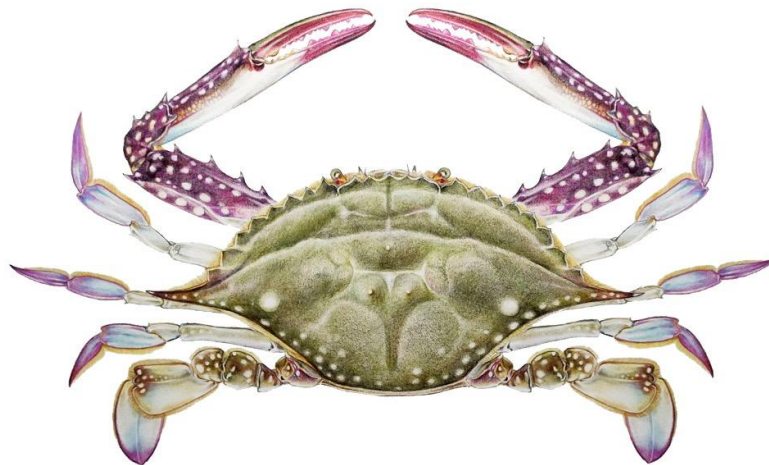




China Sustainable Seafood Assessment (CSSA)

Aquaculture



**Gazami Crab (*Portunus trituberculatus*)
Pond 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.

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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

Gazami Crab (*Portunus trituberculatus*) is the most widely farmed swimming crab species in China's coastal areas, with a national production of 109,017 tons in 2022, and Fujian, Jiangsu, Zhejiang, Shandong being the four provinces with the largest yield.

Since the 1980s, the technology of temporary rearing of Gazami Crab in ponds and nursing techniques has matured and been applied in coastal areas. At present, Gazami Crab aquaculture in China is mostly multi-species pond farming, the common species for this mixed-culture are shrimp, shellfish. To be more specific, species such as Chinese White Shrimp (*Penaeus chinensis*), Kuruma Shrimp (*Marsupenaeus japonicus*), Ridgetail Prawn (*Palaemon carinicauda*), Chinese Razor Clam (*Sinonovacula constricta*), Manila Clam (*Ruditapes philippinarum*), etc. Gazami Crab aquaculture is managed by national laws and regulations related to mariculture production, processing and transportation. Provinces and municipalities that have Gazami Crab aquaculture industry have also developed standards with local climatic and hydrological conditions taken into consideration. A management system targeting only the Gazami Crab industry is still missing, and the implementation status of laws and regulations is not clear yet. Besides, studies on the impacts of Gazami Crab pond farming on the surrounding environment, especially on critical habitats, are inadequate.

Disease control of Gazami Crab aquaculture has been well researched. Historically, various types of drugs have been used to prevent or treat diseases, but this has improved since the 21st century. More microbial agents and less environmentally harmful chemicals are used to regulate water quality and disinfect ponds, yet the impact of such substances entering the surrounding environment with the effluent is unknown. Due to the fact that Gazami Crabs are aquatic animals that do not move ashore unless under bad health conditions and the ponds have hardened embankments, escapes of crabs are rare. Research on better quality artificial broodstock is continuing, but there are still some farms that use wild-caught Gazami Crabs as supplements when there is a shortage of artificial broodstock. The impacts of catching wild egg-bearing crabs on stock and genetic diversity need to be paid more attention to and researched by more scientific research institutes.

A prominent problem in the Gazami Crab aquaculture industry is the use of juvenile miscellaneous fish. Some coastal aquaculture areas directly purchase miscellaneous fish at the dock or small-sized shellfish naturally grown in the mudflat. The former being an important footstone group in the marine ecosystem, and the latter being the main source of food for migratory waterbirds. The large

number of both consumed in the aquaculture industry will negatively affect the biodiversity of the coastal area and the near-shore sea.



Gazami Crab

Portunus trituberculatus

Think Twice

(Pond Farming)

Overview of the Assessed Species

Gazami Crab (*Portunus trituberculatus*) belongs to the phylum Arthropoda, class Malacostraca, order Decapoda, family Portunidae, genus *Portunus*. It is also known as swimming crab, white crab, Asian blue crab or horse crab, etc. The cephalothorax shape of Gazami Crab is like a weaving shuttle; 9 teeth on each anterolateral margin; 4 teeth on the front margin; 3 conspicuous warty protuberances on the back; and are overall teal green in color. The first pair of legs are claws, which can be used for feeding, self-defense, and mating; the second to fourth pairs of legs are walking legs, they are flattened, with pointed ends; and the last pair of legs are swimming legs, they are flattened, broad, and specialized in the shape of paddles.^{[40][27]} Similar to most species of the genus *Portunus*, Gazami Crab is an omnivorous species that consume mainly animal-based feed, and its main diet consists of crustaceans, cephalopods, and fish, with bivalves and their larvae making up the largest proportion of the diet, whereas the composition and number of species consumed varies seasonally.^[11]

Gazami Crab is adaptable in the context of temperature. It can survive from 5-35°C without drastic changes in temperature.^[15] It is mainly found in the Indo-West Pacific, and has been recorded in 17 countries, including China, Japan, Korea, Thailand, and the Philippines.^[1] It is naturally distributed in the offshore waters of coastal provinces from Liaoning in the north to Guangdong in the south, area with the largest production volume are the Yellow Sea and the Bohai Sea. Gazami Crab is a migratory species that usually comes to the shallow coastal waters to spawn in the spring and summer breeding seasons. Generally, according to their life cycle stage and the purpose of clustering, they are categorized into spawning groups, foraging groups and overwintering groups.^{[22][28]} Gazami Crab has several life history stages, including zoea, megalopae, juvenile, and adult. Their lifespan is usually 1-3 years.

As one of the most important mariculture species along the coast of China, the total national yield of Gazami Crab is 109,017 tons in 2022. Among them, Fujian was in first place by producing 31,762 tons of Gazami Crab, far outstripping the second. In addition, Jiangsu (20,811), Zhejiang (20,370), Shandong (19,083), Guangdong (13,825), Hebei (2,289), Hainan (616), and Liaoning (261) provinces also have Gazami Crab farms with relatively less production volume.^[22]

In the early 1980s, the Gazami Crab aquaculture in Shandong achieved initial success by farming in traditional ponds, and now the Gazami Crab are cultured from the north to the south in China.^[40] Pond multi-species mixed culture is the main production model, each coastal province and city takes

other factors such as location and climate condition into consideration and has also developed other models including farming in shrimp farming ponds with enclosed net, farming on lower tidal zone, cage culture, cement pond temporary culture. ^[6]

Crustacean farming industry in Shandong Province has formed a mixed culture with pond farming shrimp - crab - fish - shellfish - sea cucumber. Different types of mixed models are being tested and promoted in different cities, for example: Rizhao Donggang District to promote shrimp - Gazami Crab - Manila Clams - flatfish mixed culture, Weifang Changyi to promote Chinese shrimp - Gazami Crab mode, Binzhou Zhanhua District to promote the shrimp - Gazami Crab - razor clam model. ^[12]

Gazami Crabs are mostly sold fresh in the market, and there is usually no distinction between the sources (wild-caught or farmed) at the time of sale. Due to the different climatic conditions, the aquaculture cycle and the time of ready for market are different, therefore Gazami Crabs may be circulated and traded across the provinces. Nowadays, seafood consumers' demand for crab products is gradually diversifying, so semi-finished products such as frozen Gazami Crab lumps, meat, and shelled crab meat, as well as deep processed products such as canned crab meat, crab oil, crab paste, and crab roe paste, have begun to appear in the market. ^[39]

In recent years, the problem of heavy metal pollution in aquatic ecosystems has become increasingly serious, and the heavy metal accumulation in seafood products has received more and more attention from consumers, among which the excessive arsenic (As) and cadmium (Cd) in the Gazami Crab has also received attention from the food safety authorities and environmental protection organizations. Studies have shown that long-term consumption of aquatic products containing excessive As may lead to chronic poisoning and damage to the skin, liver and other human organs. Cd can accumulate in the human body at very low concentrations and cause irreversible damage to human organs. ^[34] A test comparing the Cd content of wild and farmed Gazami Crab in 2021 showed that the Cd content of edible tissues of the tested individuals ranged from 0.002 to 7.541 mg/kg. The Cd level of each part was in the order of gonads, pectoral muscles, and leg muscles in descending order, and the Cd content of edible tissues of wild Gazami Crabs was higher than that of farmed ones. ^[4] Since June 30, 2023, the Cd residue in Gazami Crabs has been adjusted to a maximum limit of 3.0 mg/kg, which is six times the previous standard, but there are still Gazami Crabs detected with Cd residue exceeding the standard in random tests afterwards.

FULL ASSESSMENT

Criterion 1: Aquaculture Method and Management Status

Aquaculture method and industry overview

Gazami Crabs farming ponds subject to geographic environment, breeding strains and other factors, the area ranging from 10 to 50 mu (1 mu = 666 m²) with a depth of 1-1.8 meters. The salinity needs to be greater than 16 ‰, Gazami Crab can survive but no longer gain weight if the salinity falls to 7-8 ‰. The release of seedling happens in the spring to early summer, the density of seedling released depends on different sizes, for example, 4-30 ind./g specifications of juvenile crabs can be released as a density of 2000-3000 ind./mu. ^[5] The mutual mutilation of Gazami Crab is common to be seen, and the survival rate is 30-50% when harvest, that is 1,000/mu juvenile crabs put into the pond, only 300-500/mu adult crabs can be harvested when the production cycle ends. Therefore, it is necessary

to ensure sufficient feed in all periods of the breeding process. From October to November (around Mid-Autumn Festival) is common market time, and in some areas the male crabs are harvested earlier than the female crabs, and the time of harvesting crabs can be up to around New Year's Day. The temperature is lower in the northern part of China, and the ponds are usually empty from New Year's Day to April of next year. However, there is no empty-pond period for multi-species (e.g. shellfish) mixed culture.

The main Gazami Crab aquaculture system is pond culture located mostly near the estuary. In recent years, provinces and cities have developed multi-species mixed culture modes in accordance with local climatic and hydrological conditions, with bivalve shellfish and shrimp as the main mixed species. In a 2020 experiment comparing the three aquaculture modes of Gazami Crab mono-culture, Ridgetail Prawn mono-culture, and Gazami Crab-Ridgetail Prawn mix-culture, it was found that the survival rate, average body weight, and yield of Gazami Crab were slightly higher for mix-culture than mono-culture mode. ^[10]

Location	Species Mixed	Description
Rizhao, Shandong Province	Chinese White Shrimp, Chinese Razor Clam ^[13]	The razor clams seedlings are put into ponds in late March, Chinese White Shrimp seedlings are released in mid-April, and juvenile Gazami Crabs are farmed from early May; razor clams feed on plankton, Chinese White Shrimp feed on Gammaridea species and other organisms, and Gazami Crab seedlings feed on fresh small clams (i.e. <i>Potamocorbula laevis</i>) and chilled small-sized shrimps, in later stages of production there are more chilled fish used
Weihai, Shandong Province	Chinese White Shrimp, Sea Cucumber ^[43]	Sea Cucumber are cultivated from October to May, the ponds would be cleaned and disinfected after harvest in May, then release Chinese White Shrimp in mid-May and release Gazami Crab seedlings in late-May, and then clean and disinfect the ponds for Sea Cucumber production after shrimp and crabs are harvested in September
Dongtai, Jiangsu Province	Giant Tiger Prawn, Hard Clam ^[30]	First release Gammaridea into the pond then put Hard Clam seedlings, and put Giant Tiger Prawn seedlings in late March, put Gazami Crab seedlings in early May; in mid-June start harvesting the prawns, and harvest the crabs by the end of the year, the clams are harvested within the year and then replenish the seedling, on the next year harvest the bigger clams and leave the small ones in
Huanghua, Hebei Province	Kuruma Shrimp, Whiteleg shrimp, Branded goby ^[14]	Kuruma Shrimp seedlings are released in late April, Gazami Crab and Whiteleg shrimp seedlings are released in mid-May, catching wild Branded goby

		seedlings in the drainage ditch in mid-June; harvest Kuruma Shrimp in mid-June, harvest Whiteleg shrimp and male Gazami Crabs in mid- to early-August crabs, harvest female Gazami Crabs at the end of September after finishing harvest all male crabs, harvest Branded goby in November
Ningbo, Zhejiang Province	Chinese Razor Clam, Ridgetail Prawn ^[16]	Chinese Razor Clam are released around the Qingming Festival, Gazami Crab seedlings are released by the end of May, wild-caught Ridgetail Prawn seedlings are released twice by end of May and late June to early July; harvest Ridgetail Prawn around the 1 st October, harvest Gazami Crab and Chinese Razor Clam around the Spring Festival
Tangshan, Hebei Province	Tiger Puffer ^[31]	Factory farming Gazami Crab adults are released around the 1 st October, Tiger Puffers are transferred from pond to indoor plant in late October to early November for wintering; harvest Gazami Crab from New Year's Day to the Spring Festival, and harvest Tiger Puffers from the middle to the end of April to sell or put them back into the ponds for breeding
Zhoushan, Zhejiang Province	Large Yellow Croaker ^[24]	Putting in large-size (80-100g/tail) Large Yellow Croaker seedlings at the beginning of April, Gazami Crab seedlings are released at the end of May; male Gazami Crabs are harvested at the beginning of September, female Gazami Crabs are harvested at the beginning of November, and harvest Large Yellow Croaker according to the market demand at the middle and end of November

Gazami Crab aquaculture in coastal ponds is susceptible to low temperatures, typhoons and other extreme weather effects. For example, in the winter of 2011, Zhoushan coastal aquaculture ponds were affected by the low temperature of seawater. The temperature lethal for Gazami Crab lasted for more than 40 days, resulting in a large number of deaths, and leading to a total loss of 20 million yuan for Gazami Crab farmers in Putuo District. ^[3] In 2019, the desalination of seawater in farming ponds caused by heavy rainfall brought by Typhoon Mina led to the death of Gazami Crabs farmed in the coastal areas of Xiangshan County due to lack of oxygen, and the farmers suffered heavy losses. ^[38] In 2023, Typhoon DuSuRui and Anemone passed through the southeast coast of China, affecting the Gazami Crab aquaculture in Ningbo, Zhejiang and Lianjiang, Fujian. ^{[21][25]}

Government supervision

China has published a series of laws and regulations to regulate aquaculture, with corresponding provisions on site selection, seedling selection, aquacultural chemicals, marketing, etc. In 2003, the Ministry of Agriculture and Rural Affairs (MARA) issued the "Regulations on the Management of Quality and Safety of Aquaculture", which unified the requirements for water usage, production,

feeds, and chemicals used in aquaculture. In 2020, MARA issued "Several Opinions on Accelerating the Green Development of Aquaculture Industry", which includes "Five Actions" to promote sustainable healthy aquaculture - the promotion of sustainable farming methods, the management of aquaculture effluent, reducing the use of drugs, promoting the amount of feed alternative to juvenile miscellaneous fish, and aquaculture seedling quality enhancement. In the "Complementary Feed Replacement Action Program for Juvenile Miscellaneous Fish", it is suggested that to establish more than 1 experimental pilot in Jiangsu, Zhejiang, Fujian, Shandong, Guangdong Province, the percentage of artificial feed use in Gazami Crab aquaculture should be higher than 30%. In 2022, the Ministry of Ecology and Environment (MEE) and the MARA jointly issued the "Opinions on Strengthening the Regulation of the Environmental Impact of Mariculture", which put forward requirements from four perspectives, namely, the management of environmental assessment and optimization of layout, the implementation of the investigation and remediation of aquaculture outlets, the reinforcement of monitoring and supervision inspections, and the enhancement of policy support and implementation, to promote the green development of the mariculture industry. There are national standards, such as the *Technical Specifications for the Selection of Good Species of Gazami Crab*, *Technical Specification for Artificial Breeding of Gazami Crab*, *Parental Crab of Gazami Crab* etc. [9] All of the above national policies are applicable to the seawater pond culture of Gazami Crab.

Gazami Crab aquaculture has a history of many years and is an important source of livelihood for some coastal communities. In order to guarantee the quality of aquaculture products and the income of farmers, many areas have introduced technical standards and industry norms for Gazami Crab industry. For example, the Aquatic Technology Promotion Station of Zhejiang and the Zhejiang Institute of Marine Aquatic Research Institute drafted the *Technical Specification for Gazami Crab Farming as a Pollution-Free Food* in 2002 [35]. Shandong Province also has its local standards which is the *Technical Regulations for Gazami Crab Fostering* in 2006. Fujian Province has released a local standard called *Technical Specification for Gazami Crab Farming* in 2013, and so on.

#	标准号	标准名称	省市区	状态	批准日期	实施日期	备案号	备案日期
1	DB21/T 3370-2021	三疣梭子蟹增殖放流效果评价技术规范	辽宁省	现行	2021-01-30	2021-03-02	79045-2021	2021-02-03
2	DB1302/T 511-2020	中国对虾与三疣梭子蟹池塘混养技术规范	唐山市	现行	2020-09-15	2020-09-25	76323-2020	2020-12-03
3	DB21/T 3167-2019	三疣梭子蟹增殖放流及验收技术规范	辽宁省	现行	2019-08-30	2019-09-30	63299-2019	2019-10-17
4	DB21/T 2825.5-2017	池塘混养技术规范 第5部分：中国对虾与三疣梭子蟹	辽宁省	现行	2017-06-26	2017-09-26	58498-2018	2017-12-14
5	DB33/T 395.1-2015	三疣梭子蟹 第1部分：苗种生产技术规范	浙江省	现行	2015-08-06	2015-09-06	52576-2017	2016-02-26
6	DB21/T 2208-2013	三疣梭子蟹放流增殖技术规范	辽宁省	现行	2013-12-12	2014-01-12	40995-2014	2014-01-13
7	DB35/T 1319-2013	三疣梭子蟹养殖技术规范	福建省	现行	2013-02-20	2013-05-20	38242-2013	2013-08-13
8	DB32/T 1946-2011	三疣梭子蟹活体运输技术规范	江苏省	现行	2011-11-10	2012-01-10	31609-2011	2011-11-16
9	DB33/T 795-2010	三疣梭子蟹增殖放流技术规范	浙江省	现行	2010-07-30	2010-08-30	29866-2011	2011-02-17
10	DB37/T 1193-2009	三疣梭子蟹苗种生产技术规范	山东省	现行	2009-02-17	2009-03-01	24799-2009	2009-03-18
11	DB32/T 1195-2008	三疣梭子蟹土池育苗技术规范	江苏省	现行	2008-02-28	2008-04-28	22543-2008	2008-03-24
12	DB37/T 715-2007	三疣梭子蟹放流增殖技术规范	山东省	现行	2007-10-09	2007-11-01	22208-2008	2008-02-25
13	DB32/T 1141-2007	三疣梭子蟹苗种集约化繁育规程	江苏省	现行	2007-11-26	2008-01-26	21622-2008	2007-12-28
14	DB37/T 621-2006	三疣梭子蟹养成技术规范	山东省	现行	2006-08-01	2006-10-01	19262-2006	2006-08-25
15	DB32/T 768-2005	三疣梭子蟹、菲律宾蛤仔混养技术规范	江苏省	现行	2005-02-03	2005-04-20	16517-2005	2005-02-18

Criterion 2: Habitat Impact

Habitat impacts

Gazami Crab aquaculture is mostly located near estuaries. Although most of the aquaculture ponds are set on traditional aquaculture designated areas, there are also cases where the ponds directly occupy coastal mudflat habitats. Similar to shrimp ponds and other types of pond culture, ponds

need to be regularly tilled to prevent the degradation of the substrate, and the organic matter produced by tilling may have influences to the surrounding environment. There have been disease outbreaks in mariculture crabs in recent years, and there is still a lack of regulations or standards for post-disease disposal measures. Pathogen-carrying effluent or infected crabs may cause illness in wild crustaceans in natural habitats.

At present, much emphasis is placed on precautionary measures in the green aquaculture of Gazami Crabs, relying on better water quality to maintain the health of farmed crabs, and increasing the amount and frequency of water exchanges as one of the methods to maintain water quality, which may lead to incomplete degradation of organic matter discharged from ponds, and consequently exacerbate the pollution of surrounding habitats. After MARA issued "Several Opinions on Accelerating the Green Development of Aquaculture Industry" in 2020, governmental departments at all levels began to pay attention to effluent treatment, and imposed strict requirements on the quality of water discharged from aquaculture ponds into the environment. However, small and medium-sized Gazami Crab farmers can hardly bear the cost of additional treatment equipment, which leads to difficulties in actual implementation and regulation. Especially during the later period of the aquaculture cycle when additional chilled fish are used as feeds, if the quantity and frequency of feeding are not reasonable, resulting in residual entering the drainage ditch, the untreated effluent may also lead to the pollution of the local habitat. Mixed culture of Gazami Crab and benthic filter-feeding shellfish can improve the water quality problem to a certain extent and achieve the goal of biological control.

In 2007, the "Pond Aquaculture Water Discharge Requirements" was released and implemented, and many places across the country have also promoted the policies of recovering lakes, wetlands, agricultural land to their original status, and further strengthened the comprehensive law enforcement of the water environment in an effort to achieve the harmonious unification of economy and ecology. The "Opinions of the State Council of the Central Committee of the Communist Party of China on Deepening the Battle Against Pollution" requires the standardization of aquaculture pond outlets, and the promotion of aquaculture effluent management in the main aquaculture production areas. In order to promote the management of aquaculture pollution, MEE and MARA 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.

Although there have been no reports of environmental pollution by Gazami Crab pond farming, it is generally recognized that the aquaculture activities in coastal areas may affect the offshore water quality to a greater or lesser extent. Some of the traditional coastal aquaculture areas have been withdrawn and restored to beach or mudflats. For example, there were a large number of aquaculture ponds along the coast of Jiaonan, Qingdao, Shandong Province, and some of them were relocated to Rizhao, Shandong Province, for Gazami Crab aquaculture after the restoration.

Criterion 3: Chemical Use and Disease Control

Chemical use

At present, China has published and implemented the "Regulations on Aquaculture Quality and Safety Management", "Several Opinions on Accelerating the Green Development of Aquaculture" and other laws and regulations, which require the use of water, production procedure, feeds, and chemical use. Among them, the use of drugs during the aquaculture process should follow a White List System, which means to strictly follow the "The Permitted Drug List for Aquaculture Use 2022 (No. 1 and 2)". Drugs can only be used when it is an approved medicine for aquaculture use, and is on the "Feed Ingredients Catalog" and "Feed Additives Catalog" list, that is the feed and feed additive products produced by enterprises that have obtained production licenses in accordance with the law.

Before the millennium, farmed saltwater crab disease treatment and control often used malachite green, antimicrobials, quinolinic acid, formalin, etc. to treat ponds and crabs infected with bacterial, fungal or internal parasitic diseases, while bleach, trichlorfon, and smoke filament dipping solutions were also used to prevent or treat external parasites.^[45] This phenomenon was obviously reduced after the implementation of "Regulations on Aquaculture Quality and Safety Management" in 2003, and more farmers adhered to the concept of "prevention first, treatment when necessary". To reduce the occurrence of diseases in aquaculture by maintaining good water quality, feeding high-quality feed, regularly patrolling the ponds to observe changes in the water color and the activities of crabs, not feeding fresh feed with pathogens, and cutting off the propagation of pathogens in a timely manner. Currently, commonly used chemicals include quicklime and camomile seed concentrate (cake) used to clear ponds prior to releasing seedlings, water quality protectants with zeolite powder and calcium peroxide as the main ingredients, bleach used for water disinfection, and microbial preparations based on photosynthetic and heterotrophic bacteria.^[23]

Disease control

Since Gazami Crab was included as an aquaculture crab species in the 1980s, with the increase in farming density, disease has become increasingly common. Diseases are mainly caused by four categories of pathogen, including bacteria, fungi, viruses and parasites.

Bacterial diseases: 1) Vibriosis. A type of disease caused by *Vibrio spp.* It is the most frequent bacterial disease in marine crustaceans. It is usually caused by the deterioration of external environmental conditions, which leads to an increase in the number of disease-causing *Vibrio spp.* and a decline of immunity. The peak of the disease is during the hatching period of the seedlings and the summer when the water temperature is high. At the early stage of infection, Gazami Crab show loss of appetite and slow movement, and with the increase of the degree of infection, they can stop eating or become comatose, and eventually lose the ability to move completely, which will lead to the death of the crabs. 2) Rotting gills disease. Mainly caused by *Vibrio*, *Aeromonas hydrophila*, *Edwardsiella* and other bacteria, the peak period of incidence is July-August. At the early stage of infection, Gazami Crabs would show loss of appetite and slow movement, gill filaments would turn dark gray or black. At the time when the infection is serious, crabs would stop eating, gill filaments will turn black completely with mucus attached, which will eventually lead to asphyxiation and death. 3) Leucothrix infection. More common in early stage, the peak is during the nursery stage when there is excessive organic matter in the water, especially in the summer when high temperature occurs as well as during the reproductive shed period of Gazami Crabs. 4) Shell ulcer disease. Caused by bacteria with the

ability to decompose chitin, the peak period is when the water temperature is above 17°C, most prevalent from April to September. At the early stage of infection, the symptoms are reddish-brown spots on the carapace, and when the infection is serious, the spots gradually develop into lumps and are accompanied by ulcers in the center, which can lead to systemic ulcers and shed difficulties, and ultimately death.

Fungal diseases: 1) Yeast. Infection is highly related to crab health condition, water temperature, water quality, etc. Usually, the onset of yeast infection is rapid and extensive, with a high mortality rate. 2) Streptococcus. The incidence of infection is low, but the damage is severe. Its mycelium can be attached to the surface of fertilized eggs at the nursery, and the infected crab will lose vitality and cannot feed, and may cause deaths in serious cases. 3) Lagenidialesosis. The peak of incidence is the period of early larvae stage, especially the outbreak in the nursery stage to megalopae stage, which is mainly caused by factors such as excessive farming density and lack of water exchange.

Viral diseases: 1) Herpes viruses. Mainly parasitizes blood cells. 2) Rhabdoviruses and Picornavirus. Mainly parasitizes liver cells. 3) White spot syndrome virus. The most common marine crab virus that causes serious harm in China.

Parasitic diseases: 1) Internal parasitism. It affects the host more seriously and does more harm. Common parasites are whipworm, microsporidium, and paranophrysiasis. Symptoms of whipworm infection are dull coloration of the body surface, whitish coloration at the muscle and joint membranes, fragile joints of the walking legs that are easy to dislodge, and loss of appetite or stop eating. Microsporidium parasitism will lead to varying degrees of lesions in the muscle, body cavity, and body surface, and the phenomena of muscle fiber fracture and liquefaction can be observed. In later stage, the muscle cells are replaced by a large number of microsporidians. In 2014, the incidence had led to massive yield reduction and even zero yield from Gazami Crab farms in the coasts of Tianjin and Hebei. ^[33] Paranophrysiasis infections are common in the overwintering period and are characterized to have high prevalence and pathogenicity. 2) In vitro parasitism. Barnacles, sacculina, fixed ciliates.

At present, bacterial diseases in marine crabs are mainly preventive, such as regulating water quality and maintaining better environmental conditions, and there is no effective treatment other than the use of antibiotic drugs; research on prevention and control of fungal diseases are not the current focus of crab disease management, but they should be given attention from the perspective of better aquaculture performance; viral diseases, except for herpesvirus, Rhabdoviruses, and Picornavirus disease that have already been reported, the study of the other pathogens and pathologies is not yet fully understand; and parasitic diseases are mainly relied upon to preventive measures and correctly diagnose in order to safeguard the growth and health of the farmed crabs. ^[42] Since Gazami Crabs are mostly mixed cultured with shrimps, stocks with high disease resistance are preferred in seedling selection to prevent outbreaks of shrimp-crab co-diseases.

Criterion 4: Escape Risk and Response Method

Escape risk

Due to the fact that Gazami Crabs are aquatic animals that do not move ashore unless under bad health conditions, and the inlet and outlet of ponds are usually screened to prevent escapes, the risk of escape is relatively low. There have been no reports of large numbers of Gazami Crabs escaping

from coastal ponds, resulting in yield reduction.

Gazami Crabs are commonly cultured in the coastal areas, and have a wide natural distribution in China's waters. Initially, most of the cultured fry came from wild-caught crabs, so there is no reproductive segregation between cultured and wild individuals. In recent years, due to the decline in the resources of wild populations, farmed crabs are used to replenish their natural population, i.e., the stocking enhancement. Thus, it is prone to crossbreeding between farmed and wild crabs, resulting in a decrease in the genetic diversity of the wild population. A study in 2013 on the genetic effects of increased aquaculture of Gazami Crab in Haizhou Bay on the wild population found that the genetic diversity of the wild population in Haizhou Bay was better than that of the farmed population, but the difference was not significant.^[7] Although the results showed that the genetic status of the Gazami Crab in Haizhou Bay is acceptable, continuous monitoring is still needed to take measures to prevent the farmed crabs from entering into the natural water environment, as well as to use large populations with high genetic diversity of wild-caught individuals for breeding^[8], to prevent the stock enhancement activity from affecting the genetic diversity of the wild populations. In addition to the impact on the genetic diversity of wild populations, released farmed crabs may compete with wild crabs for food, habitat, and other resources.

Criterion 5: Feed Requirements

Wild caught fishery resources ratio and sustainability in aquaculture feed

During the farming of Gazami Crabs, its feed type and food composition are different according to the different stages. The zoea stage when crab seedlings have poor vitality, they would feed on naturally distributed rotifers in the pond, and their diet can be supplemented with the fresh rotifers or suspended granular artificial feed;^[20] In the early stage, the main feed are brine shrimp and minced fish, but also small shellfish (e.g., *Potamocorbula spp.*) and chilled fish; in the middle stage, low-value shellfish and chilled miscellaneous fish are fed, and artificial feeds are also applied; in the late stage, feed with high protein contents are usually added, but miscellaneous fish are still the main feeds.^[5] In some of the more advanced studies on aquaculture technology, there is also a model based on high-quality artificial feeds, supplemented by low-value shellfish and miscellaneous fish.^[32]

According to the *Research Report on the Utilization of Marine Fishery Resources in Aquaculture in China*, Gazami Crab is one of the marine aquaculture species that are mainly fed with juvenile miscellaneous fish and supplemented with artificial feed, and the content of fishmeal in the feed is greater than 30%. The total yield of Gazami Crab aquaculture in 2014 was calculated to be about 118,836 tons, the feed ratio of artificial feed was 4.69%, the coefficient of artificial feed was 1.90, and the content of fishmeal/fish oil in artificial feed was about 41%, which resulted in the use of 3,051 tons of fishmeal after calculation; The ratio for juvenile miscellaneous fish used was 35.63%, the coefficient of miscellaneous fish was 4.37, the use of juvenile miscellaneous fish was 129,957 tons, corresponding to the total consumption of fishery resources was 138,857 tons, and the value of fish inputs and fish outputs was 1.66.^[19] It can be seen from the above that the Gazami Crab aquaculture is still highly dependent on wild fishery resources.

With a national call for green development of aquaculture and the emphasis on reducing aquaculture's dependence on wild fishery resources, more and more studies have begun to focus on miscellaneous fish alternative feeds in Gazami Crab aquaculture industry. In a study from 2021, it was found that fat levels of 4.2% to 13.76% and protein levels of 40% to 45% of feed would be satisfied

for the normal growth and development of Gazami Crab. Feeding only chilled fish or shellfish may be deficient in certain nutrients, and supplementation with compound feeds can balance the nutrient requirements. ^[41]

Currently, most studies generally agree that the most suitable feeding mode for Gazami Crab is the combination of artificial feed with chilled mixed fish. For example, the results of the 2018 study showed that, compared with feeding chilled fish, the artificial compound feed significantly improved the growth performance and feed utilization of juvenile Gazami Crab, and there was no significant difference in the utilization effect of juvenile crabs on red fishmeal and white fishmeal, with red fishmeal being relatively more cost-effective and can be used as the main feed protein source for Gazami Crabs;^[2] In 2019, it was found that the compound feed can make up for the deficiencies in the nutritional composition of chilled miscellaneous fish, and the beneficial bacteria that come with chilled miscellaneous fish can improve the utilization of the compound feed, thus the mixed feeding mode can make the two advantages complement each other, and it was also found that in terms of digestive ability the compound feed as a substitute for the miscellaneous fish is feasible. The use of the mixture of the compound feed and the miscellaneous fish used in the experiment can increase the immunity of Gazami Crabs, and the gonadal development. The nutrient composition of the Gazami Crab can be less affected. It can also enhance the amino acid content in the gonads and the muscles;^{[17][18]} Studies on vegetable oil substitution for fish oil used mixed vegetable oils (soybean oil: canola oil = 1:1) to replace 0%, 25%, 50%, 75%, and 100% of the fish oil in the feed. The results indicate that excessive fish oil substitution in the feed may negatively affect the survival of female crabs, and that a 50% fish oil substitution level significantly increased the protein content of the ovary and muscle, but a 100% fish oil replacement level decreased HUFA content in hepatopancreas and ovaries. ^[37]

Criterion 6: Source of Stock

Source of seedlings

Gazami Crab has been farmed in the coastal areas of China for several decades, the crab seedlings are all wild-caught at the beginning. Nowadays, artificial seedlings are produced under factor conditions, and the technology has become more and more mature in the past twenty years, but some of the seedlings still come from wild-caught egg-bearing crabs.^[20] Whether the exploitation of wild parental Gazami Crabs threatens the resources of wild populations is still to be studied in the future.

At present, the more mature Gazami Crab breed is "HuangXuan 1" and "HuangXuan 2" cultivated by the Chinese Academy of Fisheries Research, Yellow Sea Fisheries Research Institute and Hai Feng Aquaculture Company of Changyi City, of which "HuangXuan 2" parental from the "HuangXuan 1" core breeding groups and the wild crabs from Yellow River and the Yangtze River estuaries where the salinity is relatively lower. During the period from 2010 to 2015, five generations of breeding and selection have been carried out, forming a new variety of Gazami Crab with more outstanding characteristics and stable traits. After two years of comparative trials, the new variety "HuangXuan 2" was found to have the advantages of strong ability to tolerate low salt, fast growth rate, and high survival rate.^[26]

Criterion 7: Wildlife Interaction

Wildlife (especially threatened species) interaction

In natural habitat, the enemy species of Gazami Crab are mainly fish, such as eel, mackerel, Silver croaker, flounder, and goby fish. The predators are mostly prey on crab seedlings or juvenile crabs.^[36] In pond farming, screens are installed to prevent predators from entering the ponds with the seawater, so contact with wild animals is rare. ^[36] Mutual mutilation and predation by predator species are usually minimized by providing shelter in the culture ponds. ^[29] In addition, juvenile crabs may attract waterbirds for predation when they grow and shed, but there are no records of Gazami Crabs to have significant conflict with ETP species or farmers threatening or harming ETP species.

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