CONTRIBUTION 3.5

Commercial Sea Cucumber Stock Assessment to Determine Sustainable Quotas in Belize

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Abstract

The sea cucumber fishery in Belize is small-scale. Sea cucumbers have been legally harvested since the fishery opened in 2009. Then, the Belize Fisheries Department granted a limited number of sea cucumber fishing licenses and permits to sea cucumber exporters. In 2016, new management interventions were made, including size limits, gutted weight, hours of landing, and managed access requirements for sea cucumber fishing. In 2022 regulation amendments included protecting the sea cucumber spawning months, increased size limits, and designated landing sites to be determined by the Fisheries Administrator. In 2022, the fishery didn't open pending a stock assessment completed under this project. The Belize Fisheries Department and the University of Belize conducted the sea cucumber stock assessment in March 2023 in fishing areas 3, 4, 5, 6 and 7, where sea cucumbers are more abundant. In each area, sampling stations were selected using stratified random sampling based on fishery-dependent habitat selection. Twenty-two sampling stations (81 transects) measuring 100 m x 4 m (400 m2) were surveyed. Transects were run perpendicular to the coast to capture depth and habitat contour. Data collected included species, their morphometric measurements, habitat types and depths. Species found were *Holothuria floridana*, *H. mexicana, Isostichopus badionotus, H. thomasi*, and *H. grisea* sea cucumbers. The most abundant were *H. floridana* and *H. mexicana*, followed by *I. badionotus.* Both *H. floridana & H. mexicana*, and *I. badionotus* were most abundant in the Placencia lagoon and islands in front of Placencia. The total abundance for *H. floridana & H. mexicana* was 1,996, 938.22 (biomass 1,249 US tons) and for *I. badionotus*, 47,110.6 kg (biomass 51.9 US tons). Using mortality rates for both species as per the scientific literature, the Schaefer Model provided an MSY of 143,799.56 kg for *H. floridana* and *H. mexicana* and 43,834.42 kg for *I. badionotus*. Therefore, the quota (75% - MSY) was established to be 134,922.73 kg for *H. floridana & H. mexicana* and 34,704.67 for *I. badionotus*.

KEYWORDS: Sea cucumber, stock assessment, MSY, abundance, biomass

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1. INTRODUCTION

Fishing remains one of the most important industries in Belize, contributing significantly to employment and a food source for many Belizeans. In Belize, wild fish stocks include species such as the spiny lobster (*Panulirus argus*), the queen conch (*Strombus gigas*), and high-market-value finfish species (Gillet, 2004). The sea cucumber fishery in Belize is small-scale and has been legally harvested since the fishery was formalized in 2009, although fishers reported having fished sea cucumbers for over 20 years (Rogers, Hamel, & Mercier, 2018). In 2009, the Belize Fisheries Department granted ~80 fishing licenses per year for Donkey Dung (*Holothuria mexicana* and *H. floridana*) to Belizean fishers who exported them through the Rio Grande Fishers Cooperative and three individual Belizean exporters. All sea cucumber fishers must have a sea cucumber fishing license obtained from the Belize Fisheries Department for BZD$75.00 per individual license. All sea cucumber exporters must have an exporting permit from the Belize Fisheries Department. Initially the open season was from January 1 to June 30. This was changed in 2022 to February 1 to July 31 to protect the reproductive season (Statutory Instrument No. 107 of 2022, 2022).

Although only *H. floridana, H. mexicana* and *I. badionotus* are commercially fished in Belize, other commercial species found in Belize include *Astichopus multifidus* (Rogers, Hamel, & Mercier, 2018), *H. impatiens, H. Arenicola, Actinopyga agassizi* and *H. thomasi* (Hendler & Pawson, 2000) but in low abundance. Non-commercial species found in Belize include *H. thomasi, Euapta lappa, Euthyonidiella destichada, Synaptula hydroformis, Leptosynapta imswe, L. nannoplax, L. roseogradia, Synaptula hydroformis, Chiridota rotifera, Ocnus suspectus, Pseudothyone belli, I. macroparentheses, H. cubana*, and *Thyone pseudofusus* (Hendler & Pawson, 2000). *H. floridana* and *H. mexicana* are reported to hybridize (Engstrom, 1980) and are part of multispecies fisheries that often includes H. *floridana, H. thomasi, A. multifidus,* and *I. badionotus* (Purcell et al., 2023).

Sea cucumber fishing is done commercially in several countries, with the catch destined primarily for the Asian markets worldwide (Purcell et al., 2023; Toral-granda, 2008). In Belize, sea cucumber fishing helps alleviate fishing pressure on other commercial species while supplementing income for fishers. The value of these species for fishers is significant, since in 2010-2011 fishers reported that the income from sea cucumber fishing was 154 times more than the minimum wage for Belize ($3.50 BZD) at that time (Rogers et al., 2018). Although sea cucumber fisheries worldwide exhibit a boom and bust history (Purcell et al., 2013), implementing the precautionary principle without stock assessments or other necessary data is critical in ensuring the survival of these species. Stock assessments provide much needed information to make decisions regarding this fishery. Consequently, in March 2023, a national assessment of sea cucumbers was conducted. The objective of this assessment was to determine the abundance of sea cucumber species in four fishing areas in Belize, namely Area 3, which includes the areas near the Cayes around Placencia Peninsula and Placencia Lagoon; Area 5, which includes the Port Honduras Marine Reserve; Area 6, which includes the Turneffe Atolls; Area 7, Light House Reef Atoll; and Area 8, Glover's Reef Atoll (***Figure 1***). Habitats, density, abundance, biomass, and potential yield for commercial sea cucumbers were determined by the results of this study. The results of this assessment were used to determine whether the fishery should open this year and to make recommendations for a total allowable catch if the fishery is opened.

2. METHODS

Sampling stations were selected using the Stratified Random Sampling method, which identified suitable sea cucumber habitats and randomly selected sampling stations within those habitats. A total of 22 sampling stations were conducted with 81 transects of a standard length of 100 m x 4 m (400 m^2). Five sampling stations with 3 transects each were surveyed in each of the 3 atolls: Glovers, Turneffe and Lighthouse. Seven sampling stations (3 transects each) were surveyed at Port Honduras Marine Reserve (PHMR). Two sampling stations (5 transects total) were surveyed in the Placencia Lagoon, and five sampling stations (3 transects each) were surveyed around the islands in front of Placencia (***Figure 1***).

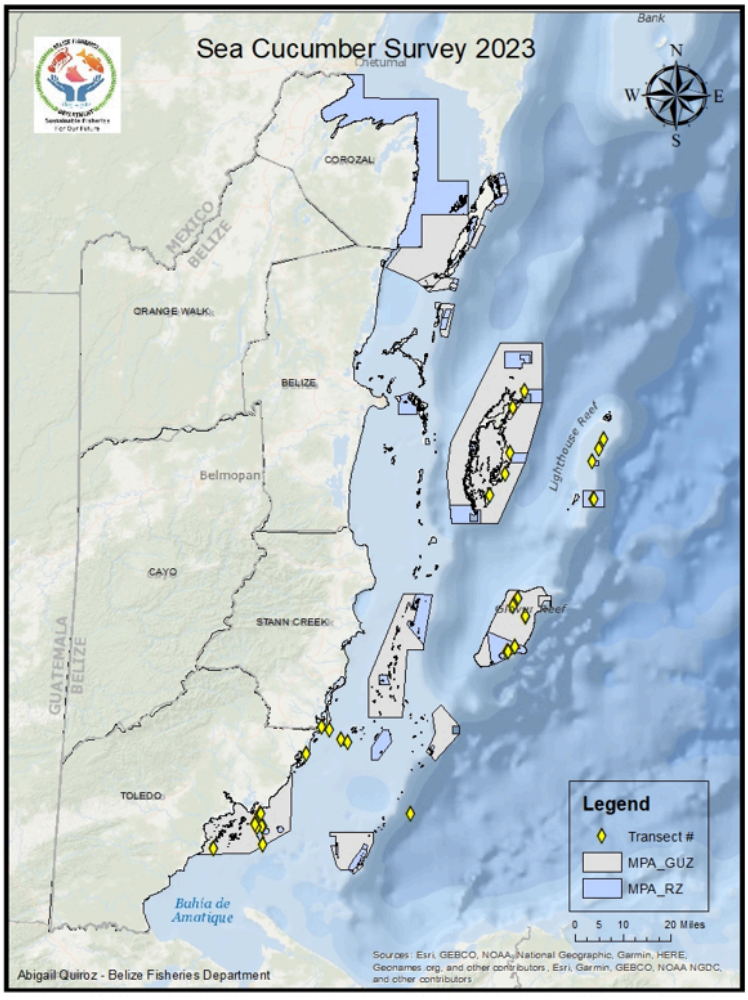

Figure 1. Data collection sites

During the survey, two snorkelers set each transect line in place, followed by two divers in SCUBA gears who conducted the underwater visual survey; each diver surveying 100 m x 2 m on their side of the transect line. Each diver documented all species of sea cucumber encountered, their total length, habitat type, depth and any other observations concerning sea cucumbers. GPS coordinates of each site were recorded using NAD 27 Zone 16 UTM. ArcGIS (Version: 10.4) was used to plot the transects and shape-file layers of coral reef, marine habitat, and marine protected areas demarcation and Lansat of Belize were used to conduct interpolation. The underwater visual survey data collected were digitized in R-Studio, and SPSS to conduct the analysis. The mean density was calculated using the following equations:

Density $\sum \frac{x}{a}$ (1)

Where:

x = number of individuals found

a = sampled area

Mean density $\left[\left(\sum \frac{x}{a}\right) 1 + \left(\sum \frac{x}{a}\right) 2 \ldots + \left(\sum \frac{x}{a}\right) n\right] /n] * A$ (2)

Where,

A = Estimated potential Sea cucumber habitat area.

The potential habitat area was determined based on a combination of habitat maps and local fishermen knowledge.

Biomass/Yield:

The method employed for estimation of potential yield of the stock was based on the formulas of Garcia et al. (1989).

The formulas are as follows:

Fox Model $MSY = MB_c exp^{((Y_c/MB_c)-1)}$ (3)

Schaefer Model $MSY = (MB_c)2/(2MB_C - Y_c)$ (4)

Where,

M = Natural Mortality Rate

B_c = average current (annual) biomass;

Y_c = total current catch

The models also assume that at MSY, Fishing mortality (F) = M and therefore Total mortality (Z) is equal to 2 M. In assessing potential yield, a range of values of M were used. The surplus production models of Schaefer and Fox were used to estimate the Maximum Sustainable Yield (MSY).

- Assumption F = M (0.72 for *H. floridana* and *H. mexicana*; Herrero-Perezrul et al., 1999)
- Previous season reported (2021) = 45359.237 kg (100,000 lbs) for *H. floridana* and *H. mexicana*.

Estimated fishable area = 42,786.14 hectares.

The formula used for the conversion of total length (cm) to wet weight (g) was:

Y= 20.786x (R^2 = 0.9176; Rogers et al., 2018)

Where y is = wet weight and x = total length

The formula used for the conversion of wet weight (g) to gutted weight (g) was:

Y= 0.8036x (R^2= 0.9881; Rogers et al., 2018**)**

Where y = gutted weight and x = wet weight

3. RESULTS

Historical production and quota for the sea cucumber fishery

In 2009 when the sea cucumber fishery was formally established, 70 sea cucumber fishing licenses were granted and a quota of 113,627.52 kg was set, but the production was only 49,895.12 kg (44% of the established quota; ***Figure 2***). In 2010, 70 licenses were granted, a quota of 49,895.12 kg was set, and the production achieved was 48,534.34 kg (97 % of the established quota; Figure 2). In 2011, 70 fishing licenses were granted, a quota of 82,893.12 was set and the production achieved was 70,261.40 kg (85% of the established quota. In 2012, 70 fishing licenses were granted, a quota of 89,300.93 kg was set, and the production achieved was 82,893.94 kg (93% of the established quota; ***Figure 2***). In 2013, 70 fishing licenses were granted, a quota of 181,436.80 kg was set, and the production achieved was 196,369.46 kg (8% above the established quota). In 2014, 80 fishing licenses were granted, a quota of 181,436.80 kg was set, and the production achieved was 158,713.66 kg (87% of the established quota; Figure 2). In 2015, 77 fishing licenses were granted, a quota of 136,077.60 kg was set, and the production achieved was 116,469.73 kg (86% of the established quota; ***Figure 2***). In 2016, 84 fishing licenses were granted, a quota of 136,077.60 kg was set, and the production achieved was 39,647.12 kg (29% of the established quota; ***Figure 2***). The fishery didn't open from 2017 – 2020. In 2021, the fishery was opened to all fishers who had a valid fishing license. The quota was set at 113,398 but the production achieved was 27,665.48 kg (24% of the established quota; ***Figure 2***).

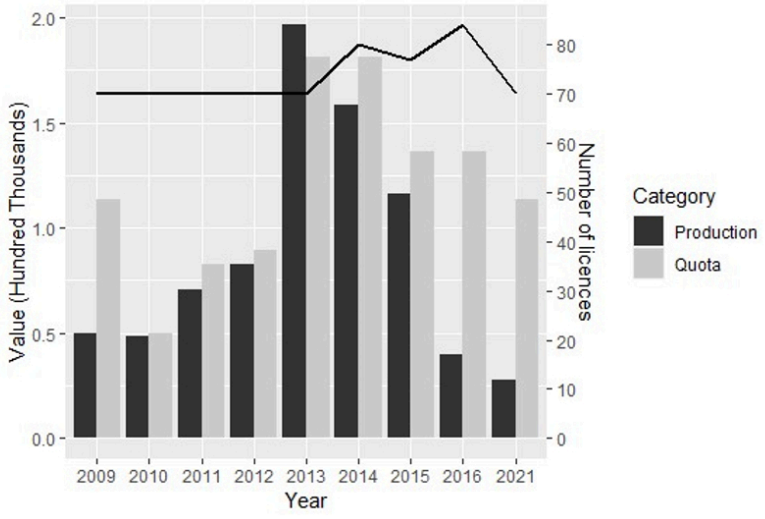

Figure 2. Sea cucumber quota, production and sea cucumber fishing licenses granted from 2009 – 2021. The sea cucumber fishery didn't open from 2017 – 2020 and 2022

Morphometric measurements and population structure for H. floridana & H. mexicana and I. badionotus

The total length of *H. floridana* and *H. mexicana* was 60 - 620 mm (average 269.1 mm) (***Figure 3***). One *H. thomasi* (Tiger Tail sea cucumber) and one *H. grisea* (Harlequin sea cucumber) were found that measured 540 mm and 260 mm, respectively. Total length for *H. floridana* and *H. mexicana* in the Placencia Lagoon was 60 - 330 mm (average 197.5 mm), in PHMR it ranged 220 - 590 mm (331.2 mm), in Turneffe it ranged from 150 - 444 mm (average 288.2 mm) and in Lighthouse it ranged 210 - 620 mm (average 438.6 mm). Total lengths for *H. floridana* and *H. mexicana* in Glover's reef were 180 - 460 mm (average 378 mm). The Tukey SD result confirmed that Turneffe, Glovers, PHMR, and Lighthouse had significantly larger *H. floridana*

and *H. mexicana* sea cucumbers (p = 0.00). The largest *H. floridana* and *H. mexicana* sea cucumbers were found in Lighthouse (620 mm), followed by PHMR (590 mm), Glovers (460 mm), and Turneffe (444 mm). The smallest *H. floridana* and *H. mexicana* sea cucumbers were found in Placencia Lagoon (60 mm). The population structure consisted of individuals measuring between 101 - 200 mm (31%) and individuals measuring between 201 – 300 mm (29%) (Figure 3). *I. badionotus* sea cucumbers were only found near fishing area 3 (islands Infront of Placencia). The total length for three rowed sea cucumber ranged from 160 - 400 mm (average 284.6mm) (see Figure 3). The population structure consisted of individuals measuring 301 – 400 mm (53.8%) and 401 - 500 (38.5%). 92.3% of the total individuals were in between 300 - 400 mm.

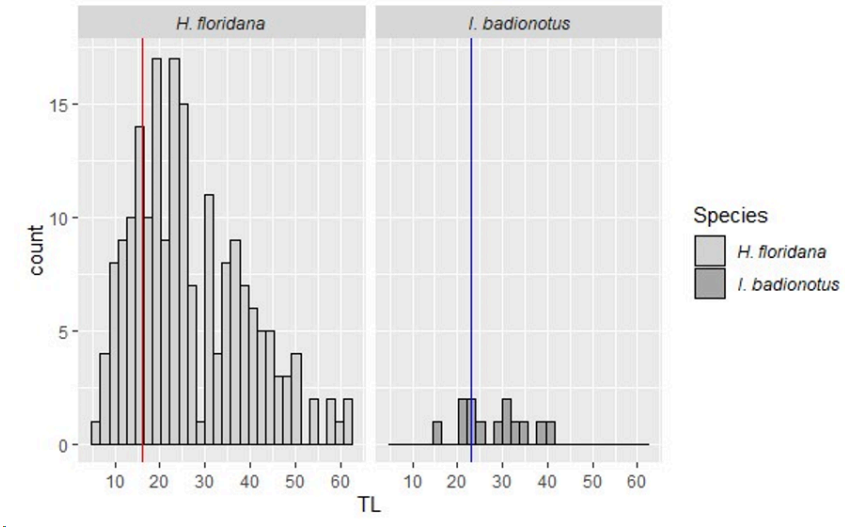

Figure 3. Population structure for H. floridana, H. mexicana (red intercept showing size at sexual maturity, 16 cm) and I badionotus (blue intercept showing size at sexual maturity, 23 cm)

Density by area for all species

The total density for *H. floridana* and *H. mexicana* was calculated at 46.67 individuals per hectare; the highest density was found in Placencia and nearby islands. In Placencia's nearby islands, there were 38.3 individuals per hectare and in the Placencia Lagoon there were 230 individuals per hectare. In the PHMR the individuals were 45 per hectare, 20 in Turneffe and 43.3 in lighthouse and 23.3 in Glovers. The density of *I. badionotus* sea cucumbers surrounding the islands in front of Placencia was 21.7 individuals per hectare. The density of *H. thomasi* sea cucumber was 1.7 individuals per hectare and was only found at Glovers reef and the density for *H. grisea* sea cucumber was 1.7 individuals per hectare and was only found in the islands in front of Placencia.

Abundance by area and site for all species

The most abundance species of sea cucumber species found among all sites was *H. floridana* and *H. mexicana* at 92.8%, with 44% found in Placencia Lagoon and 11% surrounding islands, 12.9% in PHMR, 12.4% in Lighthouse, 6.4% in Glovers Reef, and 5.7% in Turneffe. Of all species, 6.2% were *I. badionotus* sea cucumbers surrounding the islands in front of Placencia (Figure 4). Of all species, 0.5% were *H. thomasi* and were found at Glover's and 0.5% *H. grisea* were found surrounding the islands in front of Placencia (***Figure 4***).

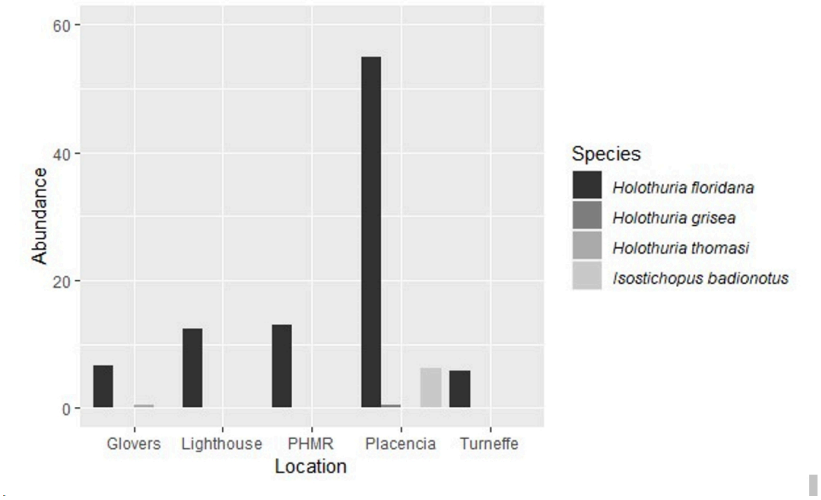

Figure 4. Species abundance in surveyed areas

Total abundance and biomass for H. floridana and H. mexicana

Total abundance for both juvenile and adult *H. floridana* and *H. mexicana* sea cucumbers was calculated to be 1,996,938.22 individuals, which was ~1,133,062.75 kg (2,497,975.8 lbs or 1,249 US tons). Total abundance for adult *H. floridana* and *H. mexicana* sea cucumbers was calculated to be 1102,207.07 individuals, which was ~ 875,923.96 kg (1,931,081.78 lbs or 965.5 US tons). The total dry weight for both juvenile and adult *H. floridana* and *H. mexicana* sea cucumbers was 169,959.4 kg (374,696.4 lbs or 187.3 US tons). The total dry weight for adult *H. floridana* and *H. mexicana* sea cucumber was 131,388.5 kg (289,662.27 lbs or 144.8 US tons).

Total abundance and biomass for I. badionotus

Total abundance for *I. badionotus* sea cucumbers was 183,452.5 individuals which was calculated to be ~47,110.6 kg (103,878.9 lbs or 51.9 US tons). The total dry weight for *I. badionotus* sea cucumbers was 3,768.8 kg (8,310 lbs or 4.2 US tons).

Potential yield for H. floridana and H. mexicana sea cucumber

Using a mean weight of 794.7 g (1.75 lbs) per individual sea cucumber, the estimated average Exploitable Biomass (B) was estimated at 875,923.96 kg (1,931,081.78 lbs) wet weight. Therefore, the total exploitable biomass was 115,557.33 kg (254,760.30 lbs) gutted weight. The potential yield of total sea cucumber meat was estimated using two surplus production models. The estimated Maximum Sustainable Yield (MSY) using the Schaefer Model was 143799.56 kg (317,023.77 lbs) wet weight and Fox Model was 114,883.81 kg (253,275.45 lbs) wet weight. Therefore, the total allowable catch (quota) using the Schaefer model is 189,956.59 lbs and 175,087.06 lbs under the Fox model.

The potential yield for *I. badionotus* was not estimated because this species' catch data is unavailable.

4. DISCUSSION

At the start of the sea cucumber fishery in 2009, fishers were relatively new to the species, therefore, the production was much less than the set quota. As fishers learned more about the species, production gradually increased. In successive years, the results of stock assessments by the Belize Fisheries Department determined the quota. In 2016, production was lower than the quota, due to exporters not purchasing sea cucumbers because of the significant drop in price at the external markets. Additionally, the bigger exporters such as the Fishing cooperatives preferred to purchase Lobster and Conch which are easier to process than the sea cucumber. The fishery was closed from 2017-2020 since the 2017 stock assessments showed declining stocks. To provide much needed income to fishers resulting from income loss during the COVID-19 pandemic, the sea cucumber fishery was reopened in 2021 to all fishers who had a valid fishing license. The production was much lower than the set quota as most fishers were not fishing full time since COVID-19 was still a threat in 2021. Additionally, out of the three (3) exporters only two (2) were purchasing sea cucumber , but very minimal due to the uncertainties which might have resulted from the pandemic.

The results of this study were compared with the last national sea cucumber assessment done in 2018. Only *H. floridana* and *H. mexicana* are compared because data collected in 2018 were for these species primarily. This study showed a 30.29% increase in mean length (267.1 mm) compared to 2018 (205 mm). Additionally, the mean density of 46.67 ind/ha showed a significant increase of 622.4% when compared to 2018 (6.46 ind/ha). A 324.5% increase in abundance was also observed in 2023 (1,996,938.2 individuals) when compared to 2018 (470,397 individuals). This led to a 310.6% increase in biomass in 2023 (876,073.9 kg wet weight) compared to 2018 (213,368.5 kg wet weight). In 2018, the average weight per individual used to calculate biomass was 453.6 g (1 lb); meanwhile, in 2023, an average weight of 567.4 g (1.07 lbs) per individual was used to calculate biomass. The assessment indicated that sea cucumber biomass has improved and can sustain commercial harvest.

The depth of the areas surveyed in this assessment was 0.94 m – 7.6 m (3 – 25 feet). *I. badionotus* sea cucumbers, however, are also found in deeper waters up to 60 m (Hernández-Flores et al., 2015). As observed in other marine species, deep-water sea cucumber stocks will likely contribute to shallower water stock abundance. The interpolation method indicated that the abundance of *H. floridana* and *H. mexicana* was estimated to be 1,996,938.22 individuals translating into a biomass of ~ 875,923.96 kg (1,931,081.78 lbs or 965.5 US tons). It is recommended that *I. badionotus* sea cucumber be commercially harvested once a comprehensive assessment of Area 5 is completed, as they are more abundant in that area. When *I. badionotus* sea cucumbers are exported, it is recommended that the BFD collects export data by species and not as total sea cucumber exports. It is recommended that only *H. floridana* and *H. mexicana* is commercially available for the 2023 season at a Total Allowable Catch of 79,418.2 kg gutted weight. Additionally, the Belize Fisheries Department should continue monitoring sea cucumber landings at designated landing sites. Mandatory submission of catch logs for the assessment of the season's catch per unit effort (CPUE) is also recommended. An assessment of the sea cucumber stock prior to the opening of the season is recommended, preferably in September.

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