China Sustainable Seafood Assessment (CSSA)

Aquaculture

Japanese Spiky Sea Cucumber (*Apostichopus japonicas*)
Coastal Pond Culture

CSSA Team

December 2023

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 for that limited natural resources to meet the market demands, the industry of sea cucumbers farming emerged. With the development of larval rearing techniques, the scale and yield of sea cucumber production has been increasing and thriving in China.

There are many problems existing in pond farming of sea cucumbers, for instance, the misuses of chemicals and disinfectors (e.g. quick lime, calcium hypochlorite, camellia seed extract) that were applied for cleaning the ponds would lead to a lower biodiversity in the surrounding area and would break the balance of nearby marine ecosystems. Long-term pond farming on a large scale can, to some extent, affects the quality of surrounding soil. Degraded soil changes the population composition of macro zoobenthos, which affects local biodiversity. Besides, pond farming of sea cucumbers occupied the coastal wetlands in the northern China. As a result, the loss of habitats would have a negative impact on East Asia-Australia migratory birds. Lower biodiversity caused by chemicals used in farming procedure also has indirectly led to food scarcity, which would threaten endangered or threatened avian species - primarily shorebirds.

The major farmed species used in pond farming originates from China. The risk of escaping from the farming ponds is low due to the fact that this species has relatively lower mobility as well as the fact that sea cucumbers are isolated from the environment. From the perspective of larval rearing and production cycle, in early stage the sea cucumbers feed on microalgae such as diatom, *Sargassum thunbergii*, and large brown macroalgae*;* juveniles are mostly on artificial diet while the mature individuals solely feed on artificial diet. The artificial diet for the sea cucumbers consists of various macro algae and sea grass including *Sargassum thunbergii, Scagassum,* and *Zostera,* which are plant-based protein. Sea mud can also be used in their diet, but the exploitation of sea mud would damage the seafloor where inhabited many benthic species. A number of sustainable substitute products are available to mitigate the impacts on the kelp forest and the seagrass meadow. Plant-based substitutes (e.g. bran, corn flour, bean cake) and animal protein from the waste of marine catches (i.e. shrimp, crab, fish) have already been used in sea cucumber diet development. These substitutes not only can meet the requirement for wider food range and nutrition, but also would improve the feeding behaviour and ingestion rate. From the current trends in sea cucumber production, a more sustainable and eco-friendly marine ranching technique would be possible by constructing an

advanced farming industry with different plants and animals structurally complementary - marine algae, sea cucumbers, and fish. This sustainable production mode is going to be the future mainstream. As for the seed supply, captive breeding is the major breeding technique applied in sea cucumber production, while the broodstock are cultivated from wild individuals.

To conclude, the CSSA team consider sea cucumbers pond farming as an industry with high yield and profit, but problems such as chemical misuse, breaking ecological/niche balance of coastal wetland, and threatening migratory birds, are still existing. There are legislations addressing the production procedures, but they are not being followed very well and have low practical values, and tidal flat reclamation and waste water disposal problems persist. Therefore, pond farming of sea cucumbers is rated RED, which means it would cause negative influences on the environment, and a stronger monitoring system with more applicable standards is needed. It is necessary to arrange and manage the tidal flats with reasonable management plans to regulate waste water disposal from sea cucumber farms in order to avoid the disposing of waste water from the farming sites and the reclamation of coastal area that may affect marine ecosystems and the habitats of endangered avian species. The government and research institutions should invest more in the development of a healthier farming mode and take the sea cucumber pond farming industry to a more eco-friendly and sustainable future. Then the industry can guarantee food safety and improve the health and integrity of ecological environment.

Japanese Spiky Sea Cucumber

Apostichopus japonicas

Not Recommend

(Pond Farming)

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 1259 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);* 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 reproduction cycle of sea cucumbers has six phases which are pre-auricularia larva, mid-auricularia larva, post-auricularia larva, doliolaria larva, pentacularia larva, and juvenile stage. Take *Apostichopus japonicus* for an example, it takes 11-12 days for them to grow from eggs to juveniles (Sun, 2013). There are many theories about the life span of sea cucumbers such as 5 years, 7-8 years, and 10-11 years. The required development time from juveniles to mature products depends on the growing condition. In general, pond farming takes 2-3 years and Stock Enhancement-based Aquaculture would take 3-5 years before harvest (Qiu, 2013). Sea cucumbers reach sexual maturity at the second year, the sex gland of males are white and that of females are orange. It is believed that 500g of parent sea cucumbers can produce 6-7 million eggs, and 250g would produce about 3 million eggs (Li, 2006).

2.Major Farming Area and Methods

The major sea cucumber farms in China are located in the coastal areas of Shandong 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). According to the "*China Fishery Statistical Yearbook*", about 250,000 tonnes of sea cucumbers were produced in 2022 and mostly from Shandong (100,000 tonnes) and Liaoning (86,000 tonnes) Province. These two provinces together take over 75% of national sea cucumber yield, while total yield of Fujian and Hebei Province are 46,000 and 16,000 tonnes respectively. (The data represent national sea cucumber output including bottom-sowing aquaculture, but the data on the yield of pond farming cannot be obtained)

For now, the major cultivation method is pond farming in China. However, many sea cucumber farmers took local conditions into account and developed techniques like fence farming, pelagic cage farming, coastal fence farming, enclosed factory farming with artificial temperature control system, as well as mixed farming of sea cucumbers with shrimps, sea cucumbers with bivalves, and sea cucumbers with fish (Zhang, et al., 2004; Huang and Wang, 2007).

This report takes coastal pond farming as the primary evaluation subjects.

3. Trade Related Status

With the improvement of living standards, sea cucumbers have been regarded as a delicacy with high commercial value by a greater number of customers. At the moment, the trading and consuming markets have centred 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 tonnes of sea cucumbers were imported from the Far East and the number rose to 5.08 tonnes in 2017. The next year in 2018, the quantity of imported sea cucumber products went up to 16 tonnes. Also in 2018, the yield dropped significantly because of massive death induced by high temperature. As a result, the price of sea cucumber kept going up (China Aquaculture Website, 2019).

4.Common Names and Main Production Area

Japanese Spiky Sea Cucumber (Apostichopus japonicas) is the primary edible sea cucumber species that is consumed and produced in China. It is from phylum *Echinodermata,* class *Holothuroidea,* order *Aspidochirotida,* genus *Stichopodidae,* and species *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 colour 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). Due to the declining of wild population, the International Union for Conservation of Nature (IUCN) rated

Apostichopus japonicas EN (Endangered) in 2013 (Hamel& Mercier, 2013).

5. Food Safety and Recommendation

In order to guarantee the food security of aquaculture products, regulations have been put forward such as *Management on the Quality and Food Security of Aquaculture Products*, *Veterinary Drugs Management, Guidelines for Using Fishery Drugs in Pollution-Free Food Production* (China Aquaculture Website, 2009). Meanwhile at the monitoring level, the Ministry of Agriculture would regularly conduct surveys of sea cucumber products on the market and selective inspections on the place of origin of sea cucumber seeds and their breeding sites. Any production that fail to meet the standard of regulations would be punished. Overall, food security risk in sea cucumber production is low because of the pulbication of *Food Safety Laws* as well as a stronger monitoring system.

Nonetheless, it is inevitable that certain diseases occurred among the sea cucumber population. This may be the result of sea cucumber farmers blindly enlarging the farming scale to pursue greater economic benefits, and the deterioration of the farming environment. Selective inspections in many cities report that the rate of qualified products ranges from 82.5% to 100%. The application of illegal drug, not following the rules during the drug-free period, and the abusing of medicines would lead to an excess of products' drug residual. The common unqualified items are the excess of Furazolidone Metabolite, Furazilin Metabolite, Total Volatile Base Nitrogen (TVB-N), Formaldehyde, and Chloramphenicol (IQILU, 2013; QingdaoNews, 2013; Daliao, 2016; China Aquaculture Website, 2015).

The transportation of sea cucumbers is relatively easy and there is no risk in illegally using chemicals. However, risks do exist when processing and selling sea cucumbers. There are circumstances where dried sea cucumbers are sold after soaking in water, which may increase the risk of illegal chemicals usage. For example, adding potassium alum into the products can boost the appearance but result in an excess of aluminium 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

At this moment, *Apostichopus japonicas* is the only sea cucumber species cultivated on a large scale. *Apostichopus japonicas* lives in the temperate zone and is distributed along the coast line of Liaoning, Shandong, Hebei, and Jiangsu Province. China has been studying artificial sea cucumber seeds production and multiplication techniques since the 1950's. In the 80's, high density artificial cultivation was carried out, while multiple advanced farming methods and techniques were applied. The highlight would be the breakthrough of aestivation issues, which consequently contributed to the industrialization of sea cucumber production in the late 90's. At the end of 1990's, industries in Shandong Province and Dalian scaled up the production and reached a peak in 2004. Ever since, Shandong and Liaoning Province have become the major farming sites. According to the statistics, the area and yield have been climbing while the number of seeds produced slightly decreased after 2015. Shandong ranked the first in the annual yield list and Liaoning ranked the second. The yield of Fujian Province has been increasing due to the flourishing/industry of sea cucumber industry these years.

The primary farming technique is pond farming, while many sea cucumber farmers took the local conditions into considerations and developed techniques like coastal enclosure farming, cage farming, factory farming with artificial temperature control system, as well as polyculture systems – sea cucumbers cultivated wit shrimps/scallops/fish. (Zhang, *et al.,* 2004; Huang and Wang, 2007).

Fig.1 Sea Cucumber Farming Ponds (Photo Credit: Wang Jianmin)

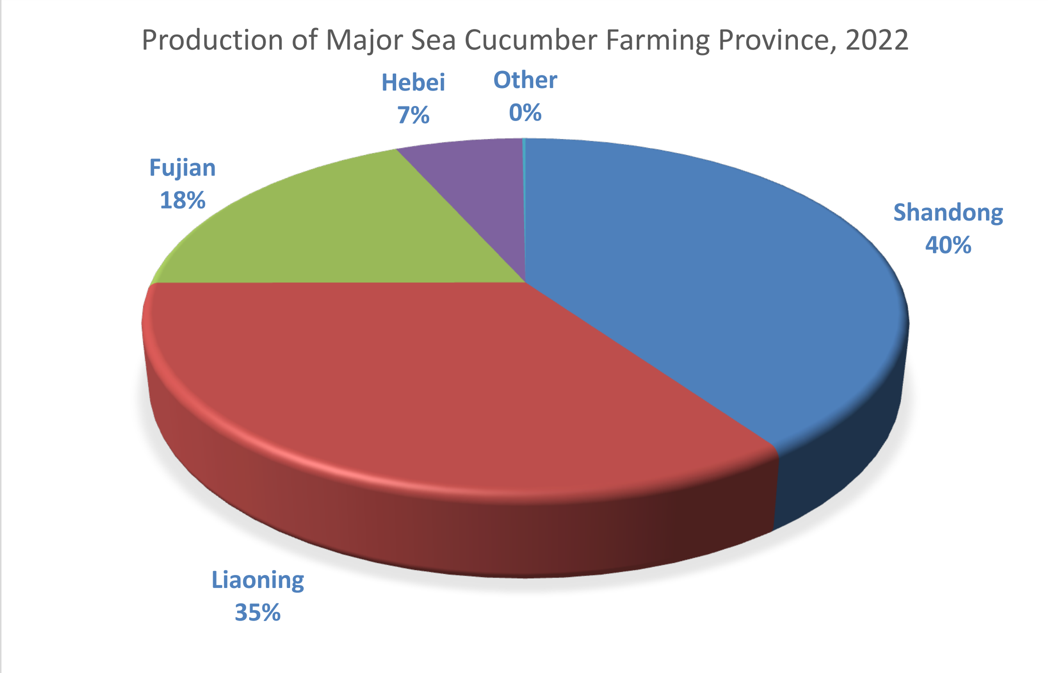

Fig 2. Production of Major Sea Cucumber Farming Province in China, 2022

Geographically, sea cucumber farming industry in Shandong Province has expanded from the east coast, its traditional base, to further west, and achieved production of scale and a new “East Sea Cucumber in the West” farming pattern. The major aquaculture area of Liaoning Province is still located in Dalian, which takes over about 90% of the total national farming area. However, cities with sea cucumber farming industry have gone beyond just Jinzhou, Yingkou, and Dandong to the entire coastal area of Liaoning Province. There are four farming modes that are being used, which are: industrialized cultivation, sea water pond farming, marine cage farming, and Stock Enhancement-based Aquaculture, with pond farming as the primary technique (Gao, 2013).

In general, *Apostichopus japonicas* cultivation applies a rotation method, which means sea cucumbers of the right sizes are collected while that are not big enough for the market would be left in the ponds. The size of sea cucumber seeds varies in different aquafarms, the most commonly used seed size being 5cm. Seeds that are 1-3cm in length can also be used if the conditions are good. More seeds are put into the ponds in the first year (about 8-10 thousand seeds per unit area), and the number of supplements in the second year is set based on the actual condition. From the third year on, sea cucumbers of different sizes will live in the ponds together. There should be 5-10 sea cucumbers per square metre under good farming conditions. There are two ways of releasing the seeds: large-size seeds are directly placed on the pile of rocks or other attachments in the ponds; smaller sized seeds are put in mesh bags and later they would crawl their way out from the openings.

Fig 3. Apostichopus japonicas Seeds

Most *Apostichopus japonicas* are collected by hand by divers in Spring or Autumn (China Aquaculture Website, 2019) due to the fact that sea cucumbers have hibernation and aestivation periods. As a result of lacking rational cultivation plans, the development of sea cucumber industry is hindered by deteriorating aquatic environment and frequently occurring diseases. The government and research institutes should put more effort in seed selection, disease control, and eco-friendly farming techniques in the industry, to make the industry greener, healthier, and more sustainable.

Fig 4. Pond Farming of Sea Cucumbers

Fig 5. Diver Collecting Sea Cucumbers

Government supervision

In China, legislations and regulations addressing sea cucumber seeds production, growing commercial products, sea cucumber processing, and marketing are all in place. *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.

With regard to waste water disposal, the government published the *Water Standard for Mariculture* (SC/T9103-2007) to encourage sustainable development of aquatic products cultivation. In order to promote the management of aquaculture pollution, Ministry of Ecology and Environment and Ministry of Agriculture and Rural Affairs jointly issued the *Implementation Plan for the Management and Supervision of Agricultural Pollution (for Trial Implementation)*, proposing to guide local authorities in the development of standards and specifications for aquaculture effluent, etc.; and jointly issued the *Opinions on Strengthening the Regulation of Mariculture Ecosystem*, which requires that coastal provinces (districts and municipalities), in accordance with the relevant requirements of the guidelines on the formulation of local standards for the aquaculture effluent control, issue relevant standards for the discharge of mariculture effluent before the end of 2023. To this end, MEE issued the *Technical Guidelines for the Formulation of Local Effluent Control Standards for Aquaculture*, which is used to guide and standardize the formulation of standards and has been in force since March 1, 2023 (MEE, 2023).

As for the processing of sea cucumbers, *Hygienic Standard for Food Additions* (GB 2760) was made to ban the utilize of any chemicals that may affect human's health, except legal food additives. Water used during the processing procedure should meet the criteria in the *Standards for Drinking Water Quality* (GB 5749). Directly sourced surface water is not allowed. Sea water used during the procedure should meet the Type I sea water quality criteria in the *Standards of Sea Water Quality* (GB 3097).

The government has published a series of legislation and regulation addressing poor compliance, production without proper licenses and illegal additives., but are not followed well. The government is responsible for the perfection of legislation system and should strengthen its monitoring system to raise the public awareness of the law, and to eventually achieve the sustainability of the industry (Dong, 2011).

Criterion 2: Habitat Impact

Habitat impacts

The pond farming of sea cucumbers is usually located at coastal area and transformed from shrimp ponds, which means there is no need for the construction of new ponds. Chemicals and antibiotics abuse would cause ecological imbalance and lower local biodiversity. In summer, the high temperature would boost the growth of lichen and weeds, thereby causing water quality deterioration and disease outbreaks (Zhao, *et al*., 2014). Besides, the seasonal tillage of sea cucumber ponds would generate mud, which, to some extents, impacts the surrounding environment (Wang, 2015).

During the rapid development of sea cucumber pond farming from 2000 to 2015, a large amount of coastal tidal flats was enclosed for aquaculture. In addition, pesticide overuse was prevailing. These two factors put devastating pressure on marine animals (Mullet – *Mugil haematocheilus* and *Mugil cephalus*, *Opogebia major*, *Potamocorbula laevis*, *Ruditapes philippinarum,* etc.) living in the same space, and may drive some local population to extinction（The Paper, 2018; Wang, 2015）. Apart from marine animals, water birds (e.g. *Platalea minor* – Black-faced Spoonbill, *Calidris tenuirostris* – Great Knot) and sea birds (e.g. *Larus saundersi* – Saunder's Gull, *Larus relictus* – Relict Gull) were also threatened by the loss of feeding and breeding sites (Zhang, 2017) (the Paper, 2018). The large scale of sea cucumber industry has encroached on natural tidal flats, hurting the self-cleaning ability of coastal water bodies and destabilizing ecological balance.

Moreover, sea mud - as an important ingredient in sea cucumber artificial diet - is not always exploited in a sustainable way, which impact the marine ecosystem negatively as well. That is because sea mud is crucial habitats for benthic animals and its formation usually takes years. It is difficult for sea mud to recover once it is damaged. The exploitation of sea mud is detrimental to the seafloor and bring negative influences to aquaculture products because of the destruction of zoobenthos habitat (Sun, 2012).

Despite the negative impacts that sea cucumber pond farming would have, sea cucumbers are very important in mixed-type aquaculture. According to research, farming sea cucumbers with shellfish would eliminate oxygen- or nitrogen- based pollutants that shellfish and algae generated. Sea cucumbers are able to take in and excrete the pollutants. Therefore, sea cucumber plays the role of "cleaner" in the farming of shrimp and shellfish-algae raft culture in order mitigate the pressure they bring on the environment in the first place (Yuan, *et al.*, 2012).

The CSSA team suggest that it is of vital importance to: popularize pollution-free farming techniques and eco-friendly cultivation methods; research and develop sustainable substitutes in sea cucumber diet; improve marine environment monitoring system and relevant legislation/regulations; reduce negative impacts on natural habitats. In order to recover the overall health of coastal wetlands that has been threatened and damaged by pond farming but of high conservation values, we encourage the government to continue supporting the restoration of tidal flats.

Criterion 3: Chemical Use and Disease Control

Chemical use

The risk of using illegal chemicals do exists in sea cucumber seed production. Medicated baths were applied on seeds in certain regions as a result of different water quality and farming methods. Additionally, changing pond water and meshes involves the application of disinfector and antidote, which increases the risks of illegal chemical uses. Wide-spectrum antibiotics, such as Cephalosporins, Floxacin, Florfenicol, Sulfa Drugs, are commonly used in the prevention and treatment of sea cucumber diseases (Luo and Zhang, 2014). These chemicals can easily increase drug tolerance of bacteria if they are overused. Meanwhile, the drug residuals may give rise to water pollution. Abusing chemicals would also have impacts on the beneficial algae in the ponds leading to dysfunctional aquatic ecosystem and poor self-cleaning ability (Fu, 2008). Besides, the residuals of chemicals like antibiotics may give rise to food safety concerns (Peng, Yang, and Huang, 2010). The drugs would enter the water bodies through feces and waste water emission. They are highly toxic for animals at the lower end of food chain. Therefore, less aquatic lives can be found in the nearby areas and the surrounding ecosystems would suffer from low biodiversity (Wang, 2012).

The ponds are sterilized before sea cucumber seeds are released using disinfectants such as Calcium hypochlorite, quick lime, Potassium permanganate, Sodium hypochlorite, and even forbidden pesticides (i.e. Dipterex, Meothrin). The application of camellia seed extract is also popular in pond cleaning processes. Camellia seed extract is the remainder of camellia seeds after the oil pressing process. One component of the extract called tea saponin is poisonous to the fish, yet has higher concentration threshold for shrimps, crabs and sea cucumbers (Peng, 2009). In most cases, the sea cucumber farmers would change the pond water after using the camellia seed extract while the waste water could decimate wild fish and shrimp in the nearby water bodies.

During the cultivation processes, camellia seed extract with low concentration would also be used for getting rid of enemies of sea cucumbers. The utilization of extracts is threatening adjacent aquatic animals and environment. Sometimes the sea cucumber farmers use Ethylene Glycol Suspension Concentrate to treat *Cladophora*, *Spirogyra communis*, *Mougeotia sp.* and *Enteromorpha* when there is an algae outbreak. The mentioned herbicides would not only affect the water quality but also kill aquatic creatures. Furthermore, chemicals like Sodium bisulfate and Chlorine Dioxide are used to solve problems occurring at the bottom of ponds.

Fig 6. Camellia Seed Extract for Pond Cleaning (Photo Credit: Zhou Xiao)

Currently the exploration of Chinese Traditional Herbal Medicine and microbe substitution for chemical is underway and they are superior to conventional chemical treatment because they leave little residual and pollution. The most frequently used Chinese Medicines are *Astragalus mongholicus, forsythia, radix isatidis, Coptis chinensis, Lonicera japonica, Glycyrrhiza uralensis, and Rhus chinensis*. In addition, commonly found microbe biological agents are *Bacillus*, lactic acid bacteria (LAB), photosynthetic bacteria (PSB), and nitrifying bacteria. These substitutes are helpful in building immunity of sea cucumbers and play a role in the prevention of water aging. They stabilize and cleanthe pond water would decompose the toxic products that sea cucumbers excrete (Feng, 2017). China has strict regulations on illegal drugs in aquaculture as well as the standards on maximum chemical residuals in aquaculture products. However, the fundamental research on sea cucumber medicine are still under development resulting in drug abuse. To produce healthy sea cucumber products, the government should: expand and refine drug residual tests; raise the public awareness on advanced farming methods; raise the farmers' awareness on the application of the right drugs; and strictly prohibit selling and using of illegal fishery drugs.

Disease control

The commonly found diseases in sea cucumbers are: 1) rotting edges symptom, which occurs during the mid-auricularia and postlate-auricularia stage. The main symptoms including hyperplasia and darkening of the body edges. At the final stage of this disease, the whole body would disintegrate. The rotting edges symptom is caused by poor water quality and bacterial infection. It has been shown that Vibrio bacteria are responsible for this disease (Zhang, *et al*., 2011). Since vibro bacteria does not respond to average drugs, Due to the fact that vibrio is not susceptible to common drugs, it is more important to take preventative measures by changing the pond water and controlling the number of bacteria (Wang, *et al*., 2015).

2) stomach ulceration symptom, leading to rotting stomach edges, rough, thickening and atrophic stomach walls. The juveniles would lose appetite, resulting in reduced growth and low metamorphosis rate (from auricularia larvae to doliolaria larvae). In the later stage of this disease, ulceration occurs on the stomach walls and finally causes sea cucumber death.

3) skin ulcer disease, which is the most common and severe disease. The infection can cause rapid and massive death, and sea cucumbers at all stages are susceptible. At the early stage of infection, partial infection occurs around the mouths, and the sea cucumbers would appear to respond slowly to outside stimulations, have swollen mouths, and then excrete their inner organs. At its later stage, the infection would grow in size, and ulceration on the skin would get worse, resulting in disintegration and death. The growing condition of sea cucumbers should be closely monitored to isolate and treat the infected individuals in time. The dead sea cucumbers should be picked out and buried (Sun, 2008).

4) ciliate disease, which is caused by Boveria species. The infected sea cucumbers are looking normal in their appearance, but showing signs of excretion of inner organs, as well as thick intestine and respiratory trees. The intestine contains almost no food and tends to be yellow in colour (Li, Zhou, and Jin, 2015). This disease has a relatively low mortality rate.

5) gas bubble disease, the symptom of which is the presence of gas bubbles on the body, as well as inside intestine tissues and respiratory trees, resulting in anorexia and poor health of the infected sea cucumbers. The excess of aeration would trigger this disease, yet it can be prevented by avoiding excessive aeration or adjusting the air flux of the ponds.

6) mycosis, which is a disease caused by excess of organic matter (feed, excrement, etc.) or massive death of algae in the ponds leading to the growth of mould. The symptomis the ulceration of skin, which usually occurs at juvenile and mature stage. It doesn’t decimate sea cucumbers but the infection inducing wounds can trigger other diseases and affect the presentation/appearance of final products. The effective preventative/precautionary measures are cleaning the ponds more often and keeping the bottom of the ponds in a good condition.

It is difficult to identify and treat the diseases after they have already spread among the populations. Thus, taking precautions against the diseases should be the top priority with treatment as supplementing methods. The typical preventive methods are: making sure the bottom of ponds are in good conditions by cleaning regularly and using substrate improvement agent? to set up a healthy growing environment for sea cucumbers; applying microbe agents (PSB， *Bacillus*， EM, etc.) to maintain the ecological stability of the ponds; installing oxygen generators to increase oxygen contents in the water and improve stress resistance of sea cucumbers; choosing the location of ponds wisely by avoiding high density cultivation sites and choosing coastal areas instead, especially areas with good water flows, no fresh water infusion, good quality sediment, and resourceful environment; constructing ponds and putting in artificial diet catering to the condition of sea cucumbers; controlling placement density, enhancing the immune system of the sea cucumbers to lower the probability of disease outbreak (Qu, 2016).

Criterion 4: Escape Risk and Response Method

Escape risk

The farming process for sea cucumbers to grow from seeds to marketable individuals is perennial. In most cases the cultivation procedure starts in April or May for seeds production; during seeds production period, sea cucumbers longer than 1cm would be picked out and cultivated until they are 3cm long (usually takes 90-105 days); afterwards they are place in ponds to grow (Lei, 2019). Sea cucumber pond farming mostly takes place in coastal areas, while industrialized farming usually takes place in indoor concrete ponds. On one hand, sea cucumbers have limited mobility and territory, the edges of ponds are effective enough to stop them from escaping; on the other hand, *Apostichopus japonicas* is a native species naturally occurring in Chinese waters, individual escapes would have relatively less visible impact on wild populations and nearby ecosystems.

Criterion 5: Feed Requirements

Wild caught fishery resources ratio and sustainability in aquaculture feed

Sea cucumbers are omnivores and scavengers. That is to say, they can feed on animals and plants like algae, as well as animal remains in marine sediments. An its early stage the sea cucumbers feed on microalgae such as diatom, *Sargassum thunbergii*, and large brown macroalgae; juveniles are mostly on artificial diet while the mature individuals solely feed on artificial diet. Apart from *Sargassum thunbergii*, sargassum and *Zostera,* marine sediment (sea mud) also plays an important role in the diet. The exploitation of sea mud would damage the seafloor, so further development of substitutes is needed to achieve the sustainable goals of higher quality sea cucumber diet.

The research on more sustainable, properly structured, and environmentally friendly diet to reduce the dependence on natural algae, which may cause problems to kelp forest and the seagrass meadow, has been an academic hotspot. Some researchers pointed out that the composition of effective diet should be 50% starch, 22% algae powder, 20% sea mud, 8% fish powder; or 60% algae powder, 30% mixture of bran, corn flour, and bean cake, 10% fish powder (Yang, Yu, and Guo, 2004). According to sea cucumber studies, *Apostichopus japonicas* feed on fish powder, shrimp powder, corn protein, soya protein and soya bean extract respectively, has shown no significant differences in growth rate. The *Apostichopus japonicas* can make use of amino acids within plant protein such as corn and soya bean, and the nutrition needs can be met (Wang, *et al.*, 2007). The study is the theoretical foundation of plant protein applications in sea cucumber diet. For now, there is no established parameters for plant-based or other types of protein, processing parameters for sea cucumber diet of all stages, or nutrition standards. Therefore, scientific data and support for practical diet production is still lacking (Xie and Bao, 2014). The research on sea cucumber diet still needs discussion in order to boost the industry by producing better, more effective, cheaper artificial diet recipes, and without compromising biodiversity.

Criterion 6: Source of Stock

Source of seedlings

Wild sea cucumbers growing in their natural habitats and cultivated sea cucumbers are the two main sources of current sea cucumber seeds. The wild population that has better spawning maturity level is the preferred choice, but the major seed source is still from artificial breeding sites in Liaoning and Shandong Province. In room temperature hatcheries, the parent sea cucumbers are from the wild ; while the increased temperature hatcheries mostly use artificially cultivated seeds. The broodstock are collected 7-10 days before spawning when the sea temperature is between 15-17℃ (China Aquaculture Website, 2014). The artificial seed production technique was invented in the 1960s'and has positive effects for the wild population has been decreasing under growing market demands. Recent year has seen the development of northern sea cucumber cultivation in the south, which takes advantages of the temperature differences in the north and the south. This method reduces the growing cycle by transporting sea cucumber seeds from northern China to further south for overwintering and sale.

The lack of long-term conservation strategy and the lack of monitoring systems, coupled with customer preferences for wild sea cucumbers, led to overfishing and a sharp plummet of wild population. Nowadays, the seed production companies use undomesticated wild cucumbers that have been cultivated in ponds for many generations as broodstock, in which case the hereditary characters severely devolve. Consequently, reduced quality, low growth rate, low stress resistance, and weakening susceptibility to diseases are in the way of sea cucumber breeding industry. The ongoing research on seed improvement and the development of stress resistance variety looks promising for the future of sea cucumber mariculture industry.

Criterion 7: Wildlife Interaction

Wildlife (especially threatened species) interaction

Sea urchin, starfish, carnivorous fish, crabs, sea birds and sea turtles are the potential enemies of juvenile sea cucumbers. Juveniles of smaller body size are prone to be hunted while the fully grown individuals have much lower chances to fall prey. *Turritella terebra* is the major species harmful to sea cucumbers. Therefore, various medicines for cleaning the pond are applied as a result of the degradation of water quality and pond bottoms during the farming processes. The chemicals would improve the pond bottoms' condition and eliminate the predators of sea cucumbers, but they would also upset the cause significant biodiversity imbalance at the farming sites. Aquaculture farmers' experiences prove that the correct use of fishery drugs, improving sediment quality, reducing transparency rate, and mixed growing with *Portunus trituberculatus* and *Busycon canaliculatu* are beneficial for controlling *Turritella terebra*'s poulation (China Aquaculture Website, 2017).

The coastal tidal flats occupied by sea cucumber pond farming have threatened the habitats for migratory birds. The Chinese coastal areas are in the middle of East Asia-Australia migratory paths for water birds, so they are crucial land for the migratory birds to rest during their long journey. Among the documented coastal migratory birds, 22 of them are identified as threatened species (Zhang, 2017). According to estimations, the wetland loss along the coast of the Yellow Sea and the Bohai Sea is over 70%, and the sea cucumber pond farming has significantly affected the migratory bird habitats. The chemicals used in the farming methods result in lower biodiversity and have indirectly caused food shortage. The lives of threatened water birds are at stake.

To sum up, we argue that the irrational exploitation of tidal flats of high international conservation values for sea cucumber pond farming, and applications of highly toxic drugs targeting fish and invertebrate species, are detrimental to wild fishery resources protection as well as wetland biodiversity. In addition, it has deadly impacts on key ecological indicators – birds that feed on invertebrates and small fish on the tidal flats. Such practice is irresponsible to the coastal ecosystems, the coastal communities, as well as the seafood consumers (Ma, 2018). The CSSA team suggest prioritizing tidal flats of high international conservation values and all types of marine protected areas (with the adjacent areas), in order to promote the development of an ecological civilization. We suggest restoring natural coastal wetlands, upgrading wetland conservation on wetland types, surface area and management expertise, and exploring more eco-friendly aquaculture methods for harmonious coexistence of water birds, intertidal shellfish, and the fishery communities.

Acknowledgement

The CSSA team sincerely thanks Dr. Cheng Bo for providing scientific and professional support for this report.

Reference

GB 2760-2014 食品安全国家标准 食品添加剂使用标准[S].
Hamel, J.-F. & Mercier, A. 2013. *Apostichopus japonicus* . The IUCN Red List of Threatened Species 2013: e.T180424A1629389. https://dx.doi.org/10.2305/IUCN.UK.2013-1.RLTS.T180424A1629389.en. Downloaded on 14 January 2020.
http://www.ji14.com/changdao-409-1.html
Daliao, 2016 大辽网. 大连食药监局抽检海参合格率为 86.3%. （2016-02-29） https://ln.qq.com/a/20160229/008037.htm
Dong, 2011. 董双林. 高效低碳-中国水产养殖业发展的必由之路[J].水产学报,2011,35(10):1595-1600.
Feng, 2017.冯亚利. 海洋光合细菌在水产养殖中的应用基础研究[D].哈尔滨工业大学,2017.
Fu, 2008.伏传永. 枯草芽孢杆菌对刺参腐皮综合病致病菌的拮抗作用以及对水质的影响[D]. 中国海洋大学,2008.
Gao and Li, 2013.高学文，李华琳. 浅谈我国海参工厂化养殖技术[J].河北渔业,2013(4):64-65.
Gao, 2013.高学文. 我国刺参养殖产业的现状与发展对策[J].黑龙江水产,2013(02):37-39.
国家食品药品监督管理总局. 食品中可能违法添加的非食用物质和易滥用的食品添加剂名单（第 1-5 批汇总）. （2018-04-27） http://samr.cfda.gov.cn/WS01/CL1975/228388.html
Hu, 2014.胡超群. 热带海参研究现状与未来发展[A]. 中国海洋湖沼学会."全球变化下的海洋与湖沼生态安全"学术交流会论文摘要集[C].中国海洋湖沼学会:中国海洋湖沼学会,2014:1.
Hu, 2016.胡玉林. 海参养殖技术研究[J].河南农业,2016(3):68.
Huang and Wang, 2007.黄华伟,王印庚. 海参养殖的现状、存在问题与前景展望[J].中国水产,2007(10):50-53.
Lei, 2019.雷帅. 关于海参养殖技术的几点思考[J].农家参谋,2019:125.
Li, Zhou, and Jin, 2015.李景胜,周井祥,金晔. 海参池塘养殖中的常见疾病[J].科学养鱼,2015:56-58.
Li, 2013.李利华. 刺参发酵饵料工艺条件优化及养殖试验中的应用[D].哈尔滨工业大学,2013.
Li, 2006.李晓霞. 海参苗种培育应注意的问题[J].河北渔业,2006(1):51-57.
Luo and Zhang, 2014.罗彩华，张永勤. 海参产品中的不安全因素及其检测方法[J].天津化工,2014,28(4):52-55.
Ma, 2018.马超.（2018）渔药使用的危害及其防范[J].河南水产, (01):12-13.
Peng, Yang, and Huang, 2010.彭宁,杨建荣,黄雪松. 海参中十种磺胺类药物残留量的高效液相色谱检测[J].食品工业科技,2010(4):355-357.
Peng, 2009.彭英 （2009）. 茶籽饼粕在水产养殖中的应用研究进展[J]. 常州工学院学报(6):75-78.
IQILU, 2013.齐鲁网. 青岛海参合格率 96.3% 选购需看检测报告. （2013-02-10） (http://qingdao.iqilu.com/qdminsheng/2013/0210/1446296.shtml.
QingdaoNews, 2013.青岛新闻网. 青岛海参仅八成合格 多杀菌剂超标可致神经炎. （2013-01-28） http://yuqing.qingdaonews.com/content/2013-01/28/content_9589731.htm
Qiu, 2013.邱天龙. 刺参生态苗种繁育关键技术原理研究与应用[D]. 中国科学院大学,2013.
Qu, 2016.曲忠. 海参养殖发病的原因及对策[J].山西农经,2016(9)：82.
Sun, 2008. 孙斌. 海参常见疾病与防治[J].科学养鱼,2008:55-56.
Sun, 2013.孙秀俊. 刺参的幼体发育与遗传育种学研究[D].中国海洋大学,2013.
Wang, 2015.王承凯. 海洋水产养殖对水域环境的影响及污染防治对策-以青岛即墨地区海参养殖为例[J].中国农业信息,2015:148.
Wang, 2014. 王海涛. 刺参池塘健康养殖技术要点[J].科学养鱼,2014,12(26)：43-44.
Wang, *et al*., 2007.王吉桥,蒋湘辉,赵丽娟等. 不同饲料蛋白源对仿刺参幼参生长的影响[J].饲料博览,2007(19):9-13.
Wang, *et al*., 2015.王磊，王玲，孟霞等. 养殖海参主要疾病及防治技术[J].河北渔业,2015(1):34-35.
Wang, 2012.王玉堂. 水产养殖用药与水产品质量安全[J].中国水产,2012(5):54-58.
Xie and Bao, 2014.谢素艳，包鹏云. 海参产业持续健康发展的途径[J].饲料工业,2014,35(24):22-25.
Xu, Pu, and Zhu, 2018.徐彩瑶,濮励杰,朱明. 沿海滩涂围垦对生态环境的影响研究进展[J].生态学报,2018,38(03):1148-1162.
Yang, Zhou, and Zhang, 2014 杨红生，周毅，张涛. 刺参生物学-理论与实践[M]，科学出版社, 2014, 1-9.
Yang, Yu, and Guo, 2004.杨娟，于凯先，郭相平. 刺参池塘养殖技术[J].齐鲁渔业,2004(11):6-9.
Yang, 2005.杨先乐. 新编渔药手册[M]. 北京: 中国农业大学出版社, 2005, 125-127

Yu, 2011.于晶晶. 刺参肠道微生态区系及致病菌防治的研究[D].辽宁大学,2011.
Yu *et al*., 2009.于世浩,何伯峰,赵倩等.海参营养与饲料研究现状[J].饲料研究,2009(10):53-54.
Yuan, 2005.袁成玉. 海参饲料研究的现状与发展方向[J]. 水产科学, 2005, (24):54-56.
Yuan *et al*., 2012.袁秀堂，王丽丽，杨红生等. 刺参对筏式贝藻养殖系统不同碳、氮负荷自污染物的生物清除[J].生态学杂志,2012,31(2):374－380.
Zhang *et al*., 2011.张春云，陈国福，徐仲等. 海参疾病学研究进展[J].水产科学,2011,30(10):644-647.
Zhang, 2017 张正旺（2017）. 中国滨海湿地的鸟类多样性及关键栖息地保护现状,《2017 年中国动物学会北方七省市区动物学学术研讨会论文集》
Zhang, 2017.张正旺. 中国滨海湿地的鸟类多样性及关键栖息地保护现状[A]. “2017 年中国动物学会北方七省市区动物学”学术研讨会论文集[C].2017.
长岛渔家乐信息网. 长岛营造海底森立 避免渤海湾变死海（图）时政要闻 烟台（2017-4-14）
Zhao *et al*., 2019.赵春龙，付仲，崔兆进等. 一种生物修复海参养殖池塘的新方法[J]. 河北渔业,2014,3:45.
Zhao, Wu, and Chen, 2019.赵丽,吴光斌，陈发河. 海参多肽提取纯化及其生物活性研究进展[J].食品工业,2019,40(2):252-255.
China Aquaculture Website, 2019.中国水产养殖网. 海参价格节节攀升，如何选择质优价廉海参受关注_海产专题（海参专题）.（2019-03-20）http://www.shuichan.cc/news_view-380375.html
China Aquaculture Website, 2017.中国水产养殖网. 海参圈里的真正敌害是它，防治工作让养殖户头疼.（2017-02-12）http://www.shuichan.cc/article_view-46861.html
China Aquaculture Website, 2018.中国水产养殖网. 海参养殖面积及产量增加，单位面积产量下降.（2018-12-12）http://www.shuichan.cc/news_view-375884.html
China Aquaculture Website, 2014.中国水产养殖网. 健康高效海参人工育苗的细节管理和关键控制技术（一）.（2014-05-02）http://www.shuichan.cc/article_view-24887.html.
China Aquaculture Website, 2019.中国水产养殖网. 青岛老伊家海洋牧场春季海参开捕 个性化定制成新时尚.（2019-03-28） http://www.shuichan.cc/news_view-380831.html
China Aquaculture Website, 2015.中国水产养殖网. 山东产海参合格率百分之百 其他水产品状况良好.（2015-01-13）http://www.shuichan.cc/news_view-231621.html
China Aquaculture Website, 2019.中国水产养殖网. 中国进口俄罗斯海参增长 16 倍.（2019-03-20）http://www.shuichan.cc/news_view-380395.html
China Fishery Statistical Yearbook, 2011.中国渔业统计年鉴[M]. 北京: 中国农业出版社, 2023.
Zhong and Hu, 2016.钟鸣, 胡超群. 海参养殖饲料学研究进展[J]. 饲料工业, 2016, (18):58-64.
PengPai, 2018.澎湃. (2018). 穿越海岸线：近海鱼荒. Retrieved from https://image.thepaper.cn/html/zt/2018/09/emptysea/article.html
Sun, 2012.孙安清.滥挖海泥无“法”遏制[J].共产党员：上半月, 2012(5):53
Ministry of Ecology and Environment (2023) Announcement on the Publication of the National Ecological and Environmental Standard "Technical Guidelines for Water Pollutant Discharge Control Standards of Aquaculture Industry". 生态环境部, 关于发布国家生态环境标准《地方水产养殖业水污染物排放控制标准制订技术导则》的 公告,https://www.mee.gov.cn/xxgk2018/xxgk/xxgk01/202302/t20230224_1017488.html, 2023