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Cover image: A seagrass meadow (*Thalassia hemprichii*) at Inhaca Island, Mozambique (© José Paula, 2017)

Fishing site mapping using local knowledge provides accurate and satisfactory results: Case study of Octopus fisheries in Madagascar

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Abstract
Accurate fishing ground maps are necessary for fisheries monitoring. In Velondriake locally managed marine area (LMMA) we observed that the nomenclature of shared fishing sites (FS) is villages dependent. Additionally, the level of illiteracy makes data collection more complicated, leading to data collectors improvising when recording FS. In this case study for Velondriake we opted for a participatory approach giving special consideration to local knowledge in mapping octopus fishing grounds. Other techniques (single or multiple GPS points) have been tried but gave overlapping maps for neighboring FS, and do not reflect reality. Local fishers know the exact extent of their fishing grounds and are able to draw them accurately. We utilized a printed habitat map or Google Earth satellite imagery, and asked fishers to draw in each FS. Using this technique, 325 sites were identified from 13 villages, without any overlaps or duplications, making a valuable contribution to fisheries management efforts. This supports the contention that local knowledge, and the participation of local fishers, is crucial in conservation. This approach strengthens the relationship between scientists, managers and local communities. This technique is cost effective and adaptable to each situation, and is now widely used by Malagasy fishing communities.

Keywords: LMMA, participatory approach, fishing site mapping, fisheries monitoring, local knowledge.

Introduction
The successes achieved in the study site in the Velondriake LMMA (www.lifewiththesea.org) is strongly linked to community support to conservation resulting from positive fisheries impacts of temporary closures for small octopus fishing sites. Velondriake LMMA is an 800 km² community-managed area in the southwest of Madagascar. It was established in 2006 and has included 15 villages since 2008, and was established with support from Blue Ventures Conservation, an award winning British-based NGO. Octopus is a major source of income for the fisher community in southwest Madagascar, and commercial collectors have gradually expanded their collection area from 3 zones in 1996 to 9 zones in 2006, to cover the whole of the southwest coast (L'haridon, 2006). Since a major part of the "Vezo" (ethnic name of the southwestern fishing community) migrate along the western coast of Madagascar (Cripps and Gardner, 2016), the success of the very first 6-month octopus fishing site closure in the village of Andavadoaka at Ankereo, spread very easily. While the number of sites within Velondriake grew from 1 to 24 from 2004 to 2008 the number of other villages joining Velondriake grew from 8 to 15 in the same period. In this case study, fishing site closure refers to the closure of one specific site for a certain period, while others (one village may have up to 20 octopus fishing sites) remain open to fishing activities. It is different to a national closure which refers that all fishing sites being closed for a certain period.

The rapid growth in the number of villages adopting fishing site closures led to the need for an urgent assessment of the effect of such closures. There was a need to firstly assess the impact of this fishing technique on the octopus habitat (reef), and secondly the impact on the octopus population itself. Assessment of the impact of closures on fishers' income was also necessary. The impact on the octopus population and on fisher income has been monitored through the collection of octopus landing data within a small region of the coastline since 2004, and focused on the Velondriake LMMA first.

Once the first data was collected it became apparent that some similarity in fishing site names occurred. The "Before and After, Control-Impact" (BACI) method was chosen in order to check the impact of the seasonal closure on catch per unit of effort (CPUE). This method required an "experimental site", which is the "closed site", and a "control site", that has never been closed before were catch 'before closure' and 'after closure' could be compared using similar fishing effort. Having a basic but accurate map of the octopus fishing site became a necessity in order to identify control sites, and it was necessary to find a method of ensuring that each site could be separated consistently by name, location and size.

Realizing that spatially delimited fishing effort data could serve as a necessary measure of fishing activity, and is key to evaluating the sustainability and environmental impacts of coastal fisheries (Stewart *et al.*, 2010), this study reviewed other examples of participatory mapping for different environments that have been reported (Close and Hall, 2006) in an attempt to develop an appropriate mapping technique for octopus fishing sites in Madagascar. This paper describes a cost effective technique that is adaptable to each field situation (including varying levels of availability of GIS data), and values and utilizes the local knowledge of fishers.

Materials and methods

The first attempt at creating maps of fishing sites entailed the use of a single GPS point for each site. This was only useful to record the location of the fishing site and its approximate distance from the neighboring village. This technique did not solve the nomenclature problem and resulted in a series of points that were often very close to each other.

The second technique that was tested took at least three GPS points of each fishing site and could provide a basic estimate the fishing site location and area. However, when the GPS points were plotted on a map (Fig. 1A) it appeared as though several of the sites were overlapping. This was the result of catch data for several sites being pooled in some cases.

The third technique was adopted when an attempt to utilize the second technique was initiated at the village of Nosy Be (island on the northern border of Velondriake), but failed due to bad weather hampering the collection of data points at sea. To save time it was decided to draw the coastline on a black board by hand so that the fishers could indicate the location of each fishing site. The aim of this exercise was to eliminate any fishing site duplicates and to confirm each fishing site or group name. After inserting contour lines for the small island based on a Google Earth map, the fishermen were asked to indicate where the listed fishing sites were located. Instead of doing so, the fishermen initially drew the shape of the coral reef around the island so that they could indicate the location and border of each fishing site. After comparison of the hand drawn maps with the layout of coral reefs and other habitats as shown on Google Earth and habitat maps produced from remote sensing, it was apparent that the fishermen had very accurate knowledge of the shape and characteristics (sand cover, sea grass, coral reef etc.) of their fishing ground. Explanation to the fishers of how the maps represented characteristics on the ground was made easier by identifying physical entities on the map such as buildings (eg. a school, a church, a hospital), a tree, a cemetery, a large rock, and so on.

GPS mapping of fishing sites using handheld GPS units cannot include every detail of the area, and the participatory mapping process, with local fishers generating accurate outline sketches of fishing sites on printed satellite images, allows the rapid production of accurate fishing site maps.

Confirmation of fishing site names

The participatory mapping process occurs in several steps, all of which must be followed in order to reduce error in fishing site nomenclature and location due to sharing between villages, and in some cases the grouping of several sites under one name.

To confirm fishing site names, a list of fishing sites across all villages was generated from the collected catch data. This was generated in collaboration with village elders and active fishers from both sexes. Once an initial list had been created this was cross-checked

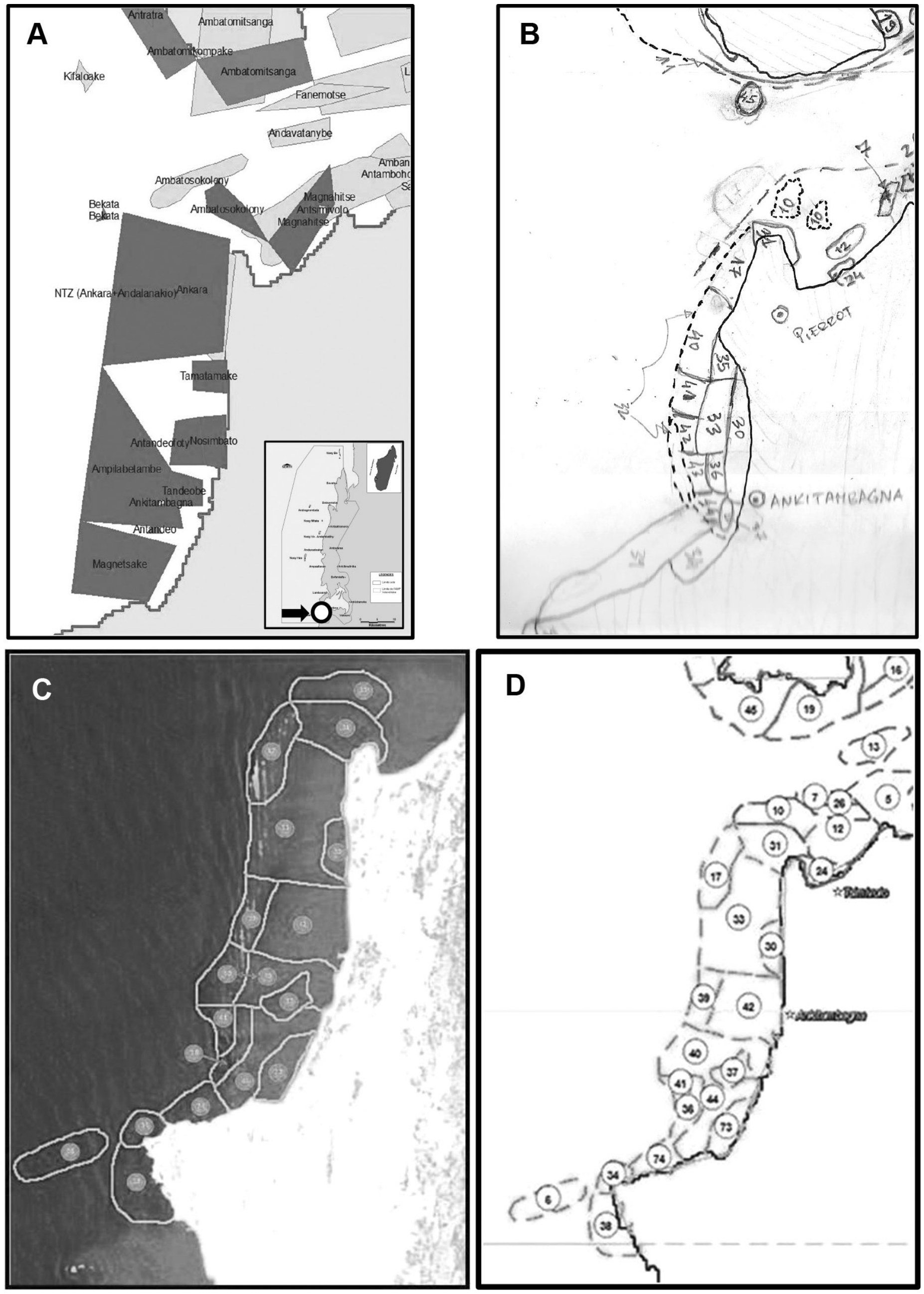

Figure 1. Comparison of techniques. A – using at least 3 GPS points. White areas represent the sea. Fishing sites are represented by polygons; B - hand drawn map on blank paper; C - fishermens' drawing on printed Google Earth satelite imagery; D - digitized version from ArcGis.

with lists from neighboring villages. At this first stage of the process all spelling variations in site nomenclature were standardized. For example, a single site may be called 'Afatsombo', 'Fatsombo', 'Amafatsombo', or 'Mafatsombo', so a single spelling variation was selected by the elders. Another common issue was the existence of an identical name for different fishing sites across villages. For example, there is a site called 'Ambatobe' (meaning "big rock") in nearly every village. Thus a unique four letter village identification code was added to the fishing site name so that sites could be immediately identified. There were also occasions when the same site was known by completely different names in two neighboring villages. In these cases, the village owning the site assigned the final name. If this could not be done, the researchers and the two parties would select one of the names as the final confirmed name. The finalized, confirmed fishing site list was then presented to different village elders and fishers for final confirmation and to ensure that an exhaustive list had been generated. In general, the data needed for this exercise included at least the name of the village, the fishing site name, and if possible, the name of the person that gave the information for further discussion later on, if required.

From manual drawing to geo referencing

A selection of village elders and fishermen were gathered and asked to initially sketch out the village fishing sites on a blank piece of paper. Due to the fact that some 'Vezo' migrate, it was important to choose native and active fishers. Local fishers harvest octopus by diving using a spear or stick (mainly male activity), or by gleaning (activity carried out mainly by woman and young children). Diving occurs on the deeper part (less than 8 meters) of the reef, and gleaning is only carried out during spring low tide when a major part of the reef flat is exposed. During this process it became clear that the village elders had a good understanding of the layout of the fishing sites and in particular were able to reference fishing sites to reef areas and natural geographical formations such as outlying rocks or sand bars. It was difficult to transfer these maps into a useful geo referenced scale (Fig. 1B). It was therefore decided to introduce a small scale, Google Earth image (Fig. 1C), and/or a high resolution habitat map from remote sensing techniques when available (Fig. 2A). These images showed at least reef contours, sand patches and rock outcrops. For this purpose, any maps from previous studies or exercises are valuable if the Google Earth image is not good enough (eg. in the case of cloud coverage). While it usually took some time to familiarize the fishers with the map and to ensure that they fully understood what they were viewing, it was clear that they did understand eventually and were often quite amazed that such an accurate image of the sea could be produced. Initially, fishers were asked to draw directly on the printed map but that technique was modified due to the fact that discussion may occur between the fishers and the map may change several times until consensus is reached. Ideally, the satellite imagery is used as a layer background, and drawings are made on a transparent sheet. The image is then scanned, digitalized and geo referenced in ArcGis. Alternatively it is possible to hand draw the sites straight into Google Earth as individual polygons.

Once the first map was produced, it was necessary to have it verified by the communities, ideally by a selection (sex, age) of fishers and elders to ensure that all sites have been located and consensus is reached. Any edits were then included and a final map generated (Fig. 1; Fig. 2B, C).

Results and discussion

Using manually gathered GPS points is a time consuming and expensive process requiring the use of a motorized boat in order to navigate easily around the edges of the sites to be mapped. The polygons generated from a small number of perimeter GPS coordinates are straight sided and do not allow the boundary to shift to encompass or avoid geographical features. Area estimates taken from this method are likely to be unreliable as the perimeter is not a true representation of the actual boundary of the site. While this is a

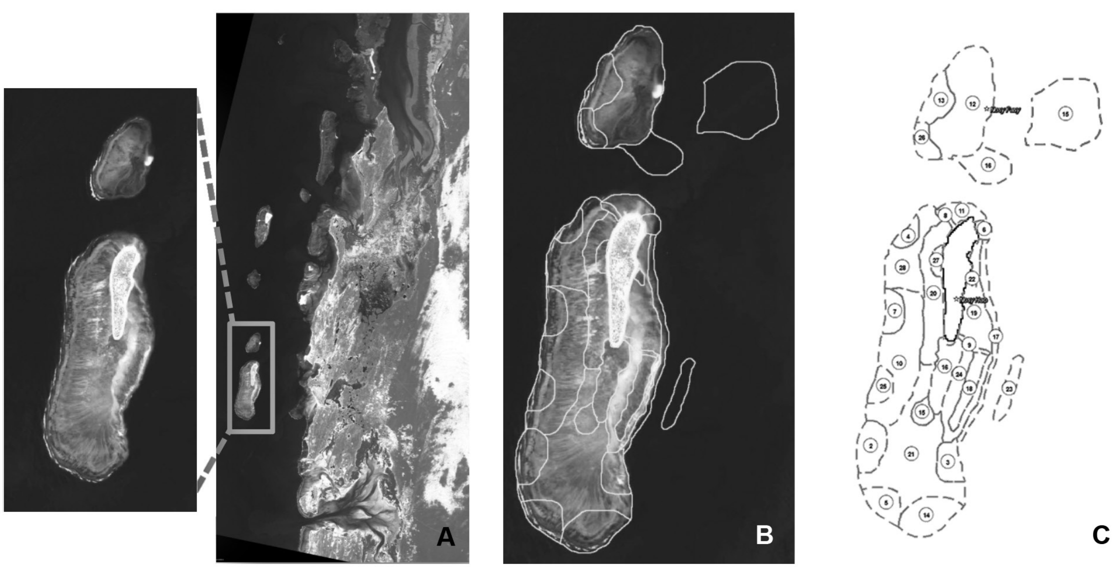

Figure 2. Method and processing. A - an example of very good satellite imagery (habitat map using high resolution remote sensing tool) used for Nosy Hao Island; B - a fishermens' drawing on a satelite map; C - digitized version from ArcGis.

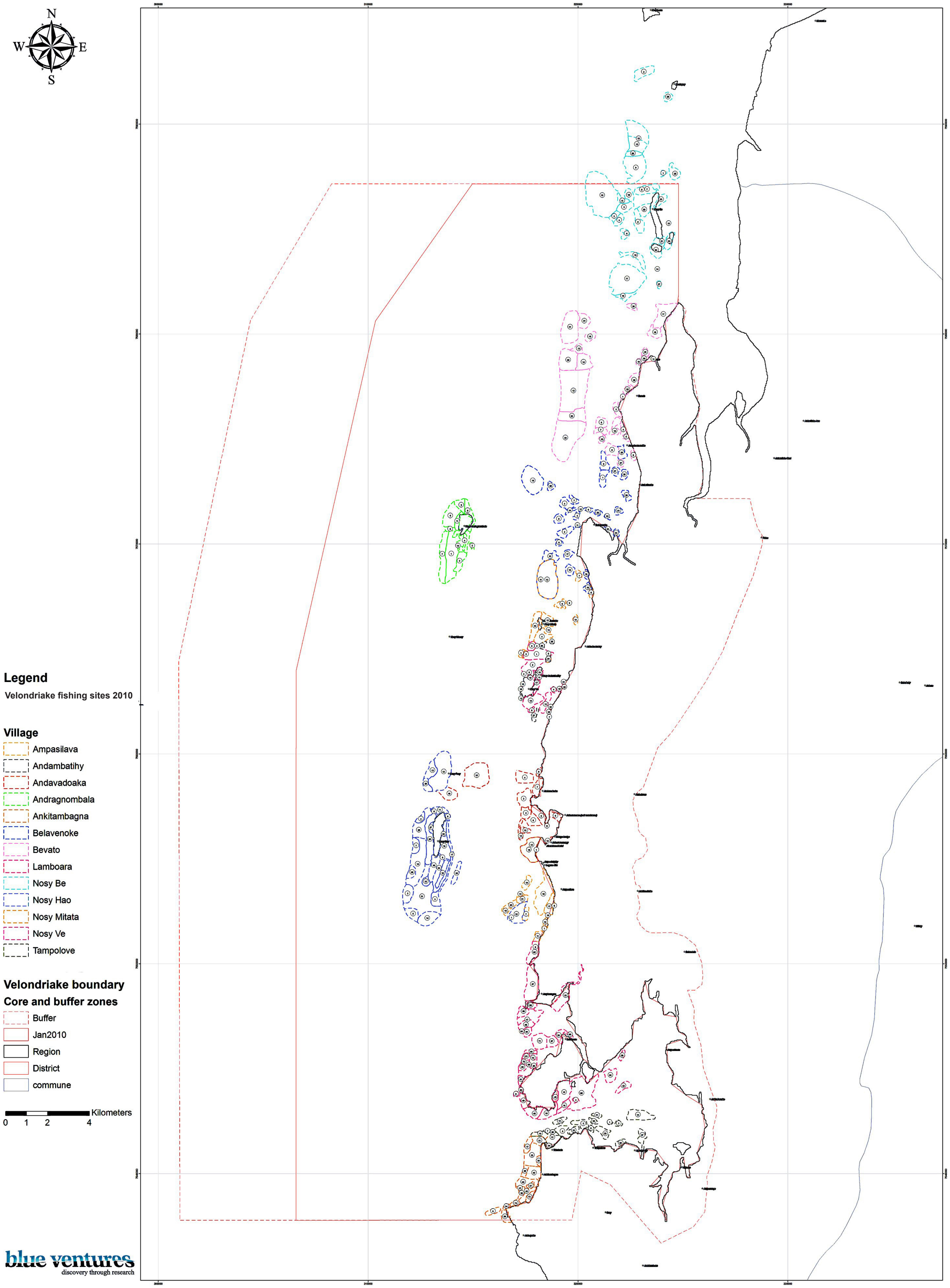

Figure 3. An example of the outcome (Velondriake LMMA in 2010).

useful way to rapidly digitalize the location of sites, it is not the best technique for detailed location.

Maps drawn by hand from memory by the village elders are more accurate, and illustrate clearly that community member have detailed knowledge of the local reef structure. Thus the use of printed satellite images allows us to maximize the local knowledge that the fishers possess, and generate a detailed fishing site map from which accurate area estimates can be taken. Any conflict of the exact location, area and various names of each fishing site can be solved through this approach. Final names of fishing sites were assigned using the original name from the village that owns it. Generally, a site belongs to the nearest village, even when two villages are very close to each other. This clear ownership is very important when villages make the choice to close a site or group of sites for a specific period, as it is respected by neighboring communities. The accurate mapping of all fishing grounds resolved the problem of overlapping fishing sites.

It is clear that each new step developed during the participatory mapping process led to increased accuracy (Fig. 1 A, B, C, D). A total number of three hundred and twenty five sites were identified and mapped from thirteen villages (Fig. 3) allowing an impact study of temporary octopus closures to be initiated. Detailed analyses of these closures from both a fisheries and economic perspective have recently been undertaken and results indicate that the closures are profitable to both communities and individual fishers (Benbow *et al*., 2014; Oliver *et al.*, 2015). These results from the Velondriake LMMA have provided an excellent example of successful management, and this approach has been adopted not only throughout Madagascar, but in other countries of the western Indian Ocean such as Zanzibar.

Conclusion and recommendations

This method of mapping is cost effective and can be conducted without spending a lot of time on a boat at sea. Existing images can be used as background layers for the participatory mapping process. Velondriake LMMA is viewed as a regional example of innovative and effective fishery management (Andriamalala, 2008), and this approach has now been adopted all along the western coastline of Madagascar. Identification of the exact size, shape and location of each fishing site is critical to allow octopus closures to be effective, and it is extremely useful for fisheries managers to have this information before the initiation of a closure. Participatory mapping is a flexible tool that includes both local knowledge and existing map resources. It is particularly useful in confirming fishing site names and in dealing with overlapping problems resulting from errors in the recording of catch data.

Despite the simplicity of the method, several challenges need to be recognized. One of the most common is the effective explanation of the map to the fishers. It is highly recommended that the practitioner working with the community knows the area before engaging with the fishers. At the very least he/she should have a knowledge of some important local reference points that could be indicated on the map, such as a large rock, sand bars, a church, a house, a tree, or another feature that is shown on the satellite imagery.

The information obtained by the process of participatory mapping described in this paper is precisely what is required to inform seasonal octopus closures and studies on the impacts thereof. We believe that this method is the most appropriate, in a practical and financial sense, for assisting in the management of the southwestern Malagasy fishing grounds. The generation of participative fishing site maps for a target species with economic importance such as octopus in southwest Madagascar allows fishery managers to enhance site selection for the temporary closure management model favored in the Velondriake LMMA, and strengthens the relationship between scientists, managers, and the local community.

Acknowledgments

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