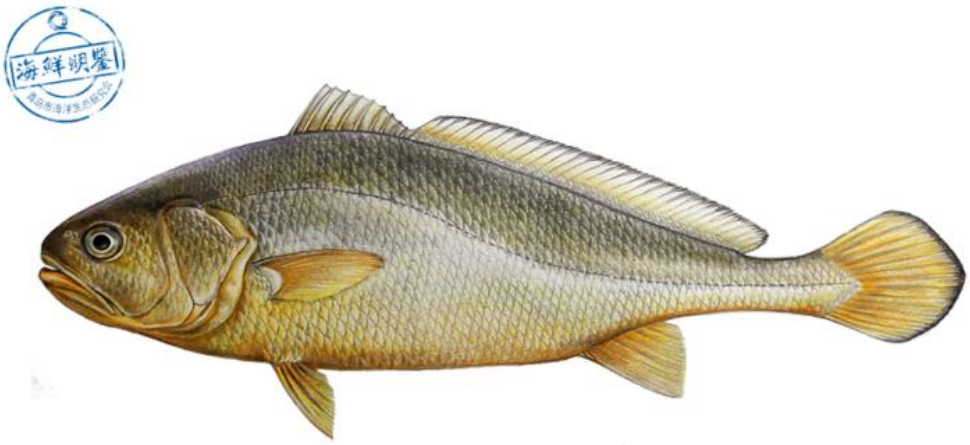
China Sustainable Seafood Assessment (CSSA)

Aquaculture



Large yellow croaker (*Larimichthys crocea*)
Cage Farming

CSSA Team

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Statement

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

Content

Introduction

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

Executive Summary

Large yellow croaker (*Larimichthys crocea*) is one of the most extensively farmed marine finfish species in China, with a production volume of 257,683 tons and a production value of nearly 3 billion RMB in 2022. Currently, large yellow croaker farming in China is mainly concentrated in Fujian Province and Zhejiang Province, accounting for 84% and 14% of the national production, respectively. Common farming methods for large yellow croaker include cage farming, pond farming, inner bay-net barring farming, subtidal-zone enclosure net farming, etc. Among them, inner bay cage farming accounts for over 85% of the total production.

China has implemented a series of laws and regulations to regulate aquaculture, covering the sectors including farming area management, seedling, medication, and market circulation, with specific provisions existing for reducing medication usage, disease control, and the use of compound feed for the large yellow croaker farming industry. These efforts contribute to promoting the green and healthy development of the large yellow croaker farming industry. Additionally, the industry has established multiple standards related to large yellow croaker farming to regulate breeding, farming, processing, and other aspects of the industry. Fujian Province has launched a special campaign to regulate the use of medications for large yellow croaker and crack down on the illegal use of veterinary drugs such as quinolone and sulfonamide.

The environmental impact of inner bay cage farming primarily involves the generation of organic waste such as excessive feed and feces, which, if accumulated over time, can lead to eutrophication of the water. Currently, there is a common problem of high density of cage in large yellow croaker farming, leading to decreased water exchange capacity and exacerbating water pollution effects. It also tends to trigger widespread diseases and adversely affect other wildlifes in the vicinity.

Common diseases in large yellow croaker farming include bacterial diseases (such as enteritis, tail and mouth rot, and gill rot), parasitic diseases (such as ciliates, nematodes, and Benedenia), white spot disease, and water mold disease. Among them, diseases caused by Vibrio bacteria are particularly severe due to their high incidence and wide prevalence.

To control disease outbreaks, antibiotics like enrofloxacin are commonly used in cage farming, along

with pesticides like trichlorphon, formalin, copper sulfate, and ferrous sulfate acting as fungicides and insecticides. The use of such drugs must strictly comply with relevant regulations. However, in recent years, incidents of enrofloxacin exceeding the limits have occurred, along with cases of illegal use of ofloxacin.

Traditional nearshore farming cages have weak resistance to storms and are susceptible to damage from natural disasters such as typhoons, leading to frequent large yellow croaker escapes. As the current farming stocks are almost entirely derived from artificially selected seedlings, escaped individuals have the chance to grow and reproduce in the wild, potentially forming stable populations, posing a potential threat to the genetic diversity of wild populations. Moreover, farmed large yellow croaker entering the wild environment without screening may also cause disease spread.

Currently, the use of compound feed in the large yellow croaker farming feed remains low, at approximately 25%, with farmers primarily relying on fresh or frozen wild small and juvenile fish as the main feed. Experts estimate that the dependence ratio for farmed large yellow croaker (below 150g) is about 1: (5-6), while for bigger individuals (over 200g) is about 1: (7-8), indicating a high dependence on wild fishery resources in the industry.

Currently, the main source of large yellow croaker seedlings come from Ningde selected from Guanjingyang stock, while over 60% of the Daiqu stock seedlings bred in Ningbo used for stock enhancement, showing a high degree of artificial selection in the large yellow croaker seedlings. Among them, the Guanjingyang stock seedlings represented by "Fufa No. 1" and the Daiqu stock seedlings represented by "Yongdai No. 1" are the most representative.

Information on interactions between large yellow croaker farming and wild animals is lacking. Apart from the potential blockage of migration routes of marine species by farming cages, there may be egrets preying on farmed large yellow croakers. Farmers generally reduce such losses by using cover nets or warning stripes, resulting in a low risk of significant impact on wild animals.

In summary, the large yellow croaker farming industry in China faces challenges such as high farming density, frequent disease outbreaks, high escape risks, and high dependence on wild fishery resources. Environmental performance of this industry needs improvement. Therefore, CSSA rates China's large yellow croaker farming as yellow—overall sustainability is good, but there is significant room for improvement.

Large Yellow Croaker

Larimichthys crocea

Think Twice

(Cage Farming)

Overview of the Assessed Species

The large yellow croaker (*Larimichthys crocea*) belongs to the order Perciformes and the family Sciaenidae. It is one of China's traditional "Four Major Marine Products" (alongside small yellow

croaker, hairtail, and cuttlefish) and holds significant economic value in China's domestic fisheries.

In China, large yellow croakers primarily inhabit coastal areas extending from the central Yellow Sea to the east of the Qiongzhou Strait, typically within depths of approximately 60 meters. They are present year-round in regions such as Fujian, Zhejiang, and the eastern part of the Qiongzhou Strait. Zhejiang, Fujian, and Guangdong are the provinces with the highest catches of large yellow croakers in China.

Due to overfishing during the 1960s and 1970s, wild large yellow croaker populations in China experienced a rapid decline. In response, China initiated research on the artificial breeding of large yellow croakers in the 1980s. Advances in technology led to significant expansion in the scale of artificial breeding, particularly in Fujian Province. For instance, in Fujian, the number of breeding cages increased from a few hundred in 1994 to over 300,000 by 2000. Major aquaculture areas include Fu'an, Fuding, Ningde, Xiapu, Luoyuan Bay, Lianjiang, Fuqing, and Pingtan in Fujian Province.[26]By 2010, China's annual production of large yellow croaker had reached approximately 100,000 tons, with Fujian Province contributing nearly 90,000 tons, Zhejiang Province 3,000 to 5,000 tons, and Guangdong several thousand tons.[7] In 2022, China's annual production of large yellow croaker reached 257,683 tons, valued at nearly 3 billion RMB. Fujian accounted for 215,231 tons of production, Zhejiang around 36,000 tons, and Guangdong approximately 5,000 tons.[19]

The market for large yellow croaker in China has expanded to inland regions and international markets. Ningde City in Fujian has emerged as a hub for production and sales, with the majority of farmed large yellow croakers being sold there. Products mainly include fresh, frozen, and salted large yellow croaker. Due to logistical challenges on live fish, fresh and frozen fish are the primary products domestically, with salted fish serving as a supplementary option.

FULL ASSESSMENT

Criterion 1: Aquaculture Method and Management Status

Aquaculture method and industry overview

Common farming methods for large yellow croaker include cage farming, pond farming, inner bay-net barring farming, subtidal-zone enclosure net farming, etc. Among these methods, inner bay cage farming represents over 85% of the total production.

Cage farmers typically utilize 4 meters x 4 meters cages with depths ranging from 5 to 8 meters, constructed with wooden frames and nylon nets. Several key factors influence cage farming efficiency, including site selection, construction techniques, cage deployment methods, and farming densities.[24]Farmers typically choose calm and well-flowing harbor areas to deploy the cages. Smaller cages are often used to raise the temporary fish, while larger cages accommodate adult fish. Larger cages allow adult fish to move around, resulting in improved fish quality and value, as well as higher survival rates, which ultimately reduce farming costs. Farming density is another crucial factor, as appropriate densities enhance production and profitability. Low densities can lead to increased

residual feed, elevating costs and impacting the fish's growth environment. Conversely, high densities may result in inadequate feed intake for some large yellow croakers, affecting their growth rates.[24]

Currently, large yellow croaker cage farming has developed into large cage farming with an area exceeding 400m^2 and water depths exceeding 10m. In this farming model, the farming density for fish of 100g size is approximately 40 individuals/m^3, and the average water yield can reach 12kg/m^3 to 15kg/m^3. While this innovative model improves the quality of farmed fish, the resistance to current has decreased. Therefore, necessary protective measures need to be taken.

Plastic cage farming involves the utilization of plastic material (HDPE) for both the cage frame and floating devices, upgrading and modifying traditional raft-style cages. HDPE cages offer several advantages over traditional rafts, including enhanced safety, prevention of white pollution from foam plastics, and environmental friendliness due to their recyclable properties. However, the initial investment cost for HDPE cages is higher compared to traditional rafts.[21]

Deep-sea cage farming involves using specialized cages in relatively deep-sea areas, typically with depths greater than 20 meters, for cultivating large yellow croaker. It serves as a supplementary form of large yellow croaker raft-style cage farming and has emerged in recent years. The cage frame is primarily constructed from HDPE material, while the net material is typically polyvinyl chloride (PVC) or copper alloy. Each cage is submerged to a depth of approximately 10 meters. Due to the stronger current in these areas, larger fish are primarily used in this model, providing ample space for their growth. However, challenges such as strong water currents, slow growth rate, high costs, and the need to enhance resistance to currents and waves have limited the widespread adoption of this farming model. Currently, this model is mainly concentrated in semi-open or open sea areas such as Nanji Island, Dachen Island, and Putuo Mountain in Zhejiang Province.[11][21]

The enclosure net farming model, which emerged in 1999, is a type of large yellow croaker farming method primarily conducted in shallow coastal areas in the subtidal zone. It involves the use of inner bay-net barring farming, subtidal-zone enclosure net farming, etc. Compared to traditional small cage farming, this model offers advantages such as larger fish activity space, fewer diseases, and higher survival rates. Additionally, it can utilize natural biological feed supplements, leading to relatively lower feed costs. However, this farming method is limited by factors such as a scarcity of suitable farming areas, weak disaster resistance, and high investment requirements. Furthermore, after several years of farming, it may lead to fish diseases due to bottom sediment pollution. Currently, its development scale is relatively small, covering an area of nearly 50 hectares.[21]

Pond farming requires high standards for pond structures and bottom substrate conditions. Poor water quality can easily lead to outbreaks of fish diseases and result in significant losses. In 1998, pond farming areas in Fujian Province reached over 20,000 mu (approximately 13.3 square kilometers), but currently, they are only around 3,000 to 5,000 mu, primarily focusing on phased farming.[21]

Table 1 China's large yellow croaker farming area in 2020 (10^4 m^2) [23]

地区	深水网箱养殖	围网养殖	普通网箱养殖
浙江	395.66	320.34	8.83
福建	33.75	136.60	6 215.40
广东	3.22	0	1 175.74
合计	432.63	456.94	7 399.97

Currently, large yellow croaker farming is primarily concentrated in Fujian Province and Zhejiang Province, which account for 84% and 14% of the national production, respectively. In 2022, China's annual production of large yellow croaker reached 257,683 tons, with a production value of nearly 3 billion RMB. Among these figures, Fujian's production amounted to 215,231 tons, Zhejiang's production was approximately 36,000 tons, and Guangdong's production stood at around 5,000 tons.[19] In Fujian, farming areas are predominantly concentrated in the waters of Ningde, representing approximately 75% of the total provincial production. [22]Additionally, areas such as Lianjiang County in Fuzhou, Wenzhou, Taizhou, Ningbo, and Zhoushan in Zhejiang Province, as well as Huidong County in Huizhou, Guangdong Province, are also important regions for large yellow croaker farming.[6]

Large yellow croaker farming involves two main stages: fish seedling cultivation and adult fish farming, starting from 3cm-long fingerlings until they reach marketable size. The farming cycle varies from 1 to 2 years depending on the desired size specifications. During the fish seedling cultivation phase (from 3cm to 10cm in total length), fingerlings are typically released into the cage in spring (April to May) or autumn (October to December), with cage sizes typically around 3m x 3m x 4m. The farming density is approximately 10,000 fingerlings per cage, and as the fingerlings grow, they are periodically distributed to control the density. The adult fish farming phase involves raising the fingerlings, typically weighing 50g each, to marketable size, which is around 350g per fish. This process takes 8 to 15 months. When the fish reach marketable size, there are usually around 1,500 fish per cage, with an average weight of 0.4kg per fish, yielding approximately 600kg of marketable fish per cage. Survival rates among different farming operations can vary significantly, with an average survival rate of 70%, reaching as high as 90% in some cases and as low as 30% in others.[13]

Government supervision

In China, a series of laws and regulations have been enacted to regulate aquaculture, covering aspects such as site selection, seedling selection, chemical use, and marketing. In 2003, the Ministry of Agriculture issued the "Management Regulations on the Quality and Safety of Aquaculture," which unified requirements for water use, aquaculture production, feed, and aquaculture drugs. In 2020, the Ministry of Agriculture and Rural Affairs released the "Opinions on Accelerating the Green Development of Aquaculture," advocating the implementation of five major actions for green and healthy development of aquaculture. These actions include promoting ecological and healthy aquaculture models, treating effluent from aquaculture, reducing the use of aquaculture drugs, replacing fresh and frozen fish feed with compound feed, and improving the quality of aquaculture

seedlings. Regarding the reduction of aquaculture drug usage, specific diseases for large yellow croaker and flounder are targeted. In the replacement of fresh and frozen fish feed with compound feed action plan, it's proposed that in 2020, at least 2 pilot sites be established in Zhejiang, Fujian, and Guangdong provinces, with a target of achieving a substitution rate of not less than 60% of fresh and frozen fish feed with compound feed for large yellow croaker marine aquaculture.[18]In 2022, the Ministry of Ecology and Environment and the Ministry of Agriculture and Rural Affairs jointly issued the "Opinions on Strengthening the Ecological Environment Regulation of Marine Aquaculture," which outlines requirements from four perspectives: environmental impact assessment management and zoning optimization, implementation of aquaculture effluent investigation and rectification, strengthening monitoring and regulatory enforcement, and enhancing policy support and organizational implementation to promote the green development of marine aquaculture.

Moreover, the aquaculture industry has introduced several standards related to the production of large yellow croaker. Fujian Province has been actively promoting the construction of industry standards for large yellow croaker, and national standards for large yellow croaker have been developed with Fujian as a reference point. In 2011, Fujian Province included large yellow croaker as a key aquatic product in its pilot project for establishing a quality and safety traceability system for aquatic products, achieving supply chain traceability. In 2018, the Fujian Provincial Bureau of Ocean and Fisheries issued the "Special Rectification Implementation Plan for Quality and Safety of Large Yellow Croaker in Fujian Province," requiring "100% coverage" to rectify the prohibited use of drugs such as quinolones and sulfonamides in the breeding and farming stages of large yellow croaker.[21]

Criterion 2: Habitat Impact

Habitat impacts

In the last two decades, cage aquaculture has undergone rapid expansion, emerging as one of the fastest-growing sectors in the global aquaculture industry. However, this rapid growth has brought about certain environmental challenges. The primary impact of cage aquaculture on the surrounding environment revolves around the production of organic waste, including residual feed and feces. A significant portion of these organic wastes settles into the sediment at the bottom of water bodies, releasing soluble nutrients like nitrogen and phosphorus into the water. This process can lead to water eutrophication, with polluted sediment becoming a potential source of pollution, posing risks to the entire aquaculture system and the health of wild organisms and humans. In recent years, there has been growing concern regarding the impact of sediment from cage aquaculture, influenced by factors such as site selection, farmed species, feed, scale of aquaculture, and the surrounding biological community's capacity to absorb solid waste.

Presently, there is a notable issue of excessive cage density in large yellow croaker aquaculture. Large yellow croaker aquaculture typically occurs in shallow seas and bays, where water exchange capacity is limited, leading to reduced purification ability. According to national technical standards, a large yellow croaker aquaculture area should have a maximum of 100 cages. However, in some regions, the number of cages has surpassed 500.[4] This overcapacity impedes water flow, exacerbating the accumulation of organic waste and resulting in water eutrophication and frequent disease outbreaks, particularly during high-temperature seasons when dissolved oxygen levels decrease significantly. This not only impacts large yellow croaker yields but also adversely affects other fish resources. Overcapacity also contributes to fish diseases, causing annual economic losses estimated at around

200-300 million yuan.[15]Therefore, controlling the scale of aquaculture in marine areas and implementing rational zone planning of aquaculture are essential steps in reducing environmental pollution arising from large yellow croaker aquaculture.

Criterion 3: Chemical Use and Disease Control

Chemical use

In the prevention and treatment of common diseases in cage-cultured large yellow croakers, various supplements like compound vitamins, immune enhancers, probiotics, along with antibiotics such as enrofloxacin, and pesticides including trichlorphon, formalin, copper sulfate, and ferrous sulfate are employed as fungicides and insecticides.[12]Despite increased government efforts to regulate and eliminate the use of prohibited chemicals, instances of non-compliance exist among some aquaculture farmers. In 2018, banned drugs like enrofloxacin were found to exceed limits in large yellow croakers during export inspections and market sampling by the Ministry of Agriculture and Rural Affairs. This indicates that certain farmers did not adhere to withdrawal period requirements, while isolated cases of ofloxacin use were also detected in 2019. [21][6]

Disease control

Appropriate regions for placing regular cages are limited. In addition, the scale of breeding keeps expanding, and cages are linked and concentrated. All these factors sharply increase the organic load in the regional sea area and contribute to eutrophication, which can easily cause widespread diseases among cage-cultured large yellow croaker.[5] Once diseases occur, controlling their spread becomes challenging.[26]Diseases encountered in large yellow croaker aquaculture can be varied and problematic. In recent years, primary epidemic diseases mainly include enteritis, rotten mouth and tail, and rotten gill, while pests are mainly ciliates, ringworms, benny worms, and water mildew. Diseases caused by Vibrio bacteria are the most harmful ones, because of extremely high incidence rate and wide epidemic range.[8] These fish health issues have a high incidence rate and can cause extensive harm, which hinder the healthy and stable development of the industry. When there is no resistant cultivar, traditional treatment uses antibiotics and chemicals. However, with food safety having increasing importance, some effective medicines are forbidden. Therefore, in some operations, some nonspecific immune system response methods are applied to the prevention and cure of diseases of large yellow croaker, for instance, the application of Chinese herbal medicine.[1]

Criterion 4: Escape Risk and Response Method

Escape risk

Traditional wooden farming cages are less resistant to winds and are vulnerable to damage from natural disasters such as typhoons. There have been serious incidents in history, with Typhoon Maria in July 2018 causing more than 500 cages in San Du Ao to be severely attacked, resulting in the escape of juveniles including large yellow croaker. According to incomplete statistics, there were about 35,000 cages affected in San Du Town, including the large yellow croaker farming cages, with losses of about 105 million yuan. Currently, Fujian Province is promoting a standardization demonstration project for large yellow croaker aquaculture, and carrying out farming cage upgrades in Ningde City, Fujian, to help farmers replace the traditional wooden rafts with the larger, stronger and more environmentally friendly HDPE cages, which can effectively resist typhoons and reduce the risk of damage to the cages.

Since almost all current cultured individuals come from artificial breedings, for the individuals who escaped from the farms, there is a chance to grow and reproduce in the wild and form stable populations, posing a potential threat to the genetic diversity of wild populations. Some molecular studies showed that the molecular sequences of wild-caught large yellow croaker individuals in Zhoushan were similar to those of Ningde cultured individuals, which may be related to the fact that Ningde artificial bred juveniles had been introduced into the Zhoushan sea area through releasing in the past. This demonstrates the possibility of establishing stable populations in the wild for artificially bred individuals.[2]The results of a study also demonstrated that the cultured croaker had significantly reduced genetic diversity in contrast to the wild populations, and also presented statistically significant differentiation from the wild, indicating that enhancement of the current wild stock should be conducted with caution, as well as the prevention of the escape from the farms. [3]

In addition to the risk of genetic pollution, large yellow croakers from artificial cage farming entering the wild environment without screening may also pose a risk of disease transmission.[25] Furthermore, considering the various issues associated with nearshore cage farming, large yellow croaker farming is gradually shifting to offshore areas for deep-sea cage farming. As the selected offshore areas are often primary habitats for wild large yellow croakers, farmed stocks may compete with wild populations for natural bait resources.[28]

Criterion 5: Feed Requirements

Wild caught fishery resources ratio and sustainability in aquaculture feed

In the cultivation and farming of large yellow croakers, three primary categories of feed are utilized: copepods, fresh-frozen wild fish, and compounded feed.[10]

For adult large yellow croakers, main feeds include compounded feed, fresh and frozen wild fish and shrimp (which needs processing into paste for feeding). Wild fish and shrimp used as feed include low-value species such as sardines, Japanese anchovy, Chinese anchovy, bombay duck fish, goby, North Pacific krill, etc. These feeds are often mixed with economically valuable species like grouper, large yellow croaker, hairtail, mackerel, pomfret, shrimps, and swimming crabs.[9]

For the parent fish, feeds mainly consist of bivalves, supplemented with live polychaete worms and compounded feed. Juvenile fish are fed rotifers, copepods, brine shrimp, and paste of wild fish and shrimps, depending on their growth stage. Seedling cultivation generally needs wild fish paste, opossum shrimp, copepods, and compounded feed.

Currently, the usage of compounded feed in the large yellow croaker farming industry remains relatively low, with farmers primarily relying on fresh-frozen wild fish for feeding.[9] Since 2017, the sales volume of compound feed has remained stable at around 100,000 tons. It is primarily used during the seedling stage, high-temperature season, and winter period, with an approximate proportion in the total feed of 25%.[6]According to calculations based on the growth cycle of large yellow croakers, the feed coefficient for farmed fish is approximately 1:5-6 for smaller fish (less than 150 g) and 1:7-8 for larger ones (over 200 g).[6] In 2022, China's aquaculture production of yellow croaker exceeded 250,000 tons, making it the highest-producing marine aquaculture species. According to a survey report, in 2014, China's aquaculture of yellow croaker was less than 130,000 tons. During aquaculture, nearly 13,000 tons of fishmeal and fish oil were used, along with approximately 440,000 tons of fresh and frozen wild fish fed to the farms. This amounted to a total

usage of about 480,000 tons of marine fishery resources, with a FIFO (Fish in fish out) ratio of approximately 5.35.[17] This indicates that the industry still heavily relies on wild fishery resources.

While the use of fresh-frozen wild fish places a burden on fisheries resources and has disadvantages for farming, such as quality control challenges and environmental concerns, compounded feed offers convenience, labor and cost savings, and easy storage.[16][20][27] However, the quality of compounded feed needs improvement, as it may lead to decreased appetite, slow growth, and higher costs compared to fresh-frozen wild fish. Therefore, farmers still prioritize the use of fresh-frozen wild fish as feed for large yellow croakers due to overall economic considerations.

Criterion 6: Source of Stock

Source of seedlings

Currently, in China, the main source of large yellow croaker seedlings come from Ningde selected from the Guanjingyang stock. The breeding sites are mainly distributed in Jiaocheng District, Fuding City, and Xiapu County in Ningde City, as well as Luoyuan County in Fuzhou City, Fujian Province, and Cangnan County and Ningbo City in Zhejiang Province. In 2020, a total of 3.3 billion large yellow croaker fingerlings were cultivated. Among them, more than 60% of the Daiqu stock fingerlings bred in Ningbo City were used for stock enhancement. There is a high degree of artificial selection in the large yellow croaker seedlings. Among them, the Guanjingyang stock seedlings represented by "Fufa No. 1" and the Daiqu stock seedlings represented by "Yongdai No. 1" are the most representative. In recent years, although the Daiqu stock large yellow croaker bred in Zhejiang Province has a slower growth rate in the early stage, its slender shape is preferred by consumers.[6]

Criterion 7: Wildlife Interaction

Wildlife (especially threatened species) interaction

The information regarding the interaction with wild animals in yellow croaker aquaculture is relatively scarce. Large yellow croaker aquaculture is currently primarily concentrated in nearshore bays, where the installation of high-density net cages may block the migration routes of marine species, occupy crucial habitats for juveniles, and disrupt water flow, thereby affecting the water quality of aquaculture areas, which may have an impact on marine species in the surrounding environment. Additionally, birds such as egrets may prey on farmed croakers, and some farmers mitigate the losses by covering bird nets, floating warning stripes, etc.

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Reference

[1] Jian J, Wu Z. Effects of traditional Chinese medicine on nonspecific immunity and disease resistance of large yellow croaker, Pseudosciaena crocea, (Richardson)[J]. Aquaculture, 2003, 218(1):1-9.

[2] Kon, T. , Pei, L. , Ichikawa, R. , Chen, C. , Wang, P. , & Takemura, I. , et al. (2021). Whole-genome resequencing of large yellow croaker (larimichthys crocea) reveals the population structure and signatures of environmental adaptation. Scientific reports, 11(1), 11235.

[3] Le, Wang, Xiaofeng, Shi, Yongquan, & Su 等. (2012). Loss of genetic diversity in the cultured stocks of the large yellow croaker, larimichthys crocea, revealed by microsatellites. International Journal of Molecular Sciences.

[4] Tom Tietenberg.环境与自然资源经济学(第 6 版)[M].北京:清华大学出版社,2005. Tom Tietenberg. (2005). Environmental and Natural Resources Economics [M].

[5] 陈艳, 吴思伟, 胡续雯,等. 网箱养殖大黄鱼的病害防治[J]. 江西农业, 2016(15):111-112. Yan, C. et al. (2016). Disease control of net-pen culture of large yellow croaker [J]. Jiangxi Agriculture. 2016(15):111-112.

[6] 韩承义，吴雄飞，许斌福，等． 2020 年中国大黄鱼产业现状分析及发展建议［J］． 渔业研究， 2022，44（4）： 395 － 406．Cheng-yi, H., Xiong-fei, W. Bin-fu, X. (2022). Analysis and development suggestions of Larimichthys crocea industry of China in 2020. Journal of Fisheries Research. 44（4）： 395 － 406．

[7] 韩承义. 我国大黄鱼产业发展历程与市场分析[J]. 中国渔业经济, 2011, 29(5):67-74. Cheng-yi, H. China's yellow croaker industry development history and market analysis [J]. Chinese Fisheries Economics. 2011, 29(5):67-74.

[8] 何丽斌,林克冰,周震.闽东海水网箱养殖大黄鱼的病害及防治方法[J].齐鲁渔业 2001，18（6）：12-15. Li-bin, H. Ke-bing, L. Zhen, Z. (2001). The Disease and Method of Prevention of Pseudosciaena Crocea in Marine Cage Culture in Mindong [J]. Shandong Fisheries. 2001，18（6）：12-15.

[9] 洪万树，刘家富，郑炜强，等． 浅论我国大黄鱼产业转型升级之对策［J］． 渔业研究， 2018，40（4）：315 － 323．Wan-shu, H., et al. (2018). Transformation and upgrading countermeasure for the large yellow croaker industry in China [J]. Journal of Fisheries Research, 2018，40（4）：315 － 323．

[10] 胡兵. 大黄鱼系列配合饲料的应用现状[J]. 中国水产, 2015(3):48-50. Bing, H. (2015). Status of the application of the complementary feeds for large yellow croaker [J]. China Fisheries, 2015(3):48-50.

[11] 胡荣炊. 大黄鱼深水网箱养殖技术[J]. 渔业研究, 2011, 33(2):62-64. Rong-chui, H. (2011). Offshore Fish Farming Technique for Pseudosciaena crocea.

[12] 李安涵. (2023). 网箱养殖大黄鱼常见病害防治技术. 黑龙江水产 (06), 500-502. An-han, L. (2023). Common disease prevention and control technology for net box culture of Larimichthys crocea [J]. Northern Chinese Fisheries. (06), 500-502.

[13] 廖红梅,林培华,高健.宁德市大黄鱼成鱼养殖现状及对策[J].贵州农业科学,2011,(01):165-168. Hong-mei, L., Pei-hua, L., Jian, G. (2011). Current Situation and Strategy of Adult Large Yellow Croaker Aquaculture in Ningde City, China [J]. Guizhou Agricultural Sciences. 2011,(01):165-168.

[14] 刘家富, 韩坤煌. 我国大黄鱼产业的发展现状与对策[J]. 渔业研究, 2011(5):4-8.

[15] 刘家富,张艺,林培华,等.论海水鱼网箱的健康养殖与节能减排[J].现代渔业信息 2009,24(7):3- 5. Jia-fu, L., Yi, Z., Pei-hua, L. et al. (2009). On Healthy Culture Marine Fish in Net Cage and Energy Saving and Emission Reduction [J]. Modern Fisheries Information. 2009,24(7):3- 5.

[16] 刘招坤. 闽东地区大黄鱼养殖中饲料的使用现状分析[J].水产科技情报,2015,42(01):41-44+49. Zhao-kun, L. Analysis of the current status of feed use in the culture of large yellow croaker in eastern Fujian Province. Fisheries Science & Technology Information. ,2015,42(01):41-44+49.

[17] 绿色和平.中国水产养殖对海洋渔业资源的利用研究报告，2017. Greenpeace East Asia. (2017). An investigation report into China’s marine trash fish fisheries.

[18] 农业农村部.(2020).农业农村部办公厅关于实施 2020 年水产绿色健康养殖“五大行动”的通知，https://www.moa.gov.cn/govpublic/YYJ/202004/t20200401_6340521.htm. Ministry of Agriculture and Rural Affairs. (2020). Circular of the General Office of the Ministry of Agriculture and Rural Affairs on the Implementation of Five Actions on Green and Healthy Aquaculture in 2020.

[19] 农业农村部渔业渔政管理局, 全国水产技术推广总站, 中国水产学会. 2023 中国渔业统计年鉴 [M]. 中国农业出版社, 2023. China Agriculture Press. (2023). 2023 Chinese Fishery Statistical Yearbook.

[20] 宋科. 东极大黄鱼养殖区的水质分析和能值分析[D].浙江海洋学院,2013. Ke S. (2013). Water Quality analysis and energy analysis of Large yellow croaker mariculture areas in Dongji. Zhejiang Ocean University.

[21] 王凡, 廖碧钗, 孙敏秋, 林国清, 陈洪清, & 黄光亮等. (2019). 福建大黄鱼产业发展形势分析. 中国水产(3), 5. Fan, W. et al. (2019). Analysis of the development situation of Fujian large yellow croaker aquaculture industry[J]. China Fisheries (3), 5.

[22] 吴雄飞. 品牌引领 创新驱动 推进大黄鱼产业高质量发展. 第一届“蓝色食品”发展研讨会, 2023 . Xiong-fei, W. Brand-led and Innovation-driven Promotion of High-quality Development of Large Yellow Croaker Industry. The First Symposium on the Development of "Blue Food", 2023.

[23] 杨卫, & 周丹丹. (2022). 我国大黄鱼产业的集聚水平研究. 海洋开发与管理, 39(10), 8. Wei, Y., Dan-dan, Z. (2022). The Level of Industrial Agglomeration of Large Yellow Croaker in China. Ocean Development and Management, 39(10), 8.

[24] 杨卫, 王春苗, 张英丽, 冯小珊, & 王陈陈. (2018). 我国大黄鱼养殖产业现状及对策研究(上). 科学养鱼(5), 1. Wei, Y. et al. (2018). Research on the status and strategy of China's large yellow croaker aquaculture industry (1) [J]. Scientific Fish Farming (5) 1.

[25] 尤锋, 张培军, 相建海,等. 海水养殖鱼类遗传多样性的保护[J]. 海洋科学, 2003, 27(12):10-13. Feng, Y. et al. (2003). Conservation of genetic diversity on marine cultured fish. Marine Sciences [J]. 27(12):10-13.

[26] 张彩兰,刘家富,李雅璀,陈植.福建省大黄鱼养殖现状分析与对策[J].上海海洋大学学报,2002,(1):77-83.. Cai-lan, Z., Jia-fu, L., et.al. Analysing the present condition and countermeasure of cultured large yellow croaker Pseudosciaena crocea in Fujian Province[J]. Journal of Shanghai Ocean University,2002,(1):77-83.

[27] 郑钦华．三都澳青山岛养殖区水质现状调查及其对策[J]．河北渔业，2010(8) : 32 一 35．Qin-hua, Z. Survey on the Current Status of Water Quality in the Aquaculture Area of Qingshan Island, Sanduao and Strategy [J]. Hebei Fisheries. 2010(8) : 32 一 35．

[28] 庄定根, 南麂岛大黄鱼产业化养殖品质改良技术开发[D].宁波大学, 2014. Ding-gen, Z. (2014). Technique Development on Improving the Industrialization Culture Quality of Large Yellow Croaker (Pseudosciaena Crocea) in the Nanji Island. Ningbo University.