China Sustainable Seafood Assessment (CSSA)

Aquaculture

Japanese Spiky Sea Cucumber (*Apostichopus japonicas*)
Bottom Sowing Culture

CSSA Team

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Statement

In the assessment of all species, the China Sustainable Seafood Assessment (CSSA) team will strictly follow the assessment criteria and refer to the latest, impartial and objective scientific data. Common sources of reference for evaluation data include literature review, official materials, objective and unbiased media reports, data obtained from field research, and expert interviews. Inevitably, many fisheries face the problem of lacking robust data, and some data are not publicly available, which may affect the assessment results to some extent. The CSSA team is committed to carrying out the assessment and evaluation of the species objectively and impartially, basing on respecting objective facts, making maximum use of open data, and relying on rigorous scrutiny of experts. The results of the species assessment do not represent the opinion of any particular expert, scholar, etc.. The CSSA team has the right to the final interpretation of the assessment results.

Content

Introduction

China is the world's largest fishing country, and also has a large consumer market for aquatic products. The food choices we make determine the present and future of our marine and freshwater ecosystems. In order to cultivate a new generation of responsible seafood foodies, Qingdao Marine Conservation Society (QMCS) has launched the China Sustainable Seafood Assessment (CSSA) project to customize scientific and interesting sustainable seafood consumption guides for domestic consumers. We hope that by raising public awareness and promoting changes in consumer behavior, we can use the power of the market to force industrial transformation and make a lasting contribution to the continuous improvement of the health of China's marine and freshwater ecosystem.

Executive Summary

The population of wild sea cucumber is declining due to overfishing. Its natural stock faces depletion. Japanese Spiky Sea Cucumber (*Apostichopus japonicas*) was rated EN(Endangered) by the IUCN Red List in 2013. In order to solve the contradiction between market and resources, the industry of sea cucumbers farming emerged. With the well-rounded skills of seedlings production, the scale and yield of sea cucumber bottom sowing culture are increasing and thriving in our country year by year, and the sea cucumber cultured by bottom sowing is a good substitute for wild sea cucumber.

Both natural parent sea cucumber and artificial seedling sea cucumber are used in sea cucumber bottom sowing culture in China. With the decrease of the number of wild seedling sea cucumber, artificial seedling has gradually become the main source of sea cucumber seedlings. However, there are also some problems such as germplasm degradation and low survival rate in artificial seedling. In order to improve the efficiency of breeding, the quality of the seafloor may be reformed before seeding, including submarine rock casting, submarine blasting reef building, etc., which may cause negative effects such as changes to natural habitats. In the process of bottom sowing culture, there is no specific regulation on the amount of sea cucumber. The actual production adopts the mode of rotation of fishing and releasing, catch the big and release the small, and the seedlings are supplemented according to the growth situation of sea cucumber. The sea cucumber cultured by bottom sowing mainly feed on natural food in the cultured sea area, without artificial feeding. There may be some risk of illegal drug use in the breeding process of sea cucumber cultured by bottom sowing, and some drug residues exceed the standard. At present, the main culture species of sea cucumbers in bottom sowing are native species， *Apostichopus japonicus*, in China. The risk of escaping from the culture area is low due to the fact that this species has relatively lower mobility. However, the selection and management of wild sea cucumber germplasm reserve should be strengthened, and the requirement to protect the genetic diversity and wild population of sea cucumber should be fully considered in the bottom sowing and the operation of marine ranching. The main harvesting method of sea cucumber cultured by bottom sowing is hand picking by diving, which has limited influence on the habitat and less risk of contact with other wild species. In regard to the ecological impact of aquaculture, the construction of marine ranches currently lacks sufficient foundational theoretical research, resulting in a considerable degree of uncertainty and arbitrariness. There is a deficiency in comprehensive data analysis and technological support to assess the specific ecological advantages and risks. China has established a marine environment observation network

to conduct long-term monitoring of dynamic changes in marine ecosystems and the environment, providing long-term, basic data and scientific basis for ensuring the ecological and environmental safety of regional coastal zones and improving the integrated management and sustainable development of coastal zones. However, due to the lack of national and industry standards and the lack of coordination between regions, the sea cucumber bottom sowing culture industry in China is still in the stage of exploration on how to conduct ecosystem-based fisheries management and maximize ecological and economic benefits.

In conclusion, despite the existing deficiencies in management and risk assessment, CSSA rate that bottom-sowing aquaculture of sea cucumbers in China as green- relatively environmentally friendly and consumers are recommended to consider consuming them.

Japanese Spiky Sea Cucumber

Apostichopus japonicas

Recommend

(Bottom Sowing)

Overview of the Assessed Species

1.Biological Features

Sea cucumber falls into the phylum Echinodermata, and is the common name for animals in the class Holothuroidea. There are now 1,259 species of sea cucumbers globally that all are marine species and distributed in tropical and temperate zone. Among them, over 140 species can be found in China. About 40 sea cucumber species are edible worldwide while about 20 of these edible species are distributed from the Bohai Bay and Liaodong Peninsula in the northern China to the Spratly Islands in the southern China. (Yang, Zhou, and Zhang, 2014) The primary species farmed in northern China is Japanese Spiky Sea Cucumber (*Apostichopus japonicas*) commonly known as sea cucumber; while more species can be found in the southern part of China, including *Acaudina molpadioides*, *Stichopus variegates*, *Thelenota ananas*, *Stichopus chloronotus*, *Actinopyga mauritiana*, *Holothuria nobilis*, and *Stichopus horens*. (Zhao, Wu, and Chen, 2019)

The main assessment species of this paper, Japanese Spiky Sea Cucumber (*Apostichopus japonicas*) is mainly distributed in Northeast Asia, including north China, Japan, North Korea, South Korea, and the shallow coastal waters of the Russian Far East. Sea cucumber mainly lives in the stony or sandy seabed where algae or seagrass grow. It feeds with its tentacles on organic debris (plant and animal remains), protozoa, microorganisms, diatoms, and feces of other animals, and plays the role of “cleaner” at the bottom of the sea.

Sea cucumbers are dioecious, with sexual maturity reached at the age of 2. The gonads of male sea cucumbers are white, while those of females are orange-red. A 500g parent sea cucumber can produce approximately 6 to 7 million eggs, while a 250g parent sea cucumber can produce around 3 million eggs (Li, 2006).

There are many theories about the life span of sea cucumbers such as 5 years, 7-8 years, and 10-11

years. The culture time from juveniles to mature products depends on the growing condition. In general, pond farming takes 2-3 years and bottom sowing culture would take 3-5 years before harvest (Qiu, 2013).

2.Major Farming Area and Methods

In China, due to the depletion of wild resources, sea cucumber culture and fishing mainly target Japanese Spiky Sea Cucumber, and the culture and fishing areas are mainly concentrated in the coastal areas around Shandong Peninsula and Liaodong Peninsula. The increasing scale and yield of sea cucumber mariculture brings significant economical profits, of which *Apostichopus japonicus* being the most profitable farm-raised species (Yang, Zhou, Zhang, 2014).

The bay with small wind wave, smooth tidal current, no fresh water injection and easy management is mainly chosen as culture area for sea cucumber. Artificial substrate improvement was carried out by means of artificial reef and sea cucumber reef to provide comfortable attachment and habitat for sea cucumber growth. Breeding algae on the reef provides food for the growth of sea cucumbers, as well as the habitat for sea cucumbers, and protects sea cucumbers from the impact of sea currents. The suitable algae mainly include *Undaria pinnatifida*, *Sargassum thunbergii*, *Gracilaria* and *Ulva lactuca*. Generally, the seeding time of *Apostichopus japonicas* is in March, April or October and November, and it is directly sown around the reefs, the sea water temperature is 8-11 ℃, the seed size is 10-50 g/individual, and the density is 5,000-10,000 individual/mu (mu, Chinese unit of land measurement that is commonly 666.7 square metres) (Yang, Zhou, and Zhang, 2014). *Apostichopus japonicas* is harvested in spring or autumn. Its fishing method is generally hand picking by diving, which adopts the mode of rotation of fishing and releasing, catch the big and release the small, and a certain number of seedlings are supplemented according to the growth and fishing situation of sea cucumber (Zhao and Run, 2017).

The bottom sowing culture of *Apostichopus japonicas* is mainly distributed in the north China, which is its natural habitat. In recent years, the scale of bottom sowing culture in Liaoning, Shandong and Hebei has been maintained at 2.4-2.5 million mu, and has shown a slight growth trend. The bottom sowing aquaculture industry chain of *Apostichopus japonicas* has become one of the economic income of fishers in northern China, and has certain social significance (Yang, Zhang, and Song, 2018). Bottom-cultured sea cucumbers rely on natural food sources, reducing farming costs. They do not require artificial feeding, thereby reducing labor and resources.

3. Trade Related Status

At the moment, the trading and consuming markets have centered in China, Singapore, Japan, South Korea, the United States, Indonesia, and Philippines (Yang, Zhou, and Zhang, 2014). Apart from the sea cucumbers produced domestically in China, imports have also been increasing for the recent years. In 2016, 0.95 tons of sea cucumbers were imported from the Far East and the number rose to 5.08 tons in 2017. The next year in 2018, the quantity of imported sea cucumber products went up to 16 tons.

Due to the high demand and high price of wild sea cucumbers in China, the overfishing of wild sea cucumbers is very serious. According to historical data, the decline of natural resources of *Apostichopus japonicas* in China is very prominent: in the 1960s, the annual output of *Apostichopus japonicas* in Shandong and Liaoning provinces was about 260-280 tons, and in the 1970s, it dropped to 60-80 tons (Zhang Yu et al., 1984; Zhang Chunyun et al., 2004). Japan, the other major producer

of *Apostichopus japonicas*, is not immune to poaching and the black market for sea cucumbers (also mainly for the Chinese market). Due to the declining of wild population, the International Union for Conservation of Nature (IUCN) rated *Apostichopus japonicas* EN (Endangered) in 2013, which is higher than that of giant panda (in 2016, considering China's long-term effective protection and the recovery of the wild panda population, IUCN downgraded giant pandas from EU to VU, namely "Vulnerable" (Hamel& Mercier, 2013). In addition to dried sea cucumber products, there are deep-processed foods such as canned sea cucumber, sea cucumber wine, sea cucumber milk, and nutritive products.

4.Common Names and Main Production Area

Apostichopus japonicas is the primary edible sea cucumber species as well as the most industrialized bottom sowing species in China. It is from phylum Echinodermata, class Holothuroidea, order Aspidochirotida, family Stichopodidae, and genus *Apostichopus*. Normally the mature individuals are 20-40cm long that have cylindrical body with bulge on the back, where has 4-6 line of uneven distributed conical protuberances. It has flat underside with dense tube feet (podia) in 3 irregular lengthwise rows. The color of its back is yellowish-brown or chestnut black; the ventral side is more of a yellowish-brown or reddish-brown. The population mainly distribute along the coast in the northern China (Dalian, Liaoning Province; Changshan Islands; Beidaihe, Hebei Province; Dongying, Qingdao, Jiaonan, Rizhao of Shandong Peninsula; Liangyungang, Jiangsu Province).

Stichopus variegatus generally has a body length of 30-40cm and shape similar to a cuboid. They have conical protuberances on their backs and mostly have pale yellow color with different shades of olive spots, grey-yellow or light brown mesh pattern, or green stripes. The major distribution sites are in Guangxi, Guangdong, Hainan Province and Xisha Islands.

Holothuria scabra has a large body size and can grow to 70cm, and its common size would be 30-40cm long and 8-10 cm wide. It has rough skin and diverse colour, which generally is dark greenish-brown with few black stripes. Along the centre line on the back, the colour is darker in the middle while lighter to the sides, and would be white at the underside. The major distribution sites are located in the coastal area of Guangdong, Guangxi, and Hainan Province. This species is one of the most important seafood in the southern China, and is relatively easy to cultivate.

Stichopus chloronotus is generally 30 cm long and has a quadrangular column shape. There are two rows of intersecting conical spines along each corner of the body. The body colour is thick green or black green, and the tube feet are black gray. It has a large production in the Xisha Islands, the south of Hainan Island and Guangxi Beihai Sea. Because it is too soft, tender and easy to self-dissolve, it needs to be processed in time after collection, otherwise it is easy to rot and decompose.

Thelenota ananas, the largest sea cucumber, has a full body extension of up to 1 meter and a general body length of 60-80 cm, with numerous and dense tubes arranged irregularly. Its back wart foot is very large and spiny. Every 3-11 spines are connected at the base and are petal-like, so it is called "plum sea cucumber", also known as "pineapple sea cucumber". Its ventral surface is flat and reddish, the tube feet are small and densely covered, the dorsal surface is orange-yellow or orange-red, with scattered yellow and brown spots, and the tentacles are yellow. Due to overfishing in the commercial market, *Thelenota ananas* is on the verge of extinction. It is distributed in Xisha Islands, Zhongsha Islands and Nansha Islands.

Actinopyga mauritiana, also known as White-spotted Sea Cucumber, has a common size of 35cm long and has 25 ~ 27 tentacles. There are many small warts scattered on the back, and there is a white ring at the base of each wart, and the back is generally brown. Because of its developed skin muscle sac, its dry products are of good quality and can be used as a first-class edible sea cucumber. It is mainly distributed in southern Taiwan Province, southern Hainan Island and Xisha Islands.

5. Food Safety and Recommendation

Sea cucumber bottom sowing culture is a rearing practice where seedlings are placed directly on the seafloor, and grow freely in a natural environment for 2-3 years (the length of the culture cycle is closely related to the natural resources of the food in the culture area). Through the collection of divers, no need to artificially put any feeds and drugs during the culture period, sea cucumbers can be closest to the natural growth situation, coupled with the culture sea environment is often far from the coast and away from the environmental pollution which makes the water quality good. The transportation of sea cucumbers is relatively easy and the risk of illegal chemical addition is low. However, in the process of sea cucumber processing and sales, such as the process of dried sea cucumbers after soaking in water, there may be risks of illegal use of chemicals. For example, adding potassium alum into the products can boost the appearance but result in an excess of aluminum in sea cucumbers. Besides, using Formaldehyde is helpful for prolonging the storage life of sea cucumbers but Formaldehyde in the products can go beyond what is legally allowed (Luo and Zhang, 2014; National Medical Products Administration, 2018). The most common way of processing is salt drying, during which adulterations are possible by adding sugar and starch into the products.

FULL ASSESSMENT

Criterion 1: Aquaculture Method and Management Status

Aquaculture method and industry overview

The sea cucumber bottom sowing culture is usually carried out by ecological cultivation technology, and diversified cultivation models such as "algae-abalone-sea cucumber", "algae-fish-sea cucumber", and "seagrass-sea cucumber - shellfish" are constructed. (Yang, Zhou, Zhang, 2014) For example, some farms in Laoshan area of Qingdao, Shandong Province adopted the mixed culture model of "seaweed - abalone - sea cucumber" to multiply large algae and sow Pacific ablone (*Haliotis discus hannai*) and *Apostichopus japonicas* on the bottom, forming three aquaculture functional groups of primary producers (phytoplankton, large algae), primary consumers (abalone) and sediment feeding consumers (sea cucumber), forming a small ecosystem on the seabed: The algae release a lot of oxygen through photosynthesis for shellfish, and the carbon dioxide emitted by the shellfish is absorbed by the algae, and the waste is eaten by the sea cucumbers. The excess organic matter such as nitrogen and phosphorus in seawater is absorbed by algae, and the algae provides rich nutrients for the growth of abalone. In the process of constructing marine ranching, artificial reefs will be built in the offshore waters, the most common way is shipwrecks and stone throwing, and there are also artificial reefs with oyster shells, but in general, stone throwing is the most common way. The appropriate location and time will be selected, so as to prevent a large number of oysters from multiplying here and unable to grow seaweed, and the place where oysters are growing will attract starfish (Chinese aquaculture network, 2011).

At present, the harvesting method of sea cucumber is mainly hand picking, and the industry insiders call the fishers "sea warriors". Sea cucumbers are generally sown at a depth of 4-5 meters, or even 10-20 meters, and after 2-3 years of growth, they can reach the product size. Divers usually choose the weather where the wind is within level 3 and the water temperature is 13-18 ° C, and identify the position of the sea cucumber to be caught. Divers enter the water for 30-40 minutes each time, too long will cause harm to them. The amount of sea cucumber caught each time is about 25-30 kg, and 250-300 kg can be caught in a day. The fishing season generally lasts for a month, and is divided into spring and autumn twice a year, that is, April-May and October-November. During harvesting, sea cucumbers are typically selected at a rate of 3 to 4 individuals per 500 grams. Upon being brought aboard, they are sorted, with smaller ones being returned to the sea (China Sea Cucumber Network, 2017). Its fishing method generally adopts the mode of rotation of fishing and releasing, catch the big and release the small, and a certain number of seedlings are supplemented according to the current population and the reasonable stocking density of sea cucumber. This traditional fishing method is risky, with high cost and low efficiency, so it is urgent to strengthen relevant research, develop automatic fishing equipment, and improve the modernization level of the industry.

Government supervision

The culture of sea cucumber involves the breeding and production of sea cucumber seedlings, bottom sowing culture, fishing and so on. In addition to seedling production, sea cucumber bottom sowing is still managed in accordance with aquaculture regulations in China, so all of the activities need to be carried out under the framework of relevant laws and regulations of culture. *The Fisheries Law of the People's Republic of China* makes relevant provisions on the planning of waters and tidal flats for aquaculture, the issuance of aquaculture certificates and the fishing industry. The government would plan and manage the use of marine areas and make decisions on which marine area or tidal flat can be utilized for aquaculture. Companies and individuals can only run the farm within the approved areas and should apply for permission from fishery department of the local government (above the county level), then the people's government at the corresponding level shall issue the licenses such as a seedling production license or a breeding production license to permit the companies and individuals to use the water area or tidal flats for culture production.

The government enacts *Standards of Water Quality for Fisheries* for aquaculture water to explicitly stipulate the content of 33 indicators in the aquatic water including heavy metal, veterinary medicines, E. coli, pH, Dissolved Oxygen (DO), etc. In coastal waters, according to different usage functions and protection objectives of the sea area, the seawater quality is classified into four categories according to the *Standards of Sea Water Quality*. The second category of seawater quality is suitable for aquaculture. That is to say the quality of sea water should reach the standards of category I or II before conducting any sea cucumber culture practices. To ensure the food safety of aquatic products, environmental conditions of the cultivation sites should meet the water quality requirements in the *Standards of Water Quality for Fisheries* as well as *Specifications for the Quality and Safety of Pollution-Free Products.*

In order to guarantee the food security of aquaculture products, regulations have been put forward such as *Regulations on Quality and Safety Management of Aquaculture, Regulations on Veterinary Drug Management, Guidelines for Using Fishery Drugs in Pollution-Free Food Production* (China Aquaculture Website, 2009). It is not allowed to apply legally forbidden drugs in the culture process (see details in the announcement no. 193 and 235 of Ministry of Agriculture); it prohibits the use of

pharmaceuticals and active pharmaceutical ingredients intended for human use; it is not allowed to apply medicine that do not have licenses or Approval Number, or fail to meet the production criteria; it is essential to follow the regulations on withdrawal time before the products enter the market. In the meantime, from the monitoring level, the Ministry of Agriculture would proceed with regular inspections on sea cucumber products on the market.

On the basis of national fishery management laws and regulations, many regions will formulate some supporting policies according to local conditions. Since 2010, Zhuanghe, Liaoning Province, has carried out comprehensive prevention and control of mariculture diseases and marine environment monitoring, regularly tested seawater quality, algal and bacteria indicators, and guided the implementation of management measures for bottom sowing production (Fisheries and Fisheries Administration Bureau, 2010). Liaoning Province attaches great importance to the construction of marine ranches, and has proposed for many years to "accelerate the construction of marine ranching" and "vigorously develop modern marine ranching" (Fisheries Administration, 2019). In 2017, the Ministry of Agriculture and Rural Affairs issued the "*National Marine Ranching Demonstration Area Construction Plan (2017-2025)*". Shandong Province issued China's first local standard of "*Marine ranching construction Standards*" to provide relevant technical support for marine ranching construction in Shandong Province, the national standard "*Technical guidelines for marine ranching construction*" was officially released in 2021.

Despite this, there is a lack of systematic management in China for the artificial reef deployment during sea cucumber bottom sowing, as well as a deficiency in technologies for natural bait proliferation and juvenile sheltering in marine ranches. Additionally, there is a shortage of regulations regarding seedling release and product harvesting standards for sea cucumber bottom sowing aquaculture. Moreover, there is a widespread lack of assessment regarding the ecological impact of sea cucumber bottom sowing aquaculture. In addition, the established technical specifications and standards related to sea cucumber seedling breeding and bottom sowing culture are not well popularized and implemented in the production, and there are phenomena of expanding production scale, increasing the density of bottom sowing culture, and exceeding the ocean carrying capacity (Xie Suyan, Bao Pengyun, 2014). As industrial pollution flows into the sea and the water environment deteriorates, sea cucumbers are prone to disease and death. The governments should strengthen the control of sewage discharge to provide a healthy culture environment for sea cucumbers and other marine organisms. At the same time, it is necessary to strengthen the aquaculture knowledge of farmers, guiding them to make informed decisions regarding seedling release and to adopt appropriate measures for disease prevention and natural disaster preparedness. This approach will help to enhance sea cucumber yield. Additionally, coordinated development in terms of the ownership and management of marine areas designated for aquaculture is also essential.

Criterion 2: Habitat Impact

Habitat impacts

In view of the increasing market demand for sea cucumbers, in recent years, artificial reefs and marine ranching are increasingly emerging to create a suitable living environment for sea cucumbers in order to increase the production of sea cucumbers. In order to improve the culture efficiency, the sediment quality of the sea area will be reformed before seeding, and the marine ranching will be built to provide comfortable attachment and habitat for the growth of sea cucumbers. The methods

of sediment material reconstruction include submarine rock casting, submarine blasting to build reefs, construction of artificial algal fields, artificial trapping and removal of predators, etc. (Wang Weimin et al., 2012). These operations, especially seabed blasting and reef building, can cause negative impacts such as changes in natural habitats, but there is a relative lack of assessment of the possible environmental impact of relevant sediment modification.

The results show that the construction of sea cucumber reef provides the adhesion base for algae, such as *Undaria pinnatifida*, *Sargassum thunbergii*, *Gracilaria* and *Ulva lactuca*, which provides habitat for sea cucumber growth, and can protect sea cucumber from the impact of sea current. Some studies suggest that artificial reefs can aggregate marine life, improve community structure, restore fishery resources, enhance carbon sequestration capacity, and have minimal impact on surrounding currents and other species, suggesting that artificial reefs are considered an effective measure for improving the marine ecological environment. (Yang, Zhou, Zhang, 2014). However, the impact of artificial reefs on the sea floor is irreversible. Artificial reefs mainly consist of stone block reefs, small structural reefs, and decommissioned fishing vessels. However, most of the reef deployment is done without proper evaluation and necessary monitoring and assessment of effectiveness. The selection of fish reef types is not always science-based, leading to issues such as drift, sinking, and burial of reef bodies in some fishing grounds. After the reefs are constructed, there is a lack of government oversight and management, allowing them to deteriorate without maintenance. Currently, there is limited research and data on the ecosystem of sea cucumber aquaculture areas, and there have been no reports of influence to the current ecological environment caused by them.

Currently, there is a lack of comprehensive assessment regarding the impact of bottom-sowing sea cucumber aquaculture to the marine habitats. To evaluate the effectiveness of aquaculture, methods such as hydroacoustic technology can be used to assess the biomass and spatial distribution of biological resources in the water column, providing insights into the effectiveness of aquaculture (Brandt, 1996; Mehner, Schulz, 2002). Additionally, underwater visual inspection or video recordings by divers can be employed to assess the habitat status of aquaculture waters, thereby facilitating ecosystem-based management strategies.

Criterion 3: Chemical Use and Disease Control

Bottom sowing sea cucumber aquaculture involves releasing cultivated seedlings directly onto the seabed, typically in waters of 4-5 meters deep or even deeper, ranging from 10 to 20 meters. After bottom-sowing, sea cucumbers grow naturally without the need for chemical intervention. Sea cucumbers grown in natural marine environments are greatly influenced by water quality conditions in the area. Diseases that may affect sea cucumbers generally do not require artificial prevention or control measures. During the hot summer months, outbreaks of seaweed such as *Enteromorpha prolifera* may lead to reduced oxygen levels and deterioration of the seabed, resulting in sea cucumber mortality. In such cases, manual removal and the use of artificial barriers are commonly employed to mitigate the impact of seaweed. Overall, bottom-sowing areas are located in open marine environments where sea cucumbers live on the seabed, and they are less affected by environmental pollution such as red tides and coastal pollutants.

However, the breeding process of sea cucumber seedlings required for bottom sowing has problems with the use of chemical drugs. At present, the breeding of sea cucumber seedlings generally adopts

the way of factory breeding. In this process, the quality of sea cucumber seedlings may be decreased due to poor quality of parents and non-standard production of seedlings, which may lead to the risk of illegal drug use. In order to ensure the survival rate during seedling rearing, the seedling production enterprises may use antibacterial drugs for disease prevention and control, and some enterprises even use prohibited nitrofuran drugs (Cheng et al., 2014; Yuan et al., 2014; Cui, 2018). In order to strengthen the management of aquatic seedlings and improve the quality level of aquatic seedlings, the Ministry of Agriculture has formulated important documents such as the *Measures for the Management of Aquatic Seedlings*, *Norms for the Production Management of Aquatic Seed and Breeding Farms*, and *Acceptance Measures for Aquatic Seed and Breeding Farms*. In response to the problem of seedling quality and safety sampling, the Ministry of Agriculture has also issued the *Technical Specifications for Inspection of Prohibited Drugs in Aquatic Seedlings*, which regulates the techniques of sampling and detection of prohibited drugs in aquatic products. Although the government has formulated many laws and regulations and taken a series of measures, there is still a phenomenon of excessive drugs in the quality and safety supervision of sea cucumber seedlings (China Fisheries Information Network, 2015), which needs to continue to strengthen supervision.

Criterion 4: Escape Risk and Response Method

Escape risk

Although some studies have shown that sea cucumbers have a certain selectivity for habitat, light and other environmental factors (Yang, Zhou, Zhang, 2014), many experts believe that at present, almost all sea cucumbers cultured by bottom sowing in China are *Apostichopus japonicus*, which is a native species in China. In addition, sea cucumbers have limited activity capacity, and the risk of escape is small. However, considering the IUNC endangered level of wild *Apostichopus japonicus*, if a large number of cultured *Apostichopus japonicus* are selected strains, there is possibility to cause genetic pollution to wild *Apostichopus japonicus* in various sea areas. It is suggested that the selection and management of wild sea cucumber germplasm reserves should be strengthened, and the need to protect the genetic diversity and wild population of sea cucumber should be fully considered in the breeding of bottom sowing and the operation of marine ranching.

Criterion 5: Feed Requirements

Wild caught fishery resources ratio and sustainability in aquaculture feed

Sea cucumber bottom sowing usually occurs in areas with sedimentary substrates rich in organic matter and abundant biological feed organisms. In most cases, bottom-sowed sea cucumbers rely entirely on natural organic matter and algal resources within the marine area for food. With the development of marine ranching technology, there are also methods such as improving seabed habitats to provide better environments and food sources for sea cucumber growth. For example, during the algae breeding season, mature spores of seaweeds such as *Undaria pinnatifida*, *Sargassum thunbergii*, *Gracilaria*, *Ulva lactuca* can be released onto the reef. After the growth of algae, they can become food sources for bottom-sowed sea cucumbers.

Criterion 6: Source of Stock

Source of seedlings

At present, the seedlings of bottom sowing and pond culture of *Apostichopus japonicus* in China are mainly derived from artificial cultivation. Since 1960s, artificial seedling technology of sea cucumber began to develop in China. With the increasing market demand, wild seedlings are becoming more and more rare, and the maturity of artificial seedling technology plays an important role in the development of sea cucumber aquaculture industry. Sea cucumber seedlings are generally divided into spring seedlings and autumn seedlings. Liaoning and Shandong provinces are the main producing areas of sea cucumber seedlings. In recent years, the practice of "cultivating sea cucumbers in the north and rearing them in the south" has become increasingly mature and popular. This method takes advantage of the temperature differences between the northern and southern regions. Sea cucumber seedlings are initially raised in the northern regions, then transferred to the southern regions for overwintering and eventual sale. This approach significantly shortens the cultivation cycle. According to the regulations, the sea cucumber breeding enterprises should purchase the required seedlings from the sea cucumber breeding farm or the nursery farm with the seedling production license. According to the *China Fishery Statistical Yearbook*, in recent years, the production of seedlings and the production of commercial sea cucumbers increased year by year. However, the overall survival rate of seedlings was not high, and remained at the level of 4%-5% for many years. The mortality rate of seedlings from early stage to commercial sea cucumber stage is high, and more than 90% of the investment in the early stage has not received effective return, which has become a serious loss in the industry. The main reason lies in the quality of the seedlings. In the sea cucumber industry chain, the seedling and farming sectors are often relatively independent, so that the breeder excessively pursues the yield of seedlings and ignores the quality(Yang, Zhou, Zhang, 2014). Under this background, the technology of ecological seedling cultivation and selection and breeding of *Apostichopus japonicus* is particularly urgent and important.

Wild sea cucumbers and cultivated sea cucumbers are the two main sources of sea cucumber seeds. At the current level of technology, it is generally believed the wild population that has better spawning maturity level and it is the preferred choice. Artificially bred sea cucumbers are also developed based on widely collected sea cucumber resources in the sea cucumber farming areas of China. The broodstock are collected 7-10 days before spawning when the sea temperature is between 15-17℃ (China Aquaculture Website, 2014).

The lack of long-term conservation strategy and the lack of monitoring systems, coupled with customer preferences on wild sea cucumbers, led to overfishing and a sharp decrease of wild population. Currently, there is a phenomenon in sea cucumber seedling factories where wild sea cucumbers that have not been domesticated are used, and in some cases, sea cucumbers that have been raised in ponds through multiple generations are used as breeding stock for seedling cultivation. This practice leads to severe degradation of genetic traits in the seedlings, resulting in reduced seedling quality, slow growth rates, weakened resistance to environmental stress, and decreased disease resistance in sea cucumbers. The decline in seedling quality has become one of the primary factors constraining the healthy development of the sea cucumber aquaculture industry. Additionally, the rapid growth in market demand drives producers to overfish sea cucumber resources, resulting in a noticeable decline in the quantity of natural sea cucumber resources. In the 1960s, the annual production of sea cucumbers in Shandong and Liaoning provinces was approximately 260-280 tons,

but by the 1970s, it decreased to 60-80 tons (Zhang Yu et al., 1984; Zhang Chunyun et al., 2004). The expansion of aquaculture scale implies further increased demand for wild seedlings, which will inevitably exert greater pressure on already declining wild resources. At present, both scientific researchers and industry practitioners in China have recognized this issue. Research on the artificial selection and improvement of sea cucumber germplasm is actively underway. The goal is to provide germplasm assurance for the further development of China's sea cucumber aquaculture industry. Considering the IUNC endangered level of wild *Apostichopus japonicus*, if a large number of artificial breeding *Apostichopus japonicus* are cultured, it may cause genetic pollution to wild *Apostichopus japonicus* in various sea areas. It is suggested that the selection and management of wild sea cucumber germplasm reserves should be strengthened, and the need to protect the genetic diversity and wild population of sea cucumber should be fully considered in the breeding of bottom sowing and the operation of marine ranching. From the perspective of biodiversity conservation (especially genetic diversity), artificial bred seedlings should be restricted to be farmed in artificial environments.

Criterion 7: Wildlife Interaction

Wildlife (especially threatened species) interaction

Since sea cucumbers cultured by bottom sowing basically grow under natural conditions, there is less human intervention, and artificial diving is only needed when harvesting, so it is less likely to have an impact on other wildlife. Of course, in a few cases, sea cucumber harvesting will also use fishing gear, fishers generally choose a relatively flat area to carry out, which has a limited impact on sensitive marine habitats such as seagrass beds. During the culture of sea cucumbers, there are few occurrences of seabirds, dolphins, etc., so there is little impact on the resources of endangered, threatened, and protected (ETP) species. However, the culture of sea cucumber occupies the natural habitat and breeding site of other aquatic species in space, and the environmental changes caused by culture may also hinder the natural reproduction of other aquatic species to a certain extent (Zhang, Wang, Rong et al.,2004).

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