Sex ratio and size at first maturity of razor clam *Solen* sp. in Pamekasan and Surabaya coastal area, East Java, Indonesia

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N Trisyani[1,*], N I Wijaya[2] and I Yuniar[1]

[1] Department of Fisheries, University of Hang Tuah, Surabaya, Indonesia
[2] Department of Marine Science, University of Hang Tuah, Surabaya, Indonesia

[*]Corresponding author: nisuht@yahoo.com

Abstract. *Solen* sp. is one species of Pelecypoda class that has commercial value. Size at first maturity is one of the reproductive aspects needed for the management of fishery resources. This study was aimed to estimate the sex ratio and the size at first maturity of *Solen* sp. Samples were collected from the coast of Pamekasan and Surabaya from October 2017 to September 2018. The sex ratios were analyzed using chi-quadrat-test while the size at first maturity was obtained from the first size of the third-gonadal-maturity stage. Sex ratio of male and female *Solen* sp. in the coast of Surabaya was 0.898: 1.049 and Pamekasan beach was 1.065: 0.928. In the coast of Pamekasan, male *Solen* sp. reached gonadal maturity stage at the size of 260 mm, and female at 263 mm, while in Surabaya the males reached gonadal maturity stage at the size of 570 mm and the female at 585 mm.

1. Introduction

Solen sp. locally known as Lorjuk or bamboo clam is one of fisheries resources having high economic value [1-2] and can be consumed in fresh or processed forms. The previous study [3] found that *Solen* sp. in Surabaya 96.86% similarity and *Solen* sp. in Pamekasan 82.69% similarity to *Solen regularis*. The higher the demand for *Solen* sp. as food material is, the more intensive the fishing effort will be [4-7], so that their population decline may occur. The fishing technique of *Solen* sp. will also affect the number of catches, size and substrate destruction [8]. The fishing technique using "*garu"* in Pamekasan will yield small-sized *Solen* sp. and cause a destruction of the bottom substrate. The fishing technique with the fine stick in Surabaya coast yields big-size individuals and does not cause substrate damage.

Sustainable use of fisheries resources tries to prevent excessive exploitation and to maintain the equilibrium between the number of catches and conservation. Over exploitation can happen when too many small individuals are caught or not enough time left for the small individuals to grow since young individuals entering the fishing ground will be fished. Size at first gonadal maturity (Lm) or 50% mature individuals has been taken as the reference of minimum size regulation catchable to prevent stock decline. This reference has been used by many fisheries manager as fish stock management measure [9-11] for 100 years to let the mature individuals lay eggs at least once or to protect the immature individuals [12]. The approach method is based on the ecosystem rules, such as an impact on stock, habitat, food web, and non-target species, besides productivity and mortality of the species, predator-prey interaction, competition, carrying capacity, population variability, and environmental parameters. The exploitation rate (E) of *Solen* sp. in Surabaya for the time period of 2014-2015 was 0.50/yr [7]. It indicates that 50% of *Solen* sp. population have got fishing pressures

and this condition reveals that *Solen* sp. has reached the optimum exploitation since E value equals to 0.5/yr. Biomass per Recruitment (B/R) is same as Yield/Recruitment (Y/R), 0.014/y, meaning that 1.4%/y of *Solen* sp. population was taken in Surabaya coast. Equal B/R to Y/R reflects that the number of *Solen* sp. catches is same as the number of biomass in the waters.

Previous finding [13] found that gonad maturity level (GML) of *Solen* sp. in Surabaya coast reached maturity level (phase III) in May, and started spawning (phase IV) in June, and gonad development declined up to resting phase (level 0) in September. In October, gonad maturity level returned to maturity level (II and III). Increased gonad maturity level of *Solen* sp. was followed with oocyte diameter development as equation GML = 0.522 ± 0.528 oocyte diameter with the correlation of 79.2 %.

This study was intended to know the sex ratio and the size at first gonad maturity of razor clam *Solen* sp. in Pamekasan and Surabaya coasts as basic catchable size determination for *Solen* sp. resource management.

2. Methods

2.1. Sampling sites and method

Solen sp. sampling was carried out in two locations, Pamekasan coast, Madura, at the geographic position of 07°08'30.1"S and 113°35'21.4"E, and Surabaya coast at 07°08'33.5"S and 113°35'27.1"E (Figure 1). It was done in October 2017 to September 2018. Gonad maturity and histological observations were conducted in the Laboratory of Biology, Airlangga University, while the morphometric study was done in Aquaculture Laboratory, Hang Tuah University.

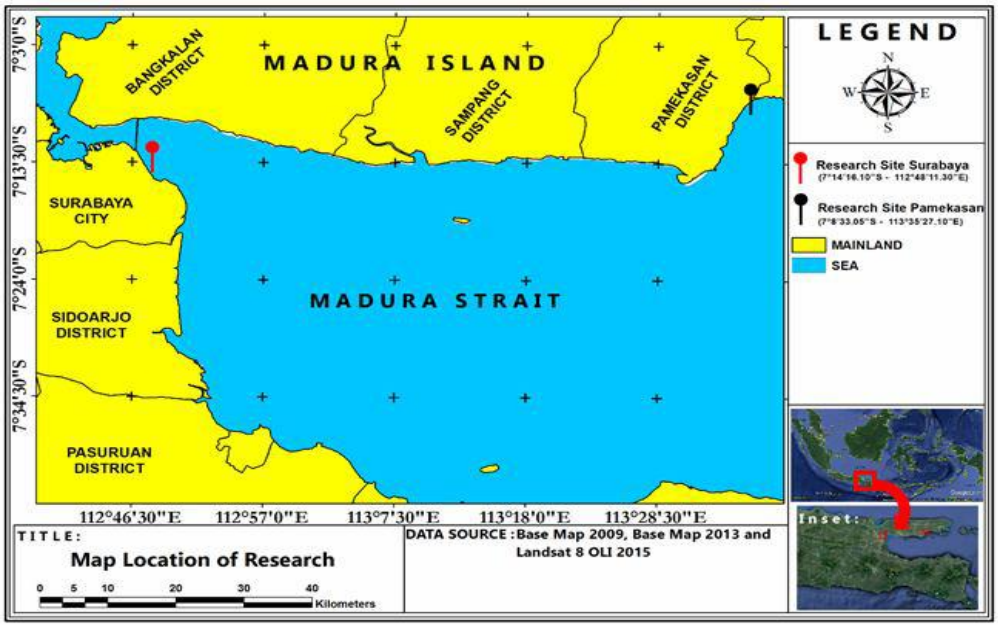

Figure 1. Sampling site.

Thirty specimens were observed at each sampling every two weeks[14] for 12 months. Samples were preserved in 5% formaldehyde soon after fishing [1]. Total length was recorded using a 0.01 cm-caliper. Observations on sex ratio and gonad maturity used fixation and staining method [1]), and gonad maturity levels were grouped based upon the photomicrographic illustration of gametogenic scale in *Ensis arcuatus* [2].

2.2. Data analysis

Sex ratio was estimated using the following formula:

$$NK = \Sigma J / \Sigma B,$$

where NK = sex ratio, ΣJ = number of male *Solen* sp. (ind.), and ΣB = number of female *Solen* sp. (ind.).

Sex ration was calculated using *Chi-Square* (χ^2) test in the form of confidence table [15]

$$X^2 = \sum_{i=1,2,3}^{s} \frac{(fi - F)^2}{F}$$

where χ^2= sex distribution value, *fi* = observation i, F = expected value i, iis 1,2,3, and S = number of observations The testing criteria are as follows: sex ratio will be 1 : 1 if $\chi^2_{cal.} \leq \chi^2_{tab.}$ (α=0.05) and sex ratio will be 1:1 if $\chi^2_{cal.} > \chi^2_{tab.}$ (α=0.05).

Determination of size at first maturity was done by separating size interval, from the smallest to the biggest. Size classes were divided into 10 size groups for *Solen* sp. from Surabaya and 6 groups for those from Pamekasan. Size at first maturity is the size related with 50% gonad maturity. It followed Udupa's method [16], in which gonad maturity level was determined on the size group following the Spearman-Karber equation:

$$\mathbf{m = x_k + \frac{x}{2} - (x\sum pi)}.$$

Where m = logarithm of length at first gonad maturity
x_k = logarithm of length at 100% of gonad maturity
x = difference of median logarithm
r_l = number of mature gonad of class i
pi = proportion of gonad maturity in class i (pi = ri/ni)
qi = 1–pi
pl = rl/nl, if nl ≠ nl+1 for *i* = 1, 2, …k-1 and
pl = rl/n, if n = nl = nl+1 for *i* = 1, 2…..k-1

Mean size at first maturity was obtained as antilog (m) = M.

Estimation of size at first maturity of *Solen* sp. was carried out by taking all male and female samples into a single group, because both sexes had the same number of maturity levels from I to IV. The total length of *Solen* sp. was then divided into size class intervals from the smallest to the largest. The asymptotic length (L_∞) estimation was also done using the Von Bertalanffy equation following Ford-Walford and Chapman [17] method by plotting Lt against Lt + 1:

$$L_{t+1} = a + b*Lt$$

$L_\infty$was obtained from a /1-b and b = exp (-KΔt)

3. Results and discussion

3.1. Sex ratio

Solen sp. sex was histologically observed. The sex difference was determined based gonad appearance, in which female gonad was white with milk texture, while male gonad was beige and granular [2]. Female and male gonads are presented in Figure 2.

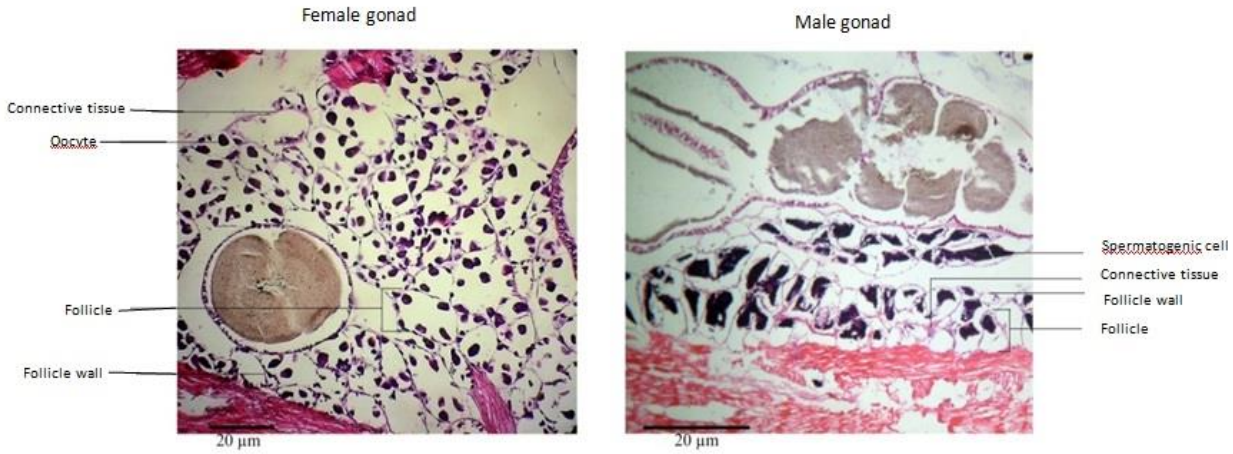

Figure 2. Female gonad (left) and male gonad (right) of *Solen* sp.

Sex ratio is one of the reproductive parameters to determine the availability of mature males and females expected to spawn. In normal condition, male-female ratio is indicated with 1:1 ratio. Besides, the sex ratio could also reveal excessive exploitation on one of the sexes or environmental changes [18]. It was calculated based on sampling time has done for one year. The Chi-Square test with sampling time and study site is demonstrated in Table 1.

Table 1 shows that from 471 individuals of *Solen* sp. collected in Surabaya coast, there are 122 males and 249 females, and in Pamekasan coast, 720 individuals are caught consisting of 367 males and 353 females. Sex ratio studies in various countries highly varied. There were 364 males and 330 females of *Solen regular* is collected in Malaysia, 344 males and 366 females in Asia Jaya Laut [14], 65 males and 59 females of *S.dactylus* in Buntal [11], 67 males and 93 females of *Zenatia* in New Zealand [19], 202 males and 169 females of *Ensis siliqua* in Irish Sea [20], 200 males and 194 females of *S.marginatus* in South Tunisia [21].

The sex ratio of *Solen* sp. in Surabaya coast was 0.898:1.049 and in Pamekasan coast, it was 1.065: 0.928. The Chi-Square test found $F^2_{calc.} > T^2_{tab.}$, meaning that *Solen* sp. in Surabaya coast did not have 1:1 sex ratio. The Chi-Square test found $F^2_{calc.} < T^2_{tab.}$, meaning that *Solen* sp. sex ratio in Pamekasan coast was 1:1. *Solen* sp. sex ratio difference between Surabaya coast and Pamekasan coast could result from the different environmental condition, particularly substrate particle, organic matter, and fishing method [8] that eventually affect the male-female ratio [18]. Spawning, especially clam, in nature is highly determined by the occurrence of males and females in the same location. The occurrence of male and female individuals is an important factor in supporting the sustainability of a population in nature since it will tend to ease the fertilization [18].

Table 1. *Solen* sp. sex ratio in Surabaya coast and Pamekasan coast.

Observations	Surabaya Coast				Pamekasan Coast			
	No. individuals		Sex Ratio		No. individuals		Sex Ratio	
	Male	Female	Male	Female	Male	Female	Male	Female
October 2017	13	16	0.813	1.231	16	14	1.143	0.875
	-	-	-	-	16	14	1.143	0.875
November 2017	13	17	0.765	1.308	15	15	1.000	1.000
	14	16	0.875	1.143	15	15	1.000	1.000
December 2017	14	16	0.875	1.143	16	14	1.143	0.875
	-	-	-	-	14	16	0.875	1.143
January 2018	-	-	-	-	16	14	1.143	0.875
					13	17	0.765	1.308
February 2018	-	-	-	-	13	17	0.765	1.308
					16	14	1.143	0.875
March 2018	14	15	0.933	1.071	13	17	0.765	1.308
	-	-	-	-	16	14	1.143	0.875
April 2018	13	15	0.867	1.154	15	15	1.000	1.000
	-	-	-	-	16	14	1.143	0.875
May 2018	13	15	0.867	1.154	14	16	0.875	1.143
	14	14	1.000	1.000	16	14	1.143	0.875
June 2108	13	16	0.813	1.231	17	13	1.308	0.765
	15	15	1.000	1.000	16	14	1.143	0.875
July 2108	14	16	0.875	1.143	16	14	1.143	0.875
	15	15	1.000	1.000	14	16	0.875	1.143
August 2018	14	16	0.875	1.143	16	14	1.143	0.875
	14	16	0.875	1.143	17	13	1.308	0.765
September 2018	14	16	0.875	1.143	15	15	1.308	0.765
	15	15	1.000	1.000	16	14	1.143	0.875
Total samples	222	249	-	-	367	353	-	-
Mean	-	-	0.898	1.049	-	-	1.065	0.928

The sex ratio of *Solen* sp. in Surabaya coast is not balanced, in which females are more than males. In several bivalve species, sex ratio varies enough, but it is, in general, balanced. The same-sex ratio is also found in *S.marginatus* in Tunisia [21], *S.tachicosel* in Vietnam [22], and *S.gordonis* in Japan [23]. The condition reflecting more females than males is one of the reproductive strategies of a population to increase the possibility of reproductive success. In normal condition, different sex ratio is a reproductive strategy in certain environmental condition**.** An occurrence tendency of more females than males in the lentic environment or more males than females in the lotic aquatic environment is one of the reproductive strategies to optimize the reproductive success [24]. *Solen* sp. is a species living in lotic waters, the intertidal area exposed to open air for certain period of time in the form of land and be submerged in other time with tidal change variations, temperature, waves, salinity, and substrate difference [8,25]

3.2. Size at first maturity (L_m)

Size at first gonad maturity (Lm) of *Solen* sp. is the smallest size of mature individuals. The present study found that male *Solen* sp. in Pamekasan coast started spawning at 2.60 cm long and the females at 2.63 cm long. In Surabaya coast, the males spawned at 5.70 cm long and the females at 5.85 cm long. The size difference in spawning activity is dependent upon the size distribution in nature. Size

at first gonad maturity of *Solen dacytilus* occurs at 4.61 cm long [11]. *Ensis arcuatus* reaches maturity in 2–3 years old with the maximum length of 8.5 cm [6]. *Solen tachicosel* in Vietnam [22] reached gonad maturity at 6.96 cm long, and *Callista chione* spawns for the first time at 5.81 cm, even though 3.0 cm-individual has, in fact, spawned [26].

Based on the calculation or size at first maturity, it appears that size at first gonad maturity of females is bigger than males. Table 2 demonstrates maximum length and length at first gonad maturity of *Solen* and *Ensis* for different species.

Table 2 shows that the longer the size of *Solen* sp. and *Ensis* sp. is, the bigger the size at first gonad maturity will be. *Solen* sp. in Pamekasan coast has the smallest size of *Solen* sp. in the world with the maximum length of 55 mm, while *Solen* sp. in Surabaya could reach the maximum length of 80 mm so that their size of initially spawning is also relatively smaller than those in Asia and Europe. This size at first maturity is different from that previous findings [2,14] that the smallest size of spawning *Solen* sp. is 4 cm long. The difference in size at first gonad maturity reveals the presence of different reproductive strategy of each species since the size of *Solen* sp is influenced by environmental factors and different fishing techniques. The fishing method could limit the individual size of fish catches [8] and will affect the estimation of size at first gonad maturity.

Table 2. L_∞ and L_m of various *Solen* sp. and *Ensis* sp.

No	Species	L_∞ (mm)	L_m (mm)	Reference
1	*Solen dactylus* (Iran)	101	46,1	[19]
2	*Ensis macha* (Argentina)	154 - 153	112	[1]
3	*Ensis arcuatus* (Ireland)	145- 149	85	[6]
4	*Ensis arcuatus* (Spain)	140- 174	-	[25]
5	*Solen* sp. (Pamekasan)	55	26.0 26.3	In process
	Solen sp. (Surabaya)	80	57.0 58.5	

The difference in size at first gonad maturity could also result from the environmental factors, i.e food availability assisting the gonad maturity process. Higher food abundance will accelerate gonad maturity process [14,21]. Fishing pressures cause the environmental disturbance on reproductive activities as well. When fish are caught at a very young age (immaturity) growth overfishing will occur [27]. Intensive exploitation makes the species have a reproductive strategy to be earlier mature than normal to produce the next generations. Nevertheless, fishing activities of small individuals are usually caused by demands [28] so that the fish population experiences fishing pressure on all size classes. Uncontrolled fishing activities could yield the change in species relative abundance, and negatively impacts on the water fertility and size at first gonad maturity. This condition occurs in *Solen* sp. in Pamekasan coast with relatively high fishing pressures using "*garu*" that makes all size be caught [8].

4. Conclusion

The sex ratio of *Solen* sp. in Surabaya coast was 0.898 : 1.049 in Surabaya coast and 1.065 : 0.928 in Pamekasan coast. The male and female ratio was not in 1:1 ratio in Surabaya coast, but those in Pamekasan coast had 1:1. Male *Solen* sp. in Pamekasan started spawning at 2.60 cm long and the females at 2.63 cm long, while in Surabaya coast, males started spawning at 5.70 cm long and females at 5.85 cm long. This difference is caused by environmental factors and fishing pressures. Thus, fishing season and size limitation should be done in order to sustainably maintain their population.

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