Presenting a new direction for small-scale marine protected area design

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Introduction

This article presents a new method for conducting coral reef species surveys over a small area and determining priorities for small-scale marine conservation programmes. The method outlined here was first described in a paper published by this author in May 2014 in the journal *PLOS ONE,* titled "Combining natural history collections with fisher knowledge for community-based conservation in Fiji."[1] The work was done by researchers from the Drew Lab at Columbia University in the United States in the summer of 2013.

Small-scale marine protected areas (MPAs) have become increasingly common around the world and especially in the Pacific, with the goal of safeguarding depleted fishing stocks and preserving endangered habitats. In particular, a move towards community-based management efforts has placed the establishment and governance of MPAs in the hands of local groups rather than national governments or international nonprofit organizations. One such example is the village of Nagigi in Fiji, where fishermen are calling for a traditional fishing closure, or *tabu*, to be set up on their local fishing ground, in response to their concerns about overfishing.

No matter who governs an MPA, any successful programme needs a reliable baseline of the ecosystem's health before the start of the programme. Tropical ecosystems in particular are complexly interconnected in ways that make it difficult to gather reliable baseline data without time-consuming and expensive periods of data collection. As pioneering marine ecologist R.E. Johannes put it in the late 1990s, "No other fisheries involve so many species, such complex and diverse habitats, so many fishers, gear types, landing sites and distribution channels per unit of catch. In the face of such Gordian complexity there is little consensus among fisheries biologists concerning even the basic dynamics of such fisheries" (Johannes 1998).

The new method outlined here involves a two-pronged approach to compiling a species list of reef fish that can be used as a baseline measure for the health of a small area of habitat. By gathering data about species diversity using two complementary strategies — destructive sampling[2] on the reef and fisher interviews — researchers could create a much more comprehensive picture of reef biodiversity than they could with either method alone. The two techniques were deployed over a brief period and over a small area, creating a snapshot of the reef's biodiversity at a moment in time. Although in this instance the techniques were used in a coral reef ecosystem in Fiji, it has the potential to be adapted for use in a variety of coastal ecosystems and inshore fisheries around the globe.

Methods

Fish collection

As part of the baseline project, over 200 specimens of finfish were collected on Nagigi's reef using spearfishing and the fish anesthetic MS-222. Fish were identified to the species level using field guides, and then preserved in formalin and shipped back to New York for inclusion in the ichthyology collection of the American Museum of Natural History. This gave us a preliminary measure of the reef's total biodiversity, but without any sense of the relative fishing pressure on various species.

Fisher interviews

At the same time, we conducted interviews with village male and female fishers about their fishing practices, long-term environmental changes on the reef, and their support of a potential conservation programme. Interviews were conducted in English, which is a national language in Fiji, with a Fijian translator available when necessary. Interviews were based on a questionnaire prepared in accordance with Columbia Institutional Review Board protocols for human research, and participants' written consent was obtained. Most interviews occurred in participants' homes, but a few occurred while female fishers fished or gleaned on the reef at low tide, and one

[1] http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0098036

[2] Destructive sampling involves invasive methods. It applies to any procedure that results in the permanent destruction or alteration (sometimes invisible) of all or a part of a natural history specimen for the purpose of performing scientific analyses (source: http://nature.ca/pdf/collections_vds_e.pdf).

interview took place during a kava-drinking session in front of the village hall. Interviews lasted anywhere from about ten minutes to over two hours, depending on context, language barriers, and interviewees' knowledge. For instance, one interview in which participants knew little to no English lasted only ten minutes, while the kava-drinking session lasted more than two hours. In total, 22 villagers were surveyed singly and in small groups across 15 interviews.

Results

Partial species list

In total, we recorded 150 species of finfish on Nagigi's reef. Fijian names were recorded for 82 species, and several additional family-level or generic-level Fijian names were recorded based on interviews. The most species-rich families were Pomacentridae (16.7%) and Labridae (10.7%). Only 11% of the species on the list were both present in the specimen collection and mentioned in interviews, which shows the importance of this dual approach in capturing a full picture of the reef's biodiversity.

Targeted species and fishing practices

Based on the frequency with which it was mentioned in fisher interviews, we determined that the thumbprint emperor (*Lethrinus harak*, Lethrinidae) is the finfish most heavily targeted by Nagigi's fishers. Octopus (*Octopus* spp., Octopodidae) and giant trevally (*Caranx ignobilis*, Carangidae) are also heavily fished, along with several other species in high demand (Table 1). Fisher interviews provided us with details about common fishing practices and life history patterns for several local populations of targeted fish that we could not have obtained otherwise. For instance, a local population of yellowstriped goatfish (*Upeneus vittatus,* Mullidae) spends most of the year in a salt lake inland of Nagigi village but migrates to a mangrove forest on the shoreline once a year to spawn. This spawning event, which occurs between October and November, is an intensive period of harvesting in Nagigi, with the entire village collaborating to celebrate the windfall. Villagers wear fine clothes and flowered garlands for the event, and the fish are shared among the villagers instead of being sold at the market.

Based on interviews, some reef species are fished primarily for selling at the market (artisanal fishing), while others are fished more for home consumption (subsistence fishing). Sea cucumbers (holothurians), for instance, are not eaten in Fiji, but are harvested exclusively for export abroad. In contrast, finfish such as emperors, trevallies, and parrotfish are caught for both home consumption and selling at the market. One female fisher described selling octopus and any fish longer than her forearm and hand (about 40–50 cm) at the market and keeping any

Table 1. At-risk reef species. The most heavily targeted species based on the number of villagers who claimed to target them. Includes perceived changes in the population of these species and the number of interviewees who made these assessments.

Fijian name	Scientific name	Number of times mentioned	Perceptions of population change
Kuita	*Octopus* sp.	8	Decreasing size (n=1) and abundance (n=3)
Kabatia	*Lethrinus harak*	6	Decreasing abundance (n=1)
Saqa	*Caranx ignobilis*	6	Decreasing abundance (n=1)
Kanace	*Moolgarda engeli*	6	Smaller, scarcer, and harder to catch (n=1)
Ulavi	Gray or white parrotfish >30 cm	5	Increasing abundance (n=1)
Vonu	Sea turtles	5	Decreasing abundance (n=2)
Labe	*Halichoeres trimaculatus*	5	N/A
Nuqa	*Siganus vermiculatus*	5	Decreasing abundance (n=1) or increasing abundance (n=1)
Kawakawa	*Epinephelus polyphekadion*	4	Decreasing size and abundance; increased fishing effort necessary (n=5)
Ta	*Naso unicornis*	4	N/A
Tabace	*Acanthurus triostegus*	4	N/A
Dridri	3 *Acanthurus* sp.	4	Increasing abundance (n=1)
Vasua	*Tridacna gigas (giant clams)*	4	Decreasing abundance (n=1)
Deou	*Upeneus vittatus*	4	N/A

N/A = not applicable

smaller fish she catches for herself. Nagigi has a substantial population of Seventh Day Adventists who do not consume or harvest shellfish, octopus or sea cucumbers.

Changes on the reef

We deliberately chose to interview older and more experienced fishers for this project, and our participants had an average age of 50. Interview subjects had an average of 44 years of experience fishing on Nagigi's reef although levels of experience varied; one young interviewee had just moved from a village farther down the shore, where an MPA had been in effect for the preceding five years.

Villagers claim to have seen a general decline in reef productivity over their years in Nagigi, with the most heavily targeted species becoming smaller, less abundant, and harder to catch in the recent past. Participants described having to go farther or work longer to catch enough fish. Octopus in particular were noticed to have declined; as one villager noted: "Before, they used to catch eight, nine [octopus] sometimes. But now, you can just catch two or three." Two villagers reported that *nuru* (in Fijian, any fish shorter than a finger's length) have become scarce and that inshore coral heads, which are an important source of habitat for *nuru*, have become degraded. Two IUCN red-listed species, the bumphead parrotfish (*Bulbometopon muricatum,* Labridae) and the humphead wrasse (*Cheilinus undulatus,* Labridae) were described as becoming scarce as well. Yellow boxfish (*Ostracion cubicus,* Ostraciidae) have apparently disappeared from the reef entirely.

Participants had varying perceptions of the root causes of the changes they had observed on the reef, and a number of causes were mentioned in multiple interviews (Table 2).

Nine villagers attributed overfishing on the reef to an increase in selling fish at the market instead of keeping them for home consumption, especially by young men searching for "quick cash," and six mentioned poaching by outsiders. Other common concerns were Nagigi's recent population increase, which has led to overfishing; night fishing, which yields a higher catch for less effort and can also lead to overharvesting; and the increased profitability of the sea cucumber fishery. Several of these concerns are interrelated, and we found it convenient to represent them graphically in the form of a flowchart (Fig. 1).

Conservation attitudes

All 22 participants in this study supported the establishment of a small, short-term MPA on Nagigi's reef. The MPA's size and location, based on a conversation with the *turaga ni koro* (elected village headman) of Nagigi, were set at one square kilometer on the reef flat and seagrass bed habitat directly in front of the village (Fig. 2).

Table 2. Perceived causes of reef dynamics over participants' lifetimes, by frequency with which they were cited.

Perceived cause of environmental change	Number of times mentioned
Increase in fishing pressure for market instead of subsistence, especially for "quick cash"	9
Poaching by outsiders	6
Increasing population of Nagigi	3
Coral smashing, either as a fishing method to flush out *nuru* or by accident while walking on the reef	3
Night fishing	3
Profitability of beche-de-mer fishery and toxicity of injured holothurians	3
Increased cost of living	2
Changing climate patterns and sea level rise	1
Demand for sea prawns from local resorts	1
Unusually hot season in 1998, which placed stress on coral ecosystem	1
Ongoing upstream development flushing sediment and weed killer onto reef	1
Use of duva root as fish poison	2
Use of nets with small openings that catch juveniles	1

This is by no means the entire area, or even the majority, of the village's fishing ground, and no participants suggested that the MPA should extend farther. Ideas about how long the MPA should last varied considerably, from a single year to ten years or "the longer the better." The *turaga ni koro,* who has been one of the most vocal proponents of the MPA plan, believes that the closure should last five years. Three young men who often fish to make "quick cash" using destructive fishing methods such as night fishing believe that a three-year closure would be enough for most fish, including the International Union for Conservation of Nature red-listed bumphead parrotfish, to regain their former size.

No fishers expressed concern about losing fishing income or subsistence catches during the period of the closure, and several spoke about their apprehension for the future if conservation steps were not taken. As one man put it, "For the sake of future generations, if we want to have an abundance of resources again, we should encourage an MPA on the fishing grounds. Our main concern is that if we're not aware of what's done, future generations won't know what those species are

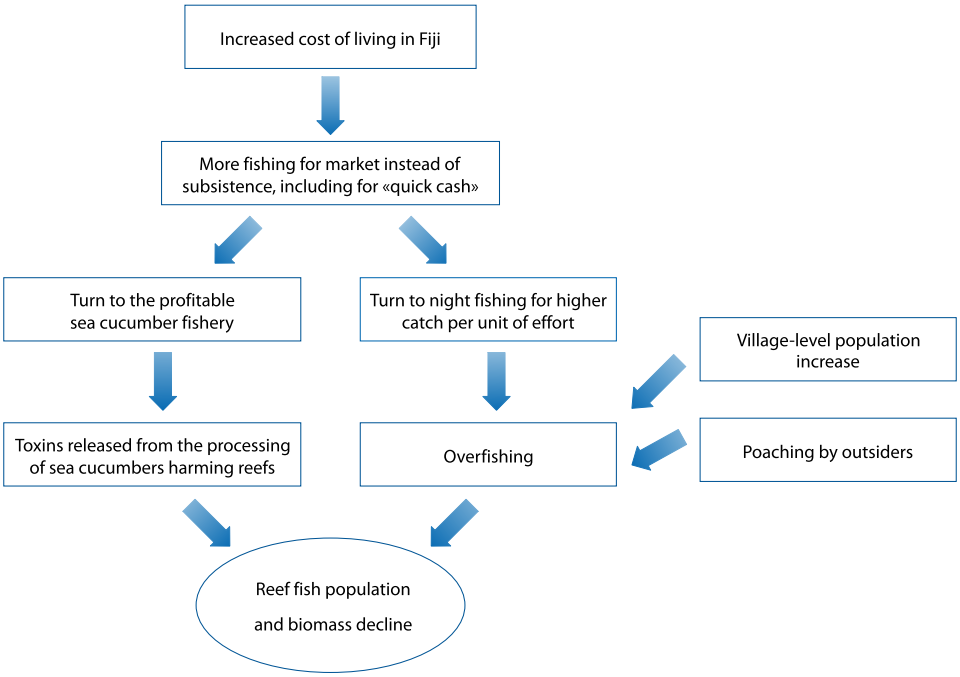

Figure 1. Summary of the perceived reasons for why reef species populations decline.

or recognize the need to gain back what they've lost." Another villager expressed the hope that the effects of the fishing closure would spill over beyond the designated MPA, leading to increased fish populations throughout the village's entire fishing ground. Only one interviewee was sceptical about the MPA plan; she had noticed that when a neighbouring village established an MPA on part of its reef, the villagers came to Nagigi's reef at night to poach. She believes that if an MPA is established in Nagigi, the village's fishermen will do the same.

Recommendations

Life history and location

One important consideration when designing an MPA is to take into account the life histories and ecological needs of the species that the MPA is designed to protect. Based on the frequency with which it was mentioned in fisher interviews, we designated the thumbprint emperor as one prime conservation target of Nagigi's MPA, and considered its ecological needs as they have a bearing on the protected area's design. Thumbprint emperors use seagrass and mangrove habitats as nursery grounds and then migrate to reef habitat later in their life cycle, suggesting that all three habitats are critical to the population's health (Unsworth et al. 2009). As proposed, the Nagigi MPA would contain small portions of reef habitat and seagrass beds but would not enclose any mangrove forest, leaving juvenile thumbprint emperors vulnerable to fishing pressure. In addition, lethrinids like the

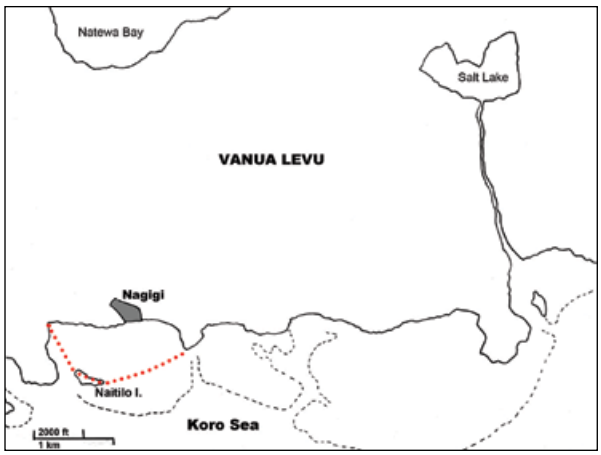

Figure 2. Nagigi's proposed marine protected area covers one square kilometre of reef flat and seagrass meadow directly in front of the village. Black dashed lines indicate fringing reefs, while the red dotted line indicates the marine protected area site proposed by the village's turaga ni koro *(elected village headman).*

thumbprint emperor can move up to 700 m, usually at night, making them vulnerable to poaching and night fishing. To keep them protected under these conditions, Jupiter and Egli (2011) suggest that no-take areas should be twice this length (1.4 km) on each side, for a total area of about 2 km^2. In Nagigi, this would mean doubling the proposed size of the MPA and including a greater diversity of habitats, especially mangrove forest.

Life history and duration

As mentioned above, villagers' estimates of the Nagigi MPA's ideal duration varied widely, from a single year to a long, indefinite period. Villagers had great faith in species' ability to recover in biomass and abundance in a short period, but a closer look at the life histories of heavily targeted species paints a different picture. The thumbprint emperor is a hermaphroditic species that begins life as a female (protogynous hermaphrodite), becoming sexually mature after one or two years, with some individuals making the transition to males at age three or four. Because of this later transition, a short-term MPA of only one or two years would not be enough to protect an entire age cohort of thumbprint emperors through complete sexual maturity.

"Our bank is in the sea"

Nagigi's coastal fishery unquestionably provides an important source of income for its many male and female fishers. As well as providing sustenance and petty cash, it has proved to be an engine of social mobility for particularly skilled fishers, such as the couple who have used fishing income to pay school fees for their four children. As one parent put it, "our bank is in the sea." The treatment of coastal fisheries as a bankable resource that can be saved up (through marine closures) or spent (through fishing) is a longstanding one in Fijian culture, and even predates Western contact. In one recent case documented by Jupiter et al. (2012), villagers on Fiji's Kia Island jointly decided to suspend their MPAs for a few days in order to raise money for community goals. Originally, the villagers aimed to raise FJD 12,000 (~ USD 7,500 at the time), but when they exceeded this goal on the fundraiser's first day, they decided to continue the harvest for five weeks. During this period they netted an estimated FJD 200,000, with a significant drop in the biomass of large-bodied fish such as acanthurids, carangids, and scarids up to a year later. Based on interviews with Nagigi's villagers, it is likely that they, too, will consider opening the MPA for short periods to pay for special projects or to feed villagers. However, as valuable as fisheries products are to communities like Nagigi, the experience of the Kia Islanders emphasizes the extent to which boosting their flagging fish populations will depend on keeping the MPA unbroken for the agreed-on period.

Next steps in Nagigi

In the summer of 2014, members of the Drew Lab returned to Nagigi to continue collections and present the results of this paper to the study participants and other villagers. In response to the ideas recommended here, the villagers decided to expand the proposed MPA across the entire bay in front of the village (see Fig. 2). This will marginally expand the total area of the closure and protect the mangrove swamp in which the yellow-striped goatfish spawns. The reef's thumbprint emperor population will also benefit from the mangrove forest inclusion because mangroves are an important nursery habitat for this species.

Conclusions

Although the recommendations presented here are necessarily specific to a particular location and conservation programme, it is hoped that the general techniques outlined here will be adapted in the future to a variety of different ecosystems and community-supported conservation plans. The "quick-and-dirty" species survey plan outlined above, which uses destructive or visual sampling in tandem with fisher interviews, should be especially well suited to remote and biodiverse ecosystems such as South Pacific coral reefs. The strategy of identifying heavily targeted species through fisher interviews is especially important in this context because it allows researchers to focus MPA or long-term reserve design on the habitat needs of the most vulnerable populations without intensive research efforts. Although MPA size, location and duration recommendations were made based primarily on the needs of, in this case, a single species, the technique can easily be expanded to take into account the life histories of multiple at-risk species.

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