BIODIVERSITAS
Volume 24, Number 9, September 2023
Pages: 4711-4722

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d240911

Morphometric study of Lola *Rochia nilotica* (Linnaeus 1767) shells from natural harvest found in Indonesian

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Manuscript received: 7 August 2023. Revision accepted: 12 September 2023.

Abstract. *Wahyudi ND, Hidayati D, Arbi UY, Ismail A. 2023. Morphometric study of Lola* Rochia nilotica *(Linnaeus 1767) shells from natural harvest found in Indonesian. Biodiversitas 24: 4711-4722.* The population of *Rochia nilotica* or Lola snails is declining due to shell exploitation for industry, which requires monitoring. The government has implemented a policy to determine *R. nilotica* regulated on a restricted basis depending on the number (quota) and size of the shell (diameter) with a standard width of 80 cm. Based on the morphometric compositions and size trends of shells, this study aimed to map the potential trade of *R. nilotica* in Indonesia using the percentage of calculated morphometric data, including Sumatra, Sulawesi, Maluku-East Nusa Tenggara (NTT), and Papua. Morphometric analysis was carried out using caliper parameters of length, width, weight, and the data distribution of morphometrics using descriptive statistics. The results revealed fluctuating yearly data. Good quality of shell size (≥80 mm) found from Sumatra (length = 95.13-104.49 mm; width = 86.61-103.46 mm; weight = 172.21-321.96 gram), Malulu-East Nusa Tenggara (NTT) (length = 91.26-106.72 mm; width = 86.53-108.73 mm; weight = 228.01-365.62 gram), Sulawesi (length = 86.92-99.1 mm; width = 84.31-96.25 mm; weight = 205.39-317.33 gram), and Papua (length = 82.46-99.58 mm; width = 76.49-101.24 mm; weight = 182.57-283.07 gram) respectively. Among 909 samples of *R. nilotica* observed, 89% had a standard width (≥80mm), indicating potential mapping of Sumatra (33%), Maluku-East Nusa Tenggara (NTT) (24%), Sulawesi (18%), and Papua (14%). In Sumatra (1.65%), Maluku-East Nusa Tenggara (NTT) (0.9%), Sulawesi (5.6%), and Papua (3.19%), non-standard width shells were sized at 51.46-72.15 mm, respectively. In total, 53.9% of protoconchs were classified as damaged. From 2014-2020, morphological observations of *R. nilotica* shells traded in Indonesia fluctuated but met the standard size. It is critical to continue monitoring the population and trade of *R. nilotica*, and the study findings can be used to make catch quota recommendations for the Ministry of Environment and Forestry.

Keywords: Exploitation, live below water, monitoring, potential mapping, size trend

INTRODUCTION

Indonesia has high biodiversity, most of which has been utilized by the community, including Lola snails. Lola snail or *Rochia nilotica*, formerly known as *Trochus niloticus*, is a type of mollusk from the gastropod class, which is considered to have a high ecological and economic significance (Purcell et al. 2019; Purcell et al. 2021), *R. nilotica* consumes turf algae, turf-algae that cover reef flats because *R. nilotica* has an ecological role as a herbivore controller for macroalgal populations (Purcell & Ceccarelli 2020; Seinor et al. 2020). Because of its high protein content, *R. nilotica* is economically important as a food source, and its shells are used to manufacture buttons and handicrafts (Abukena et al. 2014; Gillet et al. 2020; Purcell & Ceccarelli 2020; Purcell et al. 2020). The shell and flesh of *R. nilotica* cost differently depending on their locality and size of *R. nilotica* shells, which ranged from US$ 2.20 to US$ 4.00/kg on the Pacific Island approximately from 2012-2014 (Purcell & Ceccarelli 2020). In Samoa, the shell costs approximately WST5/kg or US$1.81/kg (Tiitii et al. 2021). According to Gillet et al. (2020), in 2019, the price of *Rochia nilotica* snails in Cook Island was around US$ 0.78-3.58/kg depending on the grade of the shell. In Fiji, US$ 2.30 The shell of *R. nilotica* is non-perishable and has a shelf life until the market finds a profitable price to sell (Gillet et al. 2020).

The growing market interest in *R. nilotica* shells has led to an increase in their exploitation, resulting in a decrease in *R. nilotica* population (Purcell & Ceccarelli 2020). *R. nilotica* is one of the gastropods that has a size-at-age pattern in its shell (Ulm et al. 2019). Based on Gillet et al. (2020), R. nilotica can be harvested at 8.0 cm. This prohibits the harvesting smaller than 8.0 cm (Queensland Government 2022). The handling and supervision of this law to conserve *R. nilotica* in Indonesia is still not optimal. The diameter of the *R. nilotica* shells demonstrated this. In addition, Indonesia has a National Action Plan to conserve *R. nilotica* from 2016 to 2020 (Gillet et al. 2020). Protoconch conditions were used in this study. In gastropods, shell growth begins at the protoconch or the apex. The fundamental purpose of the protoconch is to protect planktonic larvae (Turner et al. 2020). Natural conditions have a substantial influence on the protoconch conditions that cause erosion (Guallart et al. 2017).

One of the measures carried out by the government to ensure the sustainability of these snails is the limitation on the use of *R. nilotica*, which is regulated on a restricted basis depending on the number (quota) and size of the shell (diameter). Based on morphometric investigations and shell size trends, the goal of this study is to map the potential of *R. nilotica* shells traded in Indonesia, namely Sumatra, Sulawesi, Maluku-East Nusa Tenggara (NTT), and Papua, based on morphometric studies and shell size trends. The results of this study can be used as a reference source for establishing trade quota recommendations in accordance with the Ministerial Decree of the Minister of Forestry and Plantations No. 385/1999 on the Designation of Red Lola (*R. nilotica*) as a Hunted Animals, tradeable *R. nilotica* shell sizes are those with a shell diameter of 8.0 cm or greater. Many people fail to abide by the requirements outlined in the rules and regulations. However, it is unclear how these laws and regulations will continue to be implemented. The Ministry of Maritime Affairs and Fisheries prepared documents that aim to obtain data on the status of *R. nilotica* populations in potential water areas, establishing at least one conservation area for *R. nilotica* protection, increasing *R. nilotica* populations in conservation areas, creating management arrangements, and supervising the use of *R. nilotica*. *R. nilotica* has a patterned growth on its shell, by using the size of the shell, the age range could be known. Size-at-age determinations support an exploited reconstruction of the population structure over time to understand the potential impact of external pressures, including human intervention (Ulm et al. 2019).

MATERIALS AND METHODS

Study area

This research was conducted from January to March 2021. *R. nilotica* morphometric data were collected and analyzed at the Zoology Laboratory, Oceanographic Research Center, Indonesian Institute of Sciences (now Oceanographic Research Center, National Research and Innovation Agency (BRIN)), North Jakarta City, Jakarta. The materials used in this study were *R. nilotica* shells stored in P2O - LIPI obtained from the waters of Sumatra, Sulawesi, Maluku-East Nusa Tenggara (NTT), and Papua (Figure 1, Table 1), which were collected from 2014-2020. This is the location of business actors (traders) who propose quotas for the utilization of *R. nilotica* for trade purposes through the Natural Resources Conservation Agency. The traders who propose quotas will be given information to send the specified numbers of the shell, which is in accordance with the quantity requested and greater than 8 cm in size; the quota will be given to the seller.

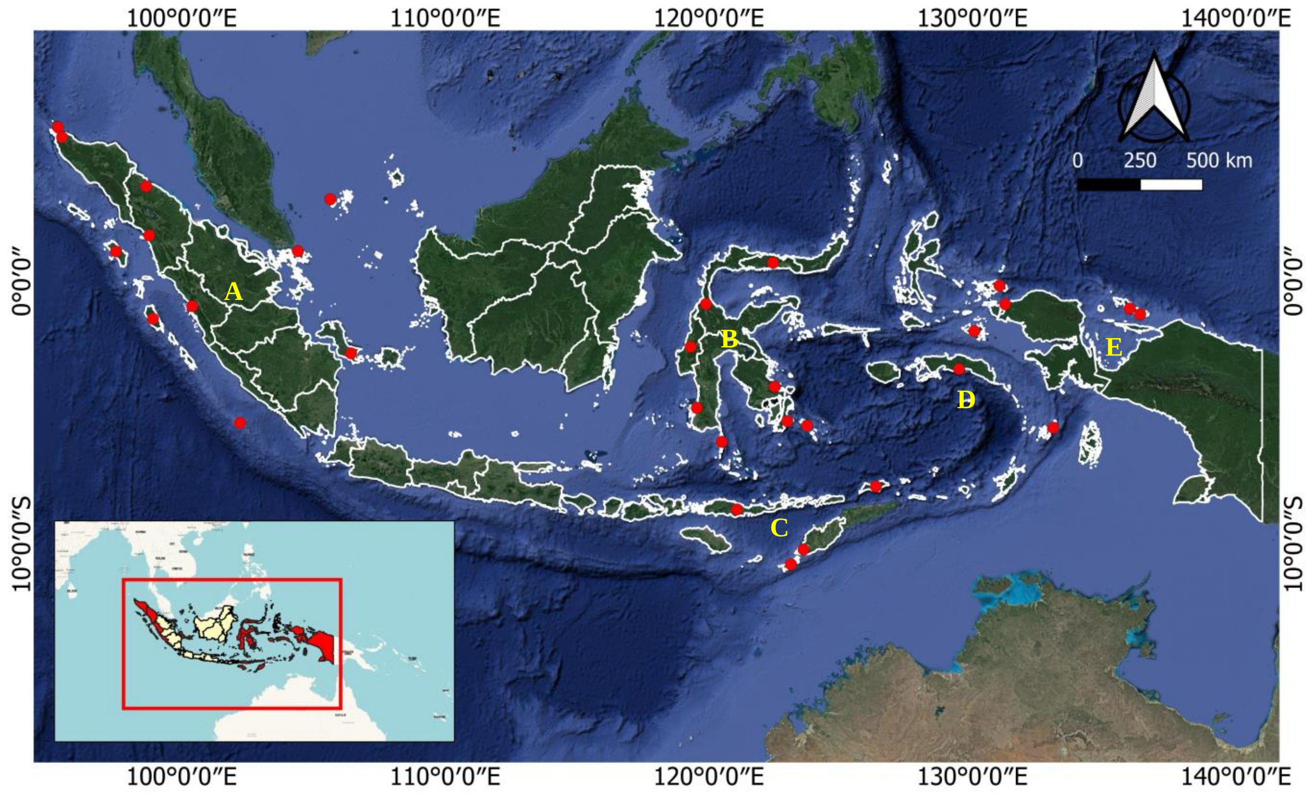

Figure 1. Location of *Rochia nilotica* harvested: A. Sumatra Region: Aceh, North Sumatra, West Sumaters, Bengkulu, Riau Island, and Bangka Belitung; B. Sulawesi: South Sulawesi, Central Sulawesi, South East Sulawesi North Sulawesi; C. East Nusa Tenggara (NTT); D. Maluku; E. Papua: Papua and West Papua. These samples were collected by the traders in the region who propose quotas for the utilization of *R. nilotica* for trade purposes through the Natural Resources Conservation Agency

Table 1. Water conditions in every location of samples of *Rochia nilotica* were taken

Location	Recency	Water condition
Sumatra		
Aceh	Sabang Island	Decreased because of natural phenomena, tsunami, that caused coral reefs (R. nilotica lives) to be washed away and loss of coastal ecosystem area. Besides natural phenomena, human activity also causes the decreased water condition in Sabang Island, which is a fishing activity with bombing (Mustaqim 2018)
	Aceh Besar	The same situation occurred on the coast of Aceh, which experienced a significant change in 2004 when the tsunami hit Aceh’s waters. In addition to these changes, it also affects changes in coastal morphology related to geo-oceanographic processes in coastal areas (Irham et al. 2021)
North Sumatra	Nias	Has great potential for marine fisheries that, in the year 2000-2018, dominated by tuna and skipjack (Purwanto et al. 2020). However, according to Hadi et al. (2019), during 2015-2016, the condition of corals decreased by approximately 12.94%, from 26.76% in 2015 to 13.82% in 2016. This can be attributed to human activities and rising sea temperatures
	Sibolga	Larger fishing industry compared to any other area on the west coast of Sumatra (Firdaus et al. 2021). However, production tends to decrease every year with an increased number of fishermen. In 2016, the number of fishermen increased by 6.54% a year before (Harahap et al. 2019). This condition feared that overfishing would occur in the water
	Medan	Low human resources and dirty oceans are caused by marine debris (Suhaidi et al. 2020)
West Sumatra	Padang	Coastal accretion and abrasion are influenced by wave and current movements. This leads to property damage and a loss of economic power (Febriandi et al. 2019)
	Mentawai Island	The sea surface temperature is influenced by the eastern Indian Ocean, which results in warmer temperatures than normal conditions (Wisha and Khoirunisa 2017). This could alter the metabolism of organisms, including *R. nilotica*
Bengkulu	Enggano Island	Scattered coral reef ecosystems in the western and eastern parts of the island. Coral reefs function as spawning, feeding, and breeding grounds for *R. nilotica*. The increased use of destructive fishing gear has also damaged coral reefs. Damage can affect the stability of coral reef ecosystems (Zamdial et al. 2016)
Riau Islands	Anambas Island	Has the richest marine biodiversity in western Indonesia. In particular, species found in coral reef ecosystems (Taufiqurrahman et al. 2023)
	Bintan Island	Waters in Bintan Island are part of Indonesia’s and coastal state of the Singapore Strait, which can be used as an international shipping lane using the straits of Malacca and Singapore as access to international trade. However, Bintan waters suffer from marine pollution due to oil sludge, which worsens during the northern season (Thahira et al. 2023)
Bangka Belitung	Bangka and Belitung Island	World’s largest tin producers. Tin mining greatly impacts the coastal environment, resulting in high sedimentation in water. This can cause physiological damage to corals owing to low light intensity (Siringoringo and Hadi 2014). In addition, damage to coral reefs in Indonesia is caused by water pollution, ship grounding, coral mining, destructive fishing, extreme and strong waves, predators of coral reefs, and rising sea surface temperatures due to global warming (Idris et al. 2021)
Sulawesi		
South Sulawesi	Selayar Island	Marine debris is transported by currents from the sea surface and deposited along the coast. The ecological impacts of these waters have an effect on the intertidal area due to floating debris that is stranded in the intertidal area. Marine debris accumulates on beaches, covering seagrasses and organisms in this area (Hermawan et al. 2017)
	Pangkajene	The decreased coverage of coral reefs where *R. nilotica* lives (Haya and Fuji 2020)
Central Sulawesi	Palu	Organic and inorganic marine debris, but most of the waste, comes from culinary activities along the coast of Palu City (Walalangi et al. 2022)
	Mamuju	High biodiversity and source of community livelihoods, also high tourism potential. This could trigger massive exploration and exploitation that leads to a decline in the quality of the coastal environment (Paddiyatu 2019)
Southeast Sulawesi	Kendari	Marine debris, particularly during the rainy season. This marine debris disturbs organisms on the coast (Rahim et al. 2020)
	Buton	High potential in marine resources. This has led to high fishing demands and the use of fishing gear that is not environmentally friendly, which has a negative impact on the sustainability of fishery products and decreases the function of coastal ecosystems (Aulia et al. 2021)
	Wakatobi	Experienced climate change, which has caused changes in sea surface temperature (Madduppa et al. 2020). This temperature change greatly affects the condition of benthic organisms, one of which *R. nilotica*

North Sulawesi	Gorontalo	High human activities allow pollution to occur. A well-maintained ecosystem balance provides a scientific cycle of the aquatic ecosystem (Kadim and Pasisingi 2018)
East Nusa Tenggara		
	Kupang	Ecotourism, most of the case from ecotourism is marine debris that results in the mixing of garbage with water or sediment particles that are used as food for suspended particle-eating biota or detritus, which will eventually cause a digestive disorder for biota that consume it. Other problems caused by coastal areas include high water turbidity, low dissolved oxygen content, imbalance of water pH resulting in low food content for marine biota, and effects on the biological activities of various marine biota (Paulus et al. 2020)
	Flores	It is inhabited by fishermen, but these fishermen have no boundaries to abide by. Therefore, the inner and outer boundaries of the waters are based on an estimate of the farthest distance that fishermen can travel as the maximum limit for inland waters. The inland boundary is used by fishing communities to conduct fishing activities (Paulus and Azmanajaya 2019). This could limit the number of *R. nilotica* in the ocean
	Rote	Poor management of coral reef conservation areas. This was caused by damage to coral reefs in the present study. The damage is caused by human activities, such as seaweed cultivation, fish bombs, potassium, and traditional macamenting activities (Widodo et al. 2023)
Maluku		
	Seram	Has a high coastal productivity that is very beneficial for people that live there. These waters are rich in biological resources. However, the use of these resources is not environmentally friendly. The mining of dead corals in seagrass ecosystems for building materials exacerbates the damage to these two ecosystems and affects other organisms living in these ecosystems (Pelasula et al. 2023)
	Kei Besar Island	The largest ecosystem of coral reefs, followed by seagrass and mangrove ecosystems, but is relatively less extensive. The size of coral reef areas is closely related to the presence of marine biota (Sahetapy et al. 2021), including *R. nilotica*
	Maluku Barat Daya	Commonly used for tourism (Kennedy et al. 2018)
Papua		
West Papua	Sorong	Transit for tourism, ship traffic, fisheries, and sand mining. This could be a threat to coastal ecosystems, especially those surrounded by coral reefs (Arafat 2022)
	Misool	Natural resource conservation area, so that its natural condition is still very well preserved (Sala et al. 2019)
	Waigeo	Oceans that have a wealth of mega diversity could be used as high-value ecotourism locations (Gustiarini et al. 2023)
Papua	Biak	There are various types of coral reefs that have an optimal potential with relatively good health (Pattiasina and Mara 2020). Thus, organisms that live around them also grow well
	Padaido	There are various qualities of coral reefs. Most of them are in good or quite good condition, but some are in bad condition due to the rampant practice of destructive fishing using explosives or bombs so that the coral is damaged and organisms around the coral are dead (Paulangan 2015)

Procedures

Morphometric data were obtained by conventional methods, namely measuring length and width using calipers with an accuracy of up to 0.01 mm, as well as measuring shell weight using digital scales (Barros et al. 2020; Yunus & Amsi 2021) (Figure 2). The digital scale used in this research had an accuracy of 0.01 gram. The measured morphometric data included shell width/diameter (Shell Width = SW), shell length/height (Shell Length = SL), and shell weight of *R. nilotica*. The shell length is measured from the apex (protoconch) to the outer part of the shell (Yunus and Samsi 2021), and the shell width measurement is the largest width of the shell perpendicular to the shell axis (Slapcinsky and Kraus 2016).

The protoconch condition can be seen from the shape of the protoconch, which is categorized into four categories: (1) Very good, (2) Quite good, (3) Not good, and (4) Damaged (Figure 6). For the first category, (1) Very good means that the protoconch is in a perfect condition, with no defect. (2) Quite good means that there is a slight imperfection in the protoconch. Not good and damaged have severe damage in the protoconch, but (4) damaged category has changed in size, while (3) not good category hasn't changed much in size.

Data analysis

Data were analyzed using descriptive statistics in Microsoft Excel 2010 to describe the object under study using the collected samples to obtain a data summary (Kaur et al. 2018; Mondal et al. 2022). The data used are the largest and smallest data from shell length (SL), shell width (SW), shell weight, and the average of each.

RESULTS AND DISCUSSION

Shell morphometrics

Shell width/diameter

Data on the shell width of *R. nilotica*, based on observations of 909 samples from four regions in Indonesia (Sumatra, Sulawesi, Maluku-East Nusa Tenggara (NTT), and Papua) that collected from 2014-2020 around September to November each year, are presented in Figure 3. This figure shows the annual average range of shell width/diameter from 2014-2020 across Indonesia. The largest annual range of shell width was found in the Maluku-East Nusa Tenggara (NTT), which ranges from 86.53-108.73 mm (SEM: 2.722). Meanwhile, the annual average range of shell widths from other regions, successively from the largest to the smallest, is: Sumatra at 86.61-103.46 mm (SEM: 2.161), in Papua at 76.49-101.24 mm (SEM: 3.234), and in Sulawesi is 84.31-96.25 mm (SEM: 1.628).

Shell length/height

Measuring the shell length of *R. nilotica* from the 909 samples observed, we obtained data on size distribution from four regions in Indonesia, namely Sumatra, Sulawesi, Maluku-East Nusa Tenggara (NTT), and Papua (Figure 4).

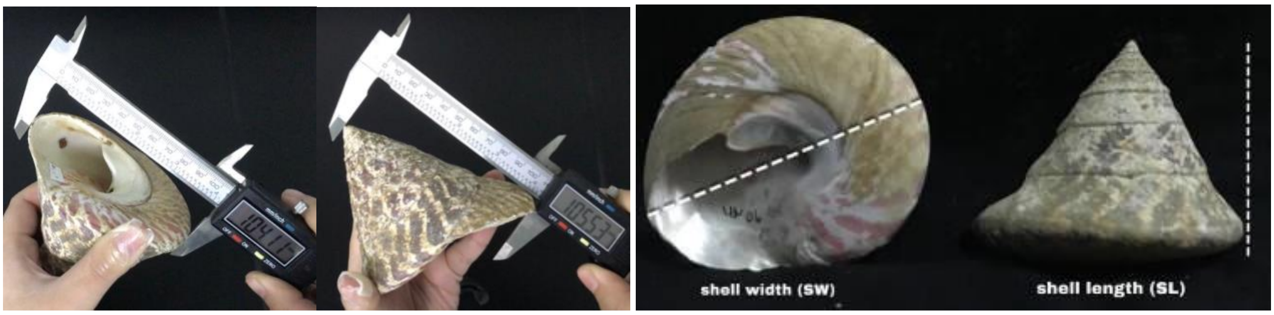

Figure 2. Sample measurement method of *Rochia nilotica*

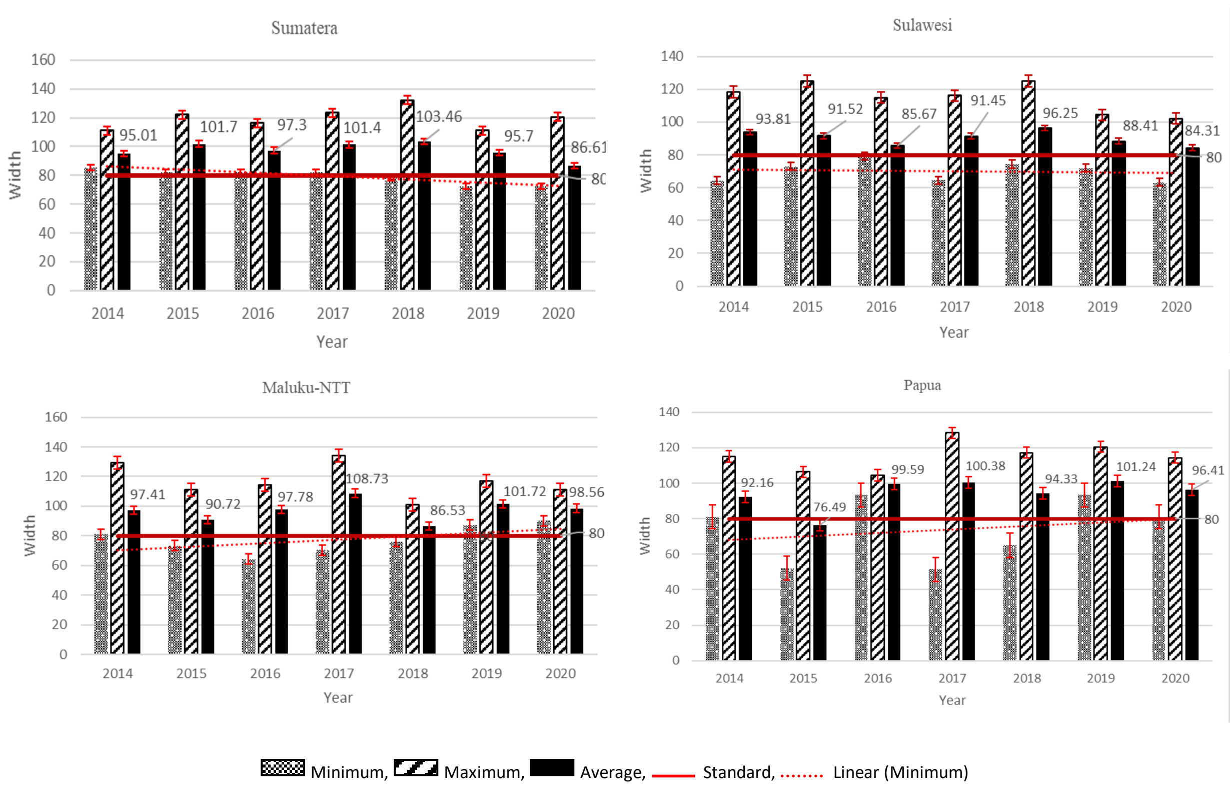

Figure 3. Average shell width/diameter of *Rochia nilotica* (mm)

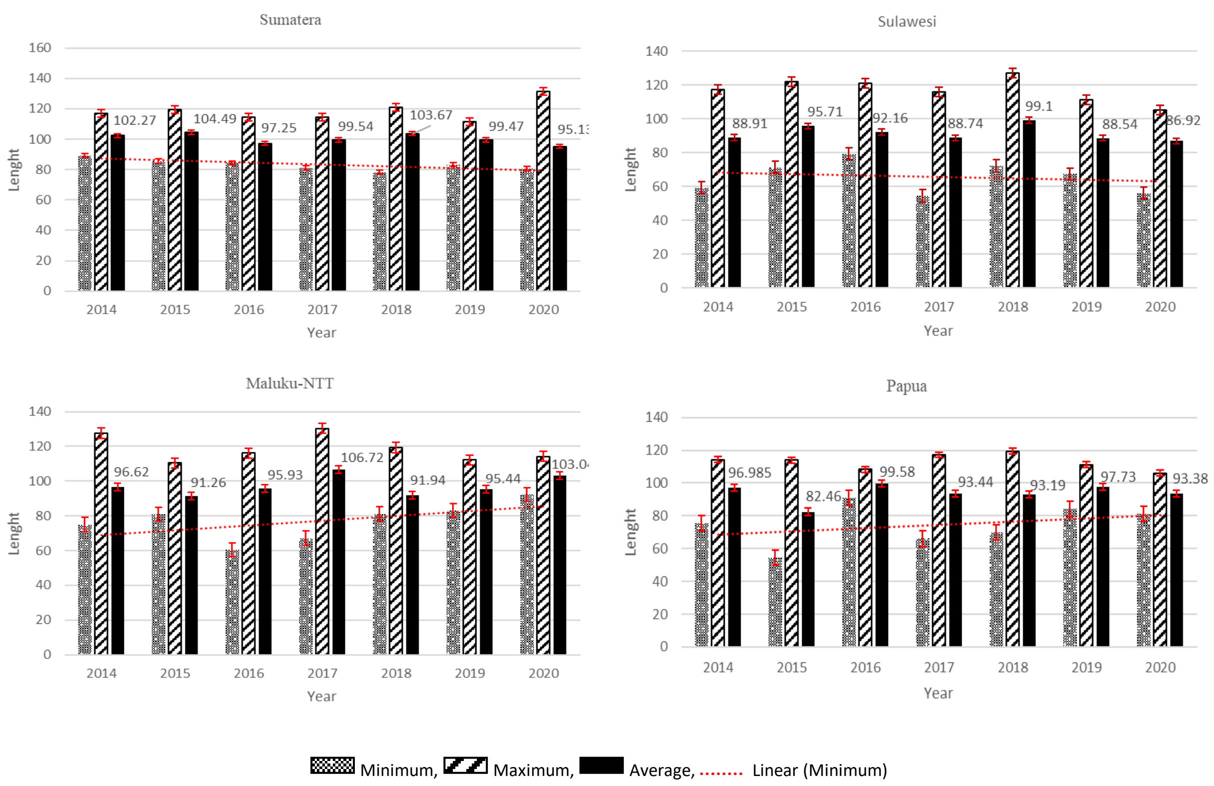

Figure 4. Average shell length/height of *Rochia nilotica* (mm)

Figure 4. shows the range of the annual average shell length from 2014-2020 across Indonesia. The largest annual range of shell length is found in the Maluku-East Nusa Tenggara (NTT), which ranges from 86.53-108.73 mm (SEM: 2.141). While the range of the annual average shell length from other regions in a row from the largest to the smallest is: Sumatra at 95.13-104.49 mm (SEM: 1.291), in the Papua region at 76.49-101.24 mm (SEM: 2.117), and in the Sulawesi is 84.31-96.25 mm (SEM: 1.690).

Shell weight

Based on the measurement results, the largest average shell weight was found in Maluku-East Nusa Tenggara (NTT), which ranged from 228.01 to 365.62 grams (SEM: 21.051). Meanwhile, the average annual range of shell weight from other regions from the largest to the smallest is: in Sulawesi, it ranges from 205.39 to 317.33 grams (SEM: 15.532). In Sumatra, it ranges from 172.21 to 321.96 grams (SEM: 19.250), and in Papua, it ranges from 182.57 to 283.07 grams (SEM: 13.490). A graph of the fluctuations in *R. nilotica* shell weight in each region is presented in Figure 5.

Protoconch conditions

The results of visual observations of 909 *R. nilotica* samples are presented in Table 1. Based on the data on the condition of the protoconch, it is found that most of the observed shells (54%) are damaged. The rest were in good condition (6.7%), quite good condition (9.3%), and not good condition (30.1%). However, biologically, it does not affect living conditions because in some species of gastropods, the older they are, the easier it is for erosion to occur (Říhová 2018). An overview of the protoconch conditions is presented in Figure 6.

Potential use of *Rochia nilotica*

Mapping results of the potential utilization of *R. nilotica* from nature based on measurements of 909 shell samples traded in Indonesia (Table 2). The greater the number of samples that conformed to the standard size, the greater the potential for utilization; conversely, the greater the number of samples that did not conform to the standard size, the lower the potential for utilization.

Table 2. Protoconch conditions in *Rochia nilotica*

Category	Amount	Percentage
Very good	60	6.7 %
Quite good	85	9.3%
Not good	274	30.1 %
Damaged	490	53.9 %
Total	909	

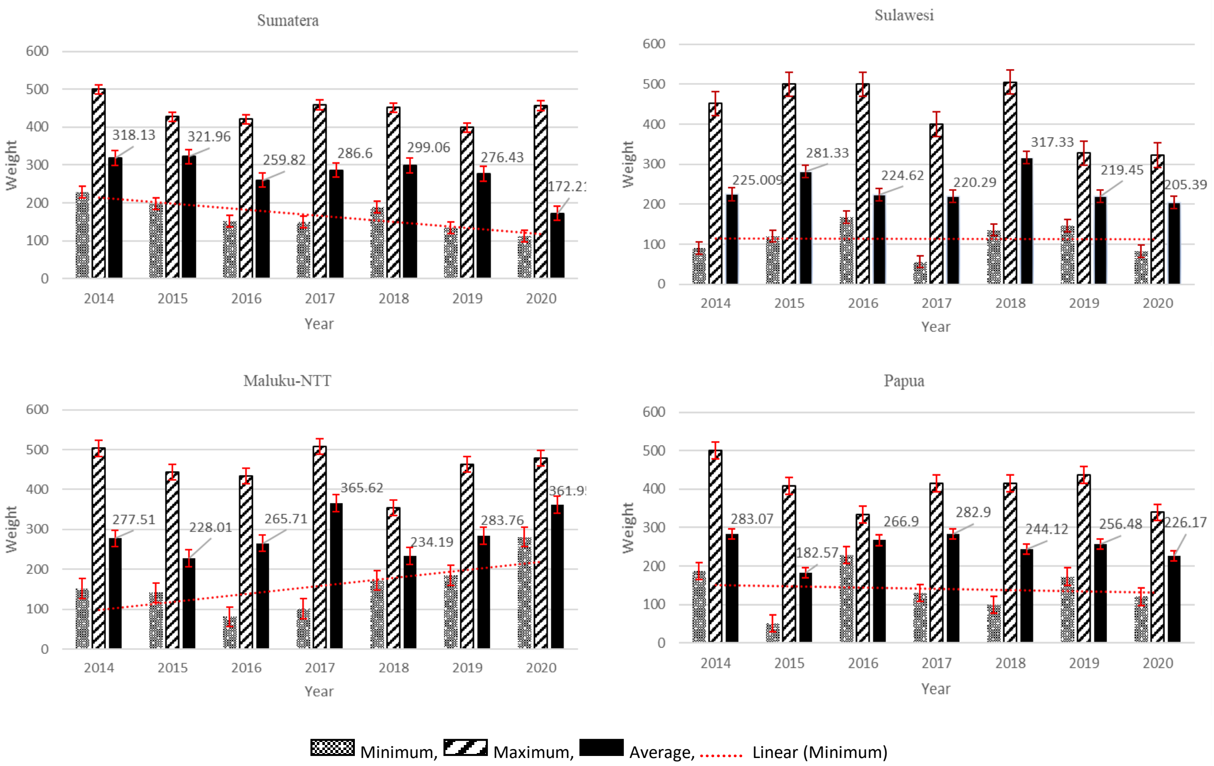

Figure 5. Average shell weight of *Rochia nilotica* (grams)

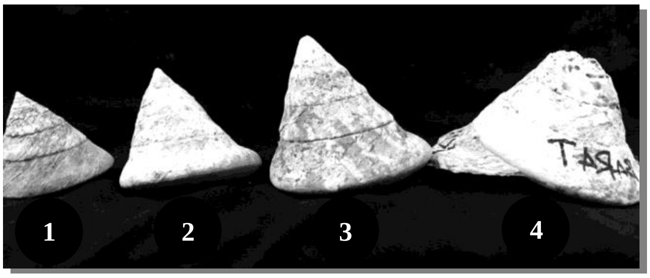

Figure 6. Description of the condition of the protoconch of *Rochia nilotica*. 1. very good, 2. quite good, 3. not good, 4. damaged (Private Doc 2021)

Discussion

Gastropods have a unique feature called protoconch or apex, which serves as the initial growing point of the gastropod. This part is considered a key characteristic in distinguishing between species (Yu et al. 2022), although it may not always be visible in mature shells because of erosion or reduction (Guallart et al. 2017). *R. nilotica*, like other members of the Tegulidae family, has a conical base shape. Its shell is large and conical in shape, with a creamy-white color and a distinctive purplish-red axial pattern that is both irregular and sizeable (Jasmine 2017). The shell consists of 8-10 whorls which partially determine the growth route of the next overlapping whorl (Jasmine 2017; Chirat et al. 2021). The inner and the outer lips are smooth. The surface texture of the shell is coarse-grained, whereas the inside of the shell is shiny and can be used as a raw material for making buttons (Tiitii and Aiafi 2016). At the bottom, the periostracum layer has a yellowish-brown color (Psomadakis et al. 2019). The whorl has a firm spiral shape and some of the initial indentations have small protrusions. The base of the shell or body whorl has the shape of an enlarged convex circle (Jasmine 2017). Body whorl can be used as a parameter to determine whether the snail is ready to be harvested and whether it is tradeable.

Shell morphometrics

Shell width/diameter

The annual data above show fluctuations in shell width from year to year in each region, but most of them (89%) have met the standards of ≥ 80 mm (Gillet et al. 2020). For 11%, shells below 80 mm will reduce catch quotas in that region. Fluctuations in shell width from year to year can occur because of differences in location (habitat), gender, and gonadal maturity level. Individual *R. nilotica* growth at different locations showed different growth rates. This is because *R. nilotica* is known to have a wide distribution, and different environmental factors can affect the developmental stages of organisms (El-Hack et al. 2022).

An analysis of the data presented in Figure 3 indicates that *R. nilotica* traded in Sumatra and Sulawesi tends to be smaller in size. This was likely due to suboptimal growth conditions resulting from environmental factors. However, human intervention in the form of excessive harvesting by local communities is also a significant factor affecting the size of snails (Doyle et al. 2022). In addition to being a standard for estimating the age and reproductive period, shell width measurement is also important for monitoring the growth and population size of *R. nilotica*. By understanding the growth pattern and size of shells, appropriate conservation efforts can be implemented to ensure the sustainability of the species.

Table 3. The potential of *Rochia nilotica* based on morphometric data

Region	Total sample	Diameter ≥ 80 mm		Diameter ≤ 80 mm	
		N	%	N	%
Sumatra	311	296	33%	15	1.6%
Sulawesi	212	161	18%	51	5.6%
Maluku-East Nusa Tenggara (NTT)	229	221	24%	8	0.8%
Papua	157	128	14%	29	3%
Total	909	806	89%	103	11%

The Ministry of Environment and Forestry (2019), *R. nilotica*, is one of the vulnerable species that the policies put in place concerning full protection, a trade arrangement based on utilization quotas, and restricted protection. Furthermore, monitoring the size of *R. nilotica* traded in the market can help prevent the illegal trade of undersized snails, which can contribute to the decline in population size. *R. nilotica* can reach gonadal maturity at around 2 years of age (Ulm et al. 2019). The lifespan of *R. nilotica* is approximately 10 years or more, and it grows to 165 mm (Ulm et al. 2019). The width of the shell can also provide an idea of the marine zone in which *R. nilotica* is harvested. The distribution of the width of *R. nilotica* can be seen based on depth; the deeper the water and the higher the surface complexity, the wider the shell (Seinor et al. 2020). According to Ulm et al. (2019), *R. nilotica* was found in two places: a shallow reef flat intertidal zone and a deeper subtidal coral reef flat at a depth of 10-15 meters. Juveniles live in shallow reef flats until they reach sexual maturity and then move to deeper subtidal reef slopes after reaching sexual maturity. In addition, the water depth is related to the ability of sunlight to penetrate the bottom of the water. Sunlight plays an important role in the photosynthesis of algae (Pereira 2021), and is the main food source for *R. nilotica.* The width of the shell under normal conditions is greatly influenced by the length of the shell, except under certain conditions for *R. nilotica*.

Shell length/height

The shell width is directly proportional to its length. In the early stage, the shell growth rate was fast, but when it reached the maturity stage, the growth was sluggish (Mantale et al. 2018). The length of the shell of *R. nilotica* is affected by several factors, including substrate type. *R. nilotica* is usually found in ecosystems with a coral substrate, where algae serve as their primary food source. Variations in habitat and environmental factors can indirectly affect the shell width-to-length ratio in *R. nilotica*. According to Shuai et al. (2018), the same species occupying different habitats produces different biological morphologies. The annual data show that there are fluctuations in the size of shell length from year to year in each region. As with fluctuations in shell width, fluctuations in shell length from year to year can occur because of differences in place (habitat), gender, and growth rate (Ulm et al. 2019; Gemelli et al. 2020; Markaide et al. 2021).

The graph presented in Figure 4, as is the case with the shell width fluctuation graph, from the shell length data, it can also be seen that *R. nilotica* that traded in Sumatra and Sulawesi tends to become smaller in size. In contrast, Maluku-East Nusa Tenggara (NTT) and Papua show an increasing trend. The decrease in the size of *R. nilotica* in Sumatra and Sulawesi can be attributed to non-optimal growth due to poor environmental conditions, as well as human intervention, such as massive harvesting by the community. However, the increase in size in Maluku-East Nusa Tenggara (NTT) and Papua may be due to more optimal environmental conditions and less human intervention. The variation in shell length ratio can be influenced by many factors, including the type of substrate in the habitat, which affects the availability of food sources. *Rochia nilotica* comestibles turf algae, which have fast growth with a high turnover rate that can tolerate stress very well and the colonization of turf algae is by coral substrate and the environment of the reef (Sweirts and Vermeij 2016; Harvey et al. 2021; De Carvalho and Villaça 2021). According to Matos et al. (2020), the width of the shell appears larger if individuals have a larger foot, which provides higher adhesion to the substrate.

Shell weight

Shell size is also influenced by food availability and food quality, also the presence of natural predators can cause changes in shell morphology (Capinpin Jr. 2018; Johnson 2021). From this statement, it can be said that the availability of feed affects the weight of snails that live in that habitat. The graph is shown in Figure 5. shows that the shell weight of *R. nilotica* in each region fluctuated. In Sumatra and Papua, the annual average shell weight tended to decrease. In contrast, in Sulawesi and Maluku-East Nusa Tenggara (NTT) the weight tended to be even greater. Size is directly proportional to weight, and the factors that affect shell weight are generally identical to those that affect shell size. The feeding behavior of an organism depends on the nutritional quality of the feed (Benítez et al. 2022).

Protoconch conditions

The damaged shell caused the surface to have dissolved patches around the surface (Oliveira et al. 2020). This damage results in a decrease in the quality of the shell on the market. Protoconch damage is a natural event, and the main factor that causes it is environmental conditions with a pH of less than 7 or acid. The erosion and dissolution of the calcium structure on the shell are caused by the dissolution of chalk/calcium materials under acidic environmental conditions (Harvey et al. 2018). These acidic environmental conditions result in ocean acidification as a result of global climate change. Continuous changes in seawater chemistry increase because the concentrations of hydrogen and bicarbonate ions increase, leading to a significant decrease in pH with the simultaneous reduction of carbonate ions, which reduces shell thickness and destroys the metabolism of gastropods (Bula et al. 2017; Harvey 2018; Brahmi et al. 2021; Baag and Mandal 2022). Global climate change, which has an impact on acidification in the marine environment, is also the cause of an increase in temperature, which then affects marine biota (Hatje et al. 2022). In addition, an empty mollusk shell or dead mollusk can act as a colonization surface for sclerobionts. Sclerobionts are capable of soiling hard substrates (Alvarado-Rodríguez et al. 2022). This can affect the formation of an organism on a hard substrate and the colonization pattern on the shell, which affects the shape of the shell (Agostini et al. 2017). The optimal temperature for the development of *R. nilotica* is 28-34ºC. Moreover, it is most likely that the growth of *R. nilotica* will not be optimal. Ocean acidification has been shown to reduce the calcification rate and dissolve the calcareous structure of marine organisms (Figuerola et al. 2021).

In addition, the age of the snails is also a concern, as age would cause the shell to erode more easily (Říhová 2018). Most of the observed shell samples were individuals who had entered the adult state. The condition of the protoconch can also be affected by various factors such as the growth rate, type of substrate, and water quality. In addition, damage to the protoconch can also be caused by predation or other environmental factors. Therefore, the presence or absence of the protoconch and its conditions can provide information about the snail growth rate and environmental history. Overall, protoconch is an important morphological feature of gastropods that can provide valuable information for taxonomic and ecological studies.

Potential use of *Rochia nilotica*

Based on the results of sample measurements from Sumatra, 296 samples (33%) were included in the standard size, while 15 samples (1.6%) did not fit the standard size. In Maluku-East Nusa Tenggara (NTT), 221 samples (24%) were included in the standard size, while eight samples (0.8%) did not fit the standard size. In Sulawesi, 161 samples (18%) fit the standard size, while 51 samples (5.6%) did not fit the standard size. In Papua, 128 samples (14%) fit the standard size, while 29 samples (3%) did not fit the standard size. The data show that the Sulawesi region has the largest percentage of samples that do not fit the standard size (≤ 80 mm**)** compared with any other region.

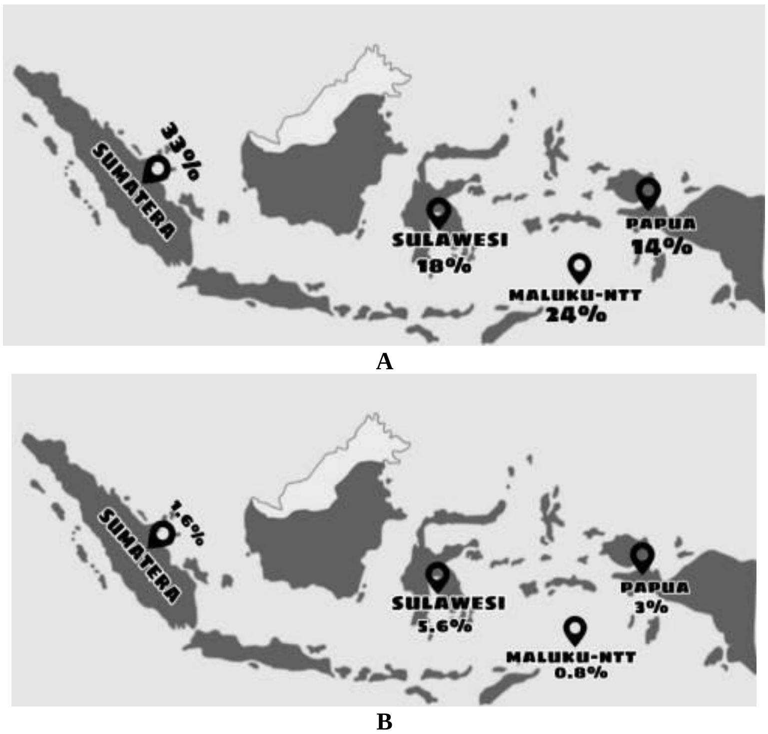

Figure 7. Description of the potential utilization of *Rochia nilotica* shells based on size standards: A. Percentage of samples that fit the standard size; B. Percentage of samples that don't fit the standard size

Referring to Table 2, most of the harvested and traded *R. nilotica* in Indonesia complied with established rules. An overview of the potential utilization of *R. nilotica* shells based on standard sizes is presented in Figure 7. In general, Sumatra was the area with the best utilization because the percentage of samples that fit the standard size was the highest (33%). Meanwhile, Sulawesi was the worst-utilized region because the percentage of samples that did not conform to standard sizes was the highest (5.6%). Based on a statistic report from the government statistic agency of Sulawesi, *R. nilotica* taken in 2018 was about 84.450 (Fisheries Statistic of South Sulawesi 2019). According to Haulussy et al. (2020), the sasi system traditionally regulates the pattern of harvesting natural resources, including *R. nilotica*, Maluku-East Nusa Tenggara (NTT), and Papua has a better utilization than other regions in Indonesia. However, the high percentage of samples that conform to standard sizes in Sumatra (33%) is due to the strict enforcement of applicable laws.

The decreasing utilization potential of *R. nilotica* indicates a need for attention and research from management authorities, such as the Ministry of Environment and Forestry through the Directorate of Biodiversity Conservation, as well as scientific authorities, such as the National Research and Innovation Agency through the Secretariat of Biodiversity Scientific Authority. The findings of the study conducted by BRIN will be considered when making recommendations to the Ministry of Environment and Forestry for setting catch quotas.

The size composition of the *R. nilotica* shells traded in Indonesia between 2014-2020 varies. However, most met the standard size imposed by the government. Only a small proportion (Sumatra 1.6%, Sulawesi 5.6%, Maluku-East Nusa Tenggara (NTT) 0.8%, and Papua 3%) of the traded shell had sizes that did not meet the required diameter, particularly those from Sulawesi. The morphometry of the shells traded in Sumatra and Sulawesi showed a decreasing trend, whereas in Maluku- East Nusa Tenggara (NTT) and Papua regions, they showed an increasing trend. More than half of the shells traded and recorded the damaged protoconch.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge financial support from the Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia for this work under the project scheme of the Publication Writing and IPR Incentive Program (PPHKI) 2023. We also want to thank the zoology laboratory at the Oceanographic Research Center, BRIN, Jakarta for conducting this research.

REFERENCES

Abukena SL, Wardiatno Y, Budiandi I, Khouw, AS. 2014. Study of *Trochus niloticus* Growth population as determination base of number and harvest time distance in Rhun Island Waters. IOSR JAVS 7 (2): 43-49.

Agostini VO, Ritter MdN, Macedo AJ, Erik Muxagata E, Erthal F. 2017. What determines sclerobiont colonization on marine mollusc shell?. PLoS ONE 12 (9): e0184745. DOI: 10.1371/journal.pone.0184745.

Alvarado-Rodríguez JF, Calderon-Aguilera LE, Cabral-Tena RA, Norzagaray-López CO, Nava H, Peiffer L, Fernández-Aldecoa, RG. 2022. High sclerobiont calcification in marginal reefs of the eastern tropical Pacific. J Exp Mar Biol Ecol 557. DOI: 10.1016/j.jembe.2022.151800.

Arafat G. 2022. Coral reef ecosystem condition in the bird’s head seascape, Sub Region, Sorong City and Sorong Regency. JRPK 4 (2): 466-475.

Aulia ED, Hadi TA, Edrus IN, Tuti Y, Abrar M, Budiyanto A, Sohouka J, Sudiar, Halimmudin LO, Sabarudin, Dzumalek AR, Iping, Halfiani WO, Sulha S, Suharsono. 2021. Coral reef benthic composition and its influence on reef fish communities in Buton Islands. IOP Conf Ser: Earth Environ Sci 860 (1). DOI: 10.1088/1755-1315/860/1/012005.

Baag S, Mandal S. 2022. Combined effects of ocean warming and acidification on marine fish and shellfish: A molecule to ecosystem perspective. Sci Total Environ 802: 14980.

Barros MRF, Chagas RA, Herrmann M, Bazerra AM. 2020. New record of the invasive snail *Melanoides tuberculata* (Gastropoda, Thiaridae) - Ceará State, Brazil’, Brazilian. Braz J Biol 80 (2): 368-372. DOI: 10.1590/1519-6984.210408.

Benítez S, Lagos NA, Griesshaber E, López J, Villanueva PA, Moscoso F, Navarro JM. 2022. Shell biomineralization and the role of nutritional quality on physiological traits of the marine turban snail *Tegula atra*. ResearchSquare 1-24.

Brahmi C, Chapron L, Le Moullac G, Soyez C, Beliaeff B, Lazareth CE, Gaertner-Mazouni, N, Vidal-Duipol J. 2021. Effect of elevated temperature and $p\mathrm{CO}_2$ on the respiration, biomineralization, and photophysiology of the giant clam *Tridacna maxima*. Conserv Physiol 9 (1): 1-7. DOI: 10.1093/conphys/coab041.

Bula W, Leiwakabessy F, Rumahlatu D. 2017. The influence of environmental factors on diversity of gastropods in Marsegu Island, Maluku. Biosaintifika 9 (3): 483-491. DOI: 10.15294/biosaintifika.v9i3.10637.

Capinpin Jr. EC. 2018. Growth, movement, and recovery of tagged topshell, *Trochus niloticus*, juveniles in Imondayon, Anda, Pangasinan, Northern Philippines. Intl J Fauna Biol 5 (1): 1-4.

Chirat R, Goriely A, Moulton DE. 2021. The physical basis of mollusk shell chiral coiling. PNAS 118 (48). DOI: 10.1073/pnas.2109210118.

De Carvalho LL, Villaça RC. 2021. Effect of fine-scale habitat differences on algal colonisation in a coral dominated subtropical reef. Acad Bras Cienc 93 (3). DOI: 10.1590/0001-3765202120191191.

Doyle D, Frias J, Gammell MP, Lynch M, Nash R. 2022. Assessing the morphological impacts of long-term harvesting in intertidal gastropods using historical data and morphometrics tools. J Molluscan Stud 88: 1-10. DOI: 10.1093/mollus/eyac019.

El-Hack MEA, El-Saadony MT, Nader MM, Salem HM, El-Tahan AM, Soliman SM, Khafaga AF. 2022. Effect of environmental factors on growth performance of nile tilapia (*Oreochromis niloticus*). Intl J Biometeorol 66: 2183-2194. DOI: 10.1007/s00484-022-02347-6.

Febriandi, Lanin D, Hermon D, Fatimah S, Triyatno, Putra A. 2019. A dynamics condition of coastal environment in Padang City-Indonesia. IOP Conf Ser: Earth Environ Sci 314. DOI: 10.1088/1755-1315/314/1/012006.

Figuerola B, Hancock AM, Bax N, Cummings VJ, Downey R, Griffith HJ, Smith J, Stark JS. 2021. A review and meta-analysis of potential impacts of ocean acidification on marine calcifiers from the Southern Ocean. Front Mar Sci 8: 1-22. DOI: 10.3389/fmars.2021.584445.

Firdaus M, Huda HM, Mira, Suryawati SH, Kurniawan T, Sari YD. 2021. Management of small-scale fisheries and their issues: Case study in Sibolga, North Sumatera, Indonesia. IOP Conf Ser: Earth Environ Sci 718 (1). DOI: 10.1088/1755-1315/718/1/012071.

Fisheries Statistic of South Sulawesi. 2019. Laporan Statistik Perikanan Sulawesi Selatan 2018. Sulawesi, Indonesia. https://dkp.sulselprov.go.id/uploads/info/Lap_Statistik_20181.pdf. [Indonesian]

Gemelli F, Johnson CR, Wright JT. 2020. Spatial patterns of abundance and shell morphologies of two gastropod species associated with different morphologies of an intertidal seaweed. Aquat Ecol 54: 653-670. DOI: 10.1007/s10452-020-09766-w.

Gillet R, McCoy M, Bertram I, Kinch J, Desurmont A. 2020. Trochus in the Pacific Islands: A review of the fisheries, management and trade. Pacific Community. Noumea, New Caledonia.

Guallart J, Pena JB, Luque AA, Templado J. 2017. Where have all the youngest gone? The post-larval and young stages of the Mediterranean endangered limpet *Patella ferruginea* Gmelin, 1791. Mediterr Mar Sci 18 (3): 385-392. DOI: 10.12681/mms.2076.

Gustiarini A, Tampubolon N, Saranga N, Mustiah D, Kurniawan. 2023. Kriteria eco resort pariwisata berkelanjutan kawasan perairan Waigeo Selatan Kepulauan Raja Ampat. J Sumberdaya Akuatik Indopasifik 7 (3): 273-282. DOI: 10.46252/jsai-fpik-unipa.2023.Vol.7.No.3.317. [Indonesian]

Hadi TA, Abrar M, Giyanto, Prayudha B, Johan O, Budiyanto A, Dzumalek AR, Alifatri LO, Sulha S, Suharsono. 2019. The Status of Indonesian Coral Reefs. Puslit Oseanografi, LIPI, Jakarta. [Indonesian]

Harahap A, Nugrahadi EW, Hutasuhut S. 2019. Factors affecting fishers' income in Sibolga City. ASSRJ 6 (7): 359-370. DOI: 10.14738/assrj.67.6770.

Harvey BP, Agostini S, Wada S, Inaba K, and Hall-Spencer JM. 2018. Dissolution: The Achilles' heel of the triton shell in an acidifying ocean. Front Mar Sci 5: 371. DOI: 10.3389/fmars.2018.00371.

Harvey BP, Allen R, Agostini S, Hoffmann LJ, Kon K, Summerfield TC, Wada S, Hall-Spencer, JM. 2021. Feedback mechanisms stabilise degraded turf algal system at a CO_2 seep site. Commun Biol 4: 219 DOI: 10.1038/s42003-021-01712-2.

Hatje V, Sarin M, Sander SG, Omanovic D, Ramachandran P, Völker C, Barra RO, Tagliabue, A. 2022. Emergent interactive effects of climate change and contaminants in coastal and ocean ecosystems. Front Mar Sci 9: 936109. DOI: 10.3389/fmars.2022.936109.

Haulussy RR, Najamuddin, Idris R, Agustang ADMP. 2020. The sustainability of the sasi lola tradition and customary law (Case study in Masawoy Maluku, Indonesia). IJSTR 9 (2): 5193-5195.

Haya LOMY, Masahiko F. 2020. Assesment of coral reef ecosystem status in the Pangkajene and Kepulauan Regency, Spermonde Archipelago, Indonesia, using the rapid appraisal for fisheries and the analityc hierarchy process. Mar Pol 118. DOI: 10.1016/j.marpol.2020.104028.

Hermawan R, Damar A, Hariyadi S. 2017. Daily accumulation and impacts of marine litter on the shores of Selayar Island Coast, South Sulawesi. Waste Technol 5 (1): 15-20. DOI: 10.14710/5.1.15-20.

Idris, Fakhrurrozi, Adiwijaya C. 2021. Assessment of coral reef health condition in Juru Seberang Village, Tanjung Pandan District, Belitung Regency - Bangka - Belitung Province. IOP Conf Ser: Earth Environ Sci 744. DOI: 10.1088/1755-1315/744/1/012030.

Irham M, Rusydi I, Haridhi HA, Setiawan I,Ilhamsyah Y, Deli A, Rusdi M, Siregar AM. 2021. Coastal vulnerability of the west coast of Aceh Besar: A coastal morphology assessment. J Mar Sci Eng 9 (8): 815. DOI: 10.3390/jmse9080815.

Jasmine. 2017. *Tectus niloticus* (Linnaeus, 1767). http://eprints.cmfri.org.in/15000/1/Tectus%20niloticus.pdf

Johnson EH. 2021. Breaking down shell strength: inferences from experimental compression from experimental compression and future directions enabled by 3D printing. Biol Rev 96 (4): 1077-1091. DOI: 10.1111/brv.12692.

Kadim MK, Pasisingi N. 2018. Status mutu perairan Teluk Gorontalo dengan menggunakan metode Pollution Index. JFMR 2 (1): 1-8. DOI: 10.21776/ub.jfmr.2018.002.01.1.

Kaur P, Stoltzfus J, Yellapu V. 2018. Descriptive statistic. Intl J Acad Med 4 (1): 60-63. DOI: 10.4103/IJAM.IJAM_7_18.

Kennedy PSJ, Tobing SJL, Heatubun AB, Lumbantoruan R. 2018. Potensi Pariwisata Maluku Barat Daya Sebuah Kajian Pustaka. National Conference of Creative Industry: Sustainable Tourism Industry for Economic Development. pp.460-475.DOI: http://dx.doi.org/10.30813/ncci.v0i0.1229

Madduppa HH, Koropitan AF, Damar A. Subhan B, Taufik M, Minsaris LOA, Taurusman AMA, Ramli A, Purwanto AB. 2020. Ecological vurberability of coral reef ecosystem in Wakatobi National Park during Indian Ocean dipole event. HAYATI J Biosci 27 (1): 57-70. DOI: 10.4308/hjb.27.1.57.

Mantale A, Patil M, Shaikh M, Lakwal V. 2018. Length-weight relationship of fresh water pulmonate snail *Indoplanorbis exustus*. JETIR 5 (12): 168-173.

Markaide P, Gairín I, Cordero D, Ibarrola I, Saavedra C. 2021. No hybridization and marked interspecific differences in individual growth rate in mixed cultures of Manila clam (*Ruditapes philippinarum*) and grooved carpet-shell clam (*R. decussatus*). Aquaculture 541. DOI: 10.1016/j.aquaculture.2021.736824.

Matos AS, Matthews-Cascon H, Chaparro OR. 2020. Morphometric analysis of the shell of the intertidal gastropod Echinolittorina lineolata (d'Orbigny, 1840) at different latitudes along the Brazilian coast. JMBA 1-7. DOI: 10.1017/S0025315420000624.

Mondal H, Swain SM, Mondal S. 2022. How to conduct descriptive statistics online: A brief hands-on guide for biomedical researchers. Indian J Vasc Surg 9 (1): 70-75. DOI: 10.4103/ijves.ijves_103_21.

Mustaqim. 2018. Analisis perubahan ekosistem kawasan pesisir Pulau Sabang. Jurnal Analisa Sosiologi 7 (2): 224-241. [Indonesian]

Oliveira IB, Freitas DB, Fonseca JG, Laranjeiro F, Rocha RJM, Hinzmann M, Machado J, Barroso CM, Galante-Oliveira S. 2020. Vulnerability of *Tritia reticulata* (L.) early life stages to ocean acidification and warming. Sci Rep 10: 5325. DOI: 10.1038/s41598-020-62169-7.

Paddiyatu N. 2019. Analisis tingkat kerusakan wilayar pesisir di Kab. Mamuju Tengah. Jurnal Linears 1 (2): 91-102. DOI: 10.26618/j-linears.v1i2.1814. [Indonesian]

Pattiasina S, Marasabessy F. 2020. Assessment of coral reef condition and management strategy in the Biak Timur Watershed, Biak Numfor Regency. AGRIKAN 13 (2): 517-525. [Indonesian]

Paulangan YP. 2015. Kondisi terumbu karang di daerah perlindungan Pulau Nusi dan Pulau Wundi Kepulauan Padaido, Kabupaten Biak Numfor. J Fish Dev 2 (3): 71-81. [Indonesian]

Paulus CA, Azmanajaya E. 2019. Socio-economic assessment of coastal communities in East Flores marine reserves of East Nusa Tenggara Province, Indonesia. RJOAS 97 (1): 46-55. DOI: 10.18551/rjoas.2020-01.06.

Paulus CA, Soewarlan LC, Ayubi AA. 2020. Distribution of marine debris in mangrove ecotourism area in Kupang, East Nusa Tenggara, Indonesia. AACL Bioflux 13 (5): 2897-2909.

Pelasula DD, Patria MP, Wouthuyzen S, Syahailatua A. 2023. Key success factors and problems in coral transplantation: A review. Aquacult Aquarium Conser Legislation 16 (1): 1-24.

Pereira L. 2021. Macroalgae. Encyclopedia 1 (1): 177-188. DOI: 10.3390/encyclopedia1010017.

Psomadakis PN, Thein H, Russell BC, Tun MT. 2019. Field identification guide to the living marine resources of Myanmar. FAO Species Identification Guide for Fishery Purposes. Rome. FAO and MOALI. http://www.fao.org/3/ca7180en/CA7180EN.pdf

Purcell S, Tiitii S, Aiafi J, Tone A, Tony A, Lesa M, Esau C, Cullis B, Gogel B, Seinor K, Ceccarelli D, Tagliafico A. 2019. Ecological and socioeconomic impacts of trochus introductions to Samoa - A project of the Australian Centre for International Agricultural Research. Noumea, New Caledonia: Pacific Community. SPC Fish Newsl 160: 36-40.

Purcell SW, Ceccarelli DM. 2020. Population colonization of introduced trochus (Gastropoda) on Coral Reef in Samoa. Ecol. Restor. 29(1): 1-12. DOI: 10.1111/rec.13312.

Purcell SW, Tagliafico A, Cullis BR, Gogel BJ. 2020. Understanding gender and factors affecting fishing in an Artisanal shellfish fisheries. Front Mar Sci 7 (297): 1-10. DOI: 10.3389/fmars.2020.00297.

Purcell SW, Tagliafico A, Cullis BR, Gogel BJ. 2021. Socioeconomic impacts of resource diversification from small-scale fishery development. Ecol Soc 26 (1): 14. DOI: 10.5751/ES-12183-260114.

Purwanto AD, Prayogo T, Marpaung S, Suhada AG. 2020. Analysis of potential fishing zones in coastal waters: A case study of Nias Island waters. Intl J Remote Sens Earth Sci 17 (1): 9-24.

Queensland Government. 2022. Business Queensland: Commercial harvest fisheries. https://www.business.qld.gov.au/industries/farms-fishing-forestry/fisheries/fisheries-profiles/commercial-harvest-fisheries/trochus

Rahim S, Widayati W, Analuddin K, Saleh F, Alfirman, Sahar S. 2020. Spatial distribution of marine debris pollution in mangrove estuaries ecosystem of Kendari Bay. IOP Conf Ser: Earth Environ Sci 412. DOI: 10.1088/1755-1315/412/1/012006.

Říhová D, Janovsky Z, Horsák M, Juričková L. 2018. Shell decomposition rates in relation to shell size and habitat condition in contrasting type of Central European forest. J Molluscan Stud 84 (10): 54-61. DOI: 10.1093/mollus/eyx048.

Sahetapy D, Limon GV, Tetelepta JMS, Pattikawa JA, Rijoly F, Masrikat JAN, Loupatty SR. 2021. Coral Reef Condition in the Coastal Waters of Kei Besar Island, Southeast Maluku-Indonesia. IOP Conf. Series: Earth & Env. Sci. 805. DOI: 10.1088/1755-1315/805/1/012002

Sala R, Marsaoly D, Dasmasela HY, Parenden D, Orisu D, Tarigan RB. 2020. Ecological status of target fishes inside and outside marine conservation area of Batbitim, Misol, Raja Ampat. IOP Conf Ser: Earth Environ Sci 429. DOI: 10.1088/1755-1315/429/1/012054.

Seinor KM, Smith SDA, Logan M, Purcell SW. 2020. biophysical habitat features explain colonization and size distribution of introduced trochus (Gastopoda). Front Mar Sci 7 (223): 1-12. DOI: 10.3389/fmars.2020.00223.

Shuai F, Yu S, Lek S, Li X. 2018. Habitat effects on intra-species variation in functional morphology: Evidence from freshwater fish. Ecol Evol 8 (22): 10902-10913. DOI: 10.1002/ece3.4555.

Siringoringo RM, Hadi TA. 2014. The condition of coral reefs in West Bangka Water. Mar Res Indones 39 (2): 63-71. DOI: 10.14203/mri.v39i2.86.

Slapcinsky J, Kraus F. 2016. Revision of Partulidae (Gastropoda, Stylommatophora of Palau, with description of a new genus for an unusual ground-dwelling species. ZooKeys 614: 27-49. DOI: 10.3897/zookeys.614.8807.

Suhaidi, Rosmalinda, Arif. 2021. Coastal tourism: Marine pollution and lack of local government efforts. Nat Volatiles Essent Oils 8 (4): 81-94.

Sweirts T, Vermeij MJA. 2016. Competitive interaction between corals and turf algae depend on coral colony form. PeerJ 4: e1984; DOI: 10.7717/peerj.1984.

Taufiqurrahman E, Prayitno HB, Ibrahim PS, Ratnawati HI, Maslukah L. 2023. Marine protected area management under the impacts of climate change and increased human activities in marine ecosystems: A review for Anambas Island MPA. IOP Conf Ser: Earth Environ Sci 1163. DOI: 10.1088/1755-1315/1163/1/012022.

Thahira A, Daulay Z, Ferdi, Syofyan S. 2023. The Strategy for the resolution of marine pollution on the northern coast of Bintan Island Indonesia due to sludge oil with the principle of cooperation to relize the sustainable development goals. IOP Conf Ser: Earth Environ Sci 1148. DOI: 10.1088/1755-1315/1148/1/012031.

The Ministry of Environment. 2019. The Sixth National Report to the Convention on Biological Diversity. Jakarta, Indonesia. https://balaikliringkehati.menlhk.go.id/wp-content/uploads/6.-Sixth-sasil-Report.pdf. [Indonesian]

Tiitii S, Aiafi, J, Tone A, Tony A, Lesa M, Esau C, Cullis B, Gogel B, Seinor K, Tagliafico A, Ceccarelli D. 2021. Reef colonization and Socioeconomic impacts from Trochus translocation to Samoa. ACIAR.

Tiitii U, Aiafi J. 2016. Assessment of Samoa’s trochus (*Tectus niloticus*) fishery: History, status and recommendations for management. Noumea, New Caledonia: Pacific Community.

Turner AH, Kaas Q, Craik DJ, Schroeder CI. 2020. Early development of *Monoplex pilearis* and *Monoplex parthenopeus* (Gastropoda: Cymatiidae): biology and morphology. Org Divers Evol 20: 51-62. DOI: 10.1007/s13127-020-00432-5.

Ulm S, McNiven, Ian J, Samantha J, Lambrides, Ariana BJ. 2019. Sustainable harvesting of *Conomurex luhuanus* and *Rochia nilotica* by Indigenous Australians on the Great Barrier Reef over the past 2000 years. J Archeol Sci Rep 28: 1-40. DOI: 10.1016/j.jasrep.2019.102017.

Walalangi JY, Lelono TD, Hertika AMS, Susilo E. 2022. The characteristic of marine debris and water quality in Palu Bay, Central Sulawesi, Indonesia. AACL Bioflux 15 (1): 261-271.

Widodo MPS, Fakhrurrozi, Fahmi RN, Adiwijaya C, Damayanti AA. 2023. Health condition of hard corals on Rote Island in The Sawu National Par Conservation Area. Jurnal Biologi Tropis 23 (2): 38-46. DOI: 10.29303/jbt.v23i2.4578. [Indonesian]

Wisha UJ, Khoirunnisa H. 2017. Sea surface temperature rising trend and its influence on the coral mortality in Pagai Strait, Mentawai Island, Indonesia. IJCIET 8 (10): 725-734.

Yu T, Pall-Gergely B, Salvador RB. 2022. Caenogastropoda and Stylommatophora (Gastropoda) from the mid-Miocene Zhangpu amber of East Asia. Paleoworld. DOI: 10.1016/j.palwor.2022.07.004

Yunus M, Samsi AN. 2021. Morphometric variations of *Nertita lineata* Gmelin 1791 in different mangrove age groups in the ecosystem. J Phys Conf Ser 1752: 1-7. DOI: 10.1088/1742-6596/1752/1/012052.

Zamdial, Kusuma AB, Bakhtiar D. 2016. Percent cover condition of coral reef at west coastal of Enggano Island. International Seminar Sustainable Utilization of Coastal Resources in Tropical Zone.