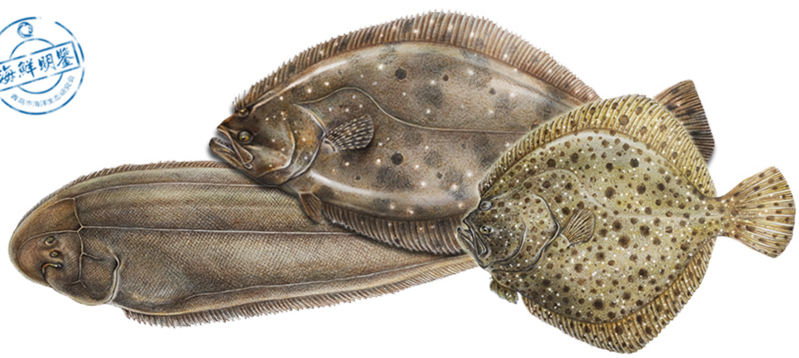
China Sustainable Seafood Assessment (CSSA)

Aquaculture



Flatfish
Olive flounder (*Paralichthys olivaceus*)
Turbo (*Scophthalmus maximus*)
Tongue sole (*Cynoglossus semilaevis*)

Industrial farming

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

Flatfish aquaculture is an important part of China's marine fish aquaculture. Flatfish (mainly turbot, flounder and tongue sole), after nearly 30 years of development in China, has formed a huge industry of annual output of more than 110,000 tons, output value of more than 5 billion yuan, contributing to over 60% of flatfish production of the world.

Unlike most aquatic products culturing in traditional pond and offshore aquaculture, China's flatfish aquaculture mostly adopts indoor factory aquaculture mode, with a high degree of industrialization. While realizing high-tech aquaculture, there are also adverse effects on environment, such as a large amount of groundwater extraction, aquaculture wastewater effluent, etc.. There are urgent needs for relevant management authorities with scientific research institutions to seek more scientific and responsible aquaculture solutions.

After evaluation, the CSSA team found that the prominent issues with the flatfish aquaculture primarily stem from the improper use of chemicals due to prevalent diseases, frequent reliance on feeding with wild fish and high dependence on fishmeal and fish oil in feed. Additionally, there are concerns about excessive extraction of groundwater resources and the improper discharge of aquaculture wastewater into nearby natural marine environments. In terms of germplasm utilization, at present, China's flatfish aquaculture industry can achieve the use of full artificial seedlings, and actively carry out the breeding of improved seedlings. However, there is still a need for improvement in maintaining the continuity of relevant superior strains, assessing the robustness of cultured individuals, and preventing the escape of artificial seedlings. In terms of escape management, although the highly industrialized aquaculture model involves water exchange with natural water bodies, the potential risk of escape for cultured species is still assessed as relatively low. Furthermore, the industrialized flatfish aquaculture is largely isolated from direct contact with surrounding wild animals, thus minimizing the risk of directly harming wild populations.

Flatfish aquaculture in China has received attention from government regulatory agencies and research institutions, leading to the establishment of a specialized research system for this industry (now expanded to a marine fish industry research system). This initiative has resulted in the development of multiple aquaculture standards or norms tailored to flatfish, as well as the implementation of various inspections for seafood safety and initiatives to guide industry development. Currently, China's flatfish industry operates within a framework of coordinated efforts among government, scientific research, and industry alliances. However, several challenges persist. Some regions lack adequate enforcement of fisheries regulations. There are negative reports about counterfeiting of fish feed and aquaculture chemicals, unauthorized aquaculture practices, and fraudulent activities in the distribution process. In terms of research, there is still a need for breakthroughs in maintaining high-quality fish breeds, disease prevention and control, and energy-efficient aquaculture. The large flatfish aquaculture industry is facing the challenge of transformation and breakthroughs to achieve sustainable development.

According to the comprehensive assessment, CSSA believes that China's flatfish aquaculture has made remarkable achievements in promoting the development of marine fish aquaculture in China and meeting the supply of self-sufficient aquatic products, and the industry is in the leading ranks in the country in the promotion of industrial aquaculture, feed research and development, and aquaculture management. But it urgently needs improvement in the fields of disease prevention and control, rational and effective use of chemicals, and scientific utilization of natural resources. Therefore, the rating of flatfish aquaculture is Yellow - a category with good overall sustainability, but still room for improvement.

Flatfish	Think Twice (Indoor Farming)

Overview of the Assessed Species

The flatfish farmed in China includes more than 10 native high-quality species and introduced species, among which the most important farmed are olive flounder (*Paralichthys olivaceus*), turbot (*Scophthalmus maximus*), and tongue sole (*Cynoglossus semilaevis*).

Fig. 1 Major farmed flatfish in China: turbo, olive flounder, tongue sole

Flatfish is an important species group in marine fish aquaculture in China. The development of flatfish aquaculture in China has a history of nearly 30 years, during which it has grown into a massive industry with an annual output of over 100,000 tons and a value of 5 billion RMB. Currently, China accounts for over 65% of the world's flatfish aquaculture production (Song Qianhong, 2010; Yunxia Zhang, Chuanhui Leng, and Qiang Li, 2014). After experiencing a period of initial growth followed by stabilization, China's flatfish production has stabilized at around 120,000 tons. Species such as turbot, olive flounder and tongue sole are not only important high-end aquatic products for Chinese consumers but also popular in Japan, South Korea, Hong Kong, Macao, and major cities in China (Teng Yu, Guo Xiaohua, Yuan Deshun, Wang Caili, 2010).

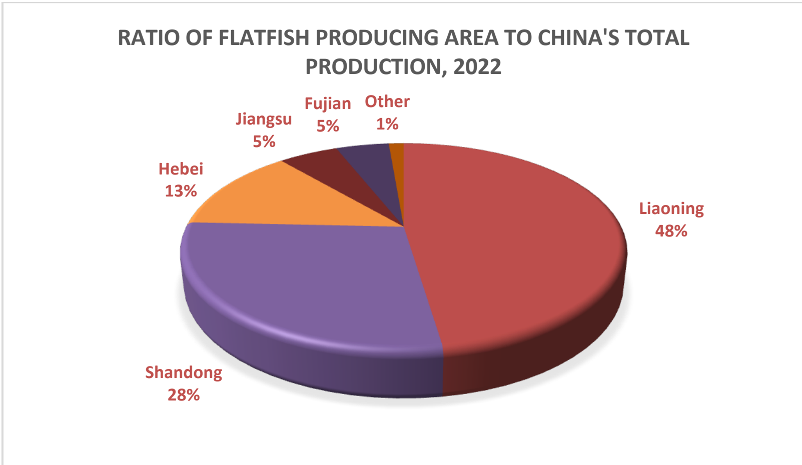


Fig. 2 Production map of China's main flatfish producing areas in 2022 (Source: China Fishery Statistics Yearbook)

Flatfish aquaculture is mainly concentrated in Liaoning, Shandong, Hebei, Tianjin, and Jiangsu provinces of China. Additionally, there are small-scale operations in Fujian and Guangdong provinces. Among these, Liaoning (especially in Dandong and Huludao) and Shandong (particularly in Yantai, Qingdao, Weihai, and Weifang) provinces contribute to around 80% of the national production (Song Qianhong, Zhao Yongfeng, 2016; Yang Zhengyong, Wang Chunxiao, 2009; Yang Zhengyong, Guo Honghu, and Zhang Yuyan, 2012; Teng Yu, Guo Xiaohua, Yuan Deshun, Wang Caili, 2010; Wang He, 2018).

In 2006 and 2015, among the main farmed species of flatfish, turbot, a food safety incident broke out that the detected drug residues exceeded the standards, causing a panic (Guan Changtao, 2016). Flatfish is more prone to diseases in aquaculture, and some farmers use drugs irregularly, and even abuse illegal drugs, resulting in the occurrence of drug residues, but their heavy metal content is far lower than the national standard. Except for individual reports of detection of nitrofuran metabolites in cultured tongue soles in 2012, and about 10% of turbot and tongue soles samples collected from several consumer channels in Tianjin in 2018 detected nitrofuran metabolites (Gao Lina, Ma Dan, Shi Wenbo, Han Xianqin, Chen Jian, Li Baohua, 2018; McConson, 2016), the vast majority of the market sampling inspection passed, proving the quality and safety of flatfish products on sale. For example, the Ministry of Agriculture turbot market and farm spot check achieved pass rate of 100% in 15-16 years. The data shows that Shandong (the main turbot producing area) has a turbot checking pass rate of more than 96% in multiple years, and Guangdong's passing rate is to 98%, ranking first among all kinds of inspected aquatic products, and in the first half of 2023, all samples of turbot and flounder collected nationwide passed the monitoring for veterinary drug residues in aquatic products (Wu Jiahui, 2016; Song Qianhong, Zhao Yongfeng, 2016; Renminribao, 2023). At present, it remains to be studied whether some flatfish nitrofuran metabolite residues will have safety effects on humans (Gao Lina, Ma Dan, Shi Wenbo, Han Xianqin, Chen Jian, Li Baohua, 2018).

The U.S. Food and Drug Administration (FDA) has issued recommendations for fish consumption based on mercury levels, including the recommended amount for flatfish is 2-3 times a week (about 4 ounces each, about 110 grams), and children should halve the amount each time to get beneficial nutrients from flatfish. When buying flatfish, it is good to have complete scales, full and transparent eyeballs, bright red and clear gills. Flatfish weighing around 500g is more suitable for household consumption, with a moderate price, while the fish weighing around 1kg is more suitable for consumption in restaurants, hotels, and similar establishments, but it comes with a higher price.

FULL ASSESSMENT

Criterion 1: Aquaculture Method and Management Status

Aquaculture method and industry overview

Olive flounder (*Paralichthys olivaceus*), turbot (*Scophthalmus maximus*), tong sole (*Cynoglossus semilaevis*), starry flounder (*Platichthys stellatus*), spotted halibut (*Verasper variegatus*), Barfin flounder (*Verasper moseri*), etc. are the main species of flatfish culture, of which turbot, olive flounder and tongue soles account for more than 95% of flatfish culture production, and turbot alone accounts for more than 80% of the total flatfish production (Song Qianhong, Zhao Yongfeng, 2016; Lei J L, Yang Zhengyong, Ni Qi, Zhang Hesen, 2010). Commonly farmed flatfish species exhibit significant growth differences between males and females. Once male fish reach sexual maturity, their weight gain slows down, while females continue to grow. Typically, female growth slows down only after reaching around 2000 grams. Female fish grow at a rate nearly twice as fast as male fish, but there are no visual differences between males and females, making it difficult to distinguish between them with the naked eye. Therefore, female fish are more favored in the aquaculture industry. At present, China has achieved a break-through of the full feminization and promotion of the main flatfish species. Although the research on total feminization of flatfish in China started later than the international level, it has overcome related technical problems and is at the forefront of the world (Zhao Chunmin, Du Wei, Gao Xiaodong, 2011; Qingdao Evening News, 2016).

China's flatfish aquaculture industry is mainly divided into the following types of models (Figure 3): 1. The flow-through indoor aquaculture system using greenhouse structures and deep well seawater is classified as a land-based industrialized aquaculture model. It primarily utilizes groundwater near the coast or brine mixed with freshwater as a source of seawater. The system is complemented by greenhouse structures for insulation, while coal or electricity is used to regulate the water temperature. This model has emerged in response to deteriorating coastal marine environments and limited water and soil resources. It focuses on raising species such as turbot and is commonly found in regions like Shandong and Liaoning in China. (Wang Tengteng, 2016; Wang Weifang, 2014). 2. The coastal pond aquaculture model. It requires deep pond water with moderate temperatures and is mainly used for breeding species such as turbot and olive flounder. However, during periods of very low temperatures, such as winter (after October), the operation needs to be moved indoors for overwintering and then returned to the ponds for cultivation the following year (China Central Radio, 2017). Such aquaculture models are represented by Yingkou area of Liaoning Province, and some of them also exist in Shandong region. 3. The cage culture model in shallow coastal water, mainly for olive flounder and turbot, but needs to be moved indoors at low temperatures, which is mainly concentrated in Shandong and Fujian (Zhao Yongfeng, 2006). 4. Recirculating aquaculture system, (RAS, figure 4), similar to factory aquaculture in mode 1, differs in water recycling (Ni Qi, Lei Jilin, Zhang Hesen, Yang Zhengyong, 2010). RAS has high technical and financial requirements, but has the characteristics of water saving, energy saving, high yield and high quality, and helps to protect the marine ecological environment. As a new aquaculture model, it is gradually developing and growing in Tianjin, Shandong and other regions (Ni Qi, Lei Jilin, Zhang Hesen, Yang Zhengyong, 2010; Sun Guiqing and Zhang Jin, 2018). In addition to the above four main flatfish culture modes, there is also a "north-south relay" method in the related aquaculture industry. The south (such as Zhangzhou, Fujian) has a higher temperature in winter suitable for outdoor nursery of fry, and then the fry are collected and transported back to the north by water truck for further farming, or the large fries from northern China are transported to the south in winter for breeding, reducing logistics costs (Xu Kaixin, Wang Chunxiao, Yang Zhengyong, 2012; Zhao Yongfeng, 2006). In addition, there are polyculture patterns with sea cucumbers and whiteleg shrimp during the culture process, as well as subculture patterns for other species such as prawns cultured during the non-flatfish period (Yu Qinghai, Gong Chunguang, Yin Rui, Sun Guiqing, Wang Qinglin, 2017; Lei J L, Yang J H, Ni Q, Zhang Hesen, 2010). The culturing cycle of flatfish is mostly 1-2 years, and some species, such as tongue sole, can reach 3 years (Yang Deli and Zeng Mingqian, 2013).

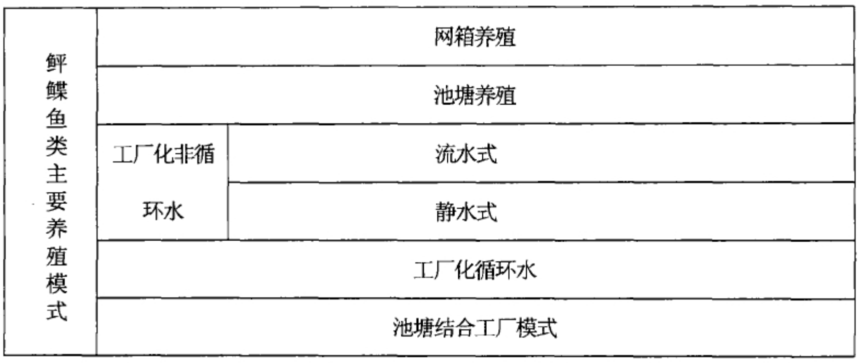


Fig. 3 Overview of common flatfish culture patterns in China (Liu Kun, 2010)

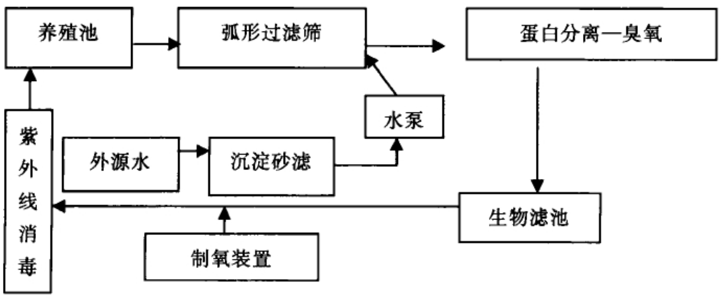


Fig. 4 Flow chart of common factory RAS mode (Jia Lei, Song Wenping, Miao Jun, and Qiao Yanlong, 2010)

Flatfish culturing has only a short history of nearly 30 years in China, but it has created a huge industry with an annual output of more than 100,000 tons and an output value of more than 5 billion yuan (Song Qianhong, 2010). At present, in the scientific research of flatfish aquaculture in China, there is not only a national-level "flatfish industry system" (divided into three research rooms: breeding/engineering equipment/healthy breeding and integration, which has been integrated into the newly established national marine fish industry research system) to focus on the healthy development of flatfish aquaculture in China (Tang Dongdong, 2017a; Song Qianhong, 2010). There has also developed an industrial alliance of flatfish enterprises such as the "Turbot Association" of the China Aquatic Products Processing and Marketing Alliance (CAPPMA), uniting and working together to promote the good and orderly development and transformation and upgrading of the industry (Tang Dongdong, 2017b).

Currently, in China, various methods of cell nuclear induction have been employed to produce all-female seedlings for flatfish cultivation (China Central Television, 2017; Zhao Chunmin, Du Wei, Gao Xiaodong, 2011). Additionally, industrialized recirculating aquaculture systems suitable for flatfish farming have been developed. Moreover, the first mass-produced marine aquaculture animal vaccine has been developed and approved by the national authorities for treating common abdominal diseases in flatfish farming, reducing the adverse effects of diseases and medication on the aquaculture industry (Zheng Yanyun, 2016). Developed domestically formulated feeds such as "Qihao" that can further improve the feed efficiency (Jia Lei, Liu Hao, Chen Jinghua, Wang Yanhuai, Song Wenping, 2010); Developed a comprehensive information management system for the aquaculture of flatfish species to systematically collect data from aquaculture enterprises for effective production guidance (Liu Hao, Song Wenping, Jia Lei, 2011); Utilized corrosion-resistant materials to establish traceable technologies compliant with international EAN/UCC standards, which have been applied and promoted in some factories (Lin Hong, Li Meng, 2012).

However, it cannot be ignored that there is still room for improvement and transformation in China's flatfish industry. In terms of aquaculture area and scale, the disorderly development in the early stage, and the overexploitation of groundwater resources for new water exchange in the process of flow-water aquaculture, have caused the shortage of groundwater resources in many places to meet the needs of aquaculture, and even the phenomenon of destroying the ecological environment such as seawater back irrigation and salinization of fertile land. During the aquaculture process, wastewater is mostly discharged directly into the surrounding environment, causing a certain degree of ecological pollution (Su Mo, Song Benben, and Wu Fan, 2013). There are many diseases and the frequency of outbreaks is high, while the existing prevention and control technologies are difficult to meet the needs of farmers, resulting in antibiotic drugs still being the mainstream of disease prevention and control (Jia Yudong, Lei Jilin and Liu Bin, 2012). The existing feeding mode of frozen and fresh trash fish is not only detrimental to the environmental protection of marine resources, but also has the risk of carrying pathogenic bacteria into the aquaculture system, and the resulting emissions are also prone to secondary pollution (Dai Yajuan, Yang Zhengyong, and Wang Fangfang, 2010; Jia Lei, Song Wenping, Miao Jun, and Qiao Yanlong, 2010; Flatfish Industrial Technology System, 2012). The organization and cultivation of industries such as industry-related aquaculture professional cooperatives is insufficient, and in the actual management, the farmers mostly work separately, and the level of aquaculture is uneven (Wang Weibo, 2016). The above are the key challenges that restrict the further expansion and development of the flatfish aquaculture industry to move towards scientific and sustainable transformation.

As China's flatfish aquaculture industry, which produces over 100,000 tons annually and accounts for over 65% of the global flatfish production, CSSA assesses that the industry has developed rapidly. It has achieved significant progress in breeding, aquaculture model development, vaccine development, and other areas. These advancements have enriched the supply of seafood in the Chinese market, elevated the level of marine aquaculture in the country, and promoted related seafood trade. However, the reasonable and orderly regulation and scientific planning in the current industry is insufficient, and the level of organization needs improvement. Addressing a series of issues such as diseases in aquaculture, excessive resource consumption, single-industry chain, and aquaculture pollution requires strengthened innovation research and improved investment in the future. The industry needs to undergo transformation alongside government management, while ensuring that measures related to seedlings, aquaculture drugs, corresponding aquaculture insurance, and enterprise financing truly and effectively serve the aquaculture industry. Furthermore, it is essential to further improve and effectively implement a traceability system for flatfish aquaculture products and establish a supporting food safety supervision and inspection mechanism to ensure the safety and reliability of related aquatic products and the sustainable development of the industry.

Government supervision

At present, China has established national and industry standards related to flatfish culture to control various elements in the culturing process (Table 1) (Lin Hong and Li Meng, 2012). Some of these standards or norms are general regulations that apply to all mariculture activities, and some regulations are exclusive to flatfish. China has also carried out multi-channel and multi-approach supervision and management from seed production to sale for farmed flatfish (unknown, n.d.), implemented special aquatic product quality and safety rectification activities such as "three fish and two medicines", carried out the marketing promotion of turbot traceability labels, established turbot association under the CAPPMA, and included the vast majority of flatfish culturing enterprises into the alliance management (China Aquatic Products Portal, 2016; Lin Hong, Li Meng, 2012). The association requires members to sign self-discipline conventions, accept social supervision, regularly accept random inspections, and jointly include member units in the scope of local quality supervision and product random inspection with local fishery authorities, so as to regulate and restrict the behavior of aquaculture production members (Tang Dongdong, 2017b).

At present, China's flatfish industry has formed a new model of government management& industry alliance self-discipline, which is conducive to promoting the healthy development of industry. However, the assessment found that some of the current government management work still needs to be improved. For example, the national and industry standards formulated are not meticulous and poorly targeted, and farmers and enterprises still have many difficulties in their application (Lin Hong and Li Meng, 2012). The relevant laws and regulations on the distribution and market supervision of flatfish still need improving, and law enforcement needs to be strengthened (Guan Changtao, 2016; Du Zhuojun, 2014). The inadequate management of the production and distribution channels of fish medicine and feed currently on sale has led to counterfeit and substandard products entering the market from time to time, disrupting normal aquaculture activities (Xu Zhong, 2012). Furthermore, there is still a lack of management and supervision in the development planning of the flatfish industry. This includes aspects such as regulating how fish farmers can properly utilize underground water resources, restraining the direct discharge of aquaculture wastewater (Yu Qinghai, Gong

Chunguang, Yin Rui, Sun Guiqing, Wang Qinglin, 2017), preventing the escape of introduced species from aquaculture facilities, and setting appropriate farming densities based on local environmental carrying capacity assessments. Addressing these issues is crucial for advancing the flatfish industry towards sustainable development.

Based on the assessment results, CSSA believes that the Chinese flatfish aquaculture industry, after nearly 30 years of development, has established certain effective regulatory models in both government management and industry self-discipline. To address various issues still present in the industry, such as disease outbreaks, lack of effective supervision in the distribution and sales sectors, environmental costs being overlooked in production, and counterfeit fish medicines and feeds, it is recommended that the government increase supervision and control over important production factors such as fish medicines and feeds used in flatfish aquaculture. Furthermore, there should be strengthened supervision and inspection of the farming and distribution markets, the formulation of scientific industry development plans, guidance for the scientific and effective development of flatfish aquaculture, establishment of relevant management constraints for various harmful aquaculture practices affecting the ecological environment (such as excessive extraction of groundwater and direct discharge of aquaculture wastewater), and enhancement of environmental impact control in aquaculture. Additionally, it is important to develop and promote aquaculture guidelines conducive to good industry practices within the sector.

Table 1 Current standards or norms for flatfish culture in China (Lin Hong, Li Meng, 2012) (some are optional)

鲆鲽类养殖过程可采用的标准或规范

Standards and specification of flounder farming

类别 Category	养殖过程采用的标准或规范 Standards and specification of flounder farming	
国家标准	GB 18407.4 – 2001	《农产品安全质量 无公害水产品产地环境要求要求》
	GB 17378.3 – 2007	《海洋监测规范 第 3 部分:样品采集、贮存与运输》
	GB 11607 – 89	《渔业水质标准》
	GB 3097 – 1997	《海水水质标准》
农业标准	NY 5362 – 2010	《无公害食品 海水养殖产地环境条件》
	NY 5152 – 2006	《无公害食品 鲆鲽鲳》
	NY 5072 – 2001	《无公害食品 渔用配合饲料安全限量》
	NY 5071 – 2002	《无公害食品 渔用药物使用准则》
	NY 5070 – 2002	《无公害食品 水产品中渔药残留限量》
水产标准	SC/T 2031 – 2004	《大菱鲆配合饲料》
	SC/T 9103 – 2007	《海水养殖水排放要求》
地方标准	DB13/T 1068 – 2009	《无公害食品 漠斑牙鲆海水养殖技术规范》

Criterion 2: Habitat Impact

Habitat impacts

Flatfish aquaculture activities are primarily concentrated in coastal areas. Aquaculture is conducted through several methods, including pond aquaculture, industrialized aquaculture, and nearshore cage aquaculture models. (Lei Jilin, Yang Zhengyong , Ni Qi and Zhang Hesen, 2010). Industrialized aquaculture or pond aquaculture has the problem of irrational use of groundwater resources, especially flow-through factory aquaculture, and the daily water replacement rate is as high as 4-8 times the aquaculture water volume. Long-term extraction of groundwater resources leads to the depletion of groundwater resources, for example, some aquaculture farms could draw water from 20 meters underground a decade ago, but now they need to dig deeper, up to 100 meters, to access water sources. The large amount of groundwater pumped also caused seawater intrusion, and the salinity of groundwater extracted at the same depth in some farms is higher than that of ten years ago, suggesting the occurrence of seawater intrusion, so the wells are drilled deeper and farther (Yu Qinghai, Gong Chunguang, Yin Rui, Sun Guiqing, Wang Qinglin, 2017; Ni Qi, Lei Jilin, Zhang Hesen, and Yang Zhengyong, 2010). In addition, aquaculture wastewater was often discharged without treatment and can easily cause negative effects on the surrounding environment. Aquaculture wastewater contains feed residues and fish excreta rich in nitrogen and phosphorus, and may even contains potential pathogenic bacteria and drug residues, most of which were directly discharged into adjacent natural water bodies (mostly offshore) without treatment, which can cause negative problems such as water pollution in surrounding waters (Yu Qinghai, Gong Chunguang, Yin Rui, Sun Guiqing, and Wang Qinglin, 2017; Li Yanhong, 2015; Wang He, 2018). The same problem exists in the offshore cage culture of flatfish, while the excreta, feed, etc. directly enter the surrounding sea area through the exchange between the cage and the external water, which aggravates the degree of eutrophication of the offshore marine environment (Li Yanhong, 2015).

At present, China still lacks effective laws and regulations to restrict the above behaviors that affect the offshore marine environment, destroy the ecological functions of offshore habitats, and over-exploit groundwater aquifers, and relevant law enforcement is not in place. For example, the amount of groundwater exploration in Huludao area can be used for many years on the basis of an average daily utilization of 100,000 tons, but the average daily extraction capacity in the early stage of industrial development has reached 200,000 tons (Zhao Yongfeng, 2006).

According to CSSA's assessment, the flatfish aquaculture has caused a certain degree of adverse impact on the offshore and coastal land-based ecosystems where it is located, mainly by the direct discharge of aquaculture wastewater into the sea, excessive and uncontrolled demand for water resources from coastal land bases, and related unsustainable behaviors have caused secondary impacts on some areas, damaged the corresponding ecosystems, and led to the loss of habitat functions. In the future, it is recommended to improve the protection of habitats, strengthen the protection of offshore environment and the centralized treatment and discharge of aquaculture wastewater, establish a reasonable mechanism for the utilization of groundwater resources, encourage the development of water-saving and energy-saving aquaculture models such as RAS, carry out research on the relationship between well salt water utilization and seawater intrusion, monitor groundwater conditions, gradually restore the damaged habitat function, and reduce the adverse impact of aquaculture on the surrounding environmental habitat.

Criterion 3: Chemical Use and Disease Control

Chemical use

Chemicals in flatfish culture are mainly used to control various bacterial, viral and parasitic diseases, and a wide variety of chemicals are used (Yang Xiaobin, Zhang Teng, Li Hua, 2013; Liang You, Wang Yingeng, Liu Zhiwei, Ni Qi, and Zhang Yulei, 2015). Different chemicals are used for different diseases. For common diseases in flatfish, chemicals such as Ciprofloxacin, oxytetracycline, enrofloxacin, and rifampicin are used. Some farmers also use homemade traditional Chinese medicine. However, there are instances where certain farmers misuse prohibited drugs, such as chloramphenicol and erythromycin (Xu Zhong and Zhang Xiang, 2016), which are restricted or limited in use by the government, for disease prevention and treatment. The types of chemicals used in the process of flatfish culturing are numerous and mixed, and the number of farmers is large and scattered, which causes certain difficulties in relevant supervision.

The Ministry of Agriculture has formulated and a list of prohibited drugs in aquaculture, and formulated a series of relevant measures such as the *Regulations on the Management of Quality and Safety in Aquaculture* and the *Guidelines for the Use of Pollution-free Food and Fishery Drugs* (Fisheries Bureau, Ministry of Agriculture, n.d.; Zeng Lingbing, n.d.), to restrict and regulate the use of chemicals in the breeding process of farmers. However, in the specific implementation, there are problems such as insufficient implementation of relevant management supervision, lack of management basis for the use of some fishery drugs, and lack of standardized control of the use of fishery drugs (Liang You, Wang Yingeng, Liu Zhiwei, Ni Qi, and Zhang Yulei, 2015). Incorrect use of chemicals continues on small-scale farms, and incidents of drug residues have been reported in some areas. For example, in Jinan's 2015 market spot check found that in turbot samples furacilin metabolites exceeded the standard, and in 2018, multiple market channels in Tianjin detected that 10% of turbot and tongue soles contained nitrofuran metabolites, indicating that there were risks of illegal use of chemicals and drug residues, and relevant supervision needed to be strengthened (Guan Changtao, 2016; Lina Gao, Dan Ma, Wenbo Shi, Xianqin Han, Jian Chen, and Baohua Li, 2018). The wide variety of chemicals used in flatfish culture and the lack of monitoring and collection of various relevant data on dosage make it difficult to assess whether and to what extent the use of various chemicals has adverse effects on the surrounding environment. In order to standardize the use of chemicals in flatfish culture, some self-regulatory alliances have been formed in the industry, such as the farmers and processors under the flatfish industrial technology system claims not to use any antibiotics, and the product quality can be traced (Wang Caili, Liu Congli, Guo Xiaohua, Yuan Deshun, Teng Yu, 2012). In 2019, the Ministry of Agriculture and Rural Affairs issued an aquaculture drug reduction plan, and implemented aquaculture drug reduction actions in various places, and turbot as a key aquaculture species to carry out the "zero medicine" technology model demonstration has also achieved initial results, and the level of legal and scientific drug use has been significantly improved. In the first half of 2023, all samples of turbot and flounder collected nationwide passed the monitoring for veterinary drug residues in aquatic products (China Agricultural Science News Network 2019; Renminribao, 2023).

In view of the above assessment results, CSSA believes that there are certain problems in the use of chemicals in flatfish culture, which are mainly reflected in the lack of implementation of relevant norms on the use of chemicals by some farmers, and the lack of corresponding monitoring and data collection systems by relevant departments. CSSA suggested that in the process of promoting industrial upgrading in the future, at the same time, we should increase the research and development of flatfish farming disease prevention and control, improve the quality of seeds, improve the disease resistance of seedlings, reduce the incidence of aquaculture, and reduce the dependence and use of chemicals from the source; Strengthen the supervision and supervision of aquaculture production and reduce the occurrence of illegal use of chemicals; Improve farmers' awareness of scientific drug use, strengthen the principle of rational use of compliant chemicals and strict prohibition of the use of illegal chemicals, and urge farmers to carry out responsible aquaculture and production activities.

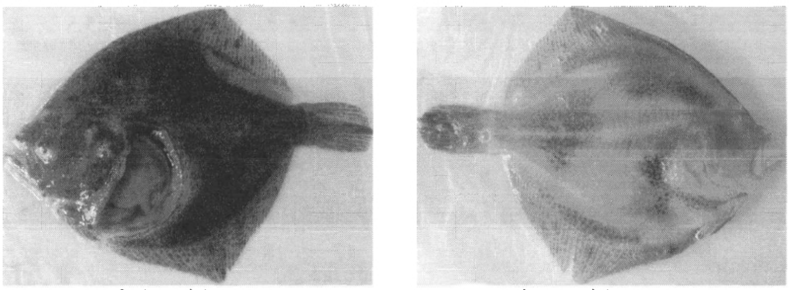
Disease control

The diseases commonly encountered in the cultivation of flatfish can be broadly categorized into three main types: bacterial, viral, and parasitic diseases. Common bacterial diseases include infection by Vibrio anguillarum, Vibrio harveyi, and Vibrio vulnificus. Viral diseases that are relatively common include viral lymphocystis disease. Parasitic diseases may involve various parasites such as Scuticociliatida, flagellate, and trichodinid. (Liang You, Wang Yingeng, Liu Zhiwei, Ni Qi, Zhang Yulei, 2015; Han Maosen, Zhang Xiaoling, Shu Yunfang, Zhu Long, and Chen Jiaxin, 2002). In the past surveys, it was found that more than 30% of farmers had reported the occurrence of one or more of the above diseases, showing the high frequency of various diseases (Yang Xiaobin, Zhang Teng, and Li Hua, 2013. Flatfish Industrial Technology System, 2012). In addition, some studies have also shown that bacterial diseases account for more than 50% of flatfish diseases (Gan Lingling, Wang Weifang, Gao Chunren, Lei Jilin, 2014), indicating that bacterial diseases are common diseases in flatfish culture.

Once disease happens, it can spread easily through water flow in the culturing system. It has been found that even if the RAS system is accompanied by ultraviolet sterilization equipment, pathogens can be found in production tools and farming systems, indicating the presence of internal infectivity (Wang Yingeng, Chen Jun, Pan Chuanyan, Zhai Jieming, Sun Lijuan, and Liu Jiangchun, 2013). There is currently a lack of relevant information and assessment data on the impact of aquaculture wastewater containing pathogenic bacteria on the natural environment, but it is speculated that it can cause a certain degree of adverse effects on the surrounding environment. In addition, the widespread operation mode of feeding frozen and fresh juvenile wild fish in aquaculture also carries the risk of transmitting pathogenic bacteria of related diseases (Dai Yajuan, Yang Zhengyong, and Wang Fangfang, 2010).

China has carried out a variety of related work in the field of flatfish disease prevention and control, including disease resistance seedling development, research of related aquatic vaccines (such as China's first live marine animal vaccine approved for production in 2015 - Edwardsia tarda vaccine, which has been verified to effectively increase the survival rate of nursery breeding by about 20% and has been promoted and used nationwide (anonymous, 2011; Zheng Yanyun, 2016)), and improve breeding technology and other means to alleviate the impact of diseases on the industry. At present, the focus of the flatfish aquaculture industry is concentrated in the field of scientific research, and there is still a lack of relevant control policies and measures at the government level. Compared with the early stage of industrial development, China has made a significant leap in the treatment of flatfish culture, mastering treatment methods of a variety of diseases, but diseases are still one of the problems plaguing the development of flatfish farming.

In summary, CSSA believes that there are many diseases in the flatfish aquaculture industry, and although certain achievements have been made in disease treatment and control, there is still room for improvement in effectively guiding farmers to deal with various disease outbreaks, scientific treatment of various diseases, and effectively alleviating the occurrence of diseases. In the future, it is recommended to strengthen the feeding management of the aquaculture industry, promote the standardized breeding technology to reduce the incidence of diseases (Liu Longteng, Zhu Xuemei, Zhao Mingjun, 2018), develop vaccines, anti-disease and immune enhancers through multiple approaches, improve the supervision and control of diseases by management, and reduce the incidence and dosage of drugs in aquaculture industry.



感染大菱鲆正面观 感染大菱鲆腹面观

Infected turbot observed from front Infected turbot observed from back

Fig. 5 Cultured turbot died from diseases (Li Shanshan, 2007)

Criterion 4: Escape Risk and Response Method

Escape risk

Currently, in China's flatfish aquaculture industry, there is a pattern of coexistence between native high-quality species and introduced foreign species. The most widely farmed species, the turbot, originates from the United Kingdom and now contributes to the greatest production. Furthermore, Atlantic halibut (*Hippoglossus hippoglossus)*, Senegalese sole (*Solea senegalensis)* and European sole (*Solea solea)* were introduced from Europe. Atlantic flounder (*Paralichthys dentatu)* and Southern flounder (*Paralichthys lethostigma)* were introduced from America. Barfin flounder (*Verasper moseri)* was introduced from Japan. Starry flounder (*Platichthys stellatus*) was introduced from Korea. Local species included tongue sole, spotted halibut (*Verasper variegatus)*, stone flounder (*Kareius bicoloratus*) and many other excellent species originated from China's coastal waters (Wang Weibo, 2016). Since the culture mode is mostly land-based aquaculture (factory culture, pond culture, etc.), the risk of escape mainly occurs during the water exchange phase, where there is a possibility of larvae or gametes entering the natural environment through discharged water. Additionally, some farmers may release diseased but not yet dead farmed individuals into the natural environment, leading to the potential escape of relevant farmed species. It is also possible that cultured individuals can escape from some near-shore net cages. However, at present, there is no analysis or research in this field in China, and no escape reports have been found after searching relevant public information. It is therefore difficult to know whether there is a related escape and its impact on the ecosystem. In addition to the introduced species, some native species have received artificial selection (Song Qianhong, 2010), and it is also unknown whether the related escape will affect the genetic diversity of the original wild population. In the data study of flatfish-related enhancement and release, no unreasonable release of introduced species was found.

In the context of serious pollution of the marine environment in China's offshore waters and high fishing intensity of offshore fisheries, it is speculated that even if introduced species escape, the impact on local ecosystems and biomes may be limited, but the possibility of escaped species establishing wild populations in China's offshore waters and the risk of competition with native species that are not conducive to the balance of the original ecosystem cannot be ignored.

Based on the research and evaluation of various data, CSSA believes that the potential escape risk and harm to farmed flatfish are unknown. In view of the large number of introduced and improved species of farmed flatfish in China, it is suggested to establish a control mechanism for aquaculture escape in the future, and at the same time conduct timely and effective monitoring and recording, carry out relevant risk assessment work at the national level and scientific research grasp potential risks, establish possible treatment mechanisms, reasonably control the farming scope of introduced and hybrid species, and avoid the impact of aquaculture escape on the local ecosystem.

Criterion 5: Feed Requirements

Wild caught fishery resources ratio and sustainability in aquaculture feed

Three types of feed are mainly used in the process of flatfish culture, including direct feeding of purchased frozen and fresh wild trash fish (mostly anchovy, pacific sand lance, blenny, etc.) (Wang Tengteng, 2016); Semi-artificial feed, that is, wet semi-artificial compound feed made by crushing fresh trash fish and rotifer and purchased premix; Complete compound feed refers to the complete pelleted feed produced and sold by feed manufacturers, divided into two categories: imported and domestic (Dai Yajuan, Yang Zhengyong, Wang Fangfang, 2010). At present, the consumption of frozen and fresh wild trash fish in the process of flatfish culture is not small, and the proportion of compound feed still needs to be improved (Wang He, 2018; Flatfish Industrial Technology System, 2012). Artificial compound feed is used in 30% of cultured turbot production, while the rest is fed by frozen trash fish. Farmers believe that the flatfish fed with fresh trash fish grows fast and has low cost, but they ignore that such frozen and fresh trash fish are not easy to store, the supply is unstable, and there are many problems such as carrying potential pathogenic bacteria, feeding residual bait polluting the environment, and production methods are extremely unsustainable for the protection of fishery resources (Xu Kaixin, Wang Chunxiao, and Yang Zhengyong, 2012; Dai Yajuan, Yang Zhengyong, and Wang Fangfang, 2010).

Fig.6 Compound fish feed for farmed flatfish

In various aquaculture modes, RAS only uses artificial pellet feed, and indoor flow-through type, pond and cage culture have a certain degree of direct feeding of frozen and fresh trash fish. In the survey on the proportion of compound feed used by the main species of flatfish, it was found that the prevalence of compound feed was the highest in tongue sole culture, followed by turbot and the lowest was olive flounder (Wang He, 2018). Among the various types of artificial compound feed sold in the market, after years of continuous research and development, the feed quality of domestic feed has gradually caught up with imported feed (Jia Lei, Liu Hao, Chen Jinghua, Wang Yanhuai, Song

Wenping, 2010). Literature analysis shows that the feed coefficient of all kinds of domestic or imported flatfish feeds is mostly between 0.7-1 (Fang Zhenhua, 2017; Jia Lei, LIU Hao, Chen Jinghua, WANG Yanhuai, SONG Wenping, 2010; Lei Ji-Lin, Yang Zheng-Yong, Ni Qi, Zhang Hesen, 2010). In addition, the protein content in general flatfish feed is about 50% (Dai Yajuan, Yang Zhengyong, Wang Fangfang, 2010), due to the high demand for protein of flatfish, according to the data provided by relevant aquatic enterprises (personal contact, Shandong Blue Ocean Technology Co., Ltd.), the content of fishmeal and fish oil in its feed is about 50% and 6% respectively, according to the above data, the corresponding fish feed grade ratio of fishmeal and fish oil is calculated (FCR is calculated by taking the median value of 0.85 between 0.7 and 1.0, and the FCR/eFCR is set to 1)：

FFER (fish meal)= (fish meal proportion*FCR/eFCR)/22.5=2.2%

FFER (fish oil)= (fish oil proportion* FCR/eFCR)/5.0=1.2%

FFDR（Forage Fish Dependency Ratio）≤ 2.9

Results show that the fish dependency ratio of flatfish are high, and there is still significant room for improvement.

According to the assessment results, CSSA believes that there is a significant room for improvement in the feed use in flatfish aquaculture, and the existing feeding mode of direct use of frozen and fresh juvenile trash fish accounts for a large proportion. In the evaluation of artificial compound feed, it was found that its feed coefficient has gradually reached less than 1 with the research and development, and the FFDR is also gradually decreasing, and industrial feed is gradually reducing its dependence on fishmeal and fish oil, but a large amount of fish meal and fish oil are still needed as feed raw materials. It is recommended to gradually reduce the use of juvenile trash fish in the future, strengthen and guide the application of artificial compound feed, and continue to increase the research and development of related feed efficiency ratios to further reduce the dependence on wild feed fish.

Criterion 6: Source of Stock

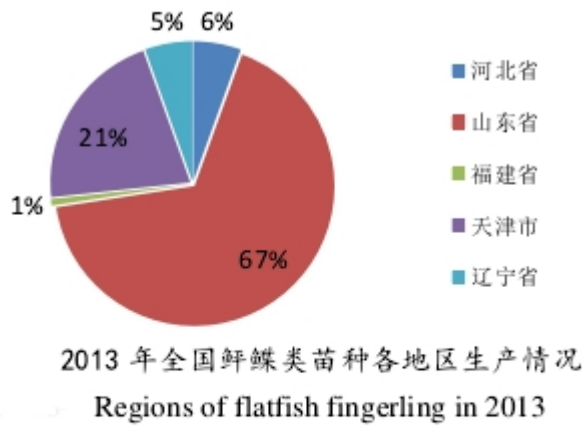
Source of seedlings

China's breeding work for flatfish aquaculture primarily relies on the breeding research laboratories within the national flatfish industry technology system, research institutions, universities, provincial-level and above original and elite seed farms. This is supplemented by numerous small-scale flatfish seed breeding units. Currently, cultured flatfish species have achieved full artificial seed breeding, and related seedling breeding and selection technologies have reached international leading levels. The province with the largest flatfish breeding in China is Shandong Province, accounting for more than 60% of the country's total, followed by Tianjin, accounting for about 20% of the market share, and cultivating about 300 million flatfish seedlings per year (Wang Weibo, 2016). Currently, all flatfish aquaculture does not require obtaining seedlings from the natural environment and relies entirely on artificial factory seedling cultivation.

Fig.7 Turbot Fries

Alongside the increase in the cultivation of seedlings, China has also initiated the breeding of related excellent varieties that exhibit faster growth rates and higher survival rates compared to ordinary breeds. (Yu Qinghai, Gong Chunguang, Yin Rui, Sun Guiqing, and Wang Qinglin, 2017). At the same time, the current artificial seeds are used to compensate for the declining fishery resources in the offshore waters, and the proliferation and release of native species such as the barfin flounder have been carried out (Rushan Times, 2018). In addition, attempts are also being made to develop improved hybridization of related varieties. It is worth noting that in some main breeding areas for flatfish, such as Qingdao, there is a phenomenon of genetic degradation in the seedlings of turbos. (Xu Zhong, 2012; Jia Lei, Song Wenping, Miao Jun, Qiao Yanlong, 2010). The progress of genetic improvement is slow, and there is a lack of awareness of good breeds in existing seedling farms. Correspondingly, there is a lack of scientific planning in seedling management. (Liu Kun, 2010; Wang Microbo, 2016).

Based on the evaluation results, CSSA believes that China has developed a diversified seedling breeding industry for flatfish, integrating production, academia, and research. The related seed industry management and production systems continue to expand, and breeding technologies are constantly innovating. However, there are still issues in the seedling production process, weak awareness of good breeding practices among enterprises, and occurrences of genetic degradation in some regions. Therefore, CSSA suggests continuing to increase research and promotion efforts for superior germplasm, enhancing awareness and technology among enterprises and seedling breeding facilities to achieve better availability of superior seed resources. Additionally, it is recommended to study and assess whether there is a competitive relationship between related superior germplasm and wild populations, and to avoid the entry of artificially cultivated improved or hybrid germplasm into natural environments, ensuring the rational use of artificial germplasm resources.



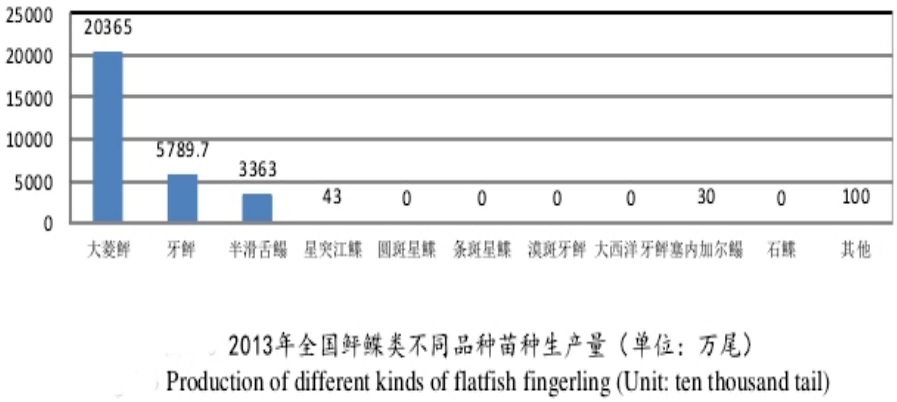


Fig.8 Production status and proportion of flatfish fries in the main producing areas in China in 2013 (Wang Weibo, 2016)

Criterion 7: Wildlife Interaction

Wildlife (especially threatened species) interaction

The vast majority of flatfish aquaculture adopts factory-based flow-through and recirculating aquaculture systems (Song Qianhong, Zhao Yongfeng, 2016; Yang Zhengyong, Guo Honghu, Zhang Yuyan, 2012), which are considered closed systems and do not allow contact with wild animals from the outside. No records of contact with wild animals have been found in pond aquaculture, likely due to its benthic characteristics and the depth of the aquaculture ponds (Zhao Yongfeng, 2006). As for nearshore cage aquaculture, there have been no studies or reports indicating contact with wild animals, but it is speculated that feeding processes may attract surrounding fish and other wild animals.

Given the fact above, CSSA believes that the contact with wild animals in flatfish culture is limited, while a small number of cage culture and other modes have such possibilities but the current lack of relevant assessment and data. Considering the isolation of cage aquaculture species from the outside environment, there is also no situation of removing predators, competitors for bait, etc. Therefore, the assessment basically indicates that there is low risk of contact with wild animals.

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