). Only to male, it is observed around the gland digestive several groups of vas deferens swollen fully filled with atypical and typical spermatozoa.
Emission	Follicular tissue occupy from 90% up to 40% of the gonad area. Connective tissue begins to be reticular. Follicles are dispersed and separate, and its wall begins to collapse. Follicle lumen can be empty or with some vitelline grains (female) or with some atypical spermatozoa (male). Follicles empty or with some oogonias and oocytes (female) or with some spermatogonias and spermatocytes (male) towards its wall. Only in male, vas deferens with size reduced and empty or with some atypical spermatozoa in its lumen.
Post-emission	Follicular tissue occupy until 10% of the gonad area. There is reticular tissue. There are some few follicles empty, break, and/or atresic. There are some follicles with few cells in different stages of developmental towards follicular wall. Nonvitelogenesis in female. There is not vas deferens in male. There is great amount of phagocytes.

developmental stages (n=42) for both of total shell length (ST) and lip thickness (LT). Conch with sexual aberrations (n=3, androgynous male) were excluded from this analyses (Table 2). In addition, the development of the secondary sexual characters (verge in male, egg groove in female) of these conch with mature and emission gonad developmental stages (n=42) was correlated with lip thickness and total shell length.

RESULTS

Of 346 *Strombus gigas* collected, only 12.14% had mature and emission gonad developmental stages. The secondary sexual characters of these conch in mature and

Table 2. Summary of the sexual polymorphism in genus *Strombus*. Lip-thickness (LT), shell total length (ST).

Size (mm)		Sex		Gonad Developmental stage	Sexual polymorphism	Source
Lt	**St**	**Macroscopic**	**Microscopic**			
--	---	male with developed verge	female	----------	feminized male	Reed, 1992, 1993
--	---	female posses both an egg groove and small deformed verge	female	----------	masculinized female	Reed, 1994, 1995
7	238	male with typical fully developed verge	female	gametogenesis	androgynous male	Avila-Poveda, 2004*
23	228	normal female with typical completely-developed egg groove	male	gametogenesis	masculinized female	Avila-Poveda, 2004*
23	232	male with typical fully developed verge	female	mature	androgynous male	This study
20	224	male with typical fully developed verge	female	mature	androgynous male	This study
20	272	male with typical fully developed verge	female	mature	androgynous male	This study

* Data observed during this study, but not reported.

emission stages were clearly developing, i.e. males exhibited a genital groove up to the point at which the verge emerge and showing a small to large protuberance where the verge was forming; females exhibited an extended egg groove running down the side of the body to the foot. These observations allowed the size at which *Strombus gigas* initiates the sexual dimorphism to be assessed. At the macroscopic level, sexual polymorphism was not observed. However, upon microscopic examination of the gonads, three conch (lip thickness of 20-23 mm) were found to be feminized; they had a typical fully developed verge without an egg groove, but with gonads at mature stage completely female under microscopic examination (Table 2). Other studies (Reed, 1992; 1993; 1994; 1995) have found similar aberrations.

Figure 1 shows that no queen conch were mature until the lip thickness reached a minimum of 2 mm in female, 5 mm in male, and 2 mm for both sexes and that 50% of the sample population reached sexual maturity at a lip thickness (LT_{mat}) of 17.5 mm for females, 13 mm for males, and 13.5 mm for both sexes. In total shell length (ST_{mat}), 50% at sexual maturity was reached at 249 mm for females, 234 mm for males, and 241 mm for both sexes. ST_{mat} and LT_{mat} is larger for females than those estimated for male. The 100% at sexual maturity recorded here were 24 mm LT and 285 mm ST for males (n=2) and 30 mm LT and 280 mm ST for females (n=2).

DISCUSSION

Size at sexual dimorphism

The development of the male secondary sexual characters, particularly with respect to the development of the verge, was found to occur at 214 mm ST with 8 mm LT on the smallest animal that had mature stage, when the conch exhibited a protuberance at the point of verge development. Appeldoorn (1988) observed this same characteristic around 222 mm ST and also indicated that verge development starts at 177 mm ST when a small protuberance is first visible. The development of secondary sexual characters (initiation of visible sexual dimorphism) in queen conch begins early in the juvenile stage, but the individual would not reach gonadal maturity until the lip thickness had reached at least 2 mm or when it had reached 205 mm in ST as found in the present study. The findings of this study agree with others that define the onset of maturation as when growth in length ceases and flared-lip formation begins (Randall, 1964; Alcolado, 1976; Wilkins *et al*., 1987; Appeldoorn, 1988; Wicklund *et al*., 1991; Berg *et al*., 1992; Stoner *et al*., 1992). Appeldoorn (1988) also indicated that the reproductive structures (verge in male, egg groove in female) are only fully developed in mature individuals, opposite to that observed by Avila-Poveda (2004), who observed queen conch of both sexes with completely formed secondary sexual characters but with gonads at undifferentiated or in gametogenesis stages.

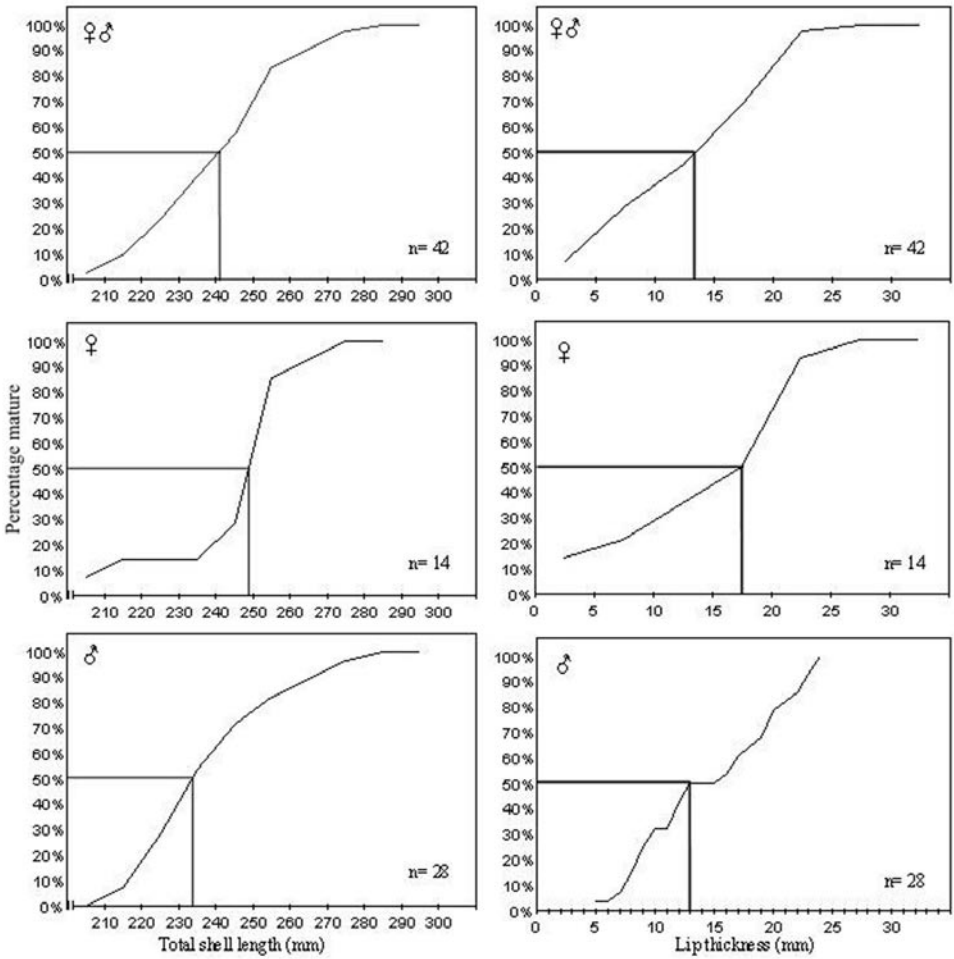

Figure 1. *Strombus gigas*. Cumulative size frequencies of individuals with mature and emission gonad developmental stages and size at sexual maturity for both total shell length (ST) and lip thickness (LT) in SAI, Colombia.

Size at sexual maturity

The size at sexual maturity (LT_{mat} and ST_{mat}) for *Strombus gigas* should be considered in the management of the fishery. A minimum legal size limit for this species in Colombian waters does not exist. Colombia has established fishery management measures for the queen conch (Resolution No. 000179 of 05 May, 1995), which is based on general knowledge of the species, a closed season, gear restrictions, closed areas, harvest quotas, and meat weight restriction that prohibits the capture of queen conch of less than 225 g without cleaning and 100 g clean by organism. Chiquillo-Espitia *et al*. (1997) recommended the implementation of other more effective morphometric measures, such as a minimum lip thickness, because there is no uniformity in the extraction and

cleaning processes. Appeldoorn (1994) and Medley (2005) indicated that an alternative management strategy is to limit harvest to sexually mature conch.

In the literature, sexual maturity in queen conch only occurs when the shell lip has started to flare and has reached a thickness of approximately 5 mm, based on assessment of external macroscopic characteristics as criteria for maturity (Duque-Goodman, 1974; Brownell, 1977; Arango-López and Márquez-Pretel, 1993; Lagos-Bayona *et al*., 1996; Chiquillo-Espitia *et al*., 1997), reproductive behavior (Stoner *et al*., 1992), or growth models (Alcolado, 1976; CFMC and CFRAMP, 1999). Size at sexual maturity of *Strombus gigas* was examined with histological methods in only one study (Egan, 1985).

The ST_{mat} and LT_{mat} found in this study are greater in females than in males. Arango-López and Márquez-Pretel (1993), and Chiquillo-Espitia *et al*. (1997) also reported that females were larger than males at ST_{50} and LT_{50} for the Colombian Caribbean; whereas, ST_{mat} and LT_{mat} are similar to ST_{50} and LT_{50} reported by other authors (Table 3). Egan (1985) reported size frequency histograms for mature stages, but without details on ST_{mat} or LT_{mat}; and only reported minimum and maximum lip thickness at which mature gonad tissue was present (minimum of 6 mm for females and 4 mm for males and a maximum of 29 mm for each sex). Similar values were observed in this study (Figure 1).

The present size restrictions or limits adopted by other Caribbean nations of 5 mm minimum LT and 180-250 mm in total shell length are not adequate to protect stocks should they be subject to heavy fishing pressure. The existence of a thin shell lip is not an efficient criterion of sexual maturity. A lip-thickness of 13.5 mm or greater appears

Table 3. *Strombus gigas*. Total shell length at sexual maturity (ST_{mat}), and lip-thickness at sexual maturity (LT_{mat}) for female, male and both sexes obtained by different methods.

Site	ST_{mat} (mm)			LT_{mat} (mm)			Source
	female	male	both sexes	female	male	both sexes	
Providencia and Santa Catalina, Colombia	240	220	---	--	--	--	Arango-López and Márquez-Pretel, 1993 *
San Bernardo Archipelago, Colombia	---	---	220	--	--	--	Lagos-Bayona *et al*., 1996 *
SAI, Colombia	239	233	---	18.5	13	--	Chiquillo-Espítia *et al*., 1997 *
SAI north cays, Colombia	238	233	---	18.5	12	--	Chiquillo-Espítia *et al*., 1997 *
SAI south cays, Colombia	240	233	---	18	16	--	Chiquillo-Espítia *et al*., 1997 *
Puerto Rico	---	---	---	--	--	7	CFMC and CFRAMP, 1999 **
SAI south cays, Colombia	249	234	241	17.5	13	13.5	This study ***

* ST_{50} and LT_{50} get based on external macroscopic characteristics of gonad.
** ST_{50} get based on growth model.
*** ST_{mat} and LT_{mat} get based on microscopic characteristics of gonad.

as to be a better maturity criterion. The LT_{mat} and ST_{mat} obtained in this study are robust and allow implementation of a minimum size of capture for fisheries management in the Caribbean as recommend by CITES (2002) and Medley (2005).

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