Overfishing of Three Siganid Species (Family: Siganidae) in Lagonoy Gulf, Philippines

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Abstract
Juvenile and older *Siganus canaliculatus*, *S. spinus* and *S. argenteus* were assessed in Lagonoy Gulf from analysis of total juvenile catch trend obtained in commercial fishing operations and using length-based fishery methods to generate evidences of overfishing of the resource. Estimates of annual instantaneous total, fishing and natural mortalities were high which corresponded to their high exploitation. Exploitation rates of the three species were higher by 34-64% beyond the level that would be sustainable. Capture lengths were generally lower than their reported maturity size which means the fishes were caught before they would have contributed to recruitment in the fishery. Total juvenile catches and catch-per-unit-effort in 2001-2004 were continuously declining, which registered 50% decline in 2003-2004. The highest volumes of juvenile catch were obtained consistently in April and May new moons although the appearance of juveniles is apparently year-round. At about the same period in summer (April and May), the larger, gravid siganids, were fished intensively although the fishery has been practiced throughout the year. The high exploitation of juveniles and larger siganids in the gulf could not be expected to decrease in coming years but rather it would intensify given the historical uptrend of fishery exploitation in the gulf If left unregulated within sustainable level for the older fish and not rationalized until completely stopped for the juveniles, this will lead to significant stock depletion that will be disadvantageous to the fishery as a whole.

Keywords: overfishing, stock assessment, siganid, settlement, new moon

Introduction

Overfishing essentially consists of catching too many fish spawners and their young. Referred to as "spawners" and "young" overfishing (Gushing 1972; Pauly 1988), respectively, the first is difficult to detect because parent stock-recruit function is often not well-defined (Gushing 1977; Ricker 1975) and the second could persist without immediate effect to the resource (Gulland 1974). Thus, the excessive catching of spawners could be more likely faulted for low recruitment than for diminished population of mature fish and the over-harvesting of young fish could be less faulted for low settlement and recruitment than for low biomass increase from growth. Their direct, more adverse lagged effects, characteristic of high exploitation regime, may take longer time to be established, but evidences on their prevalence exist and are revealing.

As a problem in fisheries of global proportion (Pauly et al. 2005; Pauly 2006), overfishing has been also reported in major Philippine fish stocks as early as the late 1970s. In San Miguel Bay, one of the most studied fishing grounds in the country, its major fish stocks had been concluded to be biologically and economically overfished (Pauly and Mines 1982). The sequence in the latter point has to be stressed, as a functional paradigm, that biological overfishing precedes economic overfishing. However, the economic consequences of overfishing are more obvious (i.e., send greater alarm signals) than the biological ones particularly to the fishers and local government management entity. It is true for many instances in tropical fisheries because the biology of overfishing are apparently more difficult to appreciate than its immediate economic impacts, and that stock assessment monitoring toward generating basis for technical measures in management are costly to undertake. Thus, rapid stock assessment methods, of shorter study duration hence more cost-effective, are often performed as in data-limited situations.

Data limited fisheries pose data-generation challenge to fishery biologists and managers. In many cases, they are faced with lack or absence of formal fishery data of an existing commercial fishery. However, assessment of exploited stocks takes primacy of the tasks prerequisite to management, and the precautionary approach

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is relevant in this context. This situation exemplifies the siganid fisheries of Lagonoy Gulf, Philippines. Siganids account for 10-15% of the gulf's annual fishery production of 23,000 mt/yr (Soliman et al. 2005). Fourteen species are targets in the fishery and three species namely *Siganus canaliculatus*, *S. spinus* and *S. argenteus* (Family: Siganidae) constitute about 90% of the total siganid catches, where only the former has been assessed (Soliman and Yamaoka unpublished). Cognizant of these, the siganids, considered by fishers in the gulf as "chickens of the sea" which provide affordable protein source for coastal people, urgently need assessment to provide scientific basis for stock management and protection.

In the paper, evidences of biological overfishing of the three most abundant siganid species of Lagonoy Gulf are examined from their exploitation rates estimated using length-based fishery assessment methods and from an analysis of the trend of total catch of the siganid juvenile fishery in the gulf in 2001-2004.

Materials and Methods

Field sampling and study stations

Nine sampling stations were defined in Lagonoy Gulf (3701km^2), southeast of Luzon, Bicol Region, Philippines (Fig. 1). The gulf is a semi-enclosed body of water where fishing is a major source of livelihood. Its coast is lined by fringing coral reefs and seagrass-seaweed beds interspersed with mangroves. Fishery for juvenile and older siganids is operated most intenstively during the dry season (March, April and May) although siganids are caught throughout the year. Most siganid juvenile occurrences happen in the East Coast of Albay Province along San Miguel Island and Cagraray Island. Siganid juveniles are fished using bagnet and seine net.

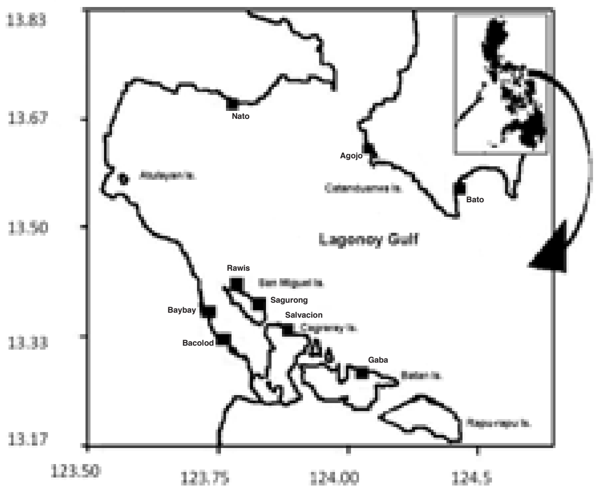

Fig. 1. Sampling stations for siganids (solid squares) during the study.

Older siganids are fished using gillnet and fish corral. The nine stations monitored for the study (from catches of the four gears) were Sagurong, Rawis, Bacolod, Salvacion, Baybay, Gaba, Nato, and Bato and Agojo (Fig. 1). Monitoring was successful in the first four stations (the first three sites are in Tabaco City and the fourth site in Bacacay, Albay) where they occurred. Length-frequency monitoring of larger siganids was done for three months per species in 2006.

Stock assessment and data analysis

The non-seasonalized version of the von Bertalanffy growth formula $L_t=L_\infty\ (1-e^{-k(t-t_0)})$ was used to quantitatively depict the growth of the siganid stocks investigated. The asymptotic length (L_∞) was estimated as $L_{max}/0.95$ (Taylor 1958), where L_{max} is the maximum total length observed during the study. Some values of growth constant per year (K/yr) and all values of length-at-first maturity (L_{mat}) used in the analysis were obtained from published literatures. Total annual instantaneous mortality (Z) was estimated from Beverton and Holt (1957) based on the mean length from commercial catches. Natural instantaneous mortality (M) was estimated from the method of Pauly (1980). Fishing mortality (F) was estimated as Z - M. The current exploitation rate (E_{curr}) was estimated as F/Z. Relative yield-per-recruit (Y'PR) corresponding to Ecurr (Current exploitation rate of a species) and $E_{0.5}$ (Exploitation rate at where F is 50% of Z) were estimated using the modified Beverton and Holt (1956) model by Pauly and Soriano (1986). The FAO-ICLARM Stock Assessment Tools or FISAT Ver. 1.2.2 (Gayanilo and Pauly 1997) was used to perform Y'PR analysis and the Bhattacharya (1967) method for resolving Gaussian components from the length- frequency data. Statistical analysis was done using SPSS 15.0.

Results

Length structure

The length distribution of the three siganid species studied showed distinct modes (Fig. 2). Mean lengths of *S. spinus* and *S. canaliculatus* were close in values at about 13 cm and 14 cm, respectively (Table 1). Cut-off lengths or the lower limit of the length-class used in the analysis were both about 10 cm for the two species. For *S. canaliculatus*, total length (TL) measurements below 10 cm (Fig. 2) were not used in the analysis but they were shown to indicate the almost non-selective gears catching young of the fish. The exclusion prevented unnecessary depression of cut-off length value. Mean and cut-off lengths of *S. argenteus* were the longest among the three

Table 1. Vital population parameters, exploitation rates and biometrics of the siganid stocks studied.

Species	L_∞ (cm)	L_{max} (cm)	K (/yr)	Z (/yr)	M (/yr)	F (/yr)	E_{CUR}	E_{05}	L_M (cm)	L' (cm)	L_{MAT}*	L_{50} (cm)	Sampling period
S. canaliculatus	28.5	27.5	0.58[a]	3.00	1.29	1.71	0.57	0.35	12.97	10	11.7/ 14.3[d]	12.66	Mar-May 2006
S. spinus	19.3	18.4	2.32[b]	3.09	1.30	1.79	0.58	0.39	13.7	9.5	14.7[e]	13.49	Mar-May 2006
S. argenteus	29.7	28.2	0.75[c]	3.17	1.51	1.66	0.52	0.37	17.0	14	20.2[f]	17.05	May-July 2006

L_M -mean total length; L' - cut-off length; L_{MAT} - TL at maturity.

[a]Soliman and Yamaoka (unpublished data); [b]Pauly (1978); [c]Kitalong and Dalzell (1994); [d]Laviña and Alcala (1973) for male and female fish, respectively; [e, f]*Fishbase*, Froese and Pauly (2008) - estimated from L_∞.

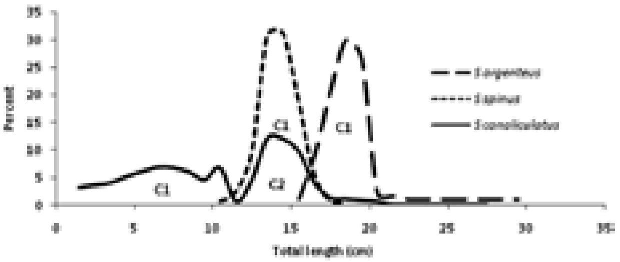

Fig. 2. Smoothed length distribution of the three siganid species studied showing where the normal components were resolved (C1, C2).

Table 2. Statistics of the Gaussian components resolved from the length frequency distributions.

Species	Components								Cases
	1				2				
	Skewness	Kurtosis	Mean	SD	Skewness	Kurtosis	Mean	SD	
S. canaliculatus	0.316	0.575	6.85	1.96	0.629	0.789	14.55	1.4	1245
S. spinus	0.254	0.818	14.17	1.18					1009
S. argenteus	0.810	0.818	15.14	1					370

species at 17 cm and 14 cm, respectively. Estimated TL at first capture (LC_{50}) for the siganids ranged from 12.66 to 17.05 cm. Two Gaussian components were resolved from the *S. canaliculatus* distribution while one component was resolved from each of the distributions of *S. spinus* and *S. argenteus* (Fig. 2 and Table 2). The measures of skewness and kurtosis were highest on S. *argenteus* (Table 2).

Vital population parameters, biometrics and exploitation rates

Population parameters, exploitation rates and biometrics of the three siganid species studied are presented in Table 1. The growth (L_∞, K, L_{MAX}, L_M, L') and maturity (L_{MAT}) measures of *S. argenteus* are the highest among the three species followed by those of *S. canaliculatus*. The lowest of these measures were exhibited by *S. spinus*. Ranges of annual Z, M and F were 3.00-3.17, 1.29- 1.51, and 1.66-1.79, respectively. Current E ranged from 0.52 to 0.58, which was higher than $E_{0.50}$ (0.35-0.39). L_M values were all lower than L_{MAT} except for male *S . canaliculatus* where $L_M > L_{MAT}$. LC_{50} values (12.66-17.05 cm) confirmed this further because LC_{50} of all three siganids were lower also than L_{MAT}.

Catch and effort of juvenile fishery

Total juvenile yield from 2001 through 2004 was declining steeply from 357 mt, 314 mt, 265 mt and 133 mt, respectively (Fig. 3). Highest yield drop of 50% was recorded during the 2003- 2004 period. *S. canaliculatus* juveniles were predominant at 78% of total annual catches; *S. spinus* and *S. argenteus* collectively composed 11% and the rest are formed by other siganid juvenile species. Catch-per-unit-effort (CPUE in kg/trip/gear unit) of bagnet and seine net showed progressive decline during the four-year period (Fig. 4). CPUE of bagnet declined faster (about 55%) than seine net CPUE (about 30%). Peak production months were April and May although there were minor peaks in September in 2001-2003 (Fig. 5). The mesh size of bagnets and seine nets used by fishers to catch siganid juveniles was 1-5 mm.

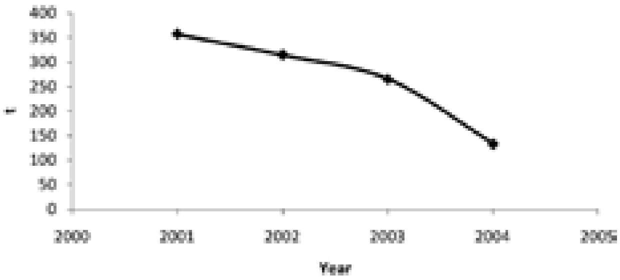

Fig. 3. Total harvest of siganid juveniles in Lagonoy Gulf.

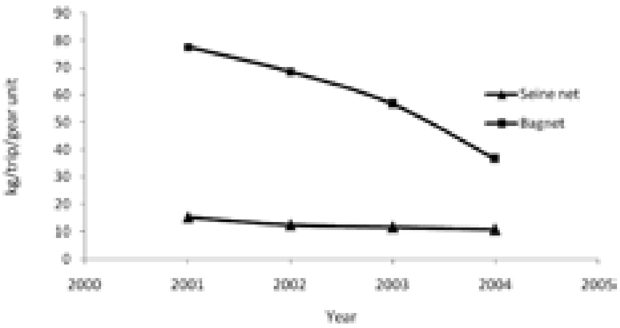

Fig. 4. Catch-per-unit-effort of gears catching siganid juveniles in Lagonoy Gulf.

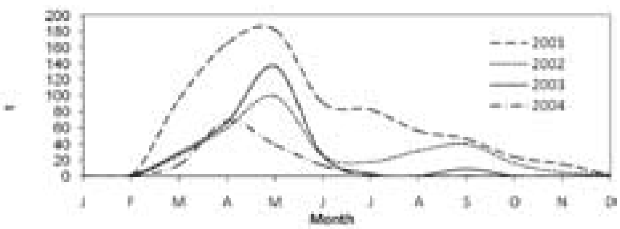

Fig. 5. Total monthly harvest of siganid juveniles in Lagonoy Gulf.

Discussion

The asymptotic lengths and growth constants obtained for the three siganid species were typical values for short-lived tropical fishes with fast biomass turn-over (Pauly 1980). *S. argenteus* possessing the longest biometric measures and *S. spinus* the shortest, are consistent with the reported biology of the two species (Woodland 1990; Woodland 2001). The most abundant species in the gulf, *S. canaliculatus*, were intermediate in size. Moreover, the finding that the length distributions of these three species were normal vouches for data quality and representativeness in the analytic methods used. Samples were collected from commercial catches in the Albay East Coast where the fishery is concentrated and monitored in the study during the peak harvest months in April and May. This assessment of the most abundant, the largest and the smallest siganids (in absolute size), which included mature and immature ones, should well represent the status of the resource in the gulf.

Estimates of annual instantaneous total, fishing and natural mortalities were high which corresponded to their high exploitation. In terms of the proportion of current B beyond $E_{0.5}$ (i.e., advising an optimum fishing mortality to be 50% of the unexploited biomass), the siganid stocks were overfished by about 3 4-64%. The principle basis of $E_{0.5}$ advances that optimum exploitation regime occurs when fishing mortality is equivalent to natural mortality (Gulland 1983; Pauly 1984). The high fishing pressure on the resource is further shown by the LC_{50} and L_M being generally lower than L_{MAT} reported for the species. This means the fish were caught before they reach maturity, or are yet to contribute to recruitment and settlement in the fishery. It appears that male *S. canaliculatus* may have been less affected by growth overfishing because their $L_M>L_{MAT}$ or $L_M>LC_{50}$. Overall, the mortality parameters, exploitation rates and key biometrics of the three species point to high fishing pressure beyond the regenerative capacity of the resource.

Fishers in the gulf have exploited the immature fish by capitalizing on their indigenous knowledge of siganid settlement. The 'runs' or migration of juveniles toward the coast (Woodland 2001), which fishers observed through the years, determine the timing of fishing activities. Bagnets and seine nets were operated on the same day juveniles occurred. Fishers do not catch juveniles that have arrived two days or more past their settlement because they would be unsuitable for consumption or fermentation as fish of this age taste bitter after they have eaten from seagrasses. Juveniles of *S. canaliculatus* were reported to appear in large schools at around new moons (Woodland, 2001). The small portion of *S. spinus* and *S. argenteus* that were caught together with *S. canaliculatus* indicates certain overlap with the latter in their spawning. Inferred from pre-juveniles and juveniles occurrence, spawning in *S. canaliculatus* have been suggested in January to May in the Philippines (Laviña and Alcala, 1973). In Okinawan waters, *S. canaliculatus* and *S. spinus* have been found to spawn on or around the new moon from April to June (Hoque et al., 1999) and from May to July (Harahap et al., 2001), respectively. In Palau, *S. canaliculatus* have been found to spawn from February to October (Bryan et al., 1975; Hasse et al., 1977). On the other hand, *S. argenteus* spawns synchronously around the last quarter moon from April to July (Salaki, 1993). *S. argenteus* juveniles were also fished heavily during their "run" in Guam (Woodland, 2001). In the present study, the highest volumes of juvenile catch were obtained consistently in April and May new moons although the appearance of juveniles is apparently year-round, but catches were on a continuous downtrend from 2001 to 2004.

At about the same period in April and May, the larger, gravid siganids, simultaneously most abundant during the period, were fished intensively although the fishery for siganids in the gulf has been practiced throughout the year. Large schools of *S. canaliculatus* juveniles were reported to appear at around spawning times in Guam (Woodland, 2001). This was also observed in the present study where juveniles co-occurred with large reproductive adults. Their simultaneous occurrence is because it is spawning time for the adults as earlier discussed and the migrating juveniles that are a month old from previous month's spawning are about to settle (Soliman and Yamaoka unpublished). This is collective fish behavior that renders both the young and adults simultaneously vulnerable to high exploitation. From resource management perspective, this vital information could be utilized to formulate policy or ordinance for closed season for the species. Further toward the end of preventing serious depletion of the resource, technical fisheries management measures could be proposed such as limiting effort in the fishery proportional to the amount beyond the sustainable level. Aggregations of the species over a very wide size range are responding to lunar cues albeit differently (Takemura et al. 2004), but the phenomenon has been met with exploitative practice. This has a long tradition among the island fishing villages in the gulf so fishing pressure could not be expected to decrease in coming years but rather intensify.

In summary, evidences to overfishing of young (“growth”) and older fishes (“recruitment”) in the three species are presented from analysis of total juvenile catch trend and results of analytic length-based fishery methods compared with biometrics of the species studied. As a major fishery resource exploited in the gulf, the fishes have been exploited from its larval, juvenile, maturing to mature stages using fishing gears that have low to almost no selectivity predisposing the resource to overfishing. Overfishing of the stocks occurred due to excessive harvesting of juveniles and high exploitation of older individuals. The latter event could have potentially caused a progressive fall in juvenile population in the four years, which is a long period to be simply due to natural recruitment variability. Intuitively, if left unregulated within sustainable level for the older fish and not rationalized until completely stopped for the juveniles, this will lead to significant stock depletion that will be disadvantageous to the fishery as a whole.

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