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Wild Sea Cucumber Trade in Rural Madagascar : Consequences for Conservation and Human Welfare

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ABSTRACT

Overexploitation of fisheries is a challenge to both marine conservation and human welfare. The trade of sea cucumbers is a multi-billion-dollar market, spanning over 70 countries. Global concern over unsustainable sea cucumber trade led to the inclusion of three species in CITES Appendix II, two of which are found in Madagascar (*Holothuria fuscogilva* and *H. nobilis*). I used 792 structured interviews (2015–2020) to study the intensity of sea cucumber collection and exportation in rural northeastern Madagascar, where 30% of all (terrestrial and aquatic) native species are threatened with extinction. Wild sea cucumber collection was common and increased tenfold during the study; one in five coastal households caught and sold wild sea cucumbers, of which more than half are threatened species, including CITES II restricted *H. nobilis* (Endangered) and *H. fuscogilva* (Vulnerable). Sea cucumber collectors were significantly wealthier and more food secure than other community members. Given both the high collection of threatened and regulated species and high regional food insecurity (58% of households), regulation of threatened species alone may not reduce levels of unsustainable catch.

MONTCLAIR STATE UNIVERSITY

Wild Sea Cucumber Trade in Rural Madagascar: Consequences for Conservation and Human Welfare

by

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INTRODUCTION

Over the last 70 years, the global sea cucumber trade has developed into a multi-billion-dollar market spanning 70 countries (Anderson et al., 2011; Purcell et al., 2012; Zhang et al., 2015; Zamora et al., 2018; Louw & Bűrgener, 2021). The western Central Pacific and Indian oceans produce a third of global dried sea cucumber product, with a market value of $1.95 billion per year (Toral-Granda et al., 2008; Conand, 2017; Tridge, 2020). Most of these sea cucumbers are exported to China, Japan, and other Asia-Pacific nations (Aydın et al., 2011; Bordbar et al., 2011). Sea cucumbers are eaten or used for their immunomodulatory and anti-inflammatory, -microbial, -oxidant, -angiogenic, and -tumoral properties (Smith, 1978; Chen, 2004; Kelly, 2005; Althunibat et al., 2009; Bordbar et al., 2011; Janakiram et al., 2015; Shahabuddin et al., 2015; MSKCC, 2019). Given the high value of these species, global collection rates and trade markets are likely to increase, yet data on wild sea cucumber collection remains sparse for many regions (Conand & Muthiga, 2007; Bordbar et al., 2011).

The sea cucumber trade market includes the collection of threatened species such as the Endangered sandfish (*H. scabra*), golden sandfish (*H. lessoni*), and black teat fish (*H. nobilis*), and Vulnerable hairy blackfish (*Actinopyga miliaris*) and white teat fish (*Holothuria fuscogilva*) (Conand et al., 2013; Hamel et al., 2013; Scarffe, 2020). Many of the threatened sea cucumbers in the genus *Holothuria* have organ tissues which contain anti-inflammatory agents comparable to synthetic counterparts such as aspirin (Smith, 1978). *H. scabra* is sold for such properties, costing 15–385 USD per kg (Purcell, 2014). Their high value has led to overfishing and population decline (Hasan, 2005; Hamel et al., 2013). To mitigate this pressure, aquaculture methods were developed to sustainably grow native sea cucumber species (Toral-Granda et al., 2008; Robinson & Lovatelli, 2015; Shahabuddin, 2015). However, collection continues to rise, putting threatened species within the *Holothuria* and *Actinopyga* genera at risk of extinction (Bruckner et al., 2003; Toral-Granda, 2008).

Population declines in wild sea cucumbers, due to commercial collection, are a potential detriment to marine ecosystems (Schneider et al., 2011; Shahabuddin et al., 2015). Sea cucumbers are essential to the functioning of ecosystems including coral reefs, seagrass beds, and the deep sea (Conand & Muthiga, 2007; Wolkenhauer et al., 2010; Jaeckle & Strathmann, 2013; Purcell et al., 2016a). As bioturbators and deposit feeders, they aerate sediments and digest sediment-associated detritus and bacteria (Conand & Muthiga, 2007; Zamora & Jeffs, 2011; Purcell et al., 2016a; Zamora et al., 2018). Sea cucumber eggs, larvae, and benthic juveniles and adults provide an important source of food for other marine species, including larval fishes and marine mammals (Francour, 1997; Larson et al., 2013). Therefore, reducing overfishing and maintaining sea cucumber populations in areas of high marine biodiversity is a priority for global conservation (Uthicke & Benzie, 2001).

The Indian Ocean is one of the most biodiverse regions in the world, containing 30% of the world's coral reefs and the world's largest estuaries (Wafar et al., 2011). A lack of regulation in collection has led to the decline of many species across the region (Conand & Muthiga, 2007; Shahabuddin, 2015). Concern over declines in threatened sea cucumber species led to the inclusion of three native Indian Ocean species within CITES Appendix II in 2019, necessitating national laws to regulate their trade (Di Simone et al. 2021; Louw & Bűrgener, 2021). In the western Indian Ocean, sea cucumber fisheries have become common and there is evidence of CITES Appendix II species being overfished, possibly due to poor management and knowledge gaps about species ecology, extraction rates, and economic drivers (Bruckner et al., 2003; Eriksson et al., 2012).

Within the Indian Ocean, Madagascar is one of the largest exporters of sea cucumbers (Conand, 2017; Tridge, 2020). The largest global importers of sea cucumbers from Madagascar are Hong Kong, China, Malaysia, Singapore, and Taiwan (Anderson et al., 2011; Pangestuti & Arifin, 2018; Louw & Bűrgener, 2021). In the last decade, Hong Kong reported a global import value of nearly eight million kilograms of sea cucumbers (Conand, 2017). Madagascar is currently the highest valued exporter of sea cucumbers to Hong Kong, followed by Seychelles and Tanzania (Louw & Bűrgener, 2021). There are at least 122 recorded sea cucumber species in the coastal waters of Madagascar, and at least 30 species are commercially collected (Rasolofonirina et al., 2003; Conand & Muthiga, 2007), two of which are protected through CITES Appendix II restrictions. Furthermore, national laws restrict the collection of sea cucumbers with a body length shorter than 11 cm (typical size at sexual maturity), or the sale of processed sea cucumber (dried) less than 8 cm (Arrêté No. 525 of the 5th of February 1975; Arrêté No. 4796/96 of 16th August 1990). However, these restrictions are rarely enforced, and regulations may not sufficiently protect species that reach sexual maturity before 11 cm, such as *H. scabra* (Conand & Muthiga, 2007; Yanti et al., 2020). Some of the most sought-after and expensive species are threatened, including *H. scabra*, *H. fuscogilva*, and *H. nobilis* (Conand, 2008). Approximately 1,620 tons of sea cucumbers are exported from Madagascar yearly, yet only 12% are produced by aquaculture; thus, 88% of exported products are wild caught (Rasolofonirina et al., 2003; Tridge, 2020). Sellers accumulate wild product from multiple small communities where individuals collect sea cucumbers from waters near where they live. The various collected sea cucumber species are combined in regional centers, and then sent to port centers such as Mahajanga, Toamasina (Tamatave), and Antalaha (Sea Rates, 2020).

Understanding the motivation and scale of trade in local rural communities is therefore essential to assess and mitigate regional exploitation (Conand & Muthiga, 2007).

Here I examine the scale of sea cucumber collection for exportation in rural Madagascar over six years (2015–2020). Specifically, I examine the scale of collection for trade, its relative reliance on threatened species, who extracts sea cucumbers and why, and the effects on conservation. This multi-annual assessment of rural sea cucumber extraction is a key step toward developing strategies to address the incentives of resource users and mitigate the negative conservation effects of this marine trade product on vulnerable stakeholders.

METHODS

I used extensive structured interviews to examine the extent of sea cucumber collection and its subsequent effects on food security and income by a total of 792 households, and 1,750 individuals aged two weeks to 91 years old, in eight coastal communities over six years (2015–2020) on the Masoala Peninsula of northeastern Madagascar. BJRR, DR, and CB are fluent or native speakers of the local dialect of Betsimisaraka Malagasy, and asked household members about their collection of marine products for food or sale, demographics, diet, health, income, and food security in a one to two-hour interview. All households were surveyed in communities with 50 households or less. In communities with more than 50 households, study households were randomly selected by using a grid system in each village, assigning a number to each household in each grid, and selecting a subset of households in all quadrants using a random number array. Individuals provided information about prices in Malagasy Ariary (MGA), and we converted estimates of cash income to United States Dollar (USD) at the conversion rate at the time of data collection (mean US$1.00 = 3,212.02 MGA). All statistical analysis was done using JMP Pro 15.2.

Scale of Sea Cucumber Trade and Reliance on Threatened Species

Households were asked about the quantity and method of capture of 24 different species, that include 14 locally recognized vernacular groups of collected sea cucumbers bought and sold during the prior year (Table 1). Local vernacular names are based on similar external phenotypes across multiple species (Supplementary Materials 1). For example, the local name traiktaira includes four scientific species within two genera, grouped due to similar external coloration and skin type. Participants recalled the number of catches from each vernacular group during the prior year. Of the 24 species collected, eight are threatened with extinction, including *H. scabra*, *H. lessoni, H. nobilis, H. fuscogilva*, and *A. miliaris* (Table 1). To examine the scale of the collection, both the total and mean (± standard deviation) number of sea cucumbers collected per household per year were calculated. Linear regression analysis was used to test whether collection rates significantly increased or decreased over time.

Who Collects Sea Cucumbers and Why

Household members were interviewed to determine who (age and gender), how (the methods and tools used for collection), and how often (frequency), they collect sea cucumbers. To determine the usage of certain tools for sea cucumber collection, a logistic regression was used to predict whether those who purchased condoms, used them for STI/pregnancy prevention or as a method of waterproofing flashlights when collectors extracted sea cucumbers at night. The distance and time traveled by collectors to reach the coast or site in which they entered the water was also asked.

Effects on Human Welfare

To determine if sea cucumber collection improves human livelihoods, I measured three indicators of human welfare: income, food security, and malnutrition. I asked individuals about each type of cash-generation activity they completed to examine the relationship between sea cucumber collection and local income. This included activities like sales, land ownership, and trade. To compare the effect of marine trade on gross domestic product (GDP) among households to regional economic standards, I subdivided all income categories into the gross and percent of total gross domestic product that each income activity provided.

To determine the influence of sea cucumber collection on food security, I used the Coping Strategies Index (CSI) (CARE, 2008) to measure changes in feelings, perceptions, and behaviors during the prior week in response to insufficient access to food (coping strategies). CSI weighted values were determined based on the qualitative perception of the severity of each coping strategy in each community (categorically ranked on a scale of 1–4). A CSI score of 0 reflects a household which perceives itself as food secure and higher CSI scores reflect greater perceived food insecurity. I defined a food insecure household as any household that could not access adequate food to feed their family for one or more days during the prior week.

To identify signs of malnutrition, I used WHO and CDC guidelines to determine whether individuals were stunted, underweight, wasted, had severely low BMIs (Body Mass Indices), MUACs (mid-upper-arm circumferences) or were anemic (WHO, 2006, 2012; Centers for Disease Control and Prevention, 2012).

Potential Effects on Conservation

To determine conservation status of each local vernacular name, I identified each scientifically named species under the International Union for Conservation of Nature (IUCN)

Redlist. I took the Redlist status of each scientific species within that local vernacular group and converted that status to a 4-point numeric scale (where 4 is Critically Endangered, and 1 is Least Concern). Data deficient species were excluded from these calculations, likely underestimating total risk. I used the mean and standard deviation of the threatened status of all scientific species to indicate the potential threatened status of local vernacular groups. I then calculated means and standard deviations of weights (dried product), as well as average numbers of whole individuals collected over the years. To understand the potential impacts on conservation, I used a two-way T-test to determine if the level of increase in intensity of collection in vulnerable and CITES Appendix II protected species was significant or not.

ETHICS

All research was approved by Human Subjects Institutional Review Boards (Protocols #2010-0595 University of Massachusetts Amherst, #15-2230 Harvard T. H. Chan School of Public Health, and #18-19-1349 Montclair State University) and the Republic of Madagascar and Madagascar National Parks (Permits 111/13, 325/14, 111/15, 228/15, 270/15, 230/16, 105/17, 85/18, 104/19, /MEEF/SG/DGF/DCB.SAPP/SCB or MESupReS/SG/DGRP/PBZT/DIR). We obtained oral informed consent and/or assent from all participants.

RESULTS

Scale of Sea Cucumber Trade and Reliance on Threatened Species

Fishers sold 7,187 kg (9,374 kg fresh weight) of sea cucumbers during the six-year study, and the collection of both overall and individual species increased (Table 2; Fig. 1). From 2015 to 2020, fishers caught a total of 31,873 sea cucumbers, including 57.14% of (8 of the 14) local vernacular groups (Table 1; Supplementary Materials 1). While over a third (38.0%) of catch occurred during the final year of the study alone (Table 2) the number of people that collected sea cucumbers significantly decreased throughout the study (R^2=0.08, χ^2=24.29, p <0.0001). Across all years, each household collected a mean of 48.59±47.58 sea cucumbers (Table 2). Local vernacular groups with a greater mean threatened score, tend to contain individuals that are sold at higher market prices, increasing their value on both economic and conservation scales (Table 1).

How Sea Cucumbers are Collected, Who Collects Them, and Why

The most common method of sea cucumber collection was hand catch using a snorkel and fins to reach the seafloor at night with a flashlight. Members of households snorkeled 8.50±5.84 times per month. These fishers traveled 29.76±20.59 minutes offshore to collect sea cucumbers at a depth of 6.72±3.32 meters. To waterproof flashlights, snorkelers secured them within condoms, which were readily available to purchase at sites. Individuals purchased most condoms (85.7±31.5% per household per year) for snorkeling and few (0.72±3.42%) were used for their intended purpose. The number of condoms purchased for use during sex significantly decreased throughout the study (R^2=0.16, F=13.81 (72,73), p<0.0001). Snorkelers increased their purchase of condoms, for the purpose of waterproofing flashlights, from 40.00±54.77% of condoms purchased per household per month (N=5) in 2015 to 100.00±0.00% (N=22) in 2020.

Sea cucumber collection was an adult (91.78%) male gendered (100.00%) activity. Most (71.23%) fishers snorkeled to earn cash income; only 20.60% snorkeled with the primary intention to feed their household. People who collected sea cucumbers made most of their money from selling other ocean products; sea cucumbers comprised only 35.36% of all income from ocean products. Income from a salaried job did not significantly reduce the likelihood that someone would collect sea cucumbers; in fact, households who collected sea cucumbers contained significantly more predictably salaried household members than those who did not (T(191.5)=3.59, $p=0.0004$; 1.01±0.99 vs. 0.68±0.93 predictably salaried household members). Those collecting sea cucumbers earned less money from ocean products than those who did not (T(183.92)=6.07, $p<0.0001$; $70.57±$108.46USD vs. $10.1±94.99USD [226,666.67±348,366.45MGA vs. 32,480.89±305,111.2MGA]). However ocean products comprised a larger proportion of the overall income of sea cucumber collectors (T(144.70)= 7.33, $p<0.0001$; 13.94±19.69% vs 1.48±7.15% of total income).

While over half (58%) of coastal households were food insecure, those who collected sea cucumbers during the prior year were significantly more food secure than those who did not (T(257.16)=-3.18, $p=0.0017$; 4.83±9.57 vs. 7.88±13.04 weighted CSI score, respectively; Supplementary Materials 2). Deciding to collect sea cucumbers also improved the economic welfare of the households throughout our study. Income from sea cucumber collection is increasing on the Masoala both overall and as a proportion of all money earned from marine products. A quarter of all income earned in 2020 (23.11±33.89%) came from the sale of marine products (Table 3; Fig. 2), and a fifth of this marine-based income (20.60±31.61%) came from the sale of sea cucumbers (Table 4). While overall household income did not increase ($R^2(280)<0.01$, F=2.48, $p=0.12$), the proportion of income from fishing increased ($R^2(280)=0.06$, F=17.33, $p<0.0001$) as did the proportion of fishing income which came from sea cucumbers ($R^2(280)=0.02$, F=7.02, $p=0.009$). This pattern of sea cucumber collectors becoming wealthier than the general population happened for the first time in 2020. Households in 2020 who collected sea cucumbers earned twice as much as those that did not (T(45.19)=1.90, $p=0.03$;

$1,341.68±1,995.14USD [4,310,846.40±6,408,455.30MGA] vs. $693.29±854.66USD [2,226,854±2,745,181MGA]).

Potential Effects on Conservation

The most collected local vernacular groups in 2020 (most recent year of data collection), were traiktaira (including the species *Holothuria pervicax* [LC] and *Stichopus horrens* [DD]), kafaoka (*Actinopyga lecanora* [DD] and *A. miliaris* [VU]), and valonono (*H. fuscogilva* [VU] and *H. nobilis* [EN]) (Table 1, 2). In 2020, traiktaira had the largest collection of fresh weight (2,255 kg) and valonono had the largest in dry weight (1,734 kg). Traiktaira, kafaoka, and valonono collection significantly increased throughout the study ($R^2(279)=0.02$, $F=4.39$, $p=0.04$; $R^2(279)=0.06$, $F=16.66$, $p<0.0001$; $R^2(279)=0.05$, $F=13.84$, $p=0.0002$, respectively; Fig.1). While traiktaira did not include threatened species, it does include Data Deficient species, such as *S. horrens* and *S. monotuberculatus*. Kafaoka includes one threatened species. Valonono, the third most collected group, was collected at a mean of 5.78±7.96 sea cucumbers per household across all years and includes CITES Appendix II threatened species *H. fuscogilva* and *H. nobilis*.

DISCUSSION

Wild sea cucumber collection is high in northeastern Madagascar. A fifth (21%) of coastal households collect more than half (57%) of the locally known variants Sea cucumber collection also significantly increased over the study to meet global demands. Over a third of all catch (38%) occurred in 2020, when each household collected a mean of 120 sea cucumbers (accumulating to more than 12,000 sea cucumbers at our study sites alone) to sell at high prices to regional operators for export to the global market. Despite the increase in sea cucumber exports from the rural northeast, Madagascar and neighboring nations' exports have declined overall (Louw & Bűrgener, 2021). This suggests that an increasing proportion of national exports may be coming from rural collectors near marine biodiversity hotspots, raising conservation concerns.

Threatened, high value species, which have been extirpated from other regions comprise a large proportion of the rural market. A third of all collected species (33%) in the northeast are threatened with extinction, including the Threatened *H. nobilis* and *H. fuscogilva*. Given their high value and subsequently high demand, *H. nobilis* and *H. fuscogilva* have been depleted elsewhere in Madagascar, and *H. fuscogilva* has been extirpated in the nearby nation of Seychelles (Purcell et al., 2012; Purcell, 2014). The diversity of Madagascar's wild sea cucumber species is decreasing (Maharavo, 2009). Yet, continued high demand (Rahman & Yusoff, 2017; Rahman et al., 2020) increases the incentive to collect threatened sea cucumber species despite their low population density. If we wish to decrease the incentives of these collectors, and therefore increase the sustainability of collection, we must understand how sea cucumbers are collected, who collects them, and why.

In a region characterized by high poverty and low food security, sea cucumber collection leads to increased wealth and food security. Those who collected sea cucumbers during the prior year became significantly wealthier and more food secure than those who did not. This is consistent with findings in the southwest of Madagascar and globally, where households depend on collecting sea cucumbers as part of their income (Rasolofonirina et al., 2003; Al-Rashdi & Claereboudt, 2010; Zulfaqar et al., 2016; Purcell et al., 2018). However, these gains are not shared equally amongst men and women; in northeastern Madagascar sea cucumbers are collected by male free divers whereas in the southwest women collect them during low tide on foot (Rasolofonirina & Conand, 1998; Conand & Muthiga, 2007). Such gendered differences in sea cucumber collection along shorelines or in deeper waters are also common across the Indo-Pacific (Purcell et al., 2016b; Shrestha et al., in press). This leads to economic advantages for women in regions where shallow water collection and farming is possible. Yet, farming is not a viable option for collectors in many regions due to the lack of shallow waters they require. This leads to an increase in the collection of wild species, and subsequent regulations which ensure sustainable catch. Such regulations, however, may reduce catch and increase both food insecurity and poverty, but only if fishers' incomes depend on threatened or less abundant species.

Fishers on the Masoala depend on threatened and regulated species as part of their livelihood. Over half (54.4%) of sea cucumber income came from threatened species (*H. nobilis*, *H. fuscogilva*, *H. scabra*, *H. lessoni*, *A. echinites*, *A. miliaris*, *A. mauritiana*, and *Thelenota ananas*), and of that, one-fifth from CITES Appendix II restricted species (*H. nobilis* and *H. fuscogilva*). Further, the catch of Endangered species such as *H. scabra*, *H. nobilis*, and *H. fuscogilva* is increasing. CITES restricted species have a disproportionate effect on benthic marine ecology (Bruckner et al., 2003). Sea cucumbers play crucial roles in their marine habitats as bioturbators and symbionts (Purcell et al., 2016a; Zamora et al., 2018). Without them, bacterial build-up in sediments would have the potential to cause mass eutrophication events in already fragile ecosystems (Purcell et al., 2016a; Zamora et al., 2018; Lee et al., 2017). Bioturbating species collected in northeastern Madagascar include the Threatened *H. lessoni* and *H. scabra*, others such as *H. fuscogilva* and *H. nobilis* form crucial symbiotic relationships with crustaceans and annelids (Bruckner et al., 2003; Purcell et al., 2016a). Thus, the reliance on these species could have ecosystem-wide consequences that affect fishers beyond sea cucumber collection. This pattern of overexploitation of the most threatened and key sea cucumbers within an ecosystem is not exclusive to northeastern Madagascar; such species are overexploited elsewhere, from southern Madagascar (Rasolofonirina et al., 2003; McVean et al., 2005) to the Great Barrier Reef (Wolfe & Byrne, 2022). Increased national regulation of sea cucumber collection on protected species will benefit marine regions both within and outside the Masoala Peninsula, yet alone it is unlikely to affect the incentives of collectors.

Fishers in northeastern Madagascar collect wild sea cucumbers for reliable income in a growing and demanding global market. Given this, a crash in the stocks of these species and the wealth and food security of their collectors is likely. Collaborative actions which ensure the long term financial and food security of rural households would therefore be mutually beneficial to collectors and marine ecosystems alike. However, these actions will only work if they truly result in fishers reducing catch of wild populations in the face of an expanding and tempting economic market. Fishers may simply continue to collect sea cucumbers in addition to new economic opportunities. Therefore, research that quantitatively tests the relative effects of various economic activities on sea cucumber collection is urgently needed.

TABLES AND FIGURES

Table 1: The local and scientific names of collected sea cucumbers and their conservation status, mean threatened status, dried weight per kg, and price in local communities (2020) on the Masoala Peninsula in Madagascar.

Local Common and Scientific Name	IUCN Status[1]	Mean Threatened Status[2]	Weight dried (Kg ind^{-1})	Price in Community 2020 (USD per kg)
Tosanga		2.00 ± 0.00	0.200	8.21
Actinopyga echinites	VU			
Kafaoka		2.00 ± 0.00	0.350	8.21
Actinopyga lecanora	DD			
Actinopyga miliaris	VU			
Dinganbato/Fotsitetraka		2.00 ± 0.00	0.200	8.21
Actinopyga mauritiana	VU			
Dingana mahintina		1.00 ± 0.00	0.005	2.00
Bohadschia atra	DD			
Holothuria atra	LC			
Dingana faraoratra		0.00 ± 0.00	0.100	2.00
Bohadschia marmorata	DD			
Bohadschia subrubra	DD			
Maroandavaka		1.00 ± 0.00	-	2.00
Bohadschia vitiensis	DD			
Holothuria cinerascens	LC			
Stilo banana		0.00 ± 0.00	-	2.00
Holothuria arenicola	DD			
Valonono		2.50 ± 0.71	0.500	32.84
Holothuria fuscogilva	VU			
Holothuria nobilis	EN			
Dinganbe/Trico		2.00 ± 1.41	0.500	54.74
Holothuria fuscopunctata	LC			
Holothuria scabra	EN			
Dinganbe madinky/Latapiso		3.00 ± 0.00	-	6.84
Holothuria lessoni	EN			
Traktaira, Logntanana		1.00 ± 0.00	0.150	19.16
Holothuria pervicax	LC			
Stichopus horrens	DD			
Stichopus monotuberculatus	DD			
Stichopus naso	LC			
Mahitsoely		1.00 ± 0.00	-	2.00
Stichopus chloronotus	LC			
Rasta		3.00 + 0.00	-	19.16
Thelenota ananas	EN			
Bily		0.00 ± 0.00	-	-
Thelenota anax	DD			
No Local Name		1.00 ± 0.00	-	-
Holothuria fuscocinerea	LC			

[1]IUCN Status is from IUCN Red List: VU = vulnerable; DD = data deficient, etc. References for each species' threatened status from the IUCN Redlist is listed in References.

[2]Mean threatened status calculated by taking the mean number of Threatened (ranked 1-4, 1: LC, 2: VU, 3: EN, 4: CR) scientific species under each local vernacular

Table 2: Mean (±SD) number of sea cucumbers collected per household (n=792) on the Masoala Peninsula of Madagascar (2015–2020).

Local Common Name	2015 (n=272)	2016 (n=43)	2017 (n=191)	2018 (n=79)	2019 (n=105)	2020 (n=102)	2015-2020 Annual Mean Collection per Household
Tosanga	2.29 ± 14.98	0.07 ± 0.46	4.76 ± 16.28	9.76 ± 20.24	6.62 ± 17.85	18.09 ± 31.49	6.93 ± 6.42
Kafaoka	0.10 ± 0.97	0.00 ± 0.00	0.97 ± 4.09	14.92 ± 40.07	4.92 ± 13.20	22.69 ± 46.71	7.27 ± 9.44
Dinganbato, Fotsitetraka	2.46 ± 20.18	0.23 ± 1.52	1.21 ± 4.71	4.76 ± 11.92	5.05 ± 11.33	19.51 ± 40.09	5.54 ± 7.11
Dingana mahintina	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Dingana faraoratra	0.96 ± 12.39	0.00 ± 0.00	1.13 ± 6.03	6.37 ± 14.47	1.67 ± 4.76	5.38 ± 13.55	2.59 ± 2.62
Maroandavaka	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Stilo banana	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Valonono	0.02 ± 0.31	0.00 ± 0.00	0.60 ± 3.14	13.57 ± 43.16	2.39 ± 6.24	18.09 ± 31.49	5.78 ± 7.96
Dinganbe, Trico	0.04 ± 0.47	0.00 ± 0.00	0.76 ± 3.68	2.76 ± 7.43	5.81 ± 13.57	1.29 ± 4.57	1.78 ± 2.22
Dinganbe madinky, Latapiso	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Traktaira, Logntanana	4.33 ± 29.88	0.12 ± 0.76	15.82 ± 60.76	32.66 ± 77.60	14.24 ± 31.18	29.71 ± 52.58	16.15 ± 13.10
Mahitsoely	0.00 ± 0.00	0.00 ± 0.00	0.60 ± 2.95	1.35 ± 3.98	1.05 ± 8.84	0.53 ± 2.31	0.58 ± 0.55
Rasta	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Bily	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
No Local Name	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
TOTAL MEAN	10.57 ± 64.64	0.42 ± 2.74	26.36 ± 83.88	91.62 ± 216.81	42.08 ± 84.44	120.47 ± 219.38	48.59 ± 47.58

Table 3: Gross yearly income by source in community households (n=792) on the Masoala Peninsula, Madagascar (2015–2020).

Gross Income by Source (USD)	2015 (Mean ± SD)	2016 (Mean ± SD)	2017 (Mean ± SD)	2018 (Mean ± SD)	2019 (Mean ± SD)	2020 (Mean ± SD)
Forest	171.19 ± 910.266	168.08 ± 914.98	8.76 ± 20.09	33.94 ± 76.25	13.55 ± 27.57	8.51 ±15.86
Land	2.04 ± 20.48	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Salary and Sales	291.98 ± 1088.69	585.68 ± 898.80	509.727 ± 1141.997	1067.48 ± 1397.13	278.61 ± 872.3868	360.55 ± 889.37
Cash Crops	65.63 ± 259.65	10.22 ± 161256.58	275.64 ± 508.41	207.80 ± 357.46	218.19 ± 462.04	249.93 ± 497.12
Ocean[1]	38.09 ± 123.12	183.26 ± 607.66	74.41 ± 230.81	276.48 ± 1084.40	100.61 ± 307.34	153.89 ± 666.27
Sea Cucumbers	5.28 ± 35.88	103.80 ± 548.06	8.35 ± 23.42	29.17 ± 63.93	28.56 ± 58.23	41.67 ± 90.36
Rice	28.43 ± 165.78	4.50 ± 17.03	1.29 ± 5.53	0.69 ± 2.82	2.48 ± 10.89	1.26 ±6.19
Agriculture and Garden	24.90 ± 293.46	38.37 ± 121.86	498.80 ± 6773.92	10.46 ± 28.30	6.39 ±21.47	7.31 ± 14.49
Livestock	36.44 ± 137.86	81.74 ± 174.00	37.66 ± 127.03	17.92 ± 63.23	13.70 ± 51.79	7.83 ± 26.50
Total per Household	658.70 ± 1519.96	1071.03 ± 27,397.91	1406.29 ± 6838.77	1614.78 ± 1696.11	633.54 ± 1356.72	789.29 ± 1197.76

[1]Not including sea cucumbers

Table 4: Percentage of total yearly income by source in community households (n=792) on the Masoala Peninsula, Madagascar (2015–2020).

% Total Income by Method	2015 (Mean ± SD)	2016 (Mean ± SD)	2017 (Mean ± SD)	2018 (Mean ± SD)	2019 (Mean ± SD)	2020 (Mean ± SD)
Forest	15.96 ± 27.22	6.21 ± 18.18	3.80 ± 10.22	3.94 ± 6.68	6.55 ± 13.05	3.73 ± 11.21
Land	0.49 ± 4.83	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Salary and Sales	35.15 ± 36.65	36.99 ± 35.30	49.07 ± 33.86	60.06 ± 32.56	26.25 ± 38.30	38.56 ± 37.43
Cash Crops	16.86 ± 27.00	21.33 ± 27.17	28.42 ± 33.22	17.32 ± 24.25	28.44 ± 38.85	26.15 ± 36.40
Ocean	12.14 ± 26.02	15.12 ± 27.37	9.77 ± 19.91	11.65 ± 22.73	24.11 ± 36.04	23.11 ± 33.89
Sea Cucumbers	1.28 ± 5.74	4.76 ± 16.22	2.31 ± 7.65	1.63 ± 3.12	8.64 ± 18.38	8.46 ± 17.23
Sea Cucumbers out of Ocean Income	4.33 ± 17.11	18.90 ± 35.80	8.29 ± 24.53	13.98 ± 29.33	15.81 ± 29.16	20.36 ± 31.61
Rice	8.90 ± 19.33	12.74 ± 30.18	0.34 ± 1.57	0.31 ± 1.72	3.01 ± 13.66	0.39 ± 1.41
Agriculture and Garden	3.37 ± 12.07	2.74 ± 7.66	2.65 ± 11.34	2.97 ±11.81	4.02 ± 12.01	2.83 ± 11.03
Livestock	6.7 ± 15.87	4.87 ± 15.54	5.41 ± 13.00	1.21 ± 3.90	4.75 ± 14.22	2.83 ± 11.03

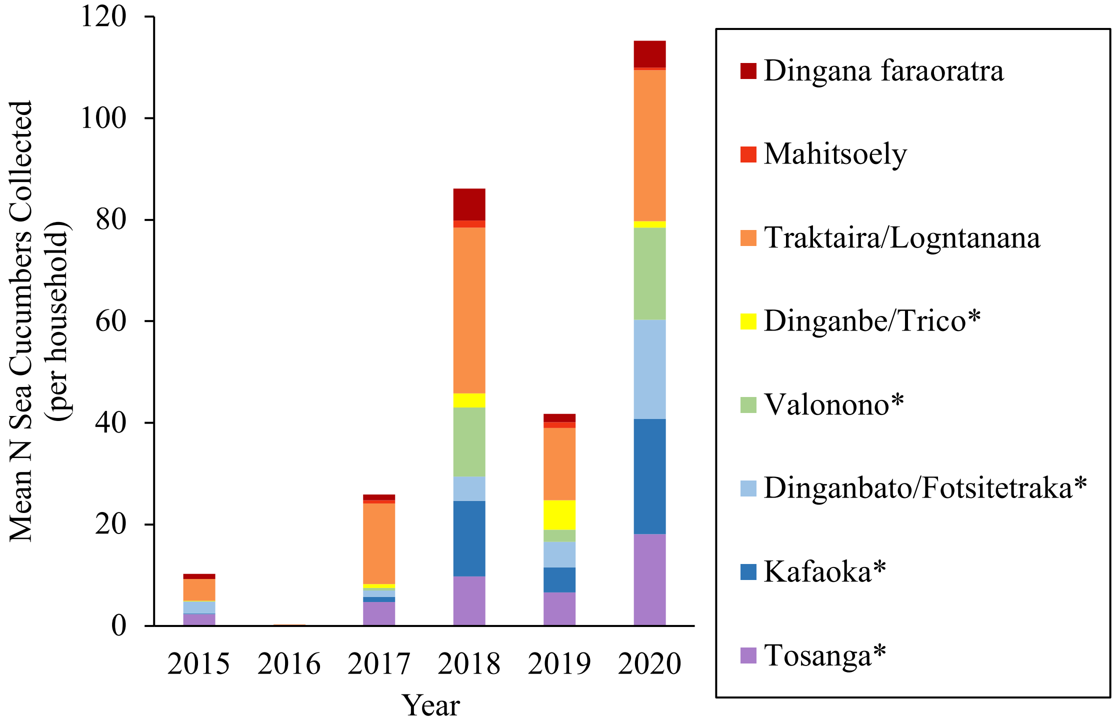

Figure 1. Mean number of sea cucumbers[1] collected by 792[2,3] coastal households in NE Madagascar (2015–2020).

*Includes species of an IUCN threatened status of vulnerable or greater.

[1]Full list of scientific species including threatened status is in Table 1.

[2]3% of the coastal population out of 24,372 households.

[3]number of households per year are listed in Table 2.

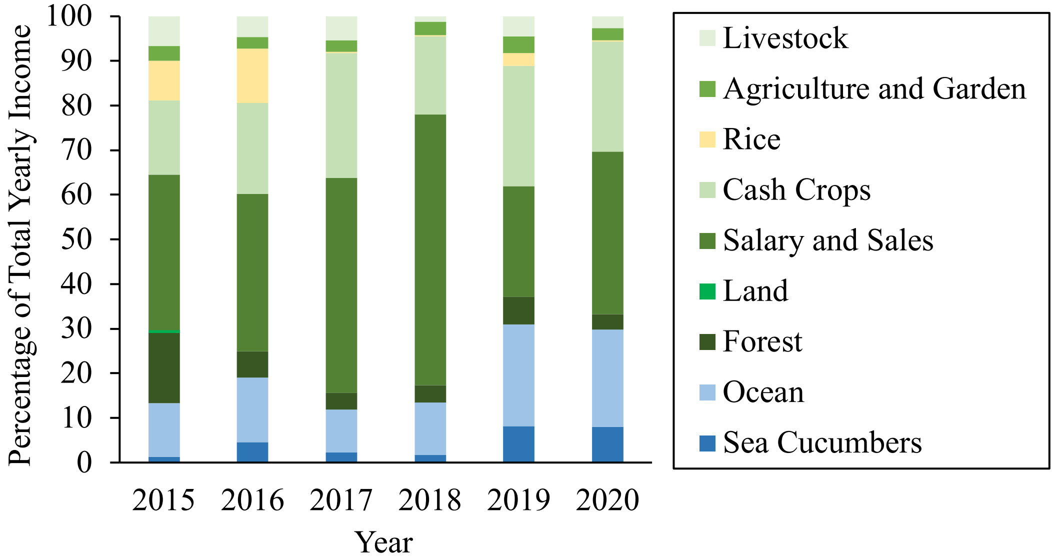

Figure 2. Percentage of total annual income by source in 792 coastal households of northeastern Madagascar (2015–2020).

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