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Population dynamics of blood clams *Tegillarca granosa* (Linnaeus, 1758) in Kendari Bay, Southeast Sulawesi, Indonesia

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Abstract. *Bahtiar, Purnama MF, Kasim M, Ishak E. 2022. Population dynamics of blood clams* Tegillarca granosa *(Linnaeus, 1758) in Kendari Bay, Southeast Sulawesi, Indonesia. Biodiversitas 23: 5084-5092.* Blood clams (*Tegillarca granosa* Linnaeus, 1758) are bivalves found in the intertidal areas of Kendari Bay which are subjected to ecological stresses. Therefore, this study aims to determine the population dynamics of blood clams in Kendari Bay, Southeast Sulawesi, in terms of their size structure, growth, mortality, and exploitation level from March 2018-February 2019. The samples were collected with scoop nets in ten 5x5 m^2 transects. Water quality parameters were monitored every sampling period. The length of the shells was measured using a caliper with an accuracy of 0.05 mm. The data were processed using the Bhattacharya method, inverse von Bertalanffy model, length-converted catch curve, and Pauly's empirical data, respectively. All of the methods were accommodated in the FiSAT II version 3.0 program. Results showed that the blood clams were divided into 2-3 size categories, namely young adult, adult, and old age, where the most dominant was the adult size group. The growth pattern of the samples was based on the equation Lt = [6.67-(6.67-0.025)] $e^{-0.72t}$. The majority of the blood clams were distributed in the 1-2 years age group. Natural, fishing and total mortalities (Z) of the blood clams were 2.18 yr^{-1}, 0.29yr^{-1}, and 3.09yr^{-1}, respectively, with an exploitation rate (E) of 0.29 (underexploited).

Keywords: Bivalves, exploitation rate, growth, mortality, size structure

INTRODUCTION

Blood clams *Tegillarca granosa* (Linnaeus, 1758) are unique bivalves (Jahangir et al. 2014). Furthermore, they are widely distributed in the world (Pathansali 1964; Yoloye 1974; Broom 1983; Mirzaei et al. 2014), including all coastal waters in Southeast Asia which are found in Indonesia (Setianingsih et al. 2016; Devi et al. 2019; Yulinda et al. 2020; Ukhrowi et al. 2021), Malaysia, Thailand, the Philippines, and Vietnam (Vijayanathan et al. 2012; Yurimoto et al. 2014). These clams are abundant in habitats with clay, silt, and high organic matter/detritus substrates (Ramli et al. 2015; Setianingsih et al. 2016; Yurimoto et al. 2021). They also provide ecological benefits by improving water quality and the food chain cycle in bay waters (Komala and Zahara 2020).

Clams of the Arcidae family, including blood clams, generally have economic values. They are often harvested for local consumption and trade (Vakily 1992; Sugiyama et al. 2004; Fauzan et al. 2108; Komala and Zahara 2020). These clams contain beneficial nutrients, including protein, essential amino acids, unsaturated fats, vitamins (A, B, D, E, and K), and essential minerals (phosphorus, iron, iodine, calcium, and zinc) (Hossen et al. 2014; Dewi et al. 2019). Thus, this clam has been cultivated on a large scale in several countries, including Malaysia, Vietnam, and Thailand (Yurimoto et al. 2013, 2014a,b) and in Rokan Hilir, Indonesia (Yulinda et al. 2020). These shellfish are cultivated in mudflats covering an area of 654 hectares on Bagan Island, Selangor Malaysia (Harith 2016) which can produce 40,000 tons in 2010 and decreased by 26,505 tons in 2011 (Ramli et al. 2013) and supplies the availability of spat for cultivation at various regions (Yurimoto et al. 2014c,d). Blood clam aquaculture production can generate as much as 180 million baht in Thailand (McCoy 2016). In Indonesia, this cultivation is very profitable, with BCR and PPC values of 1.88 and 1.92, respectively (Yulinda et al. 2020).

Harvesting of blood clams in Kendari Bay has been carried out traditionally since the 1900s and is limited by fishing communities around Kendari Bay. These shells are collected during low tide using a knife. Until now, the catch of blood clams collected by fishermen has not been properly recorded because there is no recording of the catch (time series data). Consequently, the measure of pressure imposed by these practices has not been accurately determined. This has led to the lack of awareness and control or restraint on the collection from their natural habitat in the bay. Although blood clams are often harvested by the community (30-40 kg/wk), they still have a large population in the study area. This perpetuity can be attributed to (i) the relatively faster reproduction, which occurs in the early stage of the life cycle and continuously till death (Data not yet published 2018); and (ii) the higher population growth with accelerated recruitments till the adult stage (Bahtiar et al. 2022). These conditions have facilitated population parameters, such as growth and reproductive potential, to exceed the exploitation rate, thereby ensuring that their numbers are increasing and maintained. However, the consumption of clams has increased in recent years, which is indicated by a decrease in the production of blood clams in some areas. The Fisheries Statistics Agency, South Sumatra Province, Indonesia noted that the production of *A. granosa* shellfish in 2007 reached 258.70 tons/year and decreased to 3057 tons/year in 2011 (Septifitri et al. 2010).

Kendari Bay is semi-enclosed and receives input from the mainland as the source of ecological load that influences the life of clams, including blood clams (Musni et al. 2017). Sediments carried into the bay can potentially cover the clams' natural habitat, affecting their survival (Nasrawati et al. 2017). Recently, the bay has been exposed to a large amount of ecological pressure, which was indicated by the high level of water turbidity, minimal benthic diatoms population, low diversity of phytoplankton, and the lack of living macrobenthos (Samsi et al. 2018). In addition, the natural death of blood clams is also caused by chemical content or the result of metabolic processes such as high ammonia and H_2S in the waters and loss of substrate due to coastal erosion (Jeyanny et al. 2012; Asmawi and Ibrahim 2013; Ramli et al. 2015). The increase in ammonia content in waters above the threshold of 4 mg/L caused mass mortality of clams and reduced production in Kampung Bagan Selangor (Ramli et al. 2013). Kendari Bay which receives allochthonous and autochthonous inputs in the form of household waste and weathering of organic matter in the mangroves has the potential to accumulate chemical content that can change water quality which in turn contributes to the natural death of blood clams, especially after the occurrence of rains such as in *Modiolus modulaides* in Kendari Bay (Nasrawati et al. 2017). There are no studies on the size, structure, growth, mortality, and exploitation rates of blood clams in Kendari Bay, but similar studies have been carried out in other locations, such as on Pacific Coast (Lucero-Rincón et al. 2013), Asahan North Sumatra (Fauzan et al. 2018), Sunda Strait (Komala and Zahara 2020), Penang Island, West Coast of Malaysia (Fauzan et al. 2018), North Arabian Sea (Jahangir et al. 2013), and Chone Estuary, Ecuador (Panta-Velez et al. 2020). Therefore, this study aims to determine the population dynamics, particularly the size, growth, mortality, and exploitation level of blood clams in Kendari Bay, Southeast Sulawesi. The results are expected to provide important information on managing the species' resources in the area.

MATERIALS AND METHODS

Period and location

This study was carried out from March 2018 to February 2019 in Kendari Bay, Southeast Sulawesi, Indonesia. The research location is in the intertidal and subtidal areas (the front of the mangrove area) with a water depth of ±5-10 cm at low tide. The area of potential habitat for blood clams is ±35 ha, which stretches to the west of Kendari Bay, especially at the mouth of a large river, as shown in Figure 1.

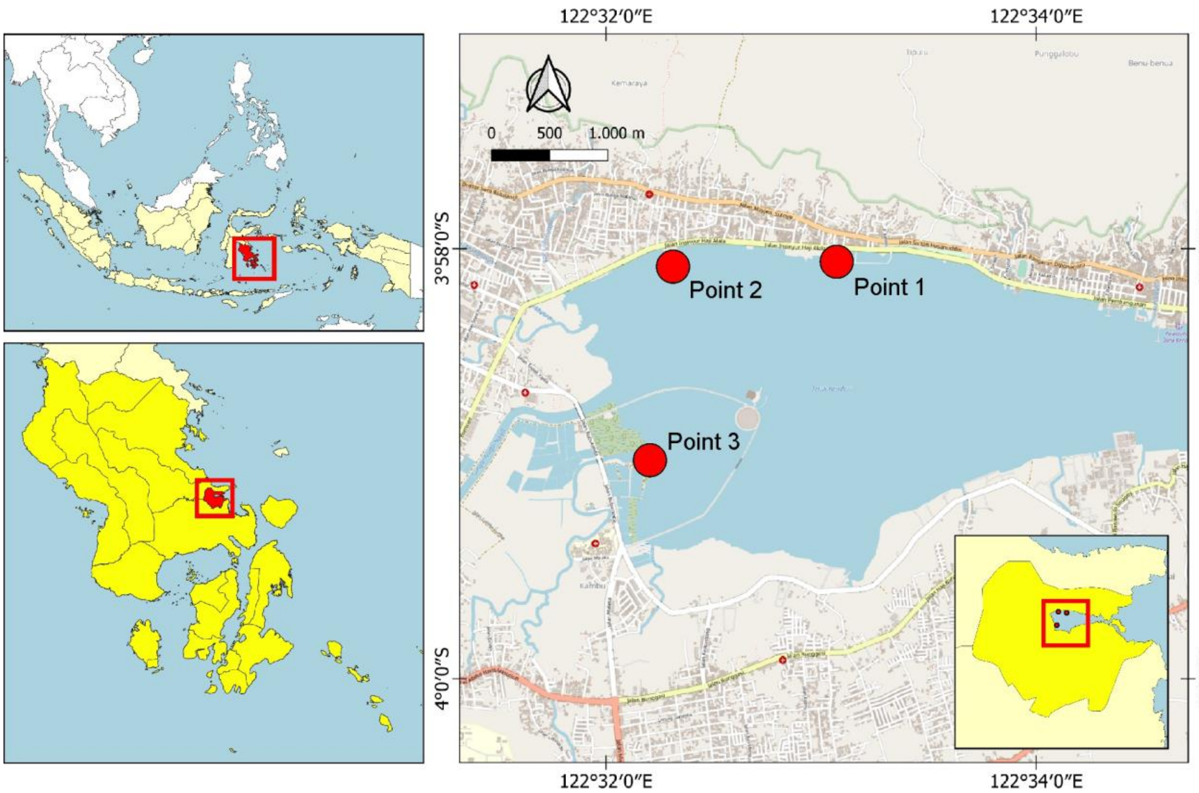

Figure 1. Map of blood clam sampling location in Kendari Bay, Southeast Sulawesi, Indonesia

Sample collection

Blood clams were obtained every month using the method with scoop nets (opening width = 30 cm, mesh size = 1 inch). Scoop nets made of iron and nylon are submerged as deep as 20 cm and pulled by 2 people as far as 1 meter within a 5x5 m^2 quadratic transect. Sampling was carried out for 3 replications at low tide in three parts of the waters. The samples in each transect were collected, after which their lengths were measured at the Faculty of Fisheries and Marine Science Laboratory (UHO FPIK). Water quality parameters (temperature, salinity, brightness, sediment organic matter) were measured after blood clam sampling at high tide. The shell length was measured using a caliper with an accuracy of 0.05 mm. Furthermore, their sex was determined by observing the color of the gonads, where the male and female gonads are white/cream and yellowish-orange, respectively (Khalil et al. 2017). There is a need to indicate the monthly number of samples.

Data analysis

Size/age structure

Classification of the blood clams into size groups was carried out using the Bhattacharya method with FAO ICLARM Stock Assessment Tools (FiSAT) 2 version 3.0 (Bahtiar 2012; Bahtiar et al. 2022). Blood clam size groups were divided into 4 categories: juvenile (<2.05 cm), young adult (2.05-2.45 cm), adult (2.46-5.45 cm), and old age groups (>5.45 cm) (Unpublished data 2018).

Growth

The growth parameters were estimated using the von Bertalanffy inverse function, as proposed by (Bahtiar et al. 2016), with the following formula:

$$Lt = L_{\infty} - (L_{\infty} - Lo)e^{-Kt}$$

Lt : length of clam at t (mm)
L_{∞} : asymptotic/maximum length of clam (mm)
K : coefficient of growth rate (per year)
Lo : size of clam as larva/glochidium
t : age at Lt (year)

Mortality

The natural mortality coefficient (M) was calculated using Pauly's empirical equation (Bahtiar et al. 2022) as follows:

$$\text{Log}(M) = -0.0066 - 0.279 \text{ Log } L_{\infty} + 0.6543 \text{ Log } K + 0.463 \text{ Log } T$$

The total mortality rate (Z) was determined using the length-converted catch from the Sickle suggested formula (Bahtiar et al. 2022):

$$Ln\frac{C(L1,L2)}{\Delta t(L1,L2)} = C - Z * t\frac{(L1+L2)}{2}$$

The equation above can be simplified to:

$$\ln(N_i/\Delta t_i) = a + b \cdot t_i$$

N_i : number of blood clams in the i-th length class
Δt_i : length of time at the i-th length class
Z : total mortality of blood clams (yr^{-1})
a and b : regression coefficient (b = -Z)
t : age with respect to t0 = 0

Explotation rate (E)

The exploitation rate of the samples was calculated using the equation proposed by (Sparre and Venema 1999), namely:

$$E = F/(F + M)$$

E : exploitation rate
F : fishing mortality rate (yr^{-1})
M : natural mortality rate (yr^{-1})

When E > 0.5, this shows that there is a high level of exploitation or overfishing, E = 0.5 indicates optimal exploitation (E_{opt}), and E < 0.5 implies that there is a low level of harvesting or underfishing (Gulland 1977). Size structure, growth, mortality coefficient, and exploitation rate were processed using the FiSAT 2 version 3.0 software from the sample data collected (Cikes-Kec and Zorica 2013).

RESULTS AND DISCUSSION

Size group

The blood clams in the waters of Kendari Bay during the observation were dominated by 2 size categories. Furthermore, their population comprised of 3 age groups from April-May and October-November. The size category of 2.46-3.18 cm was found in March-June, October-December, and February, while 3.30-4.62 cm was dominant throughout the observation period. The 5.35-5.59 cm group was obtained in May, July, October, November, and January, as shown in Figure 2.

The blood clam population in Kendari Bay consisted of 2 and 3 size groups, namely young adult, adult, and old age groups. Furthermore, the young adults have a size of 2.05-2.45 indicate the unit of measure at first maturity (Data not published 2018), while the old group was the most dominant. The high number of blood clams in the adult and old groups indicated low fishing activity (Komala and Zahara 2020; Mackenzie 2001; Stern-Pirlot and Wolff 2006). The large-sized/older population showed that the adults have the opportunity to regenerate and maintain their population in nature (Flores and Lincadeo 2010; Lucero-Rincón et al. 2013; Panta-Velez 2020). Meanwhile, the low number of the small-sized group (size of juvenile) can be caused by: 1) blood clam deaths related to sedimentation of suspended particles during rains, which leads to encasement and suffocation (Nasrawati et al. 2017). This condition is indicated by the low brightness of the waters in Kendari Bay, Indonesia. The same thing was found in the small size class of shellfish *Batissa violacea* var *celebensis* which was found with open (dead) shells at the bottom of the water due to high sedimentation at the river mouth (Basri et al. 2019; Bahtiar et al. 2016). 2) the size of fishing gear that cannot take a size smaller than 2 cm. The blood clams also experienced recruitment throughout the observation period as indicated by the young adult size and matured/spawned sample collected every month (Data not yet published 2018). This was caused by a shift in the size group to the left, which indicates that small or new generations were discovered. Moreover, there was an increase from young adult to adult every month, which was characterized by a shift to the right. The recruitments and shifts of the samples are similar to that of other shellfish species in the tropics, such as *Perna viridis* (Khan 2010) with gonad maturation and spawning throughout the year.

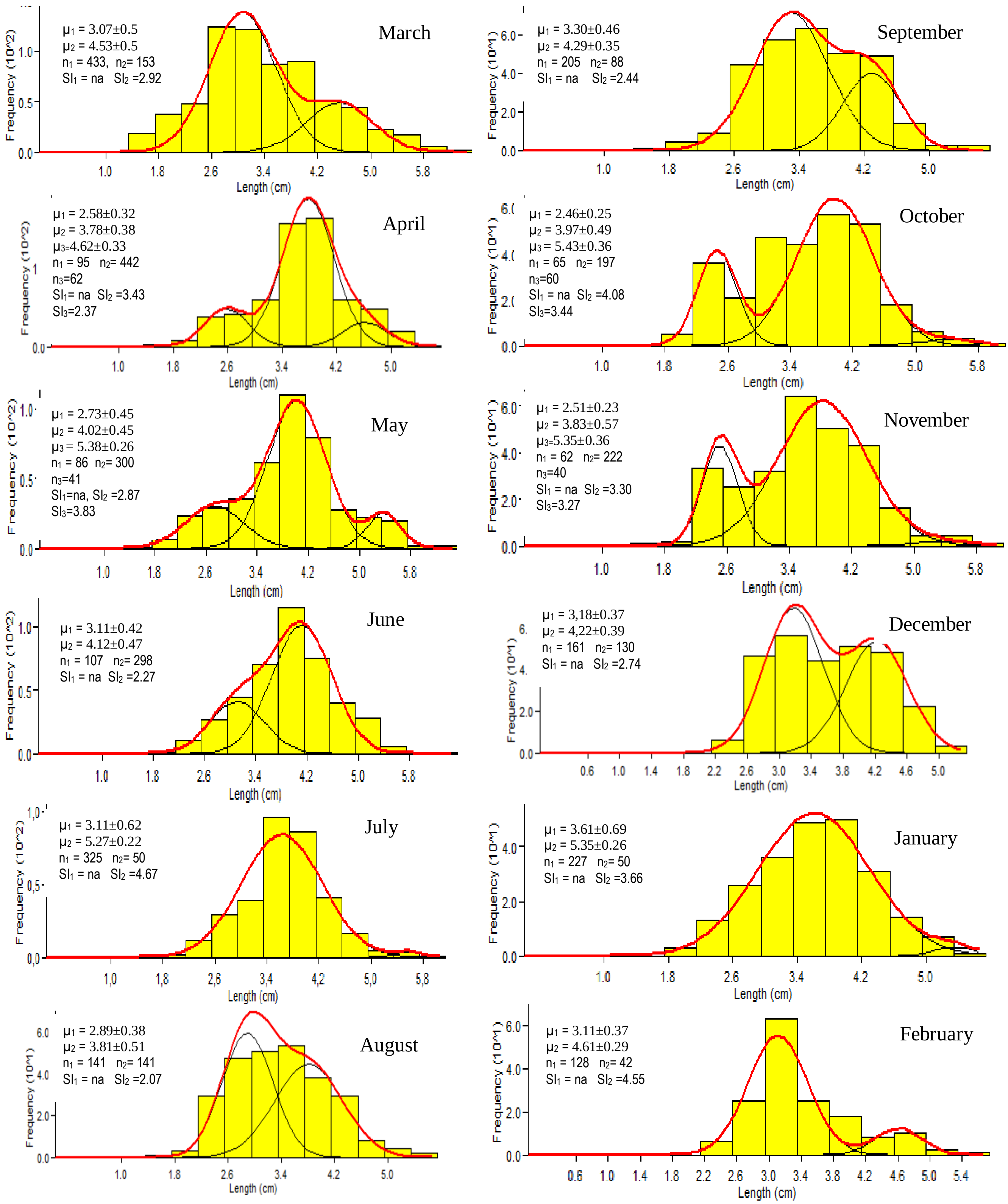

Figure 2. Blood clam size groups in Kendari Bay, Southeast Sulawesi, Indonesia. Note: SI: separation index; n: sample

The size classifications of blood clams in Kendari Bay were less diverse compared to those of other species in other estuaries, such as *Cerastoderma edule* (Callaway et al. 2013), *Darina solenoides* (Lizarralde et al. 2018), each consisting of 4 age groups, as well as beach clams, namely *Donax trunculus* (Hafsaoui et al. 2016) and *Circenita callipyga* with 3 and 3-4 age groups, respectively (Bagher et al. 2007). However, the group composition obtained had little difference from the Pokea clams exploited in the Pohara River and Lasolo River, each having 2 and 3 size categories (Bahtiar et al. 2018). Please indicate what causes these variations in size classifications between species.

The population structure in Kendari Bay was relatively stable and could support/guarantee growth. This was indicated by: (i) the presence of size groups, namely young adult, adult, and old, though the small-sized category was relatively smaller in number/juvenile size not found; (ii) the recruitments of the blood clam per month. These two conditions can provide high fitness in the population. They can also help to overcome negative ecological pressures related to the low quality of the environment, which was caused by the high flow of sedimentation in the Bay.

Growth

The asymptotic length (L∞) of the blood clams was 6.67 cm with a growth coefficient (K) of 0.72 yr^{-1}. Therefore, their growth was defined by $Lt = 6.67-(6.67-0.025)e^{-0.72t}$, as shown in Figure 3.

The blood clams of Kendari Bay had a relatively faster growth compared to others in the same genus, namely *Anadara granosa* (Narasimham 1988), *A. tuberculosa* (Stern-Pirlot and Wolff 2006; Lucero et al. 2012) and *A. cornea* (Sahin et al. 1999). However, their growth was slower than that of *A. granosa* (Vakily 1992; Mirzaei et al. 2014) and *A. gubernaculum* (Fauzan et al. 2018) (Table 1).

Samples with larger lengths are slower in reaching their maximum length compared to others with smaller lengths (Sparre and Venema 1999). However, the clams in Kendari Bay had relatively faster growth than others, including *Donax striatus* (Ocaña 2015), *Lithophaga patagonica* (Bagur et al. 2013), *Dosinia ponderosa*, *Megapitaria aurantiaca*, and *Megapitaria squalida* (Lopez-Rocha et al. 2018). They also had similar rates to *Geloina expansa* (Yahya et al. 2018), *Darina solenoides* (Lizarralde et al. 2018) as well as slower rates to *Eumarcia paupercula* (Mugabe et al. 2019), *Crassostrea lass* (Yapia et al. 2017), and *Anomalocardia brasiliana* (Mattos and Cardoso 2012). The level of clam growth is highly dependent on several conditions, namely species, exploitation level, food availability, stock density, and size distribution (Mirzaei et al. 2014). Their rapid increase in size is facilitated by (i) high productivity around coastal waters, which provides sufficient food availability (Mirzaei et al. 2014); (ii) high growth coefficient; and (iii) short life span (Sparre and Venema 1999).

Mortality and exploitation rate

The total mortality (Z) was 3.09 yr^{-1} and it is comprised of natural and fishing mortalities. Furthermore, the natural mortality (M) of blood clams at the annual mean temperature 27.7°C was higher than that of fishing (F) with values of 2.18 yr^{-1} and 0.91 yr^{-1}, respectively. This result indicates that their exploitation rate was below 0.5 under-exploited) with a value of 0.29, as shown in Figure 4.

Water quality

The results of water quality measurements showed that the temperature ranged from 27-99°C (26.65°C±1.10), the brightness of the waters ranged from 17.02-37.72% (26.94±6.07), the salinity of the waters ranged from 17-20o/oo±1.10, and the organic matter of the sediments ranged from 0.22-3.45 % (2.17 mg/L±1.10) (Figure 5).

The total mortality of blood clams in Kendari Bay consisted of natural and fishing mortalities, where the former has more contribution than the latter. A value of 3.09 yr^{-1} was greater than that of *Anadara tuberculosa* (Lucero et al. 2012), *Anadara gubernaculum* (Fauzan et al. 2018), *Donax trunculus* (Çolakoğlu 2014), *Potamocorbula faba* (Hariyadi et al. 2017), *P. acutidens* (Efriyeldi et al. 2012) and *B. violacea* var. *celebensis* (Bahtiar et al. 2022). Meanwhile, it was lower than that of the exploited species in estuaries, namely *B. violacea* var. *celebensis* (Bahtiar 2012; Bahtiar et al. 2016) and *Polymesoda erosa* (Dolorosa and Dangan-Galon 2014) (Table 2).

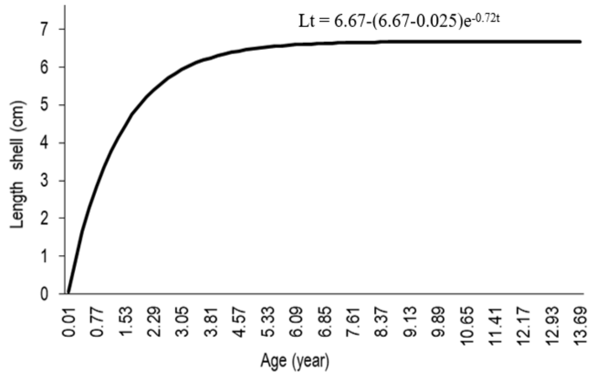

Figure 3. Growth curve of blood clams in Kendari Bay, Southeast Sulawesi, Indonesia

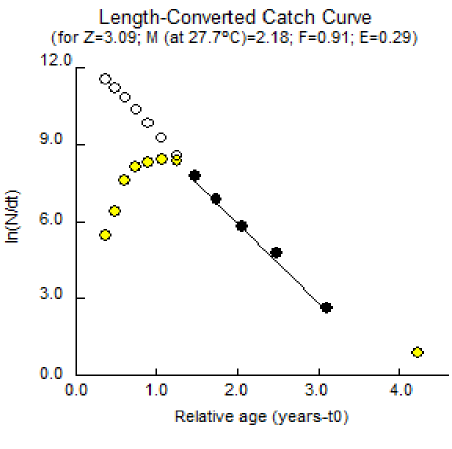

Figure 4. Mortality and exploitation rate of blood clams in Kendari Bay, Southeast Sulawesi, Indonesia

Table 1. Comparison of growth parameters of various types of shellfish in various waters in the world

Location	Species	K (yr^{-1})	L∞ (mm)	Reference
Slower growth				
Pacific Coast	*Anadara tuberculosa*	0.33	88.26-89.77	Lucero et al. (2012)
Pacific Coast, Costa Rica	*Anadara tuberculosa*	0.14	63.15	Stern-Pirlot and Wolff (2006)
Eastern Black Sea	*Anadara cornea*	0.37	75.24	Sahin et al. 1999)
Balsas Beach, Cuba	*Donax striatus*	0.8	36.1	Ocaña (2015)
Southeast Brasil	*Tagelus plebeius*	0.52	74.14	Silva et al. (2015)
Southwestern Atlantic, Argentina	*Lithophaga patagonica*	0.22	36.95	Bagur et al. (2013)
North of the Gulf California	*Dosinia ponderosa*	0.45	131.6	López-Rocha et al. (2018)
North of the Gulf California	*Megaitaria aurantiaca*	0.42	126.5	López-Rocha et al. (2018)
North of the Gulf California	*Megapitaria squalida*	0.44	106.3	López-Rocha et al. (2018)
Guaymas	*Megapitaria squalida*	0.19	104.6	Aragon-Noriega (2017)
Yafaros	*Megapitaria squalida*	0.25	91.3	Aragon-Noriega (2017)
Bohol, Phlipines	*Polymesoda expansa*	0.51	91.53	Argente and Ilano (2013)
Dumai Riau	*Pharalla acutidens*	0.59	92.70	Efriyeldi et al. (2012)
Southeast Sulawesi, Indonesia	*Batissa violacea*♂	0.71	78.40	Bahtiar (2012)
Laeya River	*Batissa violacea*♂	0.54	83.89	Bahtiar et al. (2022)
Laeya River	*Batissa violacea*	0.56	74.10	Basri et al. (2019)
Similar growth				
South China Sea	*Geloina expansa*	0.7	76.1	Yahya et al. (2018)
Southeast Sulawesi, Indonesia	*B.violacea*♀	0.91	89.40	Bahtiar (2012)
Rio Gallegos Estuary	*Darina solenoides*	0.5	49.4	Lizarralde et al. (2018)
Faster growth				
Penang Island, Malaysia	*Anadara granosa*	1.1	35.40	Mirzaei et al. (2014)
Ang Sila, Thailand	*Anadara granosa*	1.86	36.89	Vakily 1992)
Asahan Waters, North Sumatera	*Anadara gubernaculum*	1.2	43.05	Fauzan et al. (2018)
Maputo Bay, Mazambique	*Eumarcia paupercula*	1.65	40.5	Mugabe et al. (2019)
Sidoarjo Bay, Indonesia	*Potamocorbula faba*	0.81	16.40	Hariyadi et al. (2017)
West Marmara, Turkey	*Donax trunculus*	0.76	44.10	Çolakoğlu (2014)
Southwestern Atlantic, Argentina	*Lithophaga patagonica*	0.28-	14.76-	Bagur et al. (2013)
Pernambuquinho Beach (Brazil)	*Anomalocardia brasiliana*	0.61	28.68	Rodrigues et al. (2013)
Barra beach	*Anomalocardia brasiliana*	0.48	29.87	Rodrigues et al. (2013)
Flexeiras Beach	*Anomalocardia brasiliana*	0.71	37.62	Mattos and Cardoso (2012)
Cidadde beach, South-east Brasiliana	*Anomalocardia brasiliana*	0.56	42.47	Corte et al. (2015)
India	*Meretrix casta*	1.81	24.24	Laxmilatha (2013)
India	*Meretrix casta*	2.00	26.50	
Lagoons Ebrie dan Abi., Gading Beach	*Crassostrea gasar*	0.58-0.88; 1.80	135.45	Yapia et al. (2017)
Palawan, Philippines	*Polymesoda erosa*	1.0	10.71	Dolorosa and Dangan-Galon (2014)
India	*Meretrix casta*	1.81	24.20	Laxmilatha (2013)
Lasolo River	*Batissa violacea*	1.8	80.70	Bahtiar et al. (2016)

Note: K: growth coefficient **(**yr^{-1}); L∞: asymptotic length (mm)

The natural mortality of the blood clams was 2.18 yr^{-1}, and it was similar to that of others in the same genus, including *A. granosa* (Mirzaei et al. 2014) and *A. gubernaculum* (Fauzan et al. 2018), but higher than *Polymesoda expansa* (Argente and Ilano 2013), *Potamocorbula faba* (Hariyadi et al. 2017), *Donax trunculus* (Çolakoğlu 2014), *Geloina expansa* (Yahya 2017), *P. erosa* (Dolorosa and Dangan-Galon 2014), *P. acutidens* (Efriyeldi et al. 2012), and *B. violacea* var. *celebensis* (Bahtiar et al. 2016; Basri et al. 2019; Bahtiar et al. 2022). Furthermore, some shellfish have higher values than blood clams, including *Lithophaga patagonica* (Bagur et al. 2013) and *B. violacea* var. *celebensis* (Bahtiar 2012; Bagur et al. 2013) (Table 2).

The natural mortality obtained from the samples was relatively higher, and this was indicated by empty shells found at the bottom of the water, as observed in *Anadara gubernaculum* (Fauzan et al. 2018). This death was caused by high sedimentation from run-off and input from several rivers, including Wanggu, Kemaraya, Kambu, and Abeli Rivers, during rains, which brought suspended solids to their shells. This is characterized by low water quality, such as low water clarity in Kendari Bay (Figure 5) and high total suspended solids of 266-442 mg/L (Alfiani et al. 2019). Based on Marwah and Alwi (2014) that a decrease in the forest area of 19.1% (8645.5 ha) in one watershed (DAS Wanggu) causes an increase in surface run-off (RO) of 499.5 mm/yr, run-off coefficient (CRO) of 25.6% of the total rainfall that results in erosion of 23.1 t/ha/yr. Excessive siltation can interfere with the filter-feeding activities of mussels and can lead to suffocation and mortality. This death was caused by high sedimentation from run-off and input from several rivers, including Wanggu, Kemaraya, Kambu, and Abeli Rivers, during rains, which brought suspended solids to their shells. These conditions were observed in several small shells found at the base of the waters. Furthermore, a similar observation was made at the mouth of the Pohara River during sand mining, which covered the shellfish's habitat and disrupted the respiratory and food mechanisms. This led to the mass death of *B. violacea* var. *celebensis* along 2 km, especially in smaller species (Bahtiar 2012; Bahtiar et al. 2016).

Table 2. Mortality and exploitation rates of different types of shellfish in the world

Location	Species	M (yr^{-1})	F (yr^{-1})	Z (yr^{-1})	E	Reference
Pacific Coast	*Anadara tuberculosa*			1.79		Lucero et al. (2012)
Penang Island, Malaysia	*Anadara granosa*	1.84	0.48	3.02	0.20	Mirzaei et al. (2014)
Asahan Waters, North Sumatera	*Anadara gubernaculum*	1.90	0.22	2.12	0.10	Fauzan et al. (2018)
Balsas Beach, Cuba	*Donax striatus*			3.07		Ocaña (2015)
Southeast Brasil	*Tagelus plebeius*			2.58		Silva et al. (2015)
Southwestern Atlantic, Argentina	*Lithophaga patagonica*	6.50				Bagur et al. (2013)
Bohol, Phlipines	*Polymesoda expansa*		0.54		0.72	Argente and Ilano (2013)
West marmara, Turkey	*Donax trunculus*	1.07		1.082		Çolakoğlu (2014)
Sidoarjo Bay, Indonesia	*Potaocorbula faba*	1.90	0.27	2.17		Hariyadi et al. (2017)
South China Sea	*Geloina expansa*	1.10	1.0		0.47	Yahya et al. (2018)
Palawan Philippines	*Polymesoda erosa*	1.41	2.33	3.74	0.62	Dolorosa and Dangan-Galon (2014)
Dumai, Riau	*Pharalla acutidens*	0.39	0.94	1.87	0.50	Efriyeldi et al. (2012)
India	*Meretrix casta*	1.98	0.98	2.96	0.33	Laxmilatha (2013)
Laeya River, Southeast Sulawesi Indonesia	*Batissa violacea*	2.04	0.91	2.94	0.69	Bahtiar et al (2022)
Pohara River, Southeast Sulawesi Indonesia	*Batissa violacea*	2.39	4.07	6.46	0.63	Bahtiar (2012)
Lasolo River	*Batissa violacea*	3.69	8.15	11.84	0.69	Bahtiar et al. (2016)

Descriptions: Z: mortality coeffiecient (yr^{-1}); M: natural mortality coefficient (yr^{-1}); F: fishing mortality coefficient (yr^{-1}); E: exploitation rate

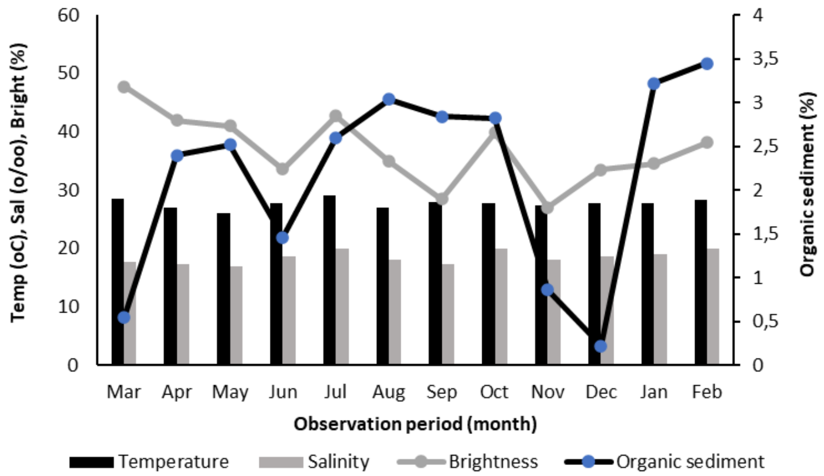

Figure 5. Water quality of Kendari Bay during the study

The fishing mortality of the blood clams in Kendari Bay was 0.29yr^{-1}, and this was higher than that of other species, namely *P. expansa* (Argente and Ilano 2013), and *Potamocorbula faba* (Hariyadi et al. 2017). Meanwhile, the value obtained was similar to that of some clams, as shown in Table 3. Low fishing mortality can be attributed to the little collection by humans for consumption and sales. The results showed that the harvest of blood clams at the study site was carried out in limited quantities to meet daily needs. The animals were sold by fishermen at local markets in the City. Lower values caused by small-scale fishing instead of natural factors indicate low or non-optimal exploitation of the species. Exploitation is optimal when fishing and natural mortality have equal value or degree (Gulland 1977). This result indicates that the blood clams in Kendari Bay can be harvested optimally to a condition where E: 0.5. This level of exploitation was also observed for other species, including *A. granosa* (Mirzaei et al. 2014) and *Anadara gubernaculum* (Fauzan et al. 2018), while *P. expansa* (Argente and Ilano 2013), *P. erosa* (Dolorosa and Dangan-Galon 2014), and *B. violacea* var. *celebensis* (Bahtiar et al. 2016) were highly harvested in other areas.

In conclusion, the existence of blood clams in Kendari Bay is in stable condition, where their population is distributed among the juvenile, young adult, and adult age groups of 1 to 2 years old. Mortality due to natural factors was higher than that of fishing, which indicates relatively low exploitations. Under these conditions, the blood clam population in the bay can persist and grow favorably.

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