RESEARCH ARTICLE

Status of Sea Cucumber Fisheries in Mindanao: Harnessing Local Knowledge in Determining Diversity and Production Values

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ABSTRACT

Sea cucumber fishery is a significant livelihood in the Philippines; however, overexploitation and inadequate management programs resulted in the decline of various sea cucumber species. This paper describes the current sea cucumber fisheries across 32 municipalities in Mindanao assessed from August 2019 to January 2020 through key informant surveys (KIS) and focus group discussions (FGD). About 47 sea cucumbers were identified from KIS, mostly for export. The high-value *Holothuria scabra* is the most exploited species across Mindanao, but the top catches are mainly composed of low to medium-value species. At least four sea cucumber species were noted by gatherers to have disappeared from some sites during the KIS. The FGDs showed that the sea cucumber fishery is small-scale, involving about 1,922 gatherers from 10 municipalities. Half of them (56%) engage in full-time sea cucumber gathering and employ various methods depending on the location of their collection grounds. Estimates of mean daily sea cucumber catch ranged from 1–7.3 $kg^{-1}gatherer^{-1}day^{-1}$, with the highest catch in Olutanga, Zamboanga Sibugay, and lowest in Laguindingan, Misamis Oriental. Catch per unit effort ranged from 0.2-1.8 $kg^{-1}gatherer^{-1}hr^{-1}$, with the highest catch rate in Dimataling, Zamboanga del Sur, and lowest in Laguindingan. Gatherers often sold their catches as fresh to consolidators or traders. Net incomes from the combined fresh catches ranged from PHP 70–950, with the highest income in Olutanga and the lowest in Laguindingan. Historical trendlines show decreasing catches in all sites over time. Overall, the sea cucumber fishery in Mindanao is rapidly declining and needs urgent management interventions to sustain stocks and livelihoods.

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1. INTRODUCTION

Sea cucumbers are a diverse group of echinoderms that have been valuable sources of livelihood for over 1000 years across the Indo-Pacific region (Asha and Muthiah 2007). They are exported mainly as *beche-de-mer* or *trepang* (referring to the stone-dried body wall) to sustain the demands in the global market (Guzman and Guevara 2002). This high demand drives rapid exploitations expanding worldwide from the Indo-Pacific regions (Bennett and Basurto 2018). With the inclination to collect these resources for traditional food and medicinal purposes, fishing efforts continue to increase, leading to the rapid decline of their natural populations (Toral-Granda and Lovatelli 2007; Purcell et al. 2018). This overexploitation is driving the risk of local extinctions of many sea cucumber species (Gonzalez-Wangüemert et al. 2018), resulting in 16 species registered as "vulnerable" or "endangered" on the IUCN red list (Conand et al. 2014).

Sea cucumber fisheries receive less attention in conservation and management despite their notable

importance in fisherfolks' livelihoods (Hasan 2009). Some countries such as Papua New Guinea (Kinch et al. 2008b), Pacific Island countries and territories (PICTs) (Pakoa and Bertram 2013), and Mexico (Bennet and Basurto 2018) have slowly implemented conservation efforts. In the Philippines, the Bureau of Fisheries and Aquatic Resources (BFAR) issued an Administrative Circular (AC) No. 248, imposing a minimum size limit of 5 cm for traded sea cucumbers. Furthermore, the policy bans the harvesting and trading three species of teatfish, *Holothuria fuscogilva, H. whitmaei*, and *H. nobilis* (Sotelo, 2020), declared by IUCN as either vulnerable or endangered. However, local policies have yet to be formulated and implemented in the major sea cucumber harvesting and trading areas. As a result, unregulated sea cucumber harvesting by small-scale fishers continues, which could lead to the collapse of the local sea cucumber populations (Pitogo et al. 2018) and severe consequences on local livelihoods.

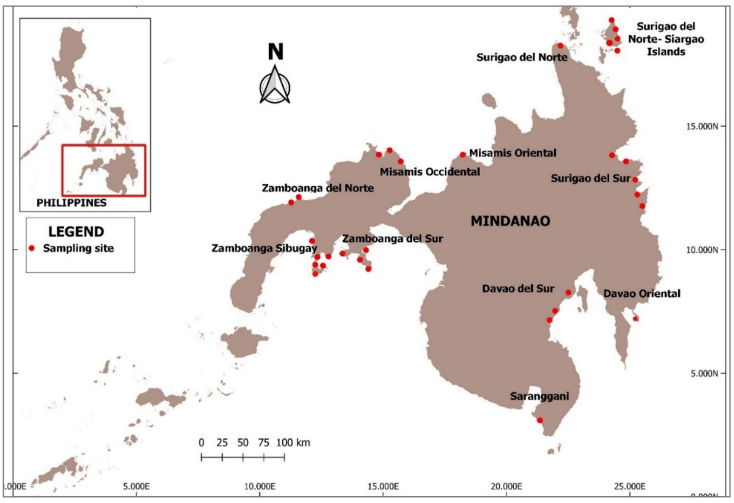
For successful and sustainable fishery management, there is a need to assess the status of the sea cucumber populations and how they change over time (Schroeter et al. 2001). However, the scientific information on sea cucumbers' biology, ecology, and fishery are inadequate (Choo 2008), especially in remote areas with limited human and financial resources from provincial fisheries offices (Kinch et al. 2008b). In addition, the multispecies nature of the fishery adds to the difficulty of management and trade reporting (Kinch et al. 2008a). Therefore, it could be a significant gap in evaluating the production of commercial sea cucumbers towards sustainable fisheries management.

Many sea cucumber studies in the Philippines mainly focus on population assessments (Olavides et al. 2010; Jontila et al. 2014; Romero and Cabansag 2014; Dela Cruz et al. 2015; Pitogo et al. 2018; De Guzman and Quiñones 2021) with limited information on the catch data and fisheries of the exploited sea cucumbers (Schoppe 2000; Gamboa et al. 2004; Olavides et al. 2010), especially in Mindanao (De Guzman and Quiñones 2013). Limited site-specific data are often cited as an obstacle in formulating a management plan (Gamboa et al. 2004). This study was conducted using participatory approaches in obtaining fishery-dependent data to characterize the sea cucumber fishery in 32 sites of Mindanao and is by far the most comprehensive assessment of this resource in the southern Philippines. Baseline information on yields, catch per unit effort, and catch composition in principal sea cucumber gathering grounds are crucial in formulating site-specific management interventions and policies for the sustainable use of the sea cucumber resources in Mindanao, Philippines.

2. MATERIALS AND METHODS

2.1 Sampling sites

This study was conducted in 32 coastal municipalities and cities in 10 provinces of Mindanao, Philippines (Fig. 1) through key informant surveys and focus group discussions. The selection of the sites was based on the presence of sea cucumber fisheries,



Province	Sampling Sites	Province	Sampling Sites
Misamis Oriental	Laguindingan^{F,K}	Saranggani	Glan^{K}
Misamis Occidental	Lopez Jaena^{K}	Surigao del Norte – Siargao Islands	Corregidor^{K}
	Baliangao^{K}		Pilar^{K}
Zamboanga del Norte	Rizal^{K}		Dapa^{K}
	Liloy^{K}		Magsaysay^{K}
	Labason^{K}		Sta. Monica^{K}
Zamboanga Sibugay	Talusan^{K}	Surigao del Norte	Surigao City^{K}
	Alicia^{K}	Surigao del Sur	Lianga^{F,K}
	Mabuhay^{K}		Barobo^{K}
	Olutanga^{F,K}		Hinatuan^{F,K}
	Payao^{K}		Bislig City^{F,K}
	Malanggas^{K}		Lingig^{F,K}
Zamboanga del Sur	Dimataling^{F,K}	Davao Oriental	Mati^{K}
	Pitogo^{F,K}	Davao del Sur	Davao City^{K}
	Vincencio E. Sagun^{K}		Digos City^{K}
	Tabina^{F,K}		Sta. Cruz^{F,K}

Note: Superscript letters showed sampling sites conducting Focus group discussion (F) and Key informant survey (K)

Figure 1. Map of Mindanao showing the sampling sites for the focus group discussion and key informant survey.

as suggested by the provincial fishery authorities. Among the 32 municipalities, 10 sites with active sea cucumber fishing were chosen for profiling the fishery through focus group discussions.

2.2 Survey methodology and data collection

Two survey techniques described below were adopted to determine the occurrence of sea cucumber species and obtain primary data on sea cucumber fisheries from August 2019 to January 2020.

2.2.1 Key informant survey (KIS)

It is a survey approach to obtain information through key informant interviews. Survey questionnaires administered to 10 sea cucumber gatherers and 1-2 traders at each site provided information on the occurrence of sea cucumber species, species extirpation, and other valuable data on sea cucumber populations. Species extirpation or local extinction is an important parameter in determining species and population declines - a type of depletion used by Anderson et al. (2011) to evaluate the status of global sea cucumber stocks. The snowball method was applied, which gathers information by asking the initial informant to suggest other informants for the survey (Ochiewo et al. 2010). Respondents were those with more than five years of experience in sea cucumber gathering and trading and, thus, knew more about the sea cucumber resources and fisheries. The survey questionnaire includes photograph identification sheets or picture guides of common sea cucumbers in the Philippines (compiled using Kerr et al. 2006; Purcell et al. 2012; De Guzman and Quiñones 2013). We used these sheets to identify and validate the presence of sea cucumbers in the respondents' area, their local names, abundance as observed in the wild (ranked by 1 - rare, 2 - adequate, 3 - abundant), habitat type, and their prevailing selling prices (both fresh and dried forms). The presence of other sea cucumbers not listed in the identification sheets was noted and described with the help of the gatherers. Data on prices from the interviews were consolidated; however, only data from municipalities with regional traders or consolidators were used to create the average price lists of the most commercially exploited sea cucumbers.

2.2.2 Focus Group Discussion (FGD)

It is a highly popular participatory approach to obtaining fishery information. A set of open-ended questions were used to prompt 10-15 sea cucumber gatherers into free discussions on the status of the fishery. This included important information on fishing methods, catch per unit effort (CPUE), seasonal calendar, historical trendlines, and issues and concerns in the sea cucumber fishery.

All collected data were transcribed and analyzed in Microsoft Excel 2016. Also known as catch rates, CPUE values were estimated using the formula (Sparre and Venema 1992):

$$(a)\ CPUE = \Sigma C_i / \Sigma f_i$$

Where C_i = catch (in kg) and f_i = fishing effort in one unit of operation (i.e., by each gatherer in one day or one hour). Mean CPUE is then calculated by dividing the sum of C_i and f_i of all gatherers and comparing across sites or municipalities.

3. Results

3.1 Sea cucumber occurrences, distribution, and extirpation

Consolidated data from KIS showed that at least 47 sea cucumber species identified by the gatherers still occur and are present in the catches across the 32 municipalities (Table 1). These sea cucumbers were often gathered for local consumption as food, but in many sites, the collected sea cucumbers were intended for export. The highest number of species (46 species) was recorded in Hinatuan, Surigao del Sur, Olutanga, Zamboanga Sibugay, and Baliangao, Misamis Occidental, and the lowest (16 species) in Malanggas, Zamboanga del Sur (Table 2). Results of KIS suggest that species extirpations or local extinctions of certain sea cucumbers may have occurred in some areas. Four sea cucumber species, *Actinopyga lecanora, Stichopus chloronotus, S. vastus,* and *Thelenota rubralineata,* that the gatherers in some municipalities declared to be present in the catches about 10 years ago were no longer observed today (Table 3).

Figure 2 shows the distribution map of the top five most exploited sea cucumbers pooled by the gatherers across 10 sampling sites in Mindanao. The most widely gathered species is *Holothuria scabra*, a high-value species in the trepang trade that occurs in eight out of 10 sites where FGDs were conducted. It is followed by the medium-value *Actinopyga echinites* and *Stichopus horrens* found in seven FGD sites. Other sea cucumber species, such as *H. fuscocinerea, H. hilla,* and *H. rigida* are also highly exploited but gathered only for local consumption

Table 2. Number of sea cucumber species identified by sea cucumber gatherers with their market category across 32 municipalities in Mindanao.

Province	Sampling sites	Number of sea cucumber species	For exports	Local consumption	Home consumption	Not exploited
Misamis Oriental	Laguindingan	37		37		
Misamis Occidental	Lopez Jaena	33	17	3	1	12
	Baliangao	46		35	3	9
Zamboanga del Norte	Rizal	35	9	1	3	22
	Liloy	35	0	0	19	16
	Labason	43	43	0	0	1
Zamboanga Sibugay	Talusan	43	35	0	4	4
	Alicia	39	24	0	3	12
	Mabuhay	45	45			
	Olutanga	46	40	0	5	1
	Payao	43	29	0	7	7
Zamboanga del Sur	Malanggas	16	10	0	1	5
	Dimataling	45	36	2	3	4
	Pitogo	44	36	1	2	5
	Vincensio E. Sagun	37				37
	Tabina	45	30	7	3	5
Saranggani	Glan	35	18	2	4	11
Surigao del Norte (Siargao Islands)	Corregidor	44				44
	Pilar	43				43
	Dapa	39	30	0	5	4
	Magsaysay	34				34
	Sta Monica	37				37
Surigao del Norte	Surigao City	40	35	0	1	4
Surigao del Sur	Lianga	41	37	0	2	2
	Barobo	34	33	0	0	1
	Hinatuan	46	31	4	3	8
	Bislig	45	25	1	2	14
	Lingig	39	19	0	3	17
Davao Oriental	Mati	38				38
	Davao City	30	30			
Davao del Sur	Digos	35	31	0	0	4
	Sta. Cruz	44	38	4	2	0

as a pickled delicacy. Highly valuable sea cucumbers are mainly sold in the trepang trade, and only one or two pieces, especially damaged ones, are retained for household consumption.

3.2 Fishing effort and practices

FGD conducted in the 10 municipalities revealed that about 1,922 fishers engaged in sea cucumber gathering, where 1,075 gatherers (56%) were involved in a full-time capacity while 847 (44%)

Table 3. Sea cucumber species that were present 10 years ago but are no longer observed at present in certain sites (*) (Data source: Key informant surveys in 32 municipalities).

Sea cucumber species	Olutanga	Payao	Malanggas	Tabina	Dapa
Actinopyga lecanora			*		
Stichopus chloronotus	*			*	
Stichopus vastus		*			
Thelenota rubralineata					*

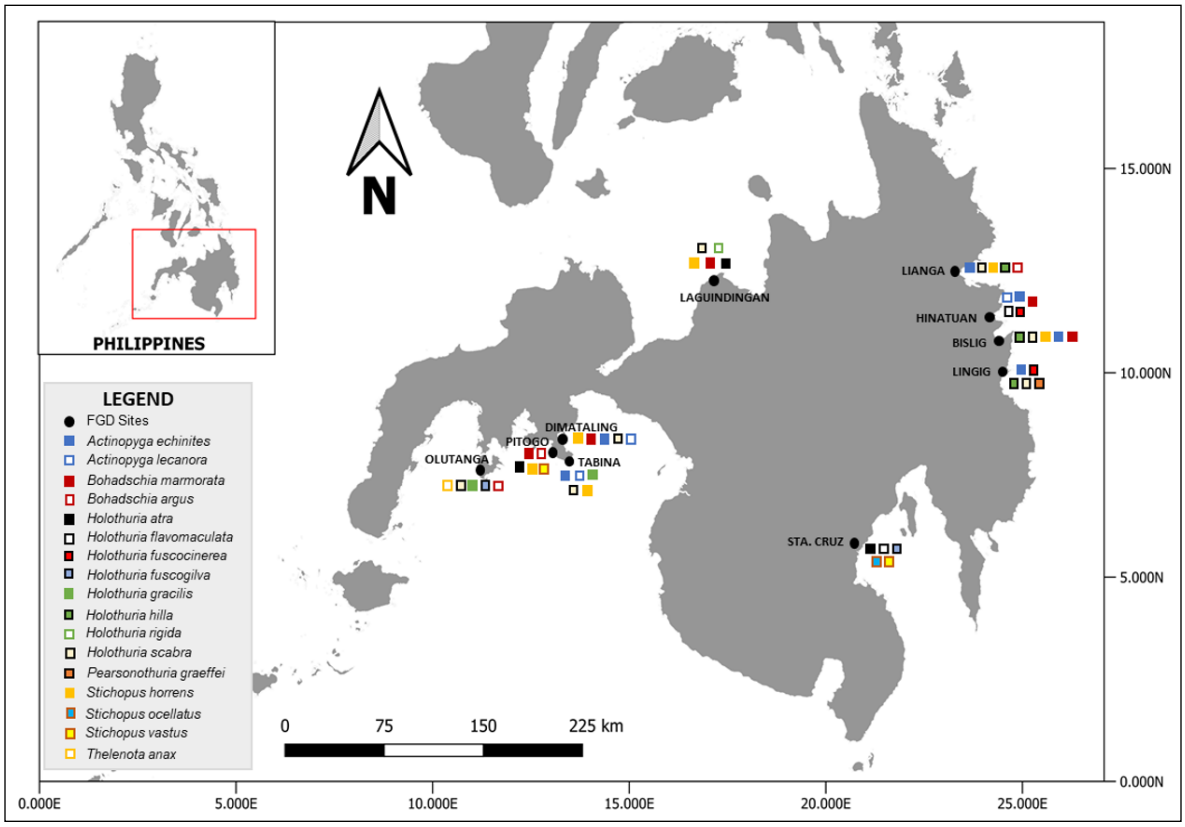


Figure 2. Distribution map of the top five most exploited sea cucumber species in selected sites in Mindanao (*Data source: FGD in 10 municipalities*).

gathered sea cucumbers as a part-time occupation. The highest number of full-time sea cucumber gatherers (N = 350) was recorded in Lingig, Surigao del Sur. At the same time, Bislig City, Surigao del Sur, had the highest number of part-time gatherers (N = 227) (Figure 3). Most sampling sites had a mix of full-time and part-time sea cucumber gatherers. Only gatherers in Olutanga were engaged solely in full-time sea cucumber collection, while those in Hinatuan were all part-time gatherers.

Sea cucumber gatherers mainly used three harvesting methods: gleaning, skin diving, and compressor diving (Figure 4). Gleaning and skin diving are the most common methods, while a tiny proportion of sea cucumber gatherers (8.69%) engaged in diving with the aid of compressors, or popularly called *hookah* diving, particularly in Olutanga and Sta. Cruz, Davao del Sur. Sea cucumber gatherers used non-motorized or motorized boats, while some merely walked and gleaned on the reef flats (Figure 5). Most gleaners spent 3–5 hours collecting sea cucumbers each day and a mean of 17 days each month. However, sea cucumber gatherers who practice skin diving and compressor fishing could spend 5–12 hours, preferably at night, as many of these organisms are nocturnal.

3.3 Daily landed catch and CPUE

The estimated daily landed catch and catch per unit effort (CPUE) in the sea cucumber fisheries

of Mindanao varied among the 10 FGD sites (Figure 6). The mean daily catch of each sea cucumber gatherer ranged from 1–7.3 kg day^{-1} (9–60 individuals), with the highest in Olutanga and the lowest in Laguindingan, Misamis Oriental (Figure 6). Furthermore, the highest mean CPUE by each gatherer was recorded in Dimataling, Zamboanga del Sur, with 1.8 kg gatherer^{-1} hr^{-1} (~15 individuals), and the lowest was also in Laguindingan with 0.2 kg gatherer^{-1} hr^{-1} (~3 individuals).

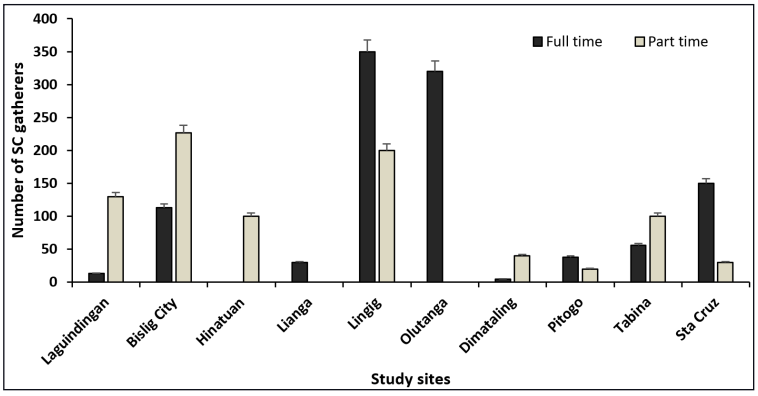


Figure 3. Comparative profile of sea cucumbers in 10 coastal municipalities of Mindanao based on focus group discussions.

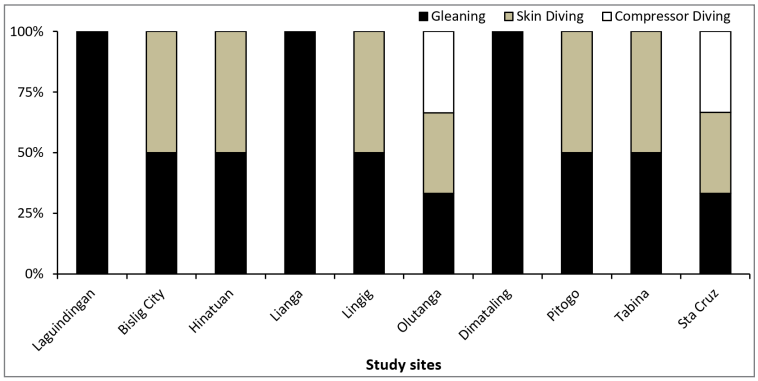


Figure 4. Comparative proportion of the sea cucumber gatherers using various methods in the 10 coastal municipalities of Mindanao obtained from FGD in each site.

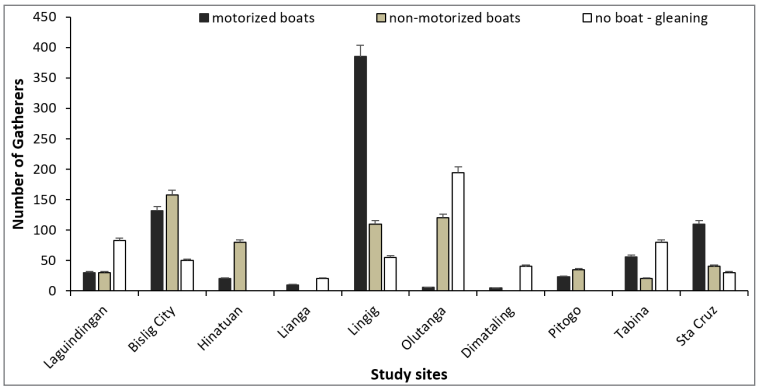


Figure 5. Comparative profile of boat- and no-boat-based sea cucumber gathering in 10 selected coastal municipalities of Mindanao based on FGDs.

3.4 Selling price, gross revenues, and net income

Gatherers often sold their catches as fresh to intermediaries (or consolidators) who are also processors and traded sea cucumbers as *beche-de-mer* to exporters. The buying prices of fresh sea cucumbers vary between selected trading centers, but Dimataling had the cheapest price (Table 4). The white teatfish, *H. fuscogilva,* commanded the highest price for fresh and dried products. Other sea cucumbers, such as *A. lecanora* and larger specimens of *S. horrens* and *S. ocellatus*, also had relatively high prices. Surprisingly, *H. scabra,* a high-value species, had lower prices for a fresh catch in most trading centers, especially in Dimataling. Nevertheless, its dried form was still expensive and could reach up to 7,000 PHP/kg for the high-quality extra-large size.

Sea cucumber gatherers earn gross revenues of PHP 70–1,050 from gathering sea cucumbers daily across 10 FGD sites. Some gatherers did not incur daily expenses for gathering, particularly in Laguindingan and Lianga, where the method used was mainly gleaning. In contrast, daily expenses for boat-based gatherings in other areas could reach PHP 300, primarily for fuel and other miscellaneous expenses such as cigarettes and food. The mean net income for sea cucumber gathering ranged from PHP 70–950, with the highest net revenue in Olutanga and the lowest in Laguindingan (Figure 7).

The FGDs conducted in the 10 municipalities revealed that sea cucumber catches were much higher in the 1970s than present (Figure 8). However, the decreasing trend of catch started in the 1980s and continued to decline in 2019–2020, when gatherers in all municipalities could only harvest 1–5 kg of fresh sea cucumbers in a day.

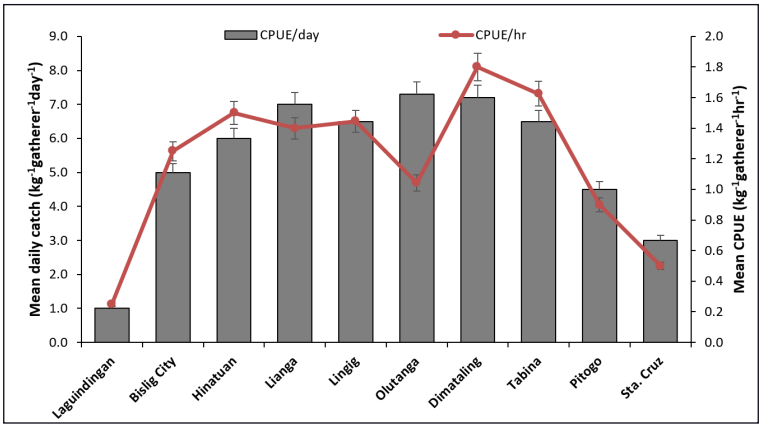


Figure 6. The estimated mean catch per unit effort (CPUE) is expressed as the number of sea cucumbers caught per day of fishing (bar) and per hour of fishing (line) across 10 study sites.

Table 4. Buying prices (in Philippine peso) of fresh and dried forms of selected, highly exploited sea cucumbers declared by selected sea cucumber traders or consolidators and gatherers who responded to the key informant surveys in four selected municipalities of Mindanao.

Scientific name	**Olutanga**		**Dimataling**		**Sta. Cruz**		**Lianga**
	Fresh (ind)	**Dried (kg)**	**Fresh (ind)**	**Dried (kg)**	**Fresh (ind)**	**Dried (kg)**	**Dried (kg)**
Actinopyga echinites	5	1000	2	1900	10	500(S)-1100(L)	500-1100
Actinopyga lecanora	120 (L)	100-4000	50	1800-4000	350/pc if 1kg, 200/pc if 500-900g	1200(S)-2500(M)-5000(L)-7000(XL)	1200-4000
Bohadschia marmorata	15	400	1	1900	15	250(S)-350(M)-700(L)	500-1000
Holothuria atra			1 for 3 pcs.		10	200	100-500
Holothuria fuscogilva	400	1200(S)-2500(M)-5000(L)-7000(XL)	100	5000	350/pc if 1kg, 200/pc if 500-900g, 100/pc below if <500g	1200(S)-2500(M)-5000(L)-7000(XL)	5000
Holothuria gracilis	15	700	7	700	10	700	
Holothuria scabra	30	1600(S)-4200 (M)- 5000(L)	2	1600(S)-4200 (M)- 5000(L)	10	1200(S)-2500(M)-5000(L)-7000(XL)	1500-5000
Pearsonothuria graeffei	10	500	1	200	10	500	150-500
Stichopus horrens	100 (L)	1000 (S)-1700 (M)-2000 (L)	1	1000 (S)-2200(M)-3000(L)	40	1800(S)-2000(M)-4000(L)	500-3000
Stichopus ocellatus			3	1000 (S)-2200(M)-3000(L)	100	1800(S)-2000(M)-4000(L)	
Thelenota anax	30	800	20	900	50	400-1000	300

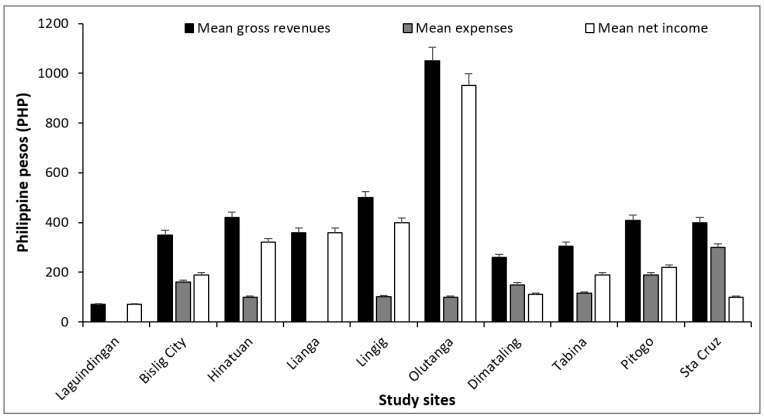


Figure 7. Mean gross revenues, expenses, and net income of sea cucumber gatherers in selected sites in Mindanao estimated from consolidated KIS results.

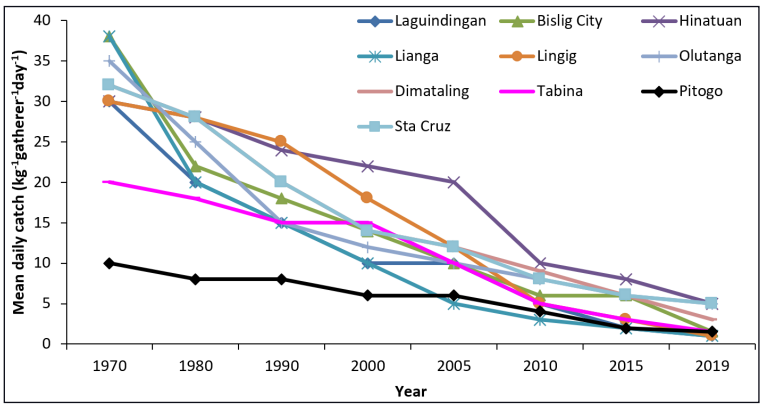


Figure 8. General historical catch trends of sea cucumbers in selected areas of Mindanao based as declared by FGD participants.

4. DISCUSSION

4.1 Sea cucumber species occurrence, distribution, and extirpations

This study identified 47 sea cucumber species across Mindanao, higher than those mentioned in earlier reports, namely 36 species in five sites in northeastern and western Mindanao (De Guzman and Quiñones 2021), 22 species in five principal sea cucumber grounds in Mindanao (Arriesgado et al. 2022), 21 species in Sarangani Bay (Pitogo et al. 2018), and slightly higher than the 45 species in Samar and Leyte (De la Cruz et al. 2015). The high number of species identified in the study is due to more sampling sites covered compared to past assessments. Furthermore, the study included deep-water species collected by skin and compressor diving practiced by some fishers in many sites. The use of FGD and KIS surveys also covered a broader range of species compared to the other studies where species identification was based on field assessment surveys (Pitogo et al. 2018; Arriesgado et al. 2022).

Sea cucumber fisheries have been reported to be overexploited, with 81% of the population declining in many countries, and at least one species was locally extinct in Egypt, Indonesia, and Malaysia (Anderson et al. 2011). This study has indicated that species extirpations in sea cucumbers may have occurred in some areas in Mindanao. At least four species may have disappeared locally, namely, *A. lecanora, S. chloronotus, S. vastus,* and *T. rubralineata*. According to gatherers in Zamboanga del Sur, Zamboanga Sibugay, and Surigao del Sur, these four species were once observed in their coastal waters, primarily in shallow areas. However, they cannot be found anymore at present. They added that the disappearances might be due to overharvesting, especially since some species fetch high prices in the export trade. For example, *S. chloronotus* commands about USD 60 kg^{-1} when traded (Purcell et al. 2012). Another reason for the disappearance might be habitat shift, where these species may have moved to deeper waters, thus making it difficult for shallow-water gatherers to see them. This would explain why some of these species are still gathered by compressor fishers capable of reaching

deeper areas. Sea cucumbers have a slow recovery rate; thus, a significant population decline negatively affects the equilibrium in the marine environment and the coastal communities that depend on it (Friedman et al. 2008).

The top five most exploited sea cucumbers varied across the 10 coastal municipalities, but the high-value *H. scabra* is variably the most exploited species across Mindanao. Generally, the composition of the top five species was mostly medium- to low-value species belonging to the genera *Bohadschia, Holothuria,* and *Stichopus*. In recent years, several studies observed the species and spatial expansion of exploitation of sea cucumber resources (Anderson et al. 2011; Purcell et al. 2013). In the study, the dominance of medium to low-value species in the catch may reflect the scarcity of high-value sea cucumbers in most areas. Our results concur with several reports that the sea cucumber fishery in many areas of the Philippines is mainly composed of low-value and few medium-value species, such as in Maasin City, Southern Leyte (Gajelan-Samson et al. 2011), and some areas in Mindanao (De Guzman and Quiñones 2021; Arriesgado et al. 2022). The shift from a high to a low value of the sea cucumber catch might indicate overfishing these valuable resources (Friedman et al. 2008). Without an effective fishery management program, sea cucumber populations will continue to decline with decreasing market value leading to a possible collapse of the fishery.

4.2 Artisanal sea cucumber fisheries

The sea cucumber fishery in Mindanao is mainly small-scale, employing various collection methods. Gleaning is mostly carried out in shallow reef areas primarily by handpicking, where catches are often low. Depending on their target species, many gatherers scour deeper sites through skin diving or compressor fishing. Schoope (2000) and Purcell et al. (2016) reported that gatherers expand their fishing grounds into deeper waters due to the depletion and low diversity of high-value shallow-water sea cucumbers. Gatherers in Sta. Cruz and Olutanga use compressor or *hookah* diving, already declared an illegal and dangerous practice, to reach deeper areas where larger and more valuable sea cucumbers such as *Holothuria fuscogilva, Thelenota ananas*, *T. anax*, and larger *Stichopus* species are found.

Several studies have documented the use of illegal fishing techniques in sea cucumber gathering in the Philippines, such as in Davao del Sur (Subaldo 2011), some municipalities in Mindanao (De Guzman and Quiñones 2013), Babatngon, Leyte Province (Romero and Cabansag 2014), and in other parts of Leyte and Samar (Dela Cruz et al. 2015). Furthermore, using motorized or non-motorized boats gives the gatherers greater ground coverage for collecting sea cucumbers, access to remote areas, and transport more catches (Friedman et al. 2008). These could result in higher fishing pressure and pose a risk of depletion of the natural stocks if no sustainable fishery management is implemented.

Sea cucumber gathering is a full-time livelihood in many areas of Mindanao, such as Olutanga, Pitogo, Lianga, and Sta. Cruz, where many gatherers continue to rely heavily on sea cucumber harvesting. To earn higher incomes from this fishery, gatherers often sell sea cucumbers as dried products despite the tedious tasks in processing. Sea cucumber gatherers often lack income opportunities, so they continue to depend on these commercial stocks despite their mostly depleted densities (Friedman et al. 2011). However, other study sites like Laguindingan, Bislig City and Hinatuan have mostly part-time sea cucumber gatherers since their primary source of income is fishing or seaweed farming. Some gatherers also have other alternative livelihoods, such as *sari-sari* stores and tricycle or motorcycle driving to supplement their daily incomes from fishing.

Sea cucumber gathering is a tedious and time-consuming livelihood, and unlike fish, fresh catches are difficult to sell for direct consumption as food. Moreover, in areas where gleaning is the primary method of gathering, sea cucumbers are often small, and catches are low, which would explain why these areas have more part-time than full-time gatherers. The results of this study concur with those of Gajelan-Samson et al. (2011), where many fishers in Samar and Leyte collected sea cucumbers as a part-time activity and often as by-catch during fishing operations.

Sea cucumber gathering is influenced by the prevailing weather condition and lunar phases. Gatherers, particularly in Dimataling, prefer the new and full moon lunar phases when the tides are lowest, and sea cucumbers are reportedly more abundant. Sea cucumbers are usually nocturnal and occur in higher densities during the nighttime (Kerr et al. 2006; Arriesgado et al. 2022). Thus, most gathering occurs at night, although daytime gleaning occurs more commonly in some sites such as Laguindingan.

Catch rates varied across study sites, most likely influenced by different factors such as type of fishing vessel, time spent on fishing, gathering methods, fishers' skills and experience, the tidal regime, and the condition of the fishing ground (Ochiewo et al. 2010).

Olutanga had the highest daily catch despite their high number of gatherers (N = 320). They expanded their fishing grounds to the deeper waters and employed various fishing methods from gleaning to compressor diving, thus having broader fishing coverage and longer fishing hours than other sites.

Although gatherers in Dimataling only gleaned in shallow areas, they also had a higher mean catch and the highest CPUE per hour across the 10 study sites. Dimataling has a wide intertidal flat and flourishing seagrass beds. This good habitat condition probably enables the sea cucumber to thrive abundantly despite the fishing pressure. Furthermore, the gatherers in Dimataling only spent 7-14 days fishing in a month, coinciding with the lowest low tides and, therefore, less sea cucumber fishing activity per month. They also have fewer gatherers (N = 45) than other study sites, resulting in lower competition for these resources. The lower fishing intensity or effort allowed more sea cucumbers to "elude" gatherers, which may explain why the gatherers in Dimataling can still harvest abundant sea cucumbers.

Other sampling sites have low CPUE suggesting the low abundance of the sea cucumbers, particularly those where gathering involves only gleaning in shallow areas. Such is the case in Laguindingan, where gatherers observed that high-value species such as *H. scabra* were scarce, and most of their catch was of low value and fit only for local consumption or sold as a pickled dish. A low abundance of high-value species and very low CPUEs indicate that sea cucumber stocks are depleted and that the fishery may be threatened. CPUE values are rough estimates provided by the gatherers during the FGDs, and detailed catch monitoring is needed to validate these estimates. The estimated CPUE of the gatherers from other municipalities in the Philippines was 0.3 kg gatherer^{-1} hr^{-1} in Guiuan, 0.2 kg gatherer^{-1} hr^{-1} in Catbalogan, Samar, 1.37 kg gatherer^{-1} hr^{-1} in Palompon, and 0.61 kg gatherer^{-1} hr^{-1} in Maasin Leyte (Gajelan-Samson et al. 2011).

4.3 Value of sea cucumber fisheries to the local economy

Sea cucumber fisheries provide a significant source of livelihood in Mindanao and other parts of the Philippines, where many are highly dependent on wild harvests. Sea cucumber gatherers sell their catches as fresh or live (either gutted or not gutted) or stone-dried (*beche-de-mer* or *trepang*). Although, some gatherers often sell their catches as fresh to avoid the tedious tasks of sea cucumber processing and obtain money quickly. However, the prices of fresh or live sea cucumbers are lower compared to stone-dried. Another issue is that the trader could dictate the price of each live sea cucumber, such as in Dimataling, where some traders buy fresh sea cucumbers at a lower price than in other areas. Because of the low price, gatherers harvest more sea cucumbers to obtain higher income, pushing even higher rates of exploitation of these diminishing resources. Therefore, other forms of livelihood are needed to supplement their earnings, as suggested by Dolorosa et al. (2017). Across the 10 municipalities, gatherers in Olutanga had the highest average net income since most of their catches are larger and high-value sea cucumbers for the export market. Conversely, gatherers in Laguindingan have the lowest net income, for they only sell their fresh catches in the local markets.

4.3.1 Historical Catch Trends

The sea cucumber fishery has been called a "boom and bust" industry, and the Philippines is considered a "hotspot" in Asia (Choo 2008). Over decades of unmanaged exploitation, sea cucumbers are in a dire state, with almost all the species being harvested, overexploited, and even depleted (Perez and Brown 2012; Eriksson and Bryne 2013). Anderson et al. (2011) reported that 81% of the sea cucumber fisheries globally have already suffered from overfishing. Furthermore, the "rareness" of some high-value species inflated their prices in the Chinese market (Purcell et al. 2018), making them more appealing to sea cucumber gatherers and adding more pressure on these overfished resources.

Sea cucumber gatherers in Mindanao reported low catches with the increasing number of gatherers. The continuous increase in fishing pressure makes the natural recovery and replenishment of sea cucumbers difficult. Currently, several studies reported a decrease in the wild stocks (Eriksson and Bryne 2013), the absence of large sizes (Dolorosa et al. 2017), the shift of the fisheries from high-value to medium and low-value species (Anderson et al. 2010; Friedman et al. 2011), and the classification of several sea cucumbers as "vulnerable" and "threatened" in the IUCN Red List (Conand et al. 2014).

CONCLUSION

The sea cucumber fishery in selected sites of Mindanao is characterized as small-scale with high dependency on the resource among many sea cucumber gatherers as this is their primary source of

income. The current study revealed that sea cucumber stocks might be dwindling, where some species have locally disappeared, characterized by low CPUEs and primarily comprising medium to low-value species. Gatherers are observed to expand their fishing grounds to deeper waters, with some resorting to using illegal methods such as compressor diving. Low incomes earned from sea cucumber gathering and the tendency of some traders or buyers to manipulate selling prices toward cheaper value are worrisome as they tend to push the gatherers toward even higher exploitation to obtain a higher income.

Given the significant contribution of sea cucumber fisheries to the livelihoods of thousands of sea cucumber gatherers across Mindanao, there is an urgent need for an effective management program and policy interventions to prevent further overexploitation of sea cucumber stocks and avert possible fishery collapse. Effective management can enhance incomes derived from sustainable sea cucumber fishing. We recommend detailed assessment and monitoring studies, particularly of the highly exploited species in major gathering grounds, to accurately determine the diversity, population status, and fisheries production values of sea cucumber resources. These data are crucial to formulating local policies and other interventions toward stock recovery and sustainability of sea cucumber fisheries and the social, economic, and ecological benefits they support. Furthermore, we recommend capacity-building activities for collectors and enumerators from local government units (LGUs) or BFAR in correctly identifying sea cucumber species up to the basic monitoring or assessment methods to generate more accurate data on the catches and updated status of the sea cucumber resources.

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AUTHOR'S CONTRIBUTION

Arriesgado EM: Conceptualization, Methodology, Validation, Data Curation, Writing - Review and Editing, Supervision, Project administration, Funding acquisition. **Sornito MB:** Data curation, Writing - Original draft preparation, Writing - Review and Editing, Visualization. **De Guzman AB:** Methodology, Validation, Writing - Reviewing and Editing, Supervision. **Zalsos JD:** Data Curation, Writing - Review and Editing. **Besoña JF:** Data Curation, Writing - Review and Editing. **Alia LC:** Data Curation, Writing - Review and Editing. **Cadeliña FA:** Data Curation, Writing - Review and Editing. **Magcanta-Mortos ML:** Data Curation, Writing - Review and Editing. **Uy WH:** Conceptualization, Methodology, Validation, Writing - Review and Editing, Supervision, Funding acquisition.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

ETHICS STATEMENT

The authors carried out no animal or human studies.

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