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Are Intertidal Mudflat Communities (Fish And Shrimp) Affected by Cockle Culture?

Soon-Loong Lee[1*], Ving-Ching Chong[1,2], Kar-Hoe Loh[2] , Tatsuya Yurimoto[3]

[1]Institute of Biological Sciences, University of Malaya, 50603 Kuala Lumpur, Malaysia.
[2] Institute of Ocean & Earth Sciences, University of Malaya, 50603 Kuala Lumpur, Malaysia.
[3]Japan International Research Institute of Agricultural Sciences (1-1 Ohwashi Tsukuba Ibaraki, 305-8686 Japan)

*leesl1988@yahoo.com (corresponding author)

ABSTRACT Extensive cockle culture on coastal intertidal mudflats which function as productive feeding grounds for fish and shrimp may affect mudflat productivity and disturb feeding activity. The aim of the present study is to examine fish ingressions into two adjacent coastal mudflat areas, one with cockle culture and the other without cockle culture, especially to compare their diversity and abundance. Two sampling sites were selected at Bagan Sungai Buloh (BSB: with cockle bed) and BaganPasir (BP: without cockle bed) in the Kuala Selangor mudflat area. Monthly samplings were carried out on spring tide using an enclosure trap (*belat lengkung*). In six months of samplings, 63 identified species of fishes and eight species of prawns were recorded. Both mudflats differed in their fish species richness, with 59 species in BSB and 41 species in BP. However, the BP mudflat had significantly higher fish biomass (142.2 ±148.7 kg/ha) than BSB mudflat (43.6 ±41.2 kg/ha) (t-test, $p<0.05$). As for mean fish abundance, the difference between two sites is not significant. Most frequent fish species that regularly occurred every month on both sites were the grey mullet *Liza subviridis* and tongue sole *Cynoglossus bilineatus*. There was no significant difference in penaeid shrimp abundance and biomass between both sites. The dominant species of shrimps in term of biomass in BSB was *Fenneropenaeus merguiensis*, whilefor BP was *Metapenaeus affinis*. Low abundance and biomass of fish species in cockle culture area are likely due to direct disturbance from culture activity as well as continually scoured sediments from cockle harvests which may affect mudflat productivity.

(**Keywords:** Mudflat, cockle culture impacts, faunal abundance and biomass)

INTRODUCTION

Blood cockles (*Tegillarca granosa*) are extensively cultured on the west coast of Peninsular Malaysia, where intertidal mudflats cover about 32,000 ha or one third of the mangrove area. These mudflats are especially developed in the Kuala Selangor and Matang areas, where Malaysia's largest blood cockle culture beds are located [1].

Coastal mudflats serve as important feeding grounds for coastal fish and invertebrates when the high tide inundates them [2, 3], and for shorebirds when the ebb tide recedes to expose them. Kuala Selangor coastal mudflats produced 41,410 tonnes (2010) of blood cockles [4]. Together with the coastal mangroves, these mudflats are believed to support the country's second largest fisheries production in the state of Selangor with an annual yield of 144,440 tonnes of fish and others [4]. A number of papers suggest that bivalves have a major effect on their environment, either directly or indirectly and are thus important ecosystem engineers or foundation species [5, 6]. Thus, cockle culture and its associated activities including cockle thinning and harvestings may disrupt mudflat ecological processes due to rapid sediment turnover, increased turbidity, reduced oxygen, increased metabolites, reduced natural in-fauna production, as well as reducing fish ingress and feeding in the mudflats. On the other hand, the natural communities may directly affect cockle culture through competition and increased predation of cockles. The major predators of blood cockles are certain species of gastropods and fishes. Broom [7] reported that the gastropod *Natica maculosa* and *Indothais lavera* are important predators of cultured blood cockles in the Kuala Selangor mudflats.

Most bivalves feed by filter feeding. Newell [6] and Dame [8] revealed that dense bivalve beds are able to control or moderate various planktonic assemblages in natural marine systems through their large filtering capacity, hence modulating feedbacks between trophic levels. In fact, species composition, primary production, food web and nutrient cycling may be well influenced by abundant bivalve populations [8, 9]. Furthermore, biodeposition can result from suspension feeding bivalves. Most bivalves in filtering large amounts of water, remove fine particulate (seston) in suspension, ingest the filtered organic material, and finally excrete the dissolved form or repackage and release these materials either as faeces or pseudofaeces. The result is a downward flux of seston which in turn may alter sediment-water nutrient exchange [10]. High rate of biodeposition may affect macrofaunal diversity by reducing oxygen availability at the water-sediment interface [11], while at low rate has a positive influence on macrofaunal diversity by providing an important food resource for benthic species without producing anaerobic conditions [12].

Thus, the impact of intensive cockle culture on the natural community of intertidal mudflats could either be detrimental or beneficial. It is therefore important to understand the cockle culture – fauna community interactions, in order to both sustain cockle production and to reduce its impact on the environment. The present study thus aimed to elucidate these interactions by comparing a cockle culture and non-culture site in terms of its fish community and the environment that it might have modified.

MATERIALS AND METHODS

Study area

The study area covered one of the most extensive mudflats in the state of Selangor, west coast of Peninsular Malaysia. The mudflat stretches from Bagan Sungai Buloh through the mouth of the Kuala Selangor estuary, to Sungai Tengkorak north of it (Figure 1). It is flanked by a narrow coastal fringe of mangrove forest (379 ha), most of which (ca. 90%) has been previously reclaimed for agricultural development on the landward side of a coastal dyke constructed during the 60s. The intertidal mudflat is rapidly accreting at and near Kuala Selangor and stable or eroding in the north. The coastal mudflats are fed by large sediment loads brought down by the state's three largest rivers, the Langat, Klang and Selangor rivers.

The median tidal range at Kuala Selangor is 3.8 m. According to data obtained from Malaysian Meteorological Department, the state has an average monthly rainfall of less than 165 mm and a mean annual temperature of 26.6 °C. Rain comes with both the northeast (NE) and southwest (SW) monsoons, although the latter is mitigated by the mountains of Sumatra. The wettest months are April (SW monsoon) and October-December (NE monsoon), the driest, January-February and July.

Sampling design

Samplings were carried out on the spring tide of each month from September 2011 to February 2012. Each monthly sampling on Bagan Sungai Buloh (BSB: with cockle bed) and BaganPasir (BP: without cockle bed) used a large enclosure trap or fyke net, locally called *belat lengkong* (Figure 1). The enclosure trap catches swimming fish and invertebrate fauna that retreat to the sea during the ebb tide. The net was deployed closest about 800 m from the mangrove fringe in water of less than 1.5 m depth. The enclosure trap net had a cod-end mesh size of 1.5 inch. During high slack, the enclosure trap was staked into the mud forming a 'V' or 'L' configuration to enclose a large area. Fish were then trapped during the subsequent ebb run. The water completely dried up and fish and swimming invertebrates were collected at the net's vertex. The area cover (ha) of the enclosure net was estimated by using a three point GPS determination of the coordinates of its two ends and vertex. The catch of the enclosure trap was normally very large, and subsampling was normally done. Usually 1/10 of the total catch by the enclosure trap were taken. If the catch was not large, all fish and shrimp were taken.

Fish and invertebrate analysis

The frozen fish and invertebrate samples were thawed first before analysis. All fish and shrimp were first identified, with the help of the following references: Munro [13], De Bruin et al. [14], Mohsin and Ambak [15], and Carpenter and Neim [16, 17]. The following measurements were measured for each individual: standard length, SL, and weight, for fish; carapace length, CL and weight, for shrimps. Valid fish and shrimp names as listed in the Fishbase by Froese and Pauly [18] and World Register of Marine Species (WoRMS) [19] were used unless not listed.

Information pertaining to the enclosure trap net characteristics, area enclosed, and subsampling were recorded or computed, They were relevant to the estimation of fish abundance based on the area covered method, expressed in terms of numbers/ha and biomass (kg/ha).

Data analysis

t-test was used to test the significant difference between fish abundance and biomass at BSB and BP mudflat. Data were $\log_{10}(x+1)$-transformed prior to the analysis to approximate normality and homogeneity of variance. Shannon-Wiener diversity index (H') and Pielou's evenness (J') were calculated for fish assemblages at both mudflat areas.

RESULTS

In the six months of samplings, a total of 63 identified species of fish and eight identified species of shrimp were recorded (Table 1). Species of fish that were exclusive to BSB were *Anodontostom achacunda, Boleophthalmus boddarti, Chelonodon patoca, Dendrophyssa russelii, Drepane punctata, Harpadon nehereus, Ilishae longata, I. melastoma, Johnius borneensis, J. carouna, Lagocephalus lunaris, Leiognathus brevirostris, Pampus chinensis, Platax tiera, Platycephalus indicus, Pomadasys kaakan, Scomberoides tol, Secutor ruconius, Synaptura commersonnii, Takifugu oblongus, Thryssa hamiltonii, Triacanthus nieuhofii* and *Upeneus sulphureus*. Species of fish that was exclusive to BP were *Lates calcarifer, Leptomelanosoma indicum, Protonibea diacanthus* and *Sillago sihama*. BSB had a higher species evenness and diversity than BP (Table 2). The enclosure net enclosed a mean area of 37,792.2 m² and 19,370.1 m² at BSB and BP respectively. The fish catch abundance at the mudflat in BSB ranged from 697 N/ha to 13,570 N/ha (Figure 2 and 3). Standing stock biomass ranged from 14.685 kg/ha to 111.239 kg/ha. In BP mudflat, the catch abundance and biomass ranged from 1,071 N/ha to 16,841 N/ha and 42.060 kg/ha to 437.491 kg/ha respectively. From the data, the three most abundant species of pelagic fish in terms of numbers in BSB mudflat were *Aspericorvina jubata, Hexanematichthyssa sagor* and *Panna microdon.* In terms of biomass, *A. jubata* ranked the highest, followed by *Otolithes ruber* and then *H. sagor.* In BP mudflat, the three most dominant fish species of fish in terms of numbers were *A. jubata, Thryssa kammalensis* and *Plicofollis argyropleuron.* In terms of biomass, it was the similar except *P. argypleuron* was replaced by *Liza subviridis.* t-test shows significant difference in mean biomass between BSB and BP ($p<0.05$) while mean abundance did not show any significant difference between both sites (Table 3).

The shrimp catch abundance in BSB mudflat gave densities that ranged from 121 N/ha to 6,532 N/ha (Figure 4 and 5). Standing stock biomass ranged from 0.218 kg/ha to 22.147 kg/ha. As for BP, density and standing stock biomass ranged from 61 N/ha to 2,341 N/ha and 0.147 kg/ha to 5.015 kg/ha respectively.The three most dominant species of shrimp in terms of biomass in BSB and BP were the same, which were *Metapenaeus affinis, M. brevicornis* and *Exopalamonstyliferus.* In terms of number, *M. affinis*, *Parapeneopsis hardwickii* and *M. brevicornis* ranked the highest in BSB mudflat while *Exopalamon styliferus*, *M. affinis* and *M. brevicornis* were the highest in BP mudflat. t-test did not indicate any significant difference in mean biomass and mean abundance between both sites (Table 4).

DISCUSSION

BP mudflat, representing community without cockle culture had significantly higher mean fish biomass (t-test, $p<0.05$) and abundance than BSB (with cockle-bed). This may be due to direct disturbance from the culture activity. According to the local fishermen, cockle harvesting are usually conducted once every two days or daily when the catches are good.

A number of manipulative studies on bivalve have shown that the physical structure of bivalves is more important in modifying the local habitat than the bivalve's biological role [20]. Such physical alteration of the soft sediment bottom of the mudflat to a hard bottom due to the presence of cockle shells could affect and deter bottom feeding by fishes. This could explain the lower fish biomass and abundance at BSB. The hard cockle substrate also attracts shelled gastropods that predate on the cockles [7] further contributing to the change from soft to hard bottom.

According to Chong et al. [21], the mudflat fish community in Kuala Selangor consisted of mainly sciaenids, clupeids, engraulids, cynoglossids, ambassids, mugilids and ariids. The present study also shows rather similar fish species, with the additional two dominant species of dasyatids and plotosids.

Fish abundance and biomass peaked in January at BP mudflat; the dominant commercial species was *A.*

jubata which accounted for 72.6% by biomass and 64.6% by abundance. Interestingly, this species was not previously reported by Sasekumar et al [22], whereas five exclusive mudflat fish species reported by Chong et al. [21], namely, the catshark *Hemiscyllium indicum*, the grey mullet *Lizaar gentea*, the silver pennah croaker *Pennahia argentata*, the spotted croaker *Protonibea diacanthus* and the anchovy *Stolephorus macroleptus* were not observed in the present study. All shrimp species found in this study were also recorded in Chong et al [21].

Shrimp species at both sites showed no significant difference in mean biomass and abundance; they may not be strongly affected by cockle culture. Leh and Sasekumar [2] reported that most of the penaeid shrimp species in Selangor's nearshore waters are opportunistic omnivores and feed more on benthic fauna. Shrimp thus ingress and feed in the mudflat area without any apparent ill effect caused by cockle culture on the mudflat.

Interestingly, the BSB mudflat had higher species diversity and species evenness than BP. It is possible that cockle culture may create habitat heterogeneity which increases fish diversity. Several reports by Lohse [23], Mohammed [24], and Borthagaray and Carranza [25] suggested that the shells create crannies and nooks on and amongst them, allowing sediments to accumulate within the matrix, thus forming different microhabitats and increasing habitat heterogeneity. In the study area, we observe that empty shells strewn the mudflat area, and in Jeram (south of the culture beds) strong currents often move the mud away to expose large areas containing hard shelly substrate. The culture of cockles attracts their natural predators into the culture area, such as gastropods, sea stars and catfishes. This attraction further increases ingressions and species interactions, thus increasing the diversity in and around the mudflat area. Nevertheless, further research on the effects of habitat modification (or habitat heterogeneity) on species diversity and abundance is needed for a conclusive result.

CONCLUSION

This study has shown that the mudflat with cockle culture may lower fish species abundance and biomass but harbors higher fish species diversity. However, extensive cockle culture activity may severely affect the mudflat habitat that acts as a feeding ground for commercially important fishes.

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Table 1. Checklist of fishes and shrimp sampled using enclosure trap on coastal mudflats in BSB and BP, Kuala Selangor (September 2011 to February 2012). *Top 10 most important species of fish.

Species	BSB	BP	Species	BSB	BP
Fish species			*Otolithes ruber*	X*	X
Ambassis gymnocephalus	X	X	*Otolithoides biauritus*	X	X
Anodontostoma chacunda	X		*Pampus argenteus*	X	X
Arius caelatus	X	X*	*Pampus chinensis*	X	
Arius maculatus	X	X	*Panna microdon*	X*	X*
Aspericorvina jubata	X*	X*	*Platax tiera*	X	
Boleophthalmus boddarti	X		*Platycephalus indicus*	X	
Chelonodon patoca	X		*Plicofollis argyropleuron*	X*	X*
Coiliadus sumieri	X	X	*Plotosus canius*	X	X*

Cynoglossus bilineatus	X	X*	*Pomadasys kaakan*	X	
Cynoglossus cynoglossus	X	X	*Protonibea diacanthus*		X
Cynoglossus lingua	X	X	*Scatophagus argus*	X	X
Cynoglossus puncdiceps	X	X	*Scomberoides tol*	X	
Dasyatis zugei	X*	X	*Secutor ruconius*	X	
Dendrophysa russelii	X		*Setipinna taty*	X	X
Drepane punctata	X		*Sillago sihama*		X
Eleutheronema tetradactylum	X*	X	*Stolephorus baganensis*	X	X
Harpadon neherus	X		*Stolephorus tri*	X	X
Hemiramphus far	X	X	*Strongylura strongylura*	X	X*
Hexanematichthys sagor	X*	X	*Synaptura commersonnii*	X	
Himantur auarnak	X	X			
Ilisha elongata	X		*Takifugu oblongus*	X	
Ilisha melastoma	X		*Terapon theraps*	X	X
Johnius belangerii	X	X	*Thryssa hamiltonii*	X	
Johnius borneensis	X		*Thryssa kammalensis*	X*	X*
Johnius carouna	X		*Triacanthus nieuhofii*	X	
Lagocephalus lunaris	X		*Trichiurus lepturus*	X	X
Lates calcarifer		X	*Upeneus sulphureus*	X	
Leptomelanosoma indicum		X	**Shrimp species**		
Leiognathus brevirostris	X*		*Exopalaemon styliferus*	X	X
Liza melinoptera	X	X	*Fenneropenaeus merguiensis*	X*	X
Liza subviridis	X*	X*	*Fenneropenaeus penicillatus*	X	X
Lobotes surinamensis	X	X	*Macrobrachium equidens*	X	X
Nibea soldado	X	X*	*Metapenaeus affinis*	X	X*
Odontamblyopus rubicundus	X	X	*Metapenaeus brevicornis*	X	X
Opisthopterus tardoore	X	X	*Parapenaeopsis hardwickii*	X	X
Osteogeneiosus militaris	X	X	*Parapenaeopsis sculptilis*	X	X

Table 2. Total number of species of fish and shrimp, species evenness and diversity for both sites.

Total number of species of fish	59	40
Total number of species of shrimp	8	8
Total number of species	67	48
Species evenness (J')	0.6806	0.5374
Shannon-Wiener diversity index, H' (log e)	2.852	2.08

Table 3. Mean (kg/Ha), standard deviation and *P* –value of fish biomass and abundance.

Site	Mean biomass (kg/Ha)	Standard deviation	*P* -value	Mean abundance (N/Ha)	Standard deviation	*P* -value
BSB	43.6	41.2	<0.05*	5157	5274	>0.05
BP	142.2	148.7		8065	5980	

Table 4. Mean (kg/Ha), standard deviation and *P* –value of shrimp biomass and abundance.

Site	Mean biomass (kg/Ha)	Standard deviation	*P* -value	Mean abundance (N/Ha)	Standard deviation	*P* -value
BSB	9.3	10.8	>0.05	2678	3109	>0.05
BP	2.3	2		770	893	

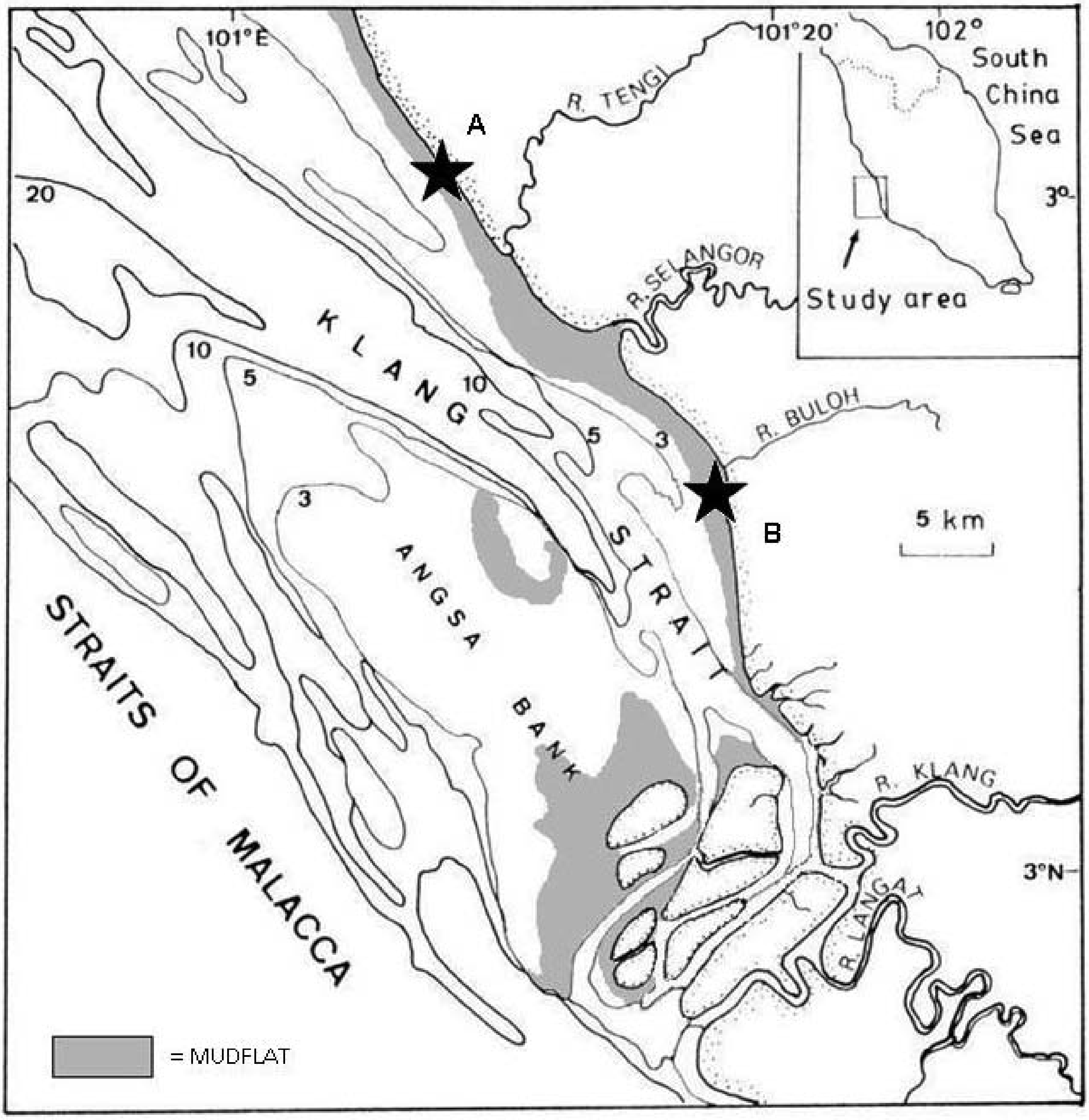

Figure 1. Map showing coastal mudflats adjacent to Kuala Selangor Mangrove Forest, Peninsular Malaysia. Study sites (stars) on the mudflat at BP (without cockle culture) and BSB (with cockle culture) are marked A and B, respectively.

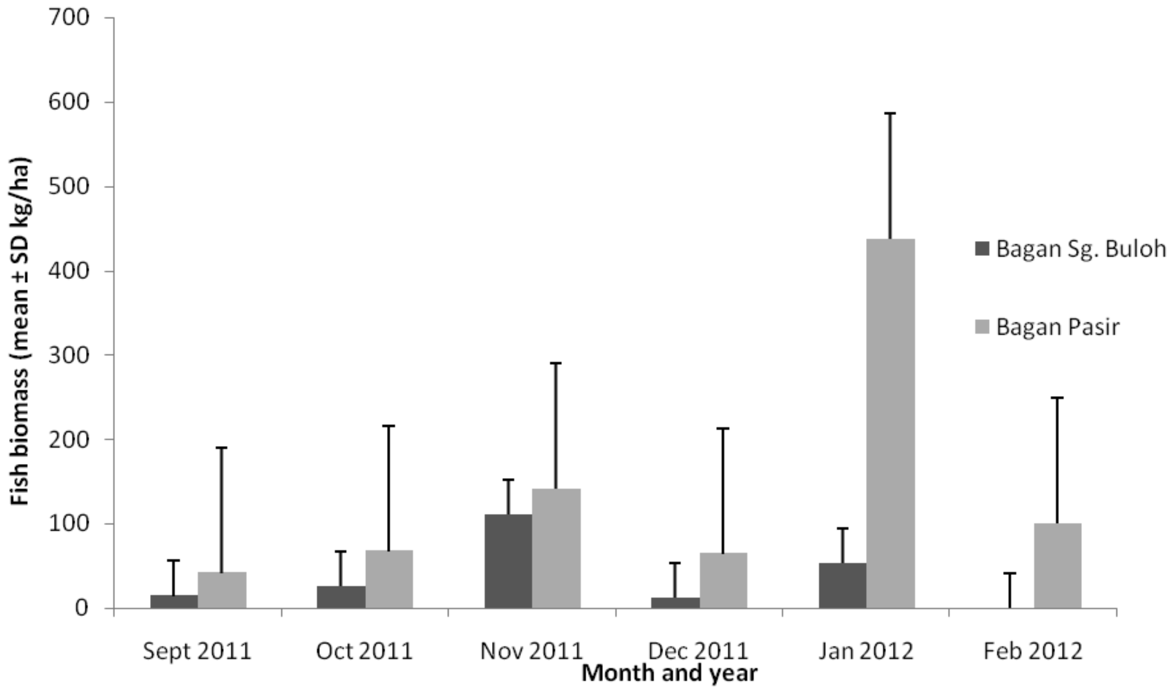

Figure 2. Monthly fish catch biomass in BSB and BP using enclosure trap.

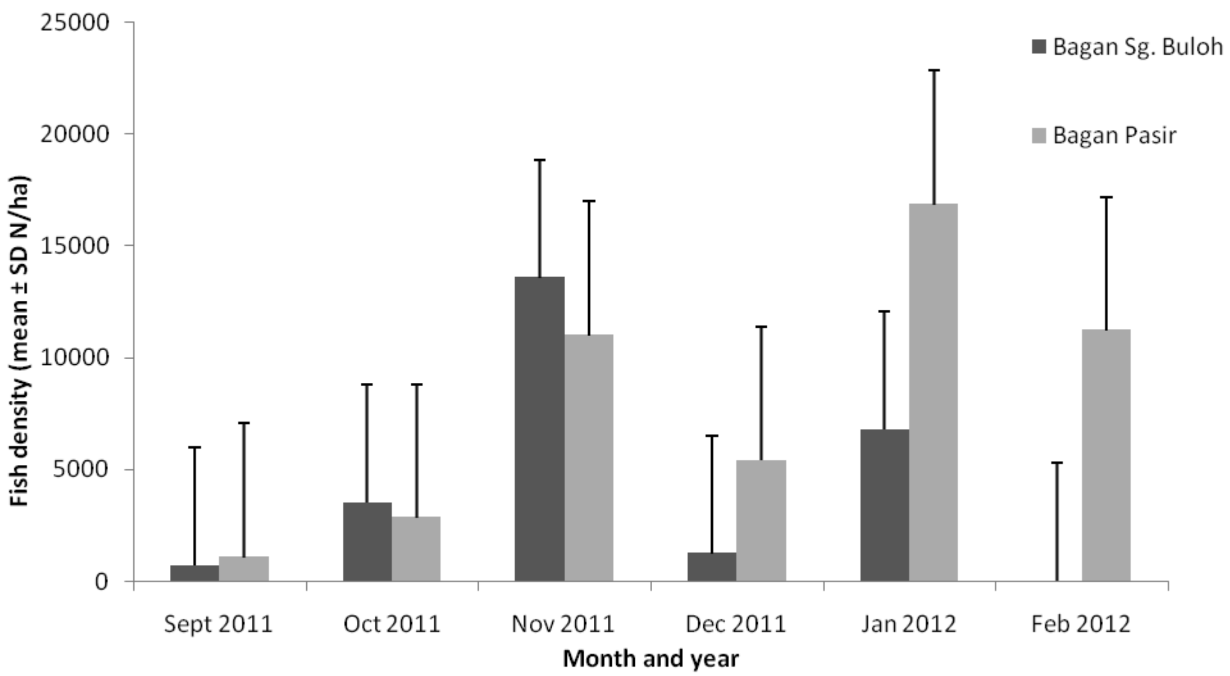

Figure 3. Monthly fish catch density in BSB and BP using enclosure trap.

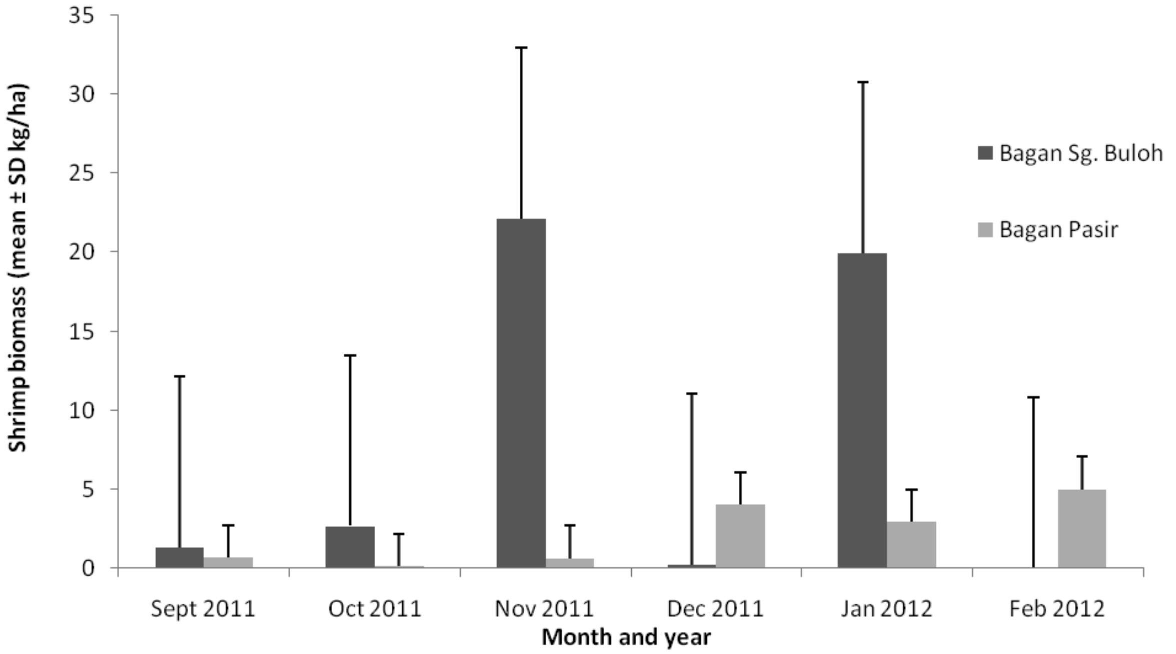

Figure 4. Monthly shrimp catch biomass in BSB and BP using enclosure trap.

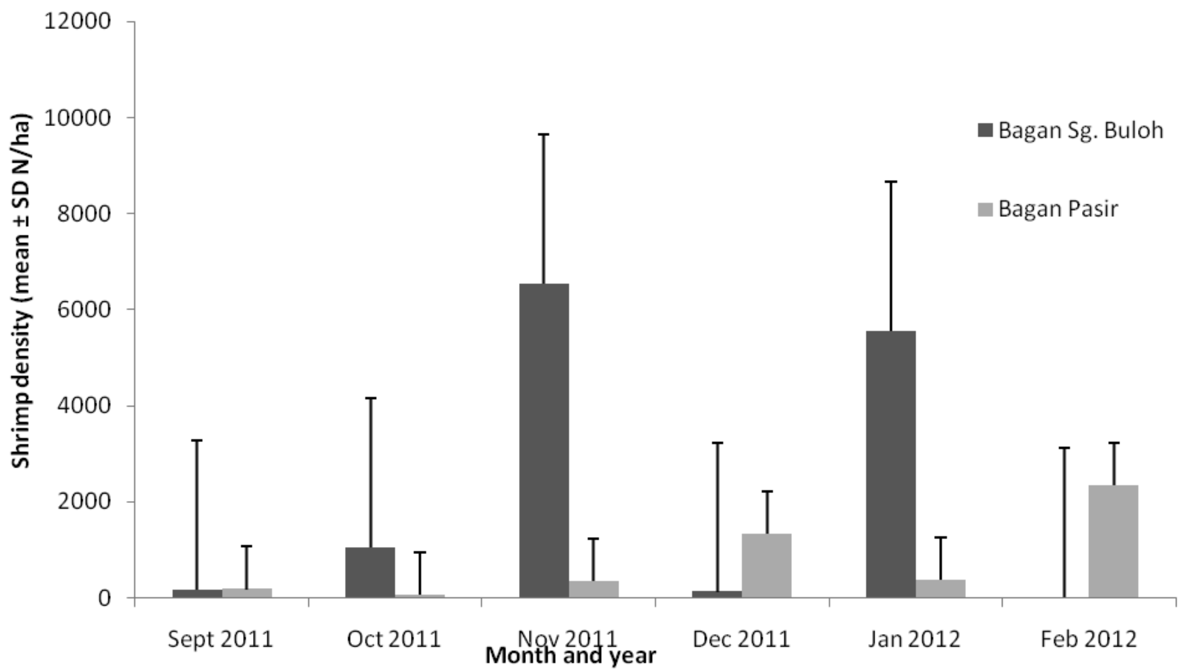

Figure 5. Monthly shrimp catch biomass in BSB and BP using enclosure trap.

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