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Fisheries and Biology of *Otolithes ruber* (Bloch & Schneider, 1801) Catch of Small-scale Fisherfolk in San Miguel Bay, Philippines

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Otolithesruber (Bloch & Schneider, 1801) is one of the major fish catches in San Miguel Bay and its processing is a seasonal livelihood among coastal villages. This study documented and described the *O. ruber* catch of small-scale fisherfolks around the Bay through on-board survey and observation. Fishing trips from 10 September to 19 November 2018 demonstrated that fisherfolks used bottom-set gill nets and commonly explored the middle to the mouth of the Bay off Mercedes and Siruma to catch *O. ruber* and other species. The analysis of 434 composite fish samples bought from the fishing trips identified 222 female and 212 male fish individuals with TL of 19.14 $\pm$ 0.11 cm and body weight of 70.76 $\pm$ 1.46 g. The majority were already mature to spawning stages and gonads had no apparent lesions. The population's reproductive capacity, based on the presence of numerous spermatocytes and oocytes, was presumed to be realized, but this may fail due to uncontrolled illegal fishing.

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1. INTRODUCTION

San Miguel Bay, a large shallow estuary, is one of the most productive fishing grounds of the Philippines and a major source of finfish, crabs, and shrimps, especially sergestid shrimps. Diverse fish species such as croakers, herrings, mullets, juvenile Spanish mackerels, anchovies, and crevalle are also frequently caught in the Bay [1] using multi-gears. Croaker *O. ruber* (Sciaenidae) had been one of the long-time target species of the San Miguel Bay small-scale fisherfolk. Locally known as "*abo*, these are abundant in estuaries and are bottom dwellers that prefer occupying muddy and sandy substrates [2].

In the Bicol Region*, O. ruber* is native and the most abundant among the other seven (7) species of Sciaenidae found in the Bay. Though considered as one of the major catches, this species had shown declining catch from 14% contribution to total catch in 1980–1981 [2] to 13% in 1992–1993 [3] and dropped to around 6% in the early 2000s [4]. Studies have revealed that fish stocks are declining and further suggested that the Bay is overfished [5].

Pauly concluded [6] that ecosystem overfishing is occurring in the Bay wherein decline through fishing of the originally abundant stock (e.g., shark rays, slipmouths) was not fully compensated for by the increase of the smaller biomass of the species that replaced it such as croakers, squids and shrimps. Moreover, growth overfishing is also observed in *O. ruber* as a result of using gears with small-meshed nets, as shown in length distribution observed in size composition of mixed gears [7].

Bundy and Pauly [8] established that small-scale fishery sector had a more wide-ranging impact on the fishery resources of the Bay than the large-scale fisheries. On one hand, the gears used by the former were versatile as it was selective and can target certain species in any habitat at a greater range of trophic levels. The latter, on the other hand, was non-selective but with a large range of harvested species. Results of the classification and ordination techniques on the catch data revealed a high degree of competition among-scale fishing gears and this is due to similarity of catch composition and target species [7].

With the present state of San Miguel Bay, there is a need to investigate the present status of its fishery resources. Thus, this study aimed to determine the fishing activities and current biological information on *O. ruber* catch of selected small-scale fisherfolk. The study specifically assessed the morphometric characteristics of *O. ruber* in terms of size (lengths and weights) and sexual maturity.

2. MATERIALS AND METHODS

2.1 Study Site

Onboard surveys and observations (fishing trips) were conducted along seven (7) San Miguel Bay municipalities from September 10 to November 19, 2018. Sampling stations (points) across the 12 sampling sites are shown in Fig. 1. These include (1) Caringo Island and Pambuhan, Mercedes; (2) Mangcamagong, Basud; (3) San Vicente and Anib, Sipocot; (4) Pandan and Castillo, Cabusao; (5) Sabang and Cagsao, Calabanga; (6) Magtang and Sogod, Tinambac; and (7) Vito, Siruma. As to schedule, the fishing trips were conducted at random dates depending on the availability of the fisherfolk, weather conditions and water situations.

Prior to on-board survey or fishing trips, brief orientations were facilitated among the fisherfolk cooperators about the purpose and flow of the survey. Methods and techniques were not disclosed to them so as to avoid potential adjustments in usual fishing activities and eventually minimize bias in the results.

The details of the entire fishing trips were noted onto underwater slates like time of departure and arrival, duration of fishing activity (deployment-catch-end), crew size, type of fishing boats (length, width, engine capacity), gears used (quantity, length, mesh size), other technology used, and catch species composition.

A GPS was used to capture the coordinates of the locations from the point of origin to the point of destination including to each area where fisherfolk deployed gears. For each fishing activity (deployment to end of fishing) at least 2 to 3 waypoints or location coordinates were taken. Track logs were also set and saved and these were used in generating maps of the actual fishing areas and routines.

2.2 Morphometric Analysis

At least 5 kg of *O. ruber* was collected from the total catch of the fisherfolk during the on-board surveys (fishing trips) conducted in 7 municipalities. All of these were stored in a freezer after collection.

Each sample was measured (total lengths in centimeters) and weighed (in grams), then photo documented. Labels were placed for each sample using the code MUN-Boat No.-Fish No. (e.g., CAL-B1-01).

Samples were dissected and its gonads were collected. Lengths (cm) and weights (cm) of gonads were measured and photos of each specimen were also taken. After which, gonads were placed in clean vials and properly labeled following the same code of the fish, then stored in a freezer to ensure the tissues stay intact.

Sex identification was based on the gross appearance such as color and size while stages of sexual maturity were determined using the 7-stage of maturity adapted by Hoda and Ajazuddin [9]. Macroscopic analyses of gonads were conducted to determine the sex of the fish as well as its maturity stage.

Gonad samples were also subject to histopathological assessment of its tissues to determine the reproductive health of the fishes. Other purposes of the assessment were to verify the sex, identify the stage of development, and document the presence of intersex, tumors, parasites and other abnormalities. Sub-samples were taken from the 434 samples using the Microsoft Excel analytical tool. The size class for each sex was determined based on the fish length and gonad weight. Mean values of the total length and gonad weight were computed for each size class.

In determining the number of sub-samples, 20% of the total number of samples for each size class was obtained. The total number of sub-samples taken for analysis was 90 (46 female and 44 male). Gonads were preserved using 10% formalin-seawater solution.

The Department of Veterinary Paraclinical Science of UPLB - College of Veterinary Medicine was commissioned to perform the histopathological analysis. The hematoxylin and eosin (H&E) staining were the technique employed. It used a combination of two dyes, hematoxylin and eosin used for demonstration of nucleus and cytoplasmic inclusions.

Sex ratio of *O. ruber* was computed manually since difference between the two was not that large. The length frequency was described for each sex using the histogram analysis.

Moreover, linear regression analysis was used in determining the degree of correlations among and between (1) fish lengths and weights, and (2) gonad lengths and weights. The correlations were determined for both female and male *O. ruber*.

3. RESULTS

3.1 Fishing Activities and Catch of *O. ruber* on Selected Fisherfolk

There were 22 onboard surveys conducted across the 12 sampling sites in the 7 municipalities. A total of 47 municipal fisherfolk participated in the onboard survey.

Table 1 enumerates the fishing effort and the corresponding catch recorded for the actual fishing trips conducted. Most of the fishing trips were done in the early morning with a common duration that ranged from 4 to 7 hours and using motorized boats with 12 horse power engine capacity and 7 to 9 meter-long.

The longest trip recorded was in Cagsao (Calabanga) which lasted for more than 7 hours. Lengths of gillnets used, particularly bottom set gillnet, ranged from 15 to 40 knots (50 to 200 m/knot) with 7 to 10 cm mesh sizes. Normally, 2–3 fisherfolks were involved in the fishing activities.

In general, municipal fisherfolk share common fishing grounds where to catch *O. ruber,* which was nearly in the middle part and outer portions of the Bay, particularly in the areas of Mercedes and Siruma (Fig. 2). The estimated water depth of the fishing areas ranged from ~3 to 21 m.

It was observed that most fisherfolks went far fishing areas to fish unlike before their fishing grounds were usually conducted near the shore. Moreover, fisherfolks were free to visit and do fishing activities, without any restriction, to other municipal waters as evidenced by the fishing trips of fisherfolk from Sipocot (San Vicente), Cabusao (Castillo), Calabanga (Sabang), and Tinambac (Sogod).

Further, some fisherfolks were not familiar with the location of the established FSMR as they traversed and perform fishing activities in those places, especially the trips in Basud and Cabusao (Pandan). Tinambac (Sogod) fisherfolk visited areas closely to Looc River, which is between Tinambac and Siruma and recorded to have catches mainly consisting of juvenile *O. ruber*.

Out of 162.69 kg total catch, 31.49% or 51.22 kg of which were *O. ruber* caught largely from Mercedes, Calabanga and Cabusao areas. According to Bailey (1982), these are places ideal for fishing activities during the southwest monsoon, which was the prevailing weather conditions at the time on-board surveys were conducted last September 10 to November 2018.

From all the trips, 3 different fishing methods were employed and observed to have *O. ruber* catches, namely (1) “patalang”; (2) “timbog”; and (3) “hugos.” The first method is considered as passive fishing method while others are active, which are prohibited in municipal waters. All of these methods used gillnet; particularly bottom set gillnet, with varying mesh sizes. The trips in Barangay Pambuhan (Mercedes) using “patalang method” recorded the highest *O. ruber* catch from among the 22 trips. A total of 18.5 kg of *O. ruber* was accounted and contributed 51.89% to the total catch of the trip. Catch from these trips also recorded the highest mean length size, which was 20.98 cm (ranged from 17.8 to 27 cm).

The second method noted was the “timbog” technique, which was done with the aid of pulse stick, locally known as “tupak.”Fisherfolks fromCabusao and Calabanga adopted the “timbog” method. This fishing practice was commonly observed in all municipalities, except Mercedes as this method is prohibited by the local government. Only few fisherfolks from Basud practiced this kind of method. Using this method, the fishing activities (for 4–5 deployment and harvesting) lasted for 5 hours. Recorded *O. ruber* catches were 9.7 kg (Sabang) and 6.5 kg (Castillo), which were accounted as the next two largest catch among all the trips.

Fisherfolks from Vito (Siruma) and Sogod (Tinambac) used the third method observed during the on-board survey. Using the hugos method, the recorded *O. ruber* catches were low that ranged from 0 to 1 kg *O. ruber*. This can be attributed to the types of fishing gears used such as the double net in Vito (Siruma) that was intended for shrimp and crab and the large mesh size of the gillnet used by fisherfolks in Magtang (Tinamabac).

Table 2 compares the attributes of the four hundred thirty-four (434) *O. ruber* samples collected from the 7 municipalities in terms of sex composition, fish lengths, length-frequency and body weights. Calabanga had the highest number both female and male followed by Cabusao, Mercedes and Sipocot. Samples from Mercedes and Basud were recorded with large mean lengths and body weights while Tinambac and Siruma had the smallest mean values. Majority of the female and male samples were under the length size class of 21 to 25 cm followed by 16 to 20 cm, which were classified as mature to spawning maturity stage.

3.2 Sex Composition

Out of 434 samples, 222 females and 212 males were identified (Fig. 3). Largest catch of both female (106) and male (62) of *O. ruber* were recorded in Calabanga. The second two highest catches of female fish were observed in Cabusao (34) and Sipocot (27) where as male recorded 55 in Sipocot and 44 in Mercedes. A 1:1 ratio of female and male was recorded.

3.3 Length Composition and Frequency

The length composition and frequency for each sex are presented in Fig. 4. The smallest size of *O. ruber* recorded was 11 cm weighing 30 g while largest size was 30.2 cm (315 g). Out of 434 samples, 246 were between 16 and 20 cm in lengths while 158 have 21 to 25 cm length sizes. Twenty-six samples belong to 10 to 15 cm class size and only few have lengths with 26 cm above. Most male *O. ruber* (150) were under the length size group of 16 to 20 cm while females (117) were from 21 to 25 cm long.

Fig. 5 provides the length composition and frequency of female and male *O. ruber* in each municipality. The aggregated mean length of all samples was 19.14 cm (19.97 cm - female and 18.27 cm–male). Average lengths per municipality ranged from 14.91 to 20.98 cm. Mercedes recorded the highest combined (female and male) mean length of 20.98 followed by Basud (20.2 cm), Calabanga (19.91 cm) and Cabusao (19.72 cm). Siruma and Sipocot recorded 18.44 cm and 17.04 cm mean lengths, respectively.

On the other hand, samples from Tinambac (14.91 cm) have the least mean total length. Samples from Mercedes have the highest mean total length for females (21.62 cm) and male (20.65 cm). It was followed by Siruma (21.55 cm), Calabanga (20.56 cm) and Cabusao (2.42 cm) for female samples. In the case of male fish, Calabanga (18.80 cm), Cabusao (18.65 cm) and Siruma (17.83 cm) noted with high mean total length. *O. ruber* samples from Sipocot and Tinambac got low mean lengths both for female (15.53 cm and 17.62 cm) and male (14.25 cm and 16.76 cm), respectively.

Table 3 enumerates the length at first maturity and maximum length of *O. ruber* from other coastal waters in other countries based from the literatures, including this study. The recorded maximum length was 90 cm, as observed in South Africa and Kuwait waters which are all found along Indian Ocean. In this study, recorded smallest length was 11 cm found in Sipocot followed by sample from Tinambac which was 12. 5 cm. The only *O. ruber* fish sample with largest total length was found in Cabusao having 30. 2 cm. Most of the samples have maximum lengths between 20 and 24 cm.

On the other hand, most of the *O. ruber* found in San Miguel Bay already reached the length at first maturity. This means that majority of them have already developed ripe gonads for the first time (www.fishbase.org.).

3.4 Fish Length-weight Relationship

Length-weight relationship (LWR) is a vital factor for assessing the fish stock, studying the biology of fishes as well as in finding out relative well-being of the fishes. It is used to estimate the average weight of the animal in a given length group by establishing a mathematical relationship between the length and weight variables [10].

Fig. 6 presents the relationship between the total length (cm) and body weight (g) of the 434 *O. ruber* samples. The two variables have a high degree of correlation as indicated in R^2 value of 88%. This means that as the body length of *O. ruber* increases its weight also increases. This implies that *O. ruber* in San Miguel Bay were still in normal condition despite changes in coastal habitat conditions, adverse change in water quality (e.g., high TSS and counts of fecal coliform) and siltation problems that resulted to decrease in water depth.

The total length of *O. ruber* samples in Mercedes ranged from 17.8 to 27 cm with a means of 20.98 cm and the body weight of 50 to 200 g with 93.74 cm mean value. For Basud, fish total length ranged from 18.3 to 22.8 cm with mean value of 20.2 cm and weight of 80 to 130 g with 106.44 cm mean value. Sipocot fish samples have 11 to 20.5 cm lengths and has 17.04 mean values while body weights ranged from 20 to 90 g with mean value of 50.54 g. Fishes lengths from Cabusao recorded 16.3 to 30.2 cm length sizes, mean value of 19.72 cm and its body weights ranged from 40 to 315 g with 82.92 g mean value.

O. ruber samples taken in Calabanga have total lengths of between 15.4 and 24.5 cm with 30 to 143 g body weights with mean values of 19.91 cm and 72.37 g, respectively. Fish samples from Tinambac measured 12.5 to 22 cm long with mean values of 14.91 cm and 20 to 100 g body weights with 32.24 g mean values. The total lengths of *O. ruber* samples in Siruma ranged from 16 to 24.5 cm (19.12 cm mean value) and have 30 to 155 g body weights (69.13 g mean value). Overall, the aggregated mean length was 19.14 cm with mean body weight of 70.76 g.

Fig. 7 shows the strong correlation of the length weight for female and male *O. ruber.* Female lengths ranged from 11 to 30.2 cm with 0.0103 to 15.60 g body weights. In the case of male *O. ruber,* total length ranged from 12. 5 to 27 cm while body weights ranged from 0.01 to 12.5 g.

Tinambac recorded the smallest total length both for male (11 cm) and female (12.5 cm) with respective body weights of 30 g and 20 g. Cabusao recorded largest total length for females (30.2 cm) while for males was noted in Mercedes (27 cm) with 315 g and 200 g body weights, respectively.

The 3 municipalities with the highest mean total length and body weight of female *O. ruber* were Mercedes (21.62 cm, 103. 91 g), Siruma (21.55 cm, 101.25 g) and Calabanga (20.56 cm, 80.28 g). Meanwhile, Mercedes (20.65 cm, 88.43 g), Calabanga (18.80 cm, 58.85 g), and Cabusao (18.65 cm, 65.40) recorded with 3 highest average total lengths and weights for males.

O. ruber samples from Tinambac have the lowest mean values for both female (15.53 cm, 37.06 g) and male (14.25 cm, 27.07 g). It was observed that female catch is larger than male as to total length and body weight.

3.5 Gonads Length-Weight Relationship

Fig. 8 describes the weak relationship (25%) between length and weight of gonads. Likewise, very weak relationship was recorded both for female and male.

3.6 Sexual Maturity

The maturity stages of the fish were determined by macroscopic examination using 7-stage of maturity [9]. Results revealed that there were 3% immature, 14% developing virgin, 7% maturing, 24% mature, 30% gravid, 22% ripe, running or spawning and 0% spent. Table 4 presents the maturity stages of male and female *O. ruber*.

For Mercedes with highest mean total lengths, maturity of females and males ranged from gravid (7, 23) to ripe or spawning (14,18) stages.

There were more spawning (43) and gravid (30) female *O. ruber* in Calabanga while males were mostly from mature to gravid stages. Majority of female *O. ruber* from Cabusao were classified under gravid stage while developing and mature for males.

Samples from Siruma have gravid to spawning stages for females while *O. ruber* males were under mature to ripe stages. Tinambac recorded the least mean length size of *O. ruber* and most of which were under developing virgin with some immature for male samples. Both female and male samples from Sipocot were mostly under the category of mature stage.

In summary, maturity stages of female *O. ruber* ranged from mature to ripe or spawning. On the other hand, most male *O. ruber* were already mature and gravid with some developing virgin. Moreover, it was observed that there were more developing virgin to maturing male as compared to females.

From the 90 samples subjected to histo-pathological analysis, there were 44 males and 46 females. All the samples were found in normal conditions or all gonads showed no apparent lesion (NAL). Majority of the gonads showed good reproductive capacity because of the presence of many spermatocytes in males and oocytes in females (Fig. 9).

Only few males showed tubules devoid of sperm or few numbers of spermatocyte. From these findings, the morphological characteristics of gonads the approximate range of sexual development can be arrived at. Those at the peak of the reproductive capacity showed plenty of spermatocytes and oocytes with few interstitial connective tissues. Those old, senile fish showed plenty of interstitial connective tissue with few remaining spermatocytes or less number of oocytes. Hence, it can be concluded based on the morphological observations of the gonads that *O. ruber* fish population across municipalities is relatively healthy in terms of their reproductive capacity.

4. DISCUSSION

Otolithes ruber or tiger-toothed croaker belongs to Family Sciaenidae, which one of the 7 croaker species found in San Miguel Bay. It is one of the top species caught in the Bay, as evidenced by the 2015–2017 landed catch data of BFAR NSAP 5. Its abundance may be attributed to the presence of many *Acetes spp.* or locally known as “balaw”, which is common on diets of post larvae and juvenile *O. ruber*.

This species occurs whole year round and observed to have large supply in the months of January to May. Calabanga recorded the largest catch of *O. ruber* followed by Tinambac and Cabusao from 2015 to 2017. On the other hand, the low catch recorded in Mercedes and Siruma was due to little amount of fisherfolks who target *O. ruber*. The large number of fisherfolks as well as the continuous trawl operations may explain the high catch in Calabanga, Cabusao and Tinambac municipalities. Proximity of fish ports to fishing areas, market availability and high market prices were other reasons for high catches of the 2 municipalities. Both Cabusao and Calabanga are known producers and suppliers of *O. ruber* dried fish and “biti.”

In general, municipal fisherfolks along with commercial fishers share common fishing grounds. *Otolithes ruber* were frequently caught at the middle to outer portions of the Bay. Fisherfolk’s commonly visited parts of Mercedes and Siruma as they consider these places with abundant *O. ruber* especially starting January until May. Approximate water depths of the actual fishing ground locations ranged from ~3 to 21 m.

The average fishing activities ranged from 4 to 7 hours using motorized boats with 2–3 fisherfolks involved. Fishing activity was done on a daily basis, usually early morning and few does it in late afternoon until evening. Catches are usually brought to Calabanga, Mercedes and Cabusao fish ports for local auction (whisper bidding) while others sold fresh catch directly to frequent middlemen or fish vendor (rigaton).

From the 22 fishing trips, 3 fishing methods were observed to have *O. ruber* catch, namely, (1) "patalang", (2) "timbog", and (3) "hugos". All of these used gillnets with varied lengths and mesh sizes. Lengths of gillnet used, particularly bottom set gillnets, ranged from 15 to 40 knots (50 to 200 m/knot) with 7 to 10 cm mesh sizes.

"Patalang" method is a passive fishing method which was done by just setting gillnets across the path of the fish with no other activities to pursuit *O. ruber*. On the other hand, both "timbog" and "hugos" methods were categorized as active fishing method as it scares and pushed the gears in the pursuit of *O. ruber*. In particular, "timbog" used pulse stick as banger to create sound and drive the fish towards the gear. The "hugos" method intentionally pushed the gears by maneuvering the boat in order to trap the fish.

Out of 162.69 kg total catch, 31.49% or 51.22 kg of which were *O. ruber* caught largely from Mercedes, Calabanga and Cabusao areas. Mercedes employed the "patalang" method while the other two employed "timbog" method. Most of the municipal fisherfolk, except those from Mercedes practiced this kind of fishing method. Although prohibited but most fisherfolks consider it as effective method and ensure high catches. The "hugos" method which was adopted in Vito (Siruma) and Magtang (Tinambac) recorded low catches of *O. ruber*.

Most *O. ruber*, either female or male, are abundant in parts of Mercedes, Calabanga, Cabusao and Sipocot even during the season of southwest monsoon (habagat) compared to other parts of the Bay such as Tinambac and Siruma where habagat has unfavorable effect to their fishing activity. On-board surveys in these two areas were conducted in October and mid-November 2018 where shift in monsoon season was occurring, thus, low fish catch was documented.

Out of 434 samples, 222 females and 212 males were identified, having a 1:1 ratio. Dominance of either sex can be influenced by different factors such as schooling behavior, maturation and even spawning [9]. The smallest size of *O. ruber* recorded was 11 cm weighing 30 g while largest size was 30.2 cm with 315 g body weight. Female lengths ranged from 11 to 30.2 cm with 0.01 to 15.60 g body weights while for male the total length ranged from 12. 5 to 27 cm and body weights ranged from 0.01 to 12.5 g.

The aggregated mean length of all samples was 19.14 cm (19.97 cm - female and 18.27 cm– male). Average lengths per municipality ranged from 14.91 to 20.98 cm. Mercedes recorded the highest combined (female and male) mean length of 20.98 followed by Basud (20.2 cm), Calabanga (19.91 cm) and Cabusao (19.72 cm). On the other hand, samples from Sipocot (17.04 cm) and Tinambac (14.91 cm) have the least mean total lengths. This explains that catch in these areas were mixed of well-grown juveniles, which just came from sea after few months of feeding and growing. Fishing activities were conducted near Cotmo-Anib River in Sipocot and Looc River in Tinambac.

Croakers were characterized as small to large fish that ranged from 10 to 200 cm in total length [11]. This means that *O. ruber* in San Miguel may reach up to 100 cm or above just like other Asian countries. However, those *O. ruber* recorded with large total lengths were found along Indian Ocean while San Miguel Bay lies along Pacific Ocean.

Length-weight relationship (LWR) is a vital factor for assessing the fish stock, studying the biology of fishes as well as in finding out relative well-being of the fishes. It is used to estimate the average weight of the animal in a given length group by establishing a mathematical relationship between the length and weight variables [10]. The total length (cm) and body weight (g) of the 434 *O. ruber* samples have a high degree of correlation as indicated in R^2 value of 88% (?). This means that as the body length of *O. ruber* increases its weight also increases. This implies that San Miguel Bay *O. ruber* were still in normal condition despite changes in coastal habitats, adverse change in quality of water and prevalence of siltation that resulted to decrease in water depth.

The high correlation was due to similarities of lengths and weights among samples particularly those from Mercedes, Basud, Cabusao, Calabanga and Siruma. The samples were collected from areas where the water depth was

Table 1. *O. ruber*catch and fishing effort based on-board surveys data (September 10 to November 19, 2018)

Municipality	Fishing method	Total catch	*O. ruber* catch	% contribution	Time spent (in hr)	Manpower	Gear type	Fishing power (hp)	Boat size (in cm)
Mercedes	Patalang	35.65	18.5	51.89%	1–4	2–3	Crab pot, gill net	12	7–12
Basud	patalang timbog	5.95	1.08	18.15%	2.5-3	1-2	BSN	10-16	7
Sipocot	Timbog	19.1	4.3	22.51%	1.5-4.5	2	BSN	12	7.5-9
Cabusao	Timbog	25.247	6.747	26.72%	2-5	2-3	BSN	12	6-9.5
Calabanga	Timbog	29.75	17.7	59.50%	4-7.5	2	BSN	12	9
Tinambac	hugos, timbog	24.3	1.3	5.35%	4-7	2	BSN, gillnet for crab	12	7–9
Siruma	timbog, hugos	22.7	1.6	7.05%	4-6	2-3	BSN, double net	12	7–9
Total		162.69	51.227	31.49%					

Note: BSN–bottom set gill net

Table 2. Total lengths and body weights of female and male *O. ruber*

Municipality	n		Total length (cm)			Length-frequency (cm)	Body weight (g)		
	Female	Male	Mean	Min	Max		Mean	Min	Max
Mercedes	23	44	20.98	17.80	27	16–20: 17 (m), 2 (f) 21–25: 25 (m), 20 (f) 26–30: 2 (m), 1 (f)	93.74	50	200
Basud	9	0	20.20	18.30	22.8	16–20: 6 (f) 21–25: 3 (f)	106.44	80	130
Sipocot	27	55	17.04	11	20.50	10–15: 7 (m), 2 (f) 16–20: 48 (m), 22 (f) 21–25: 3 (f)	50.54 (20-90)	20	90
Cabusao	34	22	19.72	16.30	30.20	16-20: 16 (m), 16 (f) 21–25: 6 (m), 17 (f) 31–35: 1 (f)	82.92	40	315
Calabanga	106	62	19.91	15.40	24.50	16-20: 54 (m), 41(f) 21–25: 8 (m), 65 (f)	72.37	30	143
Tinambac	15	14	14.91	12.50	22	10-15: 12 (m), 5 (f) 16–20: 2 (m), 9 (f) 21–25: 1 (f)	32.24	20	100
Siruma	8	15	19.12	16	24.50	16–20: 13 (m) 21–25: 2 (m), 8 (f)	69.13	30	155

Table 3. Length at first maturity and maximum length of *O. ruber*

Lm (cm)	Maximum Length(cm)	Geographical area	References
19.8		Kuwait waters	Devadoss (1969)
	45.55	Kuwait	Hussain and Abdullah (1977)
22.1		Arabian Gulf, Kuwait	www.fishbase.org
17.5	44	Indian water	Chakraborty et al. (2000)
	42.5	Yemen	Al Sakaff and Esseen (1999)
23.7		KwaZulu-Natal, South Africa	Fennessy (2000)
	90	South Africa	Fennessy (2000)
	44	Indian waters	Fennessy (2000)
	90	Kuwait waters	Dadzie and Abou-Seedo (2004); Dadzie (2007)
	30 (1950s)	Hong Kong waters	Darta (2010)
	20 (1970s)		
	20 (2000s)		
Nd	30.2	San Miguel Bay, Philippines	Bergonio (2019)

Note: Lm-length at first maturity; nd – no data

Table 4. Maturity stages of female and male *O. ruber* per municipality

Municipality	Mean total length (in cm)	Mean body weight (in g)	Maturity stagesfemale, male)
Mercedes	20.98 (17.8-27)	93.74 (50–200)	mature: 2, 3 gravid: 7, 23 ripe or spawning: 13,18
Basud	20.2 (18.3-22.8)	106.44 (80-130)	mature: 1 (f) gravid: 5 (f) ripe or spawning: 3 (f)
Sipocot	17.04 (11–20.5)	50.54 (20–90)	immature: 4 (m) developing virgin: 3, 12 maturing: 7, 5 mature: 12, 22 gravid: 5, 10 ripe or spawning: 2 (m)
Cabusao	19.72 (16.3-30.2)	82.92 (40–315)	developing virgin: 1, 9 maturing: 2, 2 mature 5, 11 gravid: 18 (f) ripe or spawning: 7 (f) spent: 1 (f)
Calabanga	19.91 (15.4-24.5)	72.37 (30–143)	developing virgin: 4, 10 maturing: 10, 4 mature: 19, 23 gravid: 30, 24 ripe or spawning: 43, 1
Tinambac	14.91 (12.5-22)	32.24 (20–100)	immature: 2, 6 developing virgin: 11, 7 mature: 1, 1 ripe or spawning: 1 (f)
Siruma	19.12 (16–24.5)	69.13 (30–155)	immature: 1 (m) developing virgin: 1 (m) mature: 5 (m) gravid: 4, 4 ripe or spawning: 3, 4

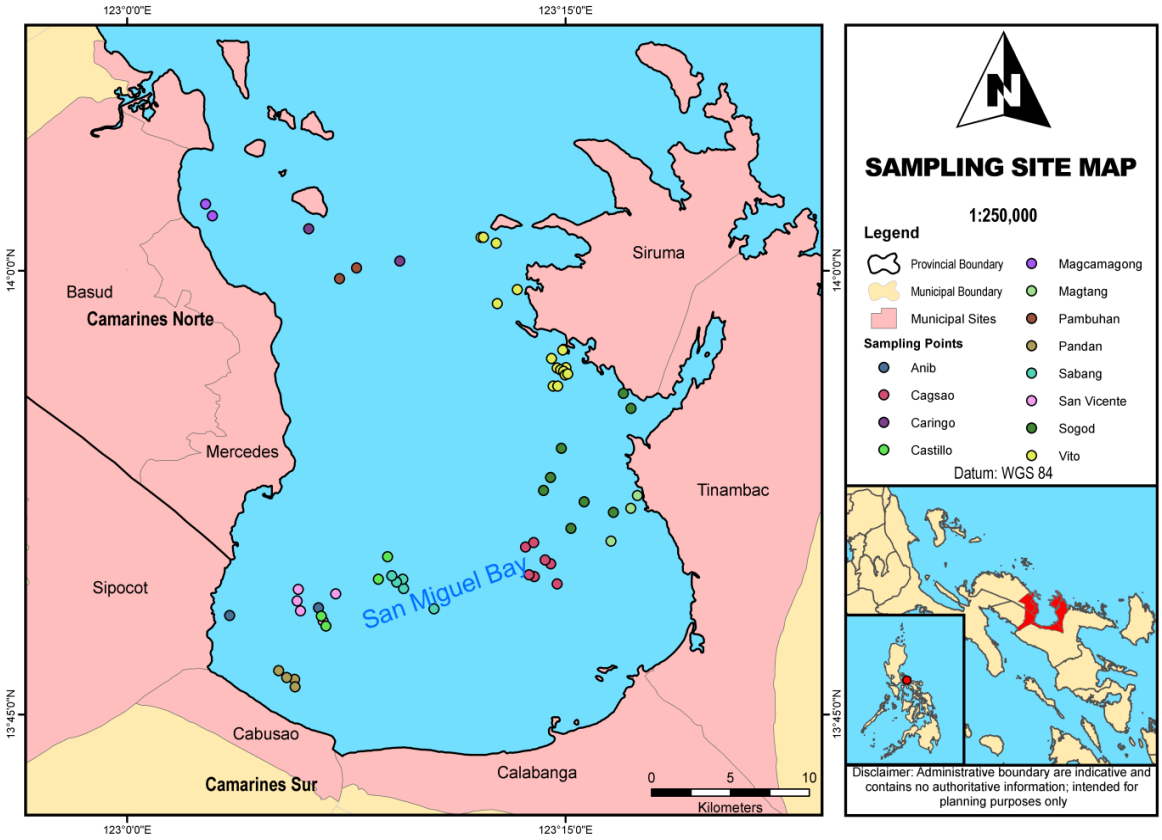

Fig. 1. Sampling stations across sampled barangays in San Miguel Bay municipalities (Source)

approximately from 7 to 16 m which were probably on the same habitat or environmental conditions like currents, type of bottom, type of sediment, etc. The parameters for length-weight relationship may vary by season, habitat and even on a daily basis [12,13]. There were several factors that could affect the LWR of a fish and these include habitat, season, degree of stomach fullness, gonad maturity, sex, health, preservation techniques and differences in the observed length ranges of the specimen caught [14-16].

Moreover, lengths of gonads of the 434 samples were quite alike but in terms of weight there were variations. This suggests further that weights of gonads vary among length size classes and sexes of fish. It also differs depending on the stage of maturity of *O. ruber*.

Results of macroscopic examination of gonads revealed that maturity stages of female *O. ruber* ranged from mature to ripe or spawning while most male *O. ruber* were already mature and gravid with some developing virgin, found mostly in Mercedes, Calabanga and Cabusao.*O. ruber* is amphidromous that regularly migrate between fresh water and the sea (in both directions), but not for the purpose of breeding (www.fishbase.org). Since the surveys were conducted in the months where wind pattern was southwest monsoon probably most of the mature species were migrating from the southern portion of the Bay (Siruma and Tinambac areas) going to the innermost part of it (Calabanga and Cabusao areas) heading towards west (Sipocot) to north (Mercedes) and back and forth. Migrations of this species are cyclical and predictable and cover more than 100 km (www.fishbase.org).

In addition, there were more developing virgin to maturing male as compared to females. The results indicate that length size of fish can be an indicator or somehow determine the stages of its maturity. In this case, *O. ruber* with longer sizes can be at the stage of gravid to ripe or spawning while those with smaller sizes were either immature or still developing. This may also denote that *O. ruber* were still in good condition as the size and color of the gonads, as examined, correspond to length and body size of the fish.

On the other hand, histopathological analysis revealed that *O. ruber* samples were still in normal condition with no apparent lesion despite changes in ecological conditions of the Bay. It means that there were no lesions noted in any form like vascular changes (congestion, edema, and hemorrhages), degenerative lesion (atrophy, aplasia), proliferative lesions (finbrosis, leucocytosis, hemosiderosis), inflammatory lesions (hepatitis, pancreatitis) or even neoplastic lesions (carcinoma, lymphoma). Majority of the gonads displayed many spermatocytes or oocytes indicating they were at the peak of reproductive capacity. The population's reproductive capacity is relatively healthy across municipalities.

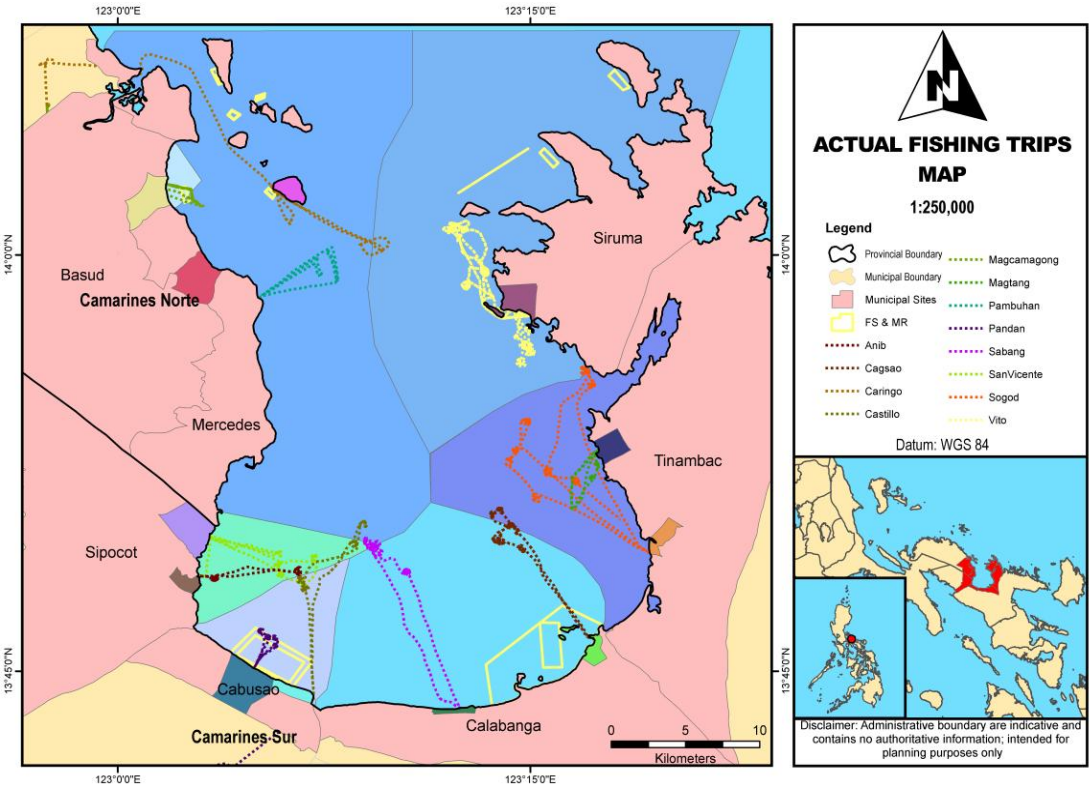

Fig. 2. Map of fishing ground locations of small-scale fishers based on actual fishing trips (Source)

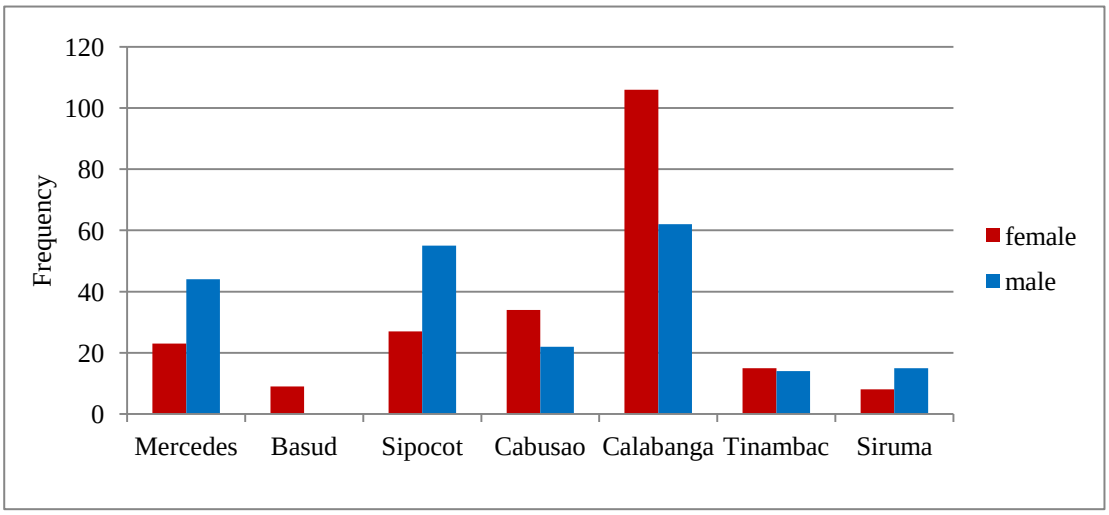

Fig. 3. Number of female and male *O. ruber* across sampling sites

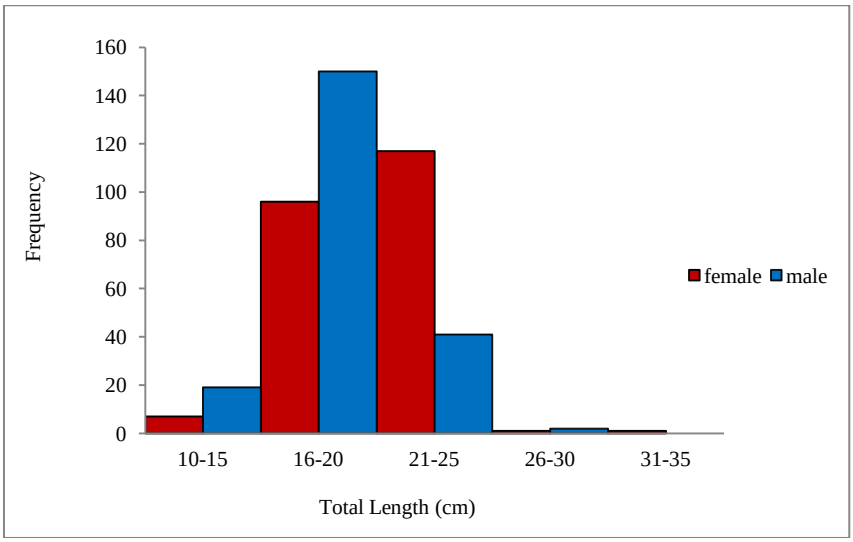

Fig. 4. Species length and abundance distribution of female and male *O. ruber*

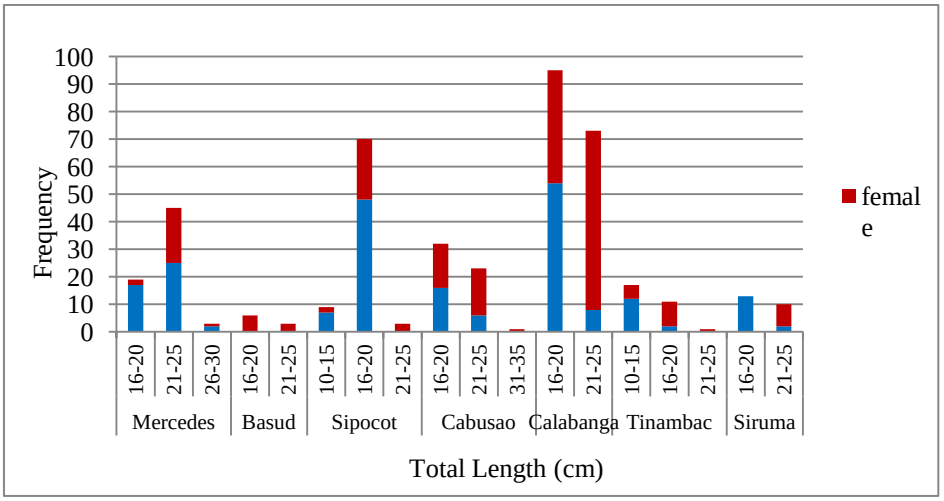

Fig. 5. Frequency and lengths of female and male *O. ruber*

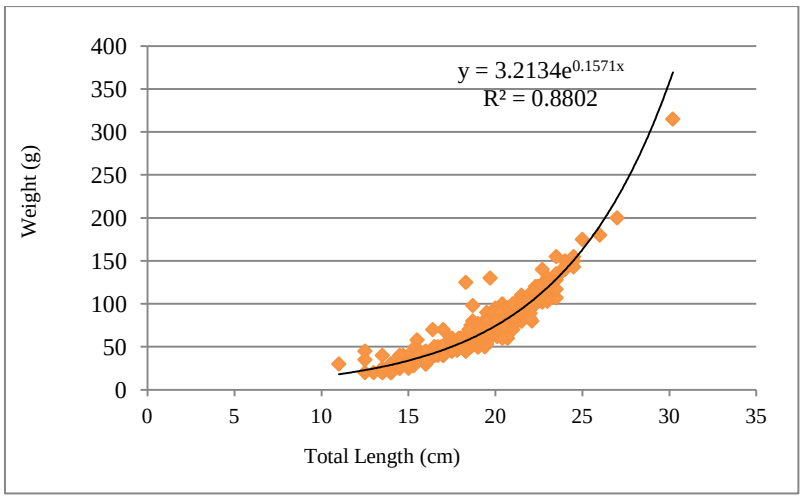

Fig. 6. Length-weight relationship of *O. ruber*

Fig. 7. Length-weight relationship of female and male *O. ruber*

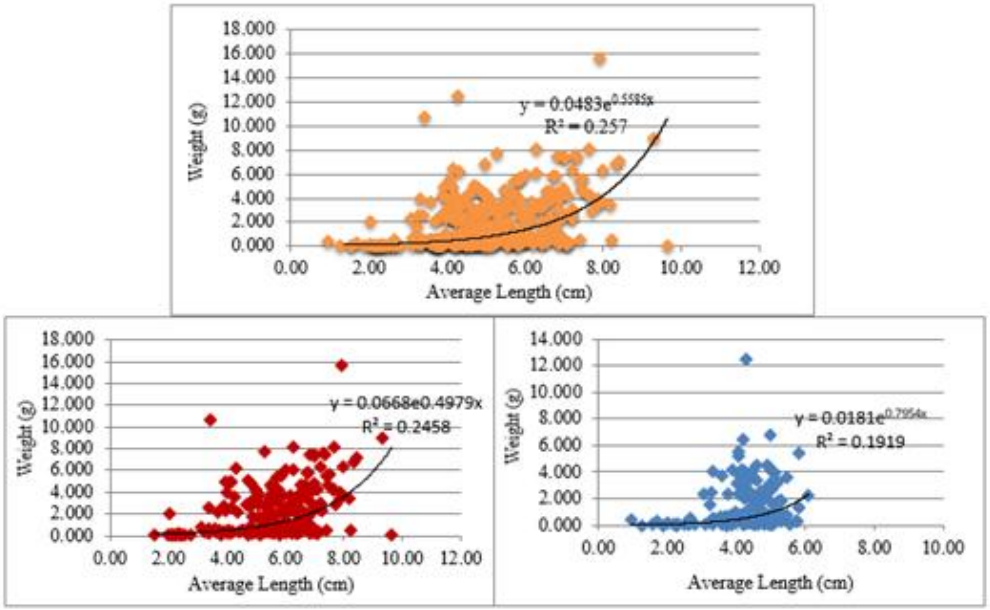

Fig. 8. Gonads Length-Weight Relationship of combined (top) and female and male (bottom) *O. ruber*

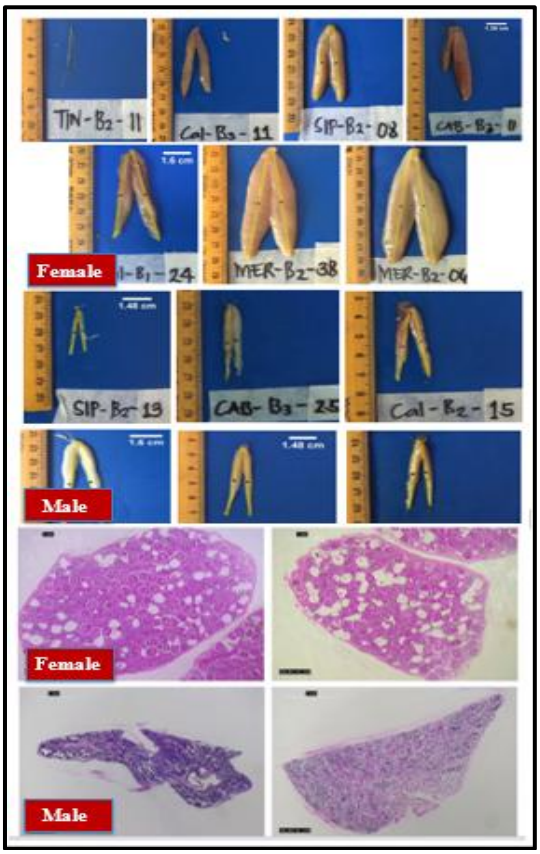

Fig. 9. Macroscopic (above) and microscopic (bottom) images of gonads of female and male *O. ruber*

5. CONCLUSION

In conclusion, the estuarine conditions of the Bay have a major effect on the growth, survival and reproduction of *O. ruber,* thus, it is still relatively abundant and healthy in terms of their reproductive capacity despite changes in coastal habitats and water quality (e.g.,hig TSS and counts of fecal coliform). However, with the prevailing fishing methods and practices (e.g.,timbog and hugos) among municipal fisherfolk including the destructive fishing practice of commercial fishers may worsen the depleting ecological conditions of the Bay. Ultimately, these would result to year-on-year decline of stocks and catch, as evidenced by the trend recorded from 2015 to 2017 catch of *O. ruber*.

Specifically, the non-stop trawl operations as well as unregulated use of prohibited fishing paraphernalia (e.g., small mesh sizes and "tupak") would have irreversible effect not only to *O. ruber* population but also to other flora and fauna composition of the Bay which in time may impair its fisheries productivity. These activities are critical issues that would destroy the marine habitat as these (trawls) are non-selective in the kind and sizes of fish caught. On the other hand, the versatility of gears of municipal fisherfolks to be selective of the target or catch certain species in any habitat or at any trophic level also has a wide-ranging impact to *O. ruber* fishery.

Moreover, legally accessible areas for municipal fisherfolk and their fishing effort are changing because the Bay is also adversely changing and becoming shallower due to siltation and other unsustainable anthropogenic and land-based activities around the Bay. These modifications may entail additional burden and expenses for them everytime they visit their fishing grounds to catch *O. ruber* and other marine species.

The Bay is considered as a nursery ground for many marine species, thus, most of the fishes caught including *O. ruber* are predominantly juveniles. Since then, the Bay, as a whole, is overexploited due to increasing number of fisherfolk that resulted to expansion of fishing

effort. Thus, it is essential that, in harmony, the 7 San Miguel Bay municipalities together with the fisherfolk through its MFARMCs must take care of the marine ecosystem by maintaining sanctuary and imposing control mechanisms, rehabilitation of important habitats like mangroves, and serious enforcement of laws. However, this should be done in a way that would not compromise the ability of the fisherfolks to earn a living.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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