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Research Article

Reproductive characteristics of *Strombus canarium* (Gastropoda: Strombidae) in Samar, Philippines

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Keywords

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Spawning season,
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Abstract

Strombus canarium or dog conch is an economically important gastropod species for food in many coastal communities in the Philippines. Therefore, there is a need for protective measures to safeguard the stock in the wild. A better understanding of reproductive characteristics is needed to establish a management strategy for the conch fisheries. This study aims to determine the sex ratio, gonadosomatic indices, spawning period, and the relationship between shell length, lip thickness, and gonadal development stage of *S. canarium*. A total of 212 individuals were collected, of which 71 were male and 141 female. The overall ratio of the population is 1:1.99, of which females dominate in all sampling months. The male dog conch spawned from August to November, with a clear peak in September and October, while the female population has no clear peak. Only three gonadal developmental stages (intermediate, active, and ripe) were observed in both sexes across all sampling months. The correlation analysis indicated that the shell length and lip thickness were reliable indices of sexual maturity for both male and female *S. canarium*. The information gathered in this study indicates that this species exhibited partial spawning behavior, with complete spawning recorded only in males during specific periods. For fishery management measures, only sexually mature *S. canarium* with 76 mm shell length should be collected to ensure the individual can reproduce before being harvested.

Article info

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Introduction

Strombus canarium, commonly known as the dog conch, is a gastropod belonging to the family Strombidae. It is widely found in the Indo-Pacific region, extending from Indonesia to the South China Sea to East India and North Australia (Cob *et al.*, 2011; Chang *et al.*, 2021). Dog conch is locally known as “bungkawil” in Samar, Leyte, and other parts of the Visayas. The gastropod lives preferably in shallow waters in a colony and is abundant wherever it occurs, making it vulnerable to overfishing. This species often inhabits seagrass beds and sandy mud bottoms (Abott, 1960).

Worldwide, marine mollusks are among the most important invertebrates, of which gastropods represent 2%. These include species of high commercial value in international markets and species that play important social roles in small-scale fisheries (Leiva and Castilla, 2002). Gastropod meat, especially the dog conch, is popular in many Southeast Asian countries. The dog conch is a highly prized seafood in Malaysia, Indonesia, and the Philippines (Cob *et al.*, 2009; Cob *et al.*, 2011; Pangarungan *et al.*, 2022). Ecologically, these mollusks play a significant role in maintaining the well-being of the seagrass bed ecosystem (Cob *et al.*, 2012). It also plays a crucial part in the food chain cycle and is used as an indicator for monitoring water quality (Ramses *et al.*, 2019).

As observed in other economically important marine species in the Philippines, regular harvesting often led to a declining population in the wild (Bantoto and Ilano, 2012). A preliminary survey in the local market (personal observation) found a wide range of conch age harvested, ranging from 50-76 mm from juvenile to mature individuals. Since the collection of the gastropod species is not regulated on all fishing grounds and there are few studies on the fisheries' biology of the species for its proper management, species depletion may soon emerge. Hence, the regulated collection of the said gastropod is necessary. Regulated collection may include implementing policies on closed seasons based on peak spawning seasons and minimum legal sizes. However, data is needed before it can be used to make policies.

Understanding a species' fundamental reproductive characteristics is critical for developing time management strategies to protect sexually mature stock populations. The gonadosomatic index (GSI) helps predict the seasonality and sexual maturity of many economically important gastropods (Elhashi *et al.*, 2013). Meanwhile, studies on the sex ratio are critical for understanding population dynamics because they provide information on which sex is more dominant in the population and estimate female spawning biomass (Adebiyi, 2013). Previous reports have also claimed that lip thickness is a good indicator of the maturity of a gastropod species as the shell continues to thicken after the length of growth stops (Stoner *et al.*, 2012). Furthermore, information on the spawning season can be used for regulated collection or establishing open and closed seasons to sustain certain marine species' fishery resources (Mazo *et al.*, 2013). In the Philippines, closed season refers to a designated period where capturing certain marine species using specific fishing gear is strictly forbidden. This fishery management strategy aims to lower catching power and fishing mortality, enhancing stock size.

Currently, the reproductive cycle of the *Strombidae* family is well-studied. However, extensive studies on this aspect of biology focus more on commercially important species in the Caribbean, like *Strombus gigas*, *Strombus pugilis*, and *Strobus gracilior* (Foley and Takahashi, 2017). In the Indo-Pacific region, reproductive aspects of *S. canarium* have only been conducted in the Johor Straits, Malaysia (Cob *et al.*, 2009), and the Andaman Sea, Thailand (Thongboon *et al.*, 2022). Although *S. canarium* is commercially exploited in the Philippines, only one study relates to the reproductive season of dog conch harvested from Miag-ao, Iloilo (Libutaque, 2000).

Given these reasons, a study on reproductive aspects like sex ratio, GSI, spawning season, and the relationship of shell length and lip thickness to the gonadal development stages of *S. canarium* was conducted. This information can support policies on the regulated collection of this species for future sustainable management efforts.

Materials and methods

Collection of Samples

A dog conch of different sizes was collected manually by commissioned fishermen from July 2021 to December 2021 in a seagrass area of Tinaugan, Zumarraga, Samar (11º 42' 6.33'' N, 124º 49' 26.00'' E) (Fig. 1) during the daytime. According to the fishermen, they were found in a seagrass area with depths ranging from 1-3 m. The collection was explicitly requested to be non-selective in size to avoid bias. After collection, samples were placed in Styrofoam filled with ice and transported to Samar State University Marine Laboratory in Catbalogan City, Samar (11º 47' 01.17'' N, 124º 52' 13.48'' E) for further analysis.

Shell Length, Lip Thickness, and Weight Measurement

A total of 212 individuals were analyzed to determine the different reproductive aspects of *S. canarium*. The shells were cleaned, and all fouling organisms were scraped off before the corresponding measurements were done. The shell length (SL) was measured from the spire's tip to the siphonal canal's anterior end (Fig. 2). Meanwhile, the lip thickness (LT) of the shell was measured in the thickest region of the flared lip. Both were measured using a Vernier caliper with 0.01mm precision (Cob *et al.*, 2008). In this study, the average SL of *S. canarium* was 58.97 mm, while LT was 2.41 mm.

The gonad of each sample was examined by cracking the shell with a hammer. The soft tissues were carefully removed from the shell, then blotted damp-dry, and weighed using the digital top-loading balance with 0.01g precision. The gonad was carefully cut using surgical scissors. Its color was noted, and the photo was documented. Each gonad sample was weighed to determine the gonad weight.

Sex Ratio and GSI Determination

Sex determination of *S. canarium* was based on the presence of the penis in the male by macroscopic observation (Fig. 3A). The penis of the male specimen is brownish-black, with an open groove on the right dorsal side of the foot.

Conversely, females have an egg groove that runs across the foot and into the pedal groove at the front of the foot (Haumahu *et al.*, 2020) (Fig. 3B). The sex ratio for each month was determined by comparing the number of females to males in the collection. The GSI for both male and female individuals was calculated based on this formula: GSI (%) = gonad weight/(soft body weight - gonad weight) x 100 (Mazo *et al.*, 2007). Male and female GSI have been segregated afterward.

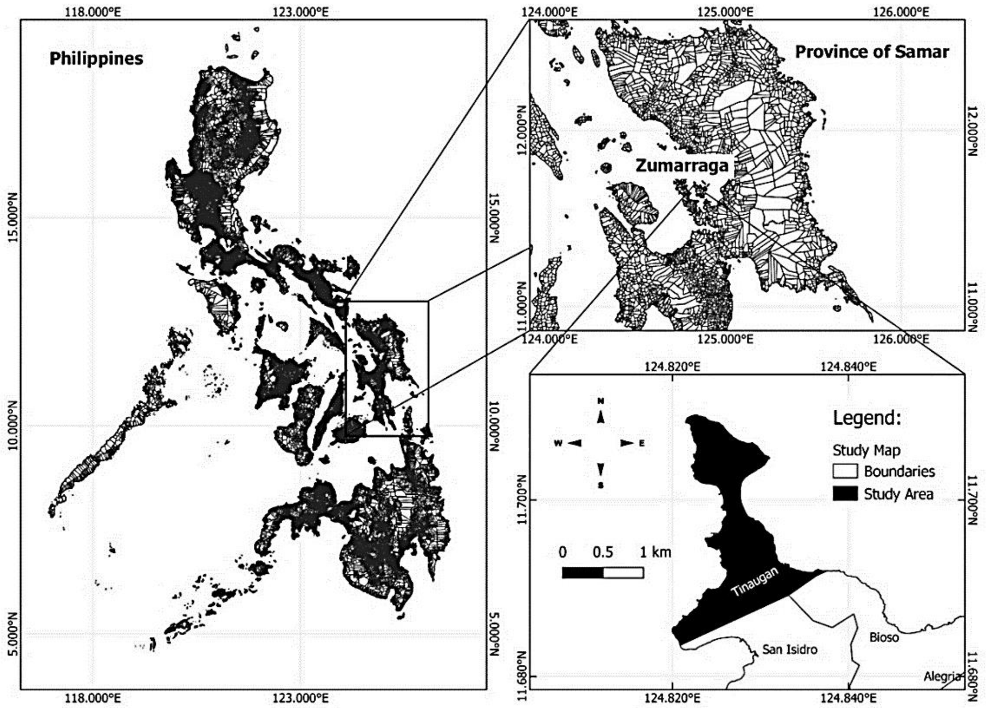

Figure 1: Map of Tinaugan, Zumarraga, Samar showing the sampling area for *Strombus canarium*.

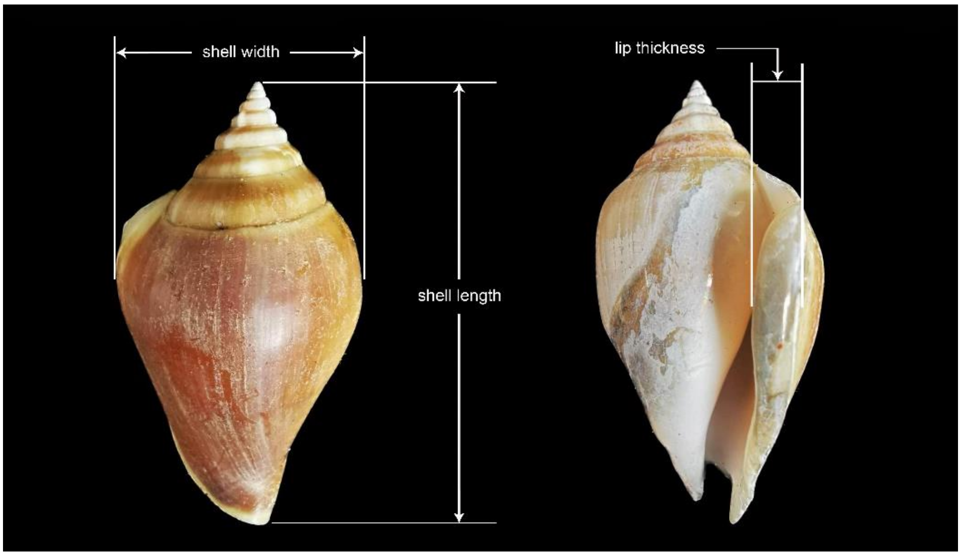

Figure 2: Linear measurement for the shell morphology of *Strombus canarium* (Cob *et al*., 2008).

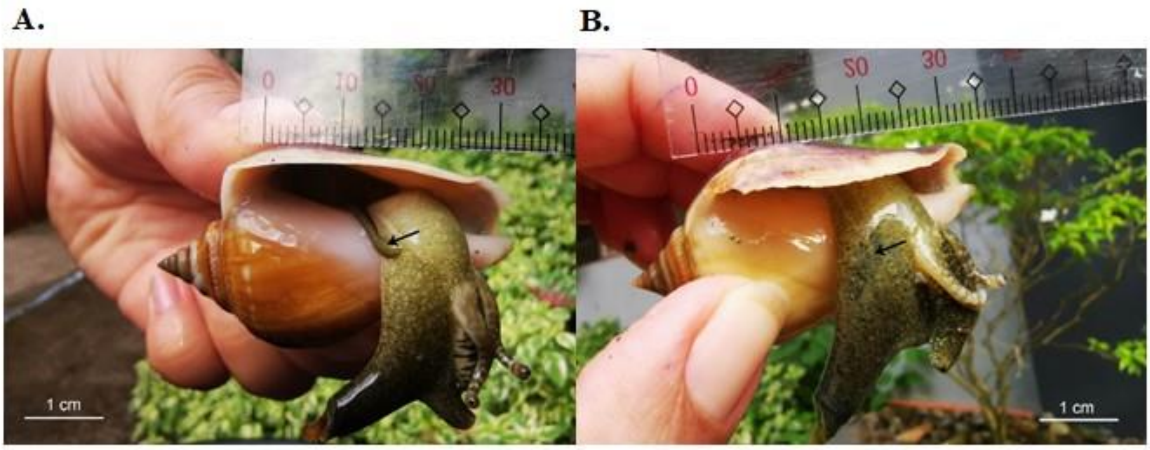

Figure 3: A male dog conch showing a well-developed penis (A) and a female dog conch (*Strombus canarium*) with an egg groove (B) (black arrow).

Gonadal Development Stage (GDS) Analysis

The maturity stage of *S. canarium* in this study was determined using a qualitative scale with four macroscopic maturation phases (Table 1) derived from the study of Elhasni *et al.* (2013).

Table 1: Macroscopic maturation scale to classify the gonad stages of *Strombus canarium* (following Elhasni *et al.*, 2013).

Gonadal development stage	Brief description
St0 - Immature	Gonads of both sexes could not be distinguished from the digestive gland. Males and females present inconspicuous seminal vesicle and capsule glands, respectively.
St1 - Intermediate	Gonads of both sexes are very small and hardly distinguished from the digestive gland.
St2 - Active	Gonads of both sexes are more developed and correspond to approximately one-third of the area of the digestive gland.
St3- Ripe	Gonads of both sexes are fully developed, inflated, and voluminous, corresponding to more than half of the area of the digestive gland. Males have a fully developed seminal vesicle and females have a large capsule gland.

Data Analysis

The difference between male and female dog conch abundance in the monthly samples was analyzed through the chi-squared test (X^2 test). An Analysis of Variance (ANOVA) was employed separately to determine if there was a variation in the GSI between the sexes and between monthly samples. Before any statistical analyses, data distributions were tested for normality and homogeneity of variances. The non-parametric Kruskal-Wallis test was performed whenever the ANOVA assumptions were not met. Pearson's correlation coefficient was used to correlate the reproductive components between sexes. All statistical analyses were carried out using SPSS Version 27.0 software. Statistical analyses were considered significant at $p<0.05$.

Results

Sex Ratio

In this study, the sex ratio data showed a preference for females, which differed significantly from the expected balance of 1:1. Overall, females dominated with 141 individuals (67%), and males had 71 individuals (33%) (Table 2). The sex ratio from July to December 2021 was 1:1.99, significantly different from parity 1:1. The lowest ratio was recorded in July at 1:1.38, while the highest value was registered in September at 1:3.75. The sex ratio significantly differed in all months except July (X^2=3.74, p>0.05). The chi-square test showed that the sex ratio of males and females in *S. canarium* is significantly different (X^2=1069.96, p<0.05). Meanwhile, month-wise observation revealed that females were abundant in all the sampling months.

Table 2: Variation in the sex ratio of *Strombus canarium* collected from July-December 2021.

Month	M	F	Total (N)	Ratio M: F	X^2 value	Significance (p-value)
July	16	22	38	1:1.38	3.74	NS
August	13	22	35	1:1.69	4.42	*
September	8	30	38	1:3.75	21.37	*
October	10	23	33	1:2.30	6.83	*
November	13	23	36	1:1.77	5.66	*
December	11	21	32	1:1.91	3.96	*
Total	71	141	212	1:1.99	1069.96	*

M = Male; F = Female; NS = Not Significant; * = Indicates samples with statistically unbalanced sex ratios (X^2 test) (p<0.05)

Gonadosomatic Index (GSI)

Figure 4 shows the monthly GSI of *S. canarium*. In females, the GSI values ranged from 10.40 in July to 19.92 in December. The female GSI slightly decreased from September (12.14) to October (11.20) but increased in November (15.08). As with males, the highest GSI value still occurred in December (19.92), while the lowest was recorded in August (10.21). There was a sudden decrease in the male GSI from July (13.94) to August (10.21). However, a continuous increase was observed from October to December (12.19-19.92). It was also noted that GSI values of >10.00 were recorded in both sexes in all sampling months.

Gonadal Development Stage (GDS)

In males, no immature stage (stage 0) of *S. canarium* was observed during the entire study period (Fig. 5A). In the intermediate stage (stage 1), a low proportion of gonads were detected early in July (6%) and August (15%). After that, it reached its maximum level in September (63%) but sharply declined in October (40%). Then, it increased again in November (62%), but a steep drop was recorded in December (36%). In the active stage (stage 2), gonads were observed in all months but at variable frequencies. The highest proportion was noted in August (62%), and the lowest was in December (18%). Meanwhile, the ripe stage (stage 3) was only recorded in July (50%), August (23%), November (15%), and December (45%) and was absent in September and October.

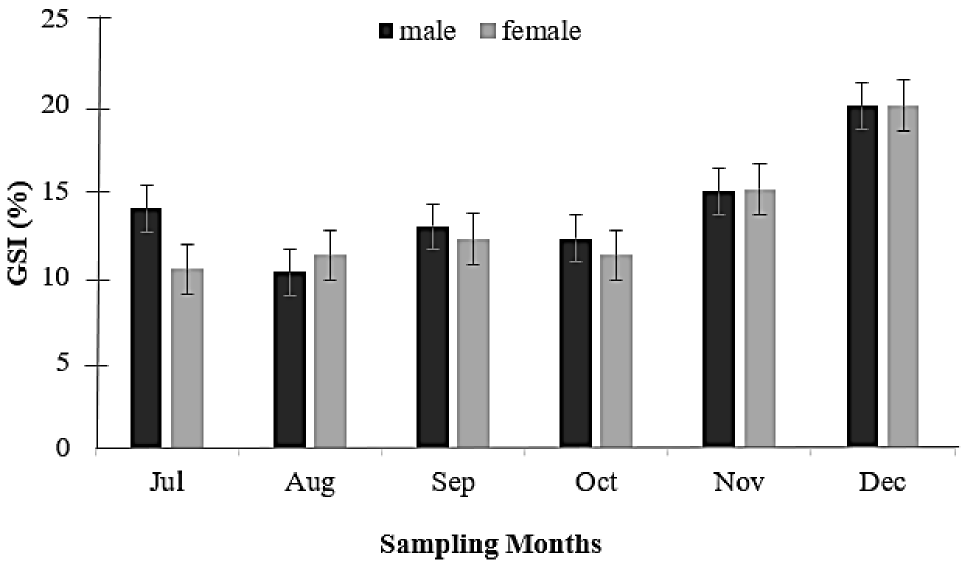

Figure 4: Monthly variation of gonadosomatic index (GSI) in *Strombus canarium*. Data presented as Mean±SE.

In females, the four gonadal stages were observed in all sampling months (except in November and December, with only three maturation stages) (Fig. 5B). The immature stage (stage 0) was recorded from July to October but was absent in November and December. The lowest percentage at this stage was documented in October (6%) and the maximum in July (14%). The intermediate stage (stage 1) was also marked throughout the study period; however, the frequency percentage shows a variable proportion. The highest percentage at this stage was recorded in November (39%), while the lowest was registered in August (14%). Like the intermediate stage, the active stage (stage 2) was present in all months, and the percentage for each month was considered high, ranging from 32% to 59%. Furthermore, ripe stage (stage 3) ovaries were noted in all months and were recorded at a maximum level in December (43%) but occurred lowest in November (17%).

Relationship of Shell Length, Lip Thickness, GSI, and Gonadal Development Stage

Table 3 shows the mean values and the minimum and maximum measurements of the shell length (SL) and lip thickness (LT) at various gonadal developmental stages of the *S. canarium.* Furthermore, the correlation between reproductive variables such as shell length, lip thickness, GSI, and gonadal development stages between sexes is summarized in Table 4. The result showed that in both male and female species, shell length (r=.490 for male; r=.360 for female) and lip thickness (r=.512 for male; r=.291 for female) have a very significant positive correlation with gonadal development stage (GDS). Meanwhile, a significant positive correlation between gonadosomatic index (GSI) and GDS was only observed for female species with r=.193. There is also a strong positive correlation between SL and

LT for both sexes of *S. canarium* (r=.786 for male; r=.670 for female).

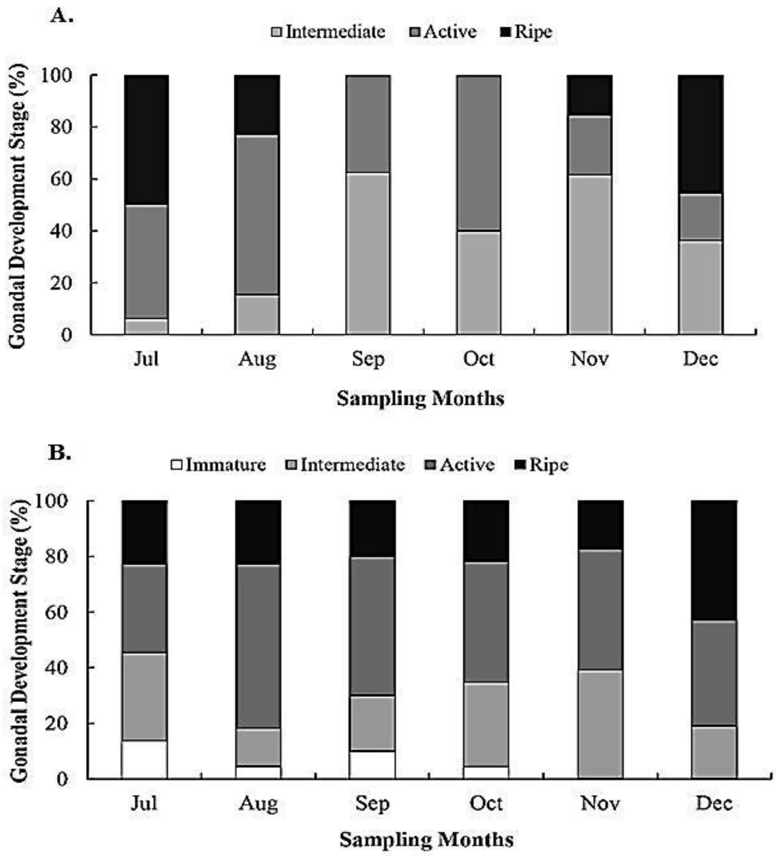

Figure 5: Percentage frequency of four gonadal development stages in (A) male and (B) female *Strombus canarium* specimens collected from July-December 2021. immature=white; intermediate= light gray; active=dark gray; spent= black.

Table 3: Mean values, minimum and maximum shell length (SL), and lip thickness (LT) of *Strombus canarium* at various gonadal development stages.

Gonad Developmental Stage	Male			Female		
	Mean Values (mm)	Minimum SL (mm)	Maximum SL (mm)	Mean Values (mm)	Minimum LT (mm)	Maximum LT (mm)
Immature	55.13	50	58	1.38	1.0	3.0
Intermediate	57.03	49	69	1.85	1.0	5.0
Active	59.89	50	76	1.42	1.0	6.0
Ripe	62.75	54	76	3.35	1.0	7.0

Table 4: Correlation between reproductive variables (shell length, lip thickness, gonadosomatic index, gonadal development stage) of male and female *Strombus canarium.*

Variables	Male				Female			
	SL	LT	GSI	GDS	SL	LT	GSI	GDS
SL	1				1			
LT	.786 **	1			.670**	1		
GSI	-.248*	-.207	1		-.138	-.208*	1	
GDS	.490**	.512**	.169	1	.360**	.291**	.193*	1

Variable definitions: SL = Shell length; LT = Lip thickness; GSI = Gonadosomatic index; GDS = Gonadal development stage. ** and * represent significance at the .01 and .05 level (two-tailed). Spearman rank correlation was used to evaluate the relationship between GDS and other parameters. Pearson correlation was utilized for the rest of the parameters evaluated.

Discussion

The sex ratio of *S. canarium* in Samar is unequal, with the female population dominating. The female-biased sex ratio occurred in all sampling months, but the highest unbalanced sex ratio value was recorded in September (1:3.75). Based on the data collected, only eight males were collected in September compared to 30 females; hence, the result will generate female dominance.

Various studies have indicated that sex ratio bias is common in Strombidae groups, of which at least three males to four females have been recorded (Cob *et al.*, 2009). Furthermore, fishing influences the sex ratio results of several Strombidae groups, particularly the economically significant species. According to Randall (1964), female *Strombus* species are generally more visible than males since they are larger and more prominent. Therefore, they are more likely to be collected. Meanwhile, Maxwell *et al.* (2017) conducted a study to determine if the sex ratio bias in *Strombus* groups is due to a sampling design issue, considering that *Strombus* been known to have low population densities and exhibit natural clustering behavior. Their research indicates that conch possesses innate genetic elements that regulate natural patterns of sex imbalance that favor the female population.

The current study on the sex ratio generally agrees with the previous reports by several authors (Maxwell *et al.*, 2017; Ramses *et al.*, 2019; Thongboon *et al.*, 2022). In West Johor Straits, Malaysia, the overall sex ratio of dog conch was 1:1.73, of which females were more dominant than males, ranging from 55.33% to 76.34% (Cob *et al.*, 2009). The present study's finding also agrees with Ramses *et al.* (2019), in which the sex ratio was 1:1.33, favoring the female population. A similar predominance of females over males also occurred in *S. canarium* caught along the reefs of Far North Queensland, Australia, where there is a strong bias towards the female population (Maxwell *et al.*, 2017). The study also agreed with other *Strombus* species. In Maluku, Indonesia, the sex ratio of *S. luhuanus* was 1.27 females per male (Haumahu *et al.*, 2020), and female *S. pugilis* dominates in Campeche, Mexico (Cardenas *et al*., 2005).

According to Aranda *et al.* (2003), there are three types of spawning patterns in the Strombidae group in response to different environmental conditions: populations with one very extended spawning phase, with or without a prominent peak; populations with two or more distinct peaks or spawning pulses; and populations with one short, defined pulse. In this study, the dog conch reproductive cycle includes partial spawning, continuous gonadal activity for females, and asynchrony in gonadal development between sexes. The male dog conch in this study might spawn for four months, from August to November, with a clear peak from September to October. The absence of ripe gonads supports this peak during these months. Meanwhile, females spawned for five months, from July to November, which was also evident in the low percentage of ripe gonads. Unlike the males, no clear peak was observed in the females.

Furthermore, the constant presence of both sexes in the intermediate, active, and ripe stages suggests a continuous gonadal cycle and partial spawning throughout the entire study period. The current result generally agrees with previous studies of the same species in Miag-ao, Iloilo, in which both sexes exhibited continuous spawning but with different peak months. Spawning peaks in that study occurred in January, April, and May for males and in April, August, September, and October for females (Libutaque, 2000).

Information about other geographical areas, like the Andaman Sea in Thailand, suggests that *S. canarium* had two significant spawning periods: December to April and August to September, with synchrony between the sexes. Females also spawned less frequently and for a shorter period than males (Thongboon *et al.*, 2022). In general, many factors can be attributed to the duration of the spawning season and the timing of the gonad stages of many gastropod species, as pointed out by several authors. Among the environmental factors, day length, seawater temperature, and food availability are the most significant environmental cues for the maturation and spawning of many marine gastropods (Sternberg *et al.*, 2010). However, the current study did not evaluate the environmental factors that could potentially affect the duration of spawning. Therefore, future research is required to explore this aspect.

The study also revealed no immature male stage and suggested two possible interpretations. The first possible reason is that the collected samples categorized as immature are juvenile. According to Catterall and Poiner (1983), conch usually occurs in groups or colonies, of which one of the common types of aggregations is juveniles. Since the male and female gonads were almost identical during the juvenile stage and the male reproductive organ is not visible, it is counted in the female sample. The second reason is that some male populations may migrate into deeper areas during low reproductive activity and return only to the shallower areas during the reproductive season. Hence, there was no accumulation of immature gametes during those months.

In this study, the GSI of *S. canarium* displayed almost similar trends throughout the sampling period except from July to August, for which there was a slight difference . Female GSI values increased slightly, while there was a sudden drop in male values. Synchronicity in GSI for both sexes in almost all months leads us to believe that gametes are released simultaneously, thus ensuring successful fertilization. In addition, there was no sudden decrease in GSI values (except in August for males), possibly indicating a continuous supply of gametes for both sexes.

The correlation analysis results imply that shell length and lip thickness are good indicators of sexual maturity for both sexes of *S. canarium.* This indicates that immature dog conchs may have their shell length ranging from 50mm-58mm and lip thickness of 1mm-3mm, while for intermediate stage, SL ranges from 49mm-69mm with LT from 1mm-5mm. Furthermore, there is minimal difference in the shell length and lip thickness of species with active and ripe gonads: 50mm-76mm for active and the latter 54mm-76mm for SL, and LT may range from 1mm-6mm for active. In contrast, species with well-developed gonads may thicken their shell up to 7mm. With lip thickness as the indicator of sexual maturity for *S. canarium*, it is evident that ripe gonads were observed on species that are thick-lipped (7mm), and immature ones had thinner shells (≥3mm). Shell formation and its growth rate, such as in the thickening of the shell apertures, provide relevant information regarding the sexual maturity of the *S. canarium* and other gastropod species. The same was observed for *Amphissa columbiana*, as shell length and the thickness of the shell's aperture strongly correlated with the sexual maturity of the organism (Pernet, 2007). Furthermore, GSI can be a good indicator of the sexual maturity of the female species. Female gonads tend to become heavier as the organism sexually matures since, aside from the development of the eggs, *S. canarium* may also have the ability to store and preserve viable sperms inside the sperm-ingesting gland prior to fecundation and spawning, as also exhibited by some gastropods such as *Hexaplex trunculus* (Elhasni *et al.* 2010).

The current study provides insights into some of the reproductive aspects of *S. canarium* in Samar, Philippines, which knowledge is essential for managing the dog conch fishery. This information suggests that the harvest of the dog conch is applicable only for sexually mature individuals beyond its ripe stage, such as those species with shell lengths of >76mm. This is to at least allow the dog conch to reproduce before collection, thus minimizing the immature dog conch's harvest and sustainably managing the dog conch fishery. These findings concord with those of Cob *et al.* (2008), suggesting using shell length and another variable, shell width, as a reference for the species' growth and further recommending it for fishery data collection.

Despite the limited sampling months, the results confirm that the species has continuous gonadal activity for females with asynchrony in gonadal development between sexes. However, further research is needed to determine which environmental factors influence the duration of spawning.

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Conflict of interest

The authors declare that there is no conflict of interest.

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