# Sandfish culture in Fiji Islands

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## Introduction

Reports of decreasing stocks of valuable tropical sea cucumbers worldwide are all too familiar. Throughout the Pacific, as elsewhere, the well-known story describes dwindling numbers, smaller individuals and increasing reliance on exploiting low value species. Management has essentially failed for a host of reasons, with some Pacific Island countries and territories (PICTs) resorting to the extreme measure of fishing moratoria to encourage stock recovery (Kinch et al. 2008; Nash and Ramofafia 2006; Purcell 2010).

Sandfish (*Holothuria scabra*) is a high value tropical sea cucumber species and is regarded as vulnerable to overfishing because of its inshore, mostly shallow, habitat. Hatchery technology for this species has been established in a number of countries in the Asia-Pacific region, including Solomon Islands, New Caledonia, Vietnam and the Philippines, through research supported by the Australian Centre for International Agricultural Research (ACIAR) and the WorldFish Center. The spawning and larval rearing of sandfish up to small juvenile size (>3 g) is now regarded as relatively straightforward. Commercial profits from harvestable adults are, however, far from certain. Hatchery production is a costly intervention. Furthermore, large areas are needed for increasing juvenile production, and grow-out in ponds or the sea is necessary for producing commercial size individuals. ACIAR research on grow-out is also underway. Pond grow-out of juvenile sandfish to market size is being developed in Vietnam (Pitt and Duy 2004; Bell et al. 2007) and sea ranching trials are being conducted in the Philippines. Farther afield, sea-pen farming in Madagascar is showing promise (Eeckhaut et al. 2008; Robinson and Pascal 2009), and a private sector and state government collaboration is planning sea ranching trials in the Northern Territory of Australia.

Recent efforts in the Pacific region involve investigating the potential for sea ranching in Fiji, using locally managed fishing areas or *qoliqoli*. Sandfish are called *dairo* in Fiji and are a traditional food item (Fig. 1). This is in contrast to most PICTs, which export sea cucumbers but do not consume them. The exception is parts of Polynesia where the internal organs may be eaten and the animal left to regenerate (Kinch et al. 2008). Although sandfish is protected by fisheries legislation for domestic consumption in Fiji, there has been widespread export, particularly since the late 1980s. Concerns about decreases in sandfish abundance and size have led to initiatives to promote sea ranching as an income generating resource and also to help rejuvenate wild stocks. We use the term "sea ranching" for a "put, grow and take" operation where Fijian owners can harvest hatchery-produced sandfish grown out in their *qoliqoli* (Bell et al. 2008a). Fortunately, there are some locations where sandfish are still locally abundant, although large mature animals are not easy to find.

This article describes the results of an ACIAR-funded sandfish culture and sea ranching mini-project (see boxed text). The study ran for two years

**Figure 1.** Sandfish (*dairo*) prepared the Fijian way.

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from May 2008 to April 2010 on Fiji's second largest island, Vanua Levu (Pickering and Hair 2008). The main aims of the project were to transfer sandfish hatchery technology to local government and private hatcheries staff, increase juvenile production, and run sea ranching trials with a local coastal community. Country partners included the Fiji Ministry of Primary Industries (Department of Fisheries), J. Hunter Pearls, Fiji Locally Managed Marine Area Network (FLMMA), University of the South Pacific and the Natuvu community of Vanua Levu.

The Australian Centre for International Agricultural Research project "Development of aquaculture-based livelihoods in the Pacific Islands region and tropical Australia" is managed by James Cook University (Townsville, Australia) in partnership with the Secretariat of the Pacific Community, WorldFish Center and University of the South Pacific. This project has initiated a number of aquaculture "mini-projects" throughout the Pacific Islands region dealing with various commodities. Mini-projects are small, targeted research interventions that address bottlenecks to sustainable aquaculture.

## Project site

Before the project began, several locations on the south side of Vanua Levu (Caukodrove Province) were inspected for their suitability for sea ranching. Site selection criteria included matching the physical characteristics recommended by Purcell (2004) in addition to human factors such as community enthusiasm, ability to provide security for released sandfish juveniles, and agreement to allow study animals to reach commercial size before harvesting. The site also needed to be located within a few hours travel of the hatchery to ensure minimum transport stress on juveniles prior to release.

The Natuvu community of Wailevu District (population ~250) fulfilled all the requirements (Fig. 2). Within their *qoliqoli* is an extensive sea grass bed, located immediately in front of their village. This habitat, measuring roughly 750 m long (parallel to shore) and 500 m wide, met the microhabitat release criteria (Purcell and Simutoga 2008; Purcell 2004). The main seagrass species was *Syringodium isoetifolium*, with smaller amounts of *Halodule uninervis* and *Halophila ovalis* closer inshore. The sediment was moderately soft with abundant invertebrate fauna (e.g. other sea cucumber species, sea urchins, sponges) as well as numerous small- to medium-sized sandfish (Fig. 3). No large rivers discharge close to the release site, although older community members recounted stories of freshwater pooling over the seagrass beds, resulting in mass mortality of sandfish during intense storm events (i.e. associated with a cyclone). We considered this potential risk one that would occur at any site and graded the site as "good" to "very good" regardless of flood risk. The Natuvu community's approval was genuine, with everyone showing great interest in the project and voluntarily ceasing harvesting sandfish before the project began in mid-2008. The village is accessible by road or sea from the hatchery.

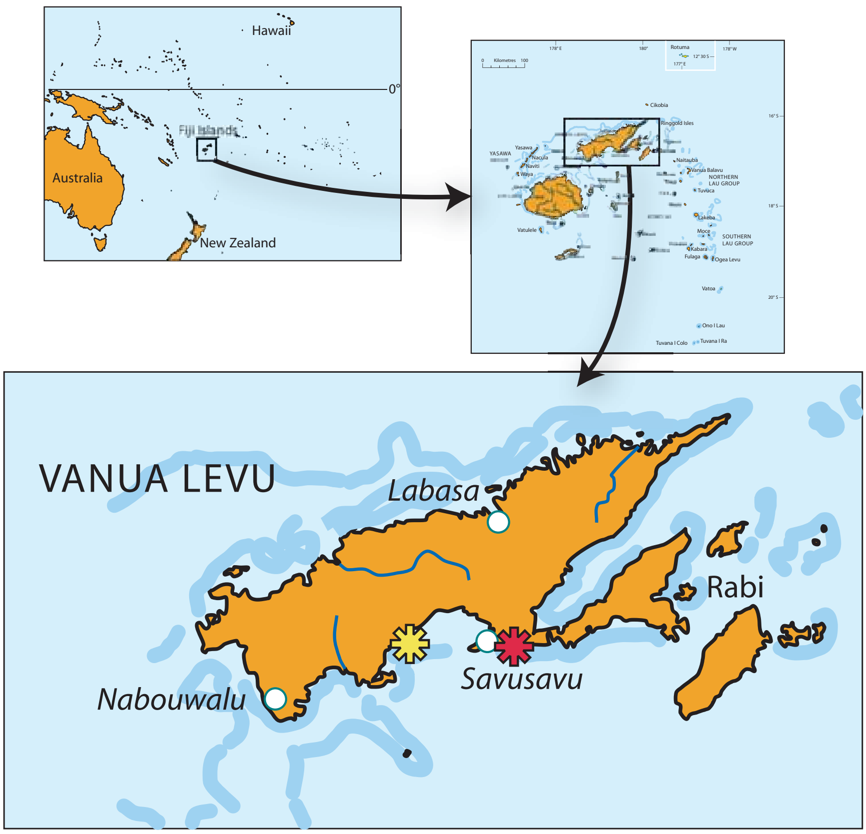


**Figure 2.**
Location of Savusavu township, J. Hunter Pearls hatchery (red star) and Natuvu village (yellow star).

**Figure 3.** Microhabitat of the release site with small wild sandfish.

## Broodstock, hatchery and larval rearing

Mature sandfish broodstock were sourced from within Savusavu Bay to ensure that genetic issues were addressed responsibly (i.e. hatchery juveniles were bred from natal stocks of the release area) (Purcell 2004). Between spawning attempts, a small pond in Savusavu was used to hold broodstock (Fig. 4). Holding groups of adults in earthen saltwater ponds before spawning can result in "conditioning" of sandfish. After conditioning, broodstock become easier to spawn. They may also spawn earlier (and their gonads develop to the same stage of maturity), improving spawning synchrony (Agudo 2006; Duy 2010). This can work well with old shrimp or in fish ponds where the substratum allows feeding and burying of sandfish. However, the 0.2 ha pond was constructed as part of a marina development and was never used for farming. The pond floor was quite rocky and lacked nutrient-rich sediment. Additionally, a broken tidal gate did not control water flow, so water levels rose and fell with the tide. The extensive diurnal tidal flushing did have the positive effect of preventing freshwater stratification during the wet season. Conversely, it also reduced pond productivity by preventing algal blooms. While broodstock survived in the pond, they did not grow and condition as expected. Added to the uncertainty of security, pond use was discontinued after one year.

**Figure 4.** The pond used for holding sandfish broodstock.

Larval production was carried out at the J. Hunter Pearls' blacklip pearl oyster hatchery (Fig. 5), about 15 km east of Savusavu town (see Fig. 2). Spawning induction and larval rearing procedures followed methods developed in New Caledonia by the WorldFish Center (Agudo 2006). Throughout the project, modifications were made to accommodate local conditions and facilities, and to adopt advances in hatchery techniques from Vietnam and the Philippines. The blacklip pearl oyster hatchery met all system requirements for sandfish culture. Microalgae food species were already in production, water quality was excellent and

**Figure 5.** J. Hunter blacklip pearl oyster hatchery (top). Note the seawater intake pipe near the trees at left of picture and white one tonne *dairo* larval tanks under the white roof. Hatchery manager, Sachin Deo (bottom).

only minor adaptations were needed to proceed with production.

Once the release site was selected and the hatchery prepared, the first training to transfer hatchery technology was held in late 2008. Private and government-sector technicians were trained in all aspects of sandfish culture, including broodstock collecting, spawning, larval rearing and transfer to juvenile grow-out areas (Fig. 6).

**Figure 6.** A Fiji Department of Fisheries senior aquaculture officer packing broodstock for transport to the hatchery.

In the course of the two-year project (May 2008 to April 2010) there were five attempts to produce sandfish juveniles: two in the summer season of 2008/2009, and three in the summer season of 2009/2010. Each involved multiple spawning inductions, and larvae were produced on each occasion. However, follow-through was variable and larvae were reared to the juvenile stage only from one spawning event in late 2008. On this occasion, about 1,500 small juveniles were transferred into diatom-conditioned raceways, and 500 of these survived to 1–10 g size to be used in sea ranching trials. The failure to produce juveniles in subsequent production runs was due to a combination of human error, unfavourable environmental conditions, and collateral damage caused by two tropical cyclones.

## Community sea ranching trial

Because of the small number of available juveniles, the trial was run at an experimental scale in order to gain information to increase the success of future releases. A University of the South Pacific post-graduate student was responsible for monitoring the trial, which comprised four 100 m$^2$ sea pens set up in the Natuvu seagrass meadow. The pens were constructed far enough from shore so that they would not dry out at low tide and close enough to be easily reached by foot. Two pens were each stocked with "large" (3–10 g) and "small" juveniles (between 1 g and 3 g). This design was driven primarily by the low number of available juveniles greater than 3 g — the minimum release size recommended by Purcell and Simutoga (2008) for good post-release survival. In addition, we were releasing juveniles into a very different habitat from other studies, thereby providing an opportunity to test this result under Fijian conditions.

Village involvement was strong, and building and deploying pens was a community affair (Fig. 7). The release of juveniles generated much local interest and was the occasion of a feast attended by many local VIPs (Fig. 8). The release of juveniles into the seagrass bed at Natuvu was carried out according to the methods recommended by the WorldFish Center, based on studies carried out in New Caledonia (Purcell and Eeckhaut 2005; Purcell and Simutoga 2008; Purcell et al. 2006). Juveniles were taken to the site the previous day and left in nets overnight to acclimate to local conditions and to "de-stress" following transport. In May 2009, 496 juveniles were released: 105 placed into each of the two large size pens (Pens A and C) and 143 into each of the small size pens (Pens B and D). They were removed from the overnight holding nets (Fig. 9), then "planted" in the sediment within the sea pens by digging a small trench with a finger, then placing them gently in it.

**Figure 7.** Pen construction on the seagrass beds in front of Natuvu Village.

**Figure 8.** Project staff, community members and VIPs at the occasion of the sandfish release.

**Figure 9.** Preparing hatchery-reared juveniles for release into the sea at Natuvu in May 2009.

Monitoring began one month after the release in June 2009, and then at approximately one to two-monthly intervals up until the conclusion of the study in April 2010. Project staff were responsible for monitoring, and were assisted by four Natuvuan men who were trained as "*dairo* wardens". These men helped the scientific staff with monitoring the released sandfish juveniles, and they checked pens regularly (Fig. 10). They were also a valuable source of knowledge regarding local conditions and their *qoliqoli* environment and fauna. During each monitoring session, the number of animals in each pen was counted and their length and width measured. The length and width data were then used to calculate weight using a formula developed by Purcell and Simutoga (2008). On two occasions, weight was checked with an electronic balance that confirmed that the weight calculated from measurements was reasonably accurate.

**Figure 10.**

Fisheries officer collecting *dairo* (top left);

Natuvu *dairo* wardens measuring ranched *dairo* 3 months after release (top right);

Natuvu *dairo* wardens monitoring ranched *dairo* 11 months after release (bottom left);

village chief inspecting *dairo* 11 months after release (bottom right).

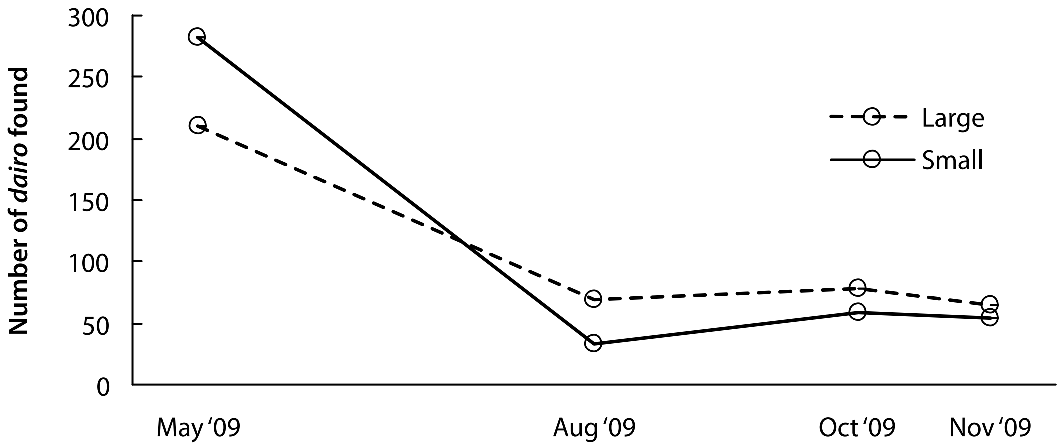


**Figure 11.** Sandfish survival in the four pens after six months.

The survival rate after six months was around 28% overall (23% for small sandfish and 33% for large sandfish) (Fig. 11). The highest overall survival rate was 41%, recorded from a pen of large sandfish. Mortality (or loss) was greatest in the first three months and then levelled off. Due to pen damage in the latter half of 2009, the six-month average is used as the survival estimate for the trial. Studies by Purcell and Simutoga (2008) also found that most mortality occurs in the first few months after release.

Growth of hatchery-produced sandfish was generally positive throughout the trial, although a period of slow growth occurred between November 2009 and January 2010 (Fig. 12). Measurements are considered most reliable up until nine months after release (February 2010), prior to Cyclone Tomas in March 2010. At this time, average sandfish size was 165 ± 5 g for small sandfish and 167 ± 6 g for large sandfish. Sandfish were measured after this time (see April 2010 data point in Fig. 12). However, it is possible that some cultured sandfish escaped and wild sandfish entered the damaged pens; therefore, results are unreliable. A data logger placed in the sea-pen area recorded sea temperatures from June 2010 (a month after release) to January 2011.

## Potential feasibility for the Pacific

The results to date are promising but due to the small number of animals released, the results may not accurately predict outcomes of a larger-scale release (Purcell and Simutoga 2008; Bell et al. 2008a). The successful collaboration of a private sector business, government fisheries agency, non-governmental organisation (NGO), an educational institution and a community was critical to the outcomes of this project. Experience and lessons learned will be

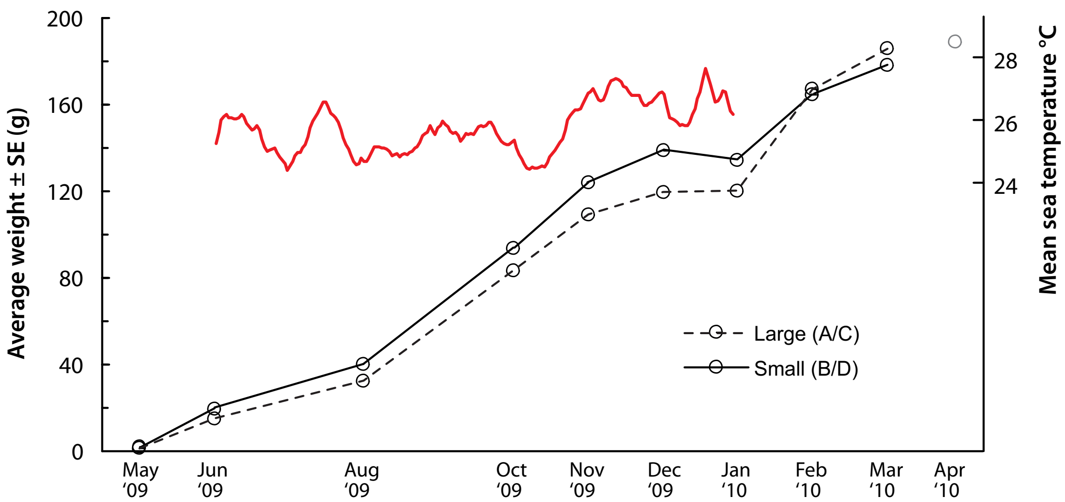


**Figure 12.** Eleven months of growth data for hatchery-produced sandfish (in the sea) at Natuvu (large sandfish from pens A and C combined, and small sandfish from pens B and D combined). March and April 2010 are sub-samples of the sandfish recorded after Cyclone Tomas and data are to be treated with caution. Red line shows average sea temperature in the sea pens between June 2009 and January 2010.

applied in follow-on work to produce more juveniles and conduct a large-scale release. We hope to be able to expand these results to produce real figures on the feasibility of the activity in Fiji and other PICTs.

Meanwhile, most PICTs have expressed concern regarding overfishing (Kinch et al. 2008) and hatchery intervention is seen as a way to ameliorate this situation. Bell et al. (2008a) define and discuss the various ways that hatchery-produced sea cucumber juveniles can be used to help restore fisheries: "Restocking" is the release of sandfish into a restricted area and protecting them as a future spawning population; "stock enhancement" is the release of cultured juveniles into wild populations to augment the natural supply of juveniles and boost harvests; "sea ranching" is the release of cultured juveniles into unenclosed marine environments for harvest at a larger size in "put, grow and take" operations (where released animals are not expected to contribute to future spawning biomass). The expected benefits from sea ranching will be compromised if effective resource management is not in place and the economic return to investors (i.e. the community) does not cover production costs. As yet, we do not know the break-even cost for hatchery production of sandfish in PICTs. However, as pointed out by SPC (2009), hatchery intervention is not the only way to restore depleted fisheries or produce more sea cucumbers (Bell et al 2008b; Friedman et al. 2008). There should be a proper investigation into the best and most cost-effective options for each PICT. Ideally, releases of cultured juveniles should add value to other forms of management (Bell et al. 2008a; Purcell 2010).

Nonetheless, restocking and sea ranching are an option for PICTs, and perhaps one of the best ways to apply the technology is through the release of juveniles into protected areas. There is a history of restocking in some PICTs, where clams have been restocked in marine protected areas or MPAs (these zones may be known by other names, such as special management areas in Tonga, and *tabu* or no-take zones in Fiji). The success of these zones in replenishing overfished populations varies (see references in Tisdell 1992; Gillett 2009). Fisheries agencies and NGOs (e.g. FLMMA) have encouraged communities to set aside no-take fishing areas in order to reduce fishing pressure and conserve marine resources. No-take zones have proven to be an acceptable management measure in the region. Benefits to stakeholders can result from "spillover" of animals from no-take zones into nearby areas that are open to fishing, and increased larval supply from protected broodstock. This second factor is likely to be particularly effective for sandfish by providing a refuge for a largely sedentary animal and promoting maintenance of a large (hence more effective) spawning biomass to increase recruitment outside the MPA. The approach was successful in the Philippines for a sea urchin species (Juinio-Meñez et al. 2008) and a network of MPAs was recommended to enhance larval exchange. Sea ranching, on the other hand, is a popular option due to the immediate need for income-generating activities, particularly in places where stocks have been depleted to a level where a vital livelihood has been lost.

Prior to the start of this study, the Natuvuan chief and community placed a temporary ban on harvesting sandfish throughout their *qoliqoli*. Later, part of the *qoliqoli* was officially declared a no-take zone (Fig. 13), a move supported and ratified by Fiji Department of Fisheries. It is interesting to note

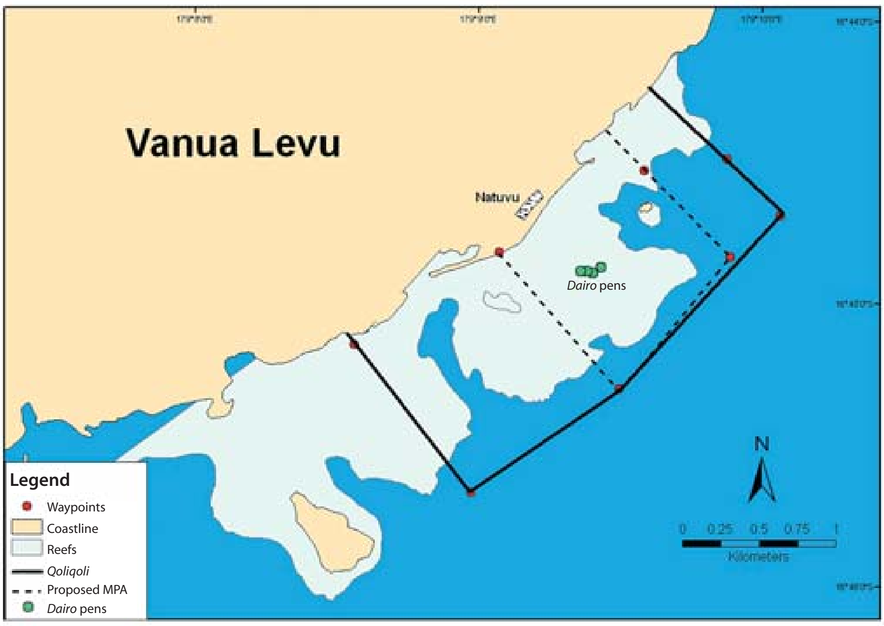


**Figure 13.**
Natuvu village, showing the extent of the *qoliqoli* (solid line) and the MPA within it (broken line). Green dots within the MPA denote sandfish sea pens.

that sandfish broodstock collected from the Natuvu *qoliqoli* showed an increase in average weight during the project — from 320 g in November 2008 to 450 g in March 2010 — possibly due to these fishing restrictions. According to the village chief, there were also noticeably more and larger sandfish and other sea cucumber species in the MPA area (Fig 14). Spawning of hatchery-produced sandfish was observed in November 2009 and March 2010 (Fig. 14), suggesting that ranched sandfish may contribute to future stock biomass, although there is yet no evidence of successful fertilisation and larval dispersal. Locals report that other valuable sea cucumber species have increased in number and size within the MPA (Fig. 14).

There is limited enforcement capacity in many PICTs but customary marine tenure enables communities to exercise some form of control and sustainable management in their areas of jurisdiction. Local ownership can promote good management of the fishery; community surveillance can reduce poaching and overfishing, allow sandfish to reach A-grade size before harvest and enforce the no-take areas.

Finally, if investment is made in sandfish sea ranching, it is imperative to improve processing and marketing in order to obtain maximum income for the final product, beche-de-mer (Ram et al. 2010; Purcell 2010). This will provide the most benefit at the grassroots level to resource owners and will also offset the costs of juvenile production. The viability of this project rests on rewarding resource owners for the hardships involved in policing their *qoliqoli*, maintaining no-take zones, or delaying harvest until the sandfish reach a large size. If this benefit can be realised, it bodes well for the future of sea cucumber culture in the Pacific.

## Acknowledgements

The authors are very grateful to Sachin Deo (J. Hunter Pearls Ltd), the staff of the Fiji Department of Fisheries based in Savusavu, and the community of Natuvu Village for their valuable assistance.

**Figure 14.** Signs of a healthy ecosystem within the Natuvu MPA: a hatchery-produced sandfish spawning inside a sea pen in March 2010 (top left), size range of sandfish (bottom left) and commercial-sized curryfish (*Stichopus herrmanni*) (right).

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