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Turrid Fishery in Central Visayas, Philippines

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Abstract

The double barrier reef in the Visayan seas is one of the most productive but heavily exploited fishing grounds in the Philippines. Signs of over-exploitation and depletion of marine resources in the area have been reported in the literature. Turrid snails, although not harvested for food, are becoming threatened due to the increasing demands for ornamental shells and pharmaceutical research on the promising bioactive compounds found in their venoms. In this study, the turrid population was assessed using compressor diving. Overall, a total of 61 turrid species were recorded from the four collection trips (from 2008 to 2010), with an average of 19% new species added to the existing species-list in every collection trip. Family Turridae has the highest contribution of 46% among the six turrid families recorded. Average turrid density extrapolated from 2 m by 50 m belt transect method was 217 individuals·ha^{-1}. Catch per unit effort was about 12 individuals·h diving^{-1}·fisher^{-1}. Repeated collection in the same sites resulted in declining catch rates. In addition, significant shell length reduction, particularly of *Crassispiracerithina*(Anton 1838) between collection trips, was observed, which could be attributed to the unsustainable harvesting activities of the organism. The results of our study serve as important baseline information of turrid populations in the double barrier reef and provide valuable fisheries management insights for the sustainability of these valuable resources.

Introduction

Turrids are an informal group that includes all of the conoideans, except the well-defined cone and auger snails (family Conidae and family Terebridae, respectively) (Seronay et al. 2010; Fedosov and Puillandre 2012). They belong to the Conoidea, a superfamily remarkable because of the possession of a venom gland and complex feeding mechanisms (Kantor and Puillandre 2012). A new operational classification of Conoidea based on molecular phylogeny includes a total of 15 families including Conidae and Terebridae (Bouchet et al. 2011).

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Turrids composed of 13 families (Clavatuliidae, Drilliide, Psuedomelatomidae, Horaiclavidae, Strictispiridae, Turridae, Cochlespiridae, Borsonidae, Mitromorphidae, Clathurellidae, Conobridae, Raphitomidae andMangeliidae), comprise the most diverse and most ubiquitous group which can occur from the shallow intertidal areas to depths exceeding 1,000 m (Bouchet et al. 2009). Owing to the relatively small sizes of most of the members, turrids are not popularly consumed compared to bigger and more palatable molluscs like the spider conch (family Strombidae) and bivalves. Harvest of shells including turrids in the Philippines is often due to their ornamental values that attract many shell collectors. Some turrids and other conoidean species collected from several areas within the Philippine archipelago are commonly sold as souvenirs for tourists in Cebu, Philippines. This therefore serves as an important livelihood in the area. In addition, recent studies showed that turrids possess various peptide compounds in their venom that could potentially be as diverse and as potent as those of the more studied cone snails (the family Conidae) (Watkins et al. 2006; Heralde et al. 2008;), providing a valuable resources for pharmaceutical research (Seronay et al. 2010).

Fisheries stocks in the Philippines on the whole have been harvested beyond their sustainable yield (Pauly 2000;Muallil et al. 2014a), and molluscs resources are mostly in a similar state (Wells 2002). The Visayan Sea where our study was conducted is among the most heavily exploited areas in the Philippines due to the high coastal populations that are highly dependent on marine resources. Signs of over-exploitation have been reported in many studies, although these studies have been focused on finfish fisheries (Lavides et al. 2010; Nañola et al. 2011). Few studies have been done on the fisheries and ecology of marine gastropods in the Visayan Sea although these resources are also suspected to be threatened by habitat destruction and unsustainable exploitation. Unregulated or poorly managed fishery resources have often been vulnerable to over-exploitation. The current status of turrid stocks and location of their fishing grounds are not well understood. The increasing demand for turrids both from the shell collectors and pharmaceutical researchers necessitates knowledge of their ecology and current population status. It is imperative to manage these valuable resources, one of the most diverse groups of species in the marine realm.

This paper aimed to gauge the profound effect of human activity through harvesting of turrid populations using a very efficient fishing technique calledcompressor diving. At the same time, we also studied its assemblage (i.e., density, diversity) in the wild to get an idea of their present ecological state. The study focused on the turrid populations in the northwestern part of the outer barrier reef in Danajon Bank, Central Visayas, which have been identified by the fishers as an important fishing ground

Material and Methods

Study sites

The study was conducted on the northwest portion of the outer reef of the Danajon Bank in Cebu, Philippines (Fig.1). Danajon Bank is a double barrier reef that traverses at least three island provinces in the Philippines, namely: Cebu, Bohol, and Leyte. The area is also characterised by extensive reef flats. Being situated in a heavily populated region and geographically located in the inner seas, the area has been subjected to high fishing pressure often associated with destructive fishing methods such as blast-fishing and poison fishing (Muallil et al. 2014a).

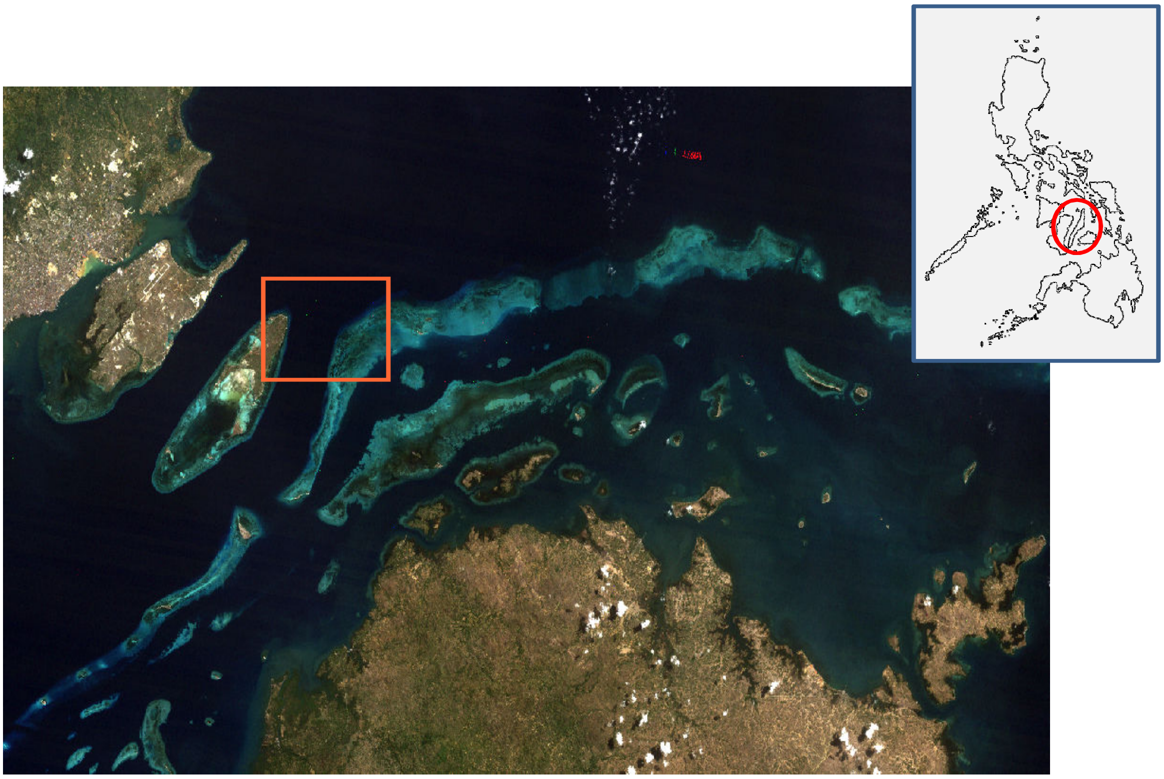

Fig. 1. Location of the study sites for the fishery-dependent turrid collection in the outer barrier reef of Danajon Bank, Mactan, Cebu.

Data collection

<u>*Fishery independent survey*</u>

The bathymetric mapping in the northwest part of Outer Barrier Reef (OBR) of Danajon Bank was done through a one-day boat survey using a fish-finder to map the bottom features of the identified turrid fishing grounds. Two stations (Station 1: N 10.28370 E 124.11559) and (Station 2: N 10.26295 E 124.10530), with a depth ranging from 15m to 22 m, were selected (Fig. 2): Station 1 located in the northern part of the outer barrier reef has been noted by fishers as a less productive area while Station 2 located southwest from Station 1 reportedly yields higher turrid catches. The bottom in studied areawas composed of clear sandy substrate (Station 2) or coral rubble (Station 1). Patches ofbrown algae mainly *Sargassum*sp. and to a lesser extent, *Padina*sp were found in both stations. The calcareous algae *Halimeda*sp. and the macrophyte*Halodule*spp. were also recorded intermittently in the sandy substrates of Station 2.

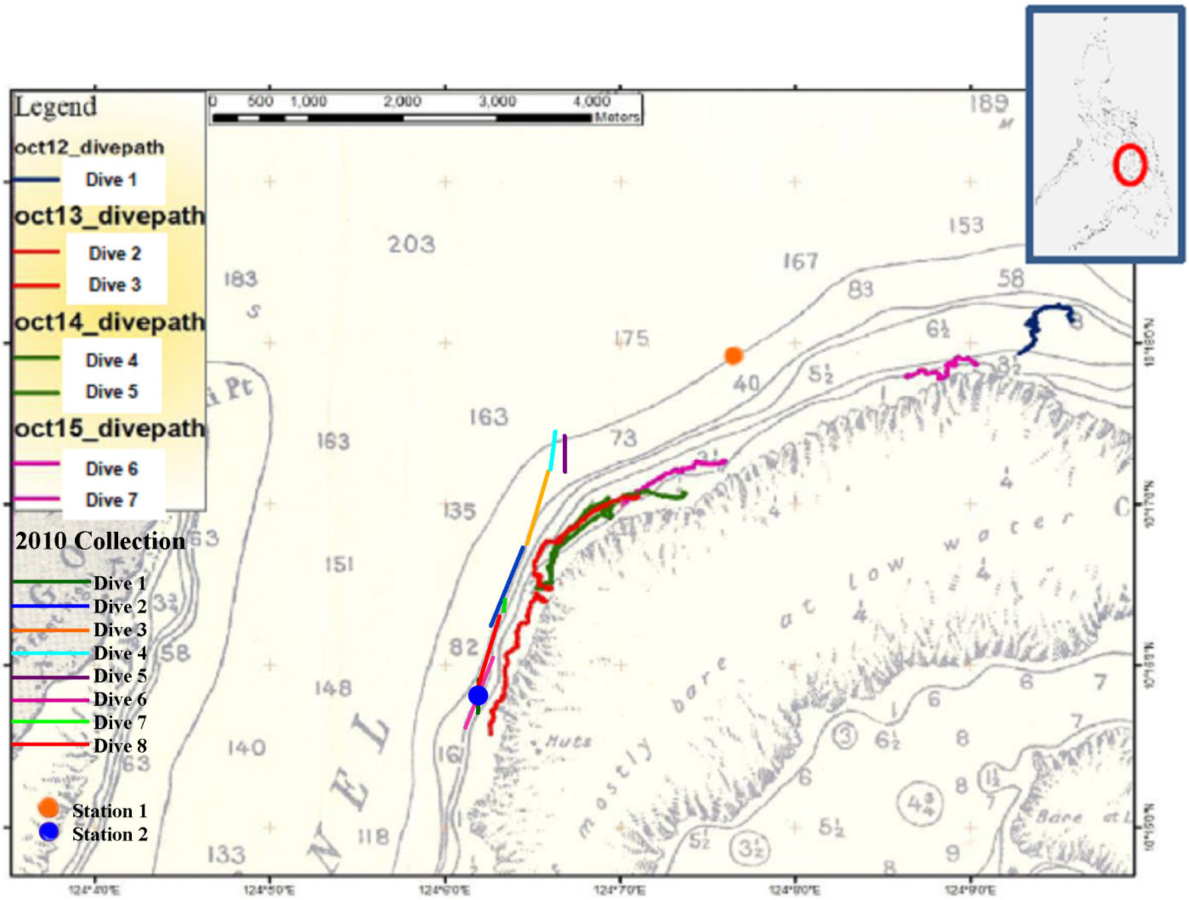

Fig. 2. Dive path of compressor divers collecting turrids in the Outer bank of Danajon Reef during Oct. 2008 and Oct. 2010 collections. Location of the two sampling stations for the fishery independent survey is indicated in the map.

The collection of turrid snails were done during nocturnal period using SCUBA within a belt transect in the two stations. Three transects with a total area covering 300 m^2 were studied on each station. Turrid snails encountered along the belt transects were collected and placed in the pre-labelled net bag. Turrid species richness, total count and density were calculated for each transect and station.

<u>*Fishery dependent survey*</u>

Turrid collection

Turrid snails were collected by compressor diving, also known as “hookah” diving, which is a common method of marine shells collection employed by local fishers in Cebu. Compressor diving uses an air compressor attached to a tube that supplies compressed air to the divers, enabling divers to stay underwater for several hours (Fig.3). The study was conducted in October 2008 (2nd collection trip), which coincided with monsoonal transition period associated with calm weather. Five fishers who are also experienced shell collectors were simultaneously collecting turrids at their own pace in Outer Barrier Reef (OBR), their usual turrid collecting site. A total of seven dive paths were covered by the five divers who congregated in the same general area and collected the snails at the same time. The number of fishing hours spent by each of the divers at each site was similar. Each diver was provided with a pre-labelled net bag as container for the turrid snails that they collected. Upon return to land, turrids were sorted from the catch for further identification. Each specimen was photographed, and morphometric measurements were done from a digitial image using the free tpsDig software version 2.12 (Rohlf 2008). Species identification was purely morphological based on Poppe (2008) and Springsteen and Leobrera (1986). Unidentified specimens were sent to turrid experts for proper identification.

Fig. 3.Hookah diver collecting a snail during night time dive.

Turrid density and catch per unit effort (CPUE)

The fishing path and fishing duration were tracked for seven dives corresponding to four nights (1, 2, 2, 2 dives) with GPS (Garmin Etrex 20) and the sites were plotted on a map (Fig. 2). The total collection area in searching and collecting turrid snail was estimated to cover 6.45 ha. Data on species richness and the number of individuals collected were combined from all five divers and seven collection dives. Turrid density was determined by dividing the total number of collected turrid snails of the five divers over the total area covered by the compressor divers per dive. Turrid CPUE was expressed in turrid catch·fisher^{-1}dive^{-1}.

Species richness and size frequency distribution

The species richness and size frequency distribution of the dominant turrid species were determined from the four major turrid collection events in OBR: August 16-19, 2008, October 12-15, 2008, December 3-7, 2009 and October 21-23, 2010. During major turrid collections, hookah divers collected turrids in OBR (generally similar area during each collection trip), identified by compressor divers (Fig. 2). The estimated area of the turrid collecting ground was about 1,775 ha.

The shell length of *Crassispiracerithina*(Anton 1838), the most abundant turrids collected in OBR was measured from the photos taken during the collection trip using the free tpsDig software. The size of *C. cerithina* population from the combined dataset was used for plotting the size frequency distribution.Difference in shell length was determined using analysis of variance.

Results

Fishery independent survey

The belt transect method in collectingturrids using SCUBA performed by four divers at 16-18 m depth covered only 600m^2 collection area for two consecutive nights. A total of 13 individuals belonging to seven species were collected in the two sampling stations in OBR (Table 1). *Gemmulamonilifera* (Pease 1860)wasthe dominant species collected in the two transects in station 2. Turrid density of 0.0267 ind·300 m^{-2}or 267 ind·ha^{-1} in station 2was also higher than in station 1 but relatively lower compared to the sites collected by the compressor divers. The average turrid density extrapolated from the fishery independent survey of 217 individuals·ha^{-1} was lower than the fishery dependent survey density results of 279 ind·ha^{-1}.Station 1 located north of Station 2 had lower turrid density based on the fishery dependent and independent survey, which confirmed the observation of the turrid collectors that Station 1 had a less productive area while Station 2 yielded higher catches. *Crassispiracerithina* and *G. monilifera* dominated in station 1 and station 2, respectively. The two mentioned species are relatively smaller in size than the other species collected. Comparing the shell length of these species, *G. monilifera* (9.1±13.5 mm) was smaller than *C. cerithina*(18.8±21.9 mm).

The smaller species were noted to be numerically more abundant than the larger species in station 1, station 2 and compressor diving sites.

Table 1. List of turrid species and number of specimens collected in the fishery independent survey stations.

Turrid Species	Station 1 (10/11-12/2008) 1800 -2000 h No. of specimen	Station 2 (10/11-12/2008) 1800 -2000 h No. of specimen
Crassispiracerithina(Anton 1838)	3	
*Xenuroturrislegitima*Iredale 1929	1	1
Turridrupa sp.	1	
Lophiotomaacuta(Perry 1811)		1
Gemmulamonilifera(Pease 1860)		5
*Turrisnadaensis*Azuma 1973		1
Total number of species	4	4
Total number of specimens	5	8
Mean Density (ind m^{-2})	0.00017	0.00027
Mean Density (ind ha^{-1})	167	267

Fishery dependent survey

Five compressor divers simultaneously collected turrids during the seven collection dives with an average of 4 h per dive covering 6.45 ha ofturrid fishing ground in OBR. During the October 2008 collection trip, a total of 1,745 turrid individuals belonging to six families and comprising 32 species were collected. Turrid density ranged from 218-339 individuals ha^{-1}, with the highest density recorded during Dives 1 and 7 (Table 2). The average CPUE ranged from 6.7- 18 turrids per diver per hour and the individual CPUE ranged from 2.1-36 turrids per dive per hour (Fig. 4). The highest CPUE was recorded during Dive 3; thus, the fishers returned near to Dive 3 site to collect more turrids and undertook three more dives (i.e. dives 4 – 6) (Table 2, Fig. 3). The lowest CPUE was noted in Dive 6; the collectors then transferred to another site for Dive 7. The numerical abundance, species richness, and turrid density declined in Dives 4 and 5 despite the wider area covered by the compressor divers. The decrease was attributed to the turrid collectors returning to the previously collected site in Dive 3. There was an area overlap of turrid collection in Dives 3, 4 and 5 (Fig. 2).

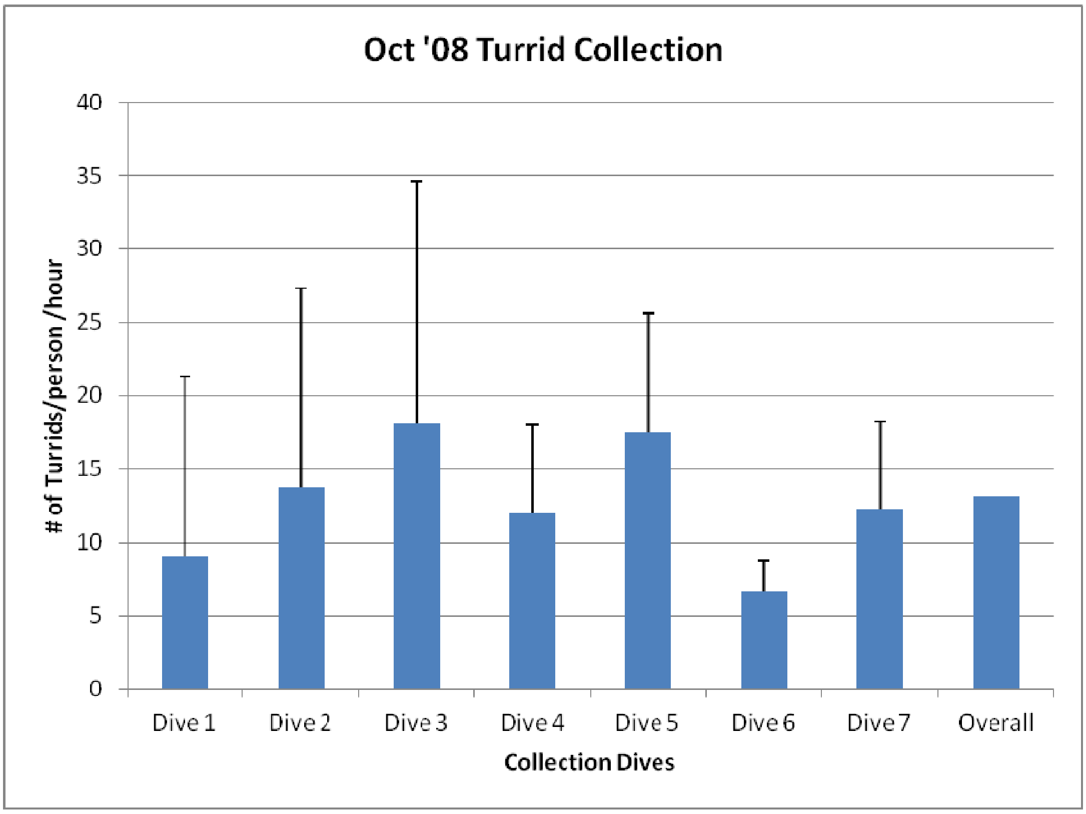

Fig. 4. Catch per unit effort of the seven collection dives with the use of compressor in OBR. Error bars denotes standard deviation.

Table 2. Parameters measured for the fishery dependent survey conducted during October 2008 collection trip in OBR. Turrid density value expressed as individual·ha^{-1} was extrapolated.

	Species Richness	Number of Ind.	Average CPUE	Area (ha)	Turrid density Ind./ha
Dive 1	16	166	9.02	0.49	338
Dive 2	25	292	13.73	1.03	278
Dive 3	22	315	18.02	1.03	331
Dive 4	20	236	11.95	1.18	221
Dive 5	14	280	17.44	1.28	218
Dive 6	16	148	6.74	0.67	225
Dive 7	21	262	12.28	0.77	339

Crassispiracerithina was the most dominant turrid species collected in all collection trips conducted in the OBR. Shell length of *C. cerithina* decreased during the October 2008 collection as compared to August 2008 collection trip. Analysis of variance test showed significant difference of shell length among a series of collection activities (ANOVA, p=0.05) (Fig. 5). The measurement in shell length of *C. cerithina* ranged from 13-21 mm with the majority falling within 16-18 mm range in August 2008 collection trip. A close interval of 2 months resulted in a reduction of shell length of the *C. cerithina* population which ranged from 7- 20 mm with the peak length of 7-9 mm. The ranges of shell sizes of *C. cerithina*collected during December 2009 and October 2010 collection were 13.5-24 mm and 5.6-12.6 mm, respectively.

Four consecutive major collection activities for turrids in OBR generated a total of 61 species belonging to families Drillidae, Horaiclavidae, Mangeliidae, Clathurellidae, Psuedomelatomidae and Turridae (Table 3). Species richness ranged from 27-36 species, with 8- 13 turrid species (an average of 19 %) added in every collection trip. The top three dominant species consistently collected in the area were *C. cerithina*, *G. monilifera* and *Clavuscanalicularis*(Röding 1798) .

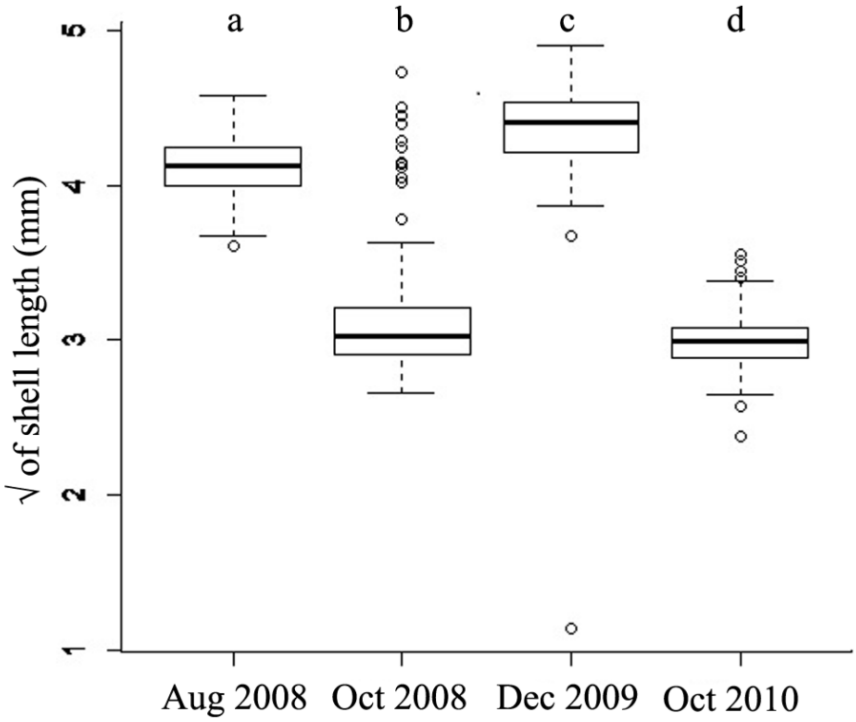

Fig. 5. Comparison, using ANOVA, of shell length of *C. cerithina* individuals collected during the four collection trips. Thick line inside the box represents the median value; lower and upper boundaries of box represent first and third quartiles, respectively. Lower and upper whiskers represent minimum and maximum values, respectively. Different letters indicate significant difference at P = 0.05.

Table 3. List of turrid species with their corresponding family collected during the three-year major collection trips in OBR.

No.	Family	Species	Aug. 2008	Oct. 2008	Dec. 2009	Oct. 2010
1	Drillidae	*Agradrillianitens*(Hinds 1843)	**0**	**0**	**1**	**0**
2	Drillidae	*Clavusbilineatus*(Reeve 1845)	**0**	**1**	**0**	**1**
3	Drillidae	*Clavuscanalicularis*(Röding 1798)	**1**	**1**	**1**	**1**
4	Drillidae	*Clavusenna cf.* (Dall1918)	**0**	**1**	**0**	**0**
5	Drillidae	*Clavusexasperatus*(Reeve 1843)	**1**	**1**	**1**	**1**
6	Drillidae	*Clavusfusconitens*(SowerbyI 1901)	**0**	**1**	**1**	**1**
7	Drillidae	*Clavusviduus*(Reeve 1845)	**1**	**1**	**1**	**0**
8	Drillidae	*Clavus*sp. 1	**1**	**1**	**0**	**1**
9	Drillidae	*Clavus*sp 2	**0**	**1**	**0**	**0**
10	Drillidae	*Clavus*sp 3	**0**	**1**	**0**	**0**
11	Drillidae	*Clavuslamberti*(Montrouzier 1860)	**0**	**1**	**0**	**0**
12	Drillidae	*Clavusunizonalis*(Lamarck 1822)	**0**	**0**	**0**	**1**
13	Drillidae	*Splendrillaproblematica*(Linnaeus 1758)	**0**	**0**	**0**	**1**
14	Horaiclavidae	*Horaiclavusmadurensis*(Schepman 1913)	**0**	**0**	**0**	**1**
15	Horaiclavidae	*Paradrilliaregia*(Reeve 1842)	**1**	**1**	**1**	**1**
16	Horaiclavidae	*Paradrilla*sp.	**0**	**0**	**1**	**0**
17	Mangeliidae	*Genotinagenotae*Vera-Peláez 2004	**0**	**0**	**0**	**1**
18	Mangeliidae	*Gingicithara cylindrical*(Reeve 1846)	**0**	**0**	**0**	**1**
19	Mangeliidae	*Gingicitharalyrica* (Reeve 1846)	**0**	**0**	**0**	**1**
20	Clathurellidae	*Lienardiapurpurata*(Souverbie 1860)	**0**	**0**	**0**	**1**
21	Psuedomelatomidae	*Comitaspeelae*Bozzetti, 1991	**1**	**0**	**0**	**0**
22	Psuedomelatomidae	*Crassispiracerithina*(Anton 1838)	**1**	**1**	**1**	**1**
23	Psuedomelatomidae	*Crassispiraquadrilirata*(E. A. Smith 1882)	**1**	**1**	**0**	**0**
24	Psuedomelatomidae	*Crassispirinae*sp 1	**0**	**1**	**0**	**0**
25	Psuedomelatomidae	*Crassispirinae*sp 2	**1**	**0**	**0**	**0**
26	Psuedomelatomidae	*Crassispirinae*sp 3	**1**	**0**	**0**	**0**
27	Psuedomelatomidae	*Funahadra*Sysoev&Bouchet 2001	**0**	**1**	**0**	**0**
28	Psuedomelatomidae	*Inquisitor aesopus*Schepman M.M. 1913	**0**	**0**	**0**	**1**
29	Psuedomelatomidae	*Inquisitor alabaster*(Reeve 1843)	**1**	**0**	**0**	**1**
30	Psuedomelatomidae	*Inquisitor chocolatus*(E.A.Smith 1875)	**0**	**0**	**0**	**1**
31	Psuedomelatomidae	*Inquisitor tuberosus*(E.A. Smith 1875)	**1**	**1**	**0**	**1**
32	Psuedomelatomidae	*Inquisitor* sp.	**0**	**0**	**0**	**1**
33	Psuedomelatomidae	*Ptychobelanudivaricosa*Kuroda and Oyama, 1971	**0**	**1**	**0**	**0**
34	Turridae	*Gemmula congener*(E. A. Smith 1894)	**1**	**0**	**0**	**1**
35	Turridae	*Gemmuladiomedea*Powell 1964	**1**	**0**	**0**	**0**
36	Turridae	*Gemmulagemmulina*(E. von Martens 1902)	**0**	**1**	**1**	**1**
37	Turridae	*Gemmulamonilifera*(Pease 1860)	**1**	**1**	**1**	**1**
38	Turridae	*Gemmularosario*Shikama 1977	**0**	**0**	**1**	**0**

39	Turridae	*Gemmularamiculata*Kuroda, Habe&Oyama, 1971	**0**	**0**	**0**	**1**
40	Turridae	*Gemmula*sp.	**0**	**1**	**0**	**1**
41	Turridae	*Xenoroturriscingulifera*(Lamarck 1822)	**0**	**1**	**1**	**1**
42	Turridae	*Lophiotomaacuta*(Perry1811)	**1**	**1**	**0**	**0**
43	Turridae	*Lophiotomaalbina*(Lamarck 1822)	**1**	**1**	**1**	**1**
44	Turridae	*Lophiotoma cf. ruthveniana*(Melvill 1923)	**0**	**0**	**1**	**0**
45	Turridae	*Lophiotomaolangoensis*Olivera 2002	**1**	**1**	**1**	**1**
46	Turridae	*Lophiotomapicturata*(Weinkauff 1876)	**0**	**1**	**1**	**1**
47	Turridae	*Turridrupabijubata*(Reeve 1843)	**1**	**1**	**0**	**1**
48	Turridae	*Turridrupacfcincta*(Lamarck 1822)	**1**	**0**	**0**	**0**
49	Turridae	*Turridrupaelongata*Hedley 1922	**0**	**0**	**1**	**0**
50	Turridae	*Turridrupajubata* (Reeve 1843)	**0**	**0**	**1**	**0**
51	Turridae	*Turridrupaweaveri*Powell 1967	**0**	**0**	**0**	**1**
52	Turridae	*Turrisbabylonia*(Linnaeus 1758)	**0**	**0**	**1**	**0**
53	Turridae	*Turriscristata*Vera-Peláez, Vega Luz & Lozano 2000	**1**	**1**	**1**	**1**
54	Turridae	*Turrishidalgoi*Vera-Peláez, J.L., R. Vega-Luz & M.C. Lozano-Francisco 2000	**0**	**0**	**0**	**1**
55	Turridae	*Turriscryptorrhaphe*(G.B.Sowerby I 1825)	**1**	**1**	**1**	**0**
56	Turridae	*Turriscrispa*(Lamarck 1816)	**1**	**0**	**1**	**0**
57	Turridae	*Turrisguidopoppei*Kilburn, Fedosov&Olivera 2012	**1**	**1**	**1**	**1**
58	Turridae	*Turrisnadaensis*Azuma 1973	**0**	**0**	**1**	**0**
59	Turridae	*Turrisnormandavidsoni*Olivera 1999	**1**	**1**	**1**	**1**
60	Turridae	*Turrisspectabilis*(Reeve 1843)	**1**	**1**	**1**	**1**
61	Turridae	*Xenuroturrislegitima*Iredale T 1929	**1**	**1**	**1**	**1**
		Total	**27**	**32**	**27**	**36**

Discussion

Fishery independent survey results revealed fewer turrid species and individuals compared to fishery dependent survey. The huge difference could be attributed to the efficiency of compressor diving in collecting turrids that covered wider areas per collection dive. The use of the efficient method in collecting turrids like compressor diving however has a tradeoff associated with higher health risks due to decompression sickness resulting from longer bottom diving time. Continuous collection of turrids in a previously collected area resulted in a decline of turrid density and species richness even if the collection area was expanded. The reduction of turrid density during Dive 4 may indicate over-harvesting. Collection Dive 5 had higher number of turrid individuals collected and CPUE but compressor divers covered a wider collection area of 1.28 ha which yielded the lowest species richness and density. The lower CPUE in Dive 6 was probably affected by the turrid area collection overlap (Fig. 4). The high variability of turrid catch among collectors could be attributed to the skills of the compressor divers in collecting turrids. A series of turrid collection activities led to the reduction of shell length of *C. cerithina*. Among the recorded shell length frequency distribution of *C. cerithina* derived from the four collection trips in OBR, October 2008 and October 2010 collection trip yielded significantly smaller specimens. Another research project recorded a collection of *C. cerithina* twice in the month of August 2010 with a total number of 1,706 individuals. Continuous targeted collections of *C. cerithina* significantly contributed to the shell length reduction (5.6-12.6 mm range) during the October 2010 collection. The extensive collection of *C. cerithina* has been used to characterise the venom peptide, a promising research on biomedical applications (Cabang et al. 2011). There could have been an increase in shell sizes of *C. cerithina* during October 2008 and October 2010 collection trips if no collection activities were done in August 2008 and August 2010. The results of size frequency distribution during December 2009 collection may indicate that *C. cerithina*almost attains its maximum sizehaving the shell length ranges from 13-24 mm. Powell (1967) recorded that the ranges of shell length of *C. cerithina* from 18-24.5 mm may indicate a sexually mature population. *C. cerithina* was listed in the Philippine Marine Mollusks book with a corresponding shell length of 20 mm collected in Olango Island or OBR (Poppe 2008).

The mean size of *C. cerithina*individualscollected in October(both in 2008 and 2010) wasmuch smaller compared to those collected in November 2009 when most individuals had attained maximum length.This observation may suggest that *C. cerithina* has an annual reproductive cycle with most individuals reaching sexual maturity sometime around the month of November.Our finding is consistent with Licuanan (2012) who showed that the peak of reproductive cycle, based on maturity and gonad sizes, in another turrid species, *Gemmulaspeciosa*, also occurs in October to January. Unfortunately, histological investigation on the reproductive system of *C. cerithina* was not done in this study and there is also no available information about the reproductive development of the species in the literature. Further investigation on the reproductive cycle is therefore needed to support our hypothesis.

Overall, a total of 61 turrid species were recorded in the four collection trips, with an average of 19% new species added to the already recorded species in every collection trip. The family Turridae represented by the highest number of species, contributed 46% to the total number of turrid species (Table 3). In addition, Kilburn et al (2012) reported that several holotypes and paratypes of new species belonging to the family Turridae were derived from OBR. These include *Turrishidalgoi*(Vera-Peláez et al. 2000), *Turristotiphyllis*(Olivera 2000), *Turriscristata*(Vera-Peláez et al. 2000) and *Turrisguidopoppei*(Kilburn et al. 2012).

The maximum sustainable yield (MSY) for island coral reef fisheries of 5 $mt \cdot km^{-2} year^{-1}$ (Newton et al 2007) has been proposed, but no studies have been conducted for turrid snails. Having MSY estimates for the turrid snail stocks is crucial to assure the sustainable use of the turrids. This enables managers to gauge the threshold of sustainable allowable catch of the turrid snails in order to prevent over-harvesting. In the absence of studies on carrying capacity for turrid snails, the highest turrid density among the seven collection dives in OBR was assumed to be indicative of its harvesting capacity. The assumption stems from the idea that turrids are not frequently collected prior to the research on drug discovery related projects in which the height of collection started from 2008 to 2010.

To prevent overharvesting of turrids, we propose that collectors should consider biannual rotation of collection sites within the OBR. The habitat area of turrids in the OBR is about 1,775 ha which is large enough for collectors to exploit other fishing grounds while allowing the previously exploited ones to recover. Periodic closure of fishing grounds would be helpful. Catch limits must also be implemented. Based on the assumption that MSY of a given population is roughly equal to half (50%) of its carrying capacity (Pauly 1980), we propose a catch limit of about 100 individuals per hectare per year for turrids in OBR.This is about 30% of the carrying capacity for turrids as estimated from our study. The proposed allowable catch is quite conservative but it would ensure long-term sustainability of turrid fishery that is increasingly becoming a more important source of income for many fishers in the area especially with the continually deteriorating condition of conventional fisheries (Muallil et al. 2014b).

Conclusion

Our study showed that turrid population is highly vulnerable to fishing as indicated by the consistently lower catch per unit effort in areas that were previously fished, i.e. 2 months ago.Shell length reduction of *C.cerithina*offers another indication of growth over-fishing attributed to continuous collection of turrids in OBR for the drug discovery related research. Over-harvesting may have been prevented if the collectors allowed for a fallow period in collecting turrids and allocating biannual rotation of concession areas in the turrid fishing ground of OBR. Unlike fish being reported to be over-fished in Visayan Sea, collection of the turrid snail in the OBR need not reach depletion or extirpation levels. However, turrid collection in OBR, if regulated, may attain sustainability if the allowable turrid collections are set at 102 turrid individuals per hectare per year. To prevent overexploitation of turrid population in the OBR, a sustainable management plan for turrid harvesting must be formulated. Fishing regulation measures such as catch limits (i.e. ~100 individuals/ha/year), periodic closure of fishing grounds, gear licensing and registration must be implemented.

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