Strategies for improving survivorship of hatchery-reared juvenile *Holothuria scabra* in community-managed sea cucumber farms

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Abstract

Community-based aquaculture of the sea cucumber *Holothuria scabra* offers a potentially profitable and ecologically sustainable complementary livelihood activity for coastal communities in the tropical Indo-Pacific region where the species is widespread. However, *H. scabra* aquaculture remains a relatively novel practice. Early efforts to farm the species as an alternative to fishing in coastal communities have commonly faced several practical challenges that have so far prevented the commercial success of the enterprise, such as unacceptably high levels of juvenile mortality during – and even more after – the transfer of juveniles from hatchery to sea pens. This study assesses the impact on survivorship of hatchery-reared juvenile *H. scabra* of a series of technical improvements to community-managed sea cucumber farming practices in southern Madagascar. The improvements included structural modifications to farming pens, better maintenance of the pens and active management regimes that included intensive culling of predatory crabs. The impacts of these improvements on the survival of *H. scabra* juveniles are analysed over three periods spanning pre- and post-implementation phases of these strategies. Results show that, prior to improvement, average juvenile survivorship three months after transfer from hatchery to sea pens was only 40.2%; a level too low to enable the farming system to cover its costs or reach profitability. The technical improvements and active management strategies introduced increased survivorship to 76.6%, a significant jump in productivity that is expected to have significant positive economic implications for the profitability of the enterprise in coastal communities. Our findings indicate that, within community-based farming settings, technical solutions must be coupled with active management to maximise the survivorship of juveniles in the first months of the farming cycle following transfer from the hatchery.

Keywords: alternate livelihoods, community-based management, marine conservation, sustainable development, natural resource dependence, overfishing, western Indian Ocean.

Introduction

Holothurian aquaculture research and practice have seen considerable progress in recent years, a development that has coincided with broad-scale collapse of many of the world's tropical coastal sea cucumber fisheries. With collection and export markets for beche-de-mer now reaching all but the remotest tropical marine environments (Price et al. 2010; Conand 2008), increased attention is being placed on holothurian farming as a means of cultivating this valuable fisheries resource. We present an overview of juvenile mortality reduction measures that have been integrated into a system of community-based holothurian aquaculture, and discuss the implications of these measures in the context of improving the productivity and profitability of this farming technique as a means of diversifying traditional coastal livelihoods.

Developments in holothurian aquaculture

Holothurian farming at a community level is not economically feasible in many parts of the developing world, as significant capital investment is required to establish the hatcheries that supply the farms with juveniles (Eriksson et al. 2011). However, Madagascar is a pioneer country in holothurian aquaculture with a research programme that started in 1999 (Jangoux et al. 2001), which led to the creation of a commercial hatchery, Madagascar Holothurie SA (MHSA) (Eeckhaut et al. 2008). The presence of this company and its will to support local communities offer a promising opportunity to develop grow-out of *H. scabra* as an innovative economic activity for coastal villages (Eeckhaut et al. 2008; Robinson and Pascal 2009). The availability of *H. scabra* locally solves the need for the communities to invest in a hatchery that requires a considerable

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technical knowhow. Once the source of juveniles is secured, holothurian farming (the grow-out of juveniles in sea pens in natural lagoon habitat) requires an acceptable initial investment, no feeding or nutrient input, and little supervision from farmers other than in safeguarding stocks from environmental disturbances, predation and poaching.

Since 2007, sea pen-based grow-out of hatchery-reared sandfish (*Holothuria scabra*) has been trialled as an alternative livelihood strategy for fishing villages along the coast, including the Velondriake locally-managed marine area (LMMA), a 800 km^2 community-managed marine conservation area (http://www.velondriake.org). Velondriake's holothurian aquaculture model is based on a public-private partnership in which juvenile sandfish are sold to community farming groups at an average size of 15 g by MHSA, which is based in the city of Toliara, approximately 200 km south of Velondriake (Fig. 1) (Eeckhaut et al. 2008). Community groups purchase juveniles from MHSA at a price subsidised by project donors, and are responsible for growing the juveniles to market size (minimum of 350 g). Market-ready adults are then sold back to MHSA for processing and export (Robinson and Pascal 2009).

Communities in southwest Madagascar belong mainly to the Vezo ethnic group, and are almost entirely dependent on seafood protein for food security and income. The Vezo are also amongst the poorest and most economically marginalised people in Madagascar, itself one of the world's poorest countries (World Bank 2011). Recent surveys show mean household income in Velondriake to be , or USD 1.43 PPP (USD 0.83) per person per day, with small-scale fisheries employing 87% of the population; generating 82.4% of the incomes and providing 99% of the protein source (Barnes-Mauthe et al. in review). Declining fisheries caused by overexploitation and the widespread use of increasingly unselective and destructive fishing gear, coupled with rapid population growth throughout this region, have led to increased recognition of the need to diversify livelihoods beyond fishing dwindling wild stocks.

Holothurian farming offers an attractive economic opportunity for coastal communities with the high value of the product (approx. USD 3 per kg in the study region in southern Madagascar) compared to reef octopus, the primary source of fishery-derived income in this region,(approximately USD 0.6–1.0 per kg based on 2011 collection prices). Furthermore, the critical ecological niche of holothurians as detritivore "ecosystem engineers" (Coleman and Williams 2002; Wolkenhauer et al. 2010) may even provide positive environmental benefits from farming through recycling of organic material, particularly in locations where wild populations have been effectively extirpated through over-exploitation. For example, growth of seagrass is higher in areas with higher densities of the tropical sandfish *Holothuria scabra*, a ubiquitous but heavily exploited Indo-Pacific species whose high value results in heavy exploitation throughout the tropical and subtropical Indo-Pacific region (Battaglene 1999; James 2004; Hamel et al. 2001; Purcell and Kirby 2006; Purcell and Simetoga 2008; Wolkenhauer et al. 2010).

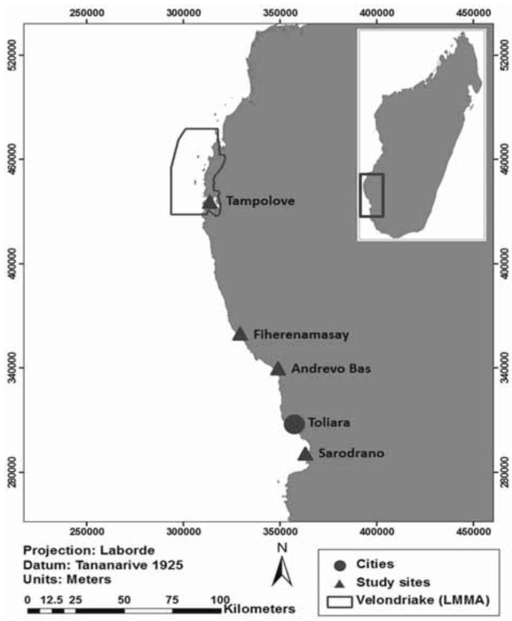

Figure 1. Map of the study area indicating farming sites (villages).

In recent years, considerable research has focused on developing technology for the large-scale hatchery and nursery production and release of *H. scabra*. Sea pens have been used in various stages of sandfish aquaculture, including broodstock holding, (Pitt 2001; Agudo 2006) to assess growth rates and survivorship of hatchery-reared juveniles and to model the effects of restocking overexploited populations (Purcell and Simetoga 2008). Drawing on research developments, a number of hatchery-reared holothurian mariculture initiatives have been established, as far afield as Asia, Southeast Asia, Australia, the Middle-East and the western Indian Ocean (Conand et al. 2004). Their objectives range from farming this valuable fishery resource as private sector ventures to establishing social enterprise initiatives that seek to diversify traditional livelihoods by developing holothurian aquaculture in coastal communities. In the latter case the concept of utilising sea pens for the grow-out of hatchery-reared sandfish juveniles to provide alternative livelihoods for coastal communities is relatively novel, and few studies have been published on this approach (Tsiresy et al. 2011; Robinson and Pascal 2009; Purcell 2010).

Although this aquaculture technique shows considerable promise as an alternative revenue source for Velondriake's Vezo communities, the income-generating potential of the initiative has not yet been realised, in large part because of the very high levels of mortality of juveniles in the period following transfer to community-run micro-farms (Tsiresy et al. 2011). An analysis of mortality rates across 42 pens in four villages during commencement of village-based *H. scabra* farming in Velondriake in the first quarter of 2009 (Robinson and Pascal 2009) showed mean mortality rates of 40.2% in the three months following transfer of juveniles from the MHSA hatchery to community sea pens.

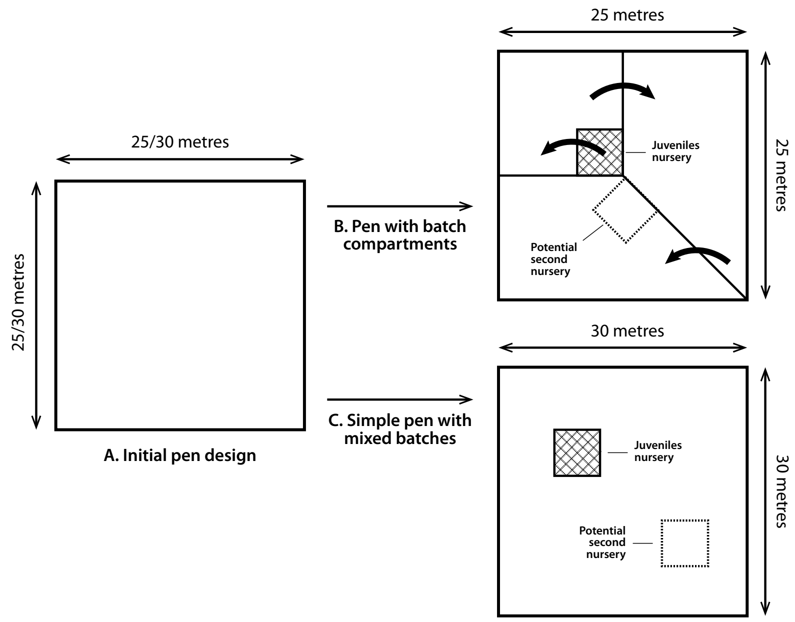

Figure 2. Schematic representation of the sea cucumber growing pens. A: Initial pens prior to improvement; B and C: Pens with a section for juvenile rearing.

Between November 2009 and February 2011, a number of technical improvements in farming and management were undertaken in the community-run holothurian aquaculture sites in order to reduce juvenile mortality in pens after transfer from the hatchery. In this study, we compare juvenile survivorship during the progressive introduction of these interventions, and discuss each intervention in turn with respect to its likely role in reducing juvenile mortality in sea pens. Our findings and recommendations are of relevance to the growing number of sea pen-based sea cucumber farming initiatives developing throughout the world's tropical and sub-tropical coastal regions.

Methods

The production model

Farming is carried out in sea pens, subtidal marine enclosures situated in suitable habitat for *H. scabra* (Fig. 2). These are shallow, sheltered areas with high levels of nutrients, including muddy substrata and seagrass beds (Tsiresy et al. 2011; Hamel et al. 2001; Agudo 2006). When identifying sites for *H. scabra* farming, site selection criteria include adequate sediment depth suitable for pen construction (at least 20 cm), close proximity to the chosen village in order to facilitate maintenance and surveillance of the pens, and a minimum water depth of 10 cm at spring low tide.

Each pen is designed to maximise growth rates by ensuring that the total biomass does not exceed the natural carrying capacity of habitats for *H. scabra*, believed to be 692 g m^{-2} for seagrass habitats near Toliara in southwest Madagascar (Lavitra 2008), which corresponds to about two adult individuals m^{-2} at commercial size.

The farming groups are mainly composed of household groups of between three and eight members, and there are also community groups, including local women's associations, youth clubs and even a local school, managed by teachers, pupils and their parents. Within each community, the pens and stocking regime have been designed to allow for multiple juvenile inputs throughout the year in order to spread both the risk of mortality and loss, as well as the anticipated financial returns.

To assess the improvement of the farming practices from the beginning of the village-based holothurian aquaculture (January 2009) until the end of this study (August 2011), the study period has been divided into three periods: period 1 being the initial situation for which survivorship was considered unacceptably low; period 2 corresponding to the introduction of the first series of juvenile mortality mitigation measures; and period 3 corresponding to a more active level of technical and managerial activities. Table 1 shows the number of farmers monitored during each of these periods.

Two stocking regimes, based around pens of 625 m^2 (Tampolove) and 900 m^2 (three other sites) with four deliveries per year of 195 to 900 juveniles were completed in period 1. In periods 2 and 3, there were deliveries of 300 and 450 juveniles to juvenile nurseries pens of 16 m^2 (Tampolove) and

25 m^2 (three other sites). For the duration of the project period, the villages received between 300 and 450 juveniles, depending on the size of the grow-out pens (between 625 m^2 and 900 m^2), either four or five times per year. Survivorship was evaluated three months after juvenile introductions throughout the project at the different sites of intervention. This three-month threshold is when juveniles reach a critical weight of approximately 50 g, after which they are considered to be markedly less vulnerable to predation (Pascal and Robinson 2011).

Table 1. Number of farmers in four villages (sites) during three periods representing the different maintenance levels.

Village/Site	Period 1	Period 2	Period 3
Andrevo	7	14	6
Fiherenamasay	5	2	0
Sarodrano	4	4	12
Tampolove	15	7	23

Mitigation measures of juvenile losses

The main focus of mortality reduction measures in periods 2 and 3 was the fight against predation – mainly from the swimming crab, *Thalamita crenata*, as well as improvements to pen structure to prevent juveniles escaping from pens. The modifications introduced during period 2 were implemented on 23 pens in four villages (Table 2). Modifications focused on improving pen design and promoting more active management and monitoring of pens by community farming groups.

Improved pen design

Previous designs of sea pens in southwest Madagascar focused on the use of locally sourced materials such as small mesh fishing nets made of soft cotton. These were stretched using polyethylene ropes (4 mm diameter) that were attached to wooden or metallic stakes at approximately 1 m intervals. Within a few months of the pens being built, it became apparent that the soft cotton net was prone to wear and tear, and some of the mesh walls started to collapse after stormy weather. The material was also too flexible to allow proper cleaning and dislodgement of fouling organisms and debris. In addition, the net was not properly fixed to the bottom, allowing some individuals to escape the pens, thereby interfering with proper monitoring of survivorship and growth. Juveniles were also introduced directly into the large farming pens designed for adult sea cucumbers. These pens were too large for effective control of predation.

Improvements made in maintenance period 2 included introduction of rigid plastic mesh of the kind designed as a wind buffer for agriculture. A horizontal wooden frame attached at the seabed and buried in the sediment ensured that animals were unable to escape. The improved durability of this system was immediately noticeable, with sea pen fences remaining in place even during stormy sea conditions. With the integrity of the farming pens assured, farmers could focus on maintenance by making sure the fence mesh remained taught and securely tied to the stakes. Any broken attachment ropes were repaired as quickly as possible. Farmers also cleaned the mesh wall with brushes regularly to remove fouling organisms.

Reduction of juvenile holothurian predation

Juvenile predation by the swimming predatory crab, *Thalamita crenata*, is considered to be the single most important factor influencing the survivorship of farmed juvenile *H. scabra* in the study area, with a single adult crab able to kill up to one *H. scabra* juvenile below 50 g per day (Pascal and Robinson 2011). Improvements to maintenance included the culling of predatory crabs by farmers and aquaculture technicians. Initially, the culling was challenging due to the large size of the pens, and was less successful. Moreover, crab culling could be carried out only during low tide, so pens were open to predators most of the time.

Table 2. Summary of measures undertaken to improve farming techniques.

Limitations in original farming technique	Improvements to address problems
Pen fence was constructed of locally- sourced material of poor durability	Introduction of a rigid plastic mesh wall
Bottom of enclosures was not secure, leading to escape of juveniles, especially during rough weather	Wooden frames tied to the bottom of enclosures and buried in the sediment to stabilise pens, thereby preventing escape of juveniles
High level of juvenile mortality during the first deliveries, mainly from predation by crabs	Introduction of roofed nursery pens housing the juveniles during the first three months after delivery
Lack of maintenance of pens and poor management of crabs	Increased maintenance of pens, particularly before delivery, and intensified culling of crabs

This problem was addressed by placing juveniles in separate enclosures within the adult farming pens. Unlike the adult pens, the surface of these juvenile pens was covered with small mesh net in order to stop predatory crabs entering the juvenile pen from above (Tsiresy et al. 2011). Juveniles were kept in these smaller covered pens (Fig. 2) for three months before transfer to the large pens once they had reached the 50 g threshold size.

The juvenile pens were 16 m^2 (Tampolove) and 25 m^2 (three other sites) and covered approximately 2.5% of the adult pen area, with the remaining area used as a grow-out pen. Each adult cohort was placed in a different compartment of the main pen to allow monitoring of survivorship and weight changes of each cohort separately. The process of transferring each cohort from the juvenile pen into the grow-out pen three to four months after input ensured that the critical stocking biomass of 692 g m^{-2} would not be exceeded in the juvenile or grow-out areas of each pen (Lavitra 2008).

Active management and monitoring

In order to further improve juvenile survival and to optimise the efficiency of the juvenile pens, project staff established farming best practices as part of the training process for farming teams (maintenance period 3). This active and better management introduced in period 3 is aimed at reducing "nursery effect" (Tsiresy et al. 2011), where farmers become over-reliant on technical improvements introduced in our case in period 2 and tend to be more neglectful, resulting in reduce effort in crab culling. Under the supervision of the project technicians, the farming teams were required to spend two to four days during each spring low tide clearing the juvenile pens of crabs before each juvenile delivery. This focus on crab culling within the juvenile pens ensures a predator free environment for the juveniles during the critical first three-month period. Thus, since 2010, crab culling in both juvenile and adult pens has continued during each spring tide, and is coupled with careful maintenance and reparation of the juvenile pens and their covering nets to prevent the entry of crabs. Supervision by project technicians ensured optimal implementation of the above measures and raised awareness among farmers of the importance of maintaining a rigorous maintenance regime.

Transport

The furthest site from the hatchery (Tampolove) is located 200 km from the city of Toliara, over eight hours' drive in an off-road 4x4 vehicle. This distance represents a considerable logistical challenge for farmers. Initial trials of transferring juveniles by sea in speed boats, with fresh seawater pumped through holding tanks during transit, showed very irregular results; on some trips, significant proportions of juveniles were eviscerated or died (up to 10.6% of juveniles arrived dead or eviscerated on the farming site in December 2009, Blue Ventures Conservation unpublished data), probably on account of the high degree of physical agitation experienced during the boat transfer.

Since March 2010, the transfer process has been drastically improved with the introduction of a new procedure, in which groups of 50 to 60 individual juveniles are packed in strong plastic bags designed for the transport of aquarium fish. These are filled with approximately four litres of seawater and pressurised with air. The bags are secured and transported in a vehicle, and care is taken to minimise shock during the road transfer. Delivery is made only during spring low tide, when farmers are able to walk easily to the farm pens, and the juveniles are released immediately after arrival at farming sites. With this procedure, the number of losses due to transportation has become insignificant (fewer than ten individuals per 20,000 juveniles delivered). This mortality level is not significantly different across all the sites, whether near the hatchery or far away.

Data analysis

Comparisons of survival of juveniles over three months after their introduction to the pens were made between each of the three periods. We also compared differences between villages within each period. In some villages, more than one delivery was made for the same maintenance period; and between cohorts, comparisons were made in order to test if variation in survivorship was influenced by delivery and the latter had confounding effects on maintenance responses.

Survivorship was compared by considering a farming pen as a random variable. Because pens were distributed in the same area and delivery was made on the same day for a particular site, variations within a site would mainly be due to differences in maintenance efforts by individual farmer groups. Assumptions of parametric statistics were tested prior to statistical comparisons. Normality of data was tested using the Shapiro-Wilk Test and homogeneity of variance with Levene's Test. Because the data were not normally distributed (Shapiro-Wilk $W = 0.95$; $P = 0.0008$) and were not of homogeneous variance (Levene's $F = 5.75$; $P = 0.004$), Kruskal-Wallis ANOVA was used in the end, and pair-wise comparisons between sites for the same period and between periods for the same site were made with Mann-Whitney Chi-squared test.

Results and discussion

The study found significant variation in survivorship between maintenance regimes and among sites for a particular maintenance period (Fig. 3; Table 3). Overall, survivorship increased from an average of 40.2% in maintenance period 1 to 76.6% in period 3. By site, comparison revealed that the highest jump in survivorship – from 21.3% to 83% – was observed in Sarodrano between maintenance periods 2 and 3. In Fiherenamasay, where comparison was made between maintenance periods 1 and 2 only, there was no significant difference in survivorship (period 1: 53.8% ± 4.4%; period 2: 52.1% ± 7.0%; $\chi^2 = 0.15$; $P = 0.70$). The lowest difference was observed in Tampolove where survivorship increased by only 29.9% from an already relatively high value (46.3%) in period 1. There was a significant difference between periods 1 and 3 ($\chi^2 = 16.91$; $P = 0.0002$). Period 2 was not significantly different from either period 1 or period 3 ($P > 0.05$).

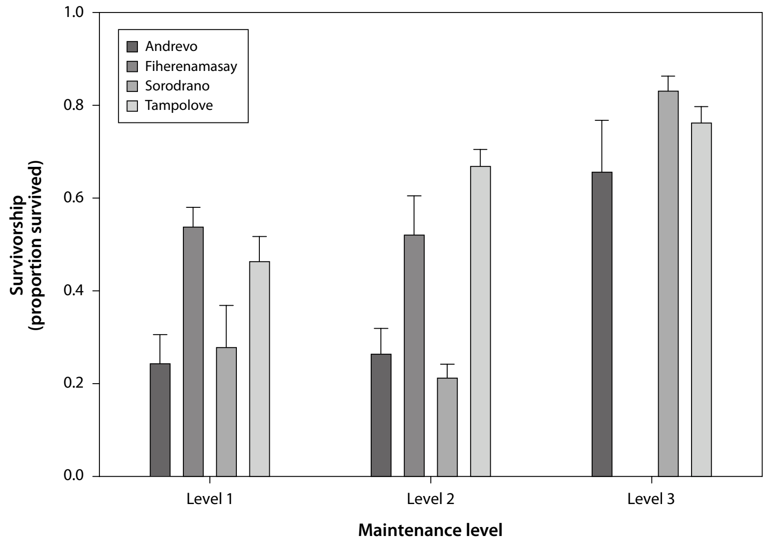

Figure 4. Within site and by maintenance level variation in survivorship.

By period, comparison showed that Fiherenamasay and Tampolove had higher survivorship values than Andrevo and Sarodrano in both periods 1 and 2. No significant difference in survivorship was observed for the three sites where data were available in period 3 (Fig. 4). Fiherenamasay, despite having one of the highest survivorships in periods 1 and 2, withdrew from the holothurian farming programme in period 3 and no comparisons could be made. Comparison between cohorts in the same period within a site showed no significant differences for all sites ($P \geq 0.5$).

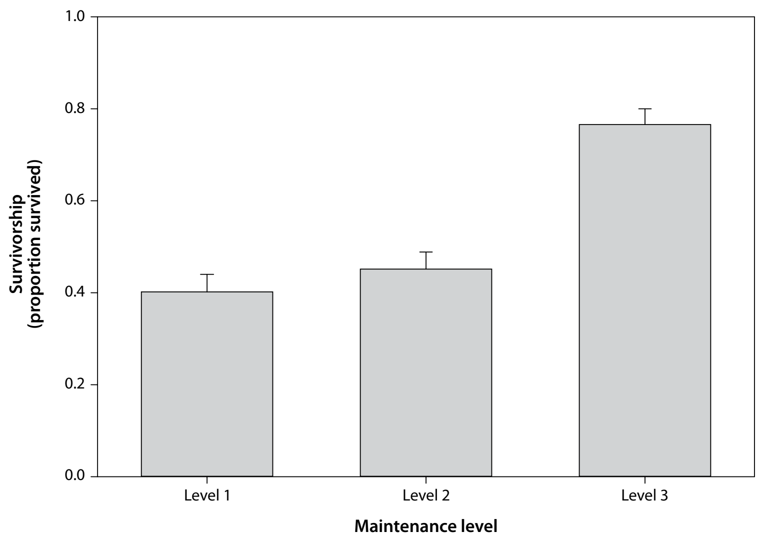

Figure 3. Variation in survivorship by maintenance level.

Table 3. Kruskal-Wallis one way comparison between maintenance periods for each village/site and all sites.

Village/Site	χ^2	*P*	Comparison
Andrevo	7.16	0.03	a, a, b
Fiherenamasay	0.15	0.7	a, a
Sarodrano	13.73	0.001	a, a, b
Tampolove	16.92	0.0002	a, ab, b
All sites	42.98	< 0.0001	a, a, b

The strong jump in average juvenile survivorship from 40.2% to 76.6% is expected to have profound practical and socio-economic implications for community-based holothurian aquaculture in southern Madagascar. The improvement was brought about by a combination of factors, including introduction of active management farming techniques and mitigation of disturbance and predation at a crucial growth stage of farmed *H. scabra*. The study underlines the need for a continuous effort in farm maintenance and control of predation by crabs.

Escape of juveniles to the outside and predation by the crab *Thalamita crenata* were the main causes of high mortality prior to the farming improvements. The replacement of the less stable and less durable cotton mesh fence by a strong plastic mesh that is able to withstand rough sea conditions, and the burial of the fence wall deeper into the sediment stops escape of juveniles to the outside. It is important to note that the new type of plastic mesh is increasing the cost of the fence from approximately USD 2.17 m^{-1} to USD 2.62 m^{-1}, introducing a minimal additional cost for a much longer durability (estimated between five and seven years as against one to two years maximum). The introduction of juvenile enclosures ensures close follow up of juveniles, which otherwise would scatter in a larger area, resulting in a higher source of error during counting and estimation of survivorship.

The small pens also help reduce predation by crabs in two ways. First, crab hunting by farmers and technicians becomes more efficient in smaller, more controllable pens. Secondly, the small mesh roofing in the juvenile pens ensures that entry of predatory crabs into the pens is limited.

In addition to the technical refinements, preparation of the juvenile pens two to three days before juvenile delivery was another important step taken in the farming technique. By closing openings, entry of crabs is reduced. Culling of existing crabs that could become trapped in the enclosures and grow, predominantly feeding on juvenile *H. scabra*, is another important step. At this acclimatisation stage from a hatchery to a farming environment, which also occurs after long transportation (up to eight hours), juveniles are probably most vulnerable to the effects of environmental stress, and predation by crabs would compound the vulnerability.

The lack of difference between maintenance periods 1 and 2 in all sites indicates that improvement of the farming technique through the introduction of roofed nursery pens for the first three months after delivery in itself is not enough to improve survivorship. The results are in agreement with previous findings that show the introduction of roofed juvenile pens is not a "silver bullet" in itself (Tsiresy et al. 2011), but a crucial step that promotes efficiency in minimising predation by crabs. The two sites with an already improved survivorship in periods 1 and 2, had either low natural density of crabs (Fiherenamasay) or maintenance in period 2 had already improved significantly (Tampolove) (unpublished data). Increased management in period 3 in Tampolove resulted in further increase in survivorship. Although no records were kept of the number of crabs culled in all pens and periods, there were instances when up to 150 crabs were killed by a single farmer in Tampolove on a single day (personal observation AR). Culling of crabs following transfer to large pens is less controlled, as maintenance efforts are highest during spring low tides and their effect is less actively controlled during periods between spring tides. However, animals in the growing pens would by then have reached the critical 50 g weight and would be less vulnerable to predation.

The *H. scabra* aquaculture is not a labour-intensive activity, and can be a promising complementary economic activity for the coastal population of southwest Madagascar. But, as described above, the technical solutions offered to maximise production cannot be the only solutions. Even with the reduction of the surface to check and clean, and the intensified physical barrier against crabs offered by the juvenile nurseries offering obvious advantages for the farmers, there is still a need to improve management of the farmed *H. scabra* at the juvenile stage. This study underlines the importance of preparation of farming pens before delivery, and continuous farm maintenance and control of predatory crabs post delivery. Holothurian farming in the region being still at a pioneer stage (Robinson and Pascal 2009), it is expected that it will take some time before continuous maintenance becomes a farming routine. Thorough supervision by trained technicians is required until the economic benefits are fully realised.

The increased survivorship will also mean increased density of large individuals. Based on observation of unexploited wild holothurian populations, a stocking density of 250 g m^{-2} has been recommended for holothurian farms (Battaglene 1999; Purcell and Simetoga 2008). This amounts to less than one individual per m^2, and assuming 100% survivorship is achieved, the density in the pens in this study would be more than two times this value (~ 2 individuals m^{-2}; Lavitra 2008). This value is based on growth study of *H. scabra* in the Toliara area of southwest Madagascar. The large difference between the two optimal density estimates indicates the need for further investigation of sediment type, nutrient content and turnover to sustain long-term holothurian farming.

The community-based holothurian aquaculture aims to provide a complementary source of income for the coastal populations of southwestern Madagascar that are highly dependent on fishing. The project's target is a minimal additional net income of USD 60 $month^{-1}$ per farming group after covering the operational cost of the farm. This would also necessitate achieving financial independence from the current funders and supporting non-governmental organisations. In order for the activity to reach this level of sustainability, and at the current cost of the farming materials and the current price for a farmed adult *H. scabra*, at least 60% of all introduced juveniles must make it to market. The new survivorship values associated with technical improvements and active maintenance exceed this value by a significant margin.

The increased income and socio-economic benefits are also expected to result in increased maintenance efforts by existing farmers and increased interest and buy-in from community members in villages supported by the project. For example, improved survivorship and increased income in the village of Tampolove has resulted in an increased number of farms, including a school farm. With "many hands" involved, the school farm is one of the best maintained, and recorded one of the highest juvenile survivorships during the most recent surveys. Involvement of the school in farming also has significant implications in terms of transfer of skills and knowledge to future generations, and in promoting development and conservation in an area with one of the world's highest poverty levels, as well as extremely high dependence on coastal ecological resources for subsistence and income.

One of the main management challenges in southwest Madagascar has been theft of market-size animals. The farmers have tackled this problem by introducing a rotation system of night guarding, involving all members. This initiative has been supported by building a watchtower to facilitate nightly surveillance. Challenges to meeting increased demand and interest from community members include the limited habitat space available to accommodate new farmers. In addition, a shortage in funding limits the extent to which the project can be expanded during this early 'pre-profit' stage.

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