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Population dynamics of *Anadara antiquata* of East Coast of Aceh, Indonesia

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Abstract. *Azmi F, Mawardi AL, Sinaga S, Nurdin MS, Febri SP, Haser TF. 2021. Population dynamics of* Anadara antiquata *of East Coast of Aceh, Indonesia. Biodiversitas 23: 436-442.* Small-scale fishery effects are often overlooked by fishery and environmental managers. This study aimed to assess the impact of traditional cockle fishery on its population in the northeastern coast of Sumatra, Indonesia. The study took place from January 2018 to December 2018. Samples were obtained from Ujung Perling in Aceh Timur Regency, which is the only fishing ground exploited at present. Parameters estimated in this study include growth, mortalities, and exploitation levels. Analysis revealed that the average length was 50.03 mm, with the maximum shell length captured is 78 mm. Von Bertalanffy K-coefficient is 2.3 with a lifespan that can reach 3 years. Natural mortality is 2.27 year^{-1}, while fishing mortality is 6.74 year^{-1}. The exploitation rate in this study is 0.75. Growth parameters indicate that Ujung Perling is a suitable habitat for the cockle to grow, but mortalities and exploitation parameters suggest overexploitation is taking place in the area. To keep the population at a safe level, exploitation needs to be lessened to 33% from the current level.

Keywords: Cockles, fisherman, gears, landings

INTRODUCTION

Despite the contribution of the small-scale fishery (SSF), which comprises of 50% of fish global total landings (Basurto et al. 2017), this sector is often overlooked in fishery management discussion (Zeller et al. 2006). The multi-gears that are used to exploit highly diverse fish, inadequate investment, unmanaged landing site, low bargaining power of fishers in determining price, and lack of social security provided to workers have been the characteristic of the SSF (Salas et al. 2007) which often take place in developing countries in the tropics (Teh and Pauly 2018). In addition to that, some of the poorest and marginalized coastal people depend on this sector because it provides immediate income through informal employment and even has moderate contribution at the national level from a macroeconomic perspective (Béné 2006; Pomeroy 2012; Teh and Sumaila 2013) hence, it helps to alleviate poverty and contribute significantly to food security (Béné et al. 2007). Small-scale bivalve fishery does not require advanced fishing gear (Narvarte et al. 2007; Maia et al. 2021). Therefore, this sector is accessible even to unskilled laborers. The use of traditional fishing gears is said to be more environmentally friendly and ensure fishery sustainability (Lagade and Muley 2018).

Among many fishery commodities, bivalves have long been integrated into human diet history. Bivalve exploitation and gardening are predated to more than eleven millennia (Toniello et al. 2019). These modern days, Bivalve constitutes a significant portion of fishery production, with more than 15 million tons of global consumption annually. Even though the production is predominately supplied by aquaculture (Wijsman et al. 2019), small-scale and wild captured bivalves are still available in the market (Bhendekar et al. 2019; Martínez-Pita and Moreno 2019).

Clams, oysters and cockles are the most exploited bivalves in the world (Smaal et al. 2019). In Kota Langsa, a district at the Northeastern Sumatra Island, Indonesia, *Anadara antiquata* (antique ark) or mangrove cockle is an important coastal commodity. In this district, it is used to be harvested together with its sympatric counterpart blood cockle, *Anadara granosa*. *A. antiquata* can be distinguished from *A. granosa* due to its hairy shells (Nurrohmah 2018), while *A. granosa* is hairless (Desrita and Susetya 2020).

More than three decades ago, these two species were harvested from three fishing grounds in the area: Kuala Langsa Village, Telaga Tujoh Village and Ujung Perling. Port development and urbanization of the area surrounding Kuala Langsa, including Telaga Tujoh has made the fishing ground in the two villages disappear. Ujung Perling became the sole ground available for exploitation which still supplies cockles to the market.

Pre-study observation on bivalve fishing behavior identified that from this fishing ground, two main bivalve commodities were harvested, i.e. oysters and clams (*Polymedosa erosa*, *Meretrix meretrix* and *A. antiquata*). Boats for clam fishing of men dominated fishers departing the Alur Dua village. Maximum fifteen boats leave Alur Dua Village on a daily basis carrying four to five men aboard on each vessel. Therefore, there are roughly 60 people involved in fishing with six working days in a week.

Harvested cockles were landed in a small landing site at Alur Dua Village. Even though the landing site is not an official fish landing port, it is the place where clams are regularly landed. A middleman who manages the site is also the owner of some vessels that usually transport fishermen from the village to Ujung Perling. Bivalves are sold to other sellers or exported to other cities and provinces. Sometimes, traders who came to the landing site also bought *A. antiquata* to be exported to Malaysia or Thailand. Often orders have been placed even before they are landed. This landing site is the only place that receives cockles and other clams regularly.

This research is the first study examining *A. antiquata* from Ujung Perling. Because the landing site is not regulated, previous report or record on landings is unavailable. However, fishermen mentioned almost 11 tons of mangrove cockles were harvested from Ujung Perling annually in the past, and only one-third of that number were harvested in the last decade (personal communication). In order to determine whether fishing pressure contributes to the landing declines, we conducted a dynamic population study in Ujung Perling, Kuala Langsa, Aceh. The information obtained from this study is expected to fill knowledge gaps and thus provide inputs to manage cockle fishery in the area.

MATERIALS AND METHODS

Study area

Ujung Perling is a small island with several islets located at 4º36.6021 north latitude and 98º00.8099 east longitude (Figure 1). It is directly bordered by the Malacca Strait to the east. The location can only be accessed via boat trip because of the thick mangrove plants covering the area. Like other mangal forest, the substrate in Ujung Perling is dominated by mudflats. The mudflat is substituted by oyster beds as it moves towards the sea. The location has harsh environmental conditions with tidal fluctuations can completely cover mangrove trees during the high tides, which mostly stand as high as four meters. Daily temperature ranges from 28 to 32ºC, with an average water temperature of 26.2ºC.

Procedures

The study covers monthly data from January to December 2018. The sampling took place once a month from January 2018 to December 2018. Samples were collected at the landing sites when all fishermen and boats had already arrived from Ujung Perling. Samples were obtained randomly from the catches which were collected, hand-picked, by the fishermen when *A. antiquata* were partially submerged or shallowly buried under the fine mud among mangrove roots. 2 kg of samples were retrieved at every sampling to ensure that samples covered various sizes and weights of the cockles caught by the fishermen. The fishermen usually collected the cockles at different times each day following tidal fluctuations because they can only be picked during the low tides. Water temperature was measured in situ. Species other than *A. antiquata*, such as *A. granosa* or ambiguous species that were present in the samples, were removed. Samples obtained from the landing site were immediately transported to the laboratory of the Aquaculture Department, Universitas Samudra, Indonesia. The length was scaled using a digital caliper with 0.01 mm accuracy, as shown in Figure 2. Weight was measured with a digital scale (0.1 gram accuracy). All specimens were discarded to the Lab. Waste Management Facility of Agricultural Faculty, Universitas Samudra after being sampled.

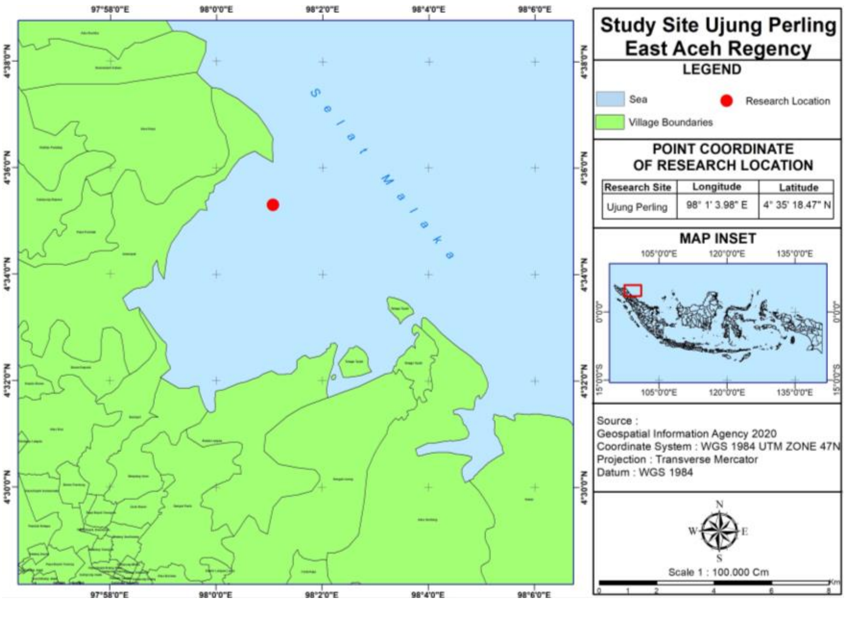

Figure 1. Study site location, Ujung Perling, Aceh, Indonesia

Figure 2. *Anadara antiquata* length

Data analysis

Length based distribution is used as the basis to estimate parameters including size frequency, growth, mortality, exploitation rate, and recruitment pattern. Growth rate was estimated using Von Bertalanffy formula:

$$L_t = l_\infty^{*}\left[1-\exp(-K^{*}(t-t_0)\right]$$

Where, Lt is shell length at age t; L_∞ is the asymptotic length; K is growth coefficient; t_0 is theoretical age when the shell length is zero. While K and asymptotic length were estimated following the formula:

$$\frac{dx}{dt} = K\,(L_\infty - l)$$

With l represents length

The theoretical age was estimated following Pauly (1980) formula:

$$\log(-t_0) = 0.3922 - 0.2752(L_\infty) - 1.3080\log(K)$$

Instantaneous mortality (natural mortality) (M) was estimated using (Pauly 1980) with the formula:

$$log_{10}M = -0.0066 - 0.279 log_{10}L_\infty + 0.6543 log_{10}K + 0.4634 log_{10}T$$

Where, T represents daily water temperature.

Total mortality (Z) was estimated using linearized length-converted catch curve based on (Pauly 1984), using the formula:

$$N_t = N_0 e^{-Zt}$$

Where, N_0 is the initial number; N_t is the number of animals survived after t (years); Z is total mortality.

From the two equations (Z and M), and instantaneous fishing mortality (F) was obtained from the formula:

$$F = Z - M$$

Exploitation rate was calculated using (Pauly 1980) as follows:

$$E = \frac{F}{Z}$$

Furthermore, relative yield per recruit were estimated using Beverton and Holt (1964)

$$\frac{Y'}{R} = E(1-c)^{M/K} x\left[1 - \frac{3(1-c)}{1+\frac{1-E}{M/K}} + \frac{3(1-c)^2}{1+\frac{2(1-E)}{M/K}} - \frac{(1-c)^2}{1+\frac{3(1-E)}{M/K}}\right]$$

Where, c: L_c/L_0, and L_c: 0.05

Length at first maturity was estimated using Hoggarth et al. (2006) as follows:

$$L_m = L_\infty * 2/3$$

Where, L_m: length at first maturity and L_∞: asymptotic length.

Using the above parameters as inputs, yield per recruit was computed based on Beverton and Holt (1964) and presented as percentage (%) and population peak can be described. Data analysis was carried out using ELEFAN in FISAT II.

RESULTS AND DISCUSSION

Size structure

A total of 708 samples were obtained during the study. *A. antiquata* captured in Ujung Perling ranged from 21.60-78 mm with average and standard deviation 50.03 ± 11.36 mm. The largest number of captured bivalves occurred at a class size of 51.55 mm, which represents 17.85% of total samples. The smallest number of catches occurred at the largest size of classes (76-80 mm) which only comprised of three individuals (Figure 3).

The Von Bertalanffy growth analysis resulted in asymptotic length that may be attained by *A. antiquata* in Ujung Perling is 80.43 mm with growth coefficient (K) was as high as 2.3 year^{-1}. The relative age may be attained at length 80.43 mm is 3 years (Figure 3).

Recruitment

Based on the length-frequency analysis, recruitment of *A. antiquata* population shows a continuous pattern over the year, except in December. The recruitment pattern shows only one peak during the year. The lowest was in November (0.16%) (Figure 5), while the curve shows higher recruitments occur from June to September and the peak of recruitment took place in July (23.65% of total catch).

Mortalities and size at first capture

At the average temperature of 26.2ºC measured during the study, the Von Bertalanffy growth analysis resulted in natural mortality (M) was 2.27 year^{-1}, whilst total mortality

(Z) and mortality attributed to fishing are 9.01 year^{-1} and 6.74 year^{-1} respectively (Figure 8a). Based on the estimated parameters, the exploitation rate was calculated and resulted in the value 0.75.

Figure 6b describes the logistic selection curve for the probability of capture, showing 25%, 50% and 75% selection length of *A. antiquata* from Ujung Perling, and it can be seen that the probability of capture of 50% or length at first capture (Lc) of *A. antiquata* from Ujung Perling was 57.10 mm. Length at first maturity of the cockle computed using (Hoggarth et al. 2006) was (53.62), slightly below Lc.

Yield per recruit analysis

The Beverton and Holt yield per recruit analysis of *A. antiquata* in Ujung Perling shows that the exploitation level where yield will reduce virgin stock at 10% (E0.1) was 0.42, the exploitation in which yield will reduce virgin stock at 50% (E0.5) was 0.810 and exploitation proportion at maximum yield (Emax) is 0.907 (Figure 7).

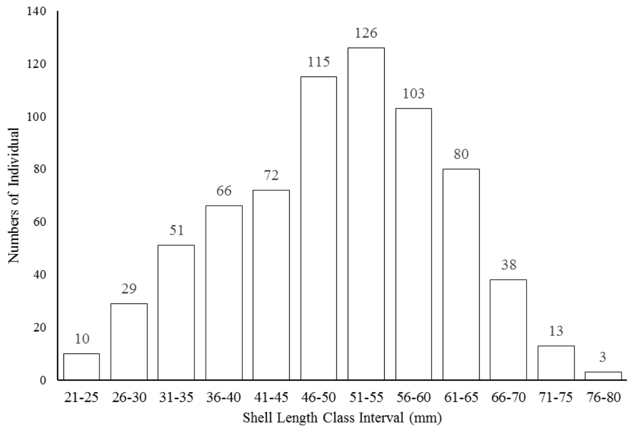

Figure 3. *Anadara antiquata* size structure in Ujung Perling, Aceh, Indonesia from the total samples

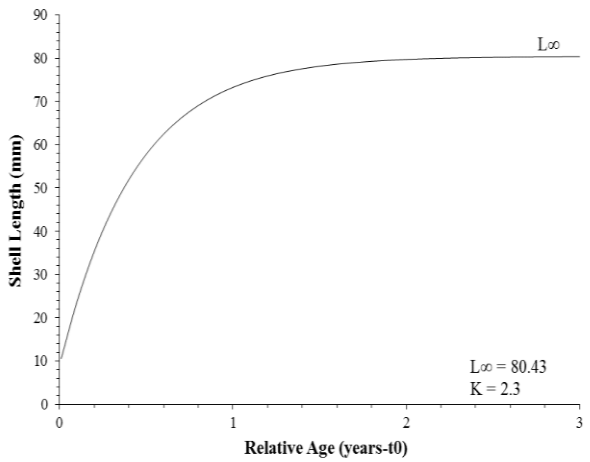

Figure 4. Von Bartalanffy growth coefficient curve

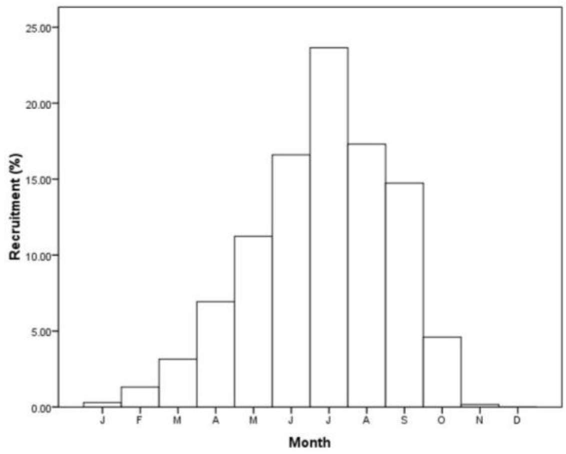

Figure 5. Monthly recruitment pattern of *Anadara antiquata* in Ujung Perling, Aceh, Indonesia

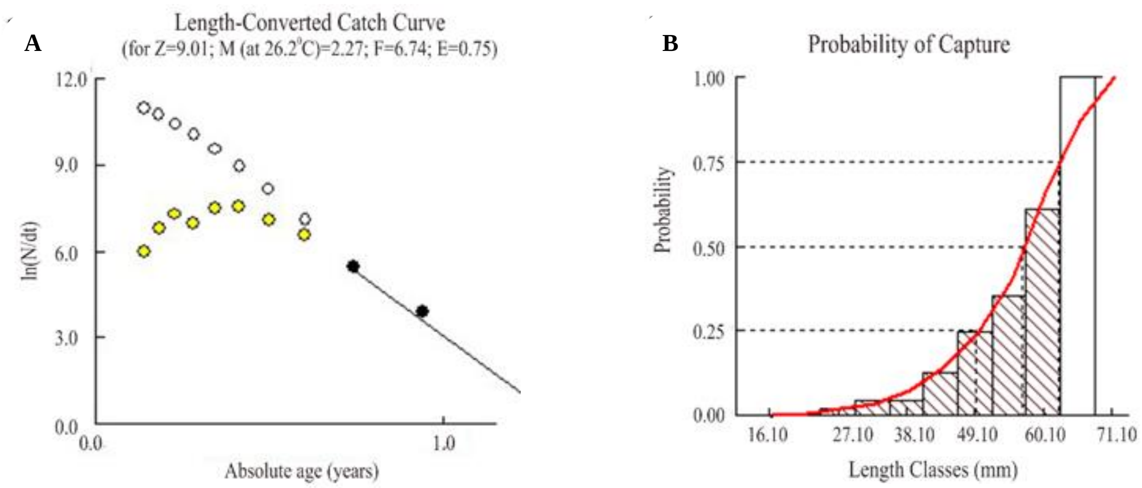

Figure 6. A. Length converted catch curve; B. Probability of capture of *Anadara antiquata* population in Ujung Perling, Aceh, Indonesia

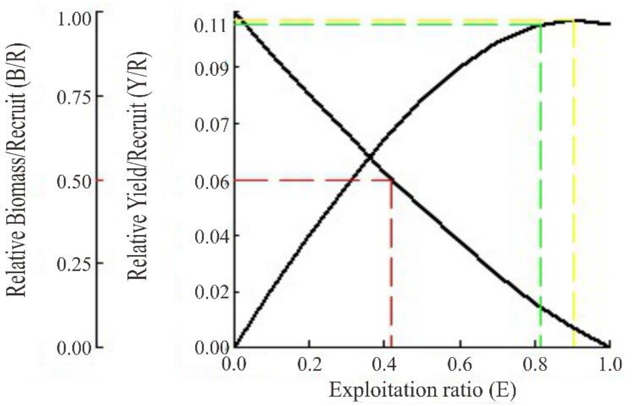

Figure 7. Beaverton and holt relative yield/recruit curve

Discussion

In Indonesia, bivalves from the genus *Anadara* are the most exploited mollusks after oysters. Cockle consumption in this country is dominated by *A. granosa* (Brotohadikusumo 1994). In Langsa District, *A. granosa* and *A. antiquata* were found to co-exist in similar places. Fishing grounds were mainly in Kuala Langsa. However, human activities taking place in the area have caused severe damages to mangrove forests (Ruzanna et al. 2019) and displaced many coastal faunas due to the mangrove forest clearing for aquaculture, timber extraction (Ilman et al. 2016; Ulfa et al. 2018), and port development. Therefore, the fishing ground of oysters and clams moved to Ujung Perling, of which the environment is still intact. Only *A. antiquata* from the two cockles can be exploited in Ujung Perling, while *A. granosa* are only occasionally found during samplings.

There are 12 size classes were found in this study. The size shows that *A. antiquata* found in Ujung Perling have a bigger size (maximum length of 78 mm and 50.03 mm on average) compared to those from other populations. Samples from West Java reported in 1994 only have a maximum length of 48 mm (Brotohadikusumo 1994), while samples from Tanzania attained a maximum length of 69 mm.

The better size of *A. antiquata* reflects external factors that can affect cockle's size captured, including gear selectivity and water temperature as components of environmental factors (Tu et al. 2018). The fact that these cockles were hand-picked from the mud makes it more selective compared to mechanical removal such as dredging, which is not only highly efficient but also disturbs the subsequent trophic level and negatively affects the ecosystem (Constantino et al. 2009). Therefore, only those of size can be picked by hands that are captured in Ujung Perling.

Growth can differ among populations from the same species depending on environmental conditions (Sparre and Venema 1998). The Von Bertalanffy Growth coefficient (K) of the antique ark in Ujung Perling is better compared to those that were reported by Simuhu and Oetama (2016) in Bungkutoko Beach, South Eastern Sulawesi. The K coefficient (2.3) in this study is far higher than other clams within the genus *Anadara*, which mostly fall below 0.5 year^{-1}. The K coefficient of *A. granosa* can be bigger than 1.0 year^{-1} (Zeinalipour et al. 2014), but the value is still below that of *A. antiquata*. The K-coefficient in this study is comparable to a non-cockle bivalve species, *Perna viridis* common K-coefficient, which ranges between 2.50-2.95 (Soon et al. 2016). *P. viridis* is well-known as a fast-growing bivalve (Eunice 2018; Isnain et al. 2020). A high K-coefficient value indicates rapid growth and short life of the cockles (Sparre and Venema 1998).

An experimental cage study demonstrated that *A. antiquata* could grow up to 0.64±0.43 mm/15 days until its length reached 30 mm. The growth rate downturns as shell size increases (Nurdin et al. 2010). Figure 4, shows that the average maximum lifespan of mangrove cockle in this population can reach 3 years. We argue that this rapid growth may be owed to the intact environmental condition at Ujung Perling. The location is far from the urban area and in a high energy flow from the thick mangrove forest, which is high in particulate organic matters, thus enhancing phytoplankton communities (Saifullah et al. 2016) which were the main source of energy of *A. antiquata* as filter feeders (Kasigwa and Mahika 1991). The fishing ground also occurs in the low latitude region where the temperature is relatively warm, which can promote organism's growth (Zeinalipour et al. 2014). Besides *A. antiquata*, other bivalves such as *P. erosa* and oysters also thrive in this location as the two later commodities are also exploited from the area.

Apart from some positive information revealed by this study regarding growth, exploitation of *A. antiquata* in Ujung Perling shows that fishery management needs to be in place. Higher mortality due to fishing (F) compared to that of natural causes (M) suggests that growth overfishing is occurring (Sparre and Venema 1998). The value of exploitation rate, which is 0.75 (25% above the exploitation of a healthy stock), also indicates that the stock is heavily exploited (Wehye et al. 2017). The value of F/M ratio, which is over Gulland's theoretical value of 1.0, supports that exploitation has exceeded the optimum limit (Renjithkumar et al. 2011). According to Modou et al. (2013), the stock is in a steady state if Z/K equals 1.0, collapsing if it is above 1.0 and overexploited if the proportion is greater than 2.0. As the Z/K value in this research reached 3.9, which is higher than 2.0, then the current stock is considered over-exploited.

The higher value of Lc (57.10 mm) compared to Lm (53.62) indicates that most of the cockle captured are mature individuals. This condition is the most desired in fishery management, where individuals are let to reach their maturity and thus allow them to reproduce before being caught. The probability of age at first capture reflects the gear utilized for fishing. As the traditional bivalve fishery in Ujung Perling uses a very traditional means, which is hand picking, it is less likely that smaller individuals will be captured. The same practice of cockle fishery was also observed in Jepara (personal observation), while in Letman water, North Maluku *A. antiquata* fishing uses a similar method with occasionally helped by knife (Silaban et al. 2021). The adequate size of *A. antiquata* captured in Ujung Perling indicates that the fishing method may not be the reason for the population decline because the size of captures represents the selectivity of fishing gears. Therefore, hand-picking can be considered environmentally friendly for cockle fishery in the studied area.

Under the Beverton and Holt yield per recruit analysis, the current fishing exploitation rate (E: 0.75) is still below the exploitation rate at maximum sustainability yield (MSY), where Emax (EMSY) was 0.907 and therefore current exploitation level is considered safe under this analysis. However, researchers have warned that MSY as a reference point must be used with precaution for fishery management because MSY means that the resource can be harvested at least once at that level in the condition that stock must be high and the population must not be continuously harvested at the MSY level. Continuous exploitation at the MSY reference point often leads the population to collapse. The more conservative approach was proposed by Gulland and Boerema to use F0.1 as the reference point, while others have used weighted virgin biomass and mortality (Caddy and Mahon 1995). Taking 50% of virgin biomass per recruit removed from the population equates the E0.1 (Figure 7) as the optimum exploitation (Modou et al. 2013). To be able to sustain the population using this optimum exploitation level, the rate must be reduced up to 33% from 0.75 (current E) to 0.42 (E0.1).

This study shows that reduction in landings of the mangrove cockle is predominantly in as much as overexploitation of the species. Because the gear selectivity (hand-picked) provides good results as the length at first capture is higher than the length at first maturity, then the overfished condition must be owed to the high fishing efforts. Small fishing ground with crowd fishermen employed and six working days in a week may beyond the natural production capacity of *A. antiquata* in Ujung Perling despite the low technology invested in the fishing. Therefore, intervention to manage the fishing practice must be imposed to sustain the population by managing fishing trips and the number of personals involved. Failure to address this issue can adversely affect the antique ark population since satisfactory growth supported by environmental quality alone cannot withstand continuous fishing pressure.

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