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FULL PAPER

Reproductive Biological Performance of *Otolithes ruber* (Bloch and Schneider 1801) in San Miguel Bay, Philippines

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ABSTRACT

The tigertooth croaker, *Otolithes ruber* (Bloch and Schneider 1801), was studied to determine its reproductive biology characteristics for 34 months from March 2015 to November 2017. A total of 7,977 individuals were sampled and the measured total lengths (TL) ranged from 8.1 cm to 32.1 cm (16.70 ± 2.53 cm) and 10.0 cm to 33.5 cm (17.95 ± 2.95 cm) for male and female, respectively. The length-weight relationship can be summarized as $W = 0.00521\ L^{3.18}$ and $W = 0.00837\ L^{3.01}$ for female and male, respectively. The length at first maturity of this species was determined to be 13.95 cm, which is smaller compared to other studies. The overall sex ratio of this species was 1:0.8, with males dominating the female sex ($P < 0.05$, $X^2 = 64.3$). In addition, synchronized development of male and female gonads was observed. It was also verified that mature individuals were present all throughout the study period indicating that this species spawn continuously and the presence of juveniles during the sampling period indicated continuous recruitment. Mean monthly GSIs indicate July to November as the main spawning season of this species. The in-site occurrence of mature and juvenile stocks in the bay further implicates that San Miguel Bay is a nursery ground for this species. The fecundity varied between 3,420 to 422,100 with an average fecundity of 86,142 eggs. Lastly, the spawning potential ratio is still above the limit reference point (SPR = 0.36), indicating that the stock can still replenish their biomass.

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1. INTRODUCTION

San Miguel Bay, considered to be the most productive coastal fishing ground of Luzon's entire eastern coast (Bailey 1982; Mines et al. 1982), is located in the Bicol Region of the Pacific coast of Luzon. It is relatively shallow (Bailey 1982), estuarine body of water with an area of 1,115 km2 and approximately 95% of the bay has soft (muddy and sandy) substrate (Silvestre 1996; Silvestre and Hilomen 2004). Because of these characteristics, the whole area of the bay is considered to be trawlable (Mines et al. 1986; Lim et al. 1995) and the only trawlable fishing ground along the Pacific coast of the country (Mines et al. 1982).

Aside from being a rich fishing ground for shrimps, a variety of fish species are also commonly caught in the bay such as herrings, mullets, juvenile Spanish mackerels, anchovies, crevalles, and croakers (Mines 1982). One of these croakers is the tigertooth croaker, *Otolithes ruber*, which is the most significant croaker species in the bay (Lim et al. 1995). This croaker, locally known as *abo*, belongs to the Sciaenidae family (croakers), is abundant in estuarine areas and prefer to occupy muddy and sandy substrata. This species is not only one of the major species in the bay but it is also considered commercially important and commands a comparatively high price compared to other species of croakers (*pagotpot* and *arakaak*), and *abo* fisheries is one of the leading industries in the bay.

However, overfishing is a major problem in San Miguel Bay (Smith et al. 1983; Smith and Pauly 1983; Sunderlin and Gorospe 1997; Garces and Silvestre 2010). As early as 1980s, several threats to the viability of the fishing industry in the bay such as, but not limited to, biological over-exploitation, economic overfishing, and the competition between the different fishing sectors had been identified (Mines et al. 1986). Garces and Silvestre (2010) reported that fish biomass, particularly of demersal stocks, declines, presumably due to excessive fishing effort as well as habitat or environmental degradation. In addition, San Miguel Bay is an ecosystem under stress due to excess fishing pressure from both large- and small-scale fishery sectors (Bundy and Pauly 2001). The study of Mines et al. (1986) suggested limiting the fishing effort, e.g. banning of commercial trawlers from municipal waters, to minimize the problem on overfishing, but the result of the study of Bundy (2004) showed that management policy of banning and phasing out trawling was not the optimal management strategy for the bay. Because of the recurring problem in the bay, there has been an observed increase in the number of fishers' organizations with a purpose to assure that the supply of the fish can be safeguarded through improve management (Sunderlin and Gorospe 1997), such as the San Miguel Bay Management Council (SMBMC) which was established in 1993 but ceased to exist by 1996 (Bundy 2004), and in 1996, the Fisheries and Aquatic Resources Management Councils (FARMCs) were formed as per Executive Order No. 240 which serves as the recommendatory bodies in fisheries matters.

Despite the relatively long history of management initiatives in San Miguel Bay and several studies to assess the status of its demersal stocks, none has given particular focus on *Otolithes ruber*. A review of the literature on the biology and stock status of this species in other Philippine fishing grounds has also yielded very scanty information. Therefore, an assessment of the population of this species is very important to understand the status of the stock. In addition, there have been no recent studies conducted on the reproductive biology of this species in San Miguel Bay, therefore, it is necessary to perform this study to understand the reproductive biological performance of this species which will serve as basis for science-based management.

In general, this study was conducted to determine the reproductive capacity of *Otolithes ruber* in San Miguel Bay. Specifically, the study aimed to determine the spawning seasonality, length-weight relationship, fecundity estimate, and the spawning potential ratio of this species.

2. MATERIALS AND METHODS

2.1 Study area

San Miguel Bay is bordered by seven coastal municipalities, namely: Mercedes and Basud (from the province of Camarines Norte), Sipocot, Cabusao, Calabanga, Tinambac, and Siruma (from the province of Camarines Sur) with seventy-nine coastal villages (barangays). The samples for the study were collected from the selected landing centers established by the Bureau of Fisheries and Aquatic Resources under the National Stock Assessment Program (NSAP) 5 located along San Miguel Bay (Figure 1). These landing centers were selected because of the high landed catch of *abo* based on the data of NSAP 5.

The established NSAP landing centers were located at Barangay 5, Barangay 7, and in Caringo Island in Mercedes; Barcelonita and Castilla in Cabusao; Sabang and Bonot-Santa Rosa in Calabanga; New Caaluan, Filarca, Salvacion Poblacion, and Sogod in Tinambac; and in Sitio Popoot, Vito in Siruma.

2.2 Sampling

Weekly collection from different gears in each sampling station was conducted for 34 months from March 2015 to November 2017. At least 5 kilos of *O. ruber* were collected in each area per week.

2.3 Sample processing and data analysis

Each specimen was weighed (in grams) and measured by its total length (in centimeters) using a measuring board from the tip of the snout to the end of the caudal fin. Fish samples were dissected, and the sex was determined based on the gross appearance of the gonads. In addition, the gonads were removed and weighed using a digital weighing balance. Nomenclature for description of the stages of the gonads were based on the five-point scale (İşmen 2003), as shown in Table 1.

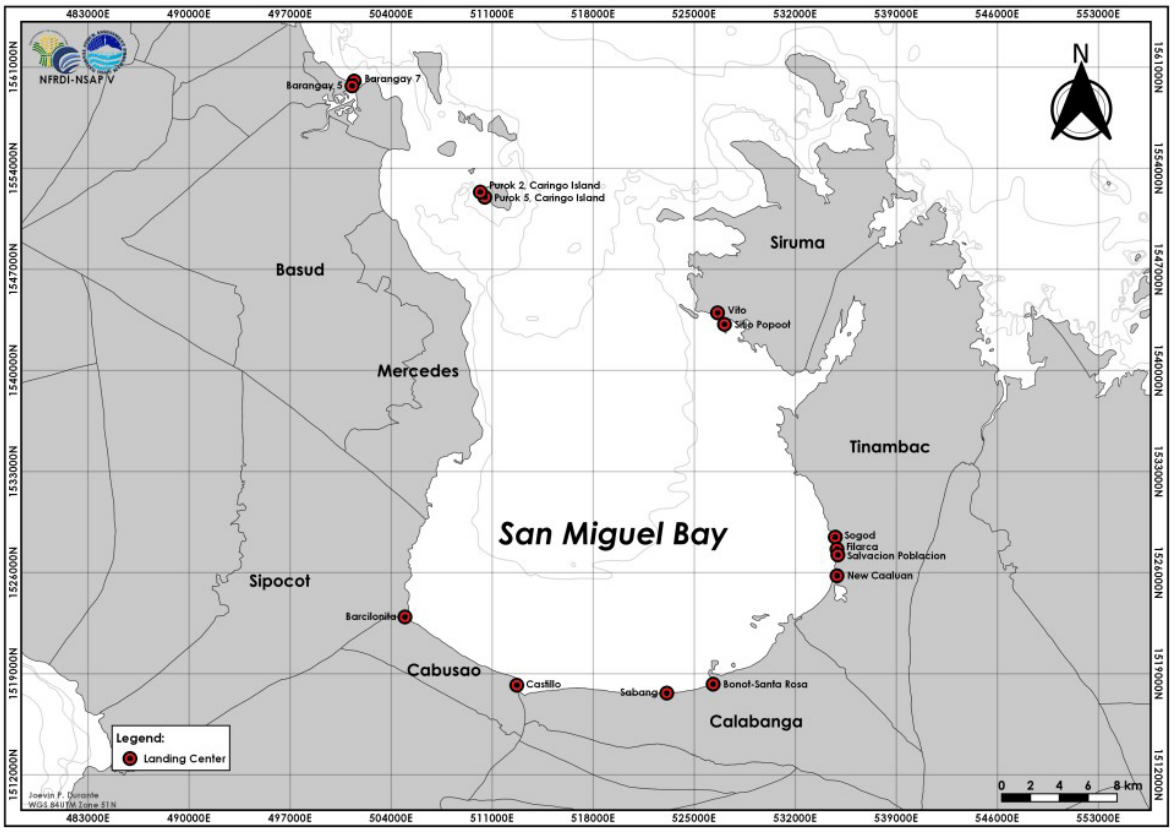

Figure 1. The sampling areas (red circles) along San Miguel Bay.

Table 1. Five-point scale in determining the gonadal maturity stages

Maturity Stages	Classification	Description
Stage I	Immature	Gonads are very small. Ovaries are pinkish translucent. Testis is whitish.
Stage II	Maturing and recovering spent	Gonads are small, dully transparent, and pinkish-whitish.
Stage III	Ripening	Gonads are enlarged. Ovary is pinkish-yellow with granular appearance. Testis is whitish to creamy. There are no transparent ova.
Stage IV	Ripe	Gonads are considerably enlarged. Ovary is orange-pink with conspicuous superficial blood vessels and is large and transparent. Ripe ova are visible. Testis is whitish-creamy, soft.
Stage V	Spent	Gonads are shortened, walls loose, flabby, empty, dark red with traces of sperm or ova.

The gonado-somatic index (GSI) was obtained to evaluate the monthly gonadal development of *O. ruber*. The GSI was calculated according to the formula (Wootton 1990):

$$GSI = \frac{weight of gonad}{total body weight} \text{ x } 100$$

For details of fecundity, only the Stage IV gonads were taken into consideration because in this stage the eggs are clearly discernible. Two lobes of the ovary from each sample fish were removed carefully by dissecting out the abdomen and were fixed in 5% formaldehyde solution immediately after taking and recording the gross measurements. This technique facilitates the easy separation of the eggs from the ovarian wall. Gravimetric method was used to determine the fecundity of fish (Murua et al. 2003). Sub-samples were obtained from anterior, middle, and posterior portions of each lobe of the ovaries. Fecundity was estimated using the formula:

$$F = \frac{Number of eggs in subsample (weight of the ovary)}{weight of the subsample}$$

Percentage of remaining spawning biomass was determined by using the Length Based Spawning Potential Ratio (LBSPR) R package (Hordyk 2019). Length data of all females were used to estimate the spawning potential ratio of the subject species. The stock parameters' L_∞ and M/k and the L_{m50} and L_{m95} were used as additional inputs in computing SPR. The L_{m50} was estimated using the method described in Stergiou (1999).

3. RESULTS

A total of 7,977 individuals were sampled from the designated landing centers around San Miguel Bay. The measured total lengths (TL) ranged from 8.10 cm to 32.10 cm and 10.00 cm to 33.50 cm for male and female, respectively. The average TL (± SD) was 16.70 ± 2.53 cm for male and 17.95 ± 2.95 cm for female. As for the relationship of the observed lengths and weights of the species, there was an observed high correlation between these variables of both sexes of the species (Figure 2). The relationship can be summarized as $W = 0.00521\ L^{3.18}$ and $W = 0.00837\ L^{3.01}$ for female and male, respectively. Based on the gathered data, the length at first maturity (L_m) was determined to be at 13.95 cm. Though the L_m is different in various areas, the computed value in San Miguel Bay was relatively smaller compared to other studies conducted outside the Philippines (Table 2).

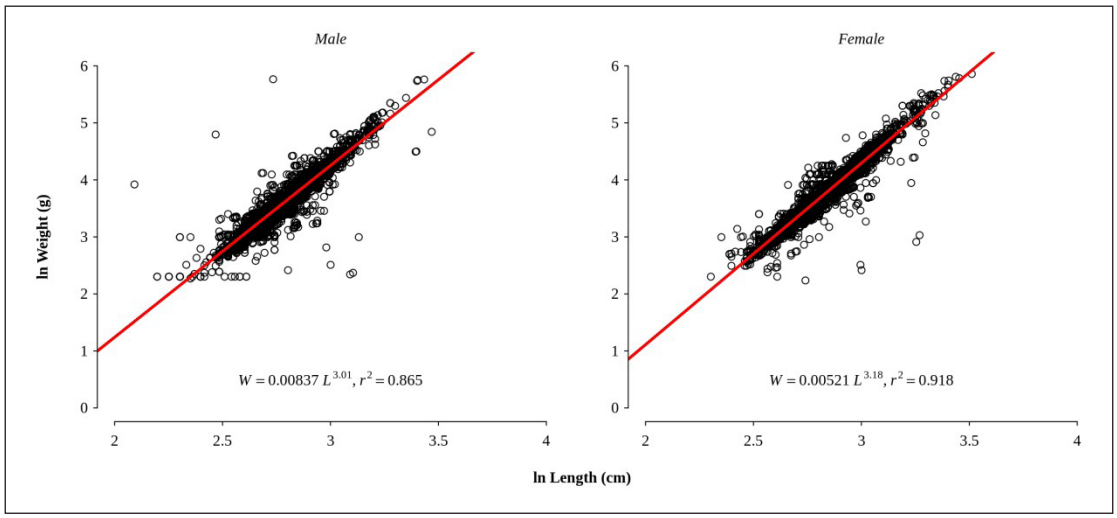

Figure 2. The length and weight relationship for both sexes.

Table 2. Computed values for the length-at-first maturity of *O. ruber* from different areas

L_m (cm)	Area	Source
13.95	San Miguel Bay, Philippines	This study
23.70	KwaZulu-Natal Coast, South Africa	Fennessy (2000)
28.00	Persian Gulf	Eskandari et al. (2012)
40.00	Oman Sea	Azhir (2008)
43.30	Makran Sea, Iran	Farkhondeh et al. (2018)

The overall sex ratio M:F was 1:0.8, which deviate significantly from the expected ratio of 1:1 in favor of males ($P < 0.05$, $X^2 = 64.3$). Unequal sex ratio in favor of male was recorded for 2015. However, female-biased sex ratio was noted in July 2016 to November 2017. During July to November this organism has a high average gonado-somatic index, and showed a fluctuating pattern but both females and males had a synchronized development of gonads (Figure 3).

All five stages of sexual maturity were observed throughout the year. Likewise, mature stocks were present throughout the year but they are abundant between the 3rd and 4th quarter of each year (Figure 4).

The fecundity of *O. ruber* varied between 3,420 to 422,100 with an average fecundity of 86,142 eggs for ovaries weighing 0.50 g to 30.00 g. Minimum fecundity was observed in a fish with 18.10 cm length, 60.90 g total weight, and 0.50 gonad weight. Gonad weight and fecundity showed a strong relationship with $r^2 = 0.8094$. Lastly, computed SPR for this species was 29%, which is near the target reference point (TRP) (Table 3). Goodyear (1993) suggests threshold level for the SPR should probably not be set much below 20% (LRP) without considerable justification, and that 30% (TRP) might be a more reasonable first choice.

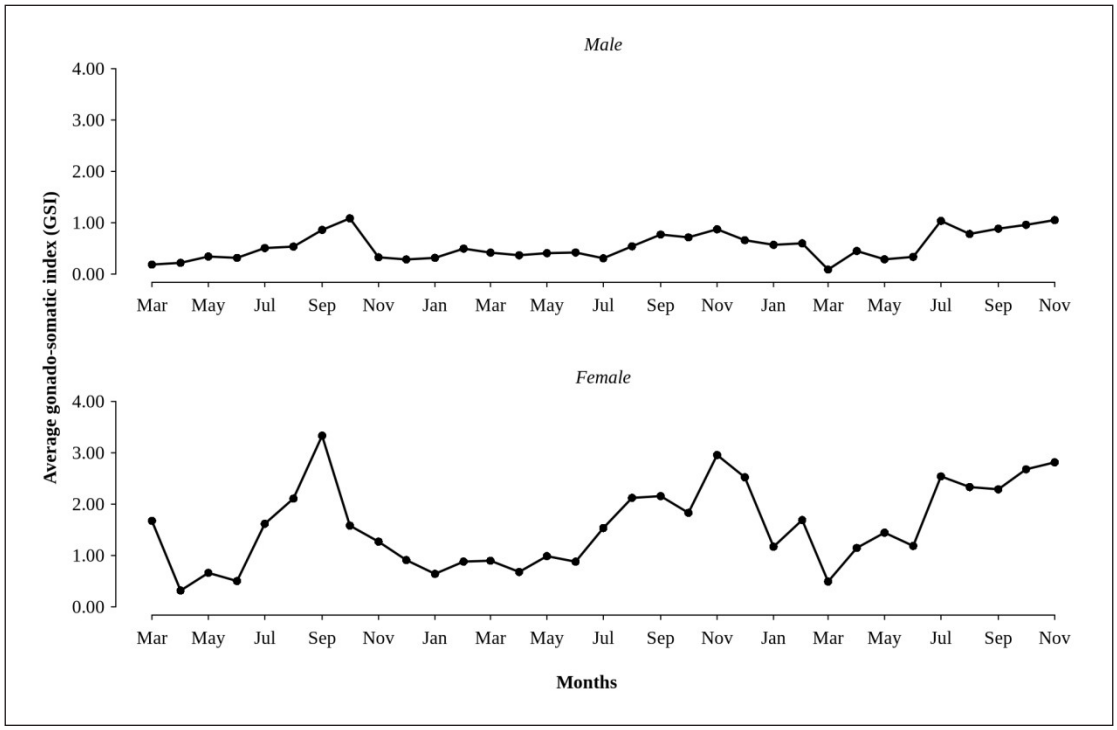

Figure 3. Gonado-somatic index of *O. ruber* collected in San Miguel Bay

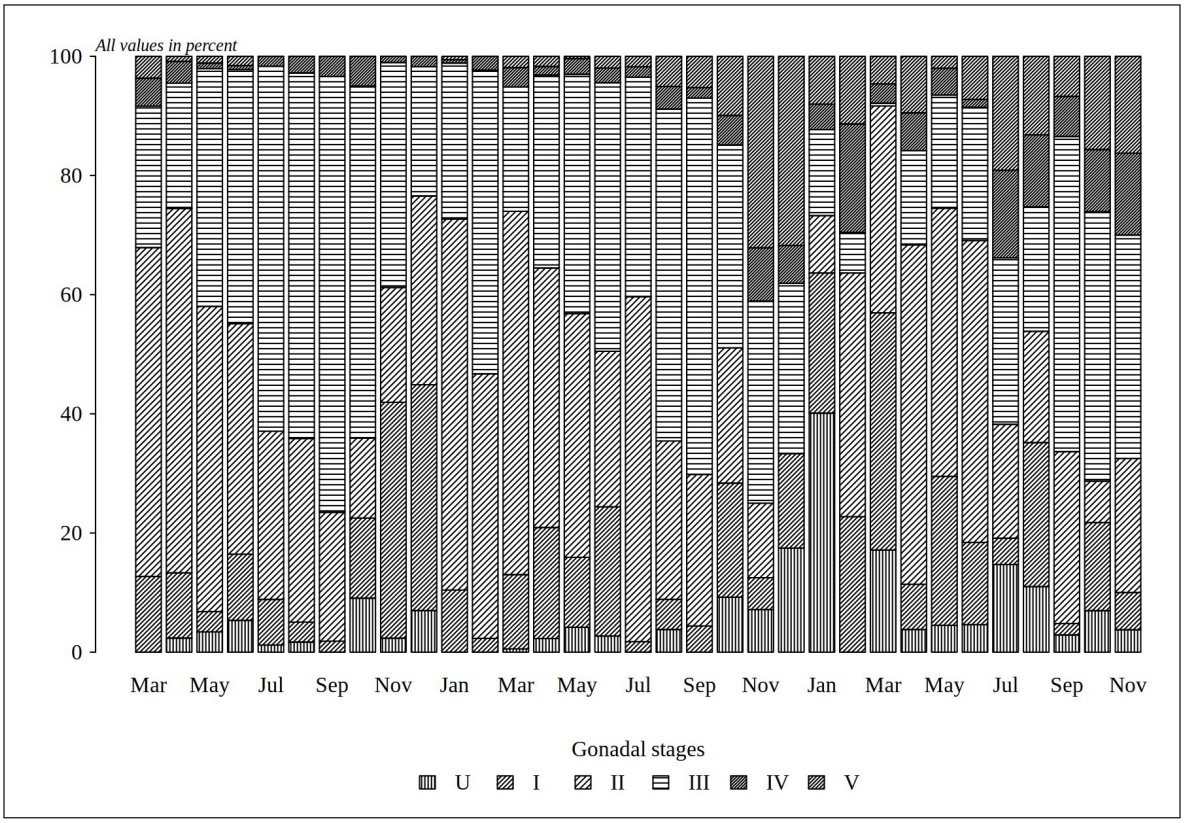

Figure 4. Monthly gonadal maturity of *O. ruber* in San Miguel Bay

Table 3. Spawning potential ratio of *Otolithes ruber*

Species	SPR	SL50	SL95	F/M
Otolithes ruber	*0.29*	*16.14*	*19.94*	*1.83*

4. DISCUSSION

The tigertooth croaker (*abo*) (Figure 5) is one of the most important fishes with high commercial value in the municipal waters of San Miguel Bay. Fish species of the family Sciaenidae are primarily coastal marine fishes and mostly demersal fishes with some confined in freshwater (Carpenter 2002). Kinoshita and Fujita (1988) claimed that sciaenids utilizes surf zone during their early life stages due to the abundance of food supply but will eventually migrate back to estuarine areas for spawning. Examining the *b* values ($b = 3.18$ and $b = 3.01$ for female and male, respectively) indicates a tendency towards slightly positive-allometric growth, in sense that there are "changes in relative dimensions of parts of organism that are correlated with changes in overall size" Gayon (2002). In addition, the *b* values shows that this species grows faster in weight than its length (Froese et al. 2011; Karachle and Stergiou 2012). The length and weight relationship can provide information about the well-being of a fish since it can be used to determine the fish condition based on the assumption that heavier fish at a given length are in better condition (Pope and Kruse 2001, as cited in AL Nahdi et al. 2016).

Figure 5. The subject species, *Otolithes ruber*, locally known as *abo*, in San Miguel Bay

At around 13 cm, the species is ready to reproduce and can now contribute to the population. As shown in Table 2, the stock in the bay matures earlier compared to other *O. ruber* stocks described in the literature. The early maturation of *O. ruber* in the bay can be attributed to the geographical and ecological differences affecting fish phenology. Temperature also has a bearing in sexual maturity (Brusle 1981) in which it could also potentially influence the maturity patterns of species (Armstrong et al. 2004) and warmer temperatures leads to an earlier and more protracted spawning period of marine fishes (Rogers and Dougherty 2019). On the other hand, the early maturation may indicate that its population is under stress from high rates of exploitation (Trippel 1995), and the length at which the species mature may further decrease in time if intensive fishing pressure prevails (Eskandari et al. 2012). The physiological aspects of the fish as well as the external condition plays an important role in the maturation and spawning of a fish. Human activities in the form of harvesting can affect the age structure of the population (Rogers and Dougherty 2019). As stated in the study of Zhao et. al. (1997), intense fishing pressure can alter the relative fitness of genotypes. Fast-growing genotypes may be more fit under increased fishing pressure while slow-growing genotypes who mature at larger sizes tend to be removed before reproduction (Eskandari et al. 2012). This can be illustrated by the reduction of larger and immature fish with time. The result of this study showed that this species was greatly affected by too much fishing pressure and further study on the population dynamics of this species is needed to confirm this.

Overall sex ratio for this species showed that males were significantly more numerous than the females due to the predominance of males in 2015. Nevertheless, a female-biased was noted in 2016 and 2017. The deviations from 1:1 sex ratio for this species was also noted in several studies (Fennessy 2000; Farkhondeh et al. 2018), and higher proportion of female *abo* were found in most of the sampling period. According to Oliveira et al. (2016), sex ratio may deviate from the expected 1:1 in the same population at different times, being influenced by several factors such as adaptation and reproductive behaviour. The disparity between sexes can be attributed to the differences in growth characteristics and mortality rates as well as in migration or spatial segregation by sex (Shadovy and Shapiro 1987) and schooling behavior and vulnerability (Shamsul Hoda and Ajazuddin 1992). Likewise, Farkhondeh et al. (2018) speculated that mature females were found to migrate towards inshore waters during the spawning season, thereby making them more accessible to fishermen.

Several studies have shown that *Otolithes ruber* is capable of spawning multiple times during the reproductive season (Dadzie 2007; Farkhondeh et al. 2018; Velip and Rivonker 2018), and mature females actively breeds throughout the year (Farkhondeh et al. 2018). In addition, this species occasionally perform their spawning activity in the nearshore coastal waters (Velip and Rivonker 2018), probably because of the presence of abundant and immediate source of food around the bay. Mature females were found throughout the study period in the bay. The presence of individuals with stage IV and V gonads in all the months revealed that this species is actively breeding throughout the year with spawning peak from July to September and may extend up to October or in later months of the year. On the other hand, juveniles were also present whole year round indicating continuous recruitment of this species. Presence of mature individuals and especially juveniles in the bay indicates that San Miguel Bay is probably utilized as a spawning and nursery ground of sciaenids. However, according to Fennessy (2000), the subject species utilizes the inshore waters as a nursery area.

The reproductive activity of the species was supported by the gonado-somatic index (GSI), which is the relationship between the weight of the fish to the weight of the gonad. The GSI provides a simple index to describe the changes in relative gonad size over time (Wootton 1990). The highest recorded average GSI for female was 3.33 in September 2015, 2.96 in November 2016, and 2.81 in November 2017. Hence, the estimated spawning season of this species in the bay is from July to November.

Numerous assessments have been conducted to update the status of the fisheries in San Miguel Bay, which all have provided conclusive evidence of overfishing. The study of Simpson (1978), the Fishery Industry Development Council, and the Natural Resources Management Center (FIDC-NRMC 1980) have concluded that the demersal biomass is heavily overfished. Spawning potential ratio (SPR) showed how much is the capacity to replenish the outstanding biomass in an unfished population with a limit reference point (LRP) of 20%. In the current study, the spawning potential ratio is still above the limit reference point, which means that the stock of the *O. ruber* is still in good condition despite the fishing pressures experiencing by this species.

Conservation approaches are needed to

maintain the sustainability of this major fisheries and commercially-important stock, and a study on stock assessment is needed to have deeper analysis on the status of the *abo* stock in San Miguel Bay. It is also needed to conduct a consultation with the stakeholders to set the harvest control rules (HCRs) and the reference points (RPs) for *abo*.

5. CONCLUSION

The study revealed that *O. ruber* is a continuous breeder since mature gonads were observed throughout the year. It has a distinctive spawning seasonality, which is from July to November. In addition, it can also be concluded that San Miguel Bay is a spawning ground for sciaenids as indicated by the presence of mature species and spawners throughout the year. Moreover, spawning potential ratio revealed that this species can still replenish its outstanding biomass. It is, therefore, our recommendation that management measures should be directed towards the sustainability of the *O. ruber* stock and its productivity in San Miguel Bay.

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