

## How to produce 100 tonnes of sandfish

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The following article is based on an ongoing collaboration in Vietnam between the WorldFish Center (formerly ICLARM) and the Ministry of Fisheries, at the Research Institute for Aquaculture No. 3, Nha Trang City, Khanh Hoa Province. The work described is oriented towards regions near the equator, where induced spawning of on-grown broodstock should be possible over about 10 months of the year. A shorter breeding season (in subtropical areas) would necessitate bigger installations, but a larger market size would have the opposite effect.

Work started here in June 2000 using locally collected animals that averaged only about 150–200 g. In the first year, after growing for some months in ponds, they could only be spawned once (in February 2000), when they averaged 260 g. In the second year, with further on-growing in ponds or seabed pens (and after an isolated spawning in August 2001), groups of 30–45 animals of 200–600 g individual weight have generally been spawned once or twice a month from November 2001 to January 2003 (so far).

Most egg batches have been reared at least through to settlement, with the production of many hundreds of thousands of juveniles of 1–2 mm. However, nursery space for further rearing has been limited. Some 50,000 juveniles have been produced in bare- and sand-tank nursery stages, and about half of these have gone out into pond, seabed pen or cage trials. The largest F1 animals have reached about 350 g and have been spawned for the first (recorded) times at less than one year of age. F2 juveniles are now being reared. All stages of the rearing cycle have now been carried out on at least a medium or pilot-commercial scale. A tentative economic evaluation of the production process therefore becomes a possibility.

The hatchery here (35 m<sup>3</sup>) has proved big enough, but the tank nursery facilities (about 230 m<sup>2</sup> total floor area) have not, and this has limited production. Facilities for further nursery have been another severe bottleneck: there have generally been not more than about 3000–4000 m<sup>2</sup> of ponds available, some 90 minutes drive from Nha Trang, and it has proved difficult to manage them effectively

at that distance. Efforts to carry out nursery culture on the seabed are under way.

What follows grew out of a back-of-an-envelope calculation. Efforts have been made to avoid the classic pitfalls — among which are the use of excessive scale-up (i.e. extrapolating directly from an aquarium to a pond), taking the best result ever achieved and applying that to all future yield calculations, and incorporating the benefits of major technical advances before they have been achieved. Disease problems also tend to increase as the scale and intensity of culture progresses. On the other hand, it is assumed that with practice routine husbandry becomes more efficient and at least some blunders can be avoided.

Figures for growth are more robust than those for survival, since it is easier to collect a sample from a pond or pen than to harvest all the animals. Often animals have been held longer at a particular stage than would have been ideal, due to lack of space in the next stage. This has probably reduced the survival rates that have up to now been achieved.

After six years of research in Solomon Islands and Vietnam a better understanding has been reached of the general scale of installations needed to produce large quantities of sandfish based on hatchery seed. There are still many questions to be answered before a commercially viable system might become possible, but it is hoped that this calculation will be useful to anybody thinking of building a sandfish culture facility or assessing the feasibility of doing so. Spreadsheet calculations are available showing the data from a wide range of nursery and on-growing attempts, in tanks, ponds, pens and cages.

### Broodstock

- 400 broodstock of 300–400 g average weight.
- Hold in at least 1000 m<sup>2</sup> of ponds or sea pens.
- Need 120 female-spawnings per year at 1.5 × 10<sup>6</sup> eggs per spawning to produce 180 × 10<sup>6</sup> eggs

Broodstock are held in ponds or seabed pens at a density not exceeding 200 g m<sup>-2</sup>. It is not known how long spawned animals take to regenerate, but at least 3 spawnings per animal per year should be

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possible. Female spawning induction success rate currently averages only about 10%. Around half the animals are male, and they generally spawn more readily.

### Hatching and larval rearing

- Stock at 0.8–1.2 eggs ml<sup>-1</sup> for about 20,000 small juveniles m<sup>2</sup> with 2% survival
- 30–60 days
- 6 batches per year
- Need 30 m<sup>3</sup> of larval tanks to produce 3.6 × 10<sup>6</sup> newly settled 1–2 mm juveniles

This stage has generally proved quite easy although unexplained crashes are not uncommon. Survival rates have been low but with a plentiful supply of eggs this has not been a major limiting factor. Indoor fibreglass or concrete tanks (of 1.7–6.4 m<sup>3</sup> each) have proved easier to manage than smaller or outdoor tanks. Only partial water changes are made, and a flexible combination of algal species is fed, supplemented by dry algae after settlement. Metamorphosis and settlement, on tanks surfaces and added pre-conditioned plate stacks, start as soon as 8–12 days after spawning, depending on temperature, rearing density and feed availability. Settled juveniles are kept indoors for 1–2 months after settlement, sometimes even longer if there are no outdoor tanks free. During this phase copepod control (using Dipterex at 1–2 ppm for a few hours) is important.

### Bare tanks for first nursery

- Stock 700 small juveniles m<sup>-2</sup> for 280 juveniles m<sup>2</sup> at harvest (40% survival)
- 20–30 days
- 12 batches per year
- Need 430 m<sup>2</sup> of tanks to produce 1.44 × 10<sup>6</sup> juveniles of 10–20 mm (0.3–1 g)

Juveniles are transferred by moving settlement plate stacks or by siphoning and hosing down tank surfaces. They are stocked in bare, shaded, outdoor fibreglass or concrete tanks. There have been quite variable results during this stage, which remains a bottleneck to mass production. On a few occasions over 500 juveniles m<sup>-2</sup> have been produced, but around half this rate is more usual.

Tank design, timing and methods of juvenile transfer, tank pre-treatment and management, diets, shade, water treatment, the use of additional pre-conditioned plates or seagrass and possible co-culture with shrimp are all factors which have been looked at, generally without definitive results. The current routine usually involves preconditioning tanks for a few days before stocking, a continuous

flow of unfiltered seawater during the daylight hours with flow rates as high as possible (25–100% exchange per day), supplementary feeding using mixtures of dry algae, seaweed powder and/or shrimp postlarva starter feed (at 0.5–1 g m<sup>-3</sup> twice a day) and quite heavy shading until most juveniles attain the adult coloration.

Growth rate is typically very variable, with some animals reaching 3–5 g while the majority are about one tenth of this size, and many remain below 0.1 g and have not even attained the adult type of skin and colour. Removal of large animals seems to help smaller ones to develop. By adding sand after some weeks, this stage and the next can be combined.

### Sand nursery in tanks

- 0.3–1 g to 1–3 g
- Stock at 200 juveniles m<sup>2</sup> for 200 g m<sup>2</sup> at harvest with 50% survival
- 20–40 days
- 10 batches per year
- Need 720 m<sup>2</sup> of tanks to produce 720,000 juveniles of over 1 g

Small juveniles are graded and transferred to tanks with floors thinly covered in fine sand, or sand is added to first nursery tanks. This is another production bottleneck, probably the most expensive stage of the process due to the very large tank area required. Good survival is quite common, and growth has sometimes been better when sandfish juveniles were reared together with shrimp post-larvae. However, growth rates are usually very variable within a batch. Frequent sorting might allow somewhat higher initial stocking densities. Dry algae, powdered or blended seaweed and shrimp food have been fed in different combinations; currently shrimp starter food is usually given twice daily at not more than 1 g m<sup>-2</sup>.

Clearly ponds are cheaper per square metre than tanks, both to build and to operate. However, transfer to ponds (or seabed pens/cages) at sizes of around 2 g has produced very variable results. Some batches have grown well while others have disappeared, immediately or within a few days, due to causes unknown. Until a protocol for pond preparation and management can be developed that yields consistently acceptable survival rates, the trade-off between tanks and ponds is hard to evaluate.

### Pond nursery

- 1–3 g to 50 g
- Stock at 8 juveniles m<sup>2</sup> for 200 g m<sup>2</sup> at harvest with 50% survival

- 40–60 days
- 6 batches per year
- Need about 1.5 ha of nursery ponds to produce 360,000 small adults

Graded juveniles are stocked in ponds, which have preferably been recently dried, cleaned and refilled. Some batches have shown surprisingly rapid growth and excellent survival but others have disappeared without trace. Sometimes, test batches are put in small pens built inside the ponds for a week or so before the main batches are stocked. Co-culture with shrimp postlarvae at low densities and feeding rates might be possible but has not yet been proved in ponds. (Shrimp nursery culture has become less common here among farmers. Most stock hatchery-supplied shrimp postlarvae are put directly in big grow-out ponds, and many small nursery ponds have been abandoned or converted.)

This stage is now also being tried in seabed pens (consisting of simple low net fences, which usually do not reach the water surface) in sheltered water of a few metres depth, and in seabed cages of several types. In some of these pens and cages carnivorous Babylon snails are farmed at the same time.

### Grow-out

- 50 g to 350 g
- Stock at 1 small adult m<sup>2</sup> for 2.8 t ha<sup>-1</sup> at harvest with 80% survival
- Density kept below 200–240 g m<sup>-2</sup> by selective harvesting
- 90–150 days
- 2–4 batches per year
- Need about 12 ha grow-out ponds or pens to produce 100 t (wet weight) of sandfish

Rapid growth and good survival are possible in ponds, but rearing attempts resulting in heavy or total mortalities remain common. The following conditions need to be prevented: salinity below about 20 ppt, stratification due to heavy rain, excessive filamentous weed growth, very black (anaerobic) and putrid pond floor conditions. Very good growth (2–3 g animal<sup>-1</sup> day<sup>-1</sup>) has been obtained in some ponds at moderate densities (up to 200–300 g m<sup>-2</sup>). There have also been ponds in which many animals developed skin lesions (not rapidly fatal but slowing growth) and others in which all animals have died. Management practices to maintain optimal conditions (of water and benthos) have not yet been seriously studied.

By thinning out the fastest-growing animals for sale periodically, a larger final size and higher stocking rates may be possible. Bigger animals gen-

erally fetch higher per-kilo prices, with 350–500 g probably the size to aim for in Vietnam. Growth rates of the generally bigger South Pacific sandfish are not known.

Seabed pen culture in big pens might be economic (if theft can be prevented), since the area enclosed by a fence increases as the square of its length (Perimeter<sup>2</sup>/4π for a round pen or Perimeter<sup>2</sup>/16 for a square one). Complete release (perhaps into an area isolated by surrounding deep water or unsuitable habitat) would be the logical extension of this idea, avoiding the costs of pen construction and maintenance entirely, but survival and recovery figures can only be guessed at.

### Algal culture

Stock culture room plus either:

- About eighty (!) 20-L carboys producing 320 L day<sup>-1</sup> at 3000 cells μl<sup>-1</sup> cme (*C. muelleri* equivalent)
- About ten 400-L polythene bags (or equivalent smaller sizes), producing 1000 L day<sup>-1</sup> of 1000 cells μl<sup>-1</sup> cme.
- About 10 m<sup>3</sup> of open tanks, producing 2000 L day<sup>-1</sup> of 500 cells μl<sup>-1</sup> cme.

### Conclusion

The major barriers to commercial sandfish culture appear to be the high costs of tank nursery (due to the low density at which it can be carried out) and the very variable results of nursery and grow-out attempts in the sea or ponds. Plus of course the rather poor prices paid for the wet animals.

Effective diets, practical methods of pond management and ways to protect juveniles in the sea are the most urgent development needs if sandfish culture is to progress further.

## Overview of sea cucumber farming and sea ranching practices in China

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### History of trepang consumption in China and present status

Eating trepang is a custom of the Chinese, especially in coastal areas. The history can be traced back to the Ming Dynasty (1368–1644 BC) at least, when sea cucumber was recorded in the *Bencao Gangmu*, a famous materia medica written by Li Shizhen. Sea cucumber was recorded as a tonic and a traditional medicine in many ancient writings (e.g. *Shiwu Bencao*, *Bencao Gangmu Shiyi*, *Wuzazu*, *Bencao Congxin*) from the Ming Dynasty to the Qing Dynasty (Huizeng Fan 2001; Yuhai Jia 1996).

According to the “analysis by principles” of traditional Chinese medicine, the sea cucumber nourishes the blood and vital essence (*jing*), tonifies kidney *qi* (treats disorders of the kidney system, including reproductive organs), and moistens dryness (especially of the intestines). It has a salty quality and warming nature. Common uses include treating weakness, impotence, debility of the aged, constipation due to intestinal dryness, and frequent urination. Traditionally, sea cucumbers are eaten by Chinese people more for their tonic value than for their seafood taste. Hence, the popular Chinese name for sea cucumber is *haishen*, which means, roughly, ginseng of the sea (Anderson 1988; Zhang Enchin (ed.) 1988).

Chinese commonly consume certain types of food as medicines for prevention and treatment of illness. Chinese cooks have revered the sea cucumber since ancient times. In particular, sea cucumber meals are offered on numerous special occasions, especially the Chinese Spring Festival. The sea cucumber is rated along with several other delicacies, such as shark fin and bird’s nest soup, as a disease preventive and longevity tonic.

From the nutritional viewpoint, sea cucumber is an ideal tonic food. It is higher in protein and lower in fat than most foods (Table 1). It contains the amino acids and trace elements essential for keeping healthy (Tables 2, 3, 4). For nourishing purposes and to clean the blood of people suffering from emaciation, it is combined in soup with pork. For impotence, frequent urination, and other signs of kidney deficiency, it is cooked with mutton. For yin and blood deficiency, especially manifesting as intestinal dryness, sea cucumber is combined with tremella (*yiner*, the silvery tree mushroom). All of these recipes are popular with the Chinese (Jilin Liu and Peck G 1995).

For modern applications, dried sea cucumber used as a nutritional supplement is prepared in capsules or tablets. The fully dried material has a protein concentration as high as 83 per cent. From the Western medical viewpoint, the reason sea cucum-

Table 1. Main food groups in various species of sea cucumber\*

Item	Protein %	Fat %	Moisture %	Carbohydrate %	Ash %
Fresh <i>Acaudina molpadioides</i>	12.94	0.03	77.00	0.43	1.03
Fresh body wall of <i>Acaudina molpadioides</i>	11.52	0.03	87.83	0.38	0.99
Dried <i>Acaudina molpadioides</i>	68.53	0.55	8.25	--	7.56
Fresh body wall of <i>Thelenota ananas</i>	16.64	0.27	76.97	2.47	1.60
Dried <i>Thelenota ananas</i>	69.72	3.70	8.55	--	9.51
Dried <i>Apostichopus japonicus</i> **	55.51	1.85	21.55	--	21.09

\* From Fangguo Wang (1997); modified by Jiixin Chen

\*\* Also contains essential amino acids