An assessment of *Holothuria scabra* growth in marine micro-farms in southwestern Madagascar

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Abstract

This article presents and compares the results of some initial *Holothuria scabra* rearing cycles in three villages on the southwestern coast of Madagascar. Growth and survival rates differ between these three pilot sites. Survival rates are very low in two of the three villages, although very fast growth is recorded for holothurians at these locations. In the third village, the situation is reversed: the survival rate is higher but first-phase growth is very slow. *In situ* trials and sediment analysis have made it possible to identify a number of parameters that influence production. The main factors are the presence of crabs, which affect juvenile survival, and sediment structure, which has an impact on growth rates. As a result of these observations, some improvements in production techniques were shown to be effective, such as ploughing and crab control systems. The purpose of this article is to review the available knowledge on small-scale farming in the natural environment.

Introduction

In the Toliara region (southwestern Madagascar), sea cucumber harvesting continues to be a widespread traditional activity in coastal communities (Rasolofonirina and Conand 1998). From the 1990s onward, overharvesting has been characterised by declining quality and size in the products sent to market (Conand et al. 1998). In response to environmental and socioeconomic threats arising from the overharvesting of sea cucumbers, hatchery and culture projects are being launched in increasing numbers around the world. Pioneering work by Aqua-Lab on the reproduction and growth of captive *Holothuria scabra* (southwestern Malagasy coast) has opened the way for a second phase applied to rural development: the creation of micro-farms managed by families of traditional fishers. These traditional fishers are currently supported by two non-governmental organisations: Trans-Mad'Développement (TMD) and Blue Ventures (BV) (Robinson and Pascal 2009).

A year after the start of TMD's mariculture project, a technical supervisory team (and the holothurian culture groups it supports in the three coastal villages) provided an initial assessment of the problems they encountered. In particular, the only available information for selecting sites favourable for farming *Holothuria scabra* is incomplete, and relevant identification methods have yet to be defined. Sites near mangroves, with sandy and/or muddy bottoms partly colonised by algae, are considered to be conducive for culturing sandfish. Past experience, however, indicates that the criteria for identifying favourable sites and our understanding of the related factors require refinement.

Materials and methods

This assessment covers 17 farms — each 900 m^2 in area, which were supplied with 450 juveniles for the first culture cycle. The farms are located in three coastal villages: five in Sarodrano, seven in Andrevo and five in Fiherenamasay.

The methodology used to assess growth processes involves the practical application of rearing techniques by aquaculturists and project staff, and consideration of the results recorded during production monitoring activities. The study protocol, therefore, results from the various village aquaculture techniques and implementation stages and the monitoring methods used by technicians.

Supply of juveniles

Juveniles were supplied by Madagascar Holothurie Société Anonyme, a company operating in Toliara and Belaza, 25 km south of Toliara (Eeckhaut et al. 2008). *H. scabra* juveniles were transported by sea

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in plastic crates to Andrevo and Fiherenamasay (a 4–10 hour trip), and by canoes to Sarodrano (a 45-minute trip in a sheltered lagoon).

Because transport time in the north is considerably longer and rougher, transport-related stress is a significant factor for juveniles delivered to Andrevo and Fiherenamasay than for those sent to Sarodrano.

Grain-size analysis and determination of organic matter content

Analyses on grain size and organic matter content were carried out in order to characterise the various sediment structures at the three holothurian farming sites. Sediment samples were collected from each site and dried for 72 hours in an oven at 60°C. A sample of dry sediment was sieved and each fraction collected was weighed so as to establish its percentage of the original sample. To determine the organic matter content, the sediment was charred for four hours at 500°C.

Monitoring farm production

In order to monitor production trends at each site, holothurians were counted at night at low tide and then weighed. Depending on weather conditions, the results of these monitoring operations may have suffered from various kinds of biases. A number of different factors may, in fact, affect holothurian behaviour (e.g. burrowing) and the conditions that influence the detection of animals (e.g. visibility in the water, low tide level, light intensity depending on the moon and available light). In each operation, more than one-quarter of the specimens initially supplied were weighed in order to gauge weight gain (i.e. at least 113 specimens weighed each time out of the 450 initially delivered).

The physio-chemical parameters known to affect sea cucumber growth and survival were assessed monthly during production monitoring work. Seawater temperature and salinity were recorded monthly (alternating with a spring tide), during the day and at night. These two parameters did not significantly vary from one site to another during the initial culture cycle. Their influence was, therefore, not considered when interpreting the results presented in this article. Water salinity remained stable at 35‰ throughout the growth cycle at the three sites. Furthermore, temperature did not differ significantly between the three growth cycles considered in this study.

Targeted trials and identification of improved farming techniques

Controlling predation

We observed a significant decline in holothurian stocks during farming, mainly due to predation by crabs (Fig. 1). To control crab predation, crab traps — made of wire mesh with an entrance hole — and simple traps (plastic buckets with monofilament line attached to the rim, and bait in the middle) were installed. The farmers also regularly organised crab hunts.

Figure 1. A crab attacking a holothurian (Photo: G. Tsiresy, TMD, 2009)

Because of the crabs' constant presence in the pens, we looked for ways to physically prevent them from approaching the most vulnerable holothurians juveniles. One solution involved setting up 25-m² nurseries (totally enclosed and roofed mini-pens, Fig. 2) in which the newly delivered juveniles were left to grow for the first few weeks before being moved to the larger pen.

Figure 2. Nursery at Belaza, 20 km at south of Toliara, Madagascar (Photo: B. Pascal, TMD, 2009).

Improving farming techniques

Having observed a very slow growth rate at Fiherenamasay (0.23g day^{-1} of growth), we carried out some experiments to improve holothurian weight gain at this site. Six experimental 4-m^2 sections were constructed within the pens, each containing 50 small holothurians (< 40 g). In two sections, the sediment was ploughed; in another two sections the surface sediment layer was scraped off (5cm); and two sections were left unchanged (i.e. were controls).

After identifying the effects of ploughing on growth, it was decided to extend the ploughing system to cover the entire bottom area of the four pens at Fiherenamasay.

Data analysis

The ANOVA (two-factor) parametric analysis technique was used to compare observed means. The statistical analysis was done using SYSTAT 6.0.1, SPSS INC software.

Results and discussion

Sites offering highly variable aquacultural potential

After five months of growth, major differences could be observed between the three sites, although these differences were obvious from the first month onward, as shown in Figure 3. In terms of survival, differences were significant (Fig. 4). The mortality rate at one site was nearly 40% (Fiherenamasay) while the other sites were over 70% (Sarodrano and Andrevo).

Growth rates varied by a factor of 1 to 8, depending on the site: from 0.23g day^{-1} at Fiherenamasay (where holothurians grew the slowest) to 1.8g day^{-1} at Andrevo (where holothurians grew the most). Five months after seeding, juvenile weights differed significantly, again depending on the site — (2-factor ANOVA; $p = 0.001$) between Sarodrano and Fiherenamasay, and ($p < 0.001$) and between Andrevo and Fierenamasay. In contrast, no significant difference was recorded between Sarodrano and Andrevo ($p = 0.870$).

It should be noted that the curve steepens from about months three and four for the Fiherenamasay site due to a technical measure involving ploughing the site, first to a limited extent by technicians and later to a greater extent by farmers. With these improvements, the growth rate increased from 0.23g day^{-1} to almost 1g day^{-1}. The sediment structure, therefore, seems to have a major effect on growth.

Irrespective of these changes, growth rates were constant at the three sites throughout the farming process as long as the biomass limit was not reached. The differences observed, therefore, relate to growth rates, regardless of the critical biomass specific to each site. Indeed, the curve shows that the environment's maximum capacity is not reached at the three sites (45 g m^{-2} of farmed biomass) due to the low holothurian densities in the pens and their low mass. If the biomass threshold was reached (biomass estimated at 692 g m^{-2} at favourable sites in the region: Lavitra 2008), the curves would look asymptotic, showing a plateau, which would mean that the holothurians would have ceased growing. This is not the case at all and the curves remain linear.

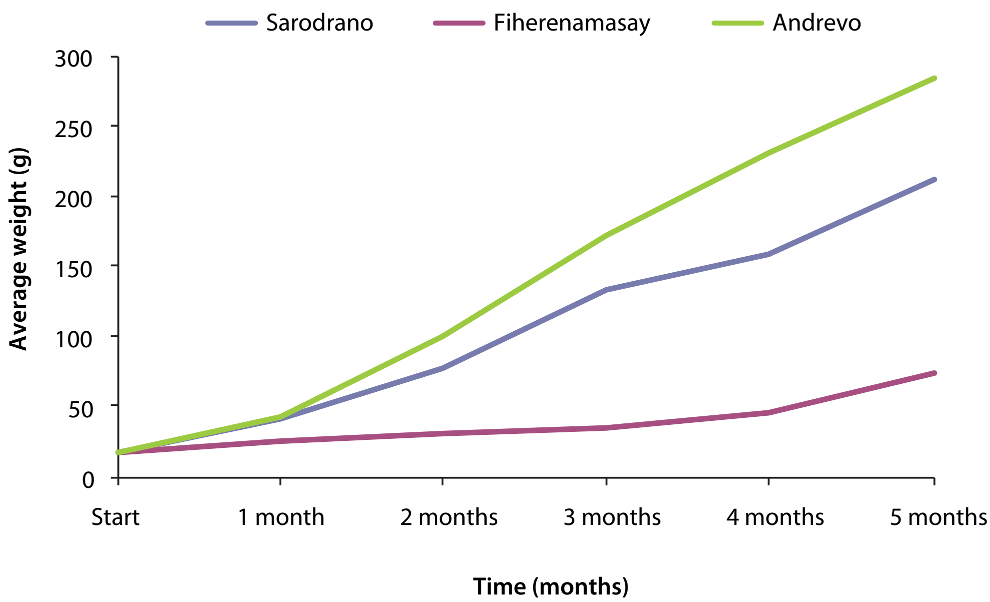

Figure 3. Observed growth rates by site.

Table 1. Sediment characteristics.*

Particle size (µm)	Sediment fraction	Sarodrano village		Andrevo village		Fiherenamasay village	
		Gran T0	Gran T4	Gran T0	Gran T4	Gran T0	Gran T4
> 1,000	Very coarse sand	13.93%	12.78%	17.40%	14.65%	24.27%	32.10%
500 to 1,000	Coarse sand	11.92%	13.83%	34.55%	35.82%	36.39%	25.15%
250 to 500	Medium sand	48.07%	36.26%	21.67%	22.16%	25.96%	20.13%
< 250	Fine sand	26.08%	37.12%	26.38%	27.37%	13.70%	22.61%
State of the surface sediment layer		Loose		Loose		Compact	
Organic matter content T0		Min 1.44% Max 1.90%		Min 1.41% Max 1.80%		Min 2.74% Max 2.93%	
Organic matter content T4		Min 2.32% Max 2.68%		Min 1.83% Max 2.18%		Min 2.88% Max3.11%	
Growth rate		1.3 g d^{-1}		1.8 g d^{-1}		0.23 g d^{-1}	

* Grain size profile and sediment organic matter content at the three sites.
Gran = granulometry; T0 = date farming began; T4 = after 4 months of farming.

A subtle combination of factors governing growth mechanisms

What emerges when interpreting the results given in Table 1 is that the amount of organic matter present in the sediment is not an adequate criterion for explaining differing growth rates. While Fiherenamasay shows an organic matter content higher than Sarodrano or Andrevo, growth rates at that site are at least five times slower.

These characteristics point to two types of environment at the three sites. Andrevo and Sarodrano have very loose sediment and high growth rates, while Fiherenamasay has compact sediment (for the surface layer), with a relatively high organic matter content and slow growth.

Research on *H. scabra's* feeding habits has shown that when sediment was ingested, this species was not selective with regard to sediment particles smaller than 2mm (Lavitra 2008). Similarities between the Sarodrano and Andrevo sites in terms of sedimentary structures, however (small proportion of particles larger than 1 mm), and growth rates, and the differences with the Fiherenamasay site, suggest that sediment grain size structure and compactness play a role in growth rates.

Thus, it is legitimate to theorise that, where growth rates (and not critical biomass) are concerned, an environment offering high organic matter content with a grain size structure dominated by coarse particles (even under 2 mm) will be less favourable than a location with a finer particle size but with a low organic matter content. Grain size features could, therefore, be a key factor in understanding growth rates.

In order to consolidate this reasoning, an understanding of organic matter composition and the abundance of its component living micro-organisms would be needed, and this could potentially vary from site to site; the organic matter at Andrevo and Sarodrano may be better suited to the nutritional requirements of *H. scabra.* The experiment carried out at Fiherenamasay supports our theory, however, because ploughing the sediment speeds up the growth rate of cultured sea cucumbers. Modifying the sediment structure has, therefore, produced very similar growth rates as at the two other sites. The sediment ploughing process produces a looser form of sediment that contains a larger proportion of large particles (32.10%) and very small (22.61%) particles, with few medium-sized ones. Skimming off the surface layer reveals a muddier, more powdery sediment. It could be that the truly determining factor is sediment structure (grain size and compactness) because of its indirect action on the associated organic matter.

While the quantity of organic matter present in the sediment is a determining factor in explaining threshold biomass, it appears that sediment structure regulates organic matter content accessibility and, therefore, drives growth rates. The types of organic matter should also be taken into consideration. Growth rate and threshold biomass can be completely independent of each other.

Early mortality

From these initial results, it can be seen that the Andrevo and Sarodrano sites are far more favourable for farming *H. scabra* than Fiherenamasay in terms of growth rates. Farming cycles can be shorter at theses two locations. However, from the point of

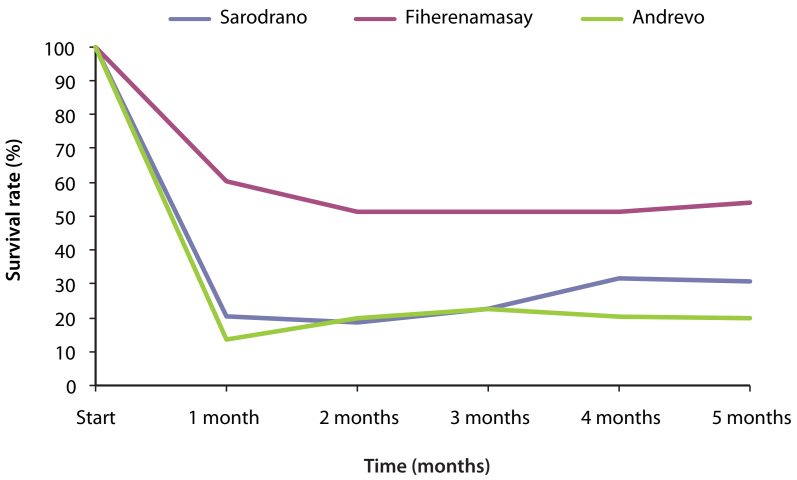

Figure 4. Survival rate by site (estimated from night censuses).

view of aquacultural development, these two sites both have the same drawback: early mortality in farmed holothurians (Fig. 4).

The three curves in Figure 4 show survival rates at the farms, and all indicate that 30 days after seeding, many juveniles die off. The shape of the curves (Fig. 4) shows that mortality occurs during the early weeks of rearing.

It can be noted that survival rates fall rapidly by between 10% and 30% in the villages of Sarodrano and Andrevo compared with 60% for Fiherenamasay. At the fifth month of rearing, the survival rates obtained in the three villages are: 30.71% at Sarodrano, 53.82% at Fiherenamasay and 20% at Andrevo. Stocks do not, therefore, seem to sustain any significant losses after the first month.

Predation: A compelling theory

Three main reasons may explain these poor survival rates: predation, disappearance (due to tidal currents or by juveniles escaping over the top of the fence) or theft.

The theft theory can be discounted immediately. First, cultured holothurians only acquire commercial value above about 100 g in weight, meaning not before the third month of growth. While end-of-cycle losses may be due to theft, first-month losses cannot be ascribed to thieves, who would try and sell the juveniles on the local market. Had these juveniles been stolen by other farmers for further growing, our monitoring work would have revealed a suspicious increase in the pens of thieves, which has not been the case.

Although it offers some probability, the explanation that holothurians disappear from the pens under the effect of marine currents does not (for now) seem sufficiently convincing. It is true that tidal currents can be quite strong in the rearing zones. Farmers say that they have observed young holothurians floating in and being carried away by currents. The close-interval monitoring we carried out after deliveries, however, has always shown that holothurians do not move very far away from their initial settlement location in the pen. Juvenile scattering toward the fence, due to currents, has never been observed, and juveniles have never been found outside the fence when checks were made.

The disappearance of juveniles because of predation emerges as the most plausible hypothesis. In the natural environment, newly stocked juveniles are frequently attacked and eaten by various fish species (Hamel et al. 2001; Pitt and Duy 2004) and crabs (Pitt and Duy 2004; Lavitra 2008). When the first deliveries were made at night, we observed crabs attacking juveniles in under 10 minutes (Figs. 5a et 5b). Other specimens were sometimes found with tegument wounds, and some remains were found during checks (Fig. 5b). The most surprising discovery was the extraordinarily high level of predation, with the entire stock (450 juveniles) in some pens disappearing in the space of two weeks.

Figure 5. a: Young holothurian after predation; **b:** Holothurian remains found in a pen (Photos: G. Tsiresy, TMD, 2009).

Nursery effect

During the second rearing cycle at Sarodrano and Andrevo — which suffer the greatest losses of juveniles — the introduction of nurseries (smaller pens covered with netting where juveniles were placed) made it possible to significantly restrict losses in the first month. The idea behind these nurseries was to physically prevent crabs from approaching juveniles during the first weeks of growth in the sea.

With this new system, 15 days after stocking, the observed survival rates were 79% for Sarodrano and 70% for Andrevo. Nurseries, therefore, produce better survival rates. Unfortunately, these positive results have led farmers to neglect crab culling, both in nurseries and in the rest of the pens, and losses after the first few days were colossal. Some 35 days after delivery, the survival rate had dropped to 33% at Andrevo, equating to a loss of 37% of stocks in 20 days in comparison with the first count. After 70 days, the survival rate had dropped to 51% at Sarodrano although it was still 79% after 15 days in the sea and76% after 35 days in the sea.

This new system seems to have no effect on juvenile growth if the stocking density is suitable for the specific biomass of each site.

Conclusion

These initial results clearly reveal the importance of certain factors in production dynamics. Excessive mortality at some sites is a major obstacle to the economic viability of the aquaculture ventures. Unless an effective counter-measure can be found, the sites where crabs occur in abundance will probably not be suitable for profitable farms. Depending on the relevant issues, technical solutions such as nurseries or sediment ploughing can be found and provide worthwhile results but will always be insufficient without close supervision by farmers of their stock.

Our results are best applied to growth mechanisms, and suggest that sediment structure is just as important for growth as high organic matter content. In order to refine the scope of these results, growth tests should be carried out in a range of sediments to validate the effect of grain size features and the role of organic matter in growth mechanisms. The composition of organic matter should also be taken into consideration so as to improve our understanding of growth mechanisms of *H. scabra*. One question remains key to a reliable future for farming: Does the consumption of organic matter over successive rearing cycles reduce the resilience of the environment? If it does, would this mean that the critical biomass threshold shrinks during farming, and that fallow systems would probably have to be brought in to avoid impoverishing the sedimentary bottom soils?

These few results show that site selection and the characterisation of their particularities enable rearing techniques to be adapted and failures to be avoided. A site offering rapid growth will not necessarily have a high critical biomass (stocking capacity) and, conversely, a slow-growth environment may potentially offer a high stocking capacity. This aspect implies that production models will vary between sites in terms of techniques (e.g. ploughing, nurseries) but also in terms of rearing densities and juvenile delivery frequency. For this purpose, there would be merit in developing a farming site classification guide. A technical protocol would have to be drafted for each type of environment so that optimum husbandry practices can be used. The availability of such a guide would make the work of field support operators much easier and help promote holothurian farming much more successfully.

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