Fishing technique and environmental factors affecting the size of razor clam *Solen* sp. in Indonesia coast

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Abstract. *Solen* sp. is one of the clam species of Pelecypoda possessing economic value. Fishing techniques are highly varied with coast. Aquatic environmental factors and substrates also influence the clam's length growth. Observations were done on the environmental factors and length distribution of *Solen* sp. and fishing technique in five study sites, Talang Siring coast in Pamekasan, Kwanyar coast in Bangkalan, east coast of Surabaya, Kajawanan coast in Cirebon, and Tanjung Solok coast in Jambi. Data analysis of environmental parameters used Principal Component Anaysis (PCA). Results showed that the size of *Solen* sp. was affected by fishing technique, substrate texture, and organic matters with variance of 57.54%. The biggest size of *Solen* sp. was recorded in clam collected in Tanjung Solok coast, Jambi, with length range of 4.0-12.3 cm and mean of 7.9±1.93 cm using line fishing. The smallest size was found in clams collected from Talang Siring coast, Pamekasan, with length range of 1.8-4.4 cm and mean of 2.8±0.41 cm using crowbar. Line fishing of *Solen* sp. has the lowest environmental impact, while the use of garu could cause damage to the sediment and water column. The severity level of fishing gear impact was influenced by fishing intensity and local environmental condition.
Key Words: line fishing, crowbar, size, substrate, Pelecypoda.

Introduction. Razor clam, *Solen* sp., is one of the clam species inhabiting the intertidal area, which is an open area for some times as terrestrial, and partly submerged area in other time, so that the organisms living in the intertidal area must be able to adapt to changing environmental conditions, such as tide, temperature, wave, salinity, substrate difference (Trisyani & Irawan 2008).

In Indonesia, *Solen* sp. is known under several local names. In Madura island and east coast of Surabaya, it is called *Lorjuk* and people also know it as bamboo clam or knife clam. *Solen* sp. is found in the coastal area of Madura, Pemekasan regency (Nurjanah & Rusyadi 2008), east coast of Surabaya (Trisyani et al 1999; Trisyani & Irawan 2008), Kejawanan coast, Cirebon (Subiyanto et al 2013), and Tanjung Solok waters, Jambi (Sugihartono 2006). DNA Barcode CO1 analysis reflects that *Solen* sp. in Surabaya is closely related with *Solen regularis* from Malaysia (Trisyani et al 2016b).

Solen sp. has been exploited all over the world using several fishing gears and different fishing techniques, depending on the target species and habitat environment. The impact of fishing gear utilization is change in sediment physical characteristics (Gaspar et al 1999; Bishop et al 2005). In Talang Siring coast, Pamekasan, *Solen* sp. collection uses crowbar to dig substrates, in Kwanyar coast, Bangkalan, uses a hoe, while in east coast of Surabaya, Kajawanan coast, Cirebon, and Tanjung Solok coast, Jambi, fishing operations use dredging tools to dig the substrate and palm leaf rib whose edge is greased with chalk-soap mixture to attract *Solen* sp. going out from the hole in low tide.

This study was aimed at examine the fishing technique and the habitat environment of on the size of *Solen* sp. caught in several coasts in Indonesia.

Material and Method

Study sites. This study was carried out in 5 coastal areas in Indoneisa, Talang Siring coast, Pamekasan, at the geographic position of 7°8'30.00"S and 113°35'21.00"E, Kwanyar coast, Bangkalan, at 7°10'2.00"S and 112°52'12.00"E, east coast of Surabaya at 7°13'48.00"S and 112°47'50.00"E, Kajawanan coast, Cirebon, at 6°44'14.00"S and 108°35'14.00"E, and Tanjung Solok coast, Cirebon, Batanghari river mouth at 1° 0'45.00"S and 103°49'0.00"E (Figure 1). The study site selection was based upon the occurrence of *Solen* sp. since not all coasts in Indonesia occur *Solen* sp.

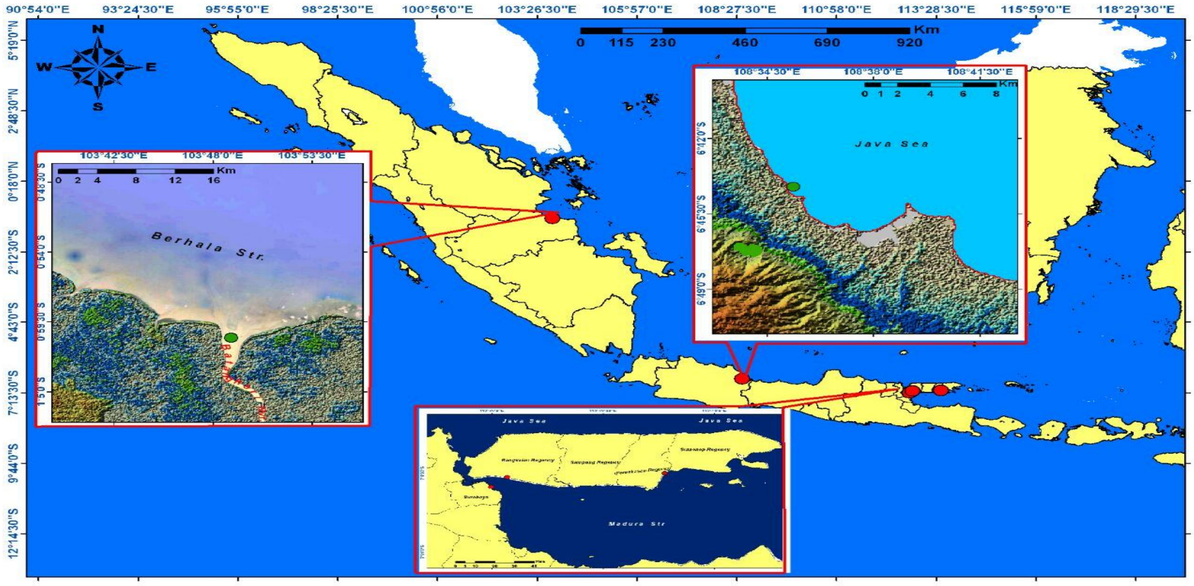

Figure 1. Map of study site.

Sample measurements. *Solen* sp. sampling was conducted every 2 weeks, 100 individuals per trip from April to July 2017. Individual length was measured using 0.1 cm caliper. Water quality measurements covered water temperature, salinity, pH, dissolved oxygen, turbidity, soil organic matter, sand texture, and mud. Fishing technique was also observed. Water quality and sediment analyses were done in Soil Chemistry and Physical Laboratory, Faculty of Agriculture, Brawijaya University, Malang.

Data analysis. Environmental parameter data were presented in a descriptive form and analyzed using Principal Component Analysis (PCA). PCA is a descriptive statistical method to present most of the information into data matrix in graphic form.

Results and Discussion

Environmental parameters. The PCA analysis on environmental parameters (Figure 2a) indicated that quadrant I had variance of 57% in which the environmental parameters dominantly affecting *Solen* sp. size were fishing technique, substrate texture dominated by sand and organic matter concentration.

Quadrant II had a variance of 29%, in which *Solen* sp. size was influenced by dissolved oxygen concentration and water pH, while quadrant III with a variance of 10%, *Solen* sp. size was affected by water temperature. These results are explained in Figure 2b indicating correlation among variables. The highest correlation of *Solen* sp. size with fishing technique was 96%, sand texture was 92%, organic matter was 86%, dissolved oxygen was 88%, pH was 80%, and water temperature was 76%.

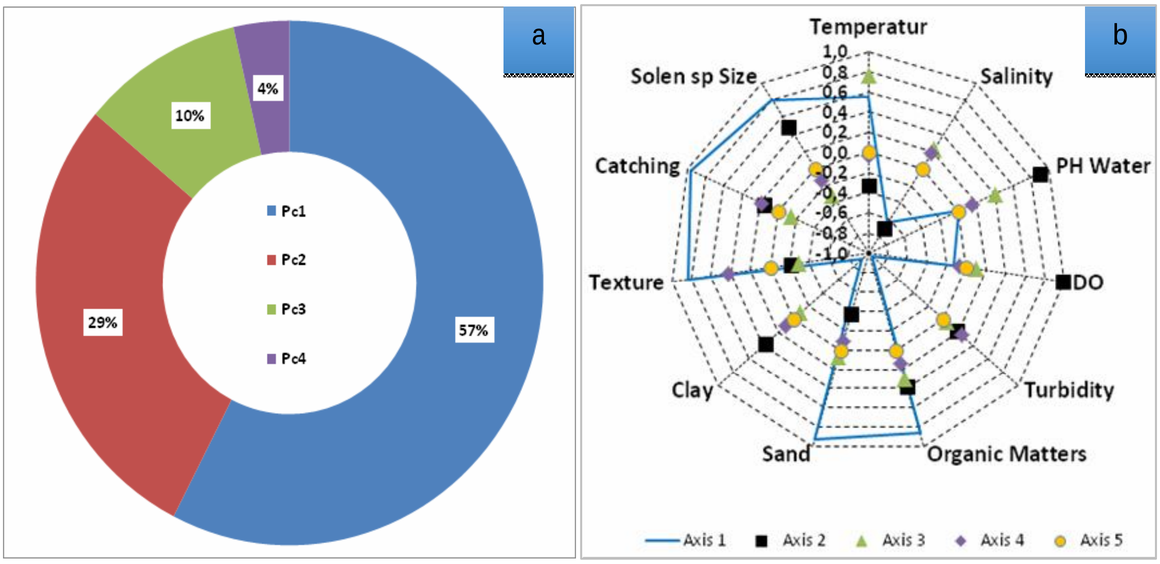

Figure 2. a). Percent qudrant of environmental parameters using PCA; b). Correlation value of environmental parameters of PCA.

Size distribution of *Solen* sp. caught using various fishing gears in 5 study sites during the study is presented in Figure 3.

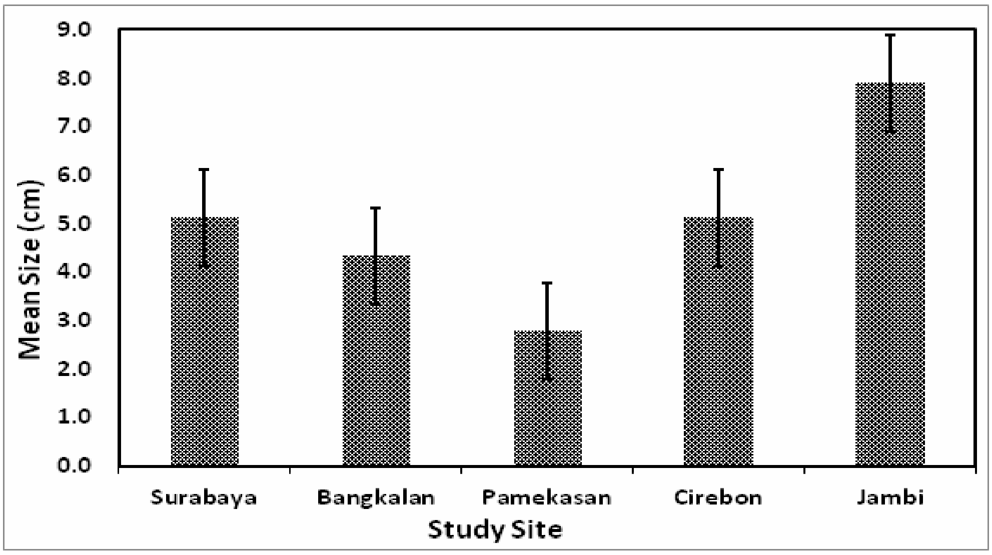

Figure 3. Length frequency distribution (cm) of *Solen* sp. with study site.

Solen sp. in Talang Siring coast, Pamekasan, had the smallest size with a range of 1.8-4.4 cm and mean of 2.8±0.41 cm, in Kwanyar coast, Bangkalan, 2.5-6.4 cm and mean of 4.3±0.85 cm, in east coast of Surabaya 1.8-6.9 cm and mean of 5.1±0.91 cm, in Kajawanan coast, Cirebon, 2.6-6.6 cm and mean of 5.1±0.48 cm and the largest in Tanjung Solok, Jambi, with length range of 4.0-12.3 cm and mean of 7.9±1.93 cm (Figure 4).

Figure 4. Size variation of *Solen* sp. in 5 study sites.

Substrate particle analysis in the 5 study sites showed that the smallest particles were found in Pamekasan with dusty clay texture dominated by 58% dust, and in Bangkalan coast with dust texture of 86.1% dust. Other 3 sites, Surabaya, Cirebon, and Jambi coast, the substrates had sand texture with 94-100% sand (Table 1).

Table 1

Substrate particle size (%) in 5 study sites

Study sites	*Texture*	*Substrate diameter distribution (mm) in %*					*Sand*	*Dust*	*Clay*
		2.0-1.0	*1.0-0.5*	*0.5-0.25*	*0.25-0.13*	*0.13-0.05*			
Pamekasan	Dusty clay	0.0	0.0	4.0	25.0	4.0	34.0	58.0	8.0
Bangkalan	Dust	0.5	0.2	0.6	6.1	2.8	10.2	86.1	3.7
Surabaya	Sand	1.0	2.0	50.0	38.0	3.0	93.0	0.0	7.0
Cirebon	Sand	0.2	0.8	17.0	67.7	14.3	100	0.0	0.0
Jambi	Sand	0.0	0.0	7.4	81.3	4.9	94.0	6.0	0.0

According to Holme (1954), the particle size of the substrate affects the distribution of 3 species of genus *Ensis*, *E. ensis, E. arcuatus,* and *E. siliqua* in England coast. In manual of marine fauna from Northwest Europa, *Ensis* and *Solen* genera are included in the Solenidae family (Hayward & Ryland 1998). Their distribution is related with particle size of the substrate due to the effect of coast slope and stability. *E. siliqua* distributed in the coast with wave hit is smaller than *E. arcuatus* inhabiting larger particle-sized substrate. Holme (1954) concluded that *E. arcuatus* in Great Britain occupied the coast of larger particle-sized substrate, 0.2-1.5 mm than *E. siliqua* or *E. ensis,* 0.21-0.0313 mm. Besides, *E. arcuatus* tolerates 35% substrate particle of 0.5 mm and sand particle < 0.0313 mm, while *E. siliqua* does not tolerate more than 5% large particles. It is related with the feet muscle strength of *E. siliqua* compared with that in *E. arcuatus*, as shown by Henderson & Richardson (1994) who compared *E. siliqua* and *E. ensis*

Ensis found in England coast, *E. arcuatus,* can reach a length between 12 and 17.5 cm, while *E. ensis* reach a length between 8 and 13 cm (Henderson & Richarson 1994; Hayward & Ryland 1998). These data are in agreement with the present study that in larger particle-sandy substrates in the east coast of Surabaya, Kajawanan coast, Cirebon, and Tanjung Solok coast, Jambi, is found larger-sized *Solen* sp.

Solen sp. is one of the organisms inhabiting the intertidal zone. This area possesses the largest environmental variations in marine ecosystem, which could be a terrestrial and submerged area in half a time. The physical factors regulating life in sandy intertidal zone are wave and its effect on the particle size. If the wave is small, the particle size will be small, and vice versa, if the wave is big and strong, the particle size will be large and coarse, and gravel deposits will occur. In Talang Siring coast, Pamekasan, and Kwanyar coast, Bangkalan, the wave movement is relatively small and close to the coast margin compared with east coast of Surabaya, Kajawanan coast, Cirebon, and Tanjung Solok coast, Jambi.

The organism distribution and abundance-related particle size influences water retention and its suitability for digging. Because of caliper force, the fine sand particles tend to hold more water in the pores in the low tide, so that the organisms could be protected from drought in the fine sand substrate (Nybakken 1992). The granule-formed soil texture, such as sand, possesses higher porosity and large pores holding enough air and water, so that species development could be supported (Pairunan et al 1997). Soil with high oxygen content is oxidative, and available nutrients in the substrate and water could be utilized for phytoplankton growth. The phyoplankton is used as food by *Solen* sp., so that its growth will be faster than that in dusty clay soil with small pores that hold only less water. This condition causes the size of *Solen* sp. in east coast of Surabaya, Kajawanan coast, Cirebon, and Tanjung Solok coast, Jambi, be larger due to obtaining more natural food.

Fishing technique. *Solen* sp. size was affected by fishing techniques. In Talang Siring coast, Pamekasan, *Solen* sp. was fished with crowbar, and in Kwanyar coast, Bangkalan, *Solen* sp. fishing used a hoe. This gear was pushed into the coastal substrate and dug upwards, then *Solen* sp. in the substrate mass was collected with hand. In the east coast of Surabaya and Cirebon, fishing used palm leaf rib whose edge was immersed in the chalk-soap mixture. The palm leaf rib was inserted into the hole in the coastal substrate after opening with scratch. When the palm leaf rib touches the clam, *Solen* sp. is then caught with hand. This fishing technique is similar to that practiced in Jambi, but the stick is much longer (Figure 5).

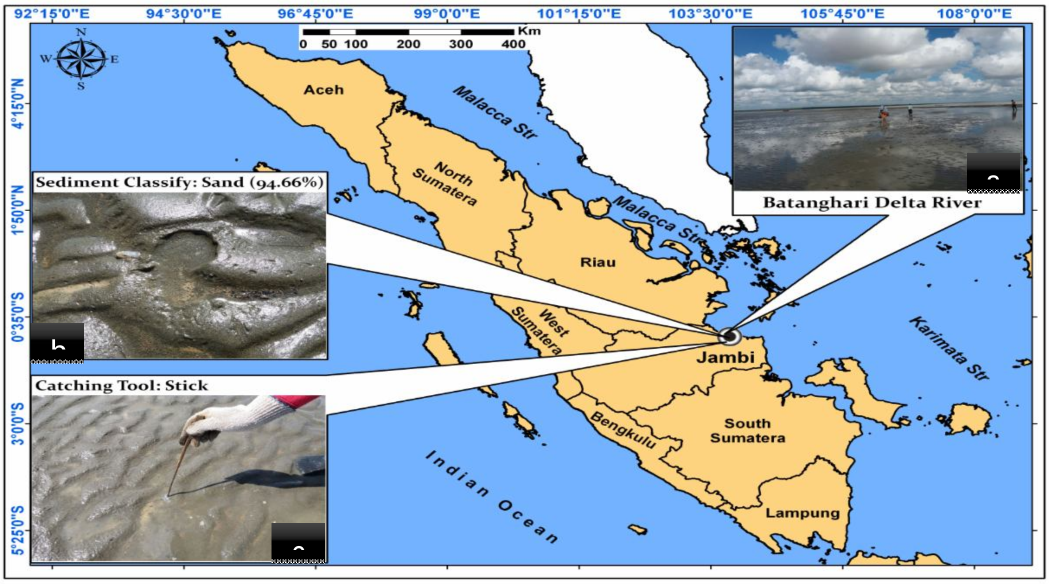

Figure 5. Substrate type and fishing technique of *Solen* sp. in Jambi

Solen sp. fishing is done at the lowest low tide in the morning or afternoon. In Pamekasan and Bangkalan coasts, *Solen* sp. collection could be done every day at the lowest low tide since the location is near the main road and easily reached. In the east coast of Surabaya and Cirebon, the fishing ground is 2-3 km from the beach by walking. In the harvest season, number of *Solen* sp. fishers could reach 30-50 people with a catch of 5-8 kg $pers^{-1}$. In famine season, only 3-5 fishers were found with a catch of 2-3 kg $pers^{-1}$. In Jambi, the fishing ground is far from the coastal line and could be reached for 1 hour by boat to get the sand mountain as *Solen* sp. habitat.

The fishing technique of *Solen* sp. in the study site is almost similar to that practiced in Sarawak, Malaysia. *Solen regularis* well-known with local name “*ambal*” is caught using a 1 m-wooden stick with sharp edge locally called as "*penugal*" embedded into the substrate. Moreover, a 30 cm-"palm leaf rib" layered with mixed pasta containing chalk ash and salt used as component to push the clam going out the hole. Other method used by Sarawak people in Buntal and Bako to collect *Solen sarawakensis* is by inserting a 60 cm-metal stick with hook on one edge into the substrate (Rahim 2011).

Several previous studies (Currie & Parry 1996; Gaspar et al 1999; Tuck et al 2000; Bishop et al 2005) reflected that there were many fishing techniques to collect *Solen* sp., but they are dependent upon the exploited habitats. The species group of genus *Solen* and *Ensis* could occupy different habitats, from protected ecosystems, such as lagoon and river mouth, or intertidal and subtidal areas up to 70 m depth, such as *Ensis siliqua* in sandy or muddy bottom (Poppe & Goto 1993). This clam is suspension feeder and vertically stays in the sediment up to deeper than 60 cm. The fishing techniques used in the intertidal are hand collection and the use of simple tolls, such as scoop or dredger, while in the subtidal fishers use SCUBA gear, mechanically and hydrolically dredging ship.

Several environmental impacts of this fishing practice is change in physical characteristics, sediment concentration, and water column, such as water turbidity, nutrition and metal, sea bottom topography, and organism biogenic structure (Gaspar et al 1999; Bishop et al 2005). However, the impact on the ecosystem damage is dependent upon the habitat, species, and harvest technique (Meyer et al 1981; Churchill 1989).

Hand fishing has the lowest environmental impact, in either intertidal or subtidal area. Hand collection does not cause habitat destruction or young clam removals. It has been practiced in the east coast of Surabaya, Kajawanan coast, Cirebon, and Tanjung Solok coast, Jambi. Trisyani et al (2016a) found that fishing mortality (F) of *Solen regularis* in the east coast of Surabaya was 2.01 yr^{-1} and exploitation rate (E) of 0.50 yr^{-1}, indicating that the fishing intensity reached an optimal condition.

Solen sp. fishing with dredging tools could result in damages in the sediment and water column (Masero et al 2008) as practiced in Talang Siring coast, Pamekasan, and Kwanyar coast, Bangkalan. The magnitude of the impact depends on several factors related with the fishing type of *Solen* sp. or local environmental conditions, such as season, water depth, tidal strength, current, substrate characteristics, and benthic community structure (Hiddink 2003; Masero et al 2008). The severity of the fishing gear utilization impact is also related with the scale and the intensity of fishing activities and local environmental conditions (Gaspar et al 1999). Dredging is alarmed to push the animals emigrate and need some time to go back to the initial habitat, and consequently it could develop predatory risk, increase mortality (Bishop et al 2005), and eventually terminates the fisheries sustainability.

Direct effect of substrate is formation of several channels with different dimensions in the sediment, depending on the sediment type and gear used, such as crowbar width, crowbar length, and depth of substrate insertion. The channel depth could exceed more than 50 cm and width variation between 1 and 5 m. Meyer et al (1981) reported 2 hours-observation up to the channel wall starting to collapse. The channel in the muddy sandy substrate is deeper and needs more time to get water agitation than sandy sediment. Similarly, the recovery of bottom substrate structure is faster in the shallow water than in deeper water (Gaspar et al 2003).

Bottom substrate recovery from gear operations is dependent upon the local water dynamics, and it usually occurs in short time (Gaspar et al 2003). Other consequence of the gear usage is water turbidity, especially in shallow water. Long water turbidity could increase mortality of invertebrates, particularly suspension feeders (Currie & Parry 1996). Sediment particle distribution in slow current after gear utilization is a limiting factor for deposit feeders. Sediment composition recovery could vary in several days (Tuck et al 2000) up to 6 months (Watling et al 2001). Change in sediment composition could occur when *Solen* sp. repeated fishing in short time and same area (Watling et al 2001). This change will impact to the benthic communities. The use of hoe or dredging tools could damage the animals through siphon cut, pedal muscle breaking, and/or shell damage (Robinson & Richardson 1998; Gaspar et al 1999).

Conclusions. The size of *Solen* sp. was affected by fishing techniques and environmental factors. In the coast with dusty sandy substrate was found the smallest size of *Solen* sp. This small size was also caused by the use of crowbar damaging the bottom substrate. The largest size was found in Tanjung Solok, Jambi, with sandy substrate and fishing technique used palm leaf rib and without damaging bottom substrate. Fishing technique of *Sole*n sp. in east coast of Surabaya, Kajawanan coast, Cirebon, and Tanjung Solok Jambi was a good one and could minimize substrate damage impact and did not destruct the body part of *Solen* sp.

Acknowledgements. I would greatly appreciate the Ministry of Research Technology and Higher Education for the financial support through Fundamental Research Grant of 2017.

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Received: 16 October 2017. Accepted: 18 December 2018. Published online: 29 January 2018.
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How to cite this article:
Trisyani N., 2018 Fishing technique and environmental factors affecting the size of razor clam *Solen* sp. in Indonesia coast. AACL Bioflux 11(1):29-36.