Fishery of commercial scallops in Asid Gulf, Philippines

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Abstract. Five species of scallops (Bivalvia: Pectinidae) support the commercial scallop fishery in Asid Gulf (Masbate) Philippines. Two species composing 96% of total annual harvest were *Decatopecten striatus* Schumacher, 1817 (57%) and *Chlamys funebris* Reeve, 1852 (39%). About 1-2 t/day of adductor muscle was extracted from the fishery. This extraction is taken from a harvest of 255 t/month of shell-on scallops except during the last quarter months of the year when weather condition was unfavorable for hookah diving to gather scallops. The fishery represents the most-diverse scallop resource exploited with very high yield from a single area. Scallop yield in 2017 declined by about 86% from 2003 and 79% from 2007 due to the combination of massive growth overfishing and fishers' retreat from the fishery due to uneconomic returns. The analytical assessment of the species revealed they grew relatively fast and exhibited single recruitment mode. High fishing mortalities were expended on them leading to elevated exploitation rates higher than their maximum sustainable levels. Mean capture lengths were significantly smaller than their maturity sizes. Implementing a rational fishing regime combined with marine reserve protection is imperative to sustain the resources.
Key Words: total yield, length-based assessment, species richness, exploitation rate, Bicol.

Introduction. The impact of fishing to a bivalve resource is defined by the effort used, the sizes of animals exploited and the manner of fishing. Scallops dredging and trawling apply relatively high rate of fishing effort (Thrush et al 1995; Kaiser et al 2006; Hall-Spencer & Moore 2000) compared to hand-picking. Use of tools for scallop harvesting can also cause more adverse effects to scallop bed ecosystem. But high, unregulated fishing effort of any method leads to overfishing, depletion of resource and eventually loss of species diversity. Published works on scallops in the Philippines were mainly on the Asian moon scallop *Amusium pleuronectes* (Linnaeus, 1758) (Llana 1978, 1979, 1988; Llana & Aprieto 1983; del Norte 1988, 1991; Belda & del Norte 1988). *A. pleuronectes* are captured by trawling. In Asid Gulf, Masbate, five scallop species were commercially collected by literally picking them at the bottom by divers equipped with hookah or "lifeline", a plastic hose directly connected to an air compressor for breathing (Soliman & Dioneda 2004). Of the five species, two (*Decatopecten striatus* and *Chlamys funebris*) composed 96% of the total annual harvest. Divers on board motorized boats (i.e., 2-3 persons/boat in 16-Hp and 5-6 in larger diesel engines) operate 18-22 days/month by collecting scallops by hand and hauling catch using large scoop nets at depths of 75-150 feet. Divers per boat harvest about 10-30 sacks of scallops a day (a sack of shell-on scallop weighs 70 kg, where about 9 kg of adductor muscle per sack can be obtained). In the Philippines, the gulf is the only remaining site where natural populations of scallops are abundantly thriving and fished commercially. Annual production in the gulf is reported at 1,100 mt of shell-on scallops (Soliman & Dioneda 2004). This harvest volume is higher than any annual yield of scallops in the Philippines reported during the period 1977-2014 (FAO 2016).

The history of scallops harvesting in the gulf has begun in 1995 (Soliman & Mendoza 2005; Soliman & Bobiles 2005). Fishers from Naro Island, Cawayan, Masbate were encouraged by transient Visayan scallop divers, the first group of fishers to harvest scallops off the island for livelihood and profit. Old fishers in the island were already seeing scallops in the coast but they were not collecting them as a means to earn a living, although few of their folks eat the adductor muscle and other innards of the animal. But in 1996 the islands fishers started to harvest scallops, initially at low volume, then, after a short period in large volumes, to extract adductor muscle from the scallops. The muscles were sold to Visayan buyers who brought the product to Cebu. Harvesting intensity swelled significantly in few months, which in less than three years caused the resource in harvest beds to collapse in 1999 (Soliman & Mendoza 2005). Commercial harvesting resumed in 2001. Since 2004 through 2009, the harvest volumes were no longer stable. However, the 150 t a month production (Soliman & Dioneda 2004) is significantly higher than the scallop production in Lingayen Gulf for the commercial and municipal catches reported by del Norte et al (1988), and it is comparable and even higher than most annual values of scallop production for all species in the Philippines (BFAR Fisheries Statistics 1972-1984). Through quick stock assessment (Beverton & Holt 1957), the range of exploitation rate in the three most dominant scallop species was found to be 0.58-0.75 indicating full to higher than optimum exploitation (Soliman & Dioneda 2004).

This paper describes the high diversity of scallop species exploited in the gulf that is exceptional in species richness and volume of harvest. Detailed analysis of the growth, mortality, exploitation rate, recruitment pattern and relative yield-per-recruit were performed on and compared between *D. striatus* and *C. funebris*, the two most dominant species composing 96% of the total production. The assessment showed the two species are exploited beyond their sustainable levels stressing that setting a harvest regulation is imperative.

Material and Method. Asid Gulf is a large body of water bordered by five towns in Masbate (Figure 1).

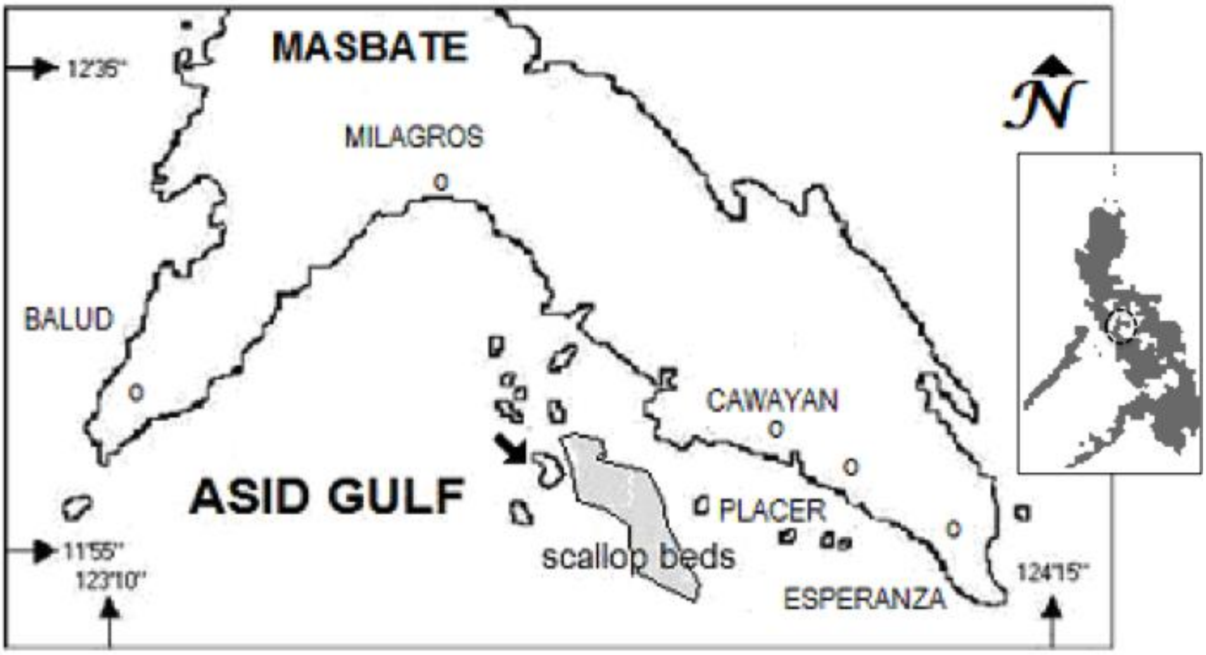

Figure 1. Asid Gulf, Masbate; Naro Island (pointed with an arrow) and scallop production bed (shaded) with Philippine map (inset) indicating the gulf (dashed circle).

There are 13 islands and islets in the gulf namely Naro, Guinauayan, Chico, Pobre (also called Cobre), Nagurang, Guinlubngan, Gilutungan, Piña, Namatyan, Naro-Dyut, Nabuctot, Bagamanoc (also called Manoc-manoc or La Manok) and Jintotolo. The islands of Guinauayan, Naro, Chico and Pobre have been declared “wilderness areas” by virtue of Presidential Proclamation 2151 of December 29, 1981. The eight islands consisting of Naro and Naro-Dyut, Guinlubngan, Gilutungan, Pobre, Piña, Bagamanoc, Chico and Namatyan, spaced about a kilometer or less apart, are within the administrative jurisdiction of Cawayan, Masbate. Almost all scallops harvested from the gulf are by fishers from Naro Island. Significant portion of the scallop production beds lie within the Recodo Marine Fishery Reserve (MFR) of Cawayan The scallop production beds in the gulf are within the Recodo Marine Fishery Reserve (MFR) of Cawayan. The Recodo MFR is established off Barangay Recodo in Cawayan by virtue of Cawayan Municipal Ordinance No. 99-02 passed in 1999. Efforts to manage the fishery reserve and the schemes to regulate and enhance scallops stocks can complement one another towards an ecosystem-based fisheries management. It is primarily because the reserve harbors a significant portion of the natural ground for scallops therefore enhancing management of the reserve (i.e., fully enforcing reserve regulations) can redound to improved protection of scallop stock.

Taxonomic identification. The two most dominant scallop species were monitored of their morphometrics by sampling commercial catches. Taxonomic references for first identification were by Eisenberg (1981) and Kira & Habe (1962-1964). Confirmative examination of the scientific names was done by the Conchology Division of the National Museum of the Philippines.

Sampling, total yield and scallop measurements. Sampling activities were focused in Naro Island that has four barangays namely Punta Batsan, Looc, Talisay and Naro. Representative samples (n = 300 per species) were obtained from commercial catches in 2007. Total aggregate yield from the scallop fishery for 2007 and 2017 were calculated from data in inventory of fishing gear such as gear units and annual trip frequency multiplied by mean catch from catch survey. Catches were monitored regularly from fishers. Data were verified from catch logs of buyers complemented by key informant interview. For length-frequency analysis, 300 individuals of each species were measured monthly of its shell height (SH) and shell width (SW). Measurements of length (0.01 cm) and weight (0.1 g) were done using vernier caliper and electronic balance. Before the length-frequency analysis, the monthly length frequency data were analyzed using spreadsheet software to generate the characteristics of each component distribution.

Analytical assessment. Growth, mortality, recruitment and yield-per-recruit analyses were performed using the FISAT II Ver. 1.2.2 (Gayanilo et al 2005). The limitations of this technique is well understood and technically considered. The von Bertalanffy Growth Function (VBGF, 1938) that expresses rate of change in size of an animal as it attains the maximum was used to depict the growth pattern of the scallops. Initial values of the VBGF parameters were derived using several methods (e.g., Taylor 1958). Coefficient of total mortality (Z/yr) was estimated through catch curve analysis. Z was split into natural (M/yr) and fishing (F/yr) mortalities. M of *C. funebris* used in the analysis was the average M (= 0.55) of *Chlamys* spp. in Orensanz et al (1991). M of *D. striatus* used was the average M (0.54) of the "pectin" genera (e.g., *Argopecten*, *Patinopecten*, *Pecten*, *Placopecten*) in Orensanz et al (1991). Use of these mean values attempts to address the limitation of directly estimating M of scallops. Exploitation rate (E) was the ratio F/Z. Current exploitation rates (E_{cur}) were compared with the E_{max} whereby the difference of E_{max} - E_{cur} (if positive) indicates "excess" exploitation rate that is converted to percentage of E_{max}. If negative, it means exploitation is within sustainable level, and 1 means the two are equal thus current exploitation is at the maximum level. An optimum E = 0.50 has been adopted (Gulland 1971).

Results. Five species of scallops are the major fishery targets in the gulf. They are *D. striatus*, *C. funebris*, *C. nobilis*, *C. macassarensis* and *C. gloriosus* (Figure 2).
The first two species constitute 96% of the total annual scallop production. Other species caught associated with scallops where their adductor muscle was also extracted were *Spondylus* spp. and *Chlamys* spp.


Commercial Species of Scallops in Asid Gulf

There are five major commercial species of scallops in the gulf namely

- *Decatopecten striatus*. They are in two colors – pale white and yellow-orange. They possess large ridges along the periostracum or outer shell. The species is locally called *Tikab*. Although the other species are called by the same name, *D. striatus* should bear the original vernacular name. They are harvested at depths of 45-100 feet.
- *Chlamys (Mimichlamys) senatoria nobilis*. They are of different colors such as yellow, light red, orange and violet. The ridges along the peristracum are fine and rough. They are called locally *Tikab de color* because of their varied colors. Divers collect them at 60-80 feet.
- *Chlamys (Mimichlamys) funebris*. The color of their outer shell is generally light purple and the inner smoother shell is light chocolate brown. The ridges in the periostracum is fine and less rough than the *C. senatoria nobilis*. They are locally called *Tikab dakula* (or larger scallop). They are collected together with the *C. senatoria nobilis*.
- *Chlamys (Annachlamys) macassarensis*. Their general natural color is light brown mottled alternately with light brown, white and dark brown along the medium-sized ridges. They are locally called *Paypay* because the outer shell is shaped like the traditional fan made of *Anahaw* palm leaf with the same local name. They are few in volume from the catch of scallop divers. They are collected at depths of 80 feet and beyond together with the *Tikab de color*.
- *Chlamys (Mimachlamys) gloriosus*. They are the largest of the scallop species in the gulf reaching 10 cm in shell height. Their natural color is light reddish pink with few small dark dots. They are locally called *Tigre* because their outer shell color resembles the tiger. They are harvested from 90 feet to deeper areas together with the pearl shells.

Figure 2. The five commercially important scallops in Asid Gulf, Masbate, Philippines (Soliman & Bobiles 2005).

Catches totaled 2308 t in 2007 (Figure 3). This is equivalent to 15.39 t adductor muscle extracted every month.

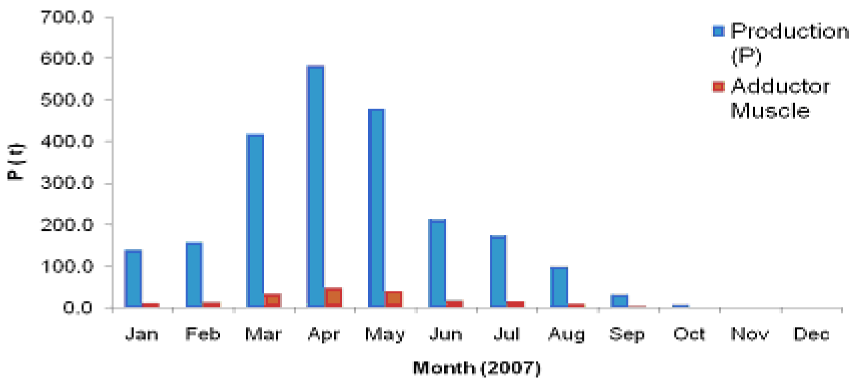

Figure 3. Total production of scallops in Asid Gulf in 2007 (Soliman et al 2010).

Adductor muscle was about 8-10% of total fresh weight. Catches peaked in March to May. Catch in October to December was lowest at 1.6-7.0 t/month. Divers worked 6-8 hours/trip. Total number of boats operated remained within 200-250 as those obtained in 2003. In 2017, total yield was estimated at 1,554 t from a mean catch of 0.6 t/boat/month from approximately 100-250 boats operating (Figure 4). This shows a significant decline of 79% from 2007 level and 86% from 2003 level.

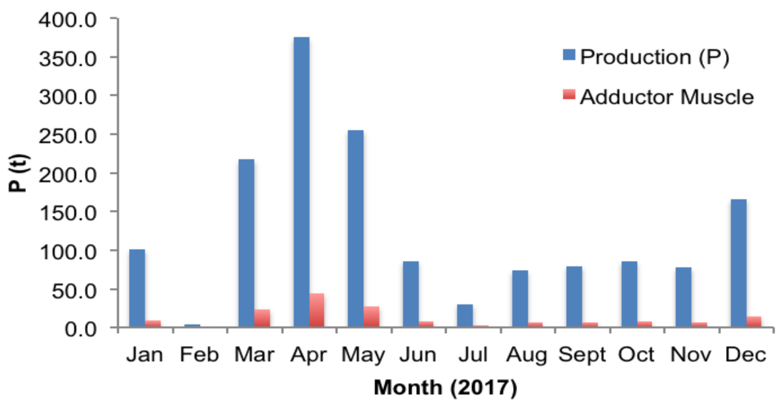

Figure 4. Total production of scallops in Asid Gulf in 2017.

The asymptotic shell height (SH_∞) obtained for the two species was 7.88 cm and 11.29 cm for *D. striatus* and *C. funebris*, respectively (Table 1).

Table 1

Population parameters and exploitation indices of the two scallop species

Species	SH_∞ (cm)	*K* (/yr)	R_n	*Z* (/yr)	*F* (/yr)	*M* (/yr)	E_{cur}	*E=0.5*	E_{max}	$E_{0.1}$	L_c (cm)
D. striatus	7.88	1.11	0.994	5.23	4.69	0.54	0.90	0.5	0.68	0.57	3.09
C. funebris	11.29	0.67	1.0	4.92	4.37	0.55	0.89	0.5	0.78	0.66	4.83

The growth constants (K/yr) were 0.67 and 1.11 whereby *D. striatus* indicated faster growth than *C. funebris*. The values of goodness of fit criteria (R_n) were very high (0.99-1.0) for both species that meant excellent fit of length-structured data to the VBGF model. Mean Z (5.08) was high equivalent to about 70% annual mortality rate. Mean F (4.53) was higher than the mean M (0.54). Relative temporal recruitment pattern for the two species was generally unimodal (Figure 5). *C. funebris* had clearer unimodal pattern than *D. striatus*. Using a t_0 = -1 to generate a time-referenced temporal pattern, the peak of recruitment obtained was May-June (Figure 5). Mean capture lengths equivalent to the SL with 50% capture probability were 3.09 cm for *D. striatus* and 4.83 cm for *C. funebris*.

The E_{cur} of the two species were high (0.89 and 0.90; Table 1). Both values of E_{cur} were also higher compared to E_{max} (0.68-0.78) obtained from the yield-per-recruit analysis (Y/R'). The Y/R' curves for both species showed distinct peaks at which Y/R' was highest at given E (Figure 6) that will allow identification of reference point for policy development and regulatory measure.

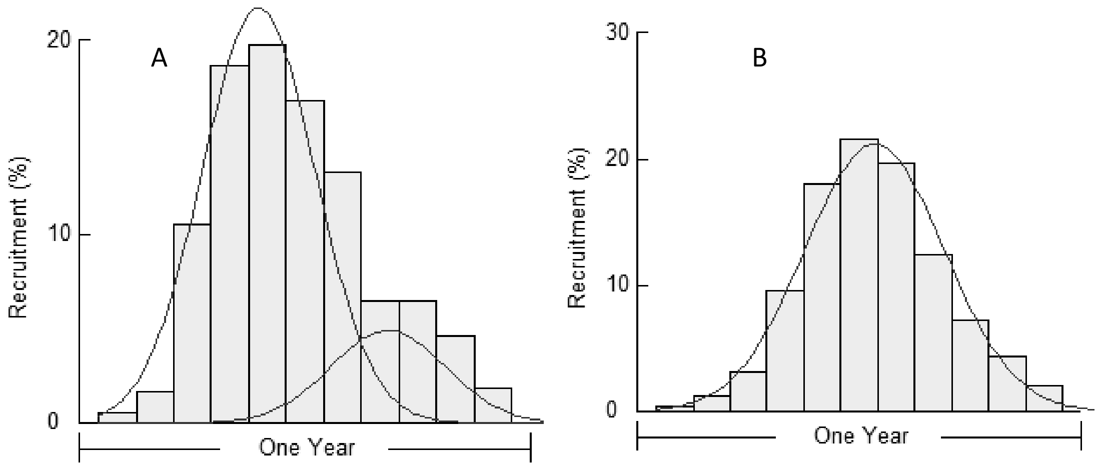

Figure 5. Temporal recruitment pattern of the scallops species assessed; (A) *Decatopecten striatus*; (B) *Chlamys funebris*.

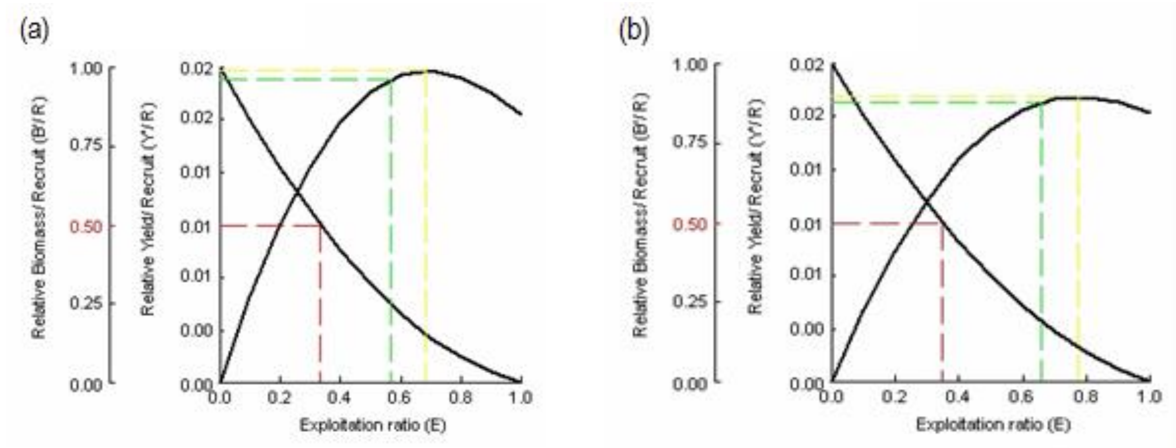

Figure 6. Relative yield/biomass-per-recruit analyses on the two commercial scallops; (a) *D. striatus*: inputs – L_c/L_∞ = 0.39, M/K = 2.54, outputs - $E_{0.1}$ = 0.57, $E_{0.5}$ = 0.33, E_{max} = 0.68; (b) *C. funebris*: inputs - L_c/L_∞ = 0.43, M/K = 2.75, outputs - $E_{0.1}$ = 0.66, $E_{0.5}$ = 0.35, E_{max} = 0.78; green line – $E_{0.1}$, red line – $E_{0.5}$, yellow line – E_{max}.

Discussion. Length-based methods for analytic stock assessment of scallops in the Philippines were applied in Del Norte (1986), Llana (1988), and Soliman & Dioneda (2004). The earlier two studies were on *A. pleuronectes*. The third study assessed three scallop species (*C. funebris*, *D. striatus*, and *C. nobilis*), commercially harvested from Asid Gulf, using a suite of length-based fishery techniques adapted for quick stock assessment. The E values obtained for the three latter pectinids were 0.75, 0.60, 0.63, respectively, indicating exploitation beyond the optimum level (E = 0.5). In the present study, the E_{cur} values (*C. funebris* = 0.89 and *D. striatus* = 0.90) were comparably higher for the two species presently studied. For *D. striatus*, an increase of E_{cur} by 18.6% occurred within four years (2003-2007). *C. funebris* suffered an E_{cur} increase of 50%

during the same period. Moreover, the reversal in the magnitude of exploitation rate expended between *C. funebris* and *D. striatus* during the two periods can be viewed to some extent as serial depletion of the stocks. Finally, there is a very plausible corroboration of the high E values between the two studies that confirms the overexploitation of stocks.

Scallop stocks in the gulf were significantly depleted in 1999 and 2004 (Soliman & Mendoza 2005; Soliman & Bobiles 2005). The fishers would not forget these economically tragic events because they caused displacement of many among them from their major source of livelihood. In 2008, there was similarly very low production in the natural beds resulting to poor harvest that caused significant economic displacement among fishers (Soliman et al 2008). For the steep production declines in 1999, 2004 and 2008, there seems to be a 4-year interval of very low population level but its exact mechanism of occurrence is still not clearly understood.

Mean values of SH at first capture (L_c) are 28-48% less than the estimated size at first maturity for the two species. The two species were estimated to mature at 6.01-6.13 cm (Soliman & Dioneda 2004) that is significantly lower than their L_c range of 3.1-4.8 cm in the 2007 study. There was also a notable decrease in the L_c values due to intensified fishing of smaller scallops from 2003 (i.e., L_c range of 4.14-5.08 cm) to 2007 (L_c = 3.09–4.83 cm) Soliman & Dioneda (2004). The mean size of the stocks is decreasing as they are continuously caught before they reach maturity sizes.

The exploitation of the five commercial species is exceptional in terms of species richness. Only one major scallop species was reported in the fisheries investigated by Del Norte (1986), Lopez (1986) and Llana (1988) in the Philippines. But in Asid Gulf, five major species are exploited commercially, including several associated pectinids. Production projected in 2003 (11,000 t) (Soliman & Dioneda 2004) was almost four times than that obtained in 2007 (2,308 t) and about seven times produced in 2017 (1554 t). The declines can be due to massive growth of overfishing that is pervasive in the gulf since the beginning of the fishery in mid-1990s. Decline in 2017 was also due to the stop of scallop diving from one (i.e., Talisay) of the four villages due to poor scallop catches. Such "exodus" of fishers could be a tipping point in resource productivity which if continues to persist is a precursor to resource depletion. The lowest yield in February can be attributed to the prohibition of harvesting due to the closed season ordinance for scallops in Cawayan. Many scallop divers also diverted their livelihood to cuttlefish fishing and gathering of seahorses and sea cucumber that command good market price. Production in October to December 2017 showed divers could force themselves to risk further (e.g., diving 125 feet deep for 6-8 hours a day) when operations yield low income compared to their scallop diving heyday in early 2000s. Large breeders are likely collected that would endanger the spawning stock. Studies are going on to evaluate this hypothesis, and if it would be true would be disastrous to the fishery. Combined effects of growth and recruitment overfishing could lead to stock depletion. Many boats were operating in 2017 so the catch per boat became too low to be profitable.

Regulating harvest level should be pursued in complementation with enhancing management effectiveness of the Recodo MFR including provision of alternative livelihood. The sustainable harvest regulation (e.g., based on Y/R' indicators) will be vouched by the existing provincial ordinance "prohibiting the use of compressor for fishing in the municipal waters of Masbate" (Provincial Ordinance No. 166-2001, s. 2001). The Recodo MFR boundaries overlap with the scallop production beds, so effective enforcement of MFR regulations directly limits scallop fishing area (Soliman et al 2002). Typically the MFR is a legally regulated fishing zone and portion of the reserve is a non-fishing zone in the Philippines.

Conclusions. Diversity ensures productivity but attracts adversity. The gulf supports a highly-diverse scallop resource but its exploitation is at levels beyond what can be sustained over long-term. Over-exploitation is exacerbated by decreasing capture lengths as immature scallops are continually harvested. Implications of the findings to fisheries management point to the: (i) urgency to regulate scallop harvesting, (ii) potential depletion of the resource over short-term, if regulation is disregarded, (iii) setting-up scallop culture pilot sites with fishers association to showcase it as viable technology and strategy for managing, and (iv) need to put in place a management policy complemented by marine reserve management, scallop culture and rational harvesting scheme spearheaded by the local government with the fishers.

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