BIODIVERSITAS
Volume 26, Number 6, June 2025
Pages: 2565-2575

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d260602

Exploitation history, status, and sustainability challenges of sea cucumber fisheries in the Sapuka Islands, Indonesia (Wallacea)

RATNAWATI GATTA[1,♥], ANDI NUR APUNG MASSISENG[2,3], AWALUDDIN[3], SUTRA NOBU[4], JAYA[2], SRI ENDAH PURNAMANINGTYAS[5]

[1]Department of Fisheries, Faculty of Agriculture, Universitas Bosowa. Jl. Urip Sumoharjo Km. 4, Makassar 90231, South Sulawesi, Indonesia. Tel./fax.: +62-411-452901, ♥email: ratnawati@universitasbosowa.ac.id
[2]Department of Fishery Agrobusiness, Faculty of Fisheries, Universitas Cokroaminoto Makassar. Jl Perintis Kemerdekaan Km. 11, Makassar 90245, South Sulawesi, Indonesia
[3]Yayasan Romang Celebes Indonesia. Jl. Nusa Tamalanrea Indah Blok FI No.11, Tamalanrea, Makassar 90245, South Sulawesi, Indonesia
[4]Post Graduate School, Universitas Hasanuddin. Jl. Perintis Kemerdekaan Km. 10, Makassar 90245, South Sulawesi, Indonesia
[5]Research Center for Conservation of Marine and Island Water Resources, National Research and Innovation Agency. Jl. Raya Jakarta-Bogor No.32, Pakansari, Cibinong, Bogor 16915, West Java, Indonesia

Manuscript received: 10 February 2025. Revision accepted: 11 May 2025.

Abstract. *Gatta R, Massiseng ANA, Awaluddin, Nobu S, Jaya, Purnamaningtyas SE. 2025. Exploitation history, status, and sustainability challenges of sea cucumber fisheries in the Sapuka Islands, Indonesia (Wallacea). Biodiversitas 26: 2565-2575.* The Sapuka Archipelago, Indonesia, located within the Wallacea Region, is known for its rich marine biodiversity, particularly its diverse sea cucumber populations. These echinoderms are highly valued in international markets due to their significant economic and export potential. However, increasing global demand has raised concerns regarding overexploitation and long-term sustainability. This study examines the historical development and current condition of sea cucumber fisheries in the region. Evidence suggests that intensive and continuous harvesting has led to notable declines in the populations of commercially valuable species. Data were obtained from fisher logbooks, focus group discussions with local communities, and trade network records. Historically, fishing practices evolved from shallow-water collection using *ladung* in the 1960s-1970s to deeper-water harvesting employing scuba gear from the 1980s onward. Of the 19 species currently recorded, 11 are considered high value, with six listed under CITES Appendix II. Most captured individuals fall within the 18-30 cm length range and weigh between 300-600 grams, indicating selective targeting of reproductively mature specimens. Both fishers' observations and historical data confirm a decline in species richness, from 30 to 19 species, and in annual production, from over 1,000 tons to under 100 tons within two decades. The need for sustainable management is urgent and should be a top priority for all of us to prevent further depletion. Export values are influenced by species, quality (moisture and condition), size, production volume, and the Rupiah-US Dollar exchange rate. Primary export markets include Singapore, Hong Kong, South Korea, and Malaysia.

Keywords: CITES, export, overexploitation, sea cucumber, Wallacea Region

INTRODUCTION

The Sapuka Islands are an outer archipelago in Pangkep District, located in a remote area geographically bordering the West Nusa Tenggara (NTB) Province, Indonesia. The Sapuka Islands are part of the biogeographic region within the Wallacea Zone, characterized by high biodiversity and distinct faunal traits compared to surrounding areas, including sea cucumbers (Holothuroidea), commonly known as *teripang* (Wattimena 2016). The Sapuka Islands have historically contributed to Indonesia's sea cucumber export volumes through small-scale fisheries, where sea cucumbers are gradually collected and traditionally preserved by drying or smoking before being sold to local traders (Tuwo and Tresnati 2015; Yusuf et al. 2017; Massiseng et al. 2023).

Sea cucumbers have a very important ecological role in marine ecosystems. As deposit feeders, sea cucumbers help maintain ecosystem balance by decomposing organic matter on the seabed and recycling nutrients. This process improves sediment quality and supports the growth of other organisms, including seagrasses and coral reefs (Purcell et al. 2023). In addition, the bioturbation activity carried out by sea cucumbers contributes to increasing the availability of oxygen on the seabed, which is important for the life of microorganisms and other benthic species (Lee et al. 2018). The loss of sea cucumber populations in a given region can lead to ecosystem imbalances, as evidenced by increased levels of undecomposed organic matter, habitat degradation, and a decline in biodiversity in the affected waters. Conversely, sea cucumbers are a nutritionally rich source of protein and contain bioactive compounds of high value for pharmaceutical and other industrial applications (Pangestuti et al. 2016; Pangestuti and Arifin 2018).

Sea cucumbers are considered a valuable fishery resource due to their high market price and status as an export commodity that is widely exploited in tropical waters, including Indonesia (Rahman et al. 2020). The increasing global demand, particularly from Asian countries such as China, Singapore, and South Korea, has driven more intensive exploitation, often without regard for resource sustainability (Purcell et al. 2018; Alam et al. 2022). Initially, harvesting methods were limited to collection during low tide in shallow waters within seagrass

and coral reef habitats. However, since the 1980s, this has expanded to include deep-sea areas through diving assisted by breathing apparatus, thereby increasing pressure on populations (Eriksson and Clarke 2015; Van-Khanh et al. 2020). This shift has contributed to overexploitation and environmentally harmful fishing practices, threatening the sustainability of sea cucumber resources, and causing habitat degradation (Rahman and Yusoff 2017; Conand 2018). Furthermore, several species are now facing extinction threats, leading to the inclusion of six species in international protection lists, such as CITES Appendix II (Friedman et al. 2011). Although some countries have implemented regulatory measures, weaknesses in law enforcement and inadequate trade monitoring have allowed exploitation to persist without sufficient control (Hughes et al. 2023).

The population status of sea cucumbers in the Sapuka Islands remains uncertain due to limited catch data from fishers and the scarcity of research in the area, largely attributed to accessibility challenges. Previous studies have generally indicated that sea cucumber populations in South Sulawesi Province, Indonesia, have significantly declined due to exploitation pressures, particularly on high-value species that are becoming increasingly rare in the natural habitats (Made and Tahang 2020). Despite their importance, sea cucumbers have not received sufficient attention in fisheries management policies in Indonesia (Husain et al. 2017). Ironically, no data on the status of sea cucumber fisheries in the Sapuka Islands, one of South Sulawesi's primary sea cucumber-producing regions, are currently available. Such data are critically needed as a foundation for sustainable fisheries management. To balance exploitation and conservation, comprehensive information on population status, exploitation trends, and ecological and economic impacts is required as a foundation for developing more sustainable fisheries policies. These policies should include ecosystem-based management strategies and the development of aquaculture as an alternative to reduce pressure on wild populations. This study aims to analyze the history and current status of sea cucumber fisheries in the Sapuka Islands, as well as the impact of exploitation on their populations.

MATERIALS AND METHODS

Study area

This study was conducted in the Sapuka Islands, which serve as both a village and the administrative center of Liukang Tangaya Sub-district, Pangkep District, South Sulawesi Province, Indonesia. The Sapuka Islands are part of the Wallacea biogeographic region. Geographically, the islands are located between 117°59'13.5" and 118°18'44.3" East Longitude and 7°02'23.0" and 7°18'30.8" South Latitude.

The village comprises 11 small islands, but only three are inhabited: Sapuka Lompo, Tinggalungang, and Kembang Lemari. The remaining eight islands (Sapuka Caddi, Cakalangan, Sambar Gitang, Sambar Jaga, Sarassang Lompo, Lamuruang, Sapiriah, and Sarassang Caddi) are uninhabited (Figure 1). The research was conducted from November 2021 to January 2023 and focused on the three inhabited islands.

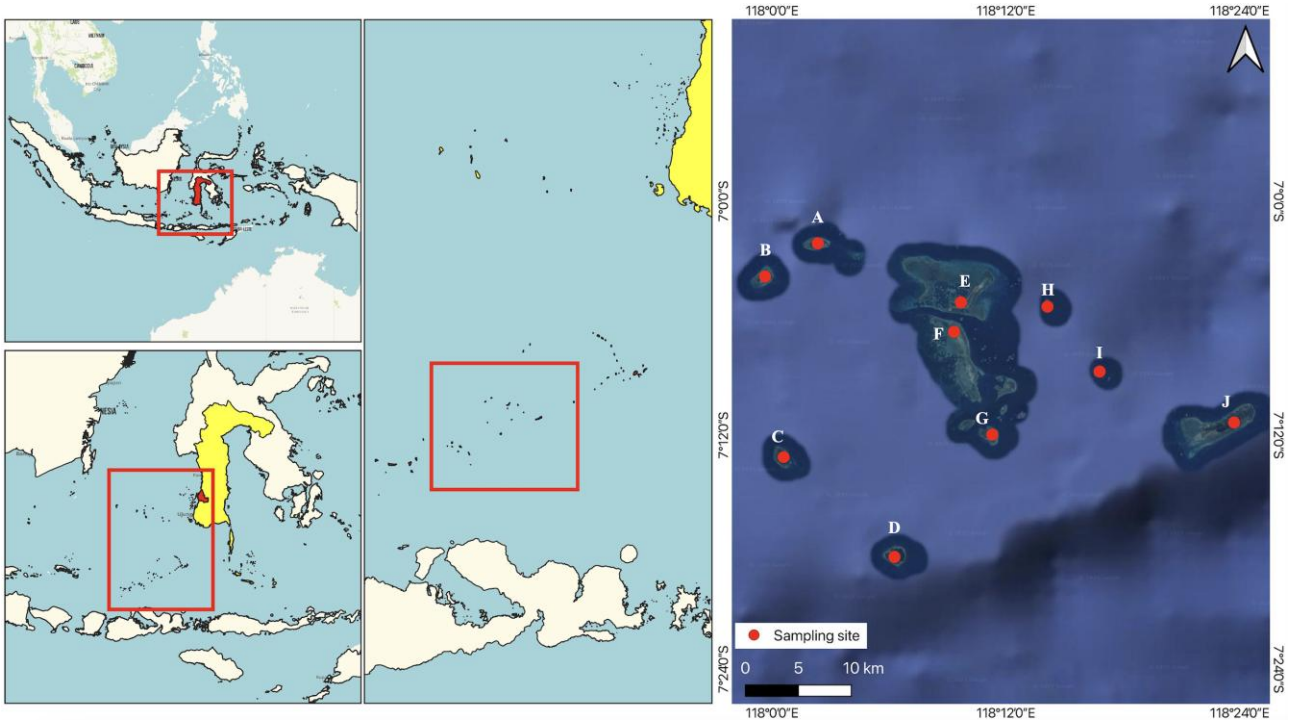

Figure 1. The Sapuka Islands, Indonesia, are part of the Wallacea biogeographic region. Geographically, the islands are located between 117°59'13.5" and 118°18'44.3" East Longitude and 7°02'23.0" and 7°18'30.8" South Latitude. A. Tinggalungang, B. Kembang Lemari, C. Cakalangan, D. Lamuruang, E. Sapuka Lompo, F. Sapuka Caddi, G. Sarassang, H. Sambarjaga, I. Sambargitang, J. Pelokang

Data collection

Primary data were collected using sea cucumber fisher logbooks from March to October 2022 involving 18 individuals, snowball sampling techniques to identify and trace the network of sea cucumber traders and Focus Group Discussions (FGDs) involving community leaders, local groups, village officials, fishers, and traders to gather information on sea cucumber harvesting activities. FGDs were conducted on three inhabited islands with a total of 20 participants, comprising 10 sea cucumber fishers, 2 village officials, 3 community leaders, 2 community group members (POKMAS), and 3 traders. Additionally, structured interviews and field observations were carried out, primarily during the landing of fishing vessels or through home visits shortly after fishers returned from the sea. Data collected included the species of sea cucumbers harvested, types of fishing gear employed, timing of capture, catch volumes, landing locations, and sales destinations. For accurate species identification, respondents were asked to provide local names of the sea cucumbers, using a standardized species identification guide as a reference (Setyastuti et al. 2019; Arbi et al. 2022).

Secondary data were obtained from various institutions, including the South Sulawesi Provincial Fisheries and Marine Office, the Coastal and Marine Resources Management Center (BPSPL) Makassar, the Agency for Control and Supervision of Marine and Fisheries Quality (BPPMHKP) Makassar, as well as from scientific publications.

Data analysis

The collected data were analyzed based on sea cucumber resources, the users (fishers and traders), and their utilization patterns. The data were tabulated, visualized in diagrams, and described descriptively.

RESULTS AND DISCUSSION

History of sea cucumber fisheries

Sea cucumber fisheries in Southeast Asia began in the late 17th century, with Makassar (South Sulawesi Province) serving as the largest trading hub for sea cucumbers at the time (Urwin et al. 2023; Pérez-Lloréns and Mouritsen 2024). This trade included international exchanges, particularly with China (Stacey 1999; Purcell et al. 2023). Indonesian fishers ventured as far as Australian waters, making Indonesia one of the oldest sea cucumber exporters. The term "trepang" used in international markets is derived from the Indonesian word *teripang* (Morgan and Archer 1999; Pérez-Lloréns and Mouritsen 2024). While Japan and China, the primary consumers, use their respective terms (*iriko* and *hai-som*), "trepang" and "beche-de-mer" (French origin) remain the most recognized terms globally (Hamel et al. 2024).

Not all sea cucumber species are classified as *teripang*. The term specifically refers to commercially traded species (Purcell et al. 2023). Historical records show that the Dutch defeat of Makassar at Buton in 1667 restricted trade, prompting many Makassar fishers to flee to Australia's Gulf of Carpentaria, returning with sea cucumbers (Urwin et al. 2023). By 1720, the Spermonde Archipelago, including the Sapuka Islands, had incorporated sea cucumbers into their trade commodities (Setyastuti et al. 2019). Remarkably, Makassar sailors are credited with discovering Pasir Island (later named Ashmore Reefs) around 1728, long before Samuel Ashmore's voyage in 1811.

Sea cucumber harvesting by Bugis-Makassar fishers in Northern Australia persisted until 1910 (Stacey 1999). Since the late 1990s, increased exploitation has followed advances in natural product research and the use of sea cucumbers as aquarium ornaments (Moore 2022). Consequently, Bugis-Makassar fishers, including those from the Sapuka Islands, focused their operations within South Sulawesi waters and nearby areas (Lampe et al. 2020; Made and Tahang 2020).

Historically, sea cucumber fisheries in the Sapuka Islands began with the arrival of fishers from Barrang Lompo Island (Makassar City) in 1962. Initially, harvesting was simple, involving collection along the shoreline during low tide. Barrang Lompo fishers also purchased catches from local fishers, encouraging widespread participation across genders and age groups. This pattern of gleaning during low tide was common across Southeast Asian coastal areas, with men diving in deeper waters and women collecting in shallow areas (Choo 2024).

By 1972, harvesting extended to deeper waters where sea cucumbers were harder to collect by hand, necessitating tools such as the "*ladung*," a gripping device operated underwater (Lampe et al. 2019). In the early 1980s, fishers from Sinjai introduced diving masks in Sapuka for deeper harvests (up to 30 meters), targeting high-value species like *teripang koro*. This period also marked the arrival of sea cucumber traders in the Sapuka Islands.

Between 1995 and the early 2000s, traders from Makassar and Galesong (Takalar District) frequented Sapuka to buy sea cucumbers, driven by high market demand and economic value (Rahman et al. 2020; Aydın et al. 2023). Madurese fishers introduced fishermen to compressor-based breathing apparatus, enabling dives up to 30 meters. However, this intensive harvesting method, conducted day and night, led to the initial decline in sea cucumber stocks (Alam et al. 2022).

Since 2000, sea cucumber catches in the Sapuka Islands have continued to decline due to overharvesting by local and external fishers (Hair et al. 2020). The sea cucumber fishers assume that since that time, water clarity in the Sapuka Archipelago has also declined, resulting in reduced seabed visibility from 20 meters to 15 meters, which has negatively affected sea cucumber catch volumes.

Technique and duration of sea cucumber harvesting

Sea cucumber harvesting in the Sapuka Archipelago is conducted during two main periods: daytime and nighttime. However, it is predominantly carried out at night, as sea cucumbers are more active in foraging and move more freely along the seabed, making them easier to collect (Minguito 2023). Nighttime conditions also offer calmer waters with minimal currents, reduced interference from

human and animal activity, and limited sun exposure, thereby facilitating more efficient harvesting (Dalpathadu 2021). Night harvesting is typically performed using compressors for 1-2 hours, whereas daytime collection is conducted through gleaning during low tide for up to 4 hours in shallow coastal areas (Choo 2008). However, compressors are also employed during daytime operations when targeting deeper waters, particularly along coral reef slopes or *goba* (deep depressions). The use of compressors enables access to greater depths and wider areas, thereby increasing the likelihood of capturing a larger quantity of sea cucumbers compared to conventional methods.

Interviews with fishermen and community leaders in the Sapuka Islands reveal that since the early 2000s, there has been a significant decline in sea cucumber catches in the area. This decline is attributed to high fishing pressures resulting from intensive fishing activities by local fishermen in the Sapuka Islands (Rahman et al. 2020; Alam et al. 2022). The use of compressors in sea cucumber harvesting has further contributed to the increased pressure on sea cucumber populations and affected the quality of the marine environment, with limited seabed visibility even at depths of 15 meters. A similar phenomenon has been observed among traditional fishermen in various regions, such as the Great Barrier Reef Marine Park, Australia (Eriksson and Byrne 2015), Campeche Bank, Mexico (Gamboa-Álvarez et al. 2020), and the Galapagos Islands, Ecuador (Ramírez-González et al. 2020), where overharvesting threatens the sustainability of sea cucumber ecosystems.

Plagányi et al. (2020) state that sea cucumber catches are greatly influenced by the duration of fishing operations and the condition of the sea cucumber population at the site. Although diving techniques and advanced equipment are employed, catches often do not correlate with the operational costs incurred. However, under certain conditions, factors such as luck may allow fishermen to obtain large catches, reaching hundreds of individuals with varying weights.

Species, number, size, weight, and status of sea cucumbers

Interviews and FGD with sea cucumber fishermen in the Sapuka Islands revealed that there are currently 19 species of sea cucumbers commonly harvested by the local community for sale. These species generally belong to the Family Holothuriidae, similar to studies conducted in Malaysian waters and other tropical countries, which found the highest number of sea cucumber species in the Family Holothuriidae (Kamarudin et al. 2015; Purcell et al. 2023). However, only 11 species are of high economic value, and six of them are classified as endangered or vulnerable, with declining populations, thus requiring protection (Table 1).

Of the 19 sea cucumber species found in the Sapuka Islands, six species are predominantly harvested by fishermen (>100 individuals/year) around the Sapuka Islands waters, namely: *Cera* (local name for *Holothuria edulis*), black sea cucumber (*Holothuria atra*), *dugong* (local name for *Thelenota anax*), black cotton sea cucumber (*Actinopyga miliaris*), smooth synaptid sea cucumber (*Bohadschia vitiensis*), and spotted synaptid sea cucumber (*Bohadschia argus*). This aligns with data from Sjafrie et al. (2024) that several species are commonly found in the Sulawesi Sea, including the waters of the Spermonde Archipelago, such as: Genus *Actinopyga* (*A. miliaris* and *A. echinites*), Genus *Holothuria* (*H. scabra*, *H. nobilis*, *H. atra*, *H. edulis*, *H. leucospilota*, *H. marmorata*, and *H. verrucossa*), Genus *Bohadschia* (*B. Argus* and *B. vitiensis*), Genus *Stichopus* (*S. Cloronotus* and *S. noctivagus*), and Genus *Thelenota* (*T. anax* and *T. ananas*).

Table 1. List of sea cucumber species collected by fishers in Sapuka Islands in 2022 with references to Setyastuti et al. (2019) and Arbi et al. (2022)

Spesies	Common name	Local name	Number of individuals	Market value	Status
*Holothuria fuscogilva**	*Teripang Susu*	*Koro*	92	Moderate price	Vulnerable/Appendix II
*Holothuria nobilis***	*Teripang Tokek*	*Koro Pakke*	4	High price	Endangered/Appendix II
Holothuria edulis	*Teripang Cera*	*Cera Merah*	177	Low price	Endangered/Appendix II
Holothuria atra	*Teripang Hitam*	*Kassi*	165	Low price	Endangered/Appendix II
Holothuria leicospilota	*Talengko*	*Talengko*	49	Low price	Open access
*Holothuria scabra***	*Teripang Pasir*	*Bibba/Bangkuli*	26	High price	Endangered/Appendix II
Holothuria ocelata	*Teripang Kacang*	*Kacang Kacang*	1	Low price	Open access
Thelenota anax	*Teripang Duyung*	*Donga*	130	Low price	Open access/Appendix II
*Thelenota ananas***	*Teripang Nanas*	*Pundong*	1	High price	Endangered/Appendix II
*Thelenota rubralineata***	*Teripang Pandang*	*Pandang*	8	High price	Open access/Appendix II
*Actinopyga echinites**	*Teripang Kunyit*	*Kunyi*	1	Moderate price	Open access
*Actinopyga miliaris**	*Teripang Kapok Hitam*	*Ballang Ulu*	223	Moderate price	Open access
Bohadschia marmorata	*Teripang Kawasa*	*Kawwas*	1	Low price	Open access
*Bohadschia vitiensis**	*Teripang Getah Polos*	*Polos*	339	Moderate price	Open access
Bohadschia argus	*Teripang Getah Bintik*	*Bintik*	168	Low price	Least Concern
*Stichopus pseudohorrens***	*Teripang Gondrong*	*Gondrong*	1	High price	Data Deficient
*Stichopus noctivagus***	*Gamat*	*Gama/Pisang-pisang*	87	High price	Appendix II
*Stichopus chloronotus**	*Teripang Jepun*	*Jappung*	90	Moderate price	Open access
Phyllophorus sp.	*Bola Bola*	*Golo-Golo*	60	Low price	Data Deficient

Note: *: Moderate price, **: High price

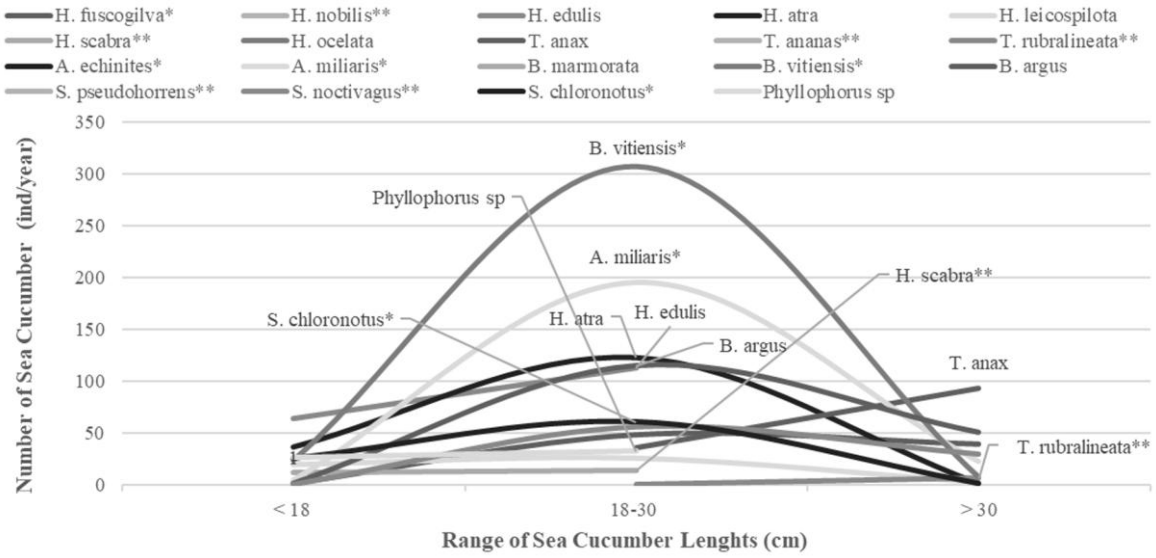

Figure 2. Number and range lengths of sea cucumber in Sapuka Islands, Indonesia (source: fisher logbooks in Sapuka Island). Note: <18 (below reproductive size), 18-30 (reproductive size), >30 (above reproductive size)

Based on Table 1 and Figure 2, it can be seen that of the six dominant sea cucumber species, only two have a moderate market value, namely the smooth synaptid sea cucumber (*B. vitiensis*) with 339 individuals/year and the black cotton sea cucumber (*A. miliaris*) with 223 individuals/year. The other four species have a low market value. The most frequently caught high-value species are the nocturnal sea cucumber (*S. noctivagus*), with 87 individuals/year, and *Bangkuli* (local name for *H. scabra*), with 26 individuals/year. Other high-value species were found in fewer than 10 individuals/year. This suggests that high-value species are becoming rarer in the wild due to long-term exploitation for export. For example, during data collection, only one individual of the shaggy sea cucumber (*S. pseudohorrens*) was found among 1,623 sea cucumber individuals. On the other hand, according to Yusuf et al. (2017), the most caught and processed sea cucumber aboard ships by fishermen is the shaggy sea cucumber.

Additionally, the most frequently caught sea cucumbers are in the size range of 18-30 cm, which is considered a reproductive size for spawning, making it likely that many of these sea cucumbers had not yet spawned when captured. Some species were even found in smaller sizes (<18 cm). This is illustrated in Figure 2, where the horizontal line graph on the left shows that the number of small-sized sea cucumbers caught is nearly equal to the number of reproductive-sized sea cucumbers. Three species fall into this category: *H. edulis*, *H. scabra*, and *Phyllophorus* sp. This condition poses a threat to the sustainability of these three species because capturing small (pre-spawning) sea cucumbers eliminates their chance to reproduce, leading to growth overfishing (González-Wangüemert et al. 2018). This is supported by the findings of Whitten et al. (2002), which reported that around the year 2000, approximately 30 sea cucumber species were present in the coastal waters of Sulawesi, with *Holothuria* being the most common genus, reaching lengths of up to 60 cm. In comparison, only about 19 species are currently found, and the average length of *Holothuria* has decreased to approximately 30 cm.

Furthermore, the line graph on the right side of Figure 2 illustrates that sea cucumbers exhibit reproductive potential not only within the reproductive size range (18-30 cm) but also at sizes exceeding 30 cm, which likely contributes to multiple reproductive cycles. Two species in this category are *T. anax* and *T. rubralineata*. These species have relatively larger bodies compared to other sea cucumber species like *Holothuria* and *Stichopus*. The sustainability of these two sea cucumber species is estimated to be higher than that of other species, as they have surpassed their peak spawning period, indicating a greater potential for reproductive contribution (Pasquini et al. 2022). If these individuals are not captured, natural mortality in the wild will reduce the risk of population decline, thereby supporting ecosystem stability and the overall sustainability of sea cucumber fisheries (Wolfe and Byrne 2022). Choo (2008) also mentioned that *Stichopus* sea cucumbers in the Spermonde Archipelago, South Sulawesi, are generally caught at small sizes, with only about 10% of the population having a catchable size (>34 cm).

The size at which sea cucumbers first reach maturity or are ready to spawn varies depending on the species and location. At this size, vitellogenesis (the formation of yolk) occurs, or reproduction processes in *H. scabra* lead to the development of Gonadal Maturity Stages (GMS). GMS in sea cucumbers cannot be determined by size and weight alone, as there is variation in GMS, even in longer and heavier sea cucumbers. For instance, the first mature size of *Holothuria* in the Arrabida National Park, Southwest Portugal, is approximately 14.2 cm for males and 16.7 cm for females (Venâncio et al. 2022). In contrast, in Algeria, the first gonadal maturation of *Holothuria* occurs at a size of 13.7 cm with a weight of 18 grams (Mezali et al. 2022). Continuously harvesting small sea cucumbers (pre-

spawning) from the wild will deplete the population. To maintain the sustainability of sea cucumbers, only those over 30 cm in size should be harvested. The findings of Yanti et al. (2020) indicate that the size at gonadal maturity of sea cucumbers in Liukang Tupabbiring Utara (Pangkep District) has decreased over time. Specifically, the body weight at which *H. scabra* (sandfish) reaches gonadal maturity declined from 354 grams to approximately 159 grams within four years. This reduction reflects a phenomenon in which sea cucumbers attain reproductive maturity at lower body weights, possibly as a response to environmental stressors or ecosystem pressures affecting growth and reproductive conditions. Such changes may have significant implications for the long-term sustainability of sea cucumber populations in the region.

However, this is still under investigation, as certain sea cucumber species may become reproductive when their size exceeds 30 cm (Pasquini et al. 2022). Larger body sizes and weights typically characterize sea cucumber broodstock. According to Altamirano and Rodriguez Jr. (2022), *H. scabra* weighing 200 grams begins to mature its gonads, and as the sea cucumber's weight increases, the number of eggs produced increases. For example, adult female *H. scabra* weighing 250 grams can release about 2 million eggs, while those weighing 450 grams can release 3-4 million eggs. According to Sitoresmi and Pursetyo (2020), sea cucumbers selected as broodstock should have a minimum weight of 250-300 grams with a length of 22-25 cm. Generally, adult sea cucumbers with a body length ranging from 20-25 cm are considered ready to reproduce (spawn).

Based on Figure 3, it can be observed that the most frequently captured sea cucumber species are in the weight range of 300-600 grams, which is generally the spawning weight for sea cucumbers. In fact, four sea cucumber species were most commonly caught at weights that are estimated to be below gonadal maturity (<300 grams), namely *H. edulis*, *H. atra*, *H. leucospilota*, and *H. scabra*. Meanwhile, the sea cucumber species caught at the spawning weight range (300-600 grams) are typically those with high economic value, such as *H. fuscogilva*, *A. Miliaris, B. vitiensis*, and *S. chloronotus*. This aligns with the findings of Ali et al. (2015), which indicate that *H. scabra* from the Red Sea coast of Sudan have an average size of 450-500 grams when they first reach gonadal maturity. This situation may lead to the scarcity of certain sea cucumber species, especially those with high market value, as market demand continues to rise. In contrast, these species are not given the opportunity to reproduce before being harvested. Evidence of this can be seen in the seven other sea cucumber species that are not displayed in the graph because their population in the wild during the year was found to be fewer than ten individuals, such as *H. nobilis, H. ocelata*, *T. ananas*, *T. rubralineata*, *A. echinites*, *B. marmorata*, and *S. pseudohorrens*. The increasing utilization of sea cucumbers has resulted in a rising capture rate year after year, with current production relying heavily on wild harvesting by fishermen. The high intensity of sea cucumber harvesting has caused a decline in size, species, and quantity (Rahman et al. 2020; Yanti et al. 2020; Dereli and Aydın 2021; Setyastuti et al. 2024).

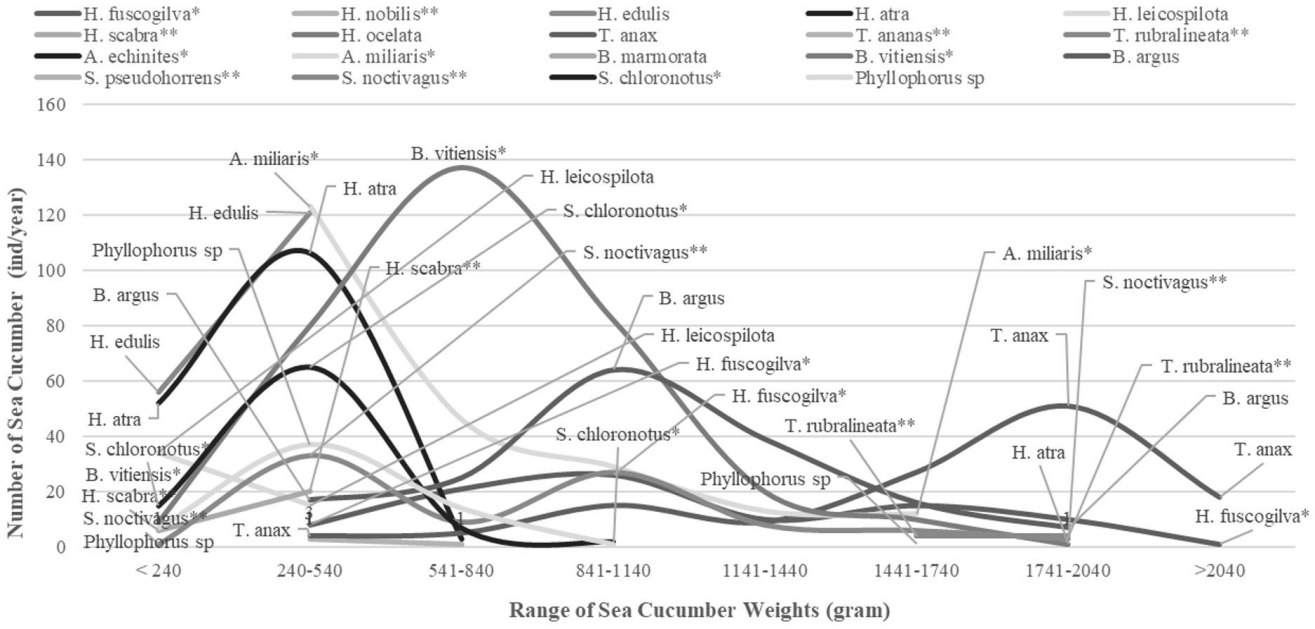

Figure 3. Number and range weights of sea cucumber in Sapuka Islands, Indonesia (source: fisher logbooks in Sapuka Island). Note: <300 (below gonadal maturity); 300-600 (gonadal maturity); >600 (above gonadal maturity)

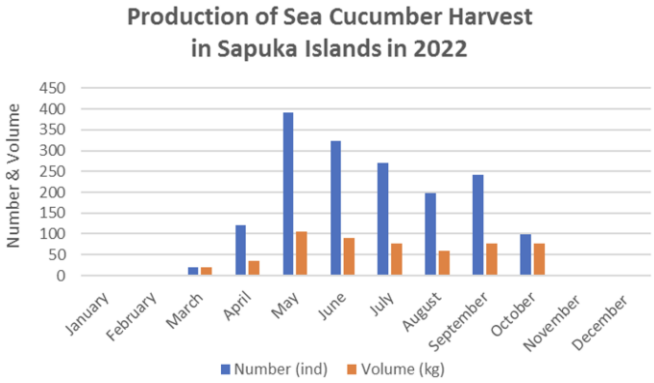

Figure 4. Number and volume of sea cucumbers in Sapuka Islands, Indonesia (source: fisher logbooks in Sapuka Island)

Based on Figure 4, it can be observed that the ratio between the number of sea cucumbers and their weight per monthly catch in the Sapuka Islands in 2022 averaged 3-4 individuals per kilogram, except for March and October, where the average weight was 1 individual per kilogram. This is suspected to be because March marks the beginning of sea cucumber harvesting after nearly four months of inactivity due to unfavorable weather conditions, giving the sea cucumbers an opportunity to grow larger and spawn (Altamirano and Rodriguez Jr. 2022). In contrast, the sea cucumbers captured in October are believed to be remnants from the previous spawning and harvest period that managed to escape the catching gear, allowing them to grow larger. Rahantoknam (2017) added that the peak spawning period of *H. scabra* from January to July occurs during the full moon cycle in May. According to Tuwo and Tresnati (2015), the sea cucumber spawning season is suspected to occur during the west monsoon between December and February. The west monsoon is a period when winds blow from the west to the east, bringing wetter and cooler weather, resulting in decreased sea-water salinity due to rain, which triggers gonadal maturation and spawning in sea cucumbers.

Based on Table 1 and Figure 4, it is evident that the sea cucumber catch in 2022 only reached 1,623 individuals per year, with 19 species, reflecting species diversity but in relatively small numbers. This contrasts with research conducted in the coastal waters of Sulawesi around 2000, which reported catches around 30 sea cucumber species (Whitten et al. 2002). The decline in catch numbers is suspected to be caused by several factors, such as overfishing, where excessive harvesting without proper management leads to a decrease in sea cucumber populations in their natural habitats (Dereli and Aydın 2021). Additionally, habitat degradation due to pollution and climate change disrupts marine ecosystems that serve as habitats for sea cucumbers, hindering their reproduction and survival processes (Garcês and Pires 2023). Ecosystem imbalances also play a role, as the decline in sea cucumber populations may disrupt the food chain within marine ecosystems more broadly (Elvevoll et al. 2022).

Production and sea cucumber marketing

The fishermen of Makassar (including those from the Sapuka Islands) successfully began exporting sea cucumbers in 1824, with a total of 300 tons valued at 350,000 guilders, equivalent to 7.5 million US dollars (Macknight 1969). Nearly two centuries later, in 2003, the export volume of sea cucumbers in South Sulawesi was approximately the same, around 281.9 tons, valued at 7,416,300 US dollars. However, in the following year, 2004, the volume increased almost fourfold, reaching 1,052.5 tons, valued at 94,450,650 US dollars (Choo 2008). The increase is suspected to be caused by factors such as the rise in the number of fishermen, expansion of the fishing area, advancements in fishing gear, improved understanding among fishermen regarding post-harvest handling standards (Aydin et al. 2023), and improvements in the sea cucumber production data-recording system in Indonesia (Rahman et al. 2020; Gianasi et al. 2021).

However, based on Figure 5, the sea cucumber production volume in South Sulawesi declined from 1,052 tons in 2004 to 734.0 tons in 2007, with a significant decrease in value as well (DKP Sulawesi Selatan 2007). Compared to the period from 2016 to 2019, the production volume continued to decline by threefold, from 251.8 tons in 2016 to approximately 60.5 tons in 2019 (BPSPL Makassar 2021). The decline in production volume continued in 2020, as evidenced by an export volume of 32.65 tons, and in 2021, it dropped to only 15.16 tons, largely due to the COVID-19 pandemic. For the period 2022-2024, production showed fluctuations with a gradual recovery, reaching around 38.12 tons in 2024 (BPPMHKP Makassar 2025). This data includes sea cucumbers that may have originated from other provinces. The increase in export volume in 2022 is believed to be related to the stabilization of human activity post-pandemic, with fishermen resuming sea cucumber harvesting and trade returning to normal, indicating a possible recovery of sea cucumber stocks in the wild.

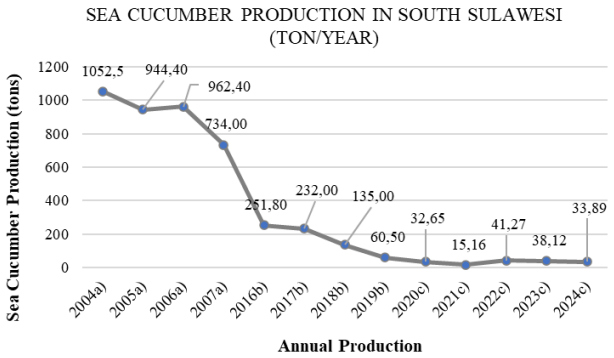

Figure 5. Production of sea cucumbers in South Sulawesi, Indonesia 2004-2024. Source: [a]: DKP Sulawesi Selatan (2007), [b]:BPSPL Makassar (2021), [c]:BPPMHKP Makassar (2025)

Overall, based on the sea cucumber production volume over 20 years (2004-2024), there has been a consistent long-term decline. In the last five years (2020-2024), the export volume of sea cucumbers through BPPMHKP Makassar has never reached 50 tons per year (Figure 5). This is evident from data collected from sea cucumber fishermen and collectors in the Sapuka Islands, which shows that the total production of sea cucumber catches in 2022 was only 538.34 kg per year. The decline in the number of sea cucumbers caught in the Sapuka Islands is suspected to be due to a decrease in their population in the wild caused by overfishing, habitat degradation, and changes in environmental conditions (Purcell et al. 2023). Additionally, the rising prices and increasing export market demand are not matched by aquaculture activities, leading to large-scale exploitation by local communities (Rahman et al. 2020; Conand et al. 2022).

The sea cucumber catch data from the Sapuka Islands cannot represent the catch data from Pangkep District. However, since there is no specific data on sea cucumber catches in Pangkep District, it can be assumed in the comparative data. It is known that Pangkep District only has three sub-districts where sea cucumber fishermen are present. One of them is the Liukang Tangayya Sub-district, with its capital on the Sapuka Islands, specifically on Pulau Sapuka Lompo (recorded as the largest sea cucumber-producing island in Pangkep District). Therefore, it is highly likely that fishermen in this district will sell their catches on this island due to the established infrastructure compared to the surrounding islands. If the sea cucumber data from the Sapuka Islands is assumed to be the same as the two other islands, the catch is still far below the sea cucumber export data from Pangkep District in 2007. This is suspected to be due to two factors: (i) A declining sea cucumber population caused by overfishing that exceeds the resource's carrying capacity; (ii) The sea cucumber catch data not being reported by fishermen or being sold outside of Pangkep District, making it recorded as a commodity from other regions. Historically, fishermen from Sapuka generally come from Barrang Lompo (Makassar City), and the area is remote, so transshipment transactions at sea may occur due to higher selling prices in Makassar City, with less operational cost required.

The price of sea cucumbers varies by region, depending on the interest of buyers (collector traders). Additionally, traders buying sea cucumbers may be unaware of the exact market price on the international (export) level. However, fluctuations in the international market price depending on the species, product quality (water content and physical condition), size, production quantity, and the exchange rate of the Indonesian rupiah to the US dollar (Bondaroff and Morrow 2024). Size is one of the factors determining the price of sea cucumbers, but what is unique is that larger sizes do not always fetch a higher price compared to smaller ones. For example, in the Hong Kong market, medium-to-large sizes of *H. fuscogilva* and *H. fuscopunctata* have higher prices compared to smaller or very large products. This trend seems to be driven by restaurant preferences for medium-to-large products for presentation as whole animals on plates (Purcell 2014).

Based on Table 1, the Sapuka Islands have six species with high market value: *H. nobilis*, *H. scabra*, *T. ananas*, *T. rubralineata*, *S. pseudohorrens*, *S. noctivagus*. Before the COVID-19 pandemic, the highest-selling species was *H. scabra*, with a price of up to IDR 1,700,000 kg^{-1}. Other *Holothuria* species commonly found in the wild are priced lower. Mid-range-priced sea cucumbers include *Actinopyga* and *Stichopus*, with a price of IDR 700,000 kg^{-1}. At the exporter level in South Sulawesi, sea cucumber prices are divided into four classes based on quality, with price ranges from IDR 150,000 kg^{-1} to IDR 2,300,000 kg^{-1} (Asriani et al. 2020). The market prices of sea cucumbers in Hong Kong and nearby areas have increased 6-12 times, with average prices across various species ranging from USD 15 to USD 385 kg^{-1} (IDR 250,000 to IDR 6,000,000 kg^{-1}). These prices are consistent with those of the South Pacific *beche-de-mer* from Singapore and Asian ports between 2001 and 2003. A direct comparison of market prices over time is difficult to make, as there appear to be no published historical prices from Hong Kong or China. Hong Kong is where high-quality sea cucumber products are sold, with some products also distributed to mainland China. Prices of *beche-de-mer* in Chinese stores vary widely (Purcell 2014).

According to the sea cucumber export data from BPPMHKP Makassar (2025), in addition to Hong Kong, seven other countries receive sea cucumber exports. However, the countries that have consistently received sea cucumber exports from Makassar over the last three years are only four, including Hong Kong. The other countries are Singapore, Malaysia, and South Korea. Hong Kong is the second largest recipient of sea cucumber exports from Makassar, following Singapore (Figure 6). Other countries that receive sea cucumber exports from Makassar include China, Vietnam, Taiwan, and Sri Lanka. The types of sea cucumber products exported consist of dried, frozen, and fresh sea cucumbers (BPSPL Makassar 2021).

Management of sea cucumber fisheries

The increase in sea cucumber catches in the Sapuka Islands appears to be disproportionate to the availability of stock in the wild. Exploitation efforts are small-scale but continuous, which threatens the sustainability of sea cucumber resources in the Sapuka Islands, particularly for certain high-value species such as *H. nobilis*, *H. scabra*, *T. ananas*, *T. rubralineata*, *S. pseudohorrens*, and *S. noctivagus*. The presence and distribution of these species are highly dependent on their habitat conditions, namely seagrass beds and coral reefs (Grayson et al. 2022). Sea cucumbers are benthic organisms found on sandy substrates, coral reefs, and seagrass beds (Purcell et al. 2023). They are important components of the food chain in coral reef ecosystems and their associated ecosystems across various trophic levels (BPSPL Makassar 2021). One way to protect sea cucumber stocks in the wild is through the establishment of Marine Protected Areas (MPAs). These efforts can safeguard sea cucumber resources along with their ecosystems, including seagrass beds and coral reefs (Nessa et al. 2020).

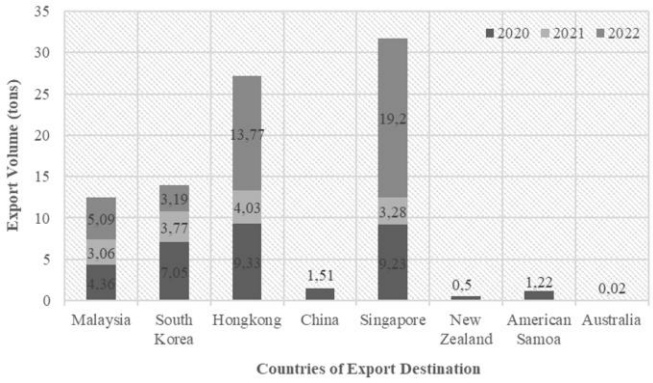

Figure 6. Export volume of sea cucumbers by destination countries from 2020-2022 (Source: BPPMHKP Makassar 2025)

On the other hand, inadequate environmental conditions pose a significant threat to the sustainability of sea cucumber resources. The continuously rising demand for sea cucumber exports has the potential to lead to resource scarcity (Ramírez-González et al. 2020). Typically, sea cucumber fishermen are bound by contracts with local collectors, who in turn have agreements with exporters (Purcell et al. 2024). This system is worrying because the market demand does not prioritize size, leading to a scarcity of larger individuals. At the same time, smaller ones are still harvested and sold, albeit at lower prices. Consequently, indiscriminate harvesting occurs across all size classes, including juveniles that have yet to reach reproductive maturity, resulting in "growth overfishing" (Rahman et al. 2020; Ramírez-González et al. 2020). Furthermore, the current lack of success in sea cucumber hatchery efforts is heightening the risk of population collapse. This underscores the pressing need for effective management strategies. These strategies, which should include the establishment of minimum size limits to protect juvenile individuals and seasonal moratoriums, particularly during the rainy season (October to February), to allow sea cucumbers to spawn before being harvested, are crucial. Implementing such measures would not only provide a window for population recovery but also foster sustainable reproduction, offering hope for the future of sea cucumbers (Venâncio et al. 2022).

Restricting sea cucumber harvesting through size-selective trade regulations is a critical step toward conserving populations and maintaining ecosystem balance. Harvesting individuals that have reached gonadal maturity or have already reproduced, particularly those measuring between 18-30 cm, is considered optimal, as sea cucumbers within this size range are in their most productive reproductive phase (Venâncio et al. 2022). The implementation of regulations that permit only sea cucumbers within this size range to be harvested can minimize the risk of capturing immature individuals, thereby supporting sustainable reproduction, and ensuring long-term population viability (Pasquini et al. 2022). Moreover, studies have shown that appropriate size regulations can enhance future catch yields by preserving reproductive potential (Purcell et al. 2023).

The current high level of sea cucumber exploitation makes conservation and natural recovery efforts insufficient (Massiseng et al. 2023). Additional strategies, such as restocking activities, are needed to accelerate the recovery of sea cucumber stocks in the wild. However, no studies have reported 100% success for this approach, as it requires support from various stakeholders, including fishermen, community leaders, government officials, traders, and exporters.

As policymakers, the government has also acted through the Ministry of Marine Affairs and Fisheries (MMAF) by establishing the National Action Plan for Sea Cucumber Conservation Period I (2016-2020). This initiative aims to support the sustainability and sustainable use of sea cucumber resources to ensure their conservation and enhance the economy of coastal communities. Furthermore, the government has issued guidelines for coral reef management through the Ministerial Decree of MMAF (KEP.38/MEN/2004).

The high pressure from sea cucumber capture has also become a serious concern globally, particularly for sea cucumber conservation efforts. Several countries and international organizations have developed policies for sea cucumber protection. Some countries, as part of the Convention on International Trade in Endangered Species (CITES) of Wild Fauna and Flora, held a COP (Conference of the Parties) meeting in Doha in 2010 to discuss proposals to include some species of sea cucumbers in CITES Appendix II. In 2019, at the 18th COP in Geneva (Switzerland), several species of sea cucumbers were added to Appendix II of CITES (Wolfe and Byrne 2022). Of the 19 sea cucumber species found in the Sapuka Islands, around nine species, including *H. fuscogilva*, *H. nobilis*, *H. edulis*, *H. atra*, *H. scabra*, *T. anax*, *T. ananas*, *T. rubralineata*, and *S. chloronotus*, are classified in Appendix II of CITES with vulnerable and endangered status (Table 1). This has resulted in a significant decline in sea cucumber species diversity, from 30 species to 19 species, as well as a drastic decline in population abundance, from over 1,000 tons per year to less than 100 tons per year over 20 years. Hence, to ensure the long-term sustainability of these ecologically and economically valuable marine resources, it is imperative to implement conservation measures such as size-selective harvesting, seasonal fishing restrictions, and habitat protection in collaboration with local communities and international stakeholders. The economic value of the sea cucumber fishery cannot be underestimated. These findings underscore the urgent need for sustainable management strategies to mitigate further population declines and maintain the ecological integrity and economic viability of sea cucumber fisheries in the Sapuka Islands.

ACKNOWLEDGEMENTS

We would like to express our gratitude to the Burung Indonesia Foundation, as a partner of the Yayasan Romang

Celebes (YRC) Indonesia, for funding this research through the Wallacea Partnership Program II grant. This program is supported by the Critical Ecosystem Partnership Fund (CEPF) in efforts to conserve biodiversity in the Wallacea biogeographic region. Our thanks also go to Mr. Muhammad Irfan Rais, S.Pi. with The Indonesian Agency for Control and Supervision of Marine and Fisheries Quality (BPPMHKP) Makassar, the Coastal and Marine Resources Management Office (BPSPL) Makassar, the government and community of Sapuka Village, as well as all parties who have provided information regarding sea cucumber fisheries in the Sapuka Islands.

REFERENCES

Alam MA, Prasad RR, Kundra S. 2022. Assessing the environmental, social and economic impacts of the sea cucumber fishery in the red sea of Eritrea. J Posit Sch Psychol 6 (7): 2519-2535.

Ali IMY, Mohamed S, Gedeiri A, Babikir Y. 2015. Some aspects of reproductive biology of the sea cucumbers *Holothuria scabra* and *Holothuria atra* (Echinodermata: Holothuroidea) from the Sudanese Red Sea. Coast Res J Fish Hydrobiol 10: 1-6.

Altamirano J, Rodriguez Jr. JC. 2022. Hatchery Production of Sea Cucumbers Sandfish (*Holothuria scabra*). Aquaculture Department, Southeast Asian Fisheries Development Center, Philippines.

Arbi UY, Wirawati I, Widyastuti E, Hadiyanto, Ibrahim PS, Vimono IB, Pitriana P, Hendriks CHAW, Nugroho DA, Sani SY. 2022. Fauna Bentos Ekosistem Pesisir Indonesia. Coremap-CTI Program, Research Center for Oceanography, National Research and Innovation Agency (BRIN), Jakarta. [Indonesian]

Aydın M, Aksay K, Karadurmuş U. 2023. Sea cucumber trade and sustainability in Türkiye: Progress, problems, and opportunities. Aquat Sci Eng 38 (3): 180-188. DOI: 10.26650/ASE20231276000.

Badan Pengendalian dan Pengawasan Mutu Hasil Kelautan dan Perikanan (BPPMHKP) Makassar. 2025. Statistik Badan Pengendalian dan Pengawasan Mutu Hasil Kelautan dan Perikanan. https://ecert.kkp.go.id/statistik/?r=stats/#_ops_volume/E,I/Kg/m//2020//nm_umum/. [Indonesian]

Balai Pengelolaan Sumberdaya Pesisir dan Laut (BPSPL) Makassar. 2021. Teripang (Sea Cucumber). Directorate General of Marine Spatial Management, Jakarta. https://kkp.go.id/djprl/bpsplmakassar/page/1857-teripang. [Indonesian]

Bondaroff TNP, Morrow F. 2024. Sea cucumber crime. In: Mercier A, Suhrbier AD (eds). The World of Sea Cucumbers. Academic Press, United Kingdom.

Choo PS. 2008. Population Status, Fisheries and Trade of Sea Cucumbers in Asia Sea Cucumbers. FAO, Rome. DOI: 10.1016/B978-0-323-95377-1.00036-9.

Choo PS. 2024. Women in sea cucumber fisheries and aquaculture, can we make their participation equal and fair? In: Mercier A, Suhrbier AD (eds). The World of Sea Cucumbers. Academic Press, United Kingdom.

Conand C, Claereboudt M, Dissayanake C, Ebrahim A, Fernando S, Godvinden R, Friedman K. 2022. Review of fisheries and management of sea cucumbers in the Indian Ocean. West Indian Ocean J Mar Sci 21 (1): 125-148. DOI: 10.4314/wiojms.v21i1.10.

Conand C. 2018. Recent status of the world sea cucumber resources and utilization: An international overview. J Fish Aquat Sci 13 (1): 1-9.

Dalpathadu KR. 2021. Evaluation of the fisheries and resource of sea cucumbers in the coastal waters of Trincomalee district, Eastern Sri Lanka. Intl J Aquat Biol 9 (5): 297-308. DOI: 10.22034/ijab.v9i5.1265.

Dereli H, Aydın M. 2021. Sea cucumber fishery in Turkey: Management regulations and their efficiency. Reg Stud Mar Sci 41: 101551. DOI: 10.1016/j.rsma.2020.101551.

Dinas Kelautan dan Perikanan (DKP) Provinsi Sulawesi Selatan. 2007. Statistik Perikanan Tangkap. DKP, Makassar. [Indonesian]

Elvevoll EO, James D, Toppe J, Gamarro EG, Jensen IJ. 2022. Food safety risks posed by heavy metals and Persistent Organic Pollutants (POPs) related to consumption of sea cucumbers. Foods 11 (24): 3992. DOI: 10.3390/foods11243992.

Eriksson H, Byrne M. 2015. the sea cucumber fishery in Australia's great barrier reef marine park follows global patterns of serial exploitation. Fish Fisheries 16 (2): 329-341. DOI: 10.1111/faf.12059. DOI: 10.1111/faf.12059.

Eriksson H, Clarke S. 2015. Chinese market responses to overexploitation of tropical sea cucumbers. Biol Conserv 184: 367-376. DOI: 10.1016/j.biocon.2015.01.018.

Friedman K, Purcell S, Bell J, Hair C. 2011. Sea Cucumber Fisheries: A Manager's Toolbox. FAO, Rome.

Gamboa-Álvarez MÁ, López-Rocha JA, Poot-López GR, Aguilar-Perera A, Villegas-Hernández H. 2020. Rise and decline of the sea cucumber fishery in Campeche Bank, Mexico. Ocean Coast Manag 184: 105011. DOI: 10.1016/j.ocecoaman.2019.105011.

Garcês A, Pires I. 2023. The guardians of the sea: Echinoderms as sentinels of marine pollution. Toxicol Intl 29 (4): 541-552. DOI: 10.18311/ti/2022/v29i4/30487.

Gianasi BL, Hamel JF, Montgomery EM, Sun J, Mercier A. 2021. Current knowledge on the biology, ecology, and commercial exploitation of the sea cucumber *Cucumaria frondosa*. Rev Fish Sci Aquac 29 (4): 582-653. DOI: 10.1080/23308249.2020.1839015.

González-Wangüemert M, Domínguez-Godino JA, Cánovas F. 2018. The fast development of sea cucumber fisheries in the mediterranean and NE Atlantic waters: From a new marine resource to its over-exploitation. Ocean Coast Manag 151: 165-177. DOI: 10.1016/j.ocecoaman.2017.10.002.

Grayson N, Clements CS, Towner AA, Beatty DS, Hay ME. 2022. Did the historic overharvesting of sea cucumbers make coral more susceptible to pathogens? Coral Reefs 41 (2): 447-453. DOI: 10.1007/s00338-022-02227-w.

Hair C, Foale S, Daniels N, Minimulu P, Aini J, Southgate PC. 2020. Social and economic challenges to community-based sea cucumber mariculture development in New Ireland Province, Papua New Guinea. Mar Policy 117: 103940. DOI: 10.1016/j.marpol.2020.103940.

Hamel JF, Bondaroff TNP, Mercier A. 2024. Beyond beche-de-mer: Sea cucumbers in nontraditional food products, health supplements, and biotechnology. In: Mercier A, Suhrbier AD (eds). The World of Sea Cucumbers. Academic Press, United Kingdom. DOI: 10.1016/B978-0-323-95377-1.00005-9.

Hughes A, Auliya M, Altherr S, Scheffers B, Janssen J, Nijman V, Edwards DP. 2023. Determining the sustainability of legal wildlife trade. J Environ Manag 341: 117987. DOI: 10.1016/j.jenvman.2023.117987.

Husain G, Tamanampo JFWS, Manu GD. 2017. Community structure of sea cucumber (Holothuroidea) in the coastal area of the island of Jailolo Sub-district Nyaregilaguramangofa South Halmahera Regency West of North Maluku. Jurnal Ilmiah Platax 5 (2): 177-188. [Indonesian]

Kamarudin KR, Usup G, Hashim R, Rehan MM. 2015. Sea cucumber (Echinodermata: Holothuroidea) species richness at selected localities in Malaysia. Pertanika 38 (1): 7-32

Lampe M, Munsi H, Adam AF. 2019. Contextual progressive: Study of fisheries practices and consequences to the environment. IOP Conf Ser Earth Environ Sci 343 (1): 012099. DOI: 10.1088/1755-1315/343/1/012099.

Lampe M, Munsi H, Luran NF. 2020. Development phases and socio-cultural contexts of the reef-based fishing economy of the Sembilan Islands community, South Sulawesi, Indonesia. AACL Bioflux 13 (2): 459-469.

Lee SY, Byrne M, Uthicke S. 2018. The ecological roles of holothurians in marine ecosystems: Biodiversity, sustainability, and conservation. Oceanogr Mar Biol Ann Rev 56: 431-463.

Macknight CC. 1969. The Macassans: A Study of the Early Trepang Industry along the Northern Territory Coast. [Dissertation]. The Australian National University, Australia.

Made AS, Tahang H. 2020. The prospect of sea cucumber (*Holothuroidea* sp.) agribusiness development in South Sulawesi Province. IOP Conf Ser Earth Environ Sci 473 (1): 012023. DOI: 10.1088/1755-1315/473/1/012023.

Massiseng ANA, Daris L, Samawi MF, Jaya J, Irwansyah, Zaenab S. 2023. Ethnoconservation of fishery resources in The Sapuka Islands, South Sulawesi Province, Indonesia. Biodiversitas 24 (12): 6461-6471. DOI: 10.13057/biodiv/d241208.

Mezali K, Lebouazda Z, Slimane-Tamacha F, Lila SD. 2022. Biometry, size structure and reproductive cycle of the sanded sea cucumbers *Holothuria poli* (Echinodermata, Holothuriidae) from the West Algerian Coast. Invertebr Reprod Dev 66 (1): 67-77. DOI: 10.1080/07924259.2022.2033331.

Minguito JT. 2023 Catch and trade of sea cucumbers in Getafe, Bohol, Philippines. Indian J Sci Technol 16 (12): 903-909. DOI: 10.17485/IJST/v16i12.1618.

Moore D. 2022. Farming giant clams in 2021: A great future for the 'blue economy'of tropical islands. In: Moore D, Heilweck M, Petros P (eds). Aquaculture: Ocean Blue Carbon Meets UN-SDGS. Springer International Publishing, Cham, Switzerland. DOI: 10.1007/978-3-030-94846-7.

Morgan A, Archer J. 1999. Overview: Aspects of seacucumber industry research and development in the South Pacific. SPC Beche-de-mer Inform Bull 12: 15-17.

Nessa N, Gatta R, Ambo-Rappe R, Jompa J, Yahya AF. 2020. The role of women in utilization of *Enhalus acoroides*: Livelihoods, food security, impacts and implication for coastal area management. IOP Conf Ser Earth Environ Sci 564: 012073. DOI: 10.1088/1755-1315/564/1/012073.

Pangestuti R, Arifin Z. 2018. Medicinal and health benefit effects of functional sea cucumbers. J Traditional Complement Med 8: 341-351. DOI: 10.1016/j.jtcme.2017.06.007.

Pangestuti R, Murniasih T, Putra MY, Rasyid A, Wibowo JT, Ardiansyah A, Untari F. 2016. Free radical scavenging activity of selected sea cucumber species from Mataram-Lombok, Indonesia. Jurnal Teknologi 78 (2): 179-185. DOI: 10.11113/jt.v78.8202.

Pasquini V, Porcu C, Marongiu MF, Follesa MC, Giglioli AA, Addis P. 2022. New insights upon the reproductive biology of the sea cucumber *Holothuria tubulosa* (Echinodermata, holothuroidea) in the Mediterranean: Implications for management and domestication. Front Mar Sci 9: 1029147. DOI: 10.3389/fmars.2022.1029147.

Pérez-Lloréns JL, Mouritsen OG. 2024. Sea cucumber: A scavenger overexploited, traded and turned into food (Even a gastronomic delicacy). Intl J Gastron Food Sci 37: 100996. DOI: 10.1016/j.ijgfs.2024.100996.

Plagányi ÉE, Murphy N, Skewes T, Dutra LX, Dowling N, Fischer M. 2020. Development of a data-poor harvest strategy for a sea cucumber fishery. Fish Res 230: 105635. DOI: 10.1016/j.fishres.2020.105635.

Purcell SW, Lovatelli A, Gonzalez WM, Solis MFA, Samyn Y, Conand C. 2023. Commercially Important Sea Cucumbers of the World-Second Edition. FAO, Rome.

Purcell SW, Tagliafico A, Cullis BR, Cocks N. 2024. Wicked problem of improving fishery livelihoods through capacity building. Mar Policy 163: 106108. DOI: 10.1016/j.marpol.2024.106108.

Purcell SW. 2014. Value, market preferences and trade of beche-de-mer from pacific island sea cucumbers. Plos One 9 (4): e95075. DOI: 10.1371/journal.pone.0095075.

Rahantoknam SPT. 2017. Maturity gonad sea cucumber *Holothuria scabra* under the month cycle. IOP Conf Ser Earth Environ Sci 89 (1): 012015. DOI: 10.1088/1755-1315/89/1/012015.

Rahman MA, Chowdhury SH, Hasan MJ, Rahman MH, Yeasmin SM, Farjana N, Parvez MS. 2020. Status, prospects and market potentials of the sea cucumber fisheries with special reference on their proper utilization and trade. Ann Res Rev Biol 35 (7): 84-101. DOI: 10.9734/arrb/2020/v35i730250.

Rahman MA, Yusoff FM. 2017. Sea cucumber fisheries: Market potential, trade, utilization and challenges for expanding the production in the South-East Asia. Intl J Adv Chem Eng Biol Sci 4 (1): 26-30. DOI: 10.15242/IJACEBS.ER0117033.

Ramírez-González J, Moity N, Andrade-Vera S, Reyes H. 2020. Overexploitation and more than a decade of failed management leads to no recovery of the galápagos sea cucumber fishery. Front Mar Sci 7: 554314. DOI: 10.3389/fmars.2020.554314.

Setyastuti A, Wirawati I, Hadiyanto H, Nurjamin N, Permadi S, Hadi TA, Sjafrie NDM. 2024. New insight into the diversity, biometric distribution, and relationships of commercial sea cucumber species from Indonesia. Fish Res 279: 107124. DOI: 10.1016/j.fishres.2024.107124.

Setyastuti A, Wirawati I, Permadi S, Vimono IB. 2019. Teripang Indonesia: Jenis, Sebaran dan Status Nilai Ekonomi. PT Media Sains Nasional, Jakarta. [Indonesian]

Sitoresmi DAN, Pursetyo KT. 2020. The effect of concrete tanks for the breeding technique of the sand sea cucumber (*Holothuria scabra*). IOP Conf Ser Earth Environ Sci 441 (1): 012054. DOI: 10.1088/1755-1315/441/1/012054.

Sjafrie NDM, Wirawati I, Zulfikar A, Widyastuti E. 2024. Using the socio-ecological system approach to guide the management of sea cucumber fisheries at Barang Lompo Island, South Sulawesi, Indonesia. Environ Dev Sustain 2024: 1-20. DOI: 10.1007/s10668-024-04821-0.

Stacey N. 1999. Boats to Burn: Bajo Fishing Activity in the Australian Fishing Zone. [Dissertation]. Faculty of Law, Bussines and Arts, Northern Territory University, Australia.

Tuwo A, Tresnati J. 2015. Sea cucumber farming in Southeast Asia (Malaysia, Philippines, Indonesia, Vietnam). In: Brown NP, Eddy SD (eds). Echinoderm Aquaculture. John Wiley & Sons, Inc., United Sates. DOI: 10.1002/9781119005810.ch15.

Urwin C, Bradley JJ, McNiven IJ, Russell L, Farid YL. 2023. Re-assessing regional chronologies for island Southeast Asian voyaging to Aboriginal Australia. Archaeol Oceania 58 (3): 245-274. DOI: 10.1002/arco.5301

Van-Khanh L, Anh NTN, Dinh TD. 2020. Survey on the current status of small-scale artisanal sea cucumber fishing in Kien Giang Province, Vietnam. J Shellfish Res 39 (3): 723-730. DOI: 10.2983/035.039.0318.

Venâncio E, Félix PM, Brito AC, Azevedo SF, Simões T, Sousa J, Pombo A. 2022. Reproductive biology of the sea cucumber *Holothuria mammata* (Echinodermata: *Holothuroidea*). Biology 11 (5): 622. DOI: 10.3390/biology11050622.

Wattimena GA. 2016. Moluccas Archipelago agroforestry. The 1st International Seminar on Agroforestry. Maluku, 2-3 November 2016. [Indonesian]

Whitten T, Mustafa M, Henderson GS. 2002. The Ecology of Sulawesi. (First Periplus Edition). Periplus Editions (HK) Ltd., USA.

Wolfe K, Byrne M. 2022. Overview of the great barrier reef sea cucumber fishery with focus on vulnerable and endangered species. Biol Conserv 266: 109451. DOI: 10.1016/j.biocon.2022.109451.

Yanti A, Tresnati J, Yasir I, Rahmani PY, Aprianto R, Tuwo A. 2020. Size at the maturity of sea cucumber *Holothuria scabra*. Is it an overfishing sign in Wallacea Region? IOP Conf Ser Earth Environ Sci 473 (1): 012056. DOI: 10.1088/1755-1315/473/1/012056.

Yusuf S, Tuwo A, Tresnati J, Moore AM, Conand C. 2017. Teripang fishing activities at Barang Lompo Island, Sulawesi, Indonesia: An update 20 years after a visit in 1996. SPC Beche-de-mer Inform Bull 37: 99-102.