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 *Acaudina molpadioides*	12.94	0.03	77.00	0.43	1.03
Fresh body wall of *Acaudina molpadioides*	11.52	0.03	87.83	0.38	0.99
Dried *Acaudina molpadioides*	68.53	0.55	8.25	--	7.56
Fresh body wall of *Thelenota ananas*	16.64	0.27	76.97	2.47	1.60
Dried *Thelenota ananas*	69.72	3.70	8.55	--	9.51
Dried *Apostichopus japonicus***	55.51	1.85	21.55	--	21.09

* From Fangguo Wang (1997); modified by Jiaxin Chen
** Also contains essential amino acids

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Table 2. **Amino acid levels in *Acaudina molpadioides* and *Thelenota ananas**

Amino acids	Fresh *Acaudina molpadioides* x 10^{-2}	Fresh body wall of *Thelenota ananas* x 10^{-2}	Dried *Acaudina molpadioides* x 10^{-2}	Dried *Thelenota ananas* x 10^{-2}
Asp	1.387	1.890	6.260	5.78
Thr **	0.519	0.712	2.438	2.58
Ser	0.459	0.721	2.008	2.07
Glv	1.658	2.865	8.994	7.86
Pro	1.302	1.408	--	1.03
Gly	2.502	2.724	14,424	10.03
Ala	1.662	1.703	5.771	5.20
Cys	0.387	--	--	--
Val**	0.374	0.688	1.944	2.43
Met**	0.158	0.339	0.614	0.86
Ile**	0.189	0.473	0.965	1.64
Lev**	0.359	0.780	1.684	2.59
Tyr	0.195	0.435	0.655	1.41
Phe**	0.223	0.567	0.847	1.67
His	0.091	0.213	0.728	0.40
Lys**	0.182	0.524	1.288	0.92
Arg	0.647	0.773	3.778	4.46
Total	12.330	16.815	52.398	50.93

* From Fangguo Wang (1997)
** Essential amino acids

ber is valuable is it serves as a rich source of the polysaccharide condroitin sulfate, which is well known for its ability to reduce arthritis pain: as little as 3 g per day of dried sea cucumber has been helpful in significantly reducing arthralgia. Its action is similar to that of glucosamine sulfate, which is useful for treating osteoarthritis. Sulfated polysaccharides also inhibit viruses; there is a Japanese patent for sea cucumber chondroitin sulfate for HIV therapy.

Chinese studies reveal that sea cucumbers also contain saponin glycosides. These compounds have a structure similar to the active constituents of ginseng, ganoderma, and other famous tonic herbs. Additional Chinese studies indicate anticancer properties of both the sea cucumber saponins and the polysaccharides. These modern studies confirm that sea cucumber can be used as a tonic and nutrient supplement. Coinciding with economic development, the demand for trepang has greatly increased in mainland of China since the early 1980s (Huizeng Fan 2001).

Table 3. **Vitamins, saponins and polysaccharides in *Acaudina molpadioides* and *Thelenota ananas**

	Vitamins						Saponins	Polysaccharides
	B1 x 10^{-5}	B2 x 10^{-5}	B6 x 10^{-5}	A x 10^{-5}	D x 10^{-5}	E x 10^{-5}	x 10^{-3}	x 10^{-5}
Fresh *A. molpadioides*	0.114	0.15	0.039	0.15	0.0066	3.95	26.76	4.21
Fresh body wall of *A. molpadioides*	0.102	0.13	0.035	0.13	0.0059	3.52	26.50	3.75
Fresh body wall of *T. ananas*	0.782	0.23	19.000	0.35	0.0180	0.90	379.40	4.12

* From Fangguo Wang (1997)

Table 4. **Trace elements contents in *Acaudina molpadioides* and *Thelenota ananas**

	Mn x 10^{-6}	Fe x 10^{-6}	Zn x 10^{-6}	Co x 10^{-6}	Cu x 10^{-6}	Se x 10^{-6}
Fresh *A. molpadioides*	1.5	2231	10.48	0.48	0.43	1.32
Fresh body wall of *A. molpadioides*	1.5	1982	9.34	0.43	0.43	1.40
Fresh body wall of *T. ananas*	7.1	794	7.35	0.23	0.36	0.34

* From Fangguo Wang (1997)

Apostichopus japonicus and its hatchery techniques

There are 134 species of sea cucumbers identified in China seas, among which about 20 species (Table 5) have commercial value for edible consumption. *Apostichopus japonicus* (Fig. 1) is the only species to be cultured in China. This is due to its high meat quality and to the success of the techniques used in commercial hatcheries (Yulin Liao 1997).

In the early 1980s the shortage of sea cucumber seed was a bottleneck for developing aquaculture. The Ministry of Agriculture prioritised setting up hatcheries of sea cucumber (*Apostichopus japonicus*) and improving techniques of seed production. Since then, sea cucumber farming has been becoming a vigorous sector in mariculture.

Sea cucumber is dioecious, but it is hard to differentiate the male from the female. The genital pore located on the posterior back of the head is very small. Most individuals only possess one genital pore, but a few have 2 or 3 pores with a spawning function.

Individuals at two years old, weighing about 250 g, enter their mature period. Females are very fecund and can produce as much as 1–2 million eggs — sometimes even 10 million — in one spawning event. Normally, fecundity is related to body weight. During mature periods, there are 220,000–290,000 eggs per gram of ovary. When the water temperature near the seabed reaches 15–17ºC, it is a good time for broodstock collection. The procedure for artificial reproduction of sea cucumber is as follows:

1. Broodstock collection: from late May to early July, when the gonad index is over 10.
2. Broodstock care in land-based tanks: 30 individuals m^{-3}, DO over 5 mg L^{-1}, feeding rate about 5–10% of body weight.
3. Spawning stimulation: thermal shock (water temperature raised by 3–5°C) and desiccation followed by seawater jet for 10–15 minutes.
4. Fertilisation: when the diameter of the oocyte is around 120–130 µm. Maximum density 200–300 eggs ml^{-1} in spawning tank; 1 million eggs m^{-3} in hatchery tank.
5. Hatching.
6. Nursery of juveniles.

Experimental results reveal that auricularia larvae and 7–10-day-old juveniles are sensitive to environmental conditions; highest mortalities will occur during these two stages. The main problems come from diseases of digestive duct, especially gastritis. Hence, the key to increasing survival rate is to provide the appropriate feed and to follow sophisticated routine management.

On entering the pre-auricularia stage, the larvae begin to feed on phytoplankton. In a commercial sea

a. Live specimen **b. Dried specimens**

Figure 1. ***Apostichopus japonicus***

Table 5. **Edible sea cucumbers in China seas**

Latin name	Common name	Latin name	Common name
Actinopyga mauritiana	Redfish; shoes trepang	*Holothuria fuscogilva*	White teat-fish
Actinopyga lecanora	Stone trepang; sea cucumber	*Holothuria nobilis***	Black teat-fish
Actinopyga echinites		*Holothuria moebii*	
Actinopyga miliaris	Black trepang	*Holothuria cinerascens*	
Bohadschia argus	Tiger-fish; spotted fish	*Holothuria arenicola*	
Bohadschia marmorata	White-fish	*Apostichopus japonicus**	Thorn trepang
Holothuria atra	Black trepang	*Stichopus chloronotus*	Square trepang
Holothuria edulis		*Stichopus horrens*	
Holothuria fuscocinerea	Stone trepang	*Stichopus variegatus*	Yellow meat
Holothuria leucospilota	Black trepang, black dog	*Thelenota ananas***	Plum-flower trepang
Holothuria pervicax	Tiger spotted trepang	*Thelenota anax*	Plum-flower trepang
*Holothuria scabra***	Sandy-fish; white-fish	*Acaudina leucoprocta*	Perfume trepang

* Highest commercial value
** High commercial value

cucumber hatchery, *Dunaliella salina, Phaeodactylum tricornutum*, and *Chaetoceros simplex*, as well as marine yeast, are commonly considered ideal feeds.

The feeding regime depends on the development stage. From pre-auricularia to post-auricularia stage, algal cells in the rearing water are gradually increased from 10,000 cells ml^{-1} to 25,000 cells ml^{-1}; the feeding frequency is 2–4 times per day. A feeding experiment indicated that the survival rate of juveniles is influenced by feed and feeding quantity (Tables 7 and 8).

Table 6 . The developmental stages from fertilised egg to juvenile (water temperature: 20–21°C)

Stages	Size (µm)	Density (/l)	Time
First polar body			20–30 min.
Second polar body			30–35 min.
First cleavage			43–48 min.
Blastula			3 hr 40 min. – 5 hr 40 min.
Hatch out		1000–1500	12–15 hrs
Pre-gastrula		500–600	14–18 hrs
Gastrula			18–25 hrs
Pre-auricularia	360–430		25–30 hrs
Mid-auricularia	600–700		5–6 days
Post–auricularia	800–1000		8–9 days
Doliolaria	400–500		about 10 days
Pentactula			about 11–12 days
Juvenile	300–400	50–100	about 12–13 days

Table 7. Influence of feed type on survival rate of larvae and juveniles (density of pre-auricularia: 1000 L^{-1})

Feed	Auricularia stage		Juvenile stage	
	Density (individuals L^{-1})	Survival rate (%)	Density (individuals L^{-1})	Survival rate (%)
Marine yeast	190	19.0	55.5	5.55
Tetraselmis sp.	9	0.9	1.85	0.18
Phaeodactylum sp.	20	2.0	50.9	5.09

Table 8. Influence of feed quantity on survival rate of juveniles (density of juveniles: 1300 L^{-1})

Feed quantity (cells ml^{-1})	Juvenile stage	
	Density (individuals L^{-1})	Survival rate (%)
5000	59.1	4.56
3000	13.7	1.54
1000	5.5	0.42

The results in Table 7 indicate that marine yeast is a desirable feed for breeding juveniles of sea cucumber. In practice, in commercial production a mixture of feed organisms is adopted that provides a range of nutrients to juveniles and increases the survival rate.

As larvae develop to doliolaria and pentactula stages, their bodies start to constrict and shrink to half the original size. About one or two days later, they metamorphose to early juveniles (about 400 µm long). During this stage, their behaviour changes from swimming to attaching. Hence, there should be substrates for attachment put in the rearing tank for this stage. Normally the attached density of juveniles should be controlled at 20–50 individuals 100 cm^{-2}.

Normally, the young seeds will spend several months in the nursery tank. Formulated feed has been used to feed the young animals until they grow to 2–3 cm. They are then moved to ponds for farming or to the open sea for sea ranching (Jiansan Jia and Jiaxin Chen 2001; Jiaxin Chen 1990).

Farming and sea ranching

In recent years, farming sea cucumber in ponds has become very popular in China. Digging new earth ponds is best, but used shrimp ponds can also be used after being improved to meet the ecological demands of sea cucumber.

Site selection

- The site must be at lower tide level, so seawater can be filled by gravity;
- There must be no pollution issues;
- The salinity should be over 27 ppt;
- Sandy or sand-muddy bottom is better;
- 2-metre depth is needed (no less than 1.5 m);
- Best pond size is in the 1–4 ha range;
- Ponds must be protected from typhoon or strong waves.

Layout of substrate of stone block

Before filling the ponds with seawater, stone blocks are laid on the bottom in rows or in cones (Fig. 2a, 2b). The stone blocks will be the "home" of the sea cucumbers, and are used as substrata to grow benthic algae and other organisms, which are a feed for the sea cucumbers.

Rows of stone blocks are 3 m wide by 1.5 m high. The interval between each row is 3–4 m. Cones of stone blocks have a diameter of 4–5 m at the base and a height of 1.5 m. The volume of stone used for substrata is around 2250 m^3 per hectare. Figure 3 shows a pond ready for sea cucumber farming.

The optimum temperature for sea cucumber growth is 10–17°C, but juveniles can maintain high growth rates at 24–25°C. In the northern part of China, the stocking season is from March to May. The stocking density depends on the size of seed (Table 9) and habitat conditions — including natural feed availability, seawater exchange rate, etc.

If the individual weight of seeds is 10 g at the start of the stocking season, mean weight of 150 g will be reached in October to November of the same year. If the seed weight is less than 1 g, it will take 15–18 months to reach commercial size.

The oxygen consumption of sea cucumber is much lower than that of shrimp (Table 10). This makes farming of sea cucumber easier than shrimp culture due to lower water exchange rate and no aeration facilities required. The cost of routine management is also much lower than that of shrimp culture.

In experimental farming, juveniles (body length: 3–4 cm) were stocked in early spring, with a density of 150,000 individuals per hectare. The yield reached 4000 to 7000 kg ha^{-1} in the following year.

Growth rates are very variable. Sampling showed that the weight of 0.5-year-olds ranges from 1.7 to 13 g, and 2.5-year-olds from 65 to 225 g. This is a factor influencing profit margins. Notwithstanding, farming sea cucumber is a lucrative industry in China that has been attracting more and more investors, transferring investment from shrimp culture to sea cucumber farming.

Sea ranching

Sea ranching of sea cucumber was initiated by the Yellow Sea Fisheries Research Institute in 1980. The results revealed that it was important to add substrata — like stone blocks — in the sea cucumber habitat. The functions of artificial substrata are to:

- protect the broodstock and their larvae against the predators,
- increase the availability of natural feed like benthic algae and accumulating organic debris, and
- improve the habitat for aestivation and hibernation.

A simple measure — to be tried in Shandong and Liaoning provinces — is to place stones or artificial reefs into selected sea areas. The criteria for site selection include water temperature (less than 25° C), salinity (27–35 ppt), and relative absence of predators like sea stars and crabs. The results indicate that the keys to success are site selection and routine management. In one site, located in Shandong Province, the output was increased by 16 fold after using enhancement practices (Jiansan Jia and Jiaxin Chen 2001; Shaodun Mu 1999.).

Marketing trends

The retail prices of beche-de-mer (dried sea cucumber) have increased dramatically since the 1980s. In 1960, the price for 1 kg of beche-de-mer (*Apostichopus japonicus*) was CYD[2] 18, in 1980 it was

Table 9. **Stocking density of different size of seed**

Size of seeds (individuals kg^{-1})	Stocking density (individuals ha^{-1})
60–100	100,000–150,000
200–400	250,000–300,000
> 1000	400,000–450,000

Table 10. **Sea cucumber oxygen consumption***

Age (yrs)	Mean body weight (g $ind.^{-1}$)	Consumption of oxygen (ml O_2 h^{-1})	Consumption rate of oxygen (ml O_2 g^{-1} h^{-1})
0.5	7.5	0.488	0.016
1.0	26.3	1.152	0.011
2.5	110.5	1.051	0.009

* Temperature: 18–20°C and salinity: 29.9–30.8 ppt

2. CYD: China Yuan Renminbi. In April 2003: CYD 100 = USD 12.10

a. Using rows of stones **b. Using cones of stones**

Figure 2. Two types of ponds used for sea cucumber farming

Figure 3. Ponds ready to be used for sea cucumber farming

CYD 500, and in 1990, CYD 600–1000. At present, the price can exceed CYD 3000 (about USD 370) per kilo! The soaring price has stimulated the development of sea cucumber farming. Prices for beche-de-mer from tropical regions — including white teatfish, black teatfish and sandfish — have increased steadily, but not as rapidly as those of *Apostichopus japonicus*. The reason for this is that the quality of these tropical species cannot compare with the quality of *Apostichopus japonicus*. The area of sea cucumber farming has reached 10,000 ha. The increase in farming area should result in productivity increase. The author estimates that prices of beche-de-mer, especially of *A. japonicus*, will stabilise in response to the increase in domestic production and imports from Russia and Japan in the near future.

New products — including frozen or lyophilised sea cucumbers, and extracts used as nutrient supplement or function food — have emerged in the domestic market. Changes to the traditional processing method have been initiated because the old method damages some useful elements like glycosaminoglycan.

It is believed that sea cucumber farming will become a prosperous sector of Chinese mariculture. It will involve the development of a processing industry and pharmaceutical industry related to the sea cucumber. Meanwhile, it plays an active role in protecting natural populations.

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