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Evolving governance structures in community-based sandfish mariculture and their interactions with livelihood outcomes: Evidence from the Philippines

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Sea cucumber mariculture is an important emerging field of practice and applied research in the coastal tropics. This is due to the existing importance of tropical sea cucumber fisheries for wealth generation and poverty reduction, and the potential for mariculture to contribute to the longer term sustainability of these fisheries while generating benefits additional to those from wild caught sea cucumber. Understanding the optimal institutional arrangements for sea cucumber mariculture is an important area of focus in this field, with a variety of arrangements currently in place. This paper documents the establishment of a communal form of sea ranching in the Philippines, as a case study of community level institutional processes. It describes the background to establishment of the sea ranch in the community of Victory, challenges encountered and how these were managed, and the evolution of governance arrangements. In charting this process, we assess the impacts on livelihood outcomes, highlighting this as a crucial aspect influencing this evolution and the nature of community involvement in the sea ranch. While the sea ranching project generated a range of benefits for livelihoods, including possible spillover effects for the surrounding fishery, substantial economic returns from harvests did not occur. Thus, the system of governing the sea ranch evolved from a communal model to a more exclusive household model primarily to improve operational efficiency. In order for possible benefits of the sea ranch to be sustained and enhanced, greater integration with fisheries management and government support will be needed.

KEYWORDS

sea cucumbers, coastal livelihoods, Southeast Asia, aquaculture, mariculture

1 Introduction

Coastal households in the tropics face a wide range of interlinked challenges when trying to navigate sustainable livelihoods. Widespread declines in fish stocks, associated environmental declines and the consequent need for better environmental governance has formed the basis of much research and the focus of many policies and projects (Pomeroy et al., 2010; Cinner et al., 2013; Foale et al., 2013; Anticamara and Go, 2016; Eriksson et al., 2016). At the same time, many coastal households have low incomes and high rates of vulnerability (Béné and Friend, 2011; Fabinyi et al., 2022; Islam and Chuenpagdee, 2022). Within this context, mariculture is a rapidly emerging economic sector that interacts with coastal livelihoods in a range of ways (Akber et al., 2020). While diverse forms of mariculture (from shellfish to grouper) can potentially promote food security and increase incomes (Bush et al., 2019; Costello et al., 2020; Willer et al., 2021), concerns are also present about environmental impacts, and about the ability of marginalized ocean users such as small-scale fishers to access these benefits (Belton et al., 2020; Farmery et al., 2021; Fiorella et al., 2021; Ferrer et al., 2022; Zhang et al., 2022). Understanding the interactions of mariculture with coastal livelihoods – and how to address these interactions to attain better environmental and social outcomes – is therefore a topic of ongoing interest and significance. This paper assesses the interactions between livelihoods and a long-term sea cucumber mariculture project over more than a decade, in the coastal community of Victory, Bolinao in the Northwestern Philippines.

While various species of sea cucumbers can be cultured, among tropical species much scientific and government attention has focused on the sandfish, *Holothuria scabra* (Hair et al., 2012; Purcell et al., 2012). When dried and processed, premium grade sandfish can reach retail prices of up to USD 1898/kg (Purcell et al., 2018) in Hong Kong. Demand for sandfish and other tropical sea cucumbers in the main market of China has boomed since the 1980s and 90s (Eriksson et al., 2015) and is expected to continue to increase (Purcell et al., 2018). However, overfishing of many species of sea cucumbers is widespread globally (Purcell et al., 2013), and in the Philippines (Brown et al., 2010). The combination of declining capture fisheries and increasing market demand has led many researchers and organizations to investigate the viability of sandfish mariculture as a sustainable supplemental livelihood activity. Compared to other cultured marine invertebrates, sandfish feed predominantly on detritus and other deposited organic matter to sustain growth (Hair et al., 2016; Dumalan et al., 2019). It requires minimal maintenance, therefore indicating potential compatibility with other livelihood activities such as fishing and farming (Juinio-Meñez et al., 2017; Gorospe, 2022).

Mariculture for sandfish has been developing since the 1990s (Battaglene et al., 1999), with greatly enhanced knowledge and understanding about key technical aspects such as genetics management, broodstock conditioning, larval rearing and juvenile feeding and ocean nursery rearing, predation and post-harvest processing (e.g., Hair et al., 2012; Ram et al., 2016; Ravago-Gotanco and Kim, 2019; Gorospe et al., 2019; 2021; Sinsona and Juinio-Meñez, 2019; Altamirano et al., 2021). More recently, increasing attention has also been paid to the institutional arrangements that govern sandfish mariculture. In addition to the various technical challenges associated with agricultural research, the pathways to translate the benefits of technical innovations into individual, household and community level benefits are affected by a vast range of social, economic, political and cultural factors (Plagányi et al., 2020; Cook et al., 2021; Curry et al., 2021). In the case of sandfish mariculture, researchers have highlighted the need for equitable interventions (Eriksson et al., 2018), the social risks involved in mariculture development (Eriksson et al., 2012), some of the challenges of effective monitoring and guarding systems (Hair et al., 2019; Hair et al., 2020), and the need to account for multiple, diverse and contested interests in the coastal zone (Juinio-Meñez et al., 2017).

In this paper, key lessons are presented about a sandfish mariculture ranch in the Philippines that was originally launched in 2007. The focus is on describing and assessing the initiation and evolution of governance arrangements, in conjunction with an assessment of the impacts on livelihoods. Our objective was to understand how project governance changed over time in relation to the nature and extent of benefits to project beneficiaries.

2 Study site

Barangay Victory is located on the island of Santiago, in the municipality of Bolinao, Pangasinan province, Philippines (Figure 1). Small-scale fishing is the main economic activity, using mostly simple gears such as gillnets, hook and line, and fish traps. Gleaning is common, as is the use of *balsa* (bamboo raft) and spearfishing in locations close to shore. Sea cucumbers and other invertebrates make up a significant component of the catch for many fishers (Table 1). These livelihood activities are often combined with farming. As elsewhere in the Philippines (Anticamara and Go 2016), local fisheries have suffered from the impacts of overfishing. Elsewhere in the municipality, large-scale aquaculture of milkfish (*Chanos chanos*) is widespread, generating pollution impacts throughout the region (San Diego-McGlone et al., 2008; Santander – de Leon et al., 2016). Tourism is also increasingly common in Bolinao, although much less so in Barangay Victory (Porter and Orams, 2014).

3 Methods

Our understanding of governance in this paper broadly draws on the 'interactive governance' perspective, which sees governing systems as composed of a diverse array of

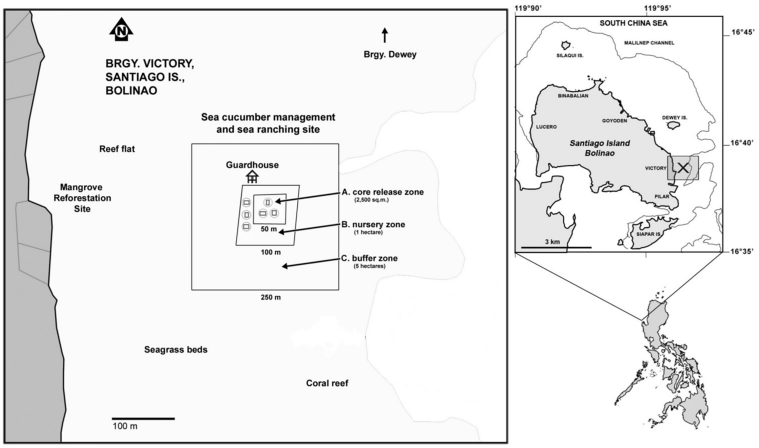

FIGURE 1
Map showing the location and the zonation of the 5-ha community-based sea cucumber ranch in Barangay Victory, Bolinao, Philippines.

stakeholders (i.e., beyond government alone), interacting with a 'system to be governed' to generate situations of more or less 'governability' (Chuenpagdee and Jentoft, 2009). Specifically, the focus is on the governance interactions between the different project proponents, including the University of Philippines Marine Science Institute (UPMSI) Sea Cucumber Research Program and a community level People's Organisation (PO) who were the formal project partners, and their interactions with wider community stakeholders at the barangay[1] and municipal levels. To conceptualise livelihood benefits, we drew broadly on the wellbeing framework – which encompasses both economic and non-economic benefits of fisheries and aquaculture (Weeratunge et al., 2014; Voyer et al., 2017) – to consider the diversity of livelihood impacts.

This paper draws on various sources of evidence. The first part of the Results presents the logic underlying the model of the community-based sea ranch, the processes in its establishment, some of the challenges encountered, and how the governance of the sea ranch evolved over time to address these challenges. This section draws primarily on project reports and data, with key events interpreted by UPMSI project leaders and personnel who were involved in the sea ranch from its inception.

The second part of the Results section focuses on the diverse livelihood impacts experienced by residents of Victory. This section draws additionally on a series of qualitative interviews with local residents in Barangay Victory (n= 30) conducted by Authors 1 and 2 in early (n=13) and late (n=14) March, and June (n=3) 2022. Authors 1 and 2 were not involved in establishment of the sea ranch, and their work conducting interviews on livelihood impacts was intended to ensure that an 'arms-length approach' could be applied to a greater degree than would not have been possible, were project personnel who had a sustained involvement in sea ranch establishment from the beginning, including advocating for its potential benefits to the community, to undertake these interviews.

The interviews were conducted in Tagalog (*lingua franca*) and were focused on understanding: details of the sea cucumber fishery, including fishing and trading patterns, the range of species caught and their prices; the perceptions about changing governance of the sea ranch; and perceptions about the range and extent of benefits the sea ranch provided to livelihoods. In order to capture a diversity of experiences and perceptions, purposive sampling was undertaken to conduct interviews with current project beneficiaries, previous project beneficiaries, and residents not involved with the sea ranch. While interviews asked about the range of economic and non-economic benefits to households, we categorized these benefits into those that were considered most significant by residents in interviews: economic returns from harvest, economic returns from spillover, and wider social benefits.

Interviews were informed by two broad concepts guiding qualitative research: triangulation and data saturation. Triangulation is a principle referring to the process of obtaining different types and sources of data to increase the confidence on findings that may be based on single (potentially biased) theories or perspectives, or limited sets of observations (Yin, 2016; Noble and Heale, 2019). In this study we used the principle of triangulation to support the internal validity of our work, by interviewing different types of key informants (e.g., direct sea ranch beneficiaries, those not involved with the sea ranch) and by accessing different types of data (e.g., landed catch data, perceptions of key informants). Data saturation occurs in interviewing when 'new data tend to be redundant of data already collected' (Grady, 1998: 26), and refers to the point at which a thorough qualitative understanding of the issue has been

1 A barangay is the smallest political unit in the Philippines, roughly translated as 'village' or 'community'.

TABLE 1 Commonly caught sea cucumbers within the Bolinao-Anda Reef Complex, Pangasinan, Northwestern Philippines.

Scientific name	Common name in Bolinao	Common English Name	Price (fresh)	Price (dried)
Holothuria scabra	Putian	Sandfish	<500 g: PHP 50/kg >500 g: Large = PHP 100/pc; Medium = PHP 50/pc.	Large = PHP 6,500/kg Medium = PHP 3,000/kg Small = PHP 2,000/kg
Stichopus cf. horrens	Hanginan/Dudlo	Selenka's sea cucumber	PHP 30/kg	Large = PHP 1500/kg Small = PHP 600/kg
Actinopyga miliaris	Khaki	Blackfish	PHP 30/kg	PHP 1500/kg
Bohadschia marmorata	Lawayan biker	Brown-spotted sandfish	PHP 10/kg	PHP 400/kg
B. argus	Lawayan pik	Leopard fish	PHP 10/kg	PHP 600/kg
A. echinites	Brown beauty	Deep-water redfish	PHP 5/kg	PHP150/kg
H.atra	Black beauty	Lollyfish	PHP 10/kg	PHP 600/kg

achieved, with the collection of further qualitative data not likely to provide additional insight. The fieldwork in March and June 2022 was approved by the Human Research Ethics Committee of the University of Technology Sydney (ETH19-4371).

4 Results

4.1 Processes in the establishment of community-based sea ranch

The five-hectare community-based (Berkes, 2007) sea cucumber sea ranch in Barangay Victory was established in September 2007, with the Bolinao municipal Local Government Unit (LGU) granting a permit to the members of the fisherfolk organization Samahan ng Maliliit na Mangingisda ng Barangay Victory (SMMV). The community-based sea cucumber ranch was legitimized in November 2007 through municipal Resolution Number 2007-49 declaring and designating a five-hectare area of the municipal water as an experimental sea cucumber ranch by the LGU of Bolinao. Additionally, limited exclusive use rights were granted to SMMV and the UPMSI Sea Cucumber Research Program as joint proponents of the sea ranch, whereby collection of any sea cucumbers species was prohibited within the 5 ha zone of the sea ranch. Other legal fishing activities such as gleaning (i.e., shellfish) and fishing were allowed in the sea ranch except in the 1-hectare core release area (Juinio-Meñez et al., 2022).

The community-based sea cucumber ranch aimed to diversify sustainable livelihood options through the addition of sea cucumber culture and increased local tourism, improve the capacity of community members through training and involvement in the various activities in the sea ranch, and improve the status of key coastal resources through rebuilding of an effective spawning population of sandfish (see McClean and Fabinyi, 2022 for further details of the wider set of projects, the logic underlying the community based model, and related sites). Criteria for site selection were primarily habitat suitability for sandfish, and the presence of an active and committed People's Organization (PO) in the barangay, with the chronology of the key processes in the establishment of the community-based sea ranch including: (1) biophysical site assessment; (2) community consultation and public orientation; (3) presentation to LGU and securing of legal permits and use rights; (4) planning and signing of partnership agreement between UPMSI and SMMV; and (5) site delineation and development. The community members, hereto referred as community partners, were comprised of 10 household members (i.e., primarily involving both husband and wife and occasionally children) of SMMV. These community partners shared responsibilities for guarding, monitoring, maintenance, and other activities related to the communal sea cucumber ranch.

The first step in the establishment of the sea ranch was site assessment for biophysical characteristics suitable for sandfish. This was followed by consultations with SMMV as the prospective community partners and the presentation of the proposed sea cucumber ranch to the LGUs at the barangay and municipal level. During these consultations, the objectives of the project were presented and discussed, and legal and institutional support from the LGUs was sought. In addition, public consultation involving other members of the community was also conducted to raise awareness and provide information about the proposed 5-ha sea cucumber ranch in their area. Activities allowed within the sea ranch were presented at public meetings, as were zones that were proposed as off-limit to all except for research purposes. While there were some concerns raised within the community regarding the reduction of fishing grounds that would occur due to the awarding of exclusive use rights to the 5-ha portion of the municipal waters to the project proponents, the proposed sea ranch obtained a general acceptance from the community members present and LGUs.

A key factor in generating this support was the role of SMMV as a proponent of the sea ranch and the potential benefits that might flow back to the community from its establishment. Thus, a legal permit was issued to the proponents by the municipal government. Finally, the 5-ha sea cucumber ranch was delineated and physical structures such as markers, monitoring pens and a guardhouse were built. On December 12, 2007 the first batch of hatchery produced sandfish juveniles (3-10 g; n=1,052) was released in the sea ranch.

4.2 Duties and responsibilities of partners

The duties and responsibilities of each partner as well as the guiding principles were specified in the partnership agreement signed by SMMV and the UPMSI Sea Cucumber Research Program. At each stage, project activities were to be undertaken jointly by research staff from UPMSI, and community members from SMMV to the greatest extent possible, taking into account the level of experience and knowledge each had with respect to specific tasks.

UPMSI Sea Cucumber Research Program committed to provide at least 10,000 sandfish *Holothuria scabra* juveniles (≥3 g) annually for the sea ranch. Releases of sandfish juveniles were done in several batches. In order to track growth performance and survival of each batch, a total of 600 sandfish juveniles per batch were released into three 100 m^2 monitoring pens. The rest of the juveniles were free ranging in the sea ranch. The relative abundance and size composition of the sandfish were monitored quarterly using belt transects in different parts of the sea ranch. In addition, UPMSI staff provided training to the community partners on juvenile release strategies and monitoring (i.e., growth and survival of sandfish). Post-harvest training on sandfish processing was also provided to the community partners to ensure high quality and ultimately better price of processed and dried products. Additionally, UPMSI funded supplies such as masks and snorkels, boots, torches, binoculars and bamboo rafts to aid in the monitoring and guarding of the sea cucumber ranch. Supplies such as coffee and sugar were also provided by UPMSI in addition to payment for labor and materials for occasional repair and maintenance of the guard house and markers. Moreover, bamboo rafts were provided to aid in the transport of the community partners to the sea ranch and for regular monitoring.

On their part, the community partners agreed to assist with technical monitoring activities under the supervision of UPMSI staff, and in addition, to check the presence of sandfish in each zone and the activity (i.e., spawning, burying behaviour) of sandfish and other sea cucumber species in the sea ranch at regular intervals, according to an agreed monitoring process. A key aspect of the community partner commitments was to lead 24-hour guarding of the sea ranch, performing the role of the Bantay Dagat (sea warden). The community partners received a monthly monetary honorarium amounting to PHP 2500 (USD 50) from the municipal government in 2012. This amount was provided to the SMMV as a whole and then divided among the individual participants based on their time invested guarding the sea ranch.

4.3 Challenges and actions taken

The major challenges that beset the community-based sea ranch are summarized in Table 2. The growth performance and survival of sandfish reared in the sea ranch was highly variable and was affected by rearing and environmental conditions. The scouring of the sediment due to high wave actions during Typhoon Chan-hom in May 2009 brought organic-rich sediment to the surface. Enhanced wave-current dynamics are among the most important factors affecting sediment suspension during typhoons (Tang et al., 2021). This nutrient-rich sediment serves as an important food source to various marine invertebrates including sandfish (Baskar, 1994). The higher sediment total organic matter in the sea ranch in May 2009 following Typhoon Chan-hom (Figure 2), coincided with rapid growth as indicated by the increase in average weight of sandfish during July 2009 compared to April 2009 (the monitoring period before Typhoon Chan-hom) (Figure 3). This indicates an increase in food abundance relative to the baseline total organic matter content recorded before the typhoon. However, the occurrence of organic-rich sediment only lasted for a short period of time, and after Typhoon Parma in September 2009 this was eventually replaced by coarse coral rubble, particularly in the northern and eastern side of the sea ranch. Additionally, reduced seawater salinity brought by high precipitation rates during the southwest monsoon may have caused physiological stress, negatively affecting the growth performance and survival of sandfish. Moreover, seasonal occurrence of the coralline algae *Amphiroa* spp. coupled with increased seagrass cover particularly during summer months, potentially reduced grazing area of sandfish affecting feeding activity. To reduce *Amphiroa* spp. cover and increase the grazing area for sandfish, weeding of the coralline algae in the sea ranch was recommended by UPMSI researchers.

To enhance growth performance, some sandfish from the sea ranch were periodically transferred to pens adjacent to the milkfish (*Chanos chanos*) mariculture farms where sediment had higher organic content. Sandfish reared in these pens attained average growth rates of 0.71 g/day for larger sandfish ~ 200g, and 1.26 g/day-1.54 g/day for those >100 g. Growth rates of sandfish reared in pens adjacent to the fish farms were comparably higher compared to those reared from the sea ranch and other grow-out sites (Juinio-Meñez et al., 2013; Juinio-Meñez et al., 2014).

Despite the initial acceptance of the proposed sea ranch following public consultations, the issue of the exclusive use

TABLE 2 List of challenges encountered by the community-based sea cucumber sea ranch at Barangay Victory, Bolinao, Northwestern Philippines.

Natural	Social		Economic
	Internal	External	
Episodic weather disturbances such as typhoons (i.e., Chan-hom, Parma) negatively affecting sediment quality, growth performance of sandfish and other physical structures in the sea ranch	Conflict of interest and frequent misunderstanding (i.e., allocation of supplies and division of honorarium from LGU) among partners	Low public support due to awarding of 5-hectare limited exclusive use rights to the community partners	Low monetary returns from *H. scabra* harvested from the sea ranch due to small sizes and poor processing quality of the dried product
Reduced salinity due to high precipitation rates during southwest monsoon	Some community partners became less interested over time. Only a few members participated in guarding, monitoring, harvesting, and processing of *H. scabra*		
Increased seagrass cover			
Seasonal overgrowth of the calcareous macroalgae *Amphiroa* spp. affecting available grazing area		Poaching	
Low growth rates resulting to long culture duration to reach harvestable size (500 g). Size at harvest was eventually reduced to 250 g	Increased conflict after passing of original leader		

rights over the sea ranch area being granted to the project proponents did prove to be a substantial problem over time. The reception of sea cucumber fishers from Barangay Victory and adjacent villages to the 5-ha sea ranch was poor during the first year of the project, as they felt that their fishing grounds were reduced due to the sea ranch. To foster public awareness about the project and the importance of the marine ecosystem, an information, education and communication campaign was conducted in schools and adjacent villages. This campaign aimed primarily to communicate that the 5-ha ranch did not exclude gleaning and fishing for species other than sandfish, except in the 1-ha core release area and the monitoring pens. In addition, small boats could pass through the 4-hectare buffer zone, since the sea ranch was not enclosed and delineated only

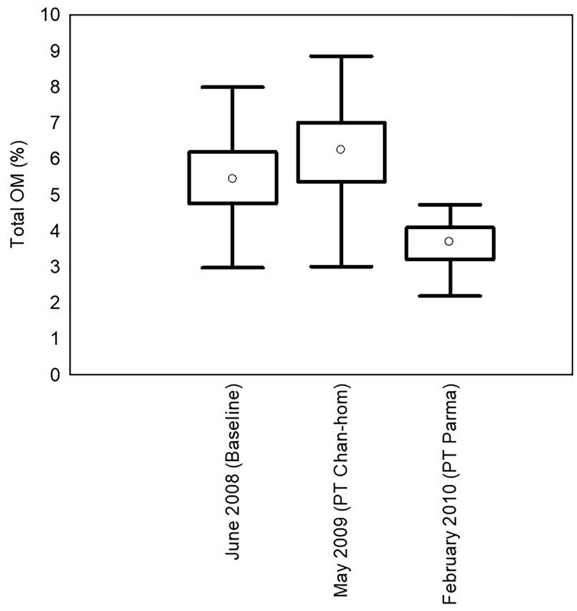

FIGURE 2
Sediment total organic matter (TOM) from the sea ranch showing the baseline (June 2008) and the increase and decrease of percentage of TOM following typhoon Chan-hom (PT Chan-hom) and Parma (PT Parma) during May 2009 and February 2010 monitoring periods, respectively.

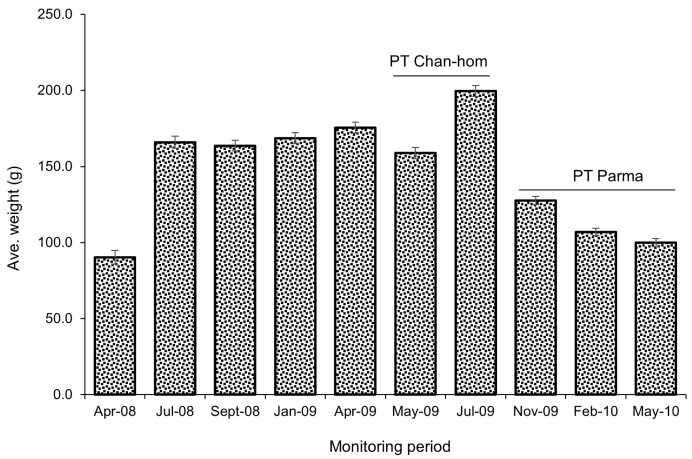

FIGURE 3
Average weight (Ave. weight ± SE) of sandfish across different monitoring periods before and after Typhoons Chan-hom and Parma hit Bolinao, Northwestern Philippines in May and September 2009, respectively.

with markers. Entry and all fishing activities were prohibited only in the 1-hectare core release area. This campaign did improve the general understanding and acceptance of the public towards the sea cucumber ranch, as reported in qualitative interviews.

While the relative openness of the sea ranch did alleviate fears of exclusion from use of the area, it also increased the risk of poaching, and the high density of free ranging sandfish in the sea ranch attracted a lot of attention. Between January to August 2009, three incidences of poaching by fishers from the adjacent village were reported by the community partners. These poaching incidences were resolved by the community partners by obtaining the name of the respondents, asking them to return the sandfish and confiscating the fishing nets. The poachers were reported to their respective barangay captain, who subsequently banned poachers from fishing in the sea ranch. Fishing nets were returned to the poachers after the issues were settled. In Bolinao, as in much of the rural coastal Philippines, the LGUs have limited capacity for enforcement.

Problems guarding the sea ranch also played a role in poaching. In November 2020, Typhoon Vamco hit Bolinao and destroyed the guardhouse, hindering the community partners from guarding the sea ranch. This was further exacerbated by mobility restrictions due to the COVID-19 pandemic from March 2020. In November 2020, a poacher was caught with approximately 3 sacks of sandfish (approximately 150 animals in total). He was apprehended and was asked by the community partners to return the sandfish to the sea ranch. However, results of the succeeding quarterly monitoring in February 2021 to November 2021, indicated continued poaching (Figure 4). This was evident in the sharp decline in the apparent survival of sandfish from the sea ranch during the three monitoring periods in 2021. It is possible that the poacher went back to collect the sandfish when no one was guarding the sea ranch.

Among the community partners, conflicts of interests and misunderstanding, particularly on the division of honoraria and supplies, led to some members leaving the project. One former member explained how he felt that the distribution of the funds was undemocratic and unfair, while another explained how his preferred schedule for guarding was not accommodated. Some of the community partners became less interested and decreased their guarding efforts. To address this, other community partners increased their efforts in guarding in response.

The eventual reduction in interest of some of the community partners could be attributed to low economic returns from the sea ranch as discussed in section 4.5 (Livelihood impacts). Out of the 10 original members, only four to five actively participated in guarding, release, and monitoring of sandfish in the sea ranch. When the leader of the community partners passed away in 2018, misunderstanding and arguments over honoraria and supplies became even more frequent under the stewardship of the succeeding leader. In June 2020, municipal-level changes whereby the enforcement of regulations for marine protected areas was delegated to the Maritime Police and the budget for the Bantay Dagat program was cut. As a result, the monthly honoraria for guarding the sea ranch from the local government stopped.

However, above all social considerations, the decrease in the interest of some of the community partners could be attributed primarily to low economic returns from the sea ranch as discussed in section 4.5 (Livelihood impacts). The changes in the biophysical characteristics negatively affecting growth performance and survival sandfish in the sea ranch resulted in

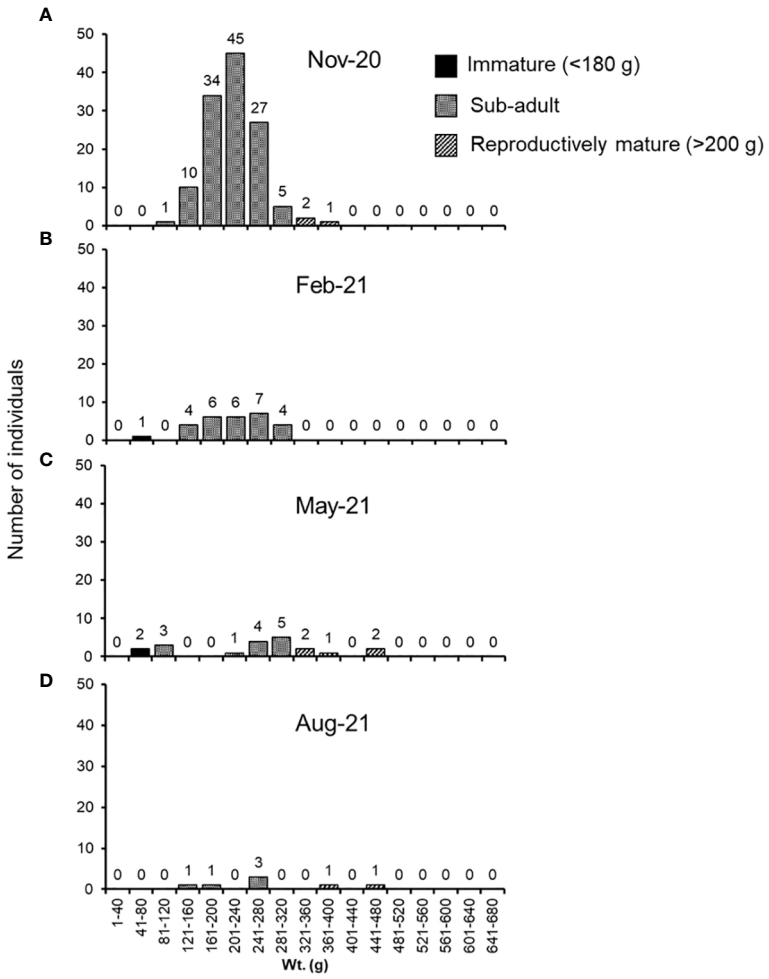

FIGURE 4
Size frequency distribution and total number of sandfish *Holothuria scabra* from the sea ranch during quarterly monitoring in **(A)** November 2020 (n = 125) before Typhoon Vancom hit Bolinao; and, **(B–D)** the total number of sandfish from the sea ranch during the quarterly monitoring in February 2021 (n = 28), May 2021 (20) and in August 2021 (n =7) following Typhoon Vancom, destruction of the guardhouse and reported poaching event within the sea ranch.

a longer culture duration resulting in low economic returns, in addition to economic loss due to poaching.

4.4 Changes in governance mechanisms

In June 2020, the project and the community partners made a consensus decision to amend the agreement on the management strategies and operations of the sea ranch, shifting from a communal model to working directly with individuals who have specific tasks assigned by the project. The partners were composed of the four active members involved in the maintenance and operations of the sea ranch. The community partners also assisted with the release of juveniles, monitoring growth, survival and documentation of poaching of sandfish in the sea ranch. A focal person was assigned to prepare materials for the repair and maintenance of the sea ranch and reports directly to the project. Each of the four members were given a monthly incentive amounting to PHP 2000 (USD 40) for guarding the sea ranch.

The poaching event in 2020 (section 4.3) prompted the UPMSI Sea Cucumber Research Program and the community partners to further assess and evaluate the management and operational mechanisms in the sea ranch. To increase the interest and involvement of the community partners, a buy-back scheme for rearing larger juveniles (> 10 g) to be released in the sea ranch was implemented in May 2022. The UPMSI Sea Cucumber Research Program provided 1500 sandfish

juveniles (initial size: 1-12 g) which were reared in three monitoring pens for a month by the community partners. Of these, about 38.8% were initially retrieved, weighed (13-66 g), and released in the sea ranch. The price of the juveniles increases with size (weight; g) to incentivize rearing of juveniles to larger sizes up to 2-3 months. Subsequent incomes from harvest of marketable sandfish from the sea ranch will accrue to SMMV members who will help in maintaining the sea ranch with a share of the proceeds given to the barangay. These mechanisms encouraged the community partners to innovate to increase the growth and survival of the sandfish juveniles in the pens and the sea ranch. For example, one of the partners narrated that he regularly checks and removed predators from the pens such as the spiny rock crab *Thalamita crenata* to increase survival of sandfish juveniles in the pens. Additionally, he mentioned that he now collects sandfish moving away from the sea ranch, and transfers them to the core or nursery zones of the sea ranch.

The changes were undertaken to improve the management and operation strategies of the sea ranch. These were necessary to facilitate the rebuilding of the sandfish population and increase the production of marketable size sandfish. Prospectively, these would improve the economic viability of the sea ranch. To increase community participation and encourage involvement of other community members, the leader of SMMV was also invited to observe the monitoring in pens, and regular feedback to the community on the status of the sea ranch will be resumed. Improvement of the management system is essential in preparation for the eventual turnover of the sea ranch to the LGU, or other interested stakeholders (e.g., the SMMV, or private investors), once the project ends.

4.5 Livelihood impacts

4.5.1 Economic returns from harvest

The harvest and income generated from the sea ranch from 2008-2018 is shown in Table 3. The income generated from selling processed and dried sandfish from the sea ranch was divided among members based on their time invested in guarding. In addition, it was agreed that the barangay will be given a 10% share of the proceeds from selling sandfish from the sea ranch. However, due to the relatively small amount generated from the harvests, the barangay was only given once their 10% share. The target weight at harvest for individual sandfish was initially set at 500 g, however, due to deterioration of sediment quality following Typhoon Parma and the seasonal increase in *Amphiroa* sp. and seagrass cover, both partners agreed to lower the size at harvest to 250 g. In December 2008, exactly one year following the first release of sandfish juveniles in the sea ranch, a total of 39.58 kg (wet weight; 127 pieces) sandfish (av. weight: 311.7 ± 39 g) were harvested and processed. When dried, the sandfish only weighed 1.3 kg and were sold at USD 38. Due to low growth rates – possibly from the protracted effect of the previous storms (Juinio- Meñez et al., 2013) – a mass harvest was done in April 2010. All sandfish weighing ≥ 80 g were harvested, and the sea ranch was left to fallow for two months before releasing the next batch of juveniles. Between 2008-2018 there have been eleven harvests conducted in the sea ranch equivalent to an estimated 467.66 kg, generating a total income of USD 558 (Table 3). The prices of dried sea cucumbers were relatively low due to their small sizes. When dry, a 250 g sandfish is only about 5 cm in length which is the minimum size limit for most traded species of sea cucumbers including sandfish (BFAR, 2013).

4.5.2 Economic returns from spillover

In February 2010, more than 2 years following the first release of juveniles in the sea ranch, the first spawning event of sandfish (150-400 g) was observed. Spawning has since become a regular event, indicating the importance of the sea ranch in establishing a spawning population to replenish the sandfish populations in the wild. *In situ* spawning observations conducted between February to May 2016 showed that three of the four documented spawning events occured during spring tide coincident with the last quarter moon phase, while the incidence of spawning in February was

TABLE 3 Cumulative harvest and income generated from the sea cucumber sea ranch at Barangay Victory.

Year	Wet weight (kg)	Dried weight (kg)	Amount (USD)
2008	*39.6*	1.3	37.6
2010	*224*	5.5	119.7
2014	*41.4*	2.2	140.8
2015	*30.9*	1.03	82.0
2016	*75*	2.5	130.5
2017	*11.8*	0.4	26.2
2018	*45*	1.5	20.9
TOTAL	**467.66**	**14.44**	**557.70**

Wet weight values in italics indicate derived values from dried weight using 0.03 correction factor.

observed during the new moon phase. Similarly, spawning events reported by the community partners in 2021 coincided with the new moon.

During interviews in 2022, interviewees were unanimous in expressing the view that the sea ranch had generated positive spillover effects. For example, fishers described how they would fish close to the boundaries of the sea ranch in order to target sandfish. While the numbers of sea cucumbers were widely described by interviewees as having declined significantly over several decades due to steadily increasing market demand and increased fishing activity, several interviewees suggested that the numbers of sandfish had stabilized or increased in the local area since the initiation of the sea ranch. Others also suggested that other species of sea cucumbers had also increased as a result of the sea ranch, such as *lawayan* (*Bohadschia marmora, B. vitiensis*) and *labuyo* (*Holothuria fuscocinerea*), as well as types of shells such as *didila (Canarium labiatum)* and *biyat-biyat (Lajonkairia lajonkairii*).

When asked for details on how he understood sandfish populations in the wild to have increased, one fisher who fished regularly for blue swimming crabs (*Portunus pelagicus*) noted that 'I have directly observed this. I go out every day at dawn for crabs, and I see the sandfish, especially near the sea ranch'. A trader that was interviewed specifically described how before the sea ranch was established, his trade included virtually zero sandfish, now he is also trading sandfish. He pointed out that the two specific sites where sandfish were regularly caught near the barangay were 1) a sandbar near the sea ranch, and 2) an area ('Malwak') near the sandfish ocean nurseries. During this interview, a fisher arrived and sold sandfish that had been caught at Malwak. These observations were validated through sandfish landed catch monitoring from 2014-2016 (Figure 5) indicating an increase in the wild sandfish population. Results suggest that spilllover effects were likely to have occurred by a combination of both regular dispersal of larvae from spawning events within the sea ranch, and from adult emigration.

There are additional reasons why the possible benefits from spillover may have value. Fishers in the barangay who rely on sea cucumbers as a significant component of their catch tend to have low levels of capital assets, i.e., do not own a boat with an engine. Instead, they fish for sea cucumbers (as well as other invertebrates such as shells, and fish) using a *balsa* (bamboo raft) and a spear, often at night time. In general, in the coastal Philippines, fishers with lower levels of capital assets tend to be more economically vulnerable (Fabinyi et al., 2017; Jones et al., 2022). In this way, the potential spillover effects may be helping to support some of the poorer community members. While it is impossible to fully confirm or validate these accounts with existing data, the strength of the perceived spillover benefits from the sea ranch is a significant finding in its own right, which has led to greater community support for the sea ranch.

4.5.3 Wider social impacts

While the economic incentives provided to community partners for guarding were and are very small, they are still meaningful and significant. For example, one family currently involved in guarding described how the honorarium provided by guarding was still an important component of their livelihoods, supporting their primary sources of income as a laborer in the fishponds (husband) and work in the municipal capital at a restaurant (wife). For another family, it supported the work of the husband as a freelance carpenter, and the work of the wife deboning milkfish and gleaning along the shoreline. As with the case of the potential spillover impacts, the direct economic benefits provided for guarding the sea ranch were viewed to have had some impacts for some of the poorest community

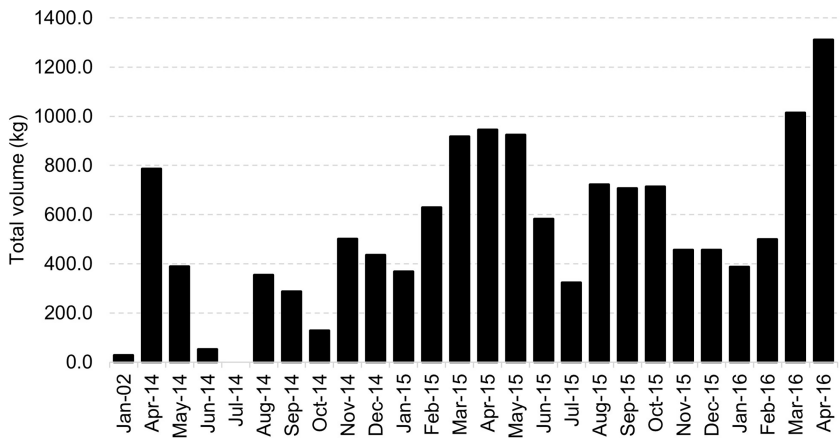

FIGURE 5
Sandfish *Holothuria scabra* landed catch from within Bolinao-Anda Reef Complex in Bolinao, Northwestern Philippines showing the baseline data from January 2002 and the relative increase in sandfish as evident in the monitoring data from April 2014 to 2016.

members. While monthly incomes for these members are highly variable, fisherfolk in the Philippines in general have a very high incidence of poverty (Philippine Statistics Authory (PSA), 2020), with incomes often well below PHP5000 per month (Fabinyi et al., 2017).

Some residents involved in guarding the sea ranch also spoke of the sense of contributing to future generations, and of their pride in hosting a sea ranch. As one older man involved with the project explained: 'I am older and mostly retired now. I have my house and my simple life, and I want to do something for those who come after me'. While these sorts of perceptions are less tangible than direct economic benefits, they are nonetheless significant. For example, a previous study about perceptions of tourism in Victory found that among the most significant aspects of tourism was its capacity to generate a sense of pride and a 'change of pace' in everyday life, providing an alternative to the monotony and struggles of everyday life (Porter, 2015).

In addition to the direct impacts of the ranch in Barangay Victory, it has served as an important learning and demonstration site for coastal resource managers, educators, researchers and for tourists. The model of the community based sea ranch has also been replicated throughout the Philippines, leading to new projects and sites in Eastern Visayas, Western Visayas and Mindanao (McClean and Fabinyi, 2022).

5 Discussion

Mariculture of sandfish has been promoted by governments and researchers in different tropical regions as a supplemental livelihood activity. While the technical processes involved in sandfish mariculture have developed significantly, challenges remain in translating the technical feasibility of holothuriculture (Hair et al., 2019) into tangible livelihood benefits in diverse contexts. In this paper we have documented the experiences of one sandfish mariculture project from its inception in 2007 until 2022.

Due to a range of factors, including adverse environmental conditions, the capacity to generate strong economic benefits from harvests was limited. This was considered to be a major reason why the level of participation in the sea ranch over time diminished among the community members. As a result of these limited direct economic benefits from harvests, the management of the project shifted from a communal approach to a more limited interaction with specific households involved in the guarding, who were willing to remain committed to the sea ranch despite these limited economic benefits. Yet despite these challenges in the harvesting process, the sea ranch did appear to generate spillover effects and to thereby increase the wild populations of sandfish, benefitting fishers who target sea cucumbers. Furthermore, those fishers who fish for sea cucumbers, and those who are involved in guarding the sea ranch, tend to be among the poorer in the community.

It is important to acknowledge that these experiences are not representative of sandfish mariculture across the tropics – even within the Philippines, diverse economic and environmental conditions in different sites generate correspondingly diverse outcomes (McClean and Fabinyi, 2022). However, there are three key implications that emerge from our findings from this one site.

First, the reduced involvement of community members over time and the changing nature of governance arrangements in this case highlights that to maintain and sustain the involvement of a broad base of community members, all labor in the establishment of the sea ranch needs to be directly compensated. Given the likelihood of limited direct economic returns from harvests in the early stages of sea ranch establishment and grow out, it is not realistic to expect that community members who are from among the poorer households especially, will be able to maintain a sustained involvement in sea ranch establishment without guarantee of reasonable remuneration in the short term. In this case, sufficient economic incentives did not exist in the communal model to make it a worthwhile value proposition for community members to forgo the opportunity to generate income from existing sources, and many community members were not able to take on the risk associated with sea ranch establishment.

Secondly, given that spillover effects from the sea ranch appear to generate the primary economic benefits, in order to maximize these benefits there is a need to integrate this spillover effect with wider fisheries management tools. In particular, given the strong correlation between sizes of dried sea cucumbers and price (Purcell, 2014) (i.e., larger sea cucumbers fetch exponentially higher prices), if the regulation on size limits was effectively enforced, this would increase prices for fishers (see also Foale and Day, 1997). Given the well-known challenges in enforcement in remote areas of tropical small-scale fisheries, due in part to limited government capacity, it may be effective for authorities to consider targeting trading 'pinch-points' (Foale, 2007; Purcell, 2010; Purcell et al., 2013; Steenbergen et al., 2019), such as export hubs in Manila.

Thirdly are the implications for financial sustainability and possible investment. Given that the economic returns from sandfish production in this context have been limited and widely dispersed (e.g. including fishers, many of whom were not directly involved in the project), the incentives for private investors appear to be limited. Instead, given the public nature of the spillover benefits, there is a potential role for governments to contribute modest support for sea ranching, where sea ranches are locally appropriate and effectively integrated with local livelihoods (Haenssgen et al., 2021; McClean and Fabinyi, 2022). This includes contributing to the direct compensation of labor during establishment and grow out phases, until such time as returns on harvest are sufficient to compensate for the effort involved in maintaining the sea ranch. Overall, the findings of this paper have highlighted the ongoing need for

tangible livelihood benefits to increase the chances of long-term project success.

Data availability statement

The interview datasets presented in this article are not readily available because a condition of the ethics protocol was that raw data would only be accessed by the researchers due to confidentiality. Biophysical data will be made available by the authors,without undue reservation. Requests to access the datasets should be directed to michael.fabinyi@uts.edu.au.

Ethics statement

The studies involving human participants were reviewed and approved by Human Research Ethics Committee of the University of Technology Sydney (ETH19-4371). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

Author contributions

MF, NM and MJ-M conceived the paper. MF, JG and MJ-M collated, collected and analysed the data. MF, JG, NM and MJ-M wrote the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

Author JG is employed by the Marine Environment and Resources Foundation (MERF), Inc., a not-for-profit non-government organization that manages projects, disburse and audit funding (ONLY) on behalf of the funding agency.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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