



Preliminary Physiological Study on the Edible Wild Bivalves in Myeik, Myanmar

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Abstract

To clarify the bivalve fishing situation in Myeik Coast, which is a well-known centre of coastal fishing in Southern Myanmar, an investigation on the physiological conditions of wild bivalves, hard clam *Meretrix casta* var. *ovum* (Hanley, 1845), soft clam *Paphia undulata* (Born, 1778), green mussel *Perna viridis* (Linnaeus, 1758), oyster *Crassostrea belcheri* (Sowerby, 1871), and pen shell *Atrina pectinata* (Linnaeus, 1767) landed in the City was done in December 2014, and March and September 2015. The bivalves were purchased at some local markets and a seafood restaurant, and their physiological conditions, including sexual maturation, food availability, and ability of nutritional absorption, were investigated through histological observations. Additionally, the concentration of paralytic shellfish poisoning (PSP) toxins was examined in the soft tissues of the bivalve samples with an enzyme-linked immune sorbent assay. The results showed that hard clam *Meretrix casta* var. *ovum* was the stable landing species through dry and wet seasons. Its spawning season was a long period extending from dry to wet seasons, ensuring good food availability and nutritional absorption. The concentrations of PSP toxins were low (<1 nM) in all bivalves, making them safe for human consumption. In conclusion, these results suggest that the Myeik Coast is suitable for hard clam fishing for the time being.

Keywords: bivalve, physiological condition, sexual maturation, food availability, Myanmar

Introduction

Myanmar has a long coastline of about 3,000 km facing the Andaman Sea and the Bay of Bengal (Oo 2002). The annual production of sea fishery was higher than 2 million tons in 2012, and the production amount ranked 10th among the fishing countries in the world (FAO 2014). In particular, the neighbourhood areas of Myeik in Southern Myanmar have a wide tidal flat up to about 4,000 ha surrounded by huge mangrove forests (Zöckler et al. 2014). Plankton blooms are often observed in the coastal waters during the dry season, and they are believed to contribute a high basal producing ability for suitable coastal fishery in the region (Su-Myat et al. 2012a; Su-Myat and Koike 2013; Maung-Saw-Htoo-Thaw et al. 2017). In addition, the fishing of wild bivalves such as oyster and clam is thriving in the same waters (FAO 1991; Holmes et al. 2014), and these bivalves are mainly used for local

consumption. Thus, the focus of the study was in the Myeik Coast which is known as the centre of coastal fishery in Myanmar that will be further developed as an important water resource for the aquaculture industry. The aim of this study was to understand the current situation of bivalve fishing. In this study, the landed bivalves were purchased from some local markets and a seafood restaurant for investigation of their physiological conditions, including sexual maturation, food availability, and nutritional status, based on the histological observation. Moreover, the study also examined the paralytic shellfish poisoning (PSP) toxins contamination in bivalves because the distribution of the causative plankton species for toxins is increasing in the coastal waters of the Southeast Asian countries (Su-Myat et al. 2012b). Thus, the contamination levels of PSP in bivalves were analysed with a specific enzyme-linked immune sorbent assay (ELISA) kit and

evaluated the stability of bivalve fishing and aquaculture in the Myeik Coast.

Materials and Methods

Wild edible bivalves landed from coastal areas around Myeik City were purchased at some local markets and a seafood restaurant in the City, in December 2014 and March and September 2015 (Fig. 1, Table 1). Four species of bivalves, hard clam *Meretrix casta* var. *ovum* (Hanley, 1845), soft clam *Paphia undulata* (Born, 1778), green mussel *Perna viridis* (Linnaeus, 1758), and oyster *Crassostrea belcheri* (Sowerby, 1871) were obtained in December 2014, three species (*M. casta* var. *ovum*, *P. viridis*, and *C. belcheri*) in March 2015, and two species *M. casta* var. *ovum* and pen shell *Atrina pectinata* (Linnaeus, 1767) in September 2015. The species were identified by the morphological observations (FAO 1998; Jahangir et al 2012; Chanrachkij 2013; Li et al. 2017). All samples except the pen shell were still alive until use for body size measurements such as shell length (height) and whole-body weight (Table 2). The shells of all bivalve samples were removed, and their soft tissues were weighed after the measurements. Subsequently, their digestive glands and gonads tissues were dissected into small blocks (5 × 5 mm), which were immersed in 10 % seawater-formalin solution for fixation. However, the pen shell, which was obtained in September 2015, was sold with its soft tissue removed from the shells at a street market. Thus, the shells were photographed at the market, and only the soft tissue was weighed before the tissue block dissection. The fixed tissue block was brought back to the laboratory and dehydrated in a series of ethanol concentrations using a well-known conventional method, and embedded in paraffin after replacing ethanol with lemosol. The paraffin block was sectioned at 5 μm with a microtome, and the sections observed under a light microscope (Eclipse 80i, Nikon, Japan) after haematoxylin-eosin staining. The sexual maturation of gonads was classified into a total of five stages, including one unsexed condition called an immature stage (I), and four sex determination stages namely developing stage (II), mature stage (III), spawning stage (IV), and spent stage (V) (Yurimoto et al. 2008, 2014a, 2014b; Maeno et al. 2009). The epithelial cell conditions in the digestive gland were classified into three stages to estimate their nutrient absorption ability, and presence of food in their digestive duct to estimate the food availability according to Yurimoto et al. (2014c). In addition, the accumulation of PSP toxins in the soft tissues of bivalve samples were determined by pooling the samples and the toxins were extracted using the AOAC (Association of Analytical Communities) method (Jellet et al. 2002). The toxin levels were analysed using an ELISA kit for PSP toxins (S-kit, Shin-Nihon-Kentei-Kyokai, Japan) (Sato et al. 2014). After colour development in ELISA, the concentration (nM) of PSP toxins was estimated with a microplate reader and

compared with the standard curve. In addition, to understand the weather condition in Southern Myanmar during the research period, the monthly averaged data on air temperature and rainfall of Victoria Point, Myanmar from September 2014 to October 2015 was obtained from an internet homepage of the Japan Meteorological Agency (http://www.data.jma.go.jp/gmd/cpd/monitor/climatview/graph_mkhtml.php?n=48112) (Fig. 1A). The monthly changes in temperature and rainfall amount are shown in Figure 2.

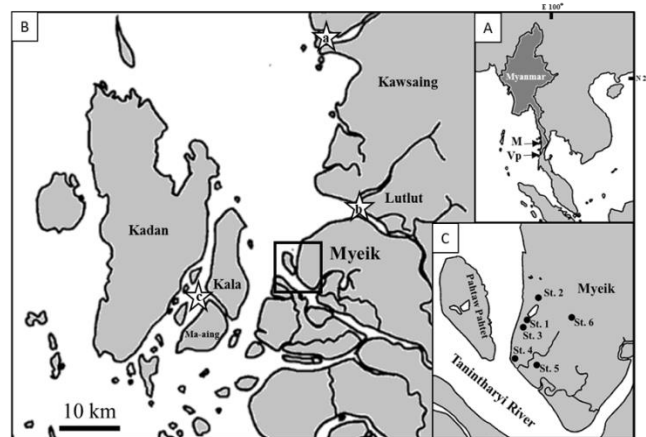


Fig. 1. Location of the bivalve survey site in Myeik City, Myanmar, and the weather monitoring station at Victoria point using weather data from the Japan Meteorological Agency homepage. A: the Union of Myanmar in Southeast Asia. M: Myeik City. Vp: Victoria point. B: survey site in Myeik City. C: the local markets and a seafood restaurant from where the bivalve samples were purchased in Myeik City. ☆: Information on the location of a main bivalve fishing ground was obtained at the markets. a: Clam, b: Oyster, c: Clam and mussel.

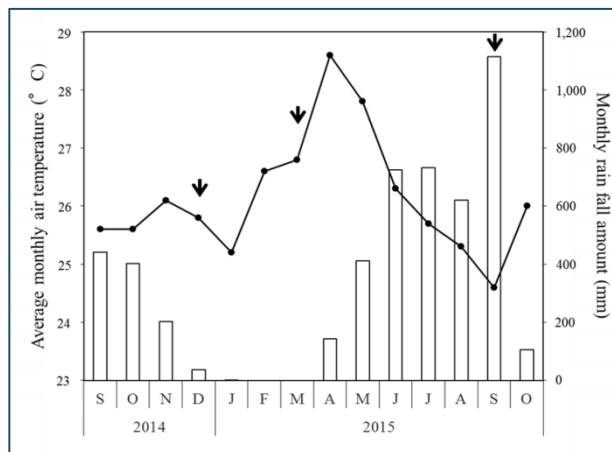


Fig. 2. Changes in average monthly air temperature (line graph) and monthly rainfall amount (bar graph) of Victoria point in the Union of Myanmar from September 2014 to October 2015. The data was obtained from the homepage of the Japan Meteorological Agency (http://www.data.jma.go.jp/gmd/cpd/monitor/climatview/graph_mkhtml.php?n=48112). Arrows in the graph indicate the months of bivalves purchased from the local markets and a seafood restaurant in Myeik City, Myanmar.

Table 1. Sampling locations of the local markets and a seafood restaurant for obtaining bivalves in Myeik City, Myanmar.

Station	Latitude	Longitude	Sample purchase	Inspection	Note
1	N12°26'32.1"	E98°35'51.1"	Dec., Mar., Sep.	Dec., Mar., Sep.	Street market
2	N12°27'04.5"	E98°36'06.3"	Mar.	Dec., Mar., Sep.	North market
3	N12°26'27.4"	E98°35'46.5"	Sep.	Dec., Mar., Sep.	Central market
4	N12°25'57.2"	E98°35'41.1"	no purchase	Dec., Mar.	Small market
5	N12°25'49.5"	E98°36'07.8"	Mar.	Dec., Mar., Sep.	South market
6	N12°26'39.4"	E98°36'44.4"	Dec.	Dec.	Seafood restaurant

Table 2. Shell length (*Meretrix casta* var. *ovum*, *Paphia undulata*, *Perna viridis*) or shell height (*Crassostrea belcheri*), whole weight and soft tissue weight of each specimen used for histological observations.

Species	Month	n	Shell length or height (mm)	Whole weight (g)	Soft tissue weight (g)
<i>Meretrix casta</i> var. <i>ovum</i> (Hanley, 1845)	Dec.	30	39 ± 12	23.1 ± 23.2	3.9 ± 3.8
	Mar.	54	34 ± 8	12.2 ± 8.1	1.8 ± 1.2
	Sep.	54	28 ± 7	6.9 ± 6.4	1.5 ± 1.3
<i>Paphia undulata</i> (Born, 1778)	Dec.	30	43 ± 3	8.2 ± 1.4	3.0 ± 0.6
<i>Perna viridis</i> (Linnaeus, 1758)	Dec.	19	69 ± 9	21.3 ± 6.6	7.2 ± 2.1
	Mar.	21	68 ± 8	22.6 ± 6.1	8.0 ± 3.0
<i>Crassostrea belcheri</i> (Sowerby, 1871)	Dec.	13	84 ± 12	110.0 ± 46.6	14.0 ± 5.1
	Mar.	5	103 ± 5	287.8 ± 40.1	32.2 ± 4.6
<i>Atrina pectinata</i> (Linnaeus, 1767)	Sep.	6	nd	nd	35.5 ± 4.0

Values are mean ± SD.
nd: no data.

Results

Sexual maturation

Sexual maturation stages of the bivalve specimens are shown in Table 3. Only two out of 30 individuals of the *Meretrix casta* var. *ovum* were in the immature stage, the male individuals were all in the mature or spawning stages, and the female individuals were in each stage from developing to spent stages in December. Thirteen out of 54 individuals were classified as immature, the males were in each stage from mature to spent stages, and the females were in each stage from developing to spent stages in March. In addition, three of 54 individuals were classified as immature: the males were in each stage from developing to spawning stages, and the females were in each stage from developing to spawning stages in September. In *Paphia undulata*, only one out of 30 individuals was classified in the immature stage, the

males were in each stage from developing to spent stages, and the females were in each stage from developing to spawning stages in December. In *Perna viridis*, five out of 19 individuals were classified in the immature stage, and both sexes were present in each stage from developing to spawning stages in December. Two of the 21 individuals were classified as immature, the males were in each stage from mature to spent stages, and the females were in each stage from spawning to spent stages in March. In *Crassostrea belcheri*, five in 13 individuals were classified in the immature stage, and both sexes were present in each stage from spawning to spent stages in December. Four out of five individuals were classified as immature, and only one male individual was in the spawning stage in March. In *Atrina pectinata*, two out of six individuals were classified in the immature stage, the males were in the spawning stage, and the females were in each stage from spawning to the spent stage in September.

Table 3. Classification of sexual maturation stages of each bivalve specimen purchased from the local markets and a seafood restaurant in Myeik City, Myanmar in December 2014 and March and September 2015.

Species	Month	n	I	Male				Female			
				II	III	IV	V	II	III	IV	V
<i>Meretrix casta</i> var. <i>ovum</i> (Hanley, 1845)	Dec.	30	2	2	9	3	2	8	4		
	Mar.	54	13	3	13	5	3	6	7	4	
	Sep.	54	3	13	3	8	17	5	4	1	
<i>Paphia undulata</i> (Born, 1778)	Dec.	30	1	4	6	7	3	5	4		
<i>Perna viridis</i> (Linnaeus, 1758)	Dec.	19	5	3	3	1	7				
	Mar.	21	2	1	8	4	2	4			
<i>Crassostrea belcheri</i> (Sowerby, 1871)	Dec.	13	5	5	1	1	1	1			
	Mar.	5	4	1							
<i>Atrina pectinata</i> (Linnaeus, 1767)	Sep.	6	2	1			2	1			

I: immature stage, II: developing stage, III: mature stage, IV: spawning stage, V: spent stage.

The stages were classified with reference to the blood cockles and pen shells (Yurimoto et al. 2008, 2014a, 2014b; Maeno et al. 2009).

Digestive gland

The results of epithelial cells condition in the digestive gland are shown in Table 4. *Meretrix casta* var. *ovum* was classified mainly to the section I in December and sections II and III were minor. In March, the majority of *M. casta* var. *ovum* was classified in section I and approximately 20 % in section II. In the case of *Paphia undulata*, section I showed majority and sections II and III were minor in December. *Perna viridis* was classified mainly in section III in December. Seven individuals were classified in section II and only three individuals in section I in December. However, on March, 18 out of 21 individuals were classified in section II, two individuals in section I, and only one

individual in section III. In the case of *Crassostrea belcheri*, eight out of 13 individuals were classified in section II, four individuals in section I, and only one individual in section III in December. Four out of five individuals were classified in section I and one individual in section II in March. All five *Atrina pectinata* individuals were classified in section I in September.

Table 4. Classification of epithelial cell conditions in the digestive gland of each bivalve specimen purchased from the local markets and a seafood restaurant in Myeik City, Myanmar in December 2014 and March and September 2015.

Species	Month	n	ns	I	II	III
<i>Meretrix casta</i> var. <i>ovum</i> (Hanley, 1845)	Dec.	30	1	28	1	
	Mar.	54		51	3	
	Sep.	54	5	37	12	
<i>Paphia undulata</i> (Born, 1778)	Dec.	30	3	21	5	1
<i>Perna viridis</i> (Linnaeus, 1758)	Dec.	19		3	7	9
	Mar.	21		2	18	1
<i>Crassostrea belcheri</i> (Sowerby, 1871)	Dec.	13		4	8	1
	Mar.	5		4	1	
<i>Atrina pectinata</i> (Linnaeus, 1767)	Sep.	6	1	5		

ns: The sample could not be analysed as the target region could not be observed after preparation of the tissue section. I: normal condition, II: partial flattening of epithelial cells, III: extensive flattening of epithelial cells. The stages were classified with reference to the blood cockle *Anadara granosa* (Yurimoto et al. 2014c).

Digestive duct

Status of food ingestion into the digestive duct of the specimens is shown in Table 5. *Meretrix casta* var. *ovum* showed the presence of food in the digestive duct in 21 out of 30 individuals in December, 37 out of 54 individuals in March, and 45 out of 53 individuals in September. *Paphia undulata* showed the presence of food in the digestive duct in 17 out of 30 individuals in December. *Perna viridis* showed the presence of food in the digestive duct in 15 out of 19 individuals in December and 18 out of 21 individuals in March. *Crassostrea belcheri* showed the presence of food in the digestive duct in six out of 13 individuals in December and two out of five individuals in March. Four out of six *Atrina pectinata* individuals showed the presence of food in their digestive duct in September.

PSP toxins

The ELISA results of PSP toxins in the bivalve specimens showed low levels (<1 nM) in *Meretrix casta* var. *ovum*, *Paphia undulata*, *Perna viridis*, and *Crassostrea belcheri* in December; in *M. casta* var. *ovum*, *P. viridis*, and *C. belcheri* in March; and in *M. casta* var. *ovum* and *Atrina pectinata* in September (Table 6).

Table 5. Observation of digestive duct for the estimation of food availability in each bivalve specimen purchased from the local markets and a seafood restaurant in Myeik City, Myanmar in December 2014 and March and September 2015.

Species	Month	n	ns	Food+	Food-
<i>Meretrix casta</i> var. <i>ovum</i> (Hanley, 1845)	Dec.	30		21	9
	Mar.	54		37	17
	Sep.	54	1	45	8
<i>Paphia undulata</i> (Born, 1778)	Dec.	30		17	13
<i>Perna viridis</i> (Linnaeus, 1758)	Dec.	19		15	4
	Mar.	21		18	3
<i>Crassostrea belcheri</i> (Sowerby, 1871)	Dec.	13		6	7
	Mar.	5		2	3
<i>Atrina pectinata</i> (Linnaeus, 1767)	Sep.	6		4	2

ns: The sample could not be analysed as the target region could not be observed after preparation of the tissue section.

The sample was classified with reference to the blood cockle *Anadara granosa* (Yurimoto et al. 2014c).

Table 6. Concentrations of paralytic shellfish poisoning (PSP) toxins in the edible soft tissue parts of the bivalve samples purchased from the local markets and a seafood restaurant in Myeik City, Myanmar in December 2014 and March and September 2015.

Species	Month	Station	n	Pooled tissue weight (g)	PSP Conc. (nM)
<i>Meretrix casta</i> var. <i>ovum</i> (Hanley, 1845)	Dec.	1	15	21	<1
		1	18	9	<1
	Mar.	2	18	58	<1
		5	18	26	<1
	Sep.	1	10	34	<1
	3	12	10	<1	
<i>Paphia undulata</i> (Born, 1778)	Dec.	6	15	42	<1
<i>Perna viridis</i> (Linnaeus, 1758)	Dec.	6	10	65	<1
		1	10	98	<1
	Mar.	5	11	71	<1
<i>Crassostrea belcheri</i> (Sowerby, 1871)	Dec.	1	10	125	<1
	Mar.	1	5	161	<1
<i>Atrina pectinata</i> (Linnaeus, 1767)	Sep.	1	6	213	<1

Weather

Annual changes in monthly average temperature and rainfall amount in Victoria Point, Myanmar, from September 2014 to October 2015 are shown in Figure 2. The average temperature was 25.6 °C in September 2014; it remained almost the same value from October 2014 to December 2014 and dropped to 25.2 °C in January 2015. Subsequently, it gradually increased and reached the maximum value of 28.6 °C in April 2015, and gradually decreased to the lowest value of 24.6 °C in September 2015. The monthly rainfall amount was 441 mm in September 2014, and it gradually decreased to 37 mm in December 2014. It ranged from 0 to 1 mm from January to March 2015, and then

gradually increased from April 2015 onwards. The amount of rainfall ranged from 620 to 725 mm from June to August 2015, and it showed a peak of over 1,000 mm in September 2015 and then dropped sharply to 105 mm in October 2015.

Discussion

Weather and bivalve landing

From the weather data of Southern Myanmar, the monthly average air temperature was above 27 °C from April to May, and below 25 °C in September. Additionally, the monthly rainfall data showed a pre-monsoon transition period from dry to wet seasons during April and May and a transition period from wet to dry seasons from October to November. The difference between dry and wet seasons was clear in Southern Myanmar, wherein the rainfall amount was almost zero millimetres from January to March and above 600 mm from June to September. Therefore, the bivalve samplings in Myeik City were carried out in early (December) and late (March) dry seasons and peak of the rainy season (September).

Some markets and a seafood restaurant were surveyed in Myeik City for collecting bivalve samples in December 2014, and March and September 2015. In the dry season, many kinds of bivalves, such as *Meretrix casta* var. *ovum*, *Crassostrea belcheri*, *Perna viridis*, and *Paphia undulata*, were sold in the markets and the restaurant. However, the bivalves landed from the surrounding waters in the wet season showed less variety because *M. casta* var. *ovum* was sold at every market, but the other bivalve, *Atrina pectinata*, was sold only at a street market. The monthly rainfall of over 600 mm continued during the wet season suggested that the landing of bivalves became unstable by the influence of flood and bad weather. Moreover, in case of *M. casta* var. *ovum*, this clam is known to be able to grow in a low-salinity environment such as 10‰ lower salinity waters, continuously for more than 3 months (Rao 1988). Therefore, *M. casta* var. *ovum* is sold during the dry and wet seasons in the Myeik Coast, then it is considered as the stable food source for local people.

Sexual maturation

In a case study of *Meretrix casta* (Chemnitz, 1782) in Mulky estuary of India, the gonads developed from August to September after the wet season; the number of individuals reaching from mature to spawning stages increased from September to March during the dry season (Rao 1988). Consequently, this period is considered a favourable season for their spawning. In case of *Meretrix casta* var. *ovum* in the Myeik Coast reached from mature to spawning stages from December to March in the dry season, and they reached mainly in the developing stage in September during the wet season. Therefore, the case of *M.*

casta var. *ovum* in the Myeik Coast was almost consistent with that of the Indian *M. casta*, suggesting that *M. casta* var. *ovum* in Myeik developed their gonads in the late wet season and the majority of them were in the spawning stage during the dry season. A study on the sexual maturation monitoring of *Paphia undulata* in Negros, the Philippines, reported that the mature to spawning stages were observed throughout the year and the favourable season was from August to November in the wet season of the blowing northeast monsoon (Nabuab et al. 2010). The present study was carried out only on the landed bivalves in the early dry season, where the majority of *P. undulata* were in the period where the gonads in both sexes were in matured to spawning stages. Thus, *P. undulata* have the main spawning season in the dry season. Each specimen of both sexes of *Perna viridis* was in the spawning stage during the dry season from December to March. However, this period was unlikely to be a favourable season for their spawning, because the spawning stage showed a low ratio in the female specimens. Therefore, their main spawning season was considered in another period.

The main spawning season of both the sexes of *Crassostrea belcheri* was in December in the early dry season. And the oysters were considered to already finish their spawning in March in the late dry season. Nevertheless, the spawning season of *Atrina pectinata* was observed in September in the wet season. These results revealed that many species of these edible bivalves in Myeik had a main spawning period during the dry season. Phytoplankton bloom often occurs in the coastal area when daylight hours increase during the dry season because the area is rich in nutrients (Su-Myat et al. 2012a; Su-Myat and Koike 2013; Maung-Saw-Htoo-Thaw at al. 2017). Thus, there is a possibility that sexual maturation of the main bivalves proceeds in the rich food (plankton) environment during dry season.

Food availability

The epithelial cells in the digestive gland of bivalves are easily flattened depending on their physiological conditions such as food availability (Ellis et al. 1998). Yurimoto et al. (2014c) reported that in blood cockle *Anadara granosa* (Linnaeus, 1758), 80 % of the individuals showed an extensive or partial flatness during a mass mortality event. In the present study, the estimation results of the presence or absence of food in the digestive duct and the condition of epithelial cells in *Meretrix casta* var. *ovum* in December 2014 and March and September 2015 showed the presence of food in over 69 % individuals and normal epithelial cell conditions in over 75 % individuals every month. These results suggested that the majority of *M. casta* var. *ovum* were in good condition for consumption and showed good nutrient absorption almost throughout the year. *Paphia undulata* showing the normal condition of the

epithelial cells were 70 %, and those showing food in their digestive duct were 57 % in all specimens in December. Whereas *Perna viridis* individuals showing normal epithelial cells were only 10–16 %, and those showing food in their digestive duct were 79–85 % in December 2014 and March 2015; the individuals showing partial flatness of their epithelial cells were 37–86 % in December and March, and those showing extensive flatness were 47 % in December. From these results, *P. viridis* were ingesting plankton but they were in low nutrient absorption ability condition during the dry season. Hence, the nutritional absorption ability might have been affected due to the spawning event, because their gonads were mainly in spawning or spent stages. Approximately 40–46 % of *Crassostrea belcheri* showed the presence of food in their digestive duct in December and March, 31–80 % showed the normal epithelial cell condition in the digestive gland and 62 % of the individuals in December showed the partially flattened epithelial cells in their digestive gland. This feeding instability of this species seems to be due to the fact that the oyster inhabits around 5 m depth in reef area of Myeik. Feed supply in the area is limited from water column compared to the resuspension area like mud flat (Maung-Saw-Htoo-Thaw et al. 2017). Among *Atrina pectinata* individuals, 67 % showed the presence of food in their digestive duct, and all individuals showed normal epithelial cell conditions in September. This species was obtained in September during the rainy season, and there was concern about the effect of their feeding by the inflow of fresh water, but it was in good feeding condition. From these results, *M. casta* var. *ovum* showed a stable feeding condition in both the dry and rainy seasons among the bivalves. Therefore, this species is a stable fishing target on the coast throughout the year.

PSP toxins

In recent years, the distribution of toxic dinoflagellates causing paralytic shellfish poisoning is expanding in the coastal areas of the Southeast Asian countries (Furio et al. 2012). In the east coast of Peninsular Malaysia, the vegetative cells of the toxic dinoflagellates, such as *Alexandrium tamiyavanichii* (Balech, 1994), and *Pyrodinium bahamense* (Plate, 1906), were observed in the water column and some poisoning events occurred in humans by their ingestion (Lim et al. 2012; Normawaty et al., 2015). Furthermore, on the west coast of Peninsular Malaysia, the vegetative cells of *P. bahamense*, *A. tamiyavanichii*, and *Gymnodinium catenatum* (Graham 1943) were observed in the water column (Lim and Leaw 2012; Su-Myat et al. 2012b), and *G. catenatum* cysts were detected in the bottom sediment of the coastal waters (Su-Myat et al., 2012b). Additionally, the vegetative cells of *A. tamiyavanichii* and cysts of *G. catenatum* were observed in the coastal waters of Myeik (Su-Myat et al. 2012a). These findings suggest a need to exercise caution for the poisoning of bivalves in the coastal areas. In this study, ELISA kit was used

for analysing the PSP toxins in the collected bivalve samples (Sato et al. 2014). The toxin samples extracted from the edible part of each bivalve specimen showed negligible concentrations (<1 nM) in December 2014 and March and September 2015 (Table 6). Therefore, these landed bivalves were safe from the contamination of PSP toxins. These results suggest that the current situation in Myeik can be determined as a low-risk for PSP toxins contamination in bivalves. However, it is well known that the vegetative cells and cysts of the toxic species are transferred from other waters with human activities such as bringing aquatic organisms for aquacultures and ballast water of tanker (Scholin et al. 1995; Bolch and de Salas 2007; Matsuyama et al. 2010). Thus, countermeasure of these factors will play an important role to prevent their contamination with PSP toxins in the Myeik Coast in future.

Conclusion

Meretrix casta var. *ovum* is the most stable landing species to the local markets from the Myeik Coast in Southern Myanmar from dry to wet seasons. The results of physiological study showed that *M. casta* var. *ovum* has a long-term spawning season extending from dry to wet seasons and the clam is landed in good food availability condition. Furthermore, the PSP toxins concentrations in all bivalve samples showed nontoxic levels (<1 nM) in all months of the study period. The results of the present study suggest that the Myeik Coast is suitable for hard clam fishing and aquaculture.

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