Local perceptions of the socioeconomic and environmental impacts of sea cucumber farming in southwestern Madagascar

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Abstract

This study explores local perceptions of the socioeconomic and environmental impacts of sea cucumber farming in southwestern Madagascar. Among the 298 households surveyed, 69 were actively engaged in sea cucumber farming, participating in sales six to nine times annually, with each farmer selling 43–158 adult sea cucumbers per period. Repurchase prices per village ranged from MGA[5] 33,660,000 to MGA 150,534,200 per year, corresponding to an average selling price of MGA 2,078,378 per farmer per year. Sea cucumber farming significantly enhances household living conditions, as indicated by impacts such as furniture acquisition, fishing gear, and home construction. Two primary challenges faced by sea cucumber farmers are theft in sea pen enclosures and conflicts over marine space initiated by non-sea cucumber farmers. Regarding environmental impacts, villagers found it challenging to respond comprehensively, primarily noting the attraction and aggregation of various marine animals around sea cucumber enclosures, including juvenile sea cucumbers, finfish, gastropods, bivalves, octopus, shrimp, and squid. In conclusion, sea cucumber farming contributes positively to the standard of living for village farmers in southwestern Madagascar. The engagement of sociologists is imperative for addressing social challenges and fostering the development of this sector.

Keywords: sea cucumber farming, socioeconomic impacts, environmental impacts, household perceptions, southwestern Madagascar

Introduction

In Madagascar, particularly in the southwest region, sea cucumber fishing constitutes one of the economically viable activities that are actively pursued by coastal communities (Rasolofonirina et al. 2004). However, the overexploitation of sea cucumbers since the beginning of 1990 has led to a decline in holothurian stocks that is evident through the shift in quality, decrease in product size, and various signs of illegal harvesting practices (Rasolofonirina et al. 2004). To address this problem, a sea cucumber mariculture project was launched in Madagascar in 1999, funded by the Belgian universities University of Mons and Université libre de Bruxelles (Jangoux et al. 2001). Under this project, the hatchery in Toliara (Aqua-Lab) was established and became operational in 2003. Aqua-Lab has produced up to 200,000 of juveniles of the most valuable sea cucumber, *Holothuria scabra* (Eeckhaut et al. 2008). The second phase of the project was initiated in 2004 and included the establishment of sea cucumber farming pens in Belaza, 20 km south of Toliara city (Eeckhaut et al. 2008). The end of the Belgium funds in March 2008 led to the creation of a tripartite partnership between the Belgium universities, Institut Halieutique et des Sciences Marines (IH.SM), and the private company Copefrito SA, which further resulted in the establishment of a private company named Madagascar Holothurie – the first trade company based on sea cucumber aquaculture (involving coastal villagers) in Madagascar (Eeckhaut et al. 2008).

In response to the objective set by the three parties, a new partnership emerged between local communities, non-governmental organisations, and the private sector. This partnership pioneered a form of community-based mariculture, in which hatchery-reared juvenile sea cucumbers were reared by coastal communities in sea pens (Robinson and Pascal 2009). The results of this test phase prompted the partners in 2012 to establish a new private company named Indian Ocean Trepang to further advance and develop sea cucumber farming on an industrial scale (Todinanahary et al. 2016; Eeckhaut 2021). Community-based sea cucumber farming with IOT began in 2015. Initially, the project targeted 25 households within two villages (Ambolimailaky and Andrevo), resulting in the production of 1.2 t of fresh products. By 2020, the initiative had expanded to involve 228 households from seven villages, resulting in a substantial increase in production to 56.1 t of fresh products.

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Despite increased efforts in sea cucumber farming over the last two decades, research addressing the impacts of these activities remains limited, especially in Madagascar. The present study aims at evaluating local perceptions regarding the socioeconomic and environmental impacts of community-based sea cucumber farming in southwestern Madagascar. The primary objective is to contribute to the development of this sector in Madagascar.

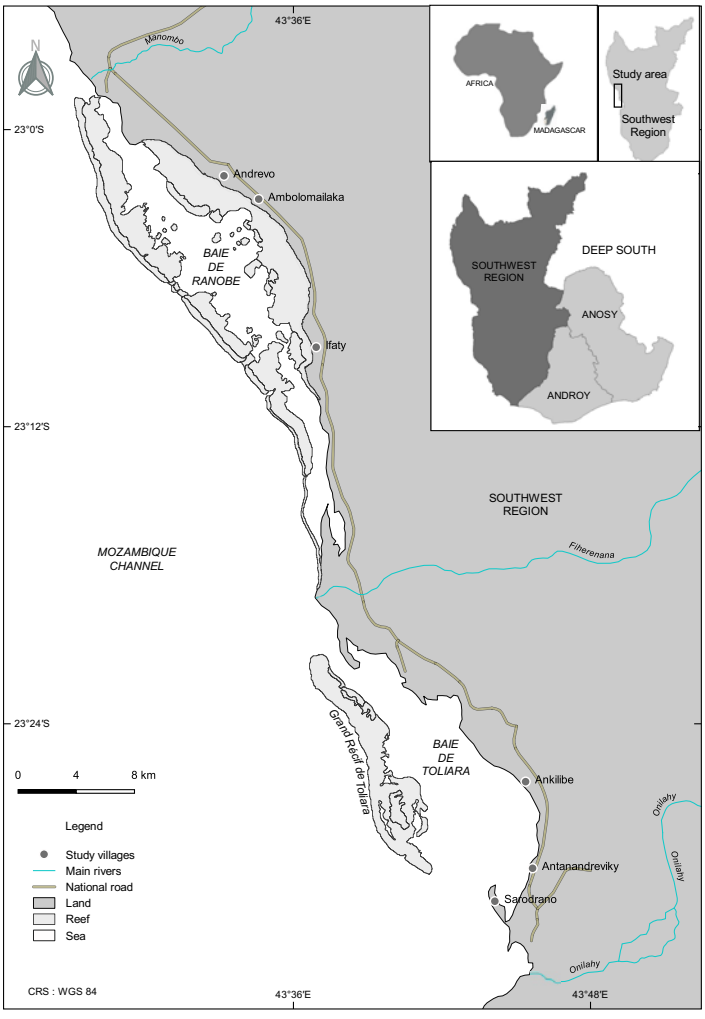
Methodology

Study area

Our study area was in the central part of the southwest region of Madagascar, delineated in the north by the Manombo River, and in the south by the Onilahy River. The study area encompassed six coastal villages along the shores of the Bay of Toliara and the Bay of Ranobe (Fig. 1). The study villages included Andrevo, Ambolomailaka, and Ifaty in the Bay of Ranobe, and Ankilibe, Antanandreviky and Sarodrano in the Bay of Toliara (Fig. 1).

Data collection approaches

The study was conducted along with an assessment of the impact of seaweed farming (not addressed in this article) in southwestern Madagascar, and focused on the six villages mentioned above. Our data collection approach combined individual surveys to collect quantitative data, and focus group discussions to collect qualitative data (Lambert and Loiselle 2008).



Figures 1. Study area and villages.

Individual surveys

We used a semi-structured interview format for the individual surveys, and targeted heads of households who are engaged in either seaweed or sea cucumber farming. In total, 298 individuals were interviewed between July and October 2022. The survey spanned approximately seven days per village, and questions were related to key household characteristics including age, gender, ethnic group, marital status, residence status, child in charge, and principal economic activity. These formulated questions aimed at exploring farmers' perceptions of the socioeconomic and environmental aspects of sea cucumber and seaweed farming. The date of the surveys, number of surveyed households, and the village the survey was conducted in are detailed in Table 1.

Of the 298 households surveyed, we interviewed 199 households engaged only in seaweed farming (66.78% of household respondents), 69 households engaged only in sea cucumber farming (23.15% of household respondents), and 30 households practicing both activities (10.07% of household respondents). This information is summarised in Table 2. Although the survey focused on both seaweed and sea cucumber, this article focuses on cucumber farming as mentioned above. As such, the results presented in this study will be derived from the 69 surveyed households practicing only sea cucumber farming.

In addition to individual surveys conducted with heads of sea cucumber farmer households, interviews were carried out with the managers and technicians of the local company Indian Ocean Trepang (IOT) to obtain insights into its sea cucumber farming operational model. Data on the income of each farmer in the study sites were also directly collected from IOT.

Focus group discussions

In addition to individual surveys, we held focus group discussions with 10 individuals (men and women) who were not involved in mariculture (either sea cucumber or seaweed farming). The discussion was held in an open manner, and participants were encouraged to express their points of view on the issues related to sea cucumber farming and its impact on their daily lives. In total, six focus groups discussion were conducted in six villages.

Data analysis

The data collected from the 69 sea cucumber farmer interviews were entered into an Excel database with 18 columns. These columns encompassed characteristics of the survey population (8 columns) and outcomes related to the perception of sea cucumber farming on the head of household's quality of life (10 columns). Subsequently, the file was converted to CSV format and processed using R software version 4.2.1.

R software played a pivotal role in data synthesis, graph generation, and summarisation of survey population characteristics. It was also crucial in conducting statistical analyses, particularly for comparing the average yearly incomes of sea cucumber farmers in the three villages: Andrevo, Ambolimailaka, and Sarodrano + Antanandreviky.

Given that the data did not follow a normal distribution (pShapiro-Wilk < 0.05) and the variance was not homogeneous (pLevene < 0.05), even after transformation, the non-parametric Kruskal-Wallis test was utilised instead of ANOVA. The significance level for all analyses was set at 5%.

Results

Characteristics of the surveyed population

Table 3 presents the characteristics of the surveyed population. The 69 households engaged in sea cucumber farming were distributed across the villages of Andrevo (24), Ambolimailaka (38), Antananreviky (02), and Sarodrano (05).

Only responses from adults (men and women aged 20 and older) were considered. The greatest number of responses came from individuals aged 30–59 (72.5% of responses). The number of men who were heads of household is higher (72.5%) than that of women (27.5%). Regarding the various ethnic groups, 5 out of 18 Malagasy ethnic groups were present during the survey, in which the Vezo ethnic group (which are known fishers) were the predominant group (75.4%). The majority of these people were married through a traditional wedding (87%) and most of them resided in the village (94.2%). More than 56.5% of households had more than four children under their care.

Among the 69 households engaged in sea cucumber farming, only 2 (2.9%) identified sea cucumber farming as their primary economic activity. The remaining households practiced it as a secondary activity with their main activity focused on fishing (78.3%), mixed with selling (8.7%), fish mongering (5.8%), and other undefined activities (4.3%).

Operating model, and technical and organisational practices

IOT is the only private company in Madagascar involved in the large-scale production of the sea cucumber *Holothuria scabra*. The different stages of sea cucumber production, from larval rearing in the hatchery to exportation, are summarised in Figure 2.

Table 1. Summary of data collection

Date of survey (year 2022)	Number of surveyed households	Village
25–31 July	21	Ankilibe
4–11 August	103	Sarodrano
19–26 August	27	Antanandreviky
27 August–2 September	45	Ambolimailaka
3–6 September, and 24 September–3 October	84	Andrevo
13–19 October	18	Ifaty
Total	**298**	**6**

Table 2. Number of surveyed households per village per farming activity.

Village	Number of surveyed households			
	Sea cucumber farmers	Seaweed farmers	Seaweed and sea cucumber farmers	**Total**
Andrevo	24	60	0	84
Ambolimailaky	38	2	5	45
Ifaty	0	18	0	18
Ankilibe	0	21	0	21
Antanandreviky	2	18	7	27
Sarodrano	5	80	18	103
Total	**69**	**199**	**30**	**298**
Percentages	*23.15%*	*66.78%*	*10.07%*	*100%*

The sea cucumber farming model in the coastal villages of southwest Madagascar is a mix of company farming and village farming. For the company farming model, IOT supplies juvenile sea cucumbers produced from its hatchery to fill their own pens. The company covers all the expenses, including staff, inputs, and infrastructure. For the village farming model, IOT supplies juveniles to village farmers for free and the cost of these juveniles is deducted at the time of harvest because those local farmers resell the juveniles that they farmed back to IOT. The company also provides the equipment needed to construct the pens, such as plastic netting and galvanised tubes. IOT also ensures that the farmers monitor the sea cucumbers by establishing a kind of contract to engage the resale back of adult sea cucumbers back to them. The farmers must maintain the pens that were provided to them (e.g. brushing them to prevent clogging) and monitor sea cucumber growth and health.

To recruit farmers, IOT advertises the number of farmers needed in its intervention villages. Interested villagers submit their expressions of interest and the selection occurs with the presence of the president and vice-president of the sea cucumber farmer association, as well as IOT technicians.

Once the farmers are identified and the pens are built in each village, IOT distributes sea cucumber juveniles weighing an average of 50 g each. Previously, this size was much smaller (around 20 g), but IOT decided to increase the size to reduce mortality rates in the pens, likely due to predators. The growth period at the village level varies from 9 to 14 months and, based on various parameters such as the sediment quality and water temperature, generally lasts around 14 months. So, for the first delivery of juveniles in the new pens, the first sale occurs at 14 months. A delivery of juveniles is made every two to three months to ensure that the sale will not occur until 14 months. This system allows the farmers to sell adult sea cucumbers every two to three months after the first sale (14 months' duration). Sometimes, the sale depends on the availability of commercially sized cucumbers, weighing no less than 400 g fresh weight.

Table 3. Characteristics of the surveyed population.

Sample characteristics		Frequency (n)	Percent (%)
Village	Andrevo	24	34.8
	Ambolimailaka	38	55.1
	Antanandreviky	2	2.9
	Sarodrano	5	7.2
Age	20–29	17	24.6
	30–59	50	72.5
	>60	2	2.9
Gender	Male	50	72.5
	Female	19	27.5
Ethnic group	Vezo	52	75.4
	Masikoro	7	10.1
	Mahafaly	4	5.8
	Tandroy	2	2.9
	Tanalana	4	5.8
Marital status	Married	60	87
	Single	6	8.7
	Widowed	3	4.3
Residence status	Resident	64	94.2
	Migrant	4	5.8
No. of children	0	5	7.3
	1–3	25	36.2
	4–6	23	33.3
	>7	16	23.2
Principal economic activity	Fishermen	54	78.3
	Sales	6	8.7
	Fishmongers	4	5.8
	Sea cucumber farming	2	2.9
	Other	3	4.3

Juvenile sea cucumber deliveries to farmer, and adults repurchased by IOT

Details of the deliveries of juveniles and the purchases of adult sea cucumbers by IOT from the farmers in the studied villages from 2020 and 2021 are presented in Table 4. In this table, data from the villages of Sarodrano and Antanandreviky are combined, just as they are in the IOT database. The data encompass all farmers involved in sea cucumber farming, whether exclusively sea cucumber farmers or engaging in both sea cucumber and seaweed farming. The number of farmers remained constant 45, 50 and 40 for the respective villages of Andrevo, Ambolimailaka, and Sarodrano + Antananderviky over the two years under consideration.

In total, IOT delivered 452,216 juveniles to village farmers, with quantities ranging from 65,789 to 87,835, depending on village context and year. Annually, each farmer received between 1390 and 2196 juveniles.

The frequency of transfers from IOT to farmers varied from five to seven times per year, with the number of juveniles ranging between 199 and 439 per farmer per delivery. The number of market-size sea cucumbers sold by farmers per year and per village varied between 13,464 and 54,131, or between 299 and 1353 per farmer per year. Sales occurred six to nine times per year, resulting in each farmer selling 43 to 158 adult sea cucumbers per repurchase period.

During the first half of 2020, the buying price for an adult sea cucumber was approximately MGA 4000 for an individual weighing around 400 g in fresh weight. This price was reduced to MGA 2500 in the second half of 2020, and has remained constant throughout 2021. This price adjustment is attributed to IOT deducting the price of one juvenile (MGA 1500) at the time of delivery. With variations in price and diverse pricing based on the size of adult sea cucumbers, the total sum of repurchase prices for adult individuals returned for each village ranged from MGA 33,660,000 to MGA 150,534,200 per year. This results in a total of MGA 748,000 to MGA 3,763,355 per year per village farmer.

It is also noted that due to the loss and mortality of juveniles, the number of adult individuals purchased back is consistently lower than the number of juveniles delivered. This ratio varied from 20% to 70%.

The variation in the average amount received by each farmer for every sale of marketable-size sea cucumbers is depicted in Figure 3. Our observation highlights that farmers in Sarodrano + Antanandreviky received a higher income than those in Ambolimailaka and Andrevo during 2020 (Fig. 3A) and 2021 (Fig. 3B), respectively. Nevertheless, statistical analysis indicates that during 2020, there is no significant difference ($p_{kw = 0.509}$) in the average sum received per farmer per purchasing period, despite a substantial sum received by

Figures 2. Stages of sea cucumber production from larval production to export.

farmers in Sarodrano + Antanandreviky (MGA 532,802) compared to Ambolimailaka (MGA 343,242) and Andrevo (MGA 273,935) (Fig. 3A). However, a significant difference is observed during 2021 (pkw = 0.001), where the amount received was significantly higher in Sarodrano + Antanandreviky (MGA 390,547) than in Ambolimailaka (MGA 217,034) and Andrevo (MGA 106,458) (Fig. 3B).

Figure 4 illustrates the distribution of income received by farmers during sales in 2020 and 2021. In Andrevo for 2020 (Fig. 4A), the amount varied between MGA 65,279 and MGA 618,933, and ranged from MGA 49,583 to MGA 211,333 in 2021 (Fig. 4B). Ambolimailka showed an average distribution between MGA 153,520 and MGA 553,500 in 2020 (Fig. 4C) and MGA 112,202 to MGA 295,990 in 2021 (Fig. 4D). In Sarodrano + Antanandreviky, the sum received per farmer per sales season varies from MGA 188,840 to MGA 904,300 in 2020 (Fig. 4E) and from MGA 157,927 to MGA 640,122 in 2021 (Fig. 4F).

Perceived impacts of sea cucumber farming on farmers' quality of life

Based on the results of our survey, farmers reported 10 impacts of sea cucumber farming that have contributed to improving their household living conditions (Fig. 5). The most perceived impacts were acquisition of home furniture (19.12%), acquisition of fishing gear (16.67%), construction of home (16.67%), and home appliance purchase, educational support with nutritional enhancement, each representing 12.25% of all responses.

Table 4. Delivered juveniles and repurchased adult sea cucumbers by Indian Ocean Trepang.

Village	Andrevo		Ambolimailaka		Sarodrano and Antanandreviky	
Year	**2020**	**2021**	**2020**	**2021**	**2020**	**2021**
Number of farmers	45	45	50	50	40	40
Total number of juveniles delivered	85,585	66,453	65,789	69,488	87,835	77,066
Average number of juveniles per farmer	1902	1477	1316	1390	2196	1927
Frequency of delivery	6	6	6	7	5	6
Average number of juveniles per farmer per delivery	317	246	219	199	439	321
Total number of adults sold	22,798	13,464	28,718	23,100	44,268	54,131
Average number of adults sold per farmer	507	299	574	462	1107	1353
Frequency of selling	6	7	7	8	7	9
Average number of adults sold per famer per selling	85	43	82	58	158	150
Total amount per year (MGA)	76,777,500	33,660,000	85,728,000	57,750,000	150,534,200	135,327,500
Average amount per farmer per year (MGA)	1,706,166	748,000	1,714,560	1,155,000	3,763,355	3,383,187
Price per piece of adults (MGA)	3368	2500	2985	2500	3400	2500
Ratio adults/juveniles (%)	26.6	20.3	43.7	33.2	50.4	70.2

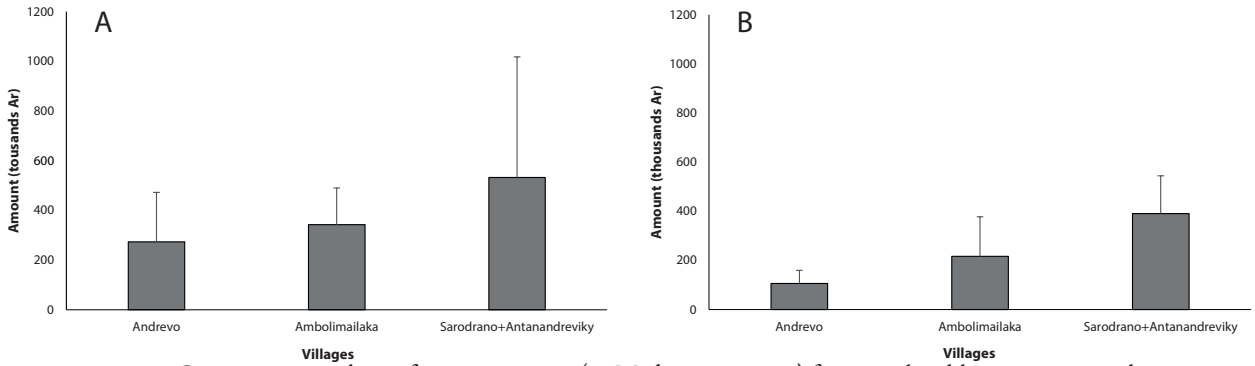


Figure 3. Comparative analysis of average income (in Madagascar ariary) from marketable-size sea cucumbers: A) Year 2020 and B) Year 2021.

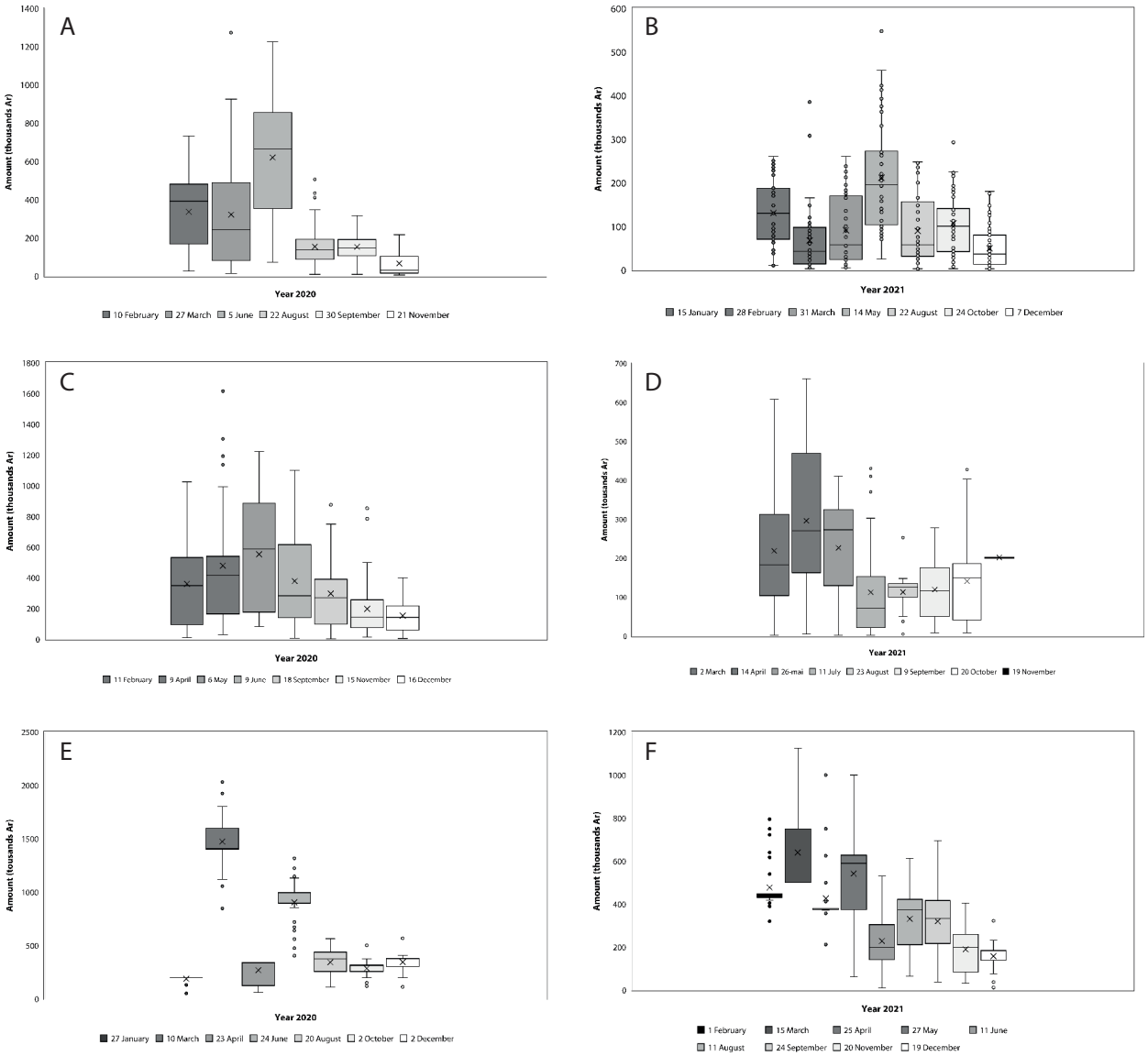


Figure 4. Distribution of income received by farmers during the sales seasons in 2020 and 2021 across different villages. Graphs indicate the average amount received by one farmer in one year (bars indicate standard deviation). A) Sarodrano, 2020; B) Sarodrano, 2021; C) Ambolimailaka,2020; D) Ambolimailaka, 2021; E) Sarodrano + Antanandreviky, 2020; F) Sarodrano + Antanandreviky, 2021.

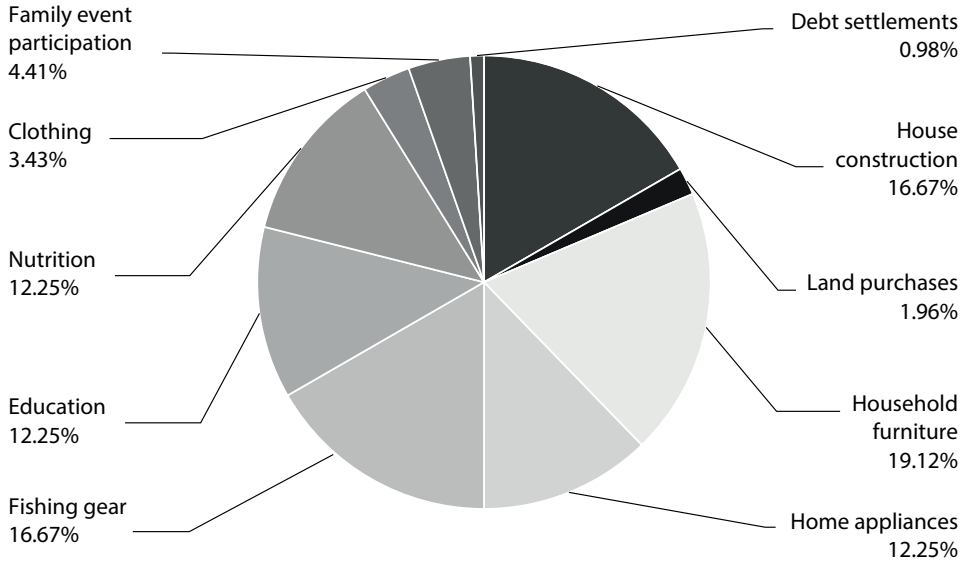


Figure 5. Impacts of sea cucumber farming on the farmers' household living conditions.

(a) Household furniture

Household furniture includes the acquisition of chests, wardrobes, glass tables, mirrors, formica shelves, formica sideboards, lounge chairs, plastic chairs, beds, mattresses, and specific kitchen utensils. Of the 69 sea cucumber farmers surveyed, 39 (56.5%) reported being able to purchase household furniture as a result of sea cucumber farming. The most commonly acquired items were lounge chairs (27.3%), glass tables (14.8%), sideboards (12.5%) and formica shelves (10.2%). While the majority of households acquired only one type of furniture (41%), others opted for two types (23.1%), and a smaller percentage bought three types (17.9%). Notably, 2 out of the 39 farmers who reported purchasing household furniture were able to specify having acquired six different types.

(b) Fishing gear

Of the all 69 farmers surveyed, 34 (49.3%) reported acquiring fishing gear through sea cucumber sales. The most common items purchased were pirogues (27 farmers), fishing nets (22 farmers), and masks for snorkeling (7 farmers). Other equipment included spear guns (4 farmers), fins (3 farmers), and a wetsuit (1 farmer). Over half of the farmers (52.9%) simultaneously purchased two types of fishing gear, with one farmer obtaining an impressive five types. While 27 farmers mentioned buying pirogues with proceeds from sea cucumber farming, the total acquired was 59, as some farmers bought 1 (15), 2 (5), 3 (5), 6 (1), and even up to 13 pirogues (1). Fishing nets were acquired by 22 farmers, and individual purchases ranged from 1 to 20 nets, resulting in a total of 109 nets for the surveyed households.

(c) House construction

Among the 69 sea cucumber farmers, 34 (49.3%) were able to build a house from the proceeds of sea cucumber farming. The majority of these houses are constructed with sheet metal (59.5%) and rush (29.7%). Others were built using permanent construction materials (2 farmers), planks (1 farmer), and mud (1 farmer). Three farmers were able to build two houses. One of them constructed both a sheet metal house and one with permanent construction materials, while the other two built one house made of rush and the other made of sheet metal.

(d) Home appliances

Among all sea cucumber farmers, 25 (36.2%) reported purchasing household appliances. Appliances included flat-screen TVs, phones, radios, speakers, boomboxes, walkmans, DVD players, solar panels, batteries, stabilisers, converters and generators. The most frequently acquired household appliances were batteries and solar panels (50%) for lighting purposes, followed by TVs, speakers (10% each) and radios (7.1%).

(e) Education

Twenty-five of the 69 sea cucumber farmers surveyed (36.2%) indicated that they used the proceeds from sea cucumber farming to help pay for their children's education. This financial support encompasses diverse expenses, including school fees, school supplies (e.g. notebooks, pens) and uniforms.

(f) Nutrition

Twenty-six farmers (37.7%) mentioned that the money generated from sea cucumber farming also played a role in improving their daily diet. Responses included purchasing a bag of rice directly for food security or being able to afford zebu meat, something that they were unable to purchase before.

(g) Family event participation

Nine farmers reported using money earned from sea cucumber farming to support various family events, including engagements, funerals, circumcisions and soron'anake. Soron'anake is a tradition observed in certain Malagasy tribes whereby a man must offer a zebu to his wife's family. This ritual, performed in the traditional way and involving the eldest member of the wife's family, is crucial for a man to establish his parental rights in the context of traditional customs. Failure to complete this tradition would result in the children born to the couple being considered as belonging to the family of the wife rather than the husband.

(h) Clothing, land purchases and debt settlements

Seven farmers (10.1%) mentioned buying clothing using funds generated from sea cucumber farming, while only four purchased land. These instances entailed the purchase of land for cultivation and were exclusive to the village of Ambolimailaka. Additionally, two farmers disclosed using funds from sea cucumber farming to settle their debts.

Problems related to sea cucumber farming and perceptions of local villagers of its environmental impacts

For those who practice sea cucumber farming, two major issues were highlighted. All heads of households interviewed (i.e. 69 out of 69) reported problems with theft in their sea cucumber pens despite using guards. Another issue stated by all farmers in Andrevo is the conflict over marine space, which has been primarily initiated by non-sea cucumber farmers.

Non-farmer responses varied from village to village. In Sarodrano, non-farmers, especially fishermen, stated that they had no issues with the development of sea cucumber farming. Their primary concern lies with the restriction of fishing areas near the shore. Non-farmers acknowledge the tangible benefits sea cucumber farming to the practitioners, including improved housing and access to education for children, acquisition of materials and goods, and a more consistent income stream.

For the residents of Antanandreviky, the concerns were severe, primarily linked to the marine space occupied by sea cucumber farming enclosures, involving not only local farmers but also IOT. Sea cucumber farming is expanding across a considerable marine area directly opposite their village. Consequently, women expressed dissatisfaction with the increased distance they had to cover to fish along the shoreline due to the enclosures (for shellfish, octopus, and other sea cucumber species) because of the establishment of sea cucumber farms. Men were significantly inconvenienced because of their pirogues, which have difficult navigating around the enclosures. Villagers also associated sea cucumber farming with additional challenges, such as the unsettling feeling of fear when encountering IOT farm guards, who restrict villagers from approaching the pens, especially at night.

In Ambolimailaka, non-sea cucumber farmers do not have any issues with sea cucumber farmers. Unlike Antanandreviky and Sarodrano, where the coastline is extensive, the only concern that was the increasing interest in the activity, despite limited marine space. These individuals also recognised that sea cucumber farmers have a better quality of life than fishermen.

In Andrevo, the issue is social conflict, with those who lack access to sea cucumber farming envious of farmers who have advantages that result in a better life. A tragic conflict occurred between the Masikoro and Vezo tribes, in which the Masikoro – harbouring jealousy towards the improved living conditions of Vezo farmers – lead to provocations and deaths. The situation escalated when the Masikoro attacked the village to pilfer sea cucumbers, resulting in their confrontation with the enclosure guards, ultimately causing a minor civil war, where families of the deceased sought revenge.

Another challenge is the frequenting of bars by male sea cucumber farmers. At times, their behaviour reflects affluence, which triggers jealousy among non-farmers. And, this contributes to the prevalence of polygamy.

With regard to the environmental impacts of sea cucumber farming, villagers had difficulty answering this question. Their responses were confined to the attraction and aggregation of various marine animals around the sea cucumber enclosures. The most frequently mentioned groups of animals included juvenile sea cucumbers, finfish, gastropods, bivalves, octopus, shrimp and squid.

Discussion

Sea cucumber farming is emerging as a supplementary endeavour for farmers because it demands only a few hours of work per week, primarily during low spring tides for paddock maintenance. This flexibility enables farmers to allocate time to other activities, particularly their primary pursuit, fishing (78.3%), which aligns seamlessly with sea cucumber farming. In southwestern Madagascar, sea cucumber farming stands out as a pioneering development. Our study underscores that the production model for 2022 remains consistent with Todinanahary et al.'s 2016 description of employing a mixed model that combines the "company farm" concept with that of "village farming".

In this context, the private company IOT ensures the sustainability of production, provides technical support to farmers, and invests in production materials, while farmers manage their plots following farming protocols (Todinanahary et al. 2016). This adopted mixed model emerges as a promising solution, enabling IOT to thrive while actively involving village farmers in local development. It is crucial to emphasise that, currently, village farmers are unable to independently secure the supply of juveniles. They remain reliant on IOT's hatchery. The hatchery and pre-grow out phase demand not only substantial investment in capital but also cutting-edge technology. Village sea cucumber farming in Madagascar stands out as a success story and can serve as a model for other coastal regions and countries (Kunzman et al. 2023).

In terms of socioeconomic impacts, the influence of sea cucumber farming on improving the standard of living for village farmers is evident. The average selling price of sea cucumbers from farming is MGA 2,078,378 per farmer per year, with the amount received ranging from MGA748,000 per farmer per year in Andrevo in 2021, to MGA 3,763,355 per farmer per year in Sarodrano + Antananderviky in 2020. This average selling price of sea cucumber (MGA 2,078,378) per farmer per year is equivalent to MGA 173,198 per farmer per month, which is not far from the minimum monthly wage set in Madagascar (MGA 250,000) according to Decree n°2023 - 563. It is noted that sea cucumber farming is not a full-time pursuit, indicating its beneficial nature for those engaged in the activity. One sea cucumber farmer family spends about three hours per day during each of the eight working days per month (Todinanahary et al. 2016), resulting in an average of 15% of the legal working time (8 hours per days, 20 days per month).

This practice indeed contributes to improving the living conditions of village farmers, as stated by the farmers themselves from their individual testimonials and through focus group discussions. The reported benefits were also supported by non-governmental organisations such as Blue Ventures and IOT (Baker-Médard and Kroger 2023). The same authors also highlight that some individuals perceive advantages in aquaculture, believing that positive outcomes are attainable with a different approach (Baker-Médard and Kroger 2023).

We gathered 10 responses from village farmers regarding the improvements in their lives due to sea cucumber farming. The most frequently mentioned improvements include the purchase of household supplies, acquisition of fishing equipment, house construction, procurement of household appliances, educational support, and nutritional improvement. These responses closely align with priorities reported by practitioners of seaweed farming in Kenya, particularly in the village of Kibuyuni on the southern coast of Kenya. The

key improvements outlined in the Kenyan study encompass constructing modern housing for the family (17%), funding family education (17%), addressing family medical needs (17%), acquiring clothing (17%), ensuring food and nutrition (17%), making business investments (4%), covering farm work expenses (4%), investing in livestock (4%), and settling family debts (3%) (Mirera et al. 2020).

Despite these advantages, some emerging social challenges – including theft, conflicts over the use of marine space, disputes between farmers and non-farmers, and behavioral shifts linked to wealth – occurred as a result of sea cucumber farming. Authors such as Baker-Médard and Kroger (2023) have raised these issues, highlighting concerns that the practice tends to disproportionately benefit recent arrivals, causing tensions and marginalisation, especially among original residents reliant on traditional fishing practices compared to newcomers engaged in aquaculture. The same authors report frequent violence related to sea cucumber theft, involving armed guards and resulting in numerous deaths, creating an atmosphere of fear in the region. A more comprehensive sociological study is recommended to address these problems.

The encountered challenges predominantly have social dimensions. To improve this situation, in depth sociological studies or targeted interventions are proposed. This underpins the importance of involving sociologists in the development of this sector. Within a new "Artisanal Mariculture and Village farming" certificate (Eeckhaut et al. 2023) funded by the Belgian ARES-CCD, a social research initiative has been launched. We also advocate for the integration of financial education for village farmers. In response to the shortage of juveniles distributed by IOT, and to expand this activity across Madagascar, we advocate the Ministry of Fisheries' support for the development of sea cucumber hatcheries in the country. A sea cucumber development plan has already been drafted for Madagascar (MPEB 2021).

Finally, regarding the environmental impacts of sea cucumber farming, limited studies have explored these impacts to date (but see Plotieau et al. 2013 for an impact on sediment quality), highlighting the necessity for more comprehensive research in this field. Initially, concerns about plastic pollution resulting from enclosure construction material were anticipated. However, Rabemanantsoa's study (2021) revealed that fishing constitutes the primary source of 30% of all plastic waste in southwest Madagascar, including items such as ropes, net fragments, sandals, floats, mosquito nets, wires and plastic bottle pieces. Surprisingly, the majority of plastic waste is attributed to everyday consumer goods, particularly plastic bags and packaging. Contrary to expectations, sea cucumber farming minimally contributes to plastic waste, and plastic waste from aquaculture is not prominently observed in the reef ecosystem, aligning with Kunzman and colleagues' findings (2023). Beyond scientific investigations, a hotelier's observation from four years ago highlighted negative impacts linked to sea cucumber farming, notably habitat change (from a sandy to a muddy beach) and nocturnal disturbances during sea cucumber sale/purchase periods, impacting local tourism. These observations emphasise the importance of a comprehensive environmental assessment, transcending farmers' perspectives, to gain a nuanced understanding of the ecological implications of this activity.

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References

Baker-Médard M. and Kroger E. 2023. Troubling the waters: Gendered dispossession, violence, and sea cucumber aquaculture in Madagascar. Society and Natural Resources. https://doi.org/10.1080/08941920.2023.2288674

DÉCRET N°2023 – 563. Fixant les salaires minima d' embauche et d'ancienneté par catégorie professionnelle et la rémunération minimale mensuelle.

Eeckhaut I. 2021. From fundamental to applied research: The history of the Indian Ocean Trepang company. SPC Beche-de-mer Information Bulletin 41:40–47

Eeckhaut I., Lavitra T., Rasolofonirina R., Rabenevanana MW, Gildas P. and Jangoux M. 2008. Madagascar Holothurie S.A.: The first trade company based on sea cucumber aquaculture in Madgascar. SPC Beche de Mer Information Bulletin 28:22–23.

Eeckhaut I., Lavitra T., Tsiresy G., Lepoint G. and Pascal B. 2023. Certificate in the Science of Artisanal Mariculture and Village Farming. SPC Beche de Mer Information Bulletin 43:63–65.

Jangoux M., Rasoloforinina R., Vaitilingon D., Ouin J.M., Seghers G., Mara E. and Conand C. 2001. A sea cucumber hatchery and mariculture project in Tuléar, Madagascar. SPC Beche-de-mer Information Bulletin 14:2–5.

Kunzmann A., Todinanahary G.G.B., Msuya F. and Alfiansah Y. 2023. Review: Comparative environmental impacts and development benefits of coastal aquaculture in three tropical countries: Madagascar, Tanzania and Indonesia. Tropical Life Sciences Research 34(3):279–302. https://doi.org/10.21315/tlsr2023.34.3.15

Lambert S.D. and Loiselle C.G. 2008. Combining individual interviews and focus groups to enhance data richness. Journal of Advanced Nursing 62(2):228–237. DOI: 10.1111/j.1365-2648.2007.04559.x

Mirera D.O., Kimathi A., Ngarari M.M., Magondu E.W., Wainaina M. and Ototo A. 2020. Societal and environmental impacts of seaweed farming in relation to rural development: The case of Kibuyuni village, south coast, Kenya. Ocean and Coastal Management 194: 105253. https://doi.org/10.1016/j.ocecoaman.2020.105253

MPEB (Ministère de la Pêche et de l'Economie Bleue). 2021. Plan de développement d'Holothuriculture [Sea Cucumber Farming Development Plan]. 25 p.

Plotieau T., Lavitra T., Gillan D. C. and Eeckhaut I. 2013. Bacterial diversity of the sediments transiting through the gut of *Holothuria scabra* (Holothuroidea; Echinodermata). Marine Biology 160:3087–3102.

Rabemanantsoa A. 2021. Évaluation des impacts environnementaux relatifs aux déchets plastiques issus des activités halieutiques et aquacoles dans le village de Sarodrano. [Assessment of environmental impacts relating to plastic waste from fishing and aquaculture activities in the village of Sarodrano]. Study report. Fisheries and Marine Sciences Institute, University of Toliara, 63 p.

Rasolofonirina R., Mara E. and Jangoux M. 2004. Sea cucumber and mariculture in Madagascar, a case study of Tuléar, south-west Madagascar. p. 133–149. In: Lovatelli A., Conand C., Purcell S., Uthicke S., Hamel J.F. and Mercier A. (eds). Advances in sea cucumber aquaculture and management. Fisheries Technical Paper No. 463. Rome, Italy: Food and Agriculture Organization of the United Nations.

Robinson G. and Pascal B. 2009. From hatchery to community – Madagascar's first village-based holothurian mariculture programme. SPC Beche-de-mer Information Bulletin 29:38–43.

Todinanahary G.G.B., Behivoke F., Nomenisoa A.L., Ravelojaona D.K., Rakotoson A.T., Tatangirafeno S., Rakotonjanahary F., Tsiresy G., Mara E.R., Eeckhaut I. and Lavitra T. 2016. Inventaire et étude de faisabilité de sites propices à l'algoculture, l'holothuriculture, la gestion de l'exploitation de poulpes et de crabes dans la Région Atsimo Andrefana [Inventory and feasibility study of sites suitable for seaweed farming, sea cucumber farming, management of octopus and crab exploitation in the Atsimo Andrefana Region]. Study report, MHSA - PRU (Contract No. 166/C/PIC2/2016). 357 p.