DOI: 10.31398/tpjf/32.1.2023-0076

RESEARCH ARTICLE

Catches and the Production of the Sea Cucumber Fishery of Mindanao, Philippines

Elgen M. Arriesgado[1,2], Marnelle B. Sornito[1,2*], Josuah D. Zalsos[2], Jomar F. Besoña[1,2], Divina B. Ignacio[4], Wilfredo H. Uy[2,3]

[1]*School of Marine Fisheries and Technology, Mindanao State University at Naawan, 9023 Naawan, Misamis Oriental, Philippines*
[2]*Sea cucumber R&D Center, Mindanao State University at Naawan, 9023 Naawan, Misamis Oriental, Philippines*
[3]*College of Marine and Allied Sciences, Mindanao State University at Naawan, 9023 Naawan, Misamis Oriental, Philippines*
[4]*Bureau of Fisheries and Aquatic Resources Region IX, 7000 Zamboanga City, Philippines*

ABSTRACT

High exploitation and limited fishery data pose challenges to the sustainable sea cucumber fishery management in the Philippines. This study provides detailed documentation of sea cucumber catches and production across Barobo, Surigao del Sur, Sta. Cruz, Davao del Sur, Olutanga, Zamboanga Sibugay, Dimataling, Zamboanga del Sur, and Bongao, Tawi-tawi. The daily catch was recorded by assigned local enumerators from December 2019 to November 2021. A total of 9 – 31 sea cucumbers were reported in the catches out of 37 commercially exploited species, with the highest number recorded in Bongao and the lowest in Barobo. The most active gatherers were observed in Olutanga and the least in Barobo (38–182). Collectors typically gather sea cucumbers 5–29 days a month, with collectors from Barobo having the most frequent days. The catch-per-unit effort (CPUE) of fresh catches peaked in Bongao at 7 kg/day, while Barobo had the lowest at 1.9 kg/day. Annual harvest production estimates from five municipalities would yield 352.31 MT of fresh sea cucumbers. Half the catches were medium-valued (51%), and only 18% were high-valued. *Bohadschia marmorata* consistently ranked among the top five species across all sites, while *Actinopyga echinites* had the highest overall catch percentage. Two species in the top catches are recorded as "vulnerable," and one is "threatened" by the IUCN Red List of Threatened Species. Sea cucumber fisheries in Mindanao are crucial for the livelihoods of marginalized fishers. However, the shift toward lower-valued species signals overexploitation, highlighting the urgent need for local management policies to ensure sustainability.

*Corresponding Author: *marnelle.sornito@msunaawan.edu.ph*
Received: *October 18, 2023*
Accepted: *February 19, 2025*

Keywords: *Beche-de-mer, CPUE, fishery management, holothurian, trepang*

1. INTRODUCTION

Sea cucumbers are among the marine resources exploited in industrialized, semi-industrialized, and artisanal (small-scale) fisheries worldwide, with high intensity throughout the tropics (Purcell et al. 2012). Their dried product, *beche-de-mer* or *trepang*, has been traded in international markets and is economically significant in the Western Pacific, particularly in the Indo-Pacific region (Purcell et al. 2013; Alejandro 2019). They are harvested and sold as a traditional luxury food due to their medicinal value, such as wound healing, neuroprotective, antitumor, anticoagulant, antimicrobial, and antioxidant (Subaldo 2011; Pangestuti and Arifin 2018). Thus, they are considered the "ginseng of the sea" (Forero et al. 2013). This increasing demand for *beche-de-mer*, along with steady price increases, has led to the worldwide intensification of sea cucumber harvesting. Recently, the increasing interest in their pharmaceutical and nutraceutical usage has been explored, fueling their fishing pressure (Rahman and Yusuff 2017). The open-access nature of this resource, combined with ineffective management due to gaps in fisheries biology knowledge of commonly targeted sea cucumbers, also encourages illegal, unregulated, and unreported (IUU) fishing, ultimately contributing to the decline of several wild stocks (Choo 2008; Perez and Brown 2012; Purcell et al. 2013; Plaganyi et al. 2020). Aside from that, poor data, difficulty distinguishing this fishery from other invertebrate species, and high prices driven by growing demand present more challenges for effective resource management and conservation (Micael et al. 2009 ; Perez and Brown 2012).

According to FAO Statistics, global sea cucumber production reached 42,000 tonnes (live weight) in 2022, accounting for 10.1% of the total production of other aquatic animals, with the highest volumes concentrated in the temperate Pacific and Northwest Atlantic regions (FAO Major Fishing Areas 61 and 21) (Purcell et al. 2023; FAO 2024). In Southeast Asia, the Philippines is the second-largest exporter of processed sea cucumber to the world market, second only to Indonesia (Alejandro 2019). In fact, sea cucumber is the 8th commodity exported and the 5th fisheries export of the country, corresponding to a value of 89,919 PHP and 713 MT in 2021 (DA-BFAR 2021). Labe (2009) accounted 47 commercially exploited species belonging to Holothuriidae, Stichopodidae, and Phyllophoridae that were commercially exploited in the country in 2009. Similarly, Arriesgado et al. (2022a) also reported 47 sea cucumbers, classified under Holothuriidae and Stichopodidae, recorded in Mindanao, with market values for both exports and local consumption. Although both studies recorded the same number of species, some species listed by Labe (2009) were not found by Arriesgado et al. (2022) and vice versa. Confirming whether these unique species are truly distinct or synonymous is challenging due to incomplete morphological descriptions, outdated data, and taxonomic reclassifications.

This rich sea cucumber diversity encourages the rapid exploitation of resources, yet the country lacks a tangible management plan for their conservation and sustainability (De Guzman and Quiñones 2021). Nevertheless, current efforts have been initiated by several scientists and government offices like BFAR, including the BFAR Administrative Circular Order 248 Series of 2013 on the size limits for sea cucumbers collected for commercial trade (Choo 2008; DA-BFAR 2013 ; Alejandro 2019) and the prohibition of the collection of the three species of teatfish in 2020 (Sotelo 2020). However, the effectiveness of enforcement is unknown, and sea cucumber gathering remains open-access, unmanaged, and unregulated (Jontila et al. 2018a).

It is essential to determine and manage stocks to protect the ecosystem and have a sustainable sea cucumber fishery (Dereli and Aydin 2021). Several studies have been conducted in the country to provide the status of the sea cucumber fishery, such as in Palawan (Jontila et al. 2018b); Samar and Leyte (Gajelon-Samson et al. 2011); Bolinao-Anda System (Olavides et al. 2011); and Mindanao (De Guzman and Quiñones 2021; Arriesgado et al. 2022a). However, the scarcity of fisheries data in various regions, coupled with challenges in catch and production as well as significant underestimation and underreporting of fishery stocks and their exports, continues to be a major bottleneck in developing a sustainable management framework for these resources in the country (Choo 2008; Labe 2009; Baker-Medard and Ohl 2019).

Hence, this study monitored the daily actual catches of sea cucumber gatherers in major trading grounds in Mindanao over a two-year period to provide information that would help manage and sustain the sea cucumber resource. Specifically, the study determined the (a) sea cucumber species composition, richness, and top catches of the daily catch, (b) fishing effort, (c) their market value and conservation status, and (d) annual production estimates for fresh and *beche-de-mer*. The results provide valuable insights for fishery managers to develop targeted, sustainable, and science-based policies and effective management frameworks for sea cucumber resources, such as species-specific regulations and guidelines for selecting species for aquaculture and restocking. It also provides an update on the catch and production statistics, which are essential for determining the status and health of the sea cucumber fishery in the country. Moreover, it will contribute to the pool of scientific information that benefits both local and international communities.

2. MATERIALS AND METHODS

The study was conducted in five coastal municipalities in Mindanao, Philippines, which have a high volume of landed sea cucumbers and major trading stations in the province. The five selected sites were Olutanga, Zamboanga Sibugay; Dimataling, Zamboanga del Sur; Barobo, Surigao del Sur; Sta. Cruz, Davao del Sur; and Bongao, Tawi-tawi (Fig. 1).

Daily catch monitoring was conducted at the five selected sites over a two-year period, from December 2019 to November 2021. Important information includes the number of gatherers and hours of fishing/gathering, catch composition, catch volume (weight), count of each species, and gross

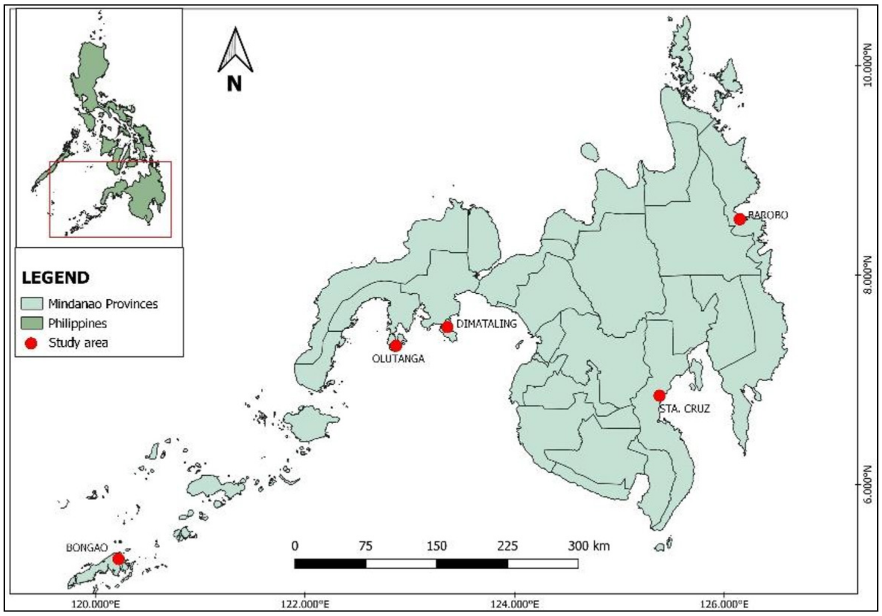

Figure 1. The map of Mindanao shows the five major sea cucumber trading stations as study sites, using QGIS software version 3.22.11.

income from sales. The daily catch monitoring was conducted by assigned enumerators from each site, who recorded logbook data on the actual sea cucumber catches per gatherer at the trading stations. The enumerators were selected based on their experience in monitoring catches from sea cucumber gathering and trading, as well as their knowledge of identifying sea cucumber species. The local names of each sea cucumber species were identified by matching them to their corresponding scientific names using published references (Olavides et al. 2010; Purcell et al. 2012; De Guzman and Quiñones 2013; Kim et al. 2013; Purcell et al. 2023). Photographs were obtained for every sea cucumber species to aid in its identification.

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Before commencing monitoring, the enumerators were thoroughly briefed on what information to collect and how to record it. The data obtained were sent to or collected by the project staff monthly for transcription and analysis. The study employed descriptive statistics using Microsoft Excel 2016.

The CPUE was estimated by using the formula of Sparre and Venema (1992):

(a) $$CPUE = \frac{\sum C_1}{\sum F_1}$$

Where: Ci = catch (in kg) and fi = fishing effort in one operation unit (i.e., by each gatherer in one day or one hour). The mean CPUE is then calculated by dividing the sum of Ci and fi of all gatherers and comparing across stations.

The study computed the percentage composition of species using the following formula:

(b) $$\%\ species\ composition = \frac{N_i}{N_{total}}\ x\ 100$$

Where: N_i is the number of individuals of species *i,* and N_{total} is the total number of individuals of all sea cucumber species. The top five species with the highest percentage composition were determined as the top five most commercially harvested sea cucumber species in each municipality.

For the average production of fresh sea cucumbers per municipality (P_{fresh}), the study used the following formula:

$$(c)\ P_{Fresh} = \frac{\sum P_{total}}{N}$$

Where: P_{total} is the total annual fresh sea cucumber production estimate for all sampling stations, and N is the number of sampling stations surveyed. To determine estimated *beche-de-mer* production estimates in Mindanao (P_{dried}), the study used the formula:

$$(c)\quad P_{dried} = P_{fresh}\ x\ 8.5\%\ x\ 30$$

Where: 8.5% is the mean wet-dry percentage for the top sea cucumber species established by the study, and 30 is the estimated number of active sea cucumber fishing/trading municipalities in Mindanao surveyed by the project.

3. RESULTS

3.1. Species composition, richness, and top catches

The actual catch landings showed that 37 species were commercially exploited, representing two families, Holothuriidae and Stichopodidae. Holothuriids include the genera *Actinopyga* (4), *Bohadschia* (7), *Holothuria* (16), and *Pearsonothuria* (1). Stichopodidae includes *Stichopus* (7) and *Thelenota* (2) genera (Table 1). The highest number of traded sea cucumbers was recorded in Bongao, with 31 species, while the lowest was in Barobo, with nine (9). Four uncommon species were observed once during the monitoring, namely *B. argus* x *vitiensis* (Fig 2A), *Bohadschia* sp. 1 (Fig 2B), and *H. edulis* "yellow variant" locally known as *"cobra"* (Fig 2C) recorded in Sta Cruz, while *H. lessoni* "blotchy variant" (Fig 2D) in Olutanga. The putative *B. argus–vitiensis* hybrid with *vitiensis* background, including transverse bands and ocellar spots of *argus* (Fig 2A) and *Bohadschia* sp. *1* (Fig 2b) has been observed and described by Kim et al. (2013).

Table 1. Checklist of traded sea cucumber species with their commercial value and Conservation Status based on the IUCN Red List of threatened species in the five stations across Mindanao based on actual catch landings. The mark (x) indicates presence in the catch.

Scientific name	Commercial Value*	Conservation Status**	Olutanga, Zamboanga Sibugay (ZS)	Dimataling, Zamboanga del Sur (ZDS)	Sta. Cruz, Davao del Sur (DDS)	Barobo, Surigao del Sur (SDS)	Bongao, Tawi-Tawi (TW)
Actinopyga echinites	M	VU	x	x	x	x	x
Actinopyga lecanora	H	DD	x	x	x		x
Actinopyga varians	M	DD			x		x
Actinopyga miliaris	M	VU	x		x		x
Bohadschia argus	M	LC	x	x	x		x
Bohadschia argus x vitiensis	M	UI			x		
Bohadschia koellikeri	M	DD	x		x		x
Bohadschia marmorata	M	DD	x	x	x	x	x
Bohadschia ocellata	M	NA	x	x	x		x
Bohadschia sp.1	M	UI			x		
Bohadschia vitiensis	M	DD	x	x	x	x	x
Holothuria atra	L	LC	x	x	x		x
Holothuria coluber	VL	LC	x		x		x
Holothuria edulis	M	LC	x	x	x		x
Holothuria roseomaculata	L	LC	x				x
Holothuria fuscocinerea	VL	LC	x			x	x
Holothuria fuscogilva	H	VU	x		x		x
Holothuria fuscopunctata	L	LC	x	x	x		x

Continuatuin of Table . Checklist of traded sea cucumber species with their commercial value and Conservation Status based on the IUCN Red List of threatened species in the five stations across Mindanao based on actual catch landings. The mark (x) indicates presence in the catch.

Scientific name	Commercial Value*	Conservation Status**	Olutanga, Zamboanga Sibugay (ZS)	Dimataling, Zamboanga del Sur (ZDS)	Sta. Cruz, Davao del Sur (DDS)	Barobo, Surigao del Sur (SDS)	Bongao, Tawi-Tawi (TW)
Holothuria gracilis	M	DD	x	x	x	x	x
Holothuria lessoni	H	EN	x	x			x
Holothuria leucospilota	VL	LC	x	x			
Holothuria pardalis	L	LC	x	x	x		x
Holothuria pervicax	VL	LC	x				x
Holothuria scabra	H	EN	x	x	x	x	x
Holothuria whitmaei	H	EN					x
Holothuria sp. 1	L	UI	x		x		x
Holothuria sp. 2	VL	UI		x	x		
Pearsonothuria graeffi	L	LC	x	x	x		x
Stichopus herrmanni	M	VU			x		x
Stichopus horrens	M	DD		x		x	x
Stichopus quadrifasciatus	M	DD			x	x	
Stichopus ocellatus	M	DD		x	x		
Stichopus sp. 1	M	IU	x	x	x		x
Stichopus sp. 2	M	IU	x	x	x		x
Stichopus vastus	L	LC				x	x
Thelenota ananas	H	EN	x				x
Thelenota anax	M	DD	x	x	x		x
Total: 37 sea cucumber species			27	21	28	9	31

Note: *H – High, M – Medium, L – Low, VL – Very Low
*EN – Endangered, VU – Vulnerable, DD – Data deficient, LC – Least Concern, IU – Unidentified, NA – No Assessment

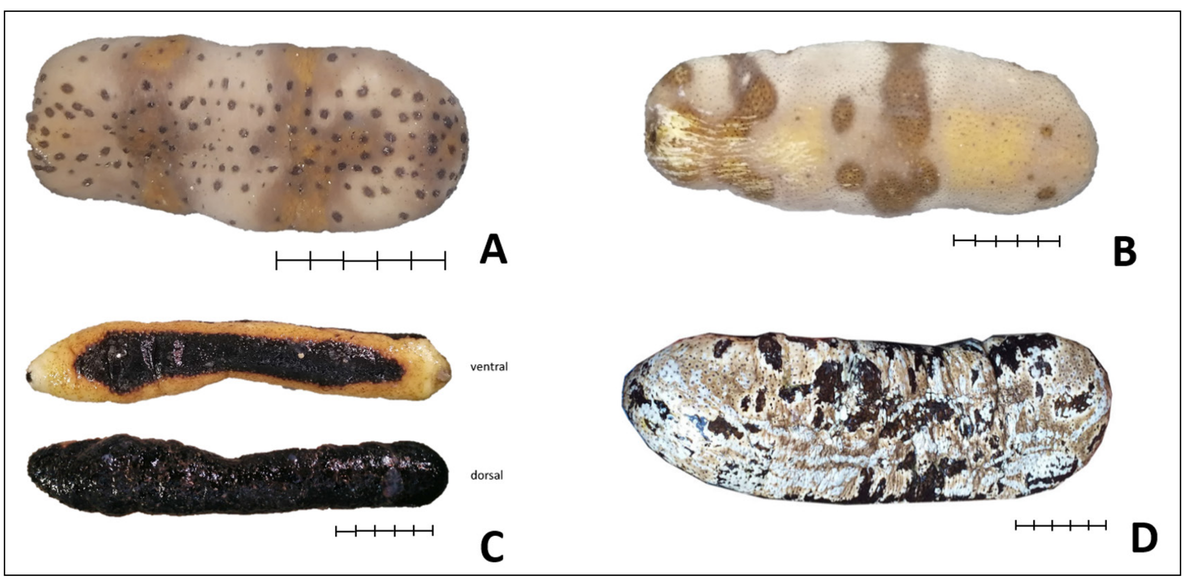

Figure 2. Four uncommon sea cucumber species were observed in the catch landings. *Bohadschia argus* x *vitiensis* (A), *Bohadschia* sp. 1 (B), and *Holothuria edulis* "yellow variant" (C) were recorded in Sta. Cruz, Davao del Sur, while *Holothuria lessoni "blotchy variant"* (D) in Olutanga, Zamboanga del Sur. Bar = 5 cm.

For the pooled percentage composition, *A. echinites* is the most collected species, comprising 26% of the total catches, followed by *S. horrens* (24%) and *B. marmorata* (18%) (Figure 3). The high-valued species, *Holothuria scabra,* ranks fourth, and another *Holothuria* species (locally known as *choco brown*) comes fifth.

Catch landing surveys revealed that the top five commercially gathered species across five municipalities varied and belonged to four genera: *Holothuria, Stichopus, Actinopyga,* and *Bohadschia* (Figure 4). They are determined based on the highest percentage composition of sea cucumber species in each station. The chalky sea cucumber, *B. marmorata,* occurred in the top catches in all sites, followed by *H. scabra* in four and *A. echinites* in three sites.

Three top commercially exploited species across the five municipalities are of high value (6-143 USD/Kg *beche-de-mer*), namely: *A. lecanora, H. scabra*, and *S. herrmanni,* while eight species are of medium value (9-76 USD/Kg) (Figure 4, Table 1). The remaining top sea cucumbers, *H. atra, H. pardalis, and H. gracilis,* are low-valued (2-11 USD/Kg). The sandfish, *H. scabra,* is the most expensive species in the catch and can reach up to 123.02 USD (~7,000 PHP) per kilogram of the XL beche-de-mer (Arriesgado et al. 2022a).

3.2 Fishing efforts

Table 2 characterizes the fishing effort applied in sea cucumber resources based on catch landing from five municipalities. Olutanga recorded the highest number (182) of active sea cucumber collectors across sampling sites, while Barobo had the least (38 gatherers). Collectors usually gather sea cucumbers 5-29 days a month, with Barobo collectors having the highest frequency of days. The daily catch per unit of effort of sea cucumber collectors ranges from 1.9 to 7 kg/day, with the highest CPUE observed in Bongao and the lowest in Barobo. Bongao still recorded the highest mean gross income from sea cucumber catches at 250 PHP fisher^{-1} day^{-1}, while Barobo had the lowest at 80 PHP fisher^{-1} day^{-1}.

3.3 Market value and conservation status

Half of the catches comprised medium-valued species (51%), followed by Low-Value Species (18%) and High-Value Species (13%) (Fig. 5, Table 1). Some very low-value sea cucumber catches were sold for local consumption in the local market as pickled delicacies.

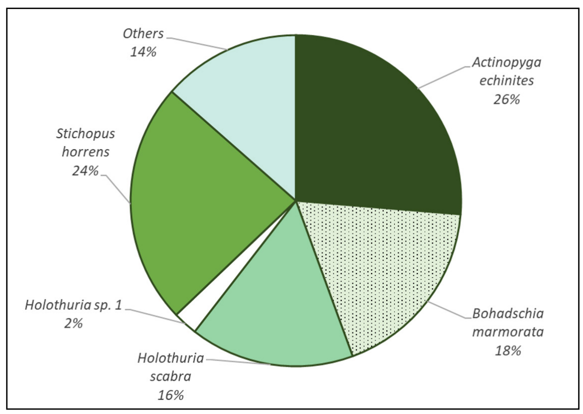

Figure 3. Composition of the top five commercially gathered sea cucumber species across five municipalities based on catch landings

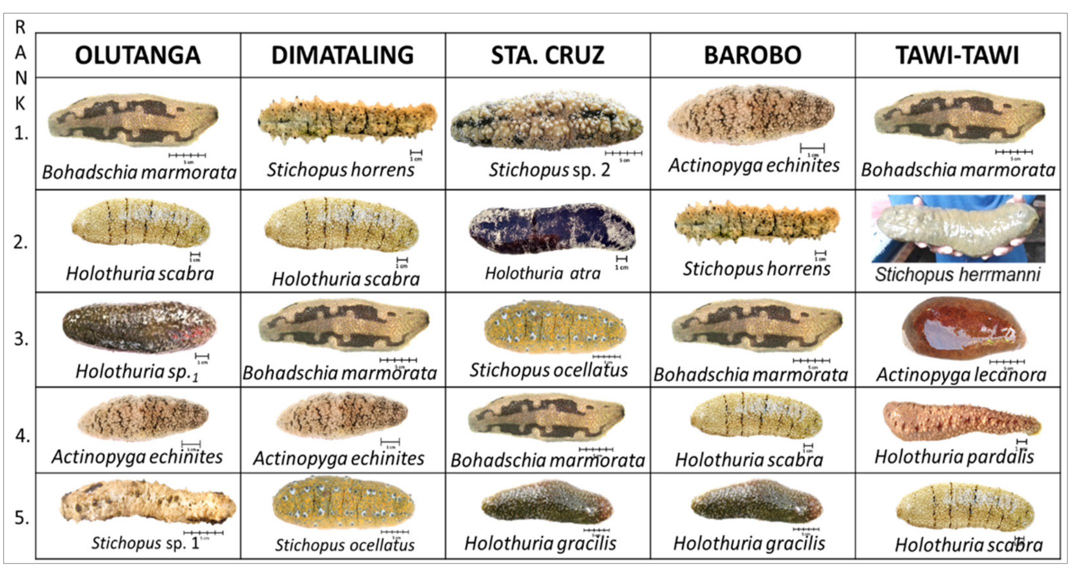

Figure 4. Top five commercially gathered sea cucumber species in five municipalities based on catch landing.

Table 2. Sea cucumber fisheries characterization in five stations across Mindanao based on actual catch landings.

Variables	Dimataling, ZDS	Olutanga, ZSP	Bongao, TW	Barobo, SDS	Sta Cruz, DDS	Total
Traded species	21	27	31	9	28	37
Total # of collectors	90	320	82	45	180	733
Active collectors or fishers	90	182	45	38	65	436
Average fishing days	15	23	23	27	14	
CPUE (kg/day)	6.5	2.3	7	1.9	2.8	
Mean gross income (PHP) fisher-1 day-1	95	285	250	80	120	
Annual production estimates (MT)	101.79	113.02	85.05	22.96	29.48	352.31

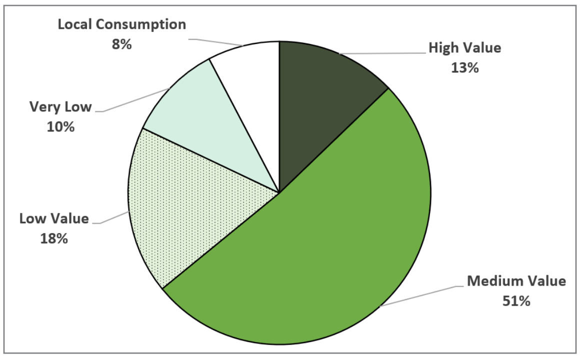

Figure 5. Pooled percentage composition of the market value of the traded sea cucumbers in the five sampling municipalities. High value: 6-143 USD/Kg *beche-de-mer*, Medium Value: 9-76 USD/Kg, Low Value: 2-11 USD/Kg, Very Low Value: 2-5 USD/Kg, Local consumption: <2 USD/glass. Exchange rate: 55 PHP = 1 USD.

For the conservation status, four sea cucumber species in the catch are listed as endangered based on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species, namely, *Holothuria lessoni, H. scabra, H. whitmaei, and Thelenota ananas* (Table 1). Four species are also listed as vulnerable, namely *A. echinites, A. miliaris, H. fuscogilva* and *S. herrmanni*. The status of the remaining sea cucumbers is either data deficient, least concerned, no assessment, or unidentified, particularly for unidentified species.

3.4 Production estimates

Annual harvest production estimates from five municipalities would yield 352.31 MT of fresh sea cucumbers or an average of 70.46 tons for every municipality (Table 2). Assuming a remaining dry weight of 8.5% after processing (based on mean samples of different species dried by traders), the production estimates from Mindanao would translate to approximately 180 metric tons of stone-dried sea cucumbers annually.

4. DISCUSSION

4.1 Species composition, richness, and top catches

The sea cucumber fishery has been a valuable source of income for over 1,000 years in the Indo-Pacific region (Asha and Muthiah 2007). A recent report revealed that 84 sea cucumber species are commonly and opportunistically exploited worldwide, often as bycatch (Purcell et al. 2023). In the Philippines, it has been part of the livelihood of coastal fishers since the late eighteenth century (Choo 2008), with 47 species recorded in Mindanao (Arriesgado et al. 2022a). In the current study, only 37 species belonging to the families Holothuriidae and Stichopodidae were commercially exploited, with Bongao, Tawi-Tawi, recording the highest number of traded species. Tawi-Tawi, located at the Southernmost tip of the Philippines, is renowned for its rich marine resources and is one of the sandfish collection hotspots (Ajik et al. 2021), thanks to its unique geographical location and current systems. Additionally, the Badjao tribe is the dominant group in the province (Usman and Baconguis 2016). They are known for their ability to dive for longer periods, enabling them to expand their fishing grounds to higher depths and gather sea cucumbers.

On the other hand, the lowest-traded species is in Barobo, Surigao del Sur. Most gatherers in Barobo are intertidal and reef gleaners, which limits the abundance and diversity of sea cucumbers in their catches. Studies have shown that the diversity, abundance, and sizes of commercial sea cucumbers have been reducedt in shallow areas due to intense fishing pressure under an open-access regime (Anderson et al. 2011; De Guzman and Quiñones 2021; Arriesgado et al. 2022b; Sornito et al. 2022a, 2022b). That is why gatherers usually scoured deeper areas to collect larger, higher-valued species (Choo 2008).

Furthermore, the presence of four uncommon species in the catch may indicate that the gatherers had searched other areas beyond their usual fishing grounds. Positively, this occurrence hints that areas within the vicinity, which may still be relatively unexplored, could harbor diverse marine resources. Specifically, Kim et al. (2013) highlighted the complexity of *Bohadschia* species, noting the rarity and challenge of collecting fresh specimens of *Bohadschia* sp. 1 and *B. vitiensis x argus*. Therefore, detecting these species at the sampling stations may represent a novel record for the country.

The catch landing survey revealed that *B. marmorata* occurred in the top five catches in all five municipalities, followed by *H. scabra* in four sites and *A. echinites* in three sites. These three sea cucumbers were commonly found in seagrass beds in shallow areas (Pitogo et al. 2018; Arriesgado et al. 2022b; Sornito et al. 2022a; Purcell et al. 2023). Easy access to these species for harvest in shallow tidal areas, as they are usually exposed, is a possible reason why they occur frequently in catch landing surveys.

The top five catches in each municipality revealed the high frequency of medium and low-value species. Moreover, only three species were recorded as high-valued, namely *H. scabra, A. lecanora,* and *S. herrmanni.* Despite the higher price of the three species in *beche-de-mer,* wet weight is much cheaper, resulting in lower revenue for these gatherers, especially those who directly sell their catches as fresh. Additionally, the high prices do not translate to improved income for coastal fishers, as individual catch sizes remain small and the cost per unit effort is high (Perez and Brown 2012). That is why other forms of livelihood are needed to supplement their earnings, as also suggested by Arriesgado et al. (2022a).

4.2 Fishing efforts

A high number of sea cucumber gatherers were recorded in Olutanga, indicating the high dependency of coastal fishers on the sea cucumber resource. Olutanga is an island, and it explains the high dependence of its inhabitants on fisheries resources, including sea cucumbers. Also, the municipality is located somewhat near Zamboanga City, one of the significant hubs for the export of fishery products in Mindanao. Easy access and proximity to the market enable gatherers and traders to encourage harvesting and consolidating fishery products, including *beche-de-mer.* On the other hand, the lowest number of active gatherers observed in Barobo is attributed to the preference of fishers for fishing. Several reports showed that sea cucumber gatherers are also fishers (those who collect commercial fish such as sardines and round scads, among others), and some were collected as bycatch or when there is a lean catch in fishing (Gajelan-Samson et al. 2011; De Guzman and Quiñones 2021; Arriesgado et al. 2022a).

Despite having only a few active gatherers, Barobo had the most fishing days and the lowest catch per unit effort (CPUE). This may indicate that the high fishing pressure exerted by gatherers in the municipality resulted in lower diversity, market value, and smaller catch sizes, consistent with the studies of Arriesgado et al. (2022b) and Sornito et al. (2022a, 2022b). It also corresponds to the lowest gross sales per fisher. In contrast, the high CPUE of collectors in Bongao and Dimataling implies the abundance of sea cucumber resources in the area. Particularly in Dimataling, the gatherers gather sea cucumbers during spring tides when the lowest low tides occur, indicating less fishing activity, thus resulting in abundant sea cucumbers being harvested (Arriesgado et al. 2022a).

4.3 Market value and conservation status

The highest proportion of medium and low-valued sea cucumbers was observed in the pooled catch from the five municipalities. It suggests that the sea cucumber fisheries at the monitored sites have shifted from high to medium and low value due to overexploitation. In fact, invertebrate fisheries have been experiencing global depletion due to overfishing, largely attributed to the lack of effective management systems and regulations (Anderson et al. 2011; Errikson and Bryne, 2013). Local extinctions have also been observed in certain species across numerous regions worldwide, including the Philippines, due to the lucrative nature of sea cucumber fishing (Baker-Medard and Ohl 2019; Arriesgado et al. 2022). Furthermore, the rarity of the high-valued species increases the prices in the global market, signaling the previously unexploited fisheries to begin supplying the market. This resulted in serial exploitation and the replacement of easy access to high-value species with newly commercialized, less valuable species, following the global trend in sea cucumber fishing (Errikson and Bryne 2013; Rawson and Hoagland 2019). This exploitation may also lead to declining sea cucumber populations, which could trigger the "Allee effect," impairing the reproductive success of the remaining individuals, particularly the breeding adults, as their numbers fall below a critical threshold (Bell et al. 2008). If not addressed, this could further reduce the economic viability of the fishery and potentially lead to its collapse, with adverse consequences for the livelihoods of the coastal communities that depend on it.

The top three most exploited species in the pooled catches from the five municipalities, namely, *A. echinites, S. horrens*, and *B. marmorata*, are all of medium value and are easily observed in shallow areas. *A. echinites* had the highest percentage in the pooled catch composition, commanding a price of 500–1100 PHP/kg (~8–19 USD) *beche-de-mer* in the trading station in Sta. Cruz (Arriesgado et al. 2022a) sold at 63 USD/kg to Chinese stores (Purcell 2014). Jun (2002) stated that *A. echinites* is popular in China as a Shanghai dish, while *S. horrens* is famous in Korea as "samsun" or "samseon," and *H. scabra* is found in Hong Kong and Singapore. Furthermore, *H. scabra,* along with *H. lessoni*, is recognized as the most valuable tropical sea cucumbers in dried seafood markets in China (Purcell 2014).

The three top catches were listed as endangered and vulnerable, based on the IUCN Red List. *H. scabra* is listed as threatened, while *A. echinites* and *S. herrmanni* as endangered (Conand et al. 2014). The high demand for these species in the Chinese markets and their delectable price, especially for *H. scabra* exposes why its wild populations are under grave threat of decline to extinction (Purcell 2014). Sea cucumbers are in a dire state, with 20% of fisheries being depleted and 38% overexploited, particularly in the Indo-Pacific (Purcell et al. 2013). This global status is further exacerbated by several factors, including inadequate resources for collecting essential scientific data for management, weak surveillance and enforcement, insufficient political commitment, and socio-economic pressures on the dependent communities (Rahman and Yusuff 2017). Furthermore, the vicious cycle of supply and demand in the sea cucumber fishery has induced overfishing, especially of the highly valued species, resulting in a global concern about depleted stocks (Perez and Brown 2012).

The exploitation of sea cucumbers in the country is regulated under the Bureau of Fisheries and Aquatic Resources (BFAR) Administrative Circular (AC) No. 248, Series of 2013, which imposes a precautionary size limit of 5 cm for all sea cucumber species. However, this regulation has a notable limitation: it may inadvertently encourage overharvesting of naturally larger sea cucumber species, such as those in the *Thelenota* genus. This discrepancy highlights the need for species-specific size regulations to more effectively manage and conserve the diverse sea cucumber populations. In addition, recently, the collection of three species of teatfish: *H. fuscogilva, H. whitmaei*, and *H. nobilis* was also prohibited (Sotelo 2020). Nevertheless, local policies and management at local scales are very limited and insufficient. Weak enforcement (and compliance) capacity for tropical fisheries is generally observed in low-income countries, such as the Philippines (Purcell et al. 2013). Furthermore, depleted marine resources were observed to be brought by a lack of proper knowledge, effective management, and conservation strategies (Rahman and Yusuff 2017). Without management interventions, species extirpations will be exacerbated at an alarming rate, affecting not just our marine resources but also the livelihoods of coastal fishers and the economic revenue.

4.4 Production estimates

The annual harvest production estimates from five municipalities yield approximately 352.31 metric tons of fresh sea cucumbers, with an estimated 180 metric tons of stone-dried sea cucumbers. In 2021, the Philippines produced 365 metric tons of stone-dried sea cucumbers (DA-BFAR 2021). This suggests that the majority of stone-dried sea cucumber production originates from Mindanao. It further suggests that Mindanao significantly contributes to the catches of the sea cucumber fisheries and the country's revenues. Moreover, it indicates the need for stringent management to sustain the sea cucumber resources in Mindanao.

5. CONCLUSION

The sea cucumber fisheries in Mindanao significantly contribute to the economic revenue of coastal fishers and the country. Commercial sea cucumbers were highly diverse in the catch, particularly in Bongao. Olutanga had the highest number of active gatherers and a diverse range of commercial sea cucumbers, indicating its dependency on sea cucumber gathering. In contrast, Barobo recorded the lowest number of active gatherers, the lowest catch per unit effort (CPUE), and the lowest volume of traded sea cucumbers. This situation may be attributed to the low species diversity in the area and the fact that gatherers primarily operate in shallow waters, which limits their sea cucumber harvesting activities. As a result, these factors likely lead to a reduced gross income from their sea cucumber fishing activities.

The presence of four uncommon species in the catches might indicate that the gatherers had scoured other areas besides their usual fishing grounds. On the positive side, the occurrence of these uncommon species suggests that unexplored areas within the vicinity may still harbor diverse marine resources, underscoring the need to protect and conserve them.

Medium to low-value sea cucumbers were the most commonly observed species in the catches. This suggests that the sea cucumber fisheries in Mindanao may experience a shift from high- to medium- to low-valued species, resulting from overexploitation. Furthermore, the presence of the sea cucumbers listed in the IUCN Red List as "threatened" and "vulnerable" in the catches is alarming. This suggests that, despite their conservation status, these species are still being harvested without sustainable management initiatives.

Local policies and interventions are generally insufficient, weak, and limited in the country, particularly in the remote areas in Mindanao. Therefore, the formulation and vigorous enforcement of management policies on a local scale are necessary to sustain sea cucumber resources. Specifically, implementing species-specific and size-specific regulations and management initiatives, such as aquaculture and restocking programs, is essential—especially for the topmost commercially harvested species. These measures are crucial for sustaining sea cucumber populations and enhancing the economic viability of the country's fisheries.

ACKNOWLEDGEMENTS

The authors sincerely extend their gratitude to the Department of Science and Technology Grants-in-Aid Program (DOST-GIA) through the DOST-Science for Change Program (DOST-S4CP), particularly the NICER for their generous funding support for the projects under the Sea Cucumber Research and Development Center. We also thank the Department of Science and Technology-Philippine Council for Agriculture, Aquatic, and Natural Resources Research and Development (DOST-PCAARRD) for their invaluable role as the project's monitoring agency. Our deepest appreciation goes to Mindanao State University at Naawan for its continuous administrative support and to the five local government units— Olutanga, Zamboanga Sibugay; Bongao, Tawi-Tawi; Barobo, Surigao del Sur; Dimataling, Zamboanga del Sur; and Sta. Cruz, Davao del Sur—for their cooperation and for facilitating the study's implementation in their respective areas. We also extend our heartfelt thanks to the dedicated local enumerators Agustin Pepito, Rosa Leah Zata, Mark Renil Samsuya, Evelyn Boladola, and Josephine Erabono for their invaluable contributions to data collection. Special appreciation is given to our project members, Sir Leemarc Alia, Ma'am Flordeline Cadeliña, and Maria Lyn Magcanta-Mortos, for their unwavering support and assistance throughout the study. Lastly, we are deeply grateful to the two anonymous reviewers for their time, effort, and insightful feedback, which significantly contributed to the improvement of this manuscript. This research is part of the project Fisheries Assessment of Sea Cucumbers in Mindanao under NICER: Sea Cucumber Research and Development Center.

AUTHOR'S CONTRIBUTIONS

Arriesgado EM: Conceptualization, Methodology, Validation, Data Curation, Writing- Review & Editing, Supervision, Project administration, Funding acquisition. **Sornito MB**: Data curation, Writing-Original draft preparation, Writing- Review & Editing, Visualization. **Zalsos JD**: Data Curation, Writing- Review & Editing. **Besoña JF**: Data Curation, Writing- Review & Editing. **Ignacio DB**: Data Curation, Writing- Review & Editing. **Uy WH**: Conceptualization, Methodology, Validation, Writing- Review & Editing, Supervision

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest, including any financial, personal, or other relationships with individuals or organizations within three years of commencing the submitted work that could inappropriately influence or be perceived to influence the work.

ETHICS STATEMENT

No animal or human studies were carried out by the authors.

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