Review of sandfish breeding and rearing methods

Rayner Pitt[1]

Summary

*Sandfish (*Holothuria scabra*) are economically important warm-water sea cucumbers. Generally, a few collected animals are found to be ripe at most times, with one or two spawning peaks in the year. Spawning is most reliably stimulated by temperature changes, but at best only about one-third of large, freshly-collected animals can be induced. Larval rearing to settlement has repeatedly been achieved in earlier work using cultured phytoplankton,* Chaetoceros *spp,* Skeletonema *spp and* Isochrysis galbena. *More recently a schedule, feeding* Chaetoceros muelleri, Chaetoceros calcitrans *and* Rhodamonas salina, *at a rate increasing from 20,000 to 40,000 cells/ml 'muelleri-equivalent', has been used. Settlement is promoted by the use of conditioned plates and early nursery carried out using these plates in conditioned outdoor tanks, sometimes under partial shade. After reaching about 20 mm (1g) juveniles can be transferred onto fine sand for further nursery. Growth of juveniles (and adults) appears to depend largely on photosynthetic production of much of their food, even when prepared feeds are added, and drops at stocking levels above about 225 g/m². This may present a bottleneck in broodstock management and in large-scale nursery production for farming or restocking. The available data suggests that adult animals can grow at about 2 g/day.*

Introduction

Among the warm-water sea cucumbers, sandfish (*Holothuria scabra*) has attracted interest as a candidate species for breeding and farming, or as an overexploited species that could benefit from stock enhancement programs (Conand 1998a, 1998b). Sandfish are often found in lagoons or somewhat estuarine areas near mangroves or on seagrass beds, suggesting that they may tolerate a wider range of conditions (of salinity, temperature and eutrophication) than deep-water species. Their diet is believed to consist largely of benthic algae and bacteria associated with organic detritus, which they extract by ingesting and excreting large quantities of substrate. This leads to hopes that low-cost feeding regimes can be developed. Their liking for substrates of sand or sandy silt/mud means that they may also fit into pond or pen culture systems as benthos processors in polyculture. Because they are slow-moving animals living in shallow inshore waters, sandfish are easily overfished.

The dried product (beche-de-mer) produced from sandfish is of high-value, and often constitutes one of the most important exported species from fisheries in small island developing states. However the weight loss during processing of beche-de-mer is about 95% (Shelley 1985; Conand 1989, 1990; Preston 1990). Little is known about the environmental tolerances of sandfish (for growth rather than just survival) or their compatibility with other cultured species, and there is surprisingly little published data on growth rates and productivity.

Several groups have claimed success in sandfish breeding. These include the Central Marine Fisheries Research Institute, Cochin, India (James et al 1994; James 1996); Mariculture Development Centre, Lampung, Sumatra, Indonesia; Research Station for Coastal Fisheries, Gondol, Bali, Indonesia (Dr Ketut Sugama, pers. comm.); and ICLARM Coastal Aquaculture Centre (CAC), Guadalcanal, Solomon Islands (Battaglene and Seymour 1998; Battaglene et al 1999). Numerous others have looked at aspects of the ecology, behavior, gonadal maturity, processing and pond or pen culture of the species. The aim of this short review is to present an outline of these findings in a compact form which will be useful for those considering carrying out culture work on this species. A comprehensive review on all aspects of the biology of *Holothuria scabra* has been prepared by Hamel et al (in preparation, 2000).

Ripeness and fecundity

The sexes cannot be distinguished externally until the start of spawning. Gonosomatic Index (GSI) and spawning studies usually show that some animals are ripe at most times in the year, with one or two seasonal peaks usually reported.

Ong Che and Gomez (1985) in Batangas, Philippines, found spawning peaks in mid-year (June–July) with high sea temperatures, and at the end of the year (either December–January or October–November) with cooler water, and rapid ripening after spawning. Conand (1989, 1993) identified in New Caledonia, from morphological and gonad-index variations, a first well-marked peak from December to February, followed by a smaller more variable one between August and October. Tuwo (1999) in southwest Sulawesi, Indonesia

1   ICLARM - the World Fish Center c/o Research Institute for Aquaculture No. 3, 33 Dand Tat Street, Nha Trang, Vietnam [E-mail: iclarm@dng.vnn.vn]

found mature gonads throughout much of the year but in increasing numbers from June to October and from February to April. Krishnaswami and Krishnan (1966) report on two breeding periods in the Krusadi Islands, Gulf of Myanmar, India in July and October.

Morgan (1999) looked at a sandfish population in a subtropical area at latitude 27° South (Stradbroke Island, Queensland, Australia) and found a GSI peak in November. While gonads and oocytes were developing from June to December the bodywall lost weight. He was able to induce spawning in all animals, suggesting a more marked seasonal pattern in this region. However (Morgan 2000) broodstock held indoors generally lost condition and many died.

Battaglene et al (in review, 2000) working with batches of, on average 28 large animals (usually of at least 500 g each) freshly collected from the Vonavona lagoon, Western Province, Solomon Islands found peak egg production in September when 35% of the animals spawned. Males spawned in every month of the year except February. Females failed in May and December. An average of 1.9 million eggs were produced per spawning female. Collection of fertilized eggs was possible on 46% of attempts. Spawning was somewhat easier during the last quarter lunar phase, and most frequent during the afternoon, evening or night before midnight (though this may have been due to the transport schedule). On average 1.9 females and 3.6 males spawned from a particular batch.

In practical terms, this means that batches of about 30 large animals freshly collected from the wild were needed to have an even chance of getting a few million eggs, but the odds were improved by working at or shortly before the month of peak ripeness.

Broodstock collection and spawning stimulation

James (1996) collected broodstock from commercial landings, selecting large healthy individuals that had not eviscerated. He then held them in broodstock tanks, where natural spawning sometimes occurred during the months of peak ripeness, though it is not clear whether this was generally shortly after collection or after some months of culture. He mentions the possibility of obtaining fertilized eggs by sacrificing animals and dissecting out ripe translucent ovaries, drying them in the shade 'for some time', puncturing the ovary in a dish of seawater and introducing sections of ripe testis. He also describes a technique for obtaining eggs from live broodstock in which the water was drained from the broodstock tank, animals were dried in the shade for about half an hour, then subjected to a powerful jet of water for a few minutes and then put back into the tank with water, which led to spawning within 2–3 hours. However, he recommends thermal stimulation, whereby animals are subjected to a 3–5 degree water temperature rise, as the best method.

In the western Solomon Islands, animals were collected by snorkeling or SCUBA in the morning and taken in an insulated container by boat to the field station (Nusa Tupe, near Gizo, Western Province) with occasional water changes but no aeration. Collection and transport times were 3–5 hours. At the field station, depending on flight availability, they were stored for a few hours in a flowing seawater tank and then packed individually in plastic bags with 500–1000 ml seawater. Between 15 and 25 bags were sent in an insulated box for the approximately two-hour flight and subsequent one-hour road journey, generally arriving at the hatchery in the evening, some 8–10 hours after collection.

Frequently, the stress of collection and transport were sufficient to induce spawning to start the same evening or night. Otherwise, further stimulation was tried either that night or on the following days, with animals generally held in a low 2000 l tank of static aerated seawater. The use of sun-warmed water to raise the temperature by up to 5 degrees was the most effective. Water changes, water jetting, short-term drying and refilling with cooled seawater and addition to the tank of 0.1 g/l of a commercially available powdered *Schizochytrium* feed (Algamac-2000 Bio-Marine, Hawthorne, California, USA) for one hour were all sometimes used.

Broodstock maintenance

James et al (1994) speaks of holding 20–30 animals on six inches of sand in a one-tonne tank with daily water changes and fortnightly sand changes, and feeding them once a week with a little freshly ground algal paste. In 1996, he recommended stocking 15–20 animals on 100 mm of mud in a one tonne tank containing 800 l of water, which is completely changed daily, and giving daily feedings of 50 g of a preparation of prawn head waste, soya bean powder and rice bran (6.5% protein). Apparently, animals held under these conditions could be used for spawning over several months and often spawned when the water was changed.

Battaglene (pers. comm.) says that animals held at low density on sand in tanks with continuously flowing seawater, fed powdered dried algal preparations and prawn pellets, would sometimes ripen and could be spawned more than once.

Morgan (1999) found weight losses of about 20% per month for unfed animals on sand in a tank (no stocking density data), reduced to about half by feeding prawn and lucerne pellets. Holding animals for up to five weeks did not appear to affect fecundity but reduced egg hatch rate.

Spawning and incubation

Side to side rolling movements, and lifting and swaying of the front end of the body, are signs that spawning may be beginning. Males usually spawn first, releasing a stream of sperm for many minutes or even hours. Females often show a bulging of the front of the body where the gonopore emerges; egg release is less continuous but may also wax and wane over an hour or more. In order to prevent excessive sperm damaging the eggs, animals of either or both sexes were often removed from the spawning stimulation tank and put in smaller containers of 10–60 litres once spawning started. (The risk that they may not start to spawn again after this transfer is greater with females.) Both eggs and sperm appeared to remain separately viable for an hour or more.

Both James (1996) and Battaglene et al. (in review, 2000) advise washing the eggs (which sink) to remove excess sperm. An alternative is to fertilize the eggs using a sperm suspension of known strength (counted on a haemocytometer cell). A final concentration of about 20,000 sperm per millilitre of water containing eggs appears to be low enough to avoid the need for washing. On at least one occasion, eggs that had been fertilized in this way and then left aerated overnight in a 60 l container were in better condition the next day than those that had been carefully washed on a sieve (50 or 80 microns) and stocked in rearing tanks.

Stocking levels of about 0.5–1 eggs/ml are indicated by James (1996), in tanks of about 800 l with light to medium aeration. Perhaps higher densities would be possible with well-handled, clean batches of eggs in good water; Battaglene (pers. comm.) suggests up to 2.5 eggs/ml. In Solomon Islands, conical-bottomed 200 l or flat-bottomed 600 l cylindrical fibreglass tanks were usually used for hatching and larval rearing.

H. scabra

James (1996) suggests about 24 hours are required for hatching (to the motile gastrula stage) and 48 hours until the appearance of early auricularia, the first feeding stage. Ramofafia et al (2000, in review) on the other hand, say that at 25–27 °C hatching to the swimming gastrula occurs after 12 hours and the transition to auricularia after 30 hours.

Larval rearing

At CAC opaque 200 l or translucent 600 l tanks with central drains and internal standpipes were used indoors, either with translucent lids or uncovered, and with bright 12-hour artificial illumination. This consisted of one or two 20 W fluorescent tubes per tank at a height of about a metre from the water surface. Water was pumped ashore from about 12 m depth, passed through pool and then cartridge filters down to (nominal) one micron. Sometimes UV treatment was also used. Temperatures were typically 27–29 °C, salinities 32–37 ppt. Aeration, from a single central airstone, was generally light in the early stages.

Water in the hatching tanks was usually unchanged for the whole of day 1, although conspicuous pink or yellow bacterial patches on the tank floor were removed by siphoning. Tanks were drained completely on day 2 (counting the day on which fertilisation occurred, usually in the evening or before midnight, as day zero) and the early auricularia larvae were collected on 80 micron sieves immersed in bowls. Care was taken that the flow rates were kept low (not more than about 10 l/min. on a cylindrical 300 mm diameter sieve) and that the larvae remained in water at all times. They were transferred by beaker periodically into aerated buckets (briefly stirred for counting aliquots) before stocking into clean rearing tanks of the same type. Suitable larval stocking density is given by James (1996) as 0.3–0.7/ml, by Battaglene and Bell (1999) as 1/ml.

Feeding has to begin on day 2. James (1996) mentions mixed diatom culture of *Chaetoceros* spp and *Skeletonema* spp plus *Isochrysis galbena* or the latter alone, maintaining a level of 20,000–30,000 cells/ml in the rearing tank. At CAC, various larval rearing trials were carried out and the feeding schedule was still under investigation at the end of 1999, but a synthesis of the experiences to date is shown in Table 1, adapted from Battaglene (pers. comm.). In the latest batches there were some indications that *C. calcitrans* could have been omitted and one tank which received only the mixed dry diets Algamac and Livic (Riken Vitamin Co. Tokyo, Japan) yielded a few pentacularia.

Larval tanks were usually completely drained down (as described above) every second day. Counts were made and larvae were then re-stocked

in clean tanks and fed a mixture of three algal species. The feeding rate was gradually increased as larvae developed. There were no counts made of residual food and no additional feeding on the alternate days. The three species, *Chaetoceros muelleri*, *Chaetoceros calcitrans* and *Rhodomonas salina* were fed on an 'equal biomass' basis. As the cells of the three species differ in size the number of cells of C. calcitrans fed had to be increased (divide by 0.75) and of *R. salina* reduced (divide by 3). The feeding rate given is the 'muelleri equivalent' of the total mixture. (Thus if on a particular day a feeding rate of 30,000 cells/ml was required it would consist of about 10,000 cells/ml of *C. muelleri*, 13,000 cells/ml of *C. calcitrans* and 3,300 cells/ml of *R. salina*). At CAC algae were generally produced indoors using artificial light and air-conditioning, in autoclaved flasks or carboys.

On about day 7 diatom plate conditioning was started. Stacks of plates similar to those used in abalone culture were put outdoors under partial shade (50–75%), in shallow tanks supplied with continuously-flowing seawater filtered to one micron to prevent the development of large numbers of copepods. (At CAC, plates were of corrugated fibreglass roofing material cut into rectangles of about 300 mm x 400 mm and assembled into stacks of four with 30 mm spaces. There was a surface area per stack of about 1m².) About 0.25–0.5 m² of plate surface was used per 100 l of larval rearing tank, and 4–7 days allowed for a biofilm to develop on the plates. James (1996) used extracts of sargassum to induce development of biofilm. There are also more managed techniques of benthic diatom culture on plates; these have not been tried.

Under good conditions, late auricularia with pronounced oil globules could be seen from day 8, some non-feeding doliolaria from day 10, and the first pentacularia from about day 12. At this stage conditioned plate stacks were put into the tanks, after rinsing in filtered seawater to remove any copepods. Batch changes were usually stopped, and continuous or semi-continuous water flow started, at a rate of 1–3 tank volumes per day. Outlet screens were of 80 or 120 microns. Microalgae continued to be fed daily, mainly for the less developed larvae. A daily supplement of a dry algal food blended in water; Algamac, *Tetraselmis* sp. (Cell Systems, Cambridge, UK), Livic or a mixture (as available) was added at a rate of about 0.05 g per 100 l of tank water.

Plates can remain in the larval rearing tanks as long as some competent auricularia are present and food availability does not limit the growth of the pentacularia and juveniles (which appear from about day 20). Eventually, the relatively small surface area and low light levels mean that the juveniles are likely to outgrow the supply of suitable food, assumed to be at this stage largely benthic or attached diatoms, or other settled algal cells.

If accurate counts and weight measurements are needed, juveniles can be detached by the use of 0.5–1% potassium chloride solution in seawater. This technique was quantified by Battaglene and Seymour (1998) who found that a 10 minute bath in 1% KCl caused less than 2% mortality in juveniles of 2–20 mm (although as many as 17% of the larger sizes eviscerated), and rapid reattachment occurred after they were put back in normal seawater. Alternatively, the plates can be taken outdoors without detaching the juveniles and counts made if needed by inspecting the individual (separated) plates. When indoor rearing tanks are drained, the use of a 1% KCl spray helps detach animals from the tank walls and floor.

Nursery

In a long series of experiments, Battaglene et al (1999) looked in detail at the conditions for rearing hatchery-bred juveniles of different sizes. Their main findings were:

1. One-month juveniles were nursed in bare conditioned fibreglass tanks (plus many plates) at a density of about 400/m² of tank floor and wall area and fed Algamac at 1g per m³. They grew from mean length 1.8 mm to mean length 13 mm in four weeks, with an average survival of 34%.

2. Juveniles were transferred into small, non-conditioned indoor aquaria with or without sand at different ages (from one to two months) and sizes (3–10 mm). They were fed Algamac at 10% of initial biomass. Survival increased markedly with size at transfer, from 52% at 3 mm to 87% for larger juveniles. Survival did not vary significantly with the substrate but growth was better on sand.

Table 1. Feeding rates for larvae of *Holothuria scabra*

Days (after spawning)	Feeding rate (cells/ml)	Treatment	Stage	Other feeds
2	20,000	batch water change	early auricularia	
4	20,000	"	auricularia	
6	25,000	"	auricularia	
8	30,000	"	late auricularia	
10	35,000	"	first doliolaria	
12 onwards	40,000 once daily	12 hours flow	first pentacularia	plates + dry algae

3.   Small juveniles (1.5 mm) were stocked in bare concrete tanks (with a few plates) at two densities (167 and 558/m² of tank including walls) and fed either Algamac or Livic at 10% of initial biomass. Survival differences (15.7% at low, 5.9% at high densities) were apparently not significant. Juveniles fed Livic initially grew faster than those fed Algamac but, by the end of the two-month experiment, length (av. 19.5 mm), weight (av. 1.1 g) and survival were not significantly different between the two diets.

4.   Four-month juveniles (av. 1.6 g) were stocked in concrete tanks at a density of 5/m² of floor plus walls (or about 10/m² of floor), with or without sand. They were fed Algamac at 1% or 10% of (adjusted) bodyweight. After two months, animals under the best treatment (sand and high food) all survived and averaged over 60 mm and 23 g. Sand was significantly better than no sand for growth (and perhaps for survival) but effects of feeding rate were not significant.

5.   One-month 1 g juveniles were reared in outdoor fibreglass tanks at stocking densities of 7.5/m² of floor plus walls (25/m² of floor), with or without sand, and with or without 70% shade cover. They were fed Algamac at 0.2 g/day. After two months, weights were significantly different: the shaded juveniles averaged 7.3 g with sand and 11.5 g without, while unshaded juveniles averaged 12.5 g without sand and 14.1 g with sand.

6.   The experiment described above was repeated a year later with 0.9 g animals at 1.8 times higher stocking levels, with double shade covers or without shade. Both shaded treatments grew very slowly (1.4 g with sand and 2 g without), while unshaded juveniles survived (95%) and grew better (10.8 g without sand and 12.1 g with sand).

7.   Five-month 1 g juveniles were stocked at three densities (7.5, 15 and 30/m² of floor plus walls or 25, 50 and 100/m² of floor) in outdoor fibreglass tanks with sand. They were fed Algamac at two levels, 1% and 10% bodyweight per day (adjusted fortnightly) for eight weeks. Final weights were inversely related to density (low 17.8 g, medium 11.8 g, high 7 g) but feeding level had no significant effect.

8.   Juveniles of 0.8 g were stocked at 15/m² of floor plus walls (50/m² of floor) in outdoor tanks that either had or had not been conditioned for two weeks prior to stocking, with either beach sand or coral sand substrate. They were either fed Algamac at 10% bodyweight daily (adjusted after four weeks) or unfed. After eight weeks the fed, conditioned, coral sand treatment juveniles were the largest but all groups' averages were within the size range 6.6–9.9 g and none of the differences were considered significant.

9.   Juveniles of 7.5 mm, (0.5 g) were stocked in larger concrete tanks (conditioned for two weeks) with or without sand, at 27.6/m² of floor plus walls (40/m² of floor) and fed Algamac at 3% of initial biomass daily. After three months, those on sand were significantly larger than those without sand (27.2 g compared to 7.2 g), but survival on sand was significantly poorer (12.4% compared with 67.2%). A few of the largest surviving juveniles of about 40 g each were stocked on fresh sand at 5/m² of floor and reared unfed for another year. Of these, 92% survived but they did not grow.

Conclusions and recommendations based on this work were as follows. Diatoms and attached algae are an important source of food for juveniles up to at least 50 mm in length. They therefore need to be grown in outdoor tanks with plenty of light. Growth slows when densities exceed about 200–225 g/m² and this is only slightly alleviated by supplementary dry algal feeding; however individuals stunted by high density later appeared to grow normally when given better conditions. Transfer of juveniles onto a sand substrate should be delayed until they reach about 20 mm length or 1 g live weight, but thereafter growth and survival are better on sand than in bare tanks. Growth of larger juveniles was approximately linear and averaged 0.5 mm or 0.2 g/day.

Therefore two nursery phases in outdoor tanks are needed; the first up to about 1 g size in bare tanks, the second on sand. For both stages there is currently no effective prepared diet; they appear to depend largely on food produced by photosynthesis and are density-limited.

For early nursery at CAC fibreglass tanks of 2.2 m diameter and 70 cm water depth were supplied with a continuous flow of about 6 l/min., ie 2–3 changes per 24 hours, filtered to 1 micron. A single shade cover was often used, and additional covers could be put on if filamentous algae threatened to dominate. Juveniles were usually fed a daily suspension of dried algae (at around 1 g/m³) and sometimes cultured phytoplankton if available (at up to 40,000 cells/ml) but, in the absence of an effective diet, stocking levels had to be kept low, or tanks periodically thinned, for growth to be maintained.

Grow-out

There are accounts from Indonesia and India about farmers practicing culture in ponds or pens based on collected small sandfish. However, there is a dearth of real data concerning the growth and survival of larger animals in tanks, ponds or pens. An experiment in India in which juveniles of 67 g stocked in a concrete well ring (top closed with a net, bottom embedded in the mud of a prawn pond) reached 284 g in six months is reported by Battaglene (1999) who apparently also saw commercial pond culture in south Sulawesi, Indonesia. He obtained good growth of juveniles in a prawn nursery tank containing sand and mud; 0.7 g/day at low and 0.3 g/day at high density with 93% survival over 20 weeks. However, larger animals stocked in a prawn growout pond disappeared without trace.

A group from the Research Institute for Marine Fisheries, Jakarta (RIMF 2000; Basuki pers. comm.) stocked about 1000 collected sandfish (av. 46 g) in a 10 x 20 m shallow water net pen on a sandy seagrass area off Kongsi Island, Pulau Seribu archipelago, Jakarta Bay, Indonesia. Subsequent monthly samplings gave average weights of 101, 113 and approximately 150 g, but until a complete harvest is carried out it is possible that part of this apparent growth could be due to selective escape or mortality of smaller individuals, or to the greater ease of finding big ones when sampling. Another pen culture trial is believed to have been carried out in Sabah, East Malaysia by an Indonesian MSc student working with Ko-Nelayan (Sabah Fishermen and Fisheries Development Corporation); however at the time of visiting (May 2000) no data were available.

In Nha Trang, Vietnam (Nguyen Chinh 1995; N.T. Xuan Thu pers. comm) 100 collected sandfish of 55–160 g (av. 68 g) were reared in a 50 m² concrete tank on sand and fed shrimp pellets 2–3 times per week. After three months 85 animals of 140–440 g (av. 350 g) were harvested. This appears to be a rare instance of good growth at high density. In nearby Cam Ranh 48 animals of 40–220 g (av. 90 g) were stocked with (fed) shrimp postlarvae in a 200 m² nursery pond on a mud and sand substrate. After three months 34 were harvested at 160–645 g (av. 353 g).

More recently in the same area, several hundred sandfish (most in the range 50–500 g) were bought from fishermen and stocked in ponds and pens. Preliminary results (R. Pitt, 2000, in preparation) indicate apparent growth rates in ponds of 2.2–3.2 g/day (varying inversely with stocking density in the range 106–170 g/m²). Survival was excellent in ponds (88-97%) until the start of the wet season, which was rapidly followed by massive mortalities. In a pen stocked at about 500 g/m² there was 98% survival but virtually no growth, while growth and survival were both fair (1.7 g/day and 90%) in a pen holding about 390 g/m² of sandfish.

Growth and survival data of wild or released cultured animals in the natural environment is also scarce. Shelley (1985) sampled sandfish in Bootless Bay near Port Moresby, Papua New Guinea for over a year. From size frequency measurements he estimated growth rate as 14 g/month and reef production of sandfish as nearly 500 kg/year. Battaglene released large adults collected elsewhere in Ndoma Bay near CAC where none had been found previously; most could be found many months later in the same vicinity. Hamel et al (2000, in preparation) released hatchery-reared juveniles on different substrates in areas of NW Guadalcanal, Solomon Islands where no sandfish had previously been found and were apparently able to observe very high growth rates of 10–15 cm/month on subsequent visits.

On the other hand, Dance (pers. comm.) had difficulty finding hatchery-bred animals (mainly in the 25–35 mm) soon after release. From 15% to 95% were missing after only 24 hours on two different seagrass release sites near Gizo, Solomon Islands. In further trials, Dance et al (2000 in review) released batches of hatchery-bred and nursed sandfish juveniles of 20–74 mm (av. 36 mm) on fine sand, or silt and fine sand areas in coral reef-flat or mangrove-seagrass sites. They then observed survival and fish behaviour at the sites. On the coral reef-flat sites mean survival was as low as 37.5% one hour after release and total mortality occurred at two of three sites within 48 hours. At mangrove–seagrass sites, only 0–5% were injured or eaten within an hour, and 70% were found alive after three days. Predation, by triggerfish, emperors and breams (Balistidae, Lethrinidae and Nemipteridae) could be prevented by the use of a small enclosure, but growth and longer-term survival were not measured.

Prospects and problems

Broodstock management

In principle, eggs can be obtained either from wild or captive broodstock. However where populations are already depleted accessible wild stocks of large animals may be hard to find. Methods for maintaining adequate captive stocks which can be reliably spawned have not yet been demonstrated. In the absence of effective prepared diets, quite large areas of tanks or pens are likely to be needed. If ex-

isting ponds (for example shrimp ponds) prove suitable for broodstock maintenance, and in particular if sandfish are found to be compatible with locally farmed species (both biologically and in terms of management) this may provide an economical solution.

Larval rearing

The use of larger tanks could have many benefits. They require relatively less labour. Physically and biologically they are more stable so a low-cost building or even just a roof should suffice. It may be possible to replace complete drain-down water changes by partial batch changes or continuous-flow, further reducing labour costs. Daylight can probably replace high levels of artificial lighting.

Phytoplankton

It should be possible to produce some or all of the algae in outdoor cultures. This would save a great deal of the capital and running costs involved in autoclaving large volumes of water, lighting the cultures artificially and removing the heat produced by the lights. Cultures have to be kept sufficiently free of contamination to survive for long enough to be useful, and also to prevent to prevent them becoming sources of unwanted organisms which can infest larval rearing tanks. Since water for algae culture is to be fertilized and then stored it probably needs more careful treatment than that for larval rearing, for example additional filtration, UV treatment, chlorination-dechlorination or heating to 60–80ºC.

Nursery

Large outdoor tank areas are currently needed because there is as yet no effective prepared diet. For early nursery about 3–5 m² (of bare floors plus walls) are required per thousand 20 mm (~1 g) juveniles although some space can probably be saved by using additional conditioned plates and by frequently grading out the larger animals. For later nursery, 30–50 m² of tanks with fine sand would be required per thousand 50 mm (≈10 g) juveniles, which might be a suitable size for ongrowing in ponds. Correspondingly more tank space will be needed if bigger animals are required for pen culture or release. This is likely to be prohibitively expensive unless ponds, pens or seabed cages can replace tanks at later stages in the nursery process.

Farming

Big areas of ponds have been constructed for shrimp farming, in Asia and elsewhere. Many shrimp farms now struggle with serious disease problems. Other species and different systems of culture are of interest if they can reduce these problems and provide alternative crops. Sandfish ingest large amounts of substrate and may improve water conditions by removing organic detritus. Even if only a small fraction of existing shrimp ponds can be maintained at salinities suitable for sandfish, and if systems can be developed to farm them either alone or in polyculture with fish, crustaceans or molluscs, the production potential will be considerable.

Restocking

Apart from the limited experiments described by Dance et al. (2000) and Hamel et al. (2000), there is still very little information on the survival of released animals. ICLARM has recently received funds from the Australian Centre for International Agricultural Research (ACIAR) to develop optimal release strategies for cultured sandfish in restocking programs. Arrangements are being made to do this work in New Caledonia in collaboration with the Provincial Governments, IFREMER, the Australian Institute of Marine Science and Melanesian fishing communities. The project will focus on identifying the optimum size-at-release, stocking density, release habitat and times for release. The possibility of using commercial shrimp farming ponds to mass-produce juvenile sandfish will be investigated.

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