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Linking seagrass ecosystem services to food security: The example of southwestern Madagascar's small-scale fisheries

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ABSTRACT

Small-scale fisheries (SSF) are crucial for food security and poverty alleviation. Many SSF are however under pressure, and in need of better management paying special attention to the key seascape ecosystems which are supporting them. This study investigates the importance of seagrass beds for SSF households and their food security in southwestern Madagascar. The specific aims of this study were to: i) analyze if and how seagrass-associated fish contributes to subsistence and/or the economy of local fishing households, ii) identify and compare seagrass ecosystem goods and services valued by local fishers in a rural and an urban setting, and iii) analyze links between local people and seagrasses in terms of local ecological knowledge, use and traditions. The results showed that seagrasses were the most important fishing habitats for most fishers. Seagrass-associated fish species were both the economically most important and most commonly fished species, and are a major source of protein in the region. Further, seagrass-derived sea urchins are important complements to local people's diets. The findings illustrate that seagrasses contribute both through subsistence and income generation to food security and wellbeing of coastal people in southwestern Madagascar. This highlights the need to consider seagrass ecosystems in management towards sustainable SSF and their ability to sustain food security for future generations.

1. Introduction

In the light of a growing world population, food security is of major societal and global concern. Major challenges are to meet the rapidly increasing demand for food in environmentally and socially sustainable ways, and, most importantly, to battle hunger amongst the world's economically poorest people (Conijn et al., 2018; Gerten et al., 2020; Godfray et al., 2010). Threats of ecosystem degradation, depleted biodiversity and climate change further aggravate the situation (Lobell et al., 2008; Springmann et al., 2018). Current estimates show that 690 million people are globally affected by hunger, and close to 750 million people are globally threatened by severe levels of food insecurity in 2019 (FAO et al., 2020). In Sub-Saharan Africa, 220 million, one fourth of the population, are facing hunger and the number of undernourished people is growing faster than in any other region of the world (FAO et al., 2020; FAO et al., 2015). In the World Food Summit (1996) it was agreed upon the definition that food security exists when "all people, at all times, have physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for a healthy and active life" (FAO, 1996). The fundamental food provisioning function of ecosystems (MEA, 2005) and the importance of SSF for food security and wellbeing has repeatedly been emphasized (Béné et al., 2016; Béné et al., 2015a; Béné et al., 2015b; Chuenpagdee et al., 2006; Garcia and Rosenberg, 2010; Kawarazuka and Béné, 2010; Thilsted et al., 2016; Weeratunge et al., 2014). Many millions of people are globally dependent on SSF (Béné, 2006). However, the contributions SSF make to human nutrition, development and poverty alleviation have largely been undervalued (Berkes et al., 2001; Chuenpagdee et al., 2006; Delgado et al., 2003; FAO, 2007; HLPE, 2014; Johnson, 2018), which is especially true for women working within SSF (de la Torre-Castro, 2019; Harper et al., 2020). In addition, most SSF are located in low-income countries, where they play a substantial role for households and local economies, as well as for social welfare (Allison and Ellis, 2001; Loring et al., 2018). Fishing is crucial for economically poor households with limited livelihood alternatives (Béné, 2006; FAO et al., 2020). For the poorest and most marginalized, the subsistence component of fishing is

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even more important than cash income, as subsistence can make the difference between good and bad nutrition, between recovered health and prolonged illness or between food security and starvation (Béné, 2006; Béné et al., 2016).

Fish adds to the nutritional security of economically poor households in two ways: through the consumption pathway (as the direct consumption of fish delivers important micronutrients and essential fatty acids) (Hicks et al., 2019) and through the cash-income pathway (as selling of fish catches leads to improved purchasing power and higher overall food consumption) (Kawarazuka and Béné, 2010). Fish consumption is therefore critical, especially for children and women in remote, resource poor areas (Béné et al., 2015a; Béné et al., 2015b). The diets of poor people in developing countries are commonly carbohydrate-based and fish constitutes thus an utterly important source of high-quality protein (Kawarazuka and Béné, 2010). Moreover, the benefits of SSF reach even beyond food security and income generation, as they contribute to social and psychological aspects of coastal livelihoods, such as self-esteem of local communities through cultural elements like collective actions, a shared cultural identity or a sense of social norms (Astuti, 1995; Béné et al., 2010; Johnson, 2018; MacGoodwin, 2001). Alarmingly, SSF are in many areas of the world under pressure due to factors such as open access fisheries, lacking livelihood diversification, growing populations, migration, climate change and insufficient management (Chuenpagdee, 2011; Cinner et al., 2012; de la Torre-Castro, 2019; Jentoft and Eide, 2011; Sumaila et al., 2016). Due to this development, millions of people are facing an insecure future, with their livelihoods and food security at risk (Allison et al., 2009; Chuenpagdee, 2011; Jentoft and Eide, 2011). Steps towards sustainability of SSF which can ensure the contributions these fisheries make against hunger and poverty, and for socio-economic development, are therefore crucially needed (FAO et al., 2015; Mills et al., 2011).

Comprehensive and inclusive approaches for better governance and management of SSF have been recommended, acknowledging the context and the interconnectivity between ecosystem health, social justice, livelihoods and food security (Chuenpagdee et al., 2005; Chuenpagdee and Jentoft, 2018; Jentoft et al., 2017). As ecosystems build the fundamental base of food production, a holistic seascape approach is recommended, including all marine habitats (like corals, seagrasses and mangroves likewise) when striving to achieve sustainable SSF systems (de la Torre-Castro et al., 2014; Nordlund et al., 2018; Unsworth and Cullen, 2010). Seagrass beds are crucial elements in marine environments (Barbier et al., 2011; Orth et al., 2006; Short and Green, 2003; Unsworth and Cullen, 2010) and provide ecosystem services of high economic importance (De la Torre-Castro, 2006; Nordlund et al., 2016; Nordlund et al., 2018). Despite previous studies pointing out the major contributions of seagrasses to fisheries production and food security in the Indo-Pacific (Unsworth and Cullen, 2010), as well as their local (e.g. de la Torre-Castro and Rönnbäck, 2004) and global social- ecological importance (Cullen-Unsworth et al., 2014; Nordlund et al, 2018), seagrasses are often not recognized as conservation priorities, and can remain with no or low management and monetary inputs (Cullen-Unsworth et al., 2016; Duarte et al., 2008; Unsworth et al., 2018). Seagrass ecosystems are reported to decline at an alarming rate all over the world (Grech et al., 2012; Orth et al., 2006; Waycott et al., 2009; Unsworth et al., 2018). The importance of seagrass conservation for supporting ecosystem services for food security has recently been discussed (Baker et al., 2015; Nordlund et al., 2018). However, studies illustrating the direct importance of seagrasses for food security are strongly needed.

Madagascar is one of the poorest countries in the world, with around 75% of the population living under the international poverty line of USD 1.90 per day in 2019 (World Bank, 2020), and 42% of all children under 5 years being chronically malnourished in 2020 (World Bank, 2021). Madagascar's fisheries are of major importance for local populations living along the extensive coastline (Le Manach et al., 2012). About half of all fishers operate in Toliara province in southwestern Madagascar, which is among the poorest areas of the country (Laroche and Ramananarivo, 1995). The arid climate in the region is aggravated by land degradation from overgrazing and deforestation, and allows only low agricultural and livestock production and little livelihood diversification (Laroche and Ramananarivo, 1995; Le Manach et al., 2012).

Despite the high importance of coastal ecosystems in Madagascar, seagrass-related research is extremely scarce (Gullström et al., 2002; Hantanirina and Benbow, 2013). Using the case of SSF on the southwest coast of Madagascar, this study investigates potential links between seagrasses and food security of fishing households empirically. The three specific aims of this study were to: i) analyze if and how seagrass-associated fish contributes to subsistence and/or economy of local fishing households, ii) identify and compare seagrass ecosystem goods and services valued by local fishers in a rural and an urban setting, and iii) analyze links between local people and seagrasses in terms of local ecological knowledge, use and traditions.

2. Methods

2.1. Study site description

Madagascar is the fourth largest island in the world, located in the Western Indian Ocean (WIO) off the African southeast coast. Madagascar's southwest coast is mainly inhabited by the indigenous Vezo people who are traditional small-scale fishers. They rely heavily on fishing, which is the primary source of income for the majority, and often the only source of cash income (Barnes-Mauthe et al., 2013; Davies et al., 2009; Hantanirina and Benbow, 2013; Harris, 2007; McClanahan et al., 2014). Traditional SSF accounted for 72% of Madagascar's total catches in the 2000s (Le Manach et al., 2012), and delivered the bulk of marine products on local markets (FAO, 2004). SSF are highly important for local food security and provide the main source of protein and income (Barnes-Mauthe et al., 2013; Laroche and Ramananarivo, 1995). However, fishers reported marine resources to be on decline for years in southwestern Madagascar and signs of overfishing have been documented (Brenier et al., 2011; Gough et al., 2020; Laroche et al., 1997). This is thought to be driven by the great increase of coastal populations and overlapping industrial fishing fleets from Europe and Asia, as well as increasing (global) market forces (Bruggemann et al., 2012; Harris et al., 2010; Gough et al., 2020). In this context of a socio-political and economic crisis, increasing numbers of fishers and competing industrial fleets, regulations and management of marine resources are strongly needed (Brenier et al., 2011; Gough et al, 2020; Laroche and Ramananarivo, 1995; Le Manach et al., 2012). The required resources for SSF management are, however, lacking (Brenier et al., 2011) and law enforcement as well as monitoring systems are deficient (Billé and Mermet, 2002; Le Manach et al., 2012). An example for the lack of enforcement is a law based on an earlier colonial decree forbidding nets with mesh sizes smaller than 25 mm (Rakotoson and Tanner, 2006). Beach seines, which are among the most destructive gears in the region, fall into this banned category, but despite degraded marine habitats, due to the lack of law enforcement, their use is still common (Gough et al., 2020; Rakotoson and Tanner, 2006; this study).

The coastlines of south-western Madagascar are characterized by fringing and patchy reefs, seagrass beds and, in some places, mangrove forests (Davies et al., 2009; Laroche and Ramananarivo, 1995). Nine of the 14 seagrass species found in the WIO (Bandeira and Björk, 2001; Gullström et al., 2002), have to date been recorded in southwestern Madagascar: *Cymodocea rotundata* (Ascherson & Schweinfurth), *C. serrulate* (R. Brown), *Halodule uninervis* (Forsskål), *H. wrightii* (Ascherson), *Halophila ovalis* (R. Brown), *H. stipulacea* (Forsskål), *Syringodium isoetifolium* (Ascherson), *Thalassia hemprichii* (Ehrenberg) and *Thalassodendron ciliatum* (Forsskål) (Hantanirina and Benbow, 2013; Lepoint et al., 2008; Vaitilingon et al., 2003). Until 2003, neither seagrass cover nor –loss had been assessed for Madagascar (Short and Green, 2003), and scientific studies remain scanty, with the exception of a study from

2013 (Hantanirina and Benbow, 2013), and social-ecological studies on local seagrasses lacking.

A number of direct and indirect factors are threatening the seagrass ecosystems in Madagascar: i) deforestation (including mangroves) and land-use change leading to soil erosion, increased siltation rates and water turbidity (Hantanirina and Benbow, 2013; Laroche and Ramananarivo, 1995; Lepoint et al., 2008); ii) pollution and eutrophication (Hantanirina and Benbow, 2013; Lepoint et al., 2008), especially in urban areas like Toliara, where urban effluents reach the shore without sewage treatment, and human and animal dejection on tidal flats are common (Hantanirina and Benbow, 2013; Laroche and Ramananarivo, 1995; Lepoint et al., 2008); iii) growing coastal populations, increasing numbers of fishers, the use of destructive fishing methods like beach seining and the effects of overfishing in general, as fishers try to outweigh declining catches by increased fishing efforts (Brenier et al., 2011; Bruggemann et al., 2012; Hantanirina and Benbow, 2013; Harris, 2007; Harris et al., 2010; Laroche and Ramananarivo, 1995); iv) trampling and digging by invertebrate collectors (Hantanirina and Benbow, 2013; Lepoint et al., 2008); and v) climate-change induced warming of the sea surface temperature (Harris, 2007).

The artisanal fisheries of Madagascar use a number of different gears and catch a high diversity of species (Davies et al., 2009). Fishing is usually done close to the shores, and the main gears used are hand lines, gillnets and beach seines, but also long lines, spear guns and spears are used (Davies et al., 2009; Laroche and Ramananarivo, 1995; Le Manach et al., 2012). Only non-motorized traditional pirogues are used, which are between 3 and 8 meters long and have a single outrigger as well as paddles or sails (Davies et al., 2009; Laroche and Ramananarivo, 1995).

The two study sites (Fig. 1) are located on Madagascar's southwest coast, in the Atsimo-Andrefana region, province of Toliara: Site 1 the settlement of Akiembe in the southern part of the urban area of Toliara and site 2 the village of Ifaty situated about 20 km north of Toliara, in the Bay of Ranobe. Toliara has over 20 000 inhabitants and is a major regional commercial administrative center lying on a major barrier reef, the Grand Récif of Toliara. Ifaty is a small village in the southern region of the Bay of Ranobe. There is little livelihood diversification and fishing is the only source of cash income for many households (Barnes-Mauthe et al., 2013; Davies et al., 2009; Whittingham et al., 2003). The two study sites were chosen in order to compare two environments with different levels of anthropogenic impacts as well as differing conditions of seagrass meadows. Although seagrass cover has not been adequately investigated in Madagascar (Short and Green, 2003), LePoint et al. (2008) describes seven different species of seagrasses close to Toliara. There is no data available for seagrasses in Ifaty or the Bay of Ranobe in general, but seagrass meadows lying north of Toliara are believed to be less degraded (Hantanirina and Benbow, 2013).

Fig. 1. Location of the study sites Ifaty and Toliara in southwestern Madagascar, Western Indian Ocean region.

3. Interviews

Data collection was conducted from October to December 2011. Qualitative and quantitative data was collected using semi-structured and in-depth interviews (Denscombe, 1998; Kvale and Brinkmann, 1997) with fin-fishers (for the interview guideline, see supplementary material Appendix S6). Participant observations (e.g. reparations of gears, leaving for and returning from fishing, preparation of fish to sell) and informal discussions with fish traders in Ifaty complemented the interview data.

A total of 120 semi-structured interviews with fishers were conducted, whereof 60 in Akiembe in the urban area of Toliara, and 60 in the rural village of Ifaty (Fig. 1). The settlement of Akiembe, Toliara, is mainly inhabited by people with origins from three regions south of Toliara: Anakao, Sarodrano and St. Augustin. To keep the sample as representative as possible, 20 fishers were chosen from each region/origin. Before any interviews were conducted, the study and its purpose were introduced to village chiefs, elders and members of the fishery committees to ask for permission. All respondents were randomly chosen, irrespective of age, gender, origin or fishing gear. However, all interviewed fin-fish fishers were male, as fin-fish fisheries in the sites were male dominated and no female fin-fish fishers have been found during the data collection for this study. Women and children collected invertebrates in the intertidal, and their activities, perceptions and contributions to local households would deserve a study on their own to complement the current study. Such data collection was not possible due to limited field time during this study. However, as men normally bring a part of the catch and parts of the monetary income to their families and households, it can be assumed that the investigated fish species bring contributions to household members irrespective of gender or age. After the respondents gave oral consent to be interviewed, the interviews were held at public meeting points, fishery landing sites or the fishers' homes. To further understand the local fisheries and their social-economical components, 25 additional in-depth interviews with fishers were conducted. With the help of local translators affiliated to the Institute Halieutique et det Sciences Marine (IHSM) in Toliara, the interviews were conducted in the Vezo dialect of Malagasy and the answers translated to French. Pictures of local seagrass species were shown to specify questions on seagrasses and avoid confusion, as there is one common word for seagrasses and algae in Vezo language. Further, questions on specific fish species were backed up with color-photographs for easier identification.

Questions on the provision of seagrass associated goods and services were based on the classification found in de la Torre-Castro (2006) and the typology of the ecosystem services approach from the Millennium Ecosystem Assessment (MEA, 2005). This approach describes ecosystem services as benefits that people gain from ecosystems (MEA, 2005). Using the same classification system as the MEA, we structured the questions on seagrass-associated ecosystem services after: provisioning services (the provision of fishing grounds, fish and invertebrates), regulating services (water filtration, sediment stabilization, reduction of wave action) and cultural services (spiritual and esthetic values as well as traditional believes). Fishers were asked to describe the importance of seagrass related ecosystem goods and services by using a scale from 1 to 5 (with 5 standing for the highest importance). This grading system was illustrated with cards showing 1 to 5 stars for facilitation. Answers were noted on the interview guideline, transcribed in English and coded for analysis (see supplementary material for the interview guideline).

3.1. Data analysis

Multivariate statistics were used to analyze similarities and/or differences between the urban site of Toliara and the less developed rural site of Ifaty. The data included in the analysis concerned the valuation of the provision of fishing grounds, nursery areas, spawning sites, foraging sites, shelter, turtles and dugongs, crustaceans, molluscs, echinoderms, erosion control, control of wave action, good water quality, tourism benefits, benefits for local communities, importance for traditional beliefs and the importance for direct use/collection. The level of importance was stated from 1 to 5 (5 being highest importance). The program PRIMER 5 for Windows v5.2.9 (Copyright® PRIMER-E Ltd) was used for the analysis, following normal procedures as stated in Clarke & Warwick (Clarke and Warwick, 2001). Based on the Bray-Curtis similarity coefficient, differences and similarities in services were visualized using a MDS diagram (Multidimensional analysis). Analysis of similarities was used to test significance and compute the r-value. The entry data was the individual responses of each fisher. Data was 4th root transformed to perform the analysis.

4. Results & discussion

4.1. Fishing practices

All interviewed finfish-fishers were men since no women were found to be involved in finfish activities in the area. Women were mainly occupied with fish processing, fish trade or invertebrate harvesting and were generally not involved in the catch activities of finfish (this study; Langley, 2006), as also documented from other SSF in the WIO (de la Torre-Castro et al., 2017; Fröcklin et al., 2013; Fröcklin et al., 2014). The respondents were 13 to 80 years of age, with a median of 32 years, and a median of fishing experience of 18 years. Fisheries were the primary source of income for 90% of the respondents (n = 120), and 88% did not have any other occupations besides fishing (Table 1). These results illustrate a high degree of dependency on SSF and local marine resources. Further, a majority of the fishers stated to be fishing every day (7 days per week, see Table 1), and all fishers stated to use traditional non-motorized pirogues, either with paddles or sails. In both study sites, the most commonly used main fishing gear was gillnets, followed by beach seines in Toliara, which in contrast were absent in Ifaty (Table 1). This difference might be explained by locally differing fishing habits, as most fishers in Toliara from sectors with roots in St. Augustin and Anakao used beach seines. Further, the efforts of the local fishing association 'Fikambanana Miaro sy Hanasoa ny Ranomasina' (FI.MI.HA.RA) – in English 'Association to Protect and Enhance the Marine Environment' in collaboration with the NGO ReefDoctor managed to exclude beach seines from Ifaty village (Belle et al., 2009; Gibbons, 2011).

Seagrasses were most often mentioned to be the most commonly fished on substrate in both Ifaty and Toliara (Table 1), followed by corals in Ifaty and sand in Toliara. This illustrates the great importance of seagrasses for local fisheries. This has also been reported in an earlier study from the WIO region (de la Torre-Castro and Rönnbäck, 2004). Forty percent of fishers from Toliara compared to only 20% from Ifaty mentioned sand as the most often fished on habitat. This difference could most likely be explained by the different fishing gears used (mainly gill nets in Ifaty and both beach seines and gill nets in Toliara), but degradation of habitats in the Toliara sites, including significant decrease in hard coral cover (Harris et al., 2010) as well as perceived decrease of seagrass cover (Brenier et al., 2011) might also be contributing factors. Also, several fishers using gillnets mentioned setting their nets between the corals and seagrasses to catch fish migrating between these habitats.

5. Contributions of seagrass-associated organisms to subsistence, economy and food security of local fishing households

The results show that Rabbitfish (Siganidae) and Emperors (Lethrinidae) were both the economically most important, and among the top three most commonly caught fish families (Fig. 2). These results conform to a previous study from the bay of Ranobe (where one of the study sites,

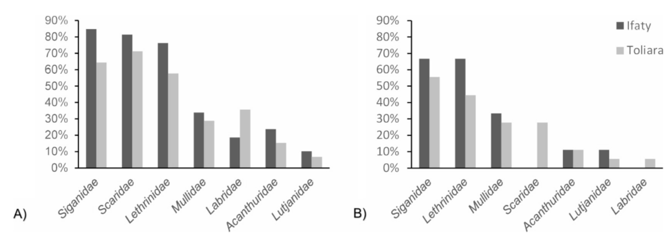

Fig. 2. A) Most commonly caught fish species and B) economically most important fish species. Based on the fishers' responses, in percent of fishers (n = 59 for both Ifaty and Toliara), multiple answers allowed.

Table 1
Age and fishing information (fishing experience, occupation and fulltime fishing, main fishing gears used and most often fished on substrates) of the fisher respondents from the two study sites Ifaty and Toliara.

Fishers' age and fishing information	Ifaty	Toliara
Age		
Age (in years)	13–80	16–64
Age median (in years)	34.5	30.5
Fishing experience		
Fishing experience (in years)	2–65	3–49
Fishing experience median (years)	20	15.5
Fishing occupation		
Fishing as fulltime occupation (in percent)	88.3% (n = 60)	91.7% (n = 60)
Fishing activity 7 days/week	95% (n = 45)	71% (n = 42)
Main fishing gears used (n = 60)		
Gill nets	70%	47%
Beach seines	0	55%
Spears	17%	0
Spear guns	15%	0
Handlines	12%	0
Substrates/habitats most often fished on (n = 60)		
Seagras	50%	42%
Corals	43%	33%
Rocky ground	33%	28%
Sand	20%	40%
Mangroves	0%	2%

Ifaty, is situated), which also found Rabbitfish and Emperors to be the most important species (Davies et al., 2009). Both fish families are seagrass-associated (Gell and Whittington, 2002; Gullström et al., 2002; Pollard, 1984). Rabbitfish (e.g. the seagrass rabbitfish *Siganus sutor*) forage actively on seagrasses, and Emperors (e.g. *Lethrinus lentjan*) use seagrass meadows as foraging habitat, feeding on invertebrates and fish (De la Torre-Castro et al., 2008; Froese and Pauly, 2016; Unsworth et al., 2008). Also, all other fish families mentioned to be most important by the interviewees are commonly associated with seagrass ecosystems in the Western Indian Ocean region (Froese and Pauly, 2016; Gell and Whittington, 2002), use seagrass ecosystems as shelter, nurseries, feeding- or breeding grounds (Nagelkerken et al., 2000; Orth et al., 1984). Interestingly, exactly the same five most commonly fished families (Siganidae, Lethrinidae, Scaridae, Mullidae and Labridae) in our study dominated the fish sold on fish markets in a study from a seagrass dominated bay in Zanzibar, Tanzania (de la Torre-Castro and Rönnbäck, 2004). Furthermore, the three most commonly landed species in a multi-gear fishery in Kenya belonged also to the families of Siganidae, Lethrinidae, and Scaridae, representing 63% of the catch (Hicks et al., 2012). Our results, along with the mentioned previous research, strengthens the notion of seagrasses being the most important habitats for many fishers. Seagrass ecosystems should therefore be considered a major contributor to the bulk of fish production for SSF in the WIO region and of major importance for local food security.

Sixty-four percent of the fishers in total (n = 83; whereof 41% from Ifaty (n = 50) and 49% from Toliara (n = 33)) stated to commonly collect other organisms than fish from seagrass beds during fishing trips. Mentioned organisms were: molluscs (collected by 32% each in both Ifaty and Toliara), sea cucumbers (19% in Ifaty and 24% in Toliara), sea urchins (20% in Ifaty and 22% in Toliara), sea horses (8% in Ifaty and 9% in Toliara), crustaceans (5% in Ifaty only) and sea turtles (mentioned only by one fisher in Toliara). The collection of such organisms from seagrass beds is also described in earlier studies for the area by Gough et al. (2009) and Laroche and Ramananarivo (1995). However, non-commercial species used for household consumption are usually collected by women, children and elderly (Langley, 2006; this study). While sea cucumbers and mollusc shells usually are sold, sea-urchins were mentioned as a welcome substitute for fish in the fisher families' own diet. Sea cucumber prices are high and some fishers stated sea cucumber collection to be more profitable than fishing, 'even on good fishing days'. Sea cucumbers collected in the WIO region are exported to mostly Asian markets, and overharvesting is common (Conand et al., 1998; Eriksson et al., 2012).

Not surprisingly, all respondents mentioned to frequently eat fish, with an average of 4.4 days of fish consumption per week. The most commonly consumed species were from the families Siganidae (mentioned by 54% of the fishers, n = 120), Scaridae (47%), Lethrinidae (29%), Clupeidae (22%), Mullidae (15%), Acanthuridae (15%) and Labridae (8%). All of these families except for Clupeidae are seagrass-associated fish (Froese and Pauly, 2016; Gell and Whittington, 2002). Many fishers added that they would eat the smallest and cheapest fish of their catches which were not of much value on the market, and that they would sell the best fish they caught. These results illustrate the two-way importance of seagrass ecosystems for food security in Madagascar, as both the economically most important species and the most commonly consumed species are species using seagrasses as habitat. Seagrass derived fish plays an important role for subsistence consumption as well as a source of monetary income for local fishers and their families.

Ninety-five percent of all respondents from Ifaty (n = 60) and 98% of the ones from Toliara (n = 60) stated to eat sea urchins, all of which specifying the striped sea urchin *Tripneustes gratilla*, which feeds in seagrass beds (Ogden, 1980). The respondents' reasons for sea urchin consumption were that sea urchins were delicious (34%; n = 74), that it was a Vezo tradition to eat sea urchins (11%), that sea urchins were nutritious (9%) and that sea urchins were available during times when fish were scarce or bad weather (strong winds) hindered them from fishing (8%). Fishers reported to eat sea urchins mixed with rice one to several times a week. Sea urchins were stated to be cheap compared to fish, and were frequently bought at local markets, or collected by the fishers and their family members for home consumption and selling. These results show that invertebrate harvesting from seagrass beds can be an important safety net in difficult times, and can contribute to subsistence and also cash income (see also de la Torre-Castro and Rönnbäck, 2004; Nordlund et al., 2010).

The results further show that fifty-nine percent of all fishers (n = 120) perceived a decline of the striped sea urchin *T. gratilla* in numbers, and 90% of these fishers (n = 71) thought that overcollection was the reason for the perceived decline. It is likely that collection could, besides other factors, contribute to decreasing numbers of *T. gratilla* in the study sites. Earlier studies from Kenya, where consumption is not common, reported instead increasing sea urchin numbers (Alcoverro and Mariani, 2002; Crona, 2006; Eklöf et al., 2008). One factor contributing to growing urchin populations in Kenya is thought to be a lack of sea urchin predators due to intense fishing (McClanahan and Shafir, 1990; Wallner-Hahn et al., 2015), which poses a serious threat to Kenyan seagrass beds, where overgrazing events have been reported (Alcoverro and Mariani, 2002). The collection of sea urchins in Madagascar for consumption might therefore be a contributing factor in preventing urchin populations from growing too large and hence from overgrazing seagrasses.

5.1. Seagrass-associated goods and services valued by local people

Concerning seagrass-associated goods and services, fishers from both study sites ascribed the on average highest importance to provisioning services like the provision of fishing grounds and spawning sites (Table 2 and Fig. 3). The provision of echinoderms was generally higher valued in Toliara than in Ifaty. Possible explanations for this could be higher densities of echinoderms in Toliara, cultural factors, or a higher importance for subsistence, which in turn might be explained by lower fish catches causing a greater need for echinoderms as a complement. However, biological as well as socio-economic data clarifying this is needed.

Also among the highest valued seagrass ecosystem services were their function as habitats for fish and other marine organisms (e.g. spawning-, foraging- and shelter sites) as well as functions for erosion control and maintenance of good water quality (Fig. 3). This indicates high levels of awareness and local ecological knowledge (LEK) on ecosystem functions among the respondents. However, more abstract but crucial services like primary productivity or oxygen production were not among the highly valued functions, which might indicate that these are more difficult to grasp, or that they are not valued to the same extent.

The lowest importance (0 points = not important) was most frequently ascribed to traditional beliefs and the collection and direct use of seagrasses, as well as the provision of molluscs (Table 2). These findings further show that only seven fishers linked taboos or traditional

Table 2
Seagrass-derived goods and services which most fishers ascribed the highest and lowest importance to. Highest importance = 5 points on a ranking from 0 to 5, lowest importance = 0 points. Based on the fishers' responses in Ifaty (n = 60) and Toliara (n = 60), in percent of fishers, several mentions allowed.

Ifaty		Toliara	
highest importance		**highest importance**	
provision of fishing grounds	78%	provision of echinoderms	70%
provision of spawning sites	55%	provision of fishing grounds	68%
provision of foraging sites	48%	provision of fish	62%
erosion control function	48%	erosion control function	62%
maintenance of good water quality	48%	provision of spawning sites	58%
provision of shelter	47%	provision of foraging sites	58%
lowest importance		**lowest importance**	
collection and direct use	92%	collection and direct use	98%
traditional believes	65%	traditional believes	73%
provision of molluscs	7%	provision of molluscs	12%

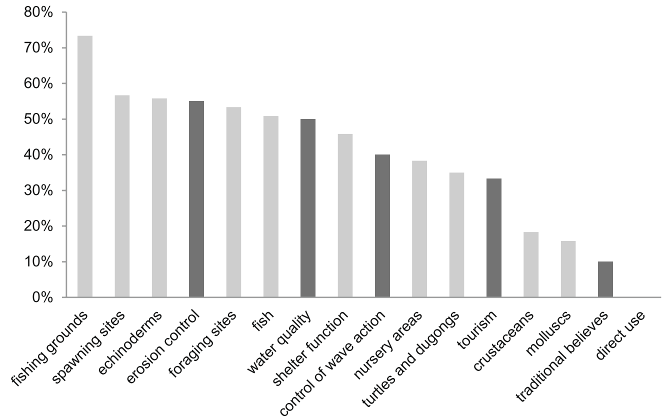

Fig. 3. Seagrass ecosystem services and -functions, in percent of fishers who ascribed the highest importance to them (5 points on a ranking from 0-5). Provisioning services (MEA 2005) in light grey color. Based on the fishers' responses, in percent of all fishers (n = 120).

beliefs to seagrasses, explaining that: it is forbidden to access certain seagrass meadows, to tear up or touch seagrasses, to use beach seines because they harm seagrasses, and that adding seagrasses to drinking water is believed to provide protection from bad spirits. Some few fishers remembered that dried seagrasses collected on the beach were earlier used as stuffing for pillows. These results indicate that the traditional and spiritual values of seagrasses are minor in southwestern Madagascar, which is concordant with a study on the role of taboos in conserving coastal resources in Madagascar, where few fishers in the southwestern region were found to respect local taboos and traditional fishing practices (Cinner, 2007). This could also be a result of a change of generations which implies that traditional beliefs, rules and regulations tend to be forgotten (Laroche et al., 1997).

By contrast, traditional and spiritual beliefs in Zanzibar, Tanzania connected to seagrasses are of medicinal, religious and instrumental value (de la Torre-Castro and Rönnbäck, 2004). However, traditional social codes, ethic rules and taboos are generally prevalent and commonly respected in Madagascar (Lambek, 1992), and the extraction of marine resources is to a certain extent restricted by such rules and taboos (Cinner, 2007; Langley, 2006), but as resources become scarce, they tend to be overlooked (Laroche et al., 1997).

The multivariate analysis showed no differences in the ascribed importance for the seagrass-derived goods and services between the rural village of Ifaty and the urban area of Toliara (Analysis of similatrity {ANOSIM} test: r = 0.038, p = 0.25; see supplementary material for Fig. 1). This result shows that seagrass ecosystems are of equal importance for fishers in both settings, despite the contextual differences like the potential differing states of seagrass meadows, gear use, infrastructure or degree of urbanization.

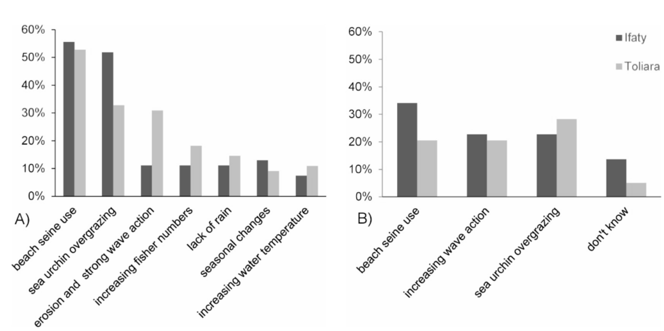

Fig. 4. A) Mentioned causes for a perceived seagrass decrease. Based on the fishers' responses, in percent of fishers from Ifaty (n = 54) and Toliara (n = 55), multiple answers allowed. B) Mentioned threats to seagrasses in Ifaty (n = 44) and Toliara (n = 39). Based on fishers' responses, in percent of fishers.

5.2. Seagrass-specific local ecological knowledge (LEK) and awareness

A majority of the fishers from both Ifaty (88%) and Toliara (93%) perceived seagrasses as declining. Fishers linked beach seine use and sea urchin overgrazing as main reasons to this decline, followed by erosion and strong wave action (Fig. 4A). These perceptions are congruent with scientific research from other areas in the WIO region, where sea urchin overgrazing has been reported to cause local and temporal seagrass declines (Alcoverro and Mariani, 2002; Eklöf et al., 2008), detrimental effects of beach seining on habitats like corals or seagrasses have been reported (Mangi and Roberts, 2006), and erosion (often due to changes in land use patterns) is listed as a major seagrass threat (Gullström et al., 2002). However, biological data on the spatial distribution of seagrasses and its' eventual changes are currently lacking and are strongly needed. The causes fishers linked to declining seagrass beds together with the valuation of seagrass goods and services, indicate high levels of awareness and LEK among fishers. Further, nearly all fishers (99%) were aware of the fact that sea urchins eat seagrasses, which indicates good knowledge about food web interactions. This question was also addressed in an interview study on food web interactions in Kenya, where a much smaller proportion of fishers (less than 50%) were aware of the feeding habits of sea urchins (Wallner-Hahn et al., 2015). The fact that sea urchins generally are not collected in Kenya could be an explanation for this difference. The LEK among the Vezo people of Madagascar has also in earlier studies been described as substantial. Mentioned examples were their LEK concerning sailing and navigating, fish community composition, seasonal changes as well as fishing grounds and habitats (Astuti, 1991; Langley, 2006). Such knowledge (LEK) can contribute important components in the management of resources like fisheries (Berkes et al., 2000), and can complement scientific information for SSF management (Berkes, 2003).

Ninety-nine percent of all fishers both in Ifaty and Toliara said that a disappearance of seagrasses would pose a serious problem to them. All fishers affirmed the importance of seagrasses as exemplified by the following selected quotes: “We, the Vezo, could not survive without seagrasses.”, “Our kids have something to eat as long as the seagrasses are there”, or “The water is always clear where the seagrasses are, this is where we go to fish.”.

Beach seine use, increasing wave action and sea urchin overgrazing were also listed to be the current threats to local seagrasses (Fig. 4B).

Fish catch trends were reported to be declining by 92% of the fishers in Ifaty and 98% in Toliara, which is a worrisome result. A majority of all fishers (52%, n = 120) mentioned increasing fisher numbers as a reason for the catch decline, followed by the decline of seagrasses (18%), overfishing (15%), the destruction of habitats like corals or seagrasses (13%), beach seine use (9%) and climate change (6%). Further, 77% of the fishers perceived the average fish size as declining. In accordance with the fishers' perceptions, such trends of overfishing, habitat degradation and decreasing resources have been described in scientific literature for (south-)western Madagascar (Brenier et al., 2011; Gough et al., 2020; Harris et al., 2010; Le Manach et al., 2012). Reasons for increasing fisher numbers are fast growing populations (Harris et al., 2012) and

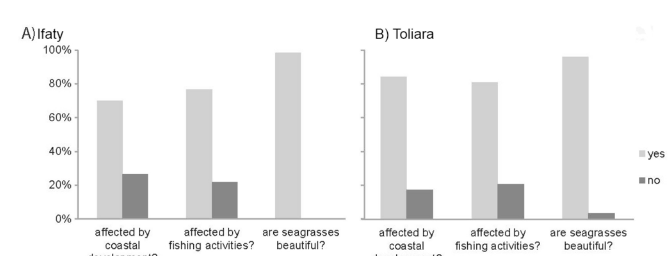

Fig. 5. Perceptions of impacts of coastal development and fishing activities, as well as the esthetical value seagrasses in A) Ifaty (n = 60) and B) Toliara (n = 60). Based on fishers' responses, in percent of fishers.

migration towards the coasts in search for occupation due to unreliable agricultural harvests inland (Cripps and Gardner, 2016). A perception study among fishers of the Toliara Bay reef fishery showed that fishers try to compensate for dwindling resources by intensifying their fishing effort (by using less selective gears with e.g. increasing net size and decreasing mesh size) and by keeping smaller proportions of their catches for subsistence consumption (Brenier et al., 2011). Alarmingly, these results suggest that food security among the fishers of south-western Madagascar already might be at risk due to decreasing marine resources.

Most fishers in both study sites were aware of the fact that seagrass ecosystems are affected by coastal development as well as fishing activities (Fig. 5). Nearly all fishers appreciated the aesthetical value of seagrasses as "decorations of the ocean" and perceived them as beautiful.

6. Conclusions

This study empirically highlights the substantial importance of seagrasses and their ecosystem services in enabling SSF to maintain their contributions to food security and monetary income in Madagascar. We believe that these results are an important contribution towards improved coastal management and are relevant even for other tropical SSF, especially in high resource dependency contexts. The results further show that seagrass-associated goods and services are highly valued among local fishers.

Seagrasses-derived fish contributes directly through consumption, and indirectly through the generation of income to food security and the livelihoods of local fisher households. As invertebrate collection activities (mostly by women) which bring important contributions to households in tropical SSF (Fröcklin et al, 2014; de la Torre-Castro et al., 2017) have not been investigated in this study, it is possible that the importance of seagrasses in southwest Madagascar has been underestimated. Future studies addressing women contributions and gender aspects would enhance the current understanding of these SSF, and provide important information for ecosystem analysis as well as policy and management.

The involvement of LEK of local fishers could benefit resource management greatly and should be valued and included in future initiatives. Traditional and spiritual beliefs concerning seagrasses exist, but are not extensive and do not seem to contribute to seagrass resource management or conservation in southwestern Madagascar. Anchoring new and/or local laws in traditional and ethic regulations might however contribute to their adoption and lead to higher compliance.

The results of our study strongly suggest that management towards more sustainable SSF as well as livelihood diversification are urgently needed to secure local livelihoods. Management should highlight: a) the ecological importance of seagrasses in the seascape, b) the crucial societal benefits that these ecosystems provide to economically poor populations with scarce livelihood alternatives and, c) the need to preserve all coastal ecosystems as a base for food production. A holistic seascape approach in research and management will be needed to build more resilient SSF which can sustain food security for future generations.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecoser.2021.101381.

References

Alcoverro, T., Mariani, S., 2002. Effects of sea urchin grazing on seagrass (Thalassodendron ciliatum) beds of a Kenyan lagoon. Mar. Ecol. Prog. Ser. 226, 255–263.
Allison, E.H., Ellis, F., 2001. The livelihoods approach and management of small-scale fisheries. Marine Policy 25 (5), 377–388.
Allison, E.H., Perry, A.L., Badjeck, M.C., Adger, W.N., Brown, K., Conway, D., Halls, A.S., Pilling, G.M., Reynolds, J.D., Andrew, N.L., Dulvy, N.K., 2009. Vulnerability of national economies to the impacts of climate change on fisheries. Fish Fish. 10, 173–196.
Astuti, R., 1991. Learning to be Vezo: the construction of the person among fishing people of western Madagascar. Ph. D. Social Anthropology. University of London, London, UK.
Astuti, R., 1995. "The Vezo are not a kind of people": identity, difference, and "ethnicity" among a fishing people of western Madagascar. Am. Ethnol. 22, 464–482.
Baker, S., Paddock, J., Smith, A.M., Unsworth, R.K.F., Cullen-Unsworth, L.C., Hertler, H., 2015. An ecosystems perspective for food security in the Caribbean: seagrass meadows in the Turks and Caicos Islands. Ecosyst. Serv. 11, 12–21.
Bandeira, S.O., Björk, M., 2001. Seagrass research in the eastern Africa region: emphasis on diversity, ecology and ecophysiology. S. Afr. J. Bot. 67 (3), 420–425.
Belle, M.S., Stewart, G.W., De Ridder, B., Komeno, R.-J.-L., Ramahatrata, F., Remy-Zephir, B., Stein-Rostaing, R., 2009. Establishment of a community managed marine reserve in the Bay of Ranobe, southwest Madagascar. Madagascar Conserv. Develop. 4, 31–37.
Barbier, E.B., Hacker, S.D., Kennedy, C., Koch, E.W., Stier, A.C., Silliman, B.R., 2011. The value of estuarine and coastal ecosystem services. Ecol. Monogr. 81 (2), 169–193.
Barnes-Mauthe, M., Oleson, K.L.L., Zafindrasilivonona, B., 2013. The total economic value of small-scale fisheries with a characterization of post-landing trends: an application in Madagascar with global relevance. Fish. Res. 147, 175–185.
Berkes, F., 2003. Alternatives to conventional management: lessons from small-scale fisheries. Environments 31, 5–19.
Berkes, F., Colding, J., Folke, C., 2000. Rediscovery of traditional ecological knowledge as adaptive management. Ecol. Appl. 10 (5), 1251–1262.
Berkes, F., Mahon, R., McConney, P., Pollnac, R., Pomeroy, R., 2001. Managing small-scale fisheries: alternative directions and methods. International Development Research Centre, Ottawa, Canada.
Billé, R., Mermet, L., 2002. Integrated coastal management at the regional level: lessons from Toliary, Madagascar. Ocean Coast. Manag. 45 (1), 41–58.
Brenier, A., Ferraris, J., Mahafina, J., 2011. Participatory assessment of the Toliara Bay reef fishery, southwest Madagascar. Madagascar Conserv. Develop. 6, 60–67.
Bruggemann, J.H., Rodier, M., Guillaume, M.M.M., Andréfouët, S., Arfi, R., Cinner, J.E., Pichon, M., Ramahatratra, F., Rasoamanendrika, F., Zinke, J., McClanahan, T.R., 2012. Wicked social-ecological problems forcing unprecedented change on the latitudinal margins of coral reefs: the case of Southwest Madagascar. Ecol. Soc. 17 (4) https://doi.org/10.5751/ES-05300-170447.
Béné, C., 2006. Small-scale fisheries: assessing their contribution to rural livelihoods in developing countries. FAO Fisheries Circular. No. 1008. Rome, FAO. 46p.
Béné, C., Barange, M., Subasinghe, R., Pinstrup-Andersen, P., Merino, G., Hemre, G.-I., Williams, M., 2015a. Feeding 9 billion by 2050 – putting fish back on the menu. Food Security 7 (2), 261–274.
Béné, C., Arthur, R., Norbury, H., Allison, E.H., Beveridge, M., Bush, S., Campling, L., Leschen, W., Little, D., Squires, D., Thilsted, S.H., Troell, M., Williams, M., 2016. Contribution of fisheries and aquaculture to food security and poverty reduction: assessing the current evidence. World Dev. 79, 177–196.
Béné, C., Barange, M., Subasinghe, R., Pinstrup-Andersen, P., Merino, G., Hemre, G.-I., Williams, M., 2015b. Feeding 9 billion by 2050-Putting fish back on the menu. Food Security 7 (2), 261–274.
Béné, C., Hersoug, B., Allison, E., 2010. Not by rent alone: analysing the pro-poor functions of small-scale fisheries in developing countries. Develop. Policy Rev. 28, 325–358.
Chuenpagdee, R., 2011. World Small-scale Fisheries: Contemporary Visions. Eburon Academic Publishers, Delft, The Netherlands.
Chuenpagdee, R., Degnbol, P., Bavinck, M., Jentoft, S., Johnson, D., Pullin, R., Williams, S., 2005. Challenges and Concerns in Capture Fisheries and Aquaculture. In: Kooiman, J., Jentoft, S., Pullin, R., Bavinck, M. (Eds.), Fish for Life: Interactive

Governance for Fisheries. Amsterdam University Press, pp. 25–38. https://doi.org/10.1017/9789048505326.003.
Chuenpagdee, R., Jentoft, S., 2018. Transforming the governance of small-scale fisheries. Maritime Studies 17 (1), 101–115.
Chuenpagdee, R., Liguori, L., Palomares, M.L.D., Pauly, D., 2006. Bottom-Up, Global Estimates of Small-Scale Marine Fisheries Catches. Fisheries Centre Research Reports, Book 14(8). The Fisheries Centre, University of British Columbia, Vancouver, Canada.
Cinner, J.E., 2007. The role of taboos in conserving coastal resources in Madagascar. SPC Tradit. Marine Resour. Manage. Knowledge Inf. Bull. 22, 15–23.
Cinner, J.E., McClanahan, T.R., Graham, N.A.J., Daw, T.M., Maina, J., Stead, S.M., Wamukota, A., Brown, K., Bodin, Ö., 2012. Vulnerability of coastal communities to key impacts of climate change on coral reef fisheries. Global Environ. Change-Hum. Policy Dimens. 22 (1), 12–20.
Clarke, K.R., Warwick, R.M., 2001. A further biodiversity index applicable to species lists: variation in taxonomic distinctness. Mar. Ecol. Prog. Ser. 216, 265–278.
Conand, C., De San, M., Refeno, G., Razafitseheno, G., Mara, E., Andrianjatovo, S., 1998. Difficulties and sustainable management of the sea cucumber fishery sector in Madagascar. South Pacific Comm. Beche-de-mer Inf. Bull. 10, 7–9.
Cripps, G., Gardner, C.J., 2016. Human migration and marine protected areas: insights from Vezo fishers in Madagascar. Geoforum 74, 49–62.
Conijn, J.G., Bindraban, P.S., Schröder, J.J., Jongschaap, R.E.E., 2018. Can our global food system meet food demand within planetary boundaries? Agric. Ecosyst. Environ. 251, 244–256.
Crona, B.I., 2006. Supporting and enhancing development of heterogenous ecological knowledge among resource users in a Kenyan Seascape. Book 11. Ecology and Society.
Cullen-Unsworth, L.C., Nordlund, L.M., Paddock, J., Baker, S., McKenzie, L.J., Unsworth, R.K.F., 2014. Seagrass meadows globally as a coupled social-ecological system: Implications for human wellbeing. Mar. Pollut. Bull. 83 (2), 387–397.
Cullen-Unsworth, L.C., Unsworth, R.K.F., Frid, C., 2016. Strategies to enhance the resilience of the world's seagrass meadows. J. Appl. Ecol. 53 (4), 967–972.
Davies, T.E., Beanjara, N., Tregenza, T., 2009. A socio-economic perspective on gear-based management in an artisanal fishery in south-west Madagascar. Fish. Manage. Ecol., 16:279–289.
de la Torre-Castro, M., 2006. Humans and Seagrasses in East Africa – A Social-ecological Systems Approach. Phd. Stockholm University, Stockholm.
de la Torre-Castro, M., 2019. Inclusive management through gender consideration in small-scale fisheries: they why and the how. Front. Mar. Sci. 6, 156.
de la Torre-Castro, M., Di Carlo, G., Jiddawi, N.S., 2014. Seagrass importance for a small-scale fishery in the tropics: the need for seascape management. Mar. Pollut. Bull. 83 (2), 398–407.
de la Torre-Castro, M., Eklöf, J.S., Rönnbäck, P., Björk, M., 2008. Seagrass importance in food provisioning services: fish stomach content as a link between seagrass meadows and local fisheries. Western Indian Ocean J. Mar. Sci.; WIOMSA 7 (1), 95–110.
de la Torre-Castro, M., Fröcklin, S., Börjesson, S., Okupnik, J., Jiddawi, N.S., 2017. Gender analysis for better coastal management – increasing our understanding of social-ecological seascapes. Marine Policy 83, 62–74.
de la Torre-Castro, M., Rönnbäck, P., 2004. Links between humans and seagrasses—an example from tropical East Africa. Ocean & Coastal Manage. 47 (2004) 361–387 47: 361–387.
Delgado, C.L., Wada, N., Rosegrant, M.W., Meijer, S., Ahmed, M., 2003. Fish to 2020: Supply and demand in changing global markets. International Food Policy Research Institute, Washington D.C.;WorldFish Center, Pengang, Malaysia.
Denscombe, M., 1998. The Good Research Guide for Small-scale Social Research Projects. Open University Press, Buckingham, UK.
Duarte, C.M., Dennison, W.C., Orth, R.J.W., Carruthers, T.J.B., 2008. The charisma of coastal ecosystems: Addressing the imbalance. Estuaries Coasts 31 (2), 233–238.
Eklöf, J.S., de la Torre-Castro, M., Gullström, M., Uku, J., Muthiga, N., Lyimo, T., Bandeira, S.O., 2008. Sea urchin overgrazing of seagrasses: a review of current knowledge on causes, consequences, and management. Estuar. Coast. Shelf Sci. 79 (4), 569–580.
Eriksson, H., de la Torre-Castro, M., Olsson, P., Ferse, S.C.A., 2012. Mobility, expansion and management of a multi-species scuba diving fishery in East Africa. PLoS ONE 7 (4).
FAO, 1996. Declaration on World Food Security. Food and Agriculture Organization, World Food Summit, Rome.
FAO, 2004. Country review Madagascar. Review of the state of world marine capture fisheries management: Indian Ocean. Fishery and Aquaculture Economics and Policy Division.
FAO, 2007. Increasing the Contribution of Small-scale Fisheries to Poverty Alleviation and Food Security. FAO Fisheries Technical Paper, Book 481, Rome.
FAO, IFAD and WFP, 2015. The state of food insecurity in the world 2015. Meeting the 2015 international hunger targets: taking stock of uneven progress. Rome, FAO.
FAO, IFAD, UNICEF, WFP, WHO, 2020. The state of food security and nutrition in the world 2020. Transforming food systems for affordable healthy diets. Rome, FAO.
Fröcklin, S., de la Torre-Castro, M., Håkansson, E., Carlsson, A., Magnusson, M., Jiddawi, N.S., Ferse, S.C.A., 2014. Towards improved management of tropical invertebrate fisheries: including time series and gender. Plos One 9 (3), e91161.
Fröcklin, S., de la Torre-Castro, M., Lindström, L., Jiddawi, N.S., 2013. Fish traders as key actors in fisheries: gender and adaptive management. Ambio 42 (8), 951–962.
Froese, R., Pauly, D., 2016. FishBase, www.fishbase.org, version (10/2016).
Garcia, S.M., Rosenberg, A.A., 2010. Food security and marine capture fisheries: characteristics, trends, drivers and future perspectives. Philos. Trans. R. Soc. B-Biol. Sci. 365 (1554), 2869–2880.
Gell, F.R., Whittington, M.W., 2002. Diversity of fishes in seagrass beds in the Quirimba Archipelago, northern Mozambique. Mar. Freshw. Res. 53 (2), 115. https://doi.org/10.1071/MF01125.
Gerten, D., Heck, V., Jägermeyer, J., Bodirsky, B.L., Fetzer, I., Jalava, M., Kummu, M., Lucht, W., Rockström, J., Schaphoff, S., Schellnhuber, H.J., 2020. Feeding ten billion people is impossible within four terrestrial planetary boundaries. Nat. Sustainability 3, 200–208.
Gibbons, E., director of the NGO Reef Doctor (2011) personal communication with the first author. Ifaty, Madagascar.
Godfray, H.C.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M., Toulmin, C., 2010. Food security: the challenge of feeding 9 billion people. Science 327 (5967), 812–818.
Gough, C., Thomas, T., Humber, F., Harris, A., Cripps, G., Peabody, S., 2009. Vezo Fishing: An introduction to the methods used by fishers in Andovadoaka Southwest Madagascar. Blue Ventures Conservation Repor, Blue Ventures, London, UK.
Gough, C., Dewar, K., Godley, B., Zafindranosy, E., Broderick, A., 2020. Evidence of overfishing in small-scale fisheries in Madagascar. Front. Mar. Sci. 7, 317.
Grech, A., Chartrand-Miller, K., Erftemeijer, P., Fonseca, M., McKenzie, L., Rasheed, M., Taylor, H., Coles, R., 2012. A comparison of threats, vulnerabilities and management approaches in global seagrass bioregions. Environ. Res. Lett. 7 (2), 024006. https://doi.org/10.1088/1748-9326/7/2/024006.
Gullström, M., de la Torre Castro, M., Bandeira, S.O., Björk, M., Dahlberg, M., Kautsky, N., Rönnbäck, P., Öhman, M.C., 2002. Seagrass ecosystems in the Western Indian Ocean. Ambio 31 (7), 588–596.
Hantanirina, J.M.O., Benbow, S., 2013. Diversity and coverage of seagrass ecosystems in south-west Madagascar. Afr. J. Mar. Sci. 35 (2), 291–297.
Harper, S., Adshade, M., Lam, V.W.Y., Pauly, D., Sumaila, U.R., Tsikliras, A.C., 2020. Valuing invisible catches: estimating the global contribution by women to small-scale marine capture fisheries production. PLoS ONE 15 (3), e0228912.
Harris, A., 2007. To live with the sea" development of the velondriake community-managed protected area network, Southwest Madagascar. Madagascar Conserv. Develop. 2, 43–49.
Harris, A., Manahira, G., Sheppard, A., Gough, C., Sheppard, C., 2010. Demise of Madagascar's once great barrier reef – change in coral reef condition over 40 years. National Museum of Natural History, Smithsonian Institution, Washington, D.C., USA.
Harris, A., Mohan, V., Flanagan, M., Hill, R., 2012. Integrating Family Planning Service Provision into Community-based Marine Conservation. Cambridge University Press, pp. 179–186, 46:2.
Hicks, C.C., Cohen, P.J., Graham, N.A.J., Nash, K.L., Allison, E.H., D'Lima, C., Mills, D.J., Roscher, M., Thilsted, S.H., Thorne-Lyman, A.L., MacNeil, M.A., 2019. Harnessing global fisheries to tackle micronutrient deficiencies. Nature 574 (7776), 95–98.
Hicks, C.C., McClanahan, T.R., 2012. Assessing Gear Modifications Needed to Optimize Yields in a Heavily Exploited, Multi-Species, Seagrass and Coral Reef Fishery. Plos One 7.
HLPE, 2014. Sustainable fisheries and aquaculture for security and nutrition. A report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Food and Agriculture Organization Rome, Italy.
Jentoft, S., Chuenpagdee, R., Barragán-Paladines, M.J., Franz, N. (eds.) 2017. The Small-Scale Fisheries Guidelines: Global Implementation. MARE Publication Series Vol. 14. Springer.
Jentoft, S., Eide, A. (Eds.), 2011. Poverty Mosaics: Realities and Prospects in Small-Scale Fisheries. Springer Netherlands, Dordrecht.
Johnson, D., 2018. The Values of Small-Scale Fisheries. In: Johnson D, Acott T, Stacey N, Urquhart J (eds.) Social Wellbeing and the Values of Small-Scale Fisheries. MARE Publication Series vol. 17. Springer.
Kawarazuka, N., Béné, C., 2010. Linking small-scale fisheries and aquaculture to household nutritional security: an overview. Food Security 2 (4), 343–357.
Kvale, S., Brinkmann, S., 1997. Den kvalitativa forskningsintervjun. Studentliteratur AB.
Lambek, M., 1992. Taboo as cultural-practice among Malagasy speakers. Man 27 (2), 245. https://doi.org/10.2307/2804053.
Langley, J.M., 2006. Vezo Knowledge: Traditional Ecological Knowledge in Andovadoaka, southwest Madagascar. Blue Ventures Conservation Report, London, UK.
Laroche, J., Ramananarivo, N., 1995. A preliminary survey of the artisanal fishery on coral reefs of the Tulear Region (southwest Madagascar). Coral Reefs 14 (4), 193–200.
Laroche, J., Razanoelisoa, J., Fauroux, E., Rabenevanana, M.W., 1997. The reef fisheries surrounding the south-west coastal cities of Madagascar. Fish. Manage. Ecol. 4 (4), 285–299.
Le Manach, F., Gough, C., Harris, A., Humber, F., Harper, S., Zeller, D., 2012. Unreported fishing, hungry people and political turmoil: the recipe for a food security crisis in Madagascar? Marine Policy 36 (1), 218–225.
Lepoint, G., Frederich, B., Gobert, S., Parmentier, E., 2008. Isotopic ratios and elemental contents as indicators of seagrass C processing and sewage influence in a tropical macrotidal ecosystem (Madagascar, Mozambique Channel). Scientia Marina 72, 109–117.
Lobell, D.B., Burke, M.B., Tebaldi, C., Mastrandrea, M.D., Falcon, W.P., Naylor, R.L., 2008. Prioritizing climate change adaptation needs for food security in 2030. Science 319 (5863), 607–610.
Loring, P.A., Fazzino, D.V., Agapito, M., Chuenpagdee, R., Gannon, G., Isaacs, M., 2018. Fish and Food Security in Small-Scale Fisheries. In: Chuenpagdee R, Jentoft S (eds.) Transdisciplinarity for Small-Scale Fisheries Governance. MARE Publication Series 21. Springer.

MacGoodwin, J.R., 2001. Understanding the cultures of fishing communities: A key to fisheries management and food security. FAO Fisheries Technical Paper, Book 401. Food and Agriculture Organization.

Mangi, S.C., Roberts, C.M., 2006. Quantifying the environmental impacts of artisanal fishing gear on Kenya's coral reef ecosystems. Mar. Pollut. Bull. 52 (12), 1646–1660.

McClanahan, T.R., Cinner, J.E., Abunge, C., Rabearisoa, A., Mahatante, P., Ramahatratra, F., Andrianarivelo, N., 2014. Perceived Benefits of Fisheries Management Restrictions in Madagascar. Ecology and Society, p. 19.

McClanahan, T.R., Shafir, S.H., 1990. Causes and consequences of sea-urchin abundance and diversity in Kenyan coral-reef lagoons. Oecologia 83 (3), 362–370.

MEA, 2005. Millennium Ecosystem Assessment. Ecosystems & Human Wellbeing: Synthesis Report.

Mills, D.J., Westlund, L., de Graaf, G., Kura, Y., Willman, R., Kelleher, K., 2011. Small-scale Fisheries Management: Frameworks and Approaches for the Developing World. CAB International, Wallingford, United Kingdom.

Nagelkerken, I., van der Velde, G., Gorissen, M.W., Meijer, G.J., Van't Hof, T., den Hartog, C., 2000. Importance of mangroves, seagrass beds and the shallow coral reef as a nursery for important coral reef fishes, using a visual census technique. Estuar. Coast. Shelf Sci. 51 (1), 31–44.

Nordlund, L., Erlandsson, J., de la Torre-Castro, M., Jiddawi, N., 2010. Changes in an East African social-ecological seagrass system: invertebrate harvesting affecting species composition and local livelihood. Aquat. Living Resour. 23 (4), 399–416.

Nordlund, L.M., Koch, E.W., Barbier, E.B., Creed, J.C., 2016. Seagrass ecosystem services and their variability across genera and geographical regions. PLoS ONE 11.

Nordlund, L.M., Unsworth, R.K.F., Gullström, M., Cullen-Unsworth, L.C., 2018. Global significance of seagrass fishery activity. Fish Fish. 19 (3), 399–412.

Ogden, J.C., 1980. Faunal Relationships in Caribbean Seagrass Beds. Garland STPM Press, New York.

Orth, R.J., Carruthers, T.J.B., Dennison, W.C., Duarte, C.M., Fourqurean, J.W., Heck, K. L., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Olyarnik, S., Short, F.T., Waycott, M., Williams, S.L., 2006. A global crisis for seagrass ecosystems. Bioscience 56 (12), 987. https://doi.org/10.1641/0006-3568(2006)56[987:AGCFSE]2.0.CO;2.

Orth, R.J., Heck, K.L., van Montfrans, J., 1984. Faunal communities in seagrass beds – a review of the influence of plant structure and prey characteristics on predator prey relationships. Estuaries 7 (4), 339. https://doi.org/10.2307/1351618.

Pollard, D.A., 1984. A review of ecological studies on seagrass fish communities, with particular reference to recent studies in Australia. Aquat. Bot. 18 (1-2), 3–42.

Rakotoson, L.R., Tanner, K., 2006. Community-based governance of coastal zone and marine resources in Madagascar. Ocean Coast. Manag. 49 (11), 855–872.

Short, F.T., Green, E.P., 2003. World Atlas of Seagrasses. UNEP-WCMC, London, UK.

Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B.L., Lassaletta, L., de Vries, W., Vermeulen, S.J., Herrero, M., Carlson, K.M., Jonell, M., Troell, M., DeClerck, F., Gordon, L.J., Zurayk, R., Scarborough, P., Rayner, M., Loken, B., Fanzo, J., Godfray, H.C.J., Tilman, D., Rockström, J., Willett, W., 2018. Options for keeping the food system within environmental limits. Nature 562 (7728), 519–525.

Sumaila, U.R., Bellmann, C., Tipping, A., 2016. Fishing for the future: An overview of challenges and opportunities. Marine Policy 69, 173–180.

Thilsted, S.H., Thorne-Lyman, A., Webb, P., Bogard, J.R., Subasinghe, R., Phillips, M.J., Allison, E.H., 2016. Sustaining healthy diets: the role of capture fisheries and aquaculture for improving nutrition in the post-2015 era. Food Policy 61, 126–131.

Unsworth, R.K.F., Cullen, L.C., 2010. Recognising the necessity for Indo-Pacific seagrass conservation. Conserv. Lett., 3:63–73.

Unsworth, R.K.F., De León, P.S., Garrard, S.L., Jompa, J., Smith, D.J., Bell, J.J., 2008. High connectivity of Indo-Pacific seagrass fish assemblages with mangrove and coral reef habitats. Mar. Ecol. Prog. Ser. 353, 213–224.

Unsworth, R.K.F., McKenzie, L.J., Nordlund, L.M., Cullen-Unsworth, L.C., 2018. A changing climate for seagrass conservation? Curr. Biol. 28 (21), R1229–R1232.

Vaitilingon, D., Rasolofonirina, R., Jangoux, M., 2003. Feeding preferences, seasonal gut repletion indices, and diel feeding patterns of the sea urchin Tripneustes gratilla (Echinodermata : Echinoidea) on a coastal habitat off Toliara (Madagascar). Mar. Biol. 143 (3), 451–458.

Wallner-Hahn, S., de la Torre-Castro, M., Eklöf, J.S., Gullström, M., Muthiga, N.A., Uku, J., 2015. Cascade effects and sea-urchin overgrazing: an analysis of drivers behind the exploitation of sea urchin predators for management improvement. Ocean Coast. Manag. 107, 16–27.

Waycott, M., Duarte, C.M., Carruthers, T.J.B., Orth, R.J., Dennison, W.C., Olyarnik, S., Calladine, A., Fourqurean, J.W., Heck, K.L., Hughes, A.R., Kendrick, G.A., Kenworthy, W.J., Short, F.T., Williams, S.L., 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. PNAS 106 (30), 12377–12381.

Weeratunge, N., Béné, C., Siriwardane, R., Charles, A., Johnson, D., Allison, E.H., Nayak, P.K., Badjeck, M.-C., 2014. Small-scale fisheries through the wellbeing lens. Fish Fish. 15 (2), 255–279.

Whittingham, E., Campbell, J., Townsley, P., 2003. Poverty and Reefs Volume 1: A Global Overview. In: IOC/UNESCO D-I- (ed).

World Bank, 2020. The World Bank Country Overview: Madagascar. Available online at: https://www.worldbank.org/en/country/madagascar/overview#1 (accessed October 21, 2021).

World Bank, 2021. The World Bank News Feature Story Reducing child stunting in Madagascar. Available online at: https://www.worldbank.org/en/news/feature/2021/07/07/reducing-child-stunting-in-madagascar (accessed October 21, 2021).