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Understanding local differences in small-scale fisheries: a comparison of two fishing settlements in Antsiranana Bay, northern Madagascar

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ABSTRACT

The small-scale fishery in Antsiranana Bay, northern Madagascar, constitutes a very active industry with fishers using multiple methods based on traditional techniques. In this first study of the fishing activities in Antsiranana Bay, two villages were surveyed, both through direct observation and by means of interviews with local fishers. Antsisikala is a small zebu-farming village whose inhabitants supplement their income through small-scale fishing, whereas Ramena is primarily a fishing village that also caters for tourism. Our results show that fishers from both villages target multiple species of reef associated fish as well as invertebrates, and use a variety of fishing gears including hook and line, gill nets, beach seine nets, spearguns and traps. There were significant differences in the types of fishing gear preferentially used and catch sizes between the two villages, as well as in opinions regarding possible measures to utilise the marine resources more sustainably. We therefore stress the importance of understanding the local differences between small-scale fisheries and their impacts on the reef in order to design more effective management strategies.

RÉSUMÉ

La pêche artisanale dans la baie d'Antsiranana, au nord de Madagascar est une activité répandue parmi les pêcheurs qui utilisent des moyens diversifiés généralement basés sur les techniques traditionnelles. D'ordinaire, on considère que la pêche artisanale a un impact négligeable sur l'environnement par rapport aux pêcheries commerciales à grande échelle. Dans cette première analyse des activités de pêche artisanale dans la baie d'Antsiranana, deux villages situés de part et d'autre de la baie ont fait l'objet d'études, à la fois par le biais d'observations directes et au moyen de questionnaires auprès des pêcheurs locaux. Antsisikala est un petit village situé à l'ouest de la baie qui dépend principalement de l'élevage de zébus mais qui augmente son revenu grâce à la pêche. Le village de Ramena est en revanche situé à l'est de la baie et est essentiellement tourné vers la pêche complétée par quelques activités touristiques. Ces villages ont été choisis pour illustrer la variabilité des niveaux de pression sur les ressources marines et côtières causés par la pêche artisanale. Nos résultats montrent des similarités et des différences entre les deux villages, car si les pêcheurs des deux villages ciblent des poissons de plusieurs familles liés au récif ainsi que diverses espèces d'invertébrés et qu'ils sont conscients d'une baisse de production de la pêche au cours des dernières années, notre étude montre cependant des différences significatives dans les types de matériel de pêche utilisés et dans l'intensité de la pêche entre les deux villages. De plus, les pêcheurs des deux villages ont des avis divergents lorsqu'ils formulent des solutions destinées à permettre l'exploitation pérenne des ressources marines. Les pêcheurs de Ramena utilisent principalement des sennes de plage, tandis que ceux d'Antsisikala emploient surtout une combinaison de méthodes en utilisant aussi bien les lignes que les filets maillants. Le type de matériel utilisé à Ramena conduit à une fréquence de pêche bien plus importante lorsque les catégories de poids plus élevés sont recherchées. Dans la mesure où la population locale continue de croître, les pressions associées à la pêche dans la baie d'Antsiranana continueront d'augmenter, à moins que des mesures efficaces ne soient mises en place. Il est donc essentiel d'établir rapidement un plan de gestion en concertation avec les populations locales, afin d'assurer la longévité de la pêcherie. Pour être efficace, ce plan de gestion devra veiller à considérer les particularités propres des différents types de pêche.

INTRODUCTION

Despite their perceived abundance, aquatic resources are limited and need appropriate management to ensure that they are utilised in a sustainable manner (Pauly 2008). Fishing is widely recognised as having a major influence on marine ecosystems throughout the world. It is well documented that industrial fishing causes serious habitat degradation through benthic dredging and trawling (Thrush and Dayton 2002), as well as overexploitation of species (Pauly et al. 2005). Traditional, artisanal and small-scale fisheries, by contrast, are generally considered to be less of a threat to marine ecosystems and tend to be associated with relatively low environmental impacts

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(Hawkins and Roberts 2004). Defining the terms traditional, artisanal and small-scale fisheries can be difficult due to geographical variations in the characteristics of a fishery (Mathew 2002): these types of fisheries, however are typically near-shore and utilised by fishers using relatively small-sized vessels and labour intensive methods with little or no modern technology (Sowman 2006, FAO 2009), as well as a variety of fishing techniques to target multiple species (Allison and Ellis 2001). In developing countries, fishing in small-scale fisheries is often part of a complex of livelihood activities, which may include agriculture and other part-time occupations (Jentoft 2000). In Madagascar the term artisanal fisheries refers to numerous motorized boats fishing for domestic and international markets, while the term traditional or small-scale fisheries refers to non-motorized, kinship-based fishing for subsistence or for local markets, undertaken by fishers who respect local customs and taboos (Mathew 2002).

In some parts of the Pacific, small-scale fisheries have been documented to have no significant impact on the state of coral reef ecosystems despite the fact that they have existed over the last thousand years (Dalzell 1998). Numerous other studies worldwide, however, have highlighted the negative impacts small-scale fisheries can have on reef systems (Mumby et al. 2006, Newton et al. 2007, Lokrantz et al. 2009). These detrimental effects are often associated with an increase in neighbouring human population densities, as well as climate change (Aronson and Precht 2006, Clark 2006). Documented impacts include reduced fish biomass of target species, high vulnerability to low intensity fishing in high trophic level families such as groupers and snappers, high vulnerability to fishing of large bodied fish (Hawkins and Roberts 2004), loss of species diversity (McClanahan et al. 2008) and the complete elimination of species from reef areas leading to ecosystem collapse (Hardt 2009). In the case of traditional forms of marine resource use, overexploitation can result in irreversible economic, social and cultural loss to fishing communities (Agardy 2000).

Over the last few centuries, only a few modifications to fishing methods have been implemented in small-scale fisheries across the world. The introduction of motorised boats and modern materials, such as monofilament nylon lines and artificial bait, constitute the main changes (Hawkins and Roberts 2004). What has changed, however, is the number of people supported by these fisheries and, driven by ever-growing coastal populations, the number of small-scale fisheries in developing countries has increased significantly in recent years (Iida 2005, Béné 2006). This has put further pressure on ecosystems that are already at risk from anthropogenic and environmental impacts.

Coral reefs support small-scale fisheries and provide an important source of protein for local communities in many developing countries worldwide (Sadovy 2005), with coral reef fisheries contributing about two to five percent of global catches (Pauly et al. 2002). An estimated annual yield of between five and 15 tons of fish and seafood per square kilometre per year can be harvested from a healthy, well-managed reef (Spalding et al. 2001) amounting to a total global annual yield of 1.4 to 4.2 million tons (Pauly et al. 2002).

Madagascar's coral reefs are rich and diverse marine ecosystems with an estimated 6,000 reef-associated species, including 752 fish species and 340 coral species (McKenna and Allen 2003). These ecosystems support multiple fisheries around the country with an estimated 43% of all fisheries per year (or 65,090 tons) being based on coral reefs (FAO 1999). As in many developing countries of the world, fishing constitutes an important source of food in Madagascar and to a lesser extent a source of income (Westmacott et al. 2000).

Antsiranana Bay, situated in the far north of Madagascar, comprises numerous sub-bays, which present a range of tropical coastal habitats including coral reef, seagrass and mangrove (Browne et al. 2007). These diverse habitats constitute an important natural resource for neighbouring villages. Due to a range of natural and anthropogenic factors, the bay exhibits variation in the condition of its reefs in terms of coral cover, fish diversity and fish biomass (Browne et al. 2007). The bay has a thriving small-scale fishing industry about which very little is known (Bigot et al. 2000), based on the daily use of fishing methods combining traditional techniques with modern materials.

This study focuses on two villages on opposite sides of the bay. The aim of the study was to use these two villages to assess the state of the fishery in Antsiranana Bay and identify trends or differences in the fishing techniques used as well as the opinion of local fishers towards resource use. The research was carried out to provide information for future resource management and conservation strategies, which take into account trends and differences between local fisheries in the bay.

METHODOLOGY

ANTSIRANANA BAY. Antsiranana Bay is located in northern Madagascar near the city of Antsiranana, formerly known as Diego Suarez (49°17'43" E, 12°17'17" S) (Figure 1). It is a shallow tropical bay with a mean depth of 30 m, entered by the Indian Ocean from the east. The interior of the bay is characterised by numerous small islands (Nosy Fano, Nosy Koba, Nosy Langoro, Nosy Laopasana, Nosy Volana, Nosy Longo), and a coastline lined with many, almost continuous, shallow fringing reefs. We divided the mainland coast of Antsiranana Bay into 13 arbitrary sectors to reflect potential differences in environmental conditions amongst the smaller sub-bays. Residents of Antsiranana, as well as eight village communities, use the bay for fishing; these include the two villages of Antsisikala and Ramena where surveys were conducted.

STUDY VILLAGES. Antsisikala, which is situated in the north of the bay, is a small village of approximately fifty houses (Antsisikala village president, pers. comm. December 2008). The villagers generate the majority of their income through zebu farming (a domestic breed of tropical cattle); fishing is carried out principally for subsistence and small-scale trading (Antsisikala village president, pers. comm. December 2008). This village was chosen because a less intensive level of fishing appears to take place there. By contrast, Ramena is a fishing village with an estimated population of 4,000 (ILO census data, Cornell University 2002) situated in the east of the bay, close to its entrance. Fishing is traditionally the main livelihood for locals in this village, although Ramena is increasingly becoming a tourist destination, and some fishers also provide tourist excursions (Ramena village member, pers. comm. July 2008). This village was chosen because a more intensive level of fishing was initially observed.

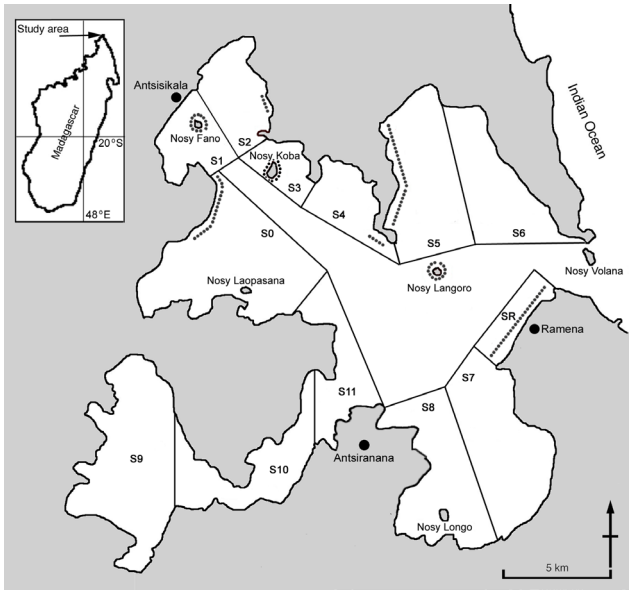

FIGURE 1. Map of Antsiranana Bay showing 13 designated study sectors (S0-S11 and Sector Ramena (SR)), islands and popular fishing areas (represented by dotted lines). Large black dots denote the regional capital Antsiranana and the two study villages Ramena and Antsisikala.

DIRECT OBSERVATIONS OF THE FISHERY. To describe the characteristics of the fishery the following observations were completed. One investigator made visual observations of fishing practices in the area surrounding Antsisikala (sectors 1, 2 and 3) between March and December 2008 and in the area surrounding Ramena (sector Ramena) between July and August 2008. These observations were made haphazardly at different times of the day depending on accessibility to fishers, with observation periods ranging from one to three hours. A total of ten hours observation over eight sampling days in Antsisikala and six hours observation over three sampling days in Ramena took place. Details of fishing effort, techniques and equipment used, time of day the fishing activity took place, and species caught were recorded.

FISHING AREAS. Each sector was surveyed for fishing vessels at random times during the day over the ten-month observation period to determine the most popular fishing areas during daylight hours (0600h to 1800h). Islands not in a sector were considered separately (Nosy Langoro, Nosy Volana). The number of fishing vessels observed in each sector or around Nosy Langoro and Nosy Volana were recorded during a period of one hour. The area of each sector/island was calculated by creating a polygon in Google Earth (version 5) and copying its properties into an online tool for Google Earth (Earthpoint 2011).

FISHER INTERVIEWS. To assess the current status of the fishery in Antsiranana Bay and to obtain fishers' opinions about resource use within the bay, a series of questionnaire interviews were conducted with fishers from the villages of Antsisikala and Ramena. Respondents were selected by asking village elders to identify specific village members who fish on a regular basis that would be willing to contribute to this study. Twenty-one different fishers were interviewed in Antsisikala on two separate occasions (July 2006 and August 2008) and 19 different fishers were interviewed in Ramena in December 2006. Interviews were conducted in Malagasy with the assistance of a translator. The interviews included fishers' personal details including age, marital status, number of children, main occupation/income and alternative sources of income. Fishers were asked questions on their use of marine resources within the bay focusing specifically on fishing activity, equipment preferences, target species, catch sizes, cultural traditions and their perceptions of how resources have changed over time. In order to determine the level of environmental awareness fishers have towards the use of marine resources within the bay, they were asked to choose the response (I strongly agree, I agree, neutral, I disagree, I strongly disagree) that best represented their opinion on a series of resource use based questions. A fish identification guide (Lieske and Myers 2001) was used to help the fishers correctly identify reef fish referenced in the interview.

DATA ANALYSIS. Chi-squared tests were performed to compare the total frequency counts for each fisher from Antsisikala and Ramena (collected during the questionnaire interviews) on the use of each gear type, the quantity of the total average daily catch, and how fish stocks have changed over time.

RESULTS

FISHERY CHARACTERISTICS OF ANTSISIKALA. In Antsisikala, fishing techniques are simple and based on traditional methods using modern materials. Fishers mainly employ a combination of methods using both hook and line and gill nets, the latter being used typically by a single fisher or by one pair of fishers. Three additional methods were observed at a lower frequency: (i) trolling, (ii) hand collection, and (iii) speargun fishing using snorkelling equipment. The use of each method differs according to the number of people and type of boat used, as described below.

The hook and line (*manjono tadim-bintana*) method is employed by all types of fishers from the village; lone fishers, fishers who work in a pair and groups of three to six fishers. Lone fishers typically use a wooden dugout canoe (pirogue) approximately two to 2.5 m in length, powered by a small sail made from rice sacks and / or a wooden oar. One pair of fishers uses a pirogue approximately three to four metres in length, powered by a small sail made from rice sacks and / or a wooden oar and / or five horsepower outboard. Groups of three to six fishers use large wooden boats approximately six metres in length powered by outboard engines ranging in horsepower between five and 25, used in combination with a large sail made from thick cotton. For all three groups of fishers, fishing activity was observed to occur during the day and night using this method. Fishing is typically carried out over a reef or on the reef edge using baited fishing hooks (ranging in hook size number 10–14) on a monofilament nylon fishing line ranging from 0.5 to 2 mm in diameter. Species caught included Carangidae, Lutjanidae, Mullidae, Siganidae, Lethrinidae, Serranidae, Nemipteridae, Labridae, Haemulidae, Caesionidae, Carcharhinidae, Scrombridae, Balistidae and Sphyraenidae. There was no by-catch observed with this method as all fish caught were landed and stored.

Gill nets (*mihaza talirano*) are typically used by lone fishers or by a pair of fishers. Nylon gill nets with floats attached to the top and weights to the bottom are used with a mesh size of three to four centimetres, ranging in length from 15 to 25 m. Nets are commonly placed over coral reefs and adjacent seagrass beds during the late afternoon, left *in situ* for up to ten hours and retrieved in the morning of the following day before sunrise. Species caught included Carangidae, Lutjanidae, Mullidae,

Siganidae, Scaridae, Nemipteridae, Acanthuridae, Lethrinidae, Haemulidae, Caesionidae, Carcharhinidae, Scrombridae, Balistidae, Dasyatidae and Sphyraenidae. There was minimal by-catch associated with this method, with only members of the family Tetraodontidae observed being caught and discarded.

Trolling (*mandraverave*) is predominantly used by pairs of fishers or groups of three to six using boats powered by large sails or outboard engines. Fishing activity was observed to occur during the day and night using this method, with up to six lines being observed in the water trolling at a single time. Fishers use thick monofilament nylon fishing line approximately three millimetres in diameter with a florescent lure attached to a three pronged hook (treble-hook) ranging in hook size number 6–10. Species caught included Carangnidae, Scrombidae and Sphyraenidae. There was no by-catch observed with this method.

The larger groups of three to six fishers hand collect edible sea cucumbers (holothuria – *trepang*) principally for export markets due to their high market value, and use speargun fishing (*saboa)* during daylight hours. Both methods used snorkelling equipment in free dives. Fish caught using the speargun method included Lutjanidae, Mullidae, Acanthuridae, Lethrinidae, Haemulidae and Serranidae.

FISHERY CHARACTERISTICS OF RAMENA. Fishers from Ramena employ larger-scale and more labour intensive fishing methods than those used in Antsisikala. Fishing takes place during daylight hours, using predominantly larger boats and beach seine nets. A total of five beach seines were noted during the observation period. Beach seines (*ragiragy)* are used by groups of six to ten fishers who assist in deploying the net from a large wooden boat (approximately six metres in length powered by outboard engines ranging in horsepower between five and 25) and bringing it to the shore with hauling ropes. Three to four men with snorkelling equipment swim or stand in the water around the net, aggressively hitting the surface of the water to herd the fish into the net. This process lasts for approximately one hour, with as many as eighteen people assisting to pull in the net. Beach seine nets are commonly modified, constructed from many pieces of different nylon nets with mesh sizes ranging from one to three centimetres, which tapers towards the back of the net, ending in a mesh size as small as one centimetre. The catch is dumped on the sand, sorted into species, placed into plastic baskets and washed. The fish species caught belonged to the following families: Clupeidae, Sphyraenidae, Lethrinidae, Siganidae, Hemirhamphidae, Fistulariidae, Tetraodontidae, Ostraciidae and Labridae. Discarded fish occasionally included pufferfish (Tetraodontidae), cowfish (Ostraciidae), cornetfish (*Fistularia* spp.), three-ribbon wrasse (*Stethojulis trilineata*) and striped catfish (*Plotosus lineatus*); these were left on the beach or in the case of striped catfish, placed in a hole in the sand and covered to prevent accidental injury caused by touching the venomous pectoral and dorsal spines. Fishing traps were seen stacked on the beach; however, no observations of the fishers deploying them were made. Guides on tourist boats within the bay were observed on three occasions attempting opportunistic fishing with spearguns. Although fishers listed use of hook and line or gill nets as fishing methods during the interviews, none of these were observed.

FISHING AREAS. The area around Ramena had the largest number of fishing vessels present per survey, suggesting a very high fishing pressure at this site in relation to its small area (2.02 km^2). Sectors 0, 4, 5 and Nosy Langoro also showed a relatively high number of fishing vessels, although not as high as in the sector surrounding Ramena (Supplementary Material S1). Nosy Langoro showed the highest level of fishing pressure relative to its size (0.01 km^2).

FISHER INTERVIEWS. The percentage of fishers responding to each question was calculated using the total number of responses given (n represents the total number of responses, not the number of respondents). Fishers from Antsisikala had an average age of 39, with the majority being married (70 %; n=21) with an average of three children. Eighty-five percent stated fishing (n=21) as their main occupation/income followed by farming (5 %; n=21) and other (10 %; n=21), including boat operator and carpenter. Alternative incomes for fishers came from farming (55 %; n=22), fishing (14 %; n=22), other (5 %; n=22), while 26 % (n=22) stated they had no alternative income. Ramena fishers had an average age of 32, with 80 % (n=19) being married with an average of two children. The majority of interviewees stated tourism (58 %; n=19) was their main income, while fishing was the main income for 42 % (n=19) fishers. Alternative incomes came from fishing (53 %; n=19) and other (5 %; n=19). Forty-two percent of fishers (n=19) said they had no alternative income.

Out of 40 interviewees 27 chose to respond to the question regarding fishers' interest in the bay (some fishers did not want to comment), stating fishing (Antsisikala 33 %; n=15, Ramena 44 %; n=18), subsistence (Antsisikala 40 %; n=15, Ramena 6 %; n=18) and transport (Antsisikala 7 %; n=15, Ramena 50 %; n=18) were the three most important in Antsiranana Bay. In Ramena, transport constituted the main interest in the bay by fishers, followed by fishing. Only 6 % (n=18) in Ramena stated subsistence was the most important interest in the bay compared to 40 % (n=15) in Antsisikala, with fishers stating that their interests in the bay can change on the basis of demand for food from the village. Twenty percent of fishers from Antsisikala declared conservation of the bay and its resources to be the main interest (n=15), none of the respondents in Ramena felt this way. Moral obligation, aesthetic value, religious value and tourism were not mentioned by fishers from either group as a main interest in the bay.

SEASONALITY. Sea conditions within the bay vary during the year with a calm season from November to March and a windy season during the austral winter from April to October, which complicates the use of areas exposed to the wind. The summer months of November to January were cited as the most favourable months for Antsisikala fishers (November 13 %, December 15 % and January 9 %; n=55). By contrast, in Ramena all fishers stated that they fish all year around with no particular preference (100 %; n=19).

RESOURCE USE. In order to identify how fishers use fish as a resource, they were asked why they target certain species. Targeting multiple species was common among fishers from Antsisikala with 80 % (n=20) targeting three species or more. Fishers (Antsisikala 32 %; n=34, Ramena 95 %; n=19) target certain species principally because they are common and widely available. Income (29 %; n=19) and the availability of gear (23 %; n=19) were only important factors for fishers from Antsisikala. Few fishers from Antsisikala targeted a particular fish species because they are what people like to eat (3 %; n=19) or because fishers are used to catching particu-

lar species (3 %; n=19). Additional reasons given for targeting specific fish by fishers from Antsisikala (9 %; n=19) included targeting abundant or 'non-competitive' species. Fishers stated that targeting fish that produce a large number of eggs would help prevent overfishing of the resource as there are many new small fish being produced. Catching large predatory fish such as sharks and jacks was considered to help boost numbers of fish lower down the food chain.

GEAR USE. To determine the differences in gear preferentially used within the two villages, fishers were asked which gear type they prefer. There is a striking difference between Ramena and Antsisikala in the types of gear used by fishers (Figure 2). Chi-square tests using the total frequency counts for fishers using each gear from Ramena and Antsisikala showed a significant association between gear use and which village the fishers come from (χ^2=16.90, p<0.005). Most notably, beach seine nets are used by 24 % (n=46) of fishers in Ramena, but none of the fishers from Antsisikala. Poison and dynamite were not mentioned as a fishing technique. When questioned about the evolution of fishing techniques, 100 % (n=21) of Antsisikala fishers and 84 % (n=19) of Ramena fishers said that they had never changed their technique for as long as 57 years. Only fishers from Ramena declared a change in fishing technique (16 %; n=19).

CATCH SIZE. To identify the quantity of fish caught on a daily basis, fishers were asked to estimate a figure of their total average daily catch (in kilogrammes). The majority of fishers from Antsisikala (95 %; n=21) reported a mean daily catch weight between 0–24 kg, compared to 58 % (n=19) from Ramena. There was a significantly higher frequency of reported catches from the 25–49 kg (Antsisikala 0 %; n=21, Ramena 21 %; n=19) and 50–75 kg (Antsisikala 6 %; n=34, Ramena 5 %; n=19) weight classes by fishers from Ramena compared to Antsisikala (χ^2=8.53, p<0.05). Five percent of fishers from Ramena reported total mean daily catch weights >75 kg. No fishers from Antsisikala reported a daily catch of over 75 kg.

PERCEPTION OF CHANGE. Fishers were asked how they perceive fish stocks to have changed over time within the bay. A greater percentage of fishers from Antsisikala perceived a recent decline in both catch size (71 %; n=21) and abundance (95 %; n=21) (Figure 3). Fishers from Ramena perceived a decrease in abundance (67 %; n=18), but no change in catch size (53 %; n=19) or average size of fish caught (63 %; n=19). Very few fishers perceived that there had been an increase in catch size, abundance or average fish size. The difference in opinions of fishers from Ramena and Antsisikala regarding the evolution of fish resources was not statistically significant (χ^2=18.45, p>0.10). Fishers were asked to provide potential reasons for the change in fish resources. There was no common answer to this question,

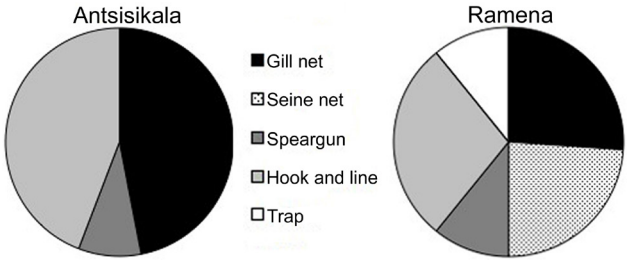

FIGURE 2. Percentage of different fishing gears used by fishers in a) Ramena (19 respondents) and b) Antsisikala (21 respondents).

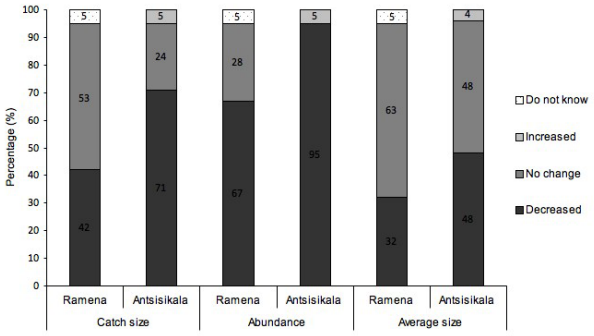

FIGURE 3. Fishers' opinion of the state of fish resources (Antsisikala, 21 respondents; Ramena, 19 respondents). The responses "do not know", "increased", "no change" and "decreased" refer to fishers' perception of how each catch parameter has changed over time.

either in Antsisikala or Ramena. Among those who perceived a change in Ramena, the majority suggested the lack of rain that forced farmers to turn to fishing (21 %; n=19); another reason stated was that octopus had moved to deeper water (11 %; n=19). Additional responses from the Ramena fishers included overfishing and climate change (5%; n=19). By contrast, in Antsisikala interviewees blamed the following: overfishing by fishers from Ramena through the use of beach seine nets; an increase in the number of fishers; climate change; seasonal variations (9 %; n=22) followed by less rain leading to more fishing instead of farming; coral damage through spear fishing techniques; and octopus moving to deeper water (5 %; n=22). Eighteen percent gave additional responses that included: the weather becoming increasingly windy; too many fishers do not throw small fish back; and there are no laws regulating fishing. Fifty-three percent of fishers in Ramena perceived no change compared to 9 % of fishers from Antsisikala.

HANDLING OF BY-CATCH. Interviewees were asked under which circumstances they would return fish to the ocean to assess their opinion on catching non-target species or juvenile fish. For each village, 20 % (Antsisikala n=35; Ramena n=15) of fishers said they would never throw any of their catch back. Fishers from Ramena would only throw fish back if they are too small (80 %; n=15). Fishers from Antsisikala would throw fish back if they are either too small (34 %; n=35), non-target species (32 %; n=35) or not valuable (14 %; n=35).

SELLING FISH. Fishers were asked where they prefer to sell their fish. The city of Antsiranana was the most popular place to sell fish for fishers from Ramena (63 %; n=19), which was followed by selling it locally (37 %; n=19). Antsisikala is different, with fishers selling the majority of their catch to their own village (44 %; n=27), with Antsiranana the second most popular place to sell fish (33 %; n=27). Fishers also chose to sell to a collector in Antsiranana (15 %; n=27). A minority of fishers from Antsisikala (7 %; n=27) chose not to sell their fish at all.

CULTURAL ASPECTS. To identify how cultural traditions influence fishing activity in the bay, fishers were asked whether they follow certain *fady* (traditional beliefs or taboos) when fishing. Out of the 20 interviewees from Antsisikala who responded to the question regarding *fady*, the majority of fishers (55 %) stated that there were no local *fady* associated with fishing in Antsiranana Bay. By contrast, all fishers from Ramena (100 %; n= 19) said that there were *fady*. The *fady* differed

from fisher to fisher and included the following: not offending the ancestors; not cursing while fishing; not fishing at night; not using lights at night to fish; not banging the water; and not using metal in the water.

ENVIRONMENTAL AWARENESS. In order to determine the level of environmental awareness towards the use of marine resources within the bay, fishers were asked to give their opinion on how best to ensure the availability of marine resources for future generations. These suggestions were provided to also gain an idea of their opinion on potential conservation and resource management strategies. The responses to these questions were very diverse (Table 1). In both villages, the majority agreed that using fishing nets with a mesh superior to four centimetres and stopping deforestation in coastal areas would help ensure the availability of marine resources in the bay. It was also thought that an increase in tourism would be beneficial in bringing alternative sources of income. A majority of fishers from both villages (Antsisikala 56 % agree (n=18)), in particular from Ramena (21 % strongly agree, 56 % agree; n=18), also stated that nothing needed to be done as there were enough fish and that fishers themselves should decide how much fish they catch. They also agreed that praying to the ancestors would help improve fish abundance. The majority of fishers from Antsisikala (39 % strongly agree, 39 % agree; n=18), and a minority in Ramena (37 % strongly agree, 10 % agree; n=18) agreed that different communities should work more closely together to manage marine resources and that fishers should catch only large fish and certain species, or only fish in specific areas and on certain days. Eating less fish was also suggested and eating more zebu was mentioned by some fishers as an alternative. In addition, a majority of fishers from Antsisikala (28 % strongly agree, 55 % agree; n=18) suggested that the village chief should control the size of fish catch, whereas in Ramena a higher proportion of fishers agreed that the government in Antsiranana should control fish catch sizes.

DISCUSSION

Antsiranana Bay provides essential marine resources for the two coastal communities studied, whose incomes depend heavily on fishing for both commercial and non-commercial gain. Since local roads are poorly maintained, the water also provides an important means of transporting for both people and goods, such as livestock and fish, between local villages and the main port of Antsiranana. The different uses of marine resources in the bay are representative of many other coastal areas in Madagascar (Laroche et al. 1997, Billé and Mermet 2002, Rakotoson and Tanner 2006).

Fishing, which is one of the principal means of income of fishers within the bay and hence constitutes an important part of the local economy, is directly affected by seasonal changes in weather. Annual differences in climatic conditions which occur in the north of Madagascar appear to affect the level of fishing activity carried out in the bay throughout the year. During the austral winter (April to October) strong onshore winds originating from the Indian Ocean are present. These winds, locally known as *varatraza*, cause considerable wave action in the bay given its enclosed nature and can prove hazardous to small vessels operating within the bay (Antsisikala village fisher, pers. comm. December 2008). Fishing practices in Antsisikala which tend to use smaller non-motorised vessels appear to be heavily influenced by the weather conditions, with more fishing activities occurring during the summer season (November to March) when sea conditions are calm. In Ramena, however, fishers who use larger motorised boats tend to fish the whole year round. The influence of seasons therefore reflects the different livelihood characteristics of each village.

The majority of fishers, both in Ramena and Antsisikala, choose to target multiple fish species using various methods. This non-discriminative fishing practice is characteristic of reef fisheries across the world (McClanahan and Mangi 2004) and in other regions of Madagascar (Laroche et al. 1997, Harris 2007),

TABLE 1. Fishers' opinion on how best to ensure the sustainable use of marine resources. Ram = Ramena, Ant = Antsisikala (Total number of respondents 40).

Question	Response									
	Strongly agree %		Agree %		Neutral %		Disagree %		Strongly disagree %	
	Ram	Ant	Ram	Ant	Ram	Ant	Ram	Ant	Ram	Ant
Communities should work together	37	39	10	39	53	11	0	11	0	0
Deforestation in coastal areas should be stopped	33	50	56	38	11	0	0	6	0	6
Each fisherman should decide ho much fish he catches	21	22	79	56	0	11	0	11	0	0
Eat less fish	17	33	11	17	72	33	0	6	0	11
Get more tourists to the bay as an alternative source of income	12	39	75	44	13	6	0	11	0	0
Nothing specific, there is enough fish	21	0	56	56	17	6	6	32	0	6
Only catch certain fish species	5	17	0	39	84	28	11	16	0	0
Only catch large fish	16	50	26	44	58	6	0	0	0	0
Only fish in specific areas	0	22	6	28	88	11	6	39	0	0
Only go out fishing on certain days	5	22	37	61	42	5	16	6	0	6
Prey for more fish/ask ancestors	37	11	58	44	5	28	0	17	0	0
The government in Diego should control fish catch size	21	6	26	33	53	33	0	17	0	11
The village head/chief should control the size of fish catches	26	28	16	55	58	11	0	0	0	6
Use fishing nets with >4cm mesh	44	33	25	44	31	17	0	6	0	0

where the assemblages over reefs contain a variety of families (Choat and Robertson 2006). The choices of fishers to target particular species could have wider implications for future fisheries management, as repeatedly targeting the same species can result in numerous associated environmental impacts in the context of overfishing (Hawkins and Roberts 2004, Lokrantz et al. 2009).

Fishing equipment often determines which species fishers catch, as different types of equipment are used to target fish at different trophic levels. The hook and line method and traps (depending on mesh size) are moderately selective, while spearguns are highly selective; beach seine nets and gill nets, by contrast, are largely non-selective (McClanahan and Mangi 2004). Gear selectivity can have impacts at different trophic levels and therefore affect the structure of the fishery and the structural complexity of food webs (McClanahan and Mangi 2004). Further study into gear selectivity and catch composition, specific to this region of Madagascar would assist in the development of gear-based management recommendations for local fisheries.

The majority of fishers from Antsisikala fish from single pirogues using hook and line or gill nets in small-scale fishing efforts for subsistence and small-scale trade rather than commercial purposes. This is typical of small-scale reef fisheries, as enough fish are caught to provide for a family or village, with any excess being sold (McGoodwin 2001). By contrast, beach seine nets and traps are used significantly more frequently in Ramena. Although these fishers claimed to use hook and line and gill nets, they were never observed using it; a contradiction that could be explained by the small sample size of fishery observations in Ramena. Hook and line, gill nets, traps and spearguns do not yield large amounts of fish, as most fishers using these techniques had an average catch weight of 0–24 kg. Fishers from Ramena tend to report heavier total average daily catches than those fishers from Antsisikala, which is likely due to the use of small mesh size beach seine nets. The use of beach seine nets requires a high fishing effort from community members, who assist in pulling the net in. With this large amount of community participation, the catch is distributed around those that helped. However, the use of beach seine nets is detrimental to the habitats where it is used, because it is both unselective and removes juveniles (McClanahan and Mangi 2004), and it also tends to destroy corals, sponges and seagrass beds over which the nets are dragged (McClanahan and Mangi 2001). The lack of selectivity of this type of gear is highlighted by the fact that catches frequently comprise a mix of reef, seagrass, reef-associated and coastal pelagic fish, including juvenile fish and non-edible fish.

The fisheries of both Ramena and Antsisikala generally have very little wastage, with fish being thrown back only if they are too small, not valuable or inedible. However, fishers using beach seine nets in Ramena were observed sorting the catch on the sand into fish types and discarding inedible or poisonous fish. Although 80 % of fishers from Ramena stated in their interviews that undersized fish were returned to the water, the contrary was often observed. This indicates a lack of understanding of the ecological importance of returning fish to the water. Indeed, if fishers used unmodified nets with transparent monofilament nylon panels of mesh inserted in the anterior region of the bunt section of the net, immediately before the mouth of the net, then it would greatly improve size selectivity and the by-catch of non-target reef species could be dramatically reduced (Gray et al. 2000). Based on the behavioural responses of fish in seine nets, the addition of these panels provides undersized or slow moving fish an alternative clear passage to entering the net mouth as fish naturally swim towards areas of the net with higher light levels (Gray et al. 2000).

By-catch on coral reefs is commonly associated with a decline in ecosystem function caused by the removal of fish, leading to cascading effects on the composition, biomass and density of other reef fish species (Hall et al. 2000). The use of non-selective equipment such as gill nets, beach seine nets and traps, particularly when modified to have small mesh sizes as in the case of the beach seine nets used in Ramena, is widely recognised as having negative impacts on coral reef ecosystems (McClanahan and Mangi 2001, 2004). Fine mesh nets and traps are commonly associated with the removal of non-target species and juvenile fish (McClanahan and Mangi 2004). There is therefore the need to implement management strategies to regulate the types of gear used to reduce by-catch.

According to fishers, techniques have not changed in the time they have been fishing with fishers from both villages observed using modern materials, reflecting similar findings in other coastal fishing communities in Madagascar (Gough et al. 2009). Nylon fishing line and nets are commonly used, as they are lighter, more durable and less visible to the fish than traditional natural materials. The use of these modern materials is likely to have led to an increase in the effectiveness of fishing methods leading to a greater proportion of available fish being caught. For these reasons, any decrease in overall fish populations could potentially have been masked (Sabetian and Foale 2006).

Fishers' opinions on the state of marine resources within the bay differ greatly between Ramena and Antsisikala. Fishers from Antsisikala generally perceived that fish populations within Antsiranana Bay have declined, with a greater proportion of fishers acknowledging a decline in catch size and abundance in Antsisikala than Ramena. Among the fishers who had noticed such a decline, most respondents believed that a certain level of overfishing was taking place. The acknowledgement of practices leading to overfishing could provide an important trigger for local people to consider the introduction of resource management plans.

Fishers stated a number of locations where they sell their catch. The high level of demand for seafood and the lucrative prices offered by wholesale buyers and restaurants in Antsiranana provides an attractive location for fishers to sell their catch (Antsisikala village fisher, pers. comm. December 2008). Fishers from Ramena are geographically closer to Antsiranana making it more convenient to sell their catch there on a daily basis. They also choose to sell it locally, which is likely to be supplying the growing demand from tourists in Ramena. Fishers from Antsisikala need to travel a greater distance to sell their catch and will thus only do so when they have a surplus of fish from an unusually large catch. Further investigation is required to accurately assess the level of demand for seafood products from Antsiranana and Ramena and how it affects local fisheries within the bay.

With an average 3.2 % population growth in Madagascar (Billé and Mermet 2002) and an increase in the number of tourists in Antsiranana Bay (Christie and Crompton 2003), fishing pressure is likely to become exacerbated, especially in Ramena where tourism is expanding (Hotel proprietor, pers. comm. July 2008). Ramena is traditionally a fishing village, although many fishers now consider tourism as their main source of income reflecting the expansion of tourism in this village. The effects of an increasing coastal population and growing demand of seafood products have been well documented by fishery studies globally (Gedamke et al. 2007) and in sub-Saharan Africa (Tietze et al. 2000, Machena and Moehl 2001). The rise in fishing pressure presents a significant management issue, which needs to be addressed to ensure fish populations are safeguarded for future generations. This increase in fishers and fishing pressure is characteristic of many other coastal areas in Madagascar (Laroche and Ramananarivo 1995, McVean et al. 2005) and beyond (Kaunda-Arara et al. 2003).

While fishing pressure is likely to increase within the bay, with many fishers from both villages perceiving a decrease in fish catch size and abundance, the collection of baseline data on fish stocks and the monitoring of changes over time are recommended to allow the development of management strategies to use fish resources sustainably. The negative responses from Ramena's fishers regarding how best to ensure the sustainable use of marine resources within the bay, suggest that they are more likely to show some resistance to management plans such as no-take zones, which would restrict where they are permitted to fish. Fishing in both Antsisikala and Ramena is one of the main livelihood activities, and imposing restrictions on fishing activity is therefore likely to affect both villages. Any future fisheries management plans for Antsiranana Bay will need to take into account these crucial differences between small-scale fisheries and opinions on resource use within the bay.

The investigation of fishing practices in Ramena and Antsisikala highlighted important differences between the two villages in their fishing style, the amount of fish they catch, the type of gear they use, and the opinions on the current state of the fishery. The methods used to obtain the data for this study were limited by a number of factors such as sea conditions, time available to carry out data collection, financial resources, accessibility to fishers and their trust towards the investigators performing the research. Therefore, a flexible approach towards data collection was employed to enable information gathering whenever opportunities presented themselves. Spending more time within the community and directly with fishers would increase levels of trust between fishers and investigators to allow a more structured and systematic approach to data collection.

RECOMMENDATIONS FOR MANAGEMENT. Community-based governance of the coastal zone and marine resources has been recommended as a management strategy by numerous studies globally and in Madagascar, to assist enforcement of regulations governing resource use (McKenna and Allen 2003, Rakotoson and Tanner 2006, Cinner and Aswani 2007). In Madagascar, *dina* as a voluntary social code of conduct that governs relations within and between communities, has become a widely-used tool to facilitate natural resource management (Andriamalala and Gardner 2010). *Dina* is a legally recognised governance tool that allows local communities to have a participatory role in managing their resources, as well as being able to enforce regulations and resolve conflicts between users. This study found that local beliefs and traditions (e.g., *fady*) are still alive in the region (e.g., Ramena). Many of these *fady* are specific to villages and may even differ within each village. Where practical, and particularly if they support resource management, incorporating local traditions and beliefs into prospective management strategies through using *dina* as its mechanism, could be a viable tool to engage local peoples to manage the marine and coastal resources of Antsiranana Bay (Rakotoson and Tanner 2006). Combining *dina* as the legitimate 'bottom up' governance tool, with legal governmental framework as the 'top down' governance tool could be a viable management strategy, as examples from other parts of Madagascar such as Antongil Bay on the north-eastern part of the country proved successful (Rakotoson and Tanner 2006).

Improving the sustainability of fisheries within Antsiranana Bay by reducing the overexploitation of fish resources is unlikely to be achieved without identifying and supporting alternative livelihoods for many of the people currently dependent on reef fisheries (Newton et al. 2007). Both villages stated that they participated in alternative livelihood activities such as tourism in Ramena and farming in Antsisikala to create income. Further diversifying their livelihood activities particularly through an increase in tourism, a strategy welcomed by many fishers from both villages, as well as encouraging children to remain in education and providing information on achievable career opportunities could help reduce the number of people from future generations becoming fishers (Davies et al. 2009).

The implementation of a regional environmental education programme including participatory workshops for the local communities that rely on the bay and its marine resources could raise awareness and knowledge on a number of important issues affecting marine resources within the bay. As the responses from each village regarding environmental awareness towards the use of the marine resources varied considerably, an education programme could help to raise awareness and understanding, which could in turn increase cooperation between villages making management strategies more likely to succeed. This could further provide a mechanism to help improve the sustainable use of the bay's resources and promote the development of responsible fishing, especially in villages like Ramena where fishing is more intensive and non-selective equipment is used. Following these initiatives, community involvement will be key to the long-term conservation of Antsiranana Bay and the sustainable use of its marine resources.

The use of mesh sizes smaller than 25 mm is illegal in Madagascar (Rakotoson and Tanner 2006) and is recognised as a highly unsustainable and destructive technique in many east African and Indian Ocean coastal states (McClanahan and Mangi 2004, Tobey and Torell 2006). However, a lack of knowledge by fishers and lack of law enforcement are likely to be the reason for the continual use of small mesh size beach seine nets. A complete ban on beach seine nets is unlikely to be successful as using this type of fishing gear is the most effective method of catching coastal pelagic species (Clupidae) that are known to be an important fish resource for coastal communities in Madagascar (McClanahan and Mangi 2004, Davies et al. 2009). Restricting the use of beach seine nets and regulating mesh sizes of all fishing nets through the use of *dina*, therefore build-

ing on the opinion of many fishers from both villages who stated that using larger mesh size nets is a viable option for exploiting marine resources more sustainably, would help reduce by-catch and diminish the negative effects of overexploitation of fish resources (Lindholm et al. 2001, McClanahan and Mangi 2004, Rakotoson and Tanner 2006).

CONCLUSIONS

With a steady growth in the population of Antsiranana and other villages around the bay and an increase in tourism, the future of the fishery in Antsiranana Bay needs to be regulated, as with many fisheries in developing and developed countries, to ensure sustainable resource use. The establishment of an Antsiranana Bay fishery alliance that would include representatives from key stakeholder groups such as fishers from each village, business and hotel owners, local government officials from Antsiranana and local conservation organisations, could help develop actions for responsible fishing practices though the use of *dina*. The formation of such a body could help to sustainably manage the bay's resources. The different needs of each village, including differences in opinion on marine resource use, who they would like to see manage these resources and the fishing techniques used as highlighted in Ramena and Antsisikala, should be taken into consideration, in addition to incorporating local beliefs and ecological/fishery information into management plans, wherever possible.

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SUPPLEMENTARY MATERIAL.

AVAILABLE ONLINE ONLY.

TABLE S1. Number of vessels recorded in each sector of the bay.
TABLE S2. Sample questionnaire – village fishers.