Impact of tidal phenomenon "Met Ef" on the exploitation of benthos at inshore shoals in Kei islands, Indonesia

Eugenius Alfred Renjaan[1], Marvin Mario Makailipessy[1]

[1]Tual State Fisheries Polytechnic, Langgur - Sathean Ring Road, Km. 6. P.O. Box 1001, Southeast Maluku, Indonesia

Email: earenjaan@polikant.ac.id

Abstract A study on benthos exploitation at five shoals located in Rosenberg and Nerong Straits, the kei islands had been conducted during period of the lowest ebb tide phenomenon which locally termed Met Ef on 2016. The purpose of the study is to know the impact of the Met Ef on benthos exploitation at the shoals by local communities during the Met Ef. Data of tidal amplitudes were obtained from the Tide Charts Mobile Applications which confirmed the observations on tide pole during October, November, and December 2013 until 2016. Data of benthos exploited during periods of Met Ef at the shoals was obtained through direct observation on benthos exploited by the local communities, also by interviewing them using questionnaires. The results showed that the lowest ebb tide of the Met Ef occurred in November, i.e., at 2 to 5 days after the full moon and/or new moon, with an average tidal range of 2.66 m and even have ever one reached 2.80 m. The most exploited benthos at the shoals is Giant clam (*Tridacna* sp.), Spider conch (*Lambis* sp.), Hammer oyster (*Malleus* sp.), Octopus (*Octopus* spp.). The intensity of benthos exploited at the shoals increased during the period of Met Ef especially in October because at that time the sea was very calm and clear due to relatively lower wind speed and the rain fall was relatively lower. This has promoted an easier accessibility of the communities to exploit benthos at shoals and, therefore October is considered by the local communities as the peak of Met Ef, instead of November. During November and, December the availability of benthos in shoals has been reduced due to it has been exploited intensely in October.

1. Introduction

Met Ef, a local term in kei language, but popularly known as Meti Kei. Met Ef is the lowest ebb tide phenomenon with maximum tidal amplitude on kei islands causing the tidal plains to become very wide, as well as the appearance of rock shoals and sandbars at sea level around the kei islands, especially kei kecil islands. The phenomenon occurs every year in October, November, and December. The Met Ef phenomenon is always accompanied by high air temperatures, low rainfall, fewer rain day frequency, and low wind speed. The phenomenon of Met Ef improves people's accessibility to exploit benthos maximally at inshore shoals located in the Rosenberg and Nerong Straits since, certain species of benthos that are now rarely found in the intertidal zones due to increasing exploitation rates from years to years. Exploitation of benthos in the inshore shoals is conducted by people from several villages. On the other hand, most of benthos species taken from the shoals have long reproductive cycles that are vulnerable to extinction. Exploitation of the shoals has been conducted from generation to generation by local people, and according to them the current number of particular benthos such as Giant clam (*Tridacna* sp.) or locally called Hanoat is more difficult to find in the shoals and tend to have smaller size. The aim of this study is to know the impact of the Met Ef Phenomenon on the intensity of benthos exploitation in several inshore shoals, located in Rosenberg and Nerong Straits, the kei kecil islands, Indonesia. The

results of this study are expected to provide basic information about the pattern of benthos exploitation in the inshore shoals, as well as the preliminary information for further studies on the sustainable use of benthos in the inshore shoals.

2. Methodology

Materials and methods used in this study include; plastic samples, tape ruler, questionnaires, Satellite Image, Tide charts mobile Applications (Copyright @ 7th gear, LLC), SAS software, Planet software ArcGIS 10.X, Software Surfer 15. While Tools used include; Tide pole, Android, laptop, GPS, and Camera. Data of tidal range and tidal time was obtained from Tide charts mobile Applications (Copyright @ 7th gear, LLC), which confirmed the observations on tide pole installed at a jetty located at Rosenberg Strait. Field tide observation only conducted at Lower Low Water (LLW) condition during October, November, and December 2013 until 2016, to confirm the results of tide chart mobile application. The survey method used to obtain benthos data is the Creel Method, which is to observe directly the benthos species taken by local people who utilized five inshore shoals located in Rosenberg Strait and Nerong Strait, the kei islands of Indonesia during Met Ef in 2016. Besides also interviews the local people who exploit the five shoals. Local names of the inshore shoals they are Wama, Tibun, Vurlilan located on the Rosenberg Strait, while North Samar, South Samar, and Wid which located in the Nerong Strait. The shoal's location maps are presented in Figure 1. The climate data that always associated with Met Ef, such as air temperature, rainfall, rainy day frequency, and wind speed from 2013 to 2016 were obtained from the Indonesian Agency for Meteorology, Climatology, and Geophysics in Langgur, kei islands, Indonesia. Monthly data from the four-year average are used to describe the climatic conditions associated with Met Ef which also enable accessibility of the people to exploit the inshore shoals.

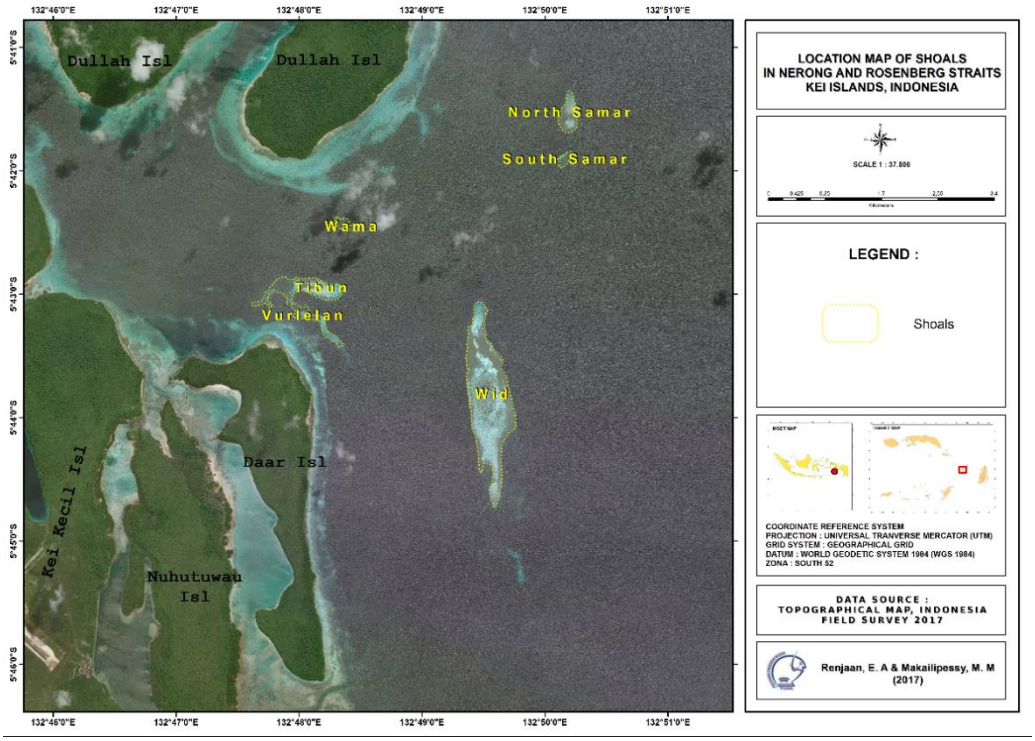

Figure 1. Map of the five inshore shoals in the Rosenberg and Nerong Straits, Kei Islands, Indonesia

Acquisition of bathymetry of the shoals' site was conducted by analyzing satellite image which described as follows.

a. Acquisition of bathymetry Data
   The bathymetry data of the study sites in from Image Marine Maps Navionics Sonar Chart (TM). The Image consists of depth contour line map that downloaded according to areas of interest by using software SAS Planet.
b. Data Processing (editing and lay outing data)
   i. Downloaded Image that is available then opened using ArcGIS 10.x software; the editing process is then conducted by creating new depth point following the contour lines that exist in satellite image.
   ii. After the process of making the point according to the depth is completed, the results are then exported to the Surfer software for the making of depth contour and distribution.
   iii. Contour and depth results are then exported back to ArcGIS for the making of water depth classes around AOI as well as map view.

3. Results

3.1. Description of the Inshore shoals

Shoals in kei local language are called "uran vat" which means pot-shaped stone, which describes the number of brain corals. In oceanography, geomorphology, and earth science, a shoal is a natural submerged ridge, a bank, or bar that consists of, or is covered by, sand or other unconsolidated material, and rises from the bed of a body of water to near the surface[19, 22). Inshore shoals Samar and Wid are located in the Nerong Strait waters that separate kei besar islands and kei kecil islands. While inshore shoals Wama, Tibun, and Vurlilan are located in the Rosenberg Strait that separates dullah islands and nuhuroa islands within the group of kei kecil islands. Some parts of the shoals are still above sea level during the daily flood tide. The seabed substrate of the shoals consists of gravel and sand with depth at flood tide ranging from 0 to 3 meters. The bathymetry map in the shoals and around the shoals as well as the geographical position and the size of the inshore shoals is presented in Figure 2 and Table 1, respectively.

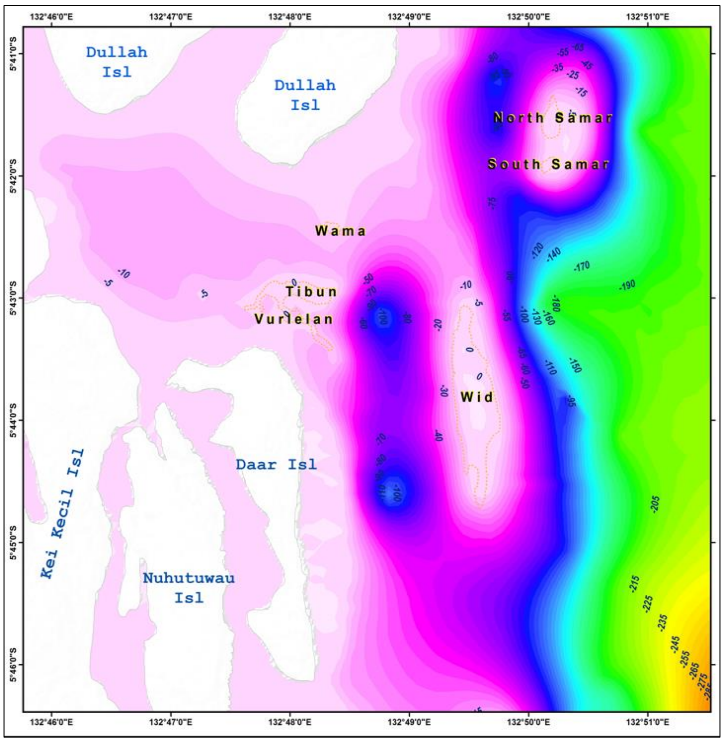

Figure 2. Bathymetry Map in and around the five inshore shoals

Table 1. Local names of shoals, geographical position, areas and position on sea level (SL) during Period of Met Ef.

No.	Names of Shoals	Latitude; Longitude	Area (Ha)	Remarks
1	North Samar	132º 50'12E; 5º41'29" S	12.5	Above SL
2	South Samar	132º50'10''E; 5º41'54" S	3.1	Above SL
3	Wid	132º49'34"E; 5º43'49"S	114.3	Above SL
4	Wama	132º48'25"E; 5o42'28"S	4.2	Below SL
5	Tibun	132º48'10"E; 5º42'28" S	12.8	Above SL
6	Vurlelan	132º48'02"E; 5º43'10"S	25.1	Above SL

The lowest depth level category on the Mef Ef period ranges from 0 to 5 meters and even partially above sea level except for the shoal Wama which ranges from 5 to 10 meters. Shoal Wid is the widest shoal compared to the other and the most accessed shoal by surrounding villagers, the second most accessed are Tibun and Vurlelan, and the third is Samar. While the Wama which is always below the sea level.

3.2. Characteristics of Met Ef as a tidal phenomenon

Type of tide in the waters of kei archipelago is categorized as a Mixed tide prevailing Semi-Diurnal; namely, tide occurs twice a day. Larger tides occur in the morning while smaller tides occur in the afternoon and evening. The peak of Met Ef in 2016 occurred on November 16, at that time the tidal amplitude reached 2.80 m. Tidal type curves, time and tidal amplitude are presented in Figure 3.

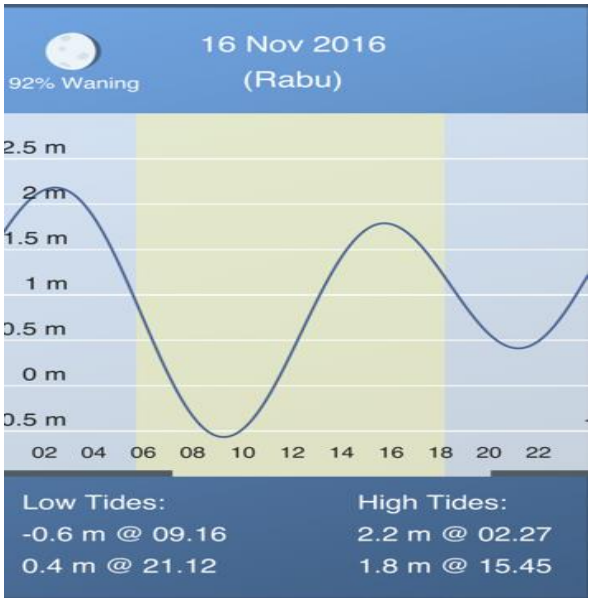

Figure 3. Tidal type curves, tidal amplitude, and time of tide on November 16, 2016 in kei islands (taken from tide charts mobile applications),

Maximum monthly average of tidal range in 2013 to 2016 increased from September to November but then back to decrease in December which had been confirmed on the tide pole is shown in Figure 4 below,

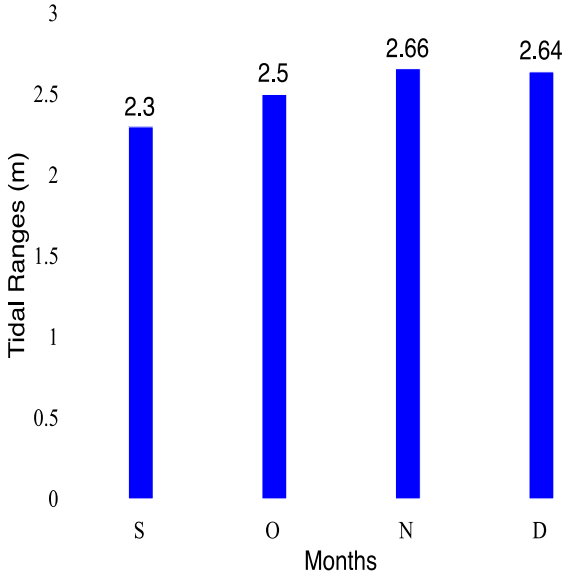

Figure 4. Maximum tidal range average during Met Ef that occurs around the full and the new moons periods in October (O), November (N), and December (D), 2013 to 2016.

The meaning of the term met ef, i.e., "met" means low tide, and "ef" means drought. The met ef term is intended for the largest tidal phenomenon occurring in October, November, and December. The local communities of the kei islands have long known that the tidal phenomenon always comes along with hot and dry climatic conditions and calm sea water surface due to low wind speed. These climatic conditions have become the indicator of the met ef period for the local communities. The average data of air temperature, rainfall, rainy day frequency and wind speed per month during 2013 to 2016 are presented in Figures 5, 6, 7 and 8.

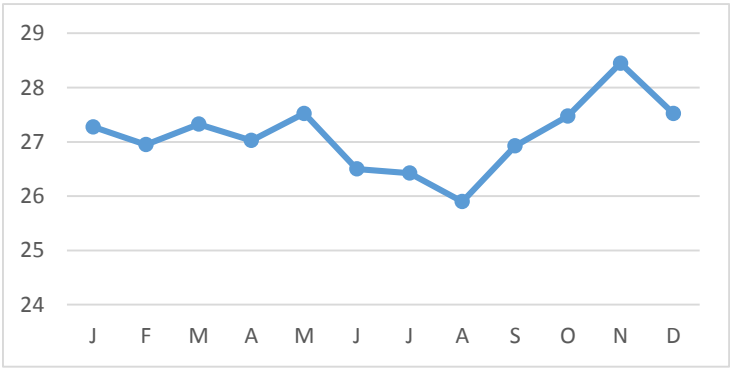

Figure 5. The average monthly (°C) air temperature from 2013 to 2016 in the kei islands

Figure 5 presents the average monthly air temperature conditions in the kei islands from 2013 to 2016. Namely, the lowest average air temperature occurred in August, (26 ° C) whereas the highest temperature occurred in November 28.5°C.

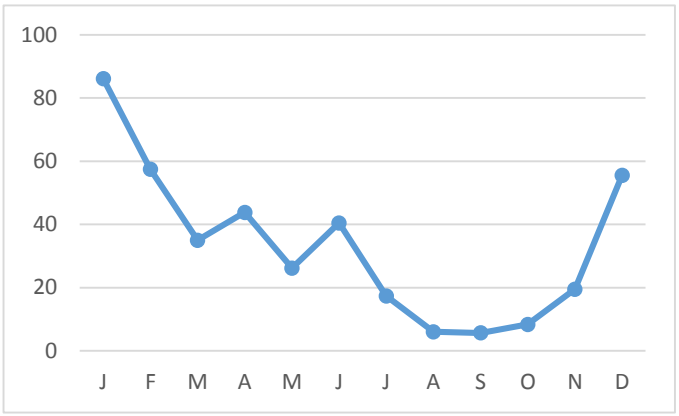

Figure 6. Rainfall (mm) monthly average from 2013 to 2016 in the kei islands

Figure 6 presents the relatively lower rainfall (mm) based on the average monthly rainfall from 2013 until 2016 occurred in August, September and October while the highest average rainfall occurred in January.

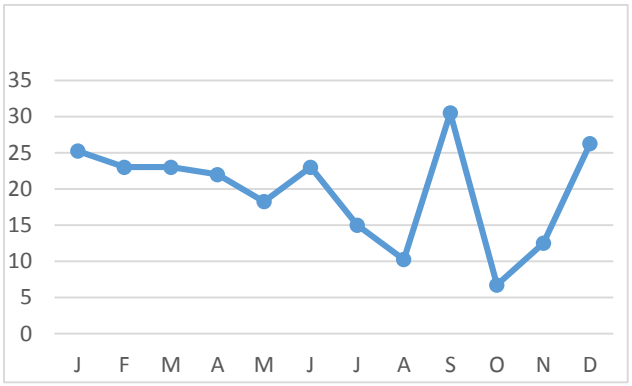

Figure 7. Frequency of average monthly rainy days from 2013 to 2016 in the kei islands

Figure 7 presents the frequency of the average monthly rainy days from 2013 to 2016 in the kei islands, i.e., the lowest rain frequency (day) occurs in October (less than 10 days) while the highest in September (30 days).

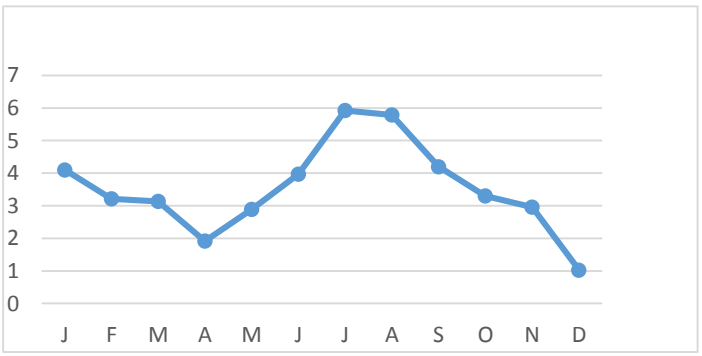

Figure 8. Monthly average wind speed (knots) from 2013 to 2016 in the kei islands

Figure 8 presents the average monthly wind speeds from 2013 to 2016 in the kei islands, i.e., the highest average speed occurred in July and the wind speed decreased gradually until reaching the lowest speed in December.

3.3. Exploitation of Benthos at the inshore shoals

The five inshore shoals are shared by several villages around shoals even though there are villages claiming to be their own. Intensive use happens only in the Met Ef period, especially October. The benthos collected by the people in the five shoals are generally Hanoat or Giant clam (*Tridacna* sp.), "Ngeng" or Spider conch (*Lambis* sp.), "Arut" or Hammer Oysters ("*Malleus* sp.") "Eb or Sea cucumber (S*tichopus* sp, and *Holothuria scabra*), and Krit or Octopus (*Octopu*s spp,). The people who exploit the shoals consist of people from several, i.e., Ohoitel, Vatran, Taar, Faan, Wearlilir, Sathean, Ibra Iso, Disuk, Revav. But Sathean and Ibra are the villages that the most intensively exploit the benthos in the shoals compared to other villages. According to the fisherman, although the number of people who exploit the benthos in the shoals has decreased lately the yields are getting smaller and size are also getting smaller. Based on interviews that the decreasing of people who currently exploits benthos in the shoals compared to previous time due to local people turn to seaweed culture business which is more economical value. The peak of benthos exploitation during the Met Ef period, occurs at least 1 to 6 times per month. It starts from the full moon to 6 days after the full moon and 2 to 6 days after the new moon. Benthos commonly collected from the shoals are presented in Table 2. The peak of benthos exploitation during the Met Ef period, occurs at least 1 to 6 times per month. It starts from the full moon to 6 days after the full moon and 2 to 6 days after the new moon.

3.4. Discussions

Met Ef phenomenon characterized by low tide with a relatively large tidal range classified as a tidal meso (2.5 m and 4 m). In addition, due to the gently sloping coastal bed topography of the kei kecil islands so that during low tide in October, November, and December where the tidal range reaches 2.60 to 2.80 m, the drought tidal plains become very wide and even the coral banks or shoals that normally lies below the surface of the water popping up above sea level. This has led to the accessibility of local communities to exploit benthos that inhabits shoals more intensively than in other months. Between October, November, and December, benthos exploitation with the highest intensity was conducted in October, this was due to at that time, the rainfall and the number of rainy days were very low, as well as the low wind speed causes the sea to be clear and calm. Similar climatic conditions also occurred in November, with the highest tidal range but since intensive exploitation has occurred in October so that in November and December, the number of people who exploit the shoals became diminished due to the reduced of benthos in those shoals.

Table 2. Benthos which collected in shoals during period of Met Ef and its user villages

No.	Name of Shoals	Local common and Scientific Names of benthos	User Village of shoals
1	North ‘Samar’	Arut (*Malleus* sp.), Ngeng (*Lambis* sp.), Hanoat (Tridacna sp.) Eb (*Stichopus* sp., *Holothuria* sp., Hanoat (*Tridacna* sp.)	Ohoitel, Vatran, Taar, Faan, Wearlilir, Sathean, Ibra
2	South ‘Samar’	Krit (*Octopus* spp.), Eb (*Stichopus* sp., *Holothuria* sp.),	Ohoitel, Vatran, Taar, Faan, Wearlilir, Sathean, Ibra
3	Wid	Hanoat (*Tridacna* sp.), Arut (*Malleus* sp.), Ngeng(*Lambis* sp.), Krit (*Octopus* spp.) Eb (*Stichopus* sp., *Holothuria* sp.,)	Sathean, Iso, Disuk, Ibra, Wain, Revav, Rumat
4	Wama	Hanoat (*Tridacna* sp.), Eb (*Stichopus* spp., *Holothuria* sp.)	Taar, Sathean, Faan, Wearlilir, Ohoitel, Vatraan

The most collected Benthos are *Tridacna* sp., *Malleus* sp., *Lambis* sp, and *Octopus* spp. The species of benthos are abundant in shoals because they are generally not exploited in other months except at Met Ef. Especially numbers of *Tridacna* sp., have been greatly reduced in the tidal plains because it has been intensively exploited for a long time to be marketed as a source of protein and other things for local communities as elsewhere in the Indo Pacific, including the kei islands. Giant clams are commercially important for the food market [16, 22), shell craft industry [10] and in the live marine aquarium trade [13]. Overexploitation of this valuable and multi-facetted resource has led to the decline of natural stocks throughout its natural Indo-Pacific range and the ecological extinction [20] in some areas of the larger species (*Tridacna gigas* Linne, 1758; *Tridacna derasa* [4, 15, 11]. The exploitation of the Giant clam is alarming because its availability in nature has been reduced, whereas the eight species of Giant clams have been defined as endangered species, and are included in the Convention of International Trade of Endangered Species, and are included in the Convention of International Trade of Endangered Species (CITES) list (25, 8]. In addition, Giant clams are also of distinct ecological significance as they contribute to reef development and are an important prey item and provide shelter for many other marine organisms [18]. The small giant clam T. maxima (max known size < 40 cm, but size modes usually between 5 and 15 cm; [6] can be found on sandy bottoms, but is typically embedded in hard substrate. With large clams being preferentially targeted by fishers given the better catch per unit effort, this species remained relatively untargeted by fishers until recently, in countries where larger species co-occur (the giant clam *T. gigas*, the fluted giant clam, the southern giant clam and the bear paw clam; [14]. The small giant clam (T. *maxima*) is currently classified as lower risk/conservation dependent (i.e. species of 'least concern') under the IUCN red list of threatened species (2004). However, with most larger species having been over-exploited, some studies report the unsustainable exploitation of this smaller species (26, 12] and recommend that the species' IUCN status be reconsidered [17].

Another benthos species also targeted for the exploitation by people in the five shoals during Met Ef is the spider conch. The common spider conch *Lambis lambis* is distributed in shallow waters of the Indo-Pacific. The conches are sought by shell collectors of Philippines, Solomon Islands, Indonesia and India [2]. It is harvested and consumed as food in Japan. The conches are found to occur mainly on sandy patches among rocks or coral reefs, from the intertidal region to depths up to 20 m [9]. Of the eleven known species of *Lambis* sp., from Indian waters [1], six are listed in Schedule IV of the Indian Wildlife Protection Act, 1972, banning commercial exploitation. Studies on breeding of *Lambis lambis* are limited, the only known published work being that of [7]. In India, studies on *Lambis* spp. are limited to its habitat and feeding [23]. The present study is an attempt to collect, maintain and breed the common spider conch *Lambis lambis* under captivity in order to develop a methodology for brood stock maintenance and to study their feeding behavior, mating, spawning and larval development. The common spider conch *Lambis lambis* is distributed in shallow waters of the Indo-Pacific. The conches are sought by shell collectors of Philippines, Solomon Islands, Indonesia and India [2]. It is harvested and consumed as food in Japan. The conches are found to occur mainly on sandy patches among rocks or coral reefs, from the intertidal region to depths up to 20 m. Of the eleven-known species of *Lambis* from Indian waters [1].

Black hammer oyster is found in seagrass meadows with the 'T' shape buried. They range in depths of 1 to 15 meters. It is also found to be growing in close colonies. Maximum shell height is about 25 cm. The outer shell is often encrusted with calcareous algae and other organisms. Black hammer oysters are locally collected in Indonesia and the Philippines for production of lime and shell craft. It has a widespread distribution – Indo-West Pacific from East Africa, including the Persian Gulf, to Melanesia; north to Japan and south to Queensland [5].

Octopuses are commonly found in the sea and subtropics around the Mediterranean region, the far eastern regions and the South Pacific. In Indonesia, allegedly present in the waters of Kalimantan, Sulawesi, Maluku and Banda. Octopus can live in shallow water and also present at the tidal boundary until somewhat deep with depth of 4000 meters to 5000 meters. Mostly swim and move together in large herds. Actually, the octopus is benthic or sticking [3], and usually forms a sanctuary within the crevices of rocks, rocks, seaweed in coastal waters. The most preferred residence is hollow rocks. Octopus is active at night or called a nocturnal animal [24, 27].

4. Conclusions

Met Ef occurs in October, November, and December. The lowest tide average during 2013 to 2016 occurs in November with an average tidal range of 2.66 m but the highest exploitation intensity tends to be in October so that in November and December the number of benthos in the shoals has decreased and the exploitation intensity also has decreased. Giant clam (*Tridacna* sp.), Spider conch (*Lambis* sp.), Hammer oyster (*Malleus* sp.), and Octopus (*Octopus* spp.) are benthos targeted for exploitation in the shoals. *Tridacna* sp. decreased in number and size compared to previous time

Acknowledgements

We are grateful to a large number of individuals who helped by answering and confirming our questions in the Sathean and Villages. We are also grateful to Dr. Serge Andréfouët from Institut de Recherche pour le Développement, France, for providing us some references. Finally, we acknowledge anonymous reviewers and the editors for their constructive comments and corrections.

References

[1] Apte, D 1998 The book of Indian shells. Oxford University Press, 115 pp.
[2] Carpenter, K. E., Niem, V. H 1998 FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific. Volume 1. Seaweeds, corals, bivalves and gastropods. *FAO*, Rome, 686 pp.
[3] Barnes, R.D 1967 Invertebrate Zoology W.B. Saunders. Co, London : 632 pp.
[4] Brown, J. and M. Muskanofola 1985 An investigation of stocks of giant clams (Family Tridacnidae) in Java and of their utilization and potential. *Aqaucult. Fish. Manage*. 16(1):25-39.
[5] Deepak, S 2013 Black Hammer Oyster – *Malleus malleus* (Linnaeus, 1758), Marine Life India, October <https://marinelifeindia.wordpress.com/2013/10/26/black-hammer-oyster-malleus-malleus-linnaeus-1758/>
[6] Gilbert, A., Remoissenet, G., Yan, L. and Andrefouet, S 2006 Special traits and promises of the giant clam (*Tridacna maxima*) in French Polynesia. Fisheries Newsletter – South Pacific Commission 118, 44–52.
[7] Hamel, J. F. and Mercier, A 2006 Note on the spawning and development of the common spider conch *Lambis lambis. SPC Trochus Information Bulletin*, 12: 19-21.
[8] Hilton-Taylor, C 2000 IUCN Red List of Threatened Species. Gland, Switzerland and Cambridge, UK: IUCN.
[9] Jagadis, I., Shanmugasundaram, k., and J. Padmanathan 2012 Observations on broodstock maintenance, breeding and early larval development of the common spider conch *Lambis lambis* (Linnaeus, 1758) in captivity. *Indian J. Fish*., 59(2): 165-169.
[10] Juinio, A., R. Menez and C. Villanoy 1987 Use of giant clam resources in the Philippines. Naga 10:7-8.
[11] Juinio, A, R. Menez and C. Villanoy, and E. Gomez 1989 Status of giant clam resources of the Philippines. *J. Moll. Stud*. 55:431-440.
[12] Kava, V., Udagawa, K. and Ikenoue 1995 H. Fishing pressure on the resource of the elongated giant clam, Tridacna maxima, in Tonga. *Fisheries Research Bulletin of Tonga* 3, 11–17.
[13] Knop, D 2004 Giant Clam Buyer's Guide. Coral - The Marine Aquarium Magazine 1(3):36.
Ecosystem Publications, California 92705, USA.
[14] Lewis, A.D., Adams, T.J.H. and Ledua, E 1988 Fiji's giant clam stocks – A review of their distribution, abundance, exploitation and management. Giant Clams in Asia and the Pacific. *ACIRA Monographs* 9, 66–72.
[15] Lucas, J.S 1988 Giant clams: description, distribution and life history. In: Copland, J. & Lucas, J.S. (Eds.), Giant clams in Asia and the Pacific. *ACIAR*, Canberra, pp. 21–32.
[16] Murakoshi, M 1986 Farming of the boring clam, *Tridacna crocea* Lamarck. Galaxea 5: 239-254.
[17] Neo, M.L. and Todd, P.A 2013 Conservation status reassessment of giant clams (Mollusca: Bivalvia: Tridacnidae) in Singapore. Nature in Singapore 6, 125–133.

[18] Neo, M.L., Eckman, W., Vicentuan, K., Teo, S.L.-M. and Todd, P.A 2015 The ecological significance of giant clams in coral reef ecosystems. *Biological Conservation* 181, 111–123.
[19] Neuendorf, K.K.E., J.P. Mehl, Jr., and J.A. Jackson, eds 2005 Glossary of Geology (5th ed.).
[20] Pandolfi, J., R. Bradbury, E. Sala, T. Hughes, K. Bjorndal, R. Cooke, D. McArdle, L. Mc Clenachan, M. Newman, G. Paredes, R. Warner and J. Jackson 2003 Global trajectories of the long-term decline of coral reef ecosystems. *Science Wash*. 301(5635):955-958.
[21] Rutecki, D, Nestler E, Dellapenna T, and Pembroke A 2014 Understanding habitat value and function of shoal/Ridge/Trough Complexes to fish and fisheries on the Atlantic and Gulf of Mexico Outter continental shelf. Draft literature synthesis for the U.S. Dept. of the interior, Bureau of ocean energy management. Contract # M12PS00031. Bureau of Ocean Energy Management. US. Department of the Interior. 116pp.
[22] Shang, Y., L. Ping Sun and J. Brown 2014 Test marketing of giant clams for food in Honolulu, Guam and Saipan and observations in Okinawa and Taiwan. Pages 69-87 in Economics of commercial giant clam marine culture.
[23] Siraimeetan, P., Ameer Hamsa, K. M. S. and Satyanarayanarao, K 1988 On the habitat, habits and food of *Lambis lambis* and *Hemifusus cochlidium*. Proceedings of the National Seminar on shellfish resources and farming. *Bull. Cent. Mar. Fish. Res. Inst*., 42 (1): 111-116.
[24] Welss, M.J 1962 Brain and Behavior in Cephalopoda, Stanford University Press, Stanford, California: 198 pp.
[25] Wells, S., R. Pyle and N. Collins 1983 Giant clams. Pages 97-107 in The IUCN Invertebrate Red Data Book, Gland, Switzerland.
[26] Zann, L.P. and Ayling, A.M 1988 Status of giant clams in Vanuatu. Giant Clams in Asia and the Pacific: *ACIAR Monographs* 9, 60–64.
[27] Roper, C.F.E., M.J. Sweeney and C.E. Nauer 1984 An Annotated and Ilustrated Catalogue of Species of Interest to Fisheries. In P.R. Boyle (Ed.). Cephalopods of The World. *FAO Fisheries Synopsis* No. 125 (3): 191-257.