Ocean nursery systems for scaling up juvenile sandfish (*Holothuria scabra*) production: ensuring opportunities for small fishers

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Abstract

Cost-effective production of juveniles to release size (>3 g) is a primary objective in the culture of *Holothuria scabra*. Ocean nursery systems were developed to help overcome the space limitations of a small hatchery set-up and shorten the rearing period in the hatchery. The growth and survival of first-stage juveniles (4–10 mm) in two ocean nursery systems—floating hapas and bottom-set hapa cages—were compared with those reared in hapa nets in a marine pond. Juveniles reared in these nursery systems were healthy and in good condition. Survival was not substantially different in hapa nets in marine ponds and floating hapas. However, growth in pond hapa nets was higher than in the two ocean nursery systems. Nonetheless, the estimated cost of producing juveniles in the floating hapa system is considerably cheaper compared with those reared in the other systems. Moreover, local community partners easily maintained the floating hapas and reared the juveniles to release size. Further, the effects of sand conditioning on juvenile quality were also investigated. The growth of sand-conditioned juveniles was higher than unconditioned ones in hatchery tanks, and more conditioned juveniles buried within the first hour of release in the field. From floating hapas, juveniles can be conditioned in sea pens for at least 1 week, or reared to bigger sizes for 1–2 months (>20 g) prior to release. However, whether this intermediate rearing procedure will be practical with large numbers of juveniles needs to be considered. Results show that ocean nursery systems are simple and viable alternative systems for scaling up juvenile sandfish production compared with hapas in marine ponds, which might not be available and accessible to small fishers.

Introduction

The sea cucumber fishery is a source of livelihood to many coastal dwellers and the basis of a multi-million dollar trepang industry in the Philippines (Gamboa et al. 2004). Various coastal towns, cities and provinces all over the country have been reported to engage in significant sea cucumber collection and processing activities (e.g. Trinidad-Roa 1987). Intense harvesting, unsustainable fishery practices and increasing demand for sea cucumber products in international trade have resulted in a progressive decline in sea cucumber stocks and the overexploitation of high-value species.

With the decline in the sea cucumber stocks, restocking hatchery-produced juvenile sea cucumbers is seen as a means to rebuild wild stocks (Battaglene 1999). At present, *Holothuria scabra* is the only species of tropical sea cucumber that can be mass cultured in the hatchery (see references in Lovatelli et al. (2004)).

The culture technology for sandfish was initially developed in India (James 1999, 2004) and then in Solomon Islands (Battaglene 1999). Culture protocols were further refined in New Caledonia (Agudo 2006) and Vietnam (Pitt and Duy 2004; Duy 2010).

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In the Philippines, experimental-scale trials of sandfish culture were initiated in 2000 (Gamboa and Juinio-Meñez 2003), and efforts to scale up juvenile production and expand community-based sea-ranching activities are ongoing. Hatchery culture protocols based on various methods reported from other hatcheries were modified and adapted to optimise larval and early juvenile rearing at the University of the Philippines Marine Science Institute's (UPMSI) Bolinao Marine Laboratory (BML). However, the costs of producing juveniles in the hatchery and marine ponds were high. Scaling up production was further constrained by space limitations in a small hatchery set-up. Given these considerations, ocean nursery systems designed to shorten the juvenile rearing period in the hatchery and reduce the cost of production were investigated. In addition, since production of juveniles is intended primarily for community-managed sea ranching, mechanisms to engage local partners in early juvenile rearing were deemed to be strategic in enhancing ownership of these initiatives.

Hatchery culture of *H. scabra* at the UPMSI Bolinao Marine Laboratory

The current techniques used for broodstock spawning and rearing juvenile sandfish are described here. For each spawning induction, 40–50 wild broodstock (>200 g) are acquired from fishers, and are maintained in sea pens near the hatchery facility or in concrete tanks in the hatchery for 2–4 weeks prior to spawning induction. Broodstock are successfully induced to spawn within 3–4 days using a combined treatment of desiccation, thermal shock and food shock (*Spirulina*) (Agudo 2006) at any time of the year.

The developing larvae are reared in larval tanks with moderate aeration and shading at a stocking density of 0.3–0.5 fertilised egg/mL. Larvae are cultured in static conditions with daily partial water change (30–50%) using UV-treated sea water (UVSW). A mixture of *Isochrysis galbana* and *Chaetoceros calcitrans* at a density of 10,000–15,000 cells/mL is fed to the larvae twice a day as they develop. Under optimal conditions (28–30 °C and 32–34 ppt), the auricularia larvae start to metamorphose to doliolaria stage by day 10. General cleaning of the tanks is done prior to introduction of *Spirulina*-coated settlement plates in the larval rearing tanks. The plates are introduced when >50% of the larvae have reached the pentactula stage, usually within 12 days of fertilisation. Both sides of the corrugated plastic settlement plates are coated with *Spirulina* paste (i.e. *Spirulina* powder dissolved in a small volume of fresh water) and air-dried for 30–60 minutes (Duy 2010). Before being placed in the larval-rearing tanks, settlement plates are soaked in tanks with flow-through UVSW for 30 minutes. The amount of *C. calcitrans* and *I. galbana* provided to the larvae twice a day is adjusted to 20,000–30,000 cells/mL when most larvae have settled by day 15. The diatom *Navicula ramossissima* and *Sargassum* extract are also provided as supplemental food for the post-settled juveniles.

This method resulted in a fivefold increase in survival from fertilised eggs to second-stage juveniles from year 1 to year 3 (Table 1). This is attributed to the low initial stocking density currently being used in the facility (0.3–0.5 fertilised egg/mL), the use of *Spirulina*-coated plates to induce settlement, and the extended use of *C. calcitrans* combined with *N. ramossissima* to feed the newly settled juveniles. Periodically, *Sargassum* extract was also provided as supplemental food. Survival from first-stage to second-stage also improved by 95% by year 3. Increase in the number of second-stage and release-size juveniles was largely due to the development of ocean nursery systems in Bolinao, which addressed the problem of slow growth and low survival due to limitation in hatchery space (i.e. high density stocking in tanks) as described below. As a result, fewer batches of larvae had to be reared per year, significantly reducing time and effort in the hatchery operations.

Ocean nursery systems

In the first year of production, early juveniles were reared to a release size of >3 g in the land-based hatchery tanks. Rearing to release size in the hatchery involved growing post-settled juveniles in settlement tanks with benthic diatoms and supplementing with *Sargassum* extract up to 90 days until the juveniles reached ~1.0 g. The juveniles were then transferred to tanks with sediment and sand-filtered sea water. Daily feeding of diatoms and periodic addition of ground *Sargassum* enriched the sediment in the tanks. Both growth rate and survival were low due to difficulties in producing sufficient benthic diatoms and maintaining good water quality in the tanks with

Table 1. Juvenile production in the Bolinao outdoor hatchery facility from May 2007 to April 2010

Spawning trial	Number of batches	Fertilised egg count (millions)	% survival to first stage (<10 mm)	% survival to second stage (10–30 mm)		Release-size juveniles (>30 mm)
				from fertilised egg	from first stage	
Year 1 (May 2007 – April 2008)	8	22.23	0.76	0.11	16.08	12,468
Year 2 (May 2008 – April 2009)	3	10.74	1.14	0.35	32.32	26,331
Year 3 (May 2009 – April 2010)	3	7.10	2.08	0.67	31.44	32,433
TOTAL	**14**					**71,232**

sediment, even with a flow-through system. After the study visit at the Research Institute for Aquaculture No. 3 (RIA3) in Nha Trang, Vietnam, in June 2008, most of the first-stage juveniles (4–10 mm) were reared in hapa nets in a marine pond following Vietnamese methods (Duy 2010). However, a suitable marine pond was about 100 km away from the BML hatchery—a travel time of ~2.5 hours. Thus, man-power resources and costs to transport juveniles were substantial. In addition, while survival was relatively high (60–73%), juvenile growth in the ponds was highly variable. Growth ranged from almost nil up to 6.1 g over 30 days. This variability was probably due to high temperatures (27–31 °C) and extreme fluctuations in salinity (13–29 ppt).

Ocean nursery systems to increase juvenile production and reduce production costs for first-stage juveniles were investigated (Juinio-Meñez et al. 2009). Bottom-set hapa cages, which were used to rear juveniles to >1.0 g during the experimental phase of sandfish culture in earlier trials, were modified to rear first-stage juveniles (4–10 mm). In addition, the use of floating hapas was pilot-tested. Initial trials conducted in high nutrient areas in northern Luzon showed that first-stage juveniles can grow up to ~1.0 g in 49 days in the floating hapas (Edullantes and Juinio-Meñez 2009). Subsequently, an experiment was conducted to compare growth and survival of first-stage juveniles in the three nursery systems—the hapa nets in ponds and the two ocean nursery systems (hapa cages and floating hapa nets). The same type of mesh was used for all set-ups. Stocking density relative to the estimated potential grazing area was 150 juveniles/m^2. The experiment ran for 30 days. Results showed that growth was higher in the hapa nets (0.6 g) in the pond than in the two ocean nursery systems, but average survival was higher in both the hapa net in the pond (57%) and the floating hapa (44%) compared with the bottom-set hapa sea cage (18%) (C. Edullantes, unpublished data). Furthermore, a 60-day juvenile rearing trial using the ocean floating hapa net with a partner community showed survival rates of 12–30%, with juveniles weighing 0.3–7.2 g.

Comparing the three early juvenile nursery systems (Table 2), the high growth and survival of juveniles and ease of retrieval are the advantages of using hapa nets in ponds compared with the other two nursery systems. The hapa cages are the most durable and least prone to extreme changes in salinity, temperature and dissolved oxygen, but they yielded the lowest growth and survival rates. However, while average growth can be lower in the ocean nursery systems, survival rates in the ocean floating hapas are comparable with those in the hapa nets in ponds. The total cost of inputs and maintenance is lowest in the ocean floating hapas and highest for pond hapas. In addition, it was also demonstrated that local community partners were able to maintain the floating hapas and rear the juveniles to release size. Considering all of these factors, the use of ocean floating hapas as a nursery system is the most cost-effective and strategic option for community-based grow-out and sea ranching.

Sand conditioning

Aside from scaling up juvenile production, improving the quality of released juveniles is crucial for successful sea ranching. Hatchery production of environmentally incompetent juveniles jeopardises restocking success (Battaglene and Bell 2004; Purcell

Table 2. Comparison of the different nursery systems (hapa nets in marine ponds, ocean floating hapas and bottom-set sea cages) using different criteria

Criteria	Nursery systems		
	Hapa nets in marine ponds	Ocean floating hapas	Ocean bottom-set cages
Growth	+++	++	++
Survivorship	+++	+++	++
Cost of materials and other inputs	+	+++	++
Maintenance	+	+++	++
Ease of retrieval	+++	++	+
Adaptability (small-scale fishers)	+	+++	++
Other considerations			
Durability of nursery units	++	+	+++
Changes in salinity, temperature, dissolved oxygen	+	++	+++

Rating: +++ = most desirable
++
+ = least desirable

2004; Oliver et al. 2008). In the hatchery, additional conditioning regimes introduce extra expense, but this might be offset by improvements in growth and survival. To improve the quality of juveniles and increase survival in the wild, it has been proposed that hatchery individuals be conditioned to optimise morphological and behavioural traits (Delgado et al. 2002; Davis et al. 2005; Brokordt et al. 2006). While juveniles can be reared to a size of ~3 g in hapa nets in both ponds and ocean nursery systems, they are not exposed to sediment, and graze primarily on biofilm on the nets. Preliminary studies at BML showed that juveniles that were reared in tanks with sediment had thicker body walls and grew faster than those reared in tanks without sediment (Schagerstrom 2003). Subsequent laboratory experiments showed that mean body weights of juveniles were substantially higher in the sand-conditioned treatment than those in treatments without sand. Moreover, up to 60% of juveniles in the sand-conditioned treatment attained a weight of more than 3 g in 30 days, compared with only 23% in the treatment without sand (Dumalan et al. 2009). After 45 days in sea cages, the average weight of sand-conditioned juveniles was higher but, because of the high variability in growth among individuals, it was not substantially different from the average weight of juveniles that were not sand-conditioned in the laboratory prior to release. The average survival rates of sand-conditioned and unconditioned juveniles were also not different. However, post-released juveniles that were not sand-conditioned took a longer time to bury into the sediment (R. Dumalan, unpublished data). This indicates that, even if juveniles can be reared in hapa nets to a release size of >3 g, sand conditioning prior to release may be necessary to improve their survival in the wild.

Proposed production scheme for juvenile sandfish for community-based grow-out

Based on the results of different experiments conducted in the hatchery and the field, as well as experience with local small fishers, production of sandfish from a small hatchery can be made cost-effective and accessible to small-scale fishers for community-based grow-out. The hatchery phase for larval rearing to post-settled stage (4–10 mm) will take 30–45 days. Post-settled juveniles can then be reared in ocean floating hapas (Figure 1) to a size of 2–3 g (25–30 mm) in 30–60 days. To condition juveniles with sediment and grow them to a bigger release size, the juveniles can be reared in bag nets or sea pens and retrieved after 15–30 days at sizes >20 g. This intermediate stage will substantially increase the survival of juveniles during the grow-out phase to marketable size. We recommend the release of these juveniles in suitable and well-managed sea-ranch areas. Based on experience in the pilot sea ranch, sandfish will attain sexual maturity within a year, and the first harvest of animals >320 g can be made after 1 year, with a subsequent harvest after

Figure 1. Ocean floating hapas within the communal sea-ranching site in Masinloc, Zambales

another 6 months. Programmed releases and selective harvesting of sandfish >320 g can maintain a viable reproductive population in the sea ranch, thus optimising both ecological and economic returns (M. Juinio-Meñez, unpublished data).

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