Assessment Report on Ecological Risk of *Procambarus clarkii* in Doulong River, Dafeng District, Yancheng City, Jiangsu Province

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1.1 Overview of Dafeng District, Yancheng, Jiangsu

1.1.1 Geographical location and climatic conditions

Dafeng District, Yancheng City, Jiangsu Province is located in the eastern coastal area of Jiangsu Province. Dafeng Port, which is a national opening-up port, is located in the southeast of Yancheng City, 120° 13′～120° 56′ east longitude and 32° 56′~ 33° north latitude. 36″. Dafeng Port borders the Yellow Sea to the east with a coastline of 112 Km, Dongtai City to the south, Xinghua City to the west, and the two counties (districts) of Sheyang and Tinghu to the north. The area is located in the transition zone from subtropical to warm temperate zone. It is a transitional type of oceanic and monsoon climate. It is affected by the continental monsoon in winter, with more northwesterly winds, drought and less rain, and low temperature frost. In summer, it is affected by the ocean monsoon, with more southeast winds, high temperature and abundant rainfall. The average annual temperature is 14.1 °C, in January and July. The monthly average temperature is 0.8°C and 27°C respectively. The annual precipitation is 1068 mm, and 63% of the precipitation is concentrated in June-September. The initial frost is late, the frost-free period is long, and the frost-free period averages 217.1 days/year [1].

1.1.2 Overview of economic and social development

Dafeng District, Yancheng City, Jiangsu Province is located at the coast of Suzhong, at the junction of Nantong, Taizhou and Yancheng. It belongs to the Yangtze River Delta Economic Development Zone along the Yangtze River, with convenient water, land and air transportation. The territory is flat and the climate is mild and humid. The city's total population is 707,000, with a total area of 3,059 square kilometers. It has 14 towns and two provincial-level economic development zones, and 3 municipal and Shanghai-owned farms. It is a health city in Jiangsu Province, a civilized city in Jiangsu Province, and a social order security city in Jiangsu Province. As well as an excellent city for national comprehensive improvement of environment. Dafeng City has an approach to the Yellow Sea and enjoys various preferential policies of the provincial party committee and the provincial government to support the development of the northern Jiangsu region and “coastal development”. Dafeng Port, a national key project, is located in the middle of the coastal coastline of Jiangsu Province. It is a strategic port that fills the blank belt center of Jiangsu coastal ports. Most of the beaches are non-agricultural land, with large environmental capacity and low development costs. Dafeng is rich in products, with a wide variety of products, and has a large quantity of agricultural products. It is one of the top ten cotton-producing counties in China. The special vegetables are the famous green food production bases in China; the aquatic resources are relatively rich, especially the variety of seafood.

1.1.3 Natural and ecological overview

(1) Ecological environment

The annual natural precipitation in Dafeng District is above 1000 mm, the high flow year is more than 2000 mm, and the low flow year is 500 mm. There are rivers such as Chuandong Port, Jiangjie River, Wanggang River, Ermaoyou River, Simaoyou River, Doulong Port, Xichao River, Dafenggan River, etc., with an average annual runoff of 510 million cubic meters. The amount of water transit is about 2.5 billion cubic meters. The underground freshwater resources are relatively abundant. According to the actual hole observation, the daily fresh water consumption of humans and animals of about 160 meters is about 200 tons, and the hot fresh water of about 400 meters (water temperature of 27 °C) is about 60 tons.

Dafeng District has the climatic characteristics of the transition from the north subtropical zone to the warm temperate zone. Its geographical advantages are conducive to various kinds of biological reproduction. The river has fertile water, the trend is smooth, and the museum has sufficient materials. It is a good place for inhabiting and breeding fish, shrimp, shellfish, crab, algae, etc. The total biological reserves of intertidal mollusks are large; there are many kinds of plant resources, and the prospects for the development and utilization of fiber plants such as rice grass are broad.

(2) Biological resources

There are more than 500 kinds of plant resources in Dafeng District, including woody plants, herbaceous plants and ground cover plants. In addition to nearly 80 kinds of artificially cultivated herbs, there are more than 200 kinds of wild herbs such as Apocynum venetum, Yinchen, gentian, Motherwort, Eclipta, Xanthium, and Verbena. As well as more than 100 species of terrestrial vertebrates. As of the end of 2013, there were 1,902 elk, accounting for one-third of the world's total. It was awarded the title of “Hometown of Chinese Elk” and built the world's largest elk nature reserve. There are 28 kinds of national first- and second-class protected animals such as red-crowned cranes, swans, white-tailed sea eagle and gingiva, as well as a variety of migratory birds. Among them, the hummingbirds found in recent years are the smallest birds in the world. There are abundant offshore resources, 145 species of phytoplankton in the intertidal zone, 68 species of zooplankton, 47 species of benthic sessile algae, and 20 species of aquatic species.

There are many kinds of aquatic animals in Dafeng, mainly including zooplankton, benthic animals and swimming animals. There are many types of benthic animals, but the number is small, mainly mollusks and crustaceans; swimming animals include large and small yellow croaker, *Procambarus clarkii*, Chinese mitten crab, grass shrimp, squid, grass shrimp, wheat ear, snail, etc.

1.2 Overview of *P. clarkii*

P. clarkii is native to the southern United States and northern Mexico. For nearly a century, *P. clarkii* has been introduced to many countries and regions in the world, including China. In China, in the late 1920s, through the introduction of Japan into the Nanjing region of China, for many decades, the original crayfish have rapidly established wild populations in the introduced areas owing to its strong resistance to stress, extensive habitat adaptation, rapid growth and high reproductive rate.

P. clarkii is not only delicious, but also nutritious. Its fresh muscle protein content is as high as 16-20%, and the dry muscle protein content is as high as 50%, which is higher than the protein content of common fish and eggs. The content of trace elements such as iodine, zinc and selenium in the original crayfish shrimp meat is also higher than other similar foods, and the muscle fiber of the original crayfish is delicate, the taste is lubricated, and it is easy to digest and absorb, especially the liver of the original crayfish, which weighs about 5% of body weight is rich in unsaturated fatty acids, proteins, free amino acids, vitamins and trace elements, and is of great medicinal value. In addition, the raw crawfish has a meat yield of up to 20%, so it can be used to process shrimp and shrimp tails. The shrimp shell of *P. clarkii* accounts for about 50-60% of its body weight. Its main component is chitin. Chitin is a natural biomacromolecular compound and the second largest renewable resource in the world after cellulose. And it is the only natural alkaline polysaccharide that has been discovered so far, so it has a very high deep processing value. In addition, chitin, chitin and chitosan extracted from the crustacean crustaceans can be used as industrial raw materials and widely used in agriculture, food, medicine, tobacco, paper, printing and dyeing, etc. In the field, the *P. clarkii* has a very high processing value-added potential.

In recent years, with the consumer's gradual understanding of the original crayfish shrimp and the extensive publicity of the media, the domestic consumption of the original crayfish is becoming more and more popular, accompanying with short supplement in the market and rising sale prices.

At present, the original crayfish is one of the hot-selling aquatic products in the world, and it is favored in the domestic and international consumer markets. The international market is in short supply. Especially in Europe and the United States, it is the main consumption area of the original crayfish, and its market space is very large. According to the statistics of the China Chamber of Commerce for Import and Export of Food, Livestock and Animals, in 2008, China's exports of *Procambarus clarks* products totaled 24,000 tons, and the total foreign exchange earned by exports was about 150 million US dollars. The annual consumption of the country totals about 300,000 tons, and the consumer groups are still expanding. “Spicy Crayfish” is well known throughout the country.

The introduction of *P. clarkii* into China has been around for nearly 90 years since 1929, The *P. clarkii* has completely adapted to the living environment of China due to its own reproductive characteristics, forming a new form of ecological balance with the local community. In addition, due to its own nutritional value, taste and economic value, these factors make the *P. clarkii* become a permanent component of the Douro River in Dafeng District, Jiangsu Province and even some aquatic ecosystems in China. How to properly breed and fish has become a problem that needs to be taken into consider seriously today[2].

1.2.1 Biological characteristics of *P. clarkii*

1.2.1.1 Morphological characteristics

The adult body is 70-130mm long from the forehead to the tail fan. Body color varies with age, from dark yellow to deep red, larvae are generally lighter in color, and shrimps are darker in color. The shrimp body is divided into two parts, the chest and the abdomen. There are 5 pairs of appendages in the head, of which the first 2 pairs are more developed, the chest has 8 pairs of appendages, the last 5 pairs are step feet, and the first 3 pairs are all chelation feet (chelating limbs). The abdomen is relatively short, with 6 pairs of appendages. The first 5 pairs are swimming limbs, the last 1 pair is combined with the tail section to synthesize the tail fan, and the tail fan is developed.

1.2.1.2 Living habits

P. clarkii burrows with chewing limbs and has a strong ability to dig caves. It is not good at swimming, generally inhabit the bottom of the water, fond of hiding in the cracks in the masonry, under the grass or in the cave. It does not like glare. The pH of the living water is required to be 7.5-8.5, and the dissolved oxygen content is 2 mg/l or more. It has a wide temperature range, 5-38 ° C can survive better. It can adapt to a range of low salinity water bodies in a short time. Its special feature is its strong resistance to disease and pollution. *P. clarkii* is aggressive, and when there is insufficient feed or competing for caves, it tends to be bullying. The larval stage has strong self-cutting and regenerative ability and is a protective adaptation shared by crustaceans.

Studies have found that *P. clarkii* prefer to live in ponds with static water or slow water flow, and the boring preference is relatively loose and has a preference for loam of certain hardness. *P. clarkii* like shade and hate sunlight, and aquatic plants are both a major source of food and a habitat for them. In the natural state, aquatic plants with poor aquatic plants have very little distribution of *P. clarkii*.

P. clarkii ,an omnivorous predator, is in the second and third trophic levels of the native ecosystem, feeding on aquatic plants, animal and plant debris, aquatic attachment organisms, plankton, aquatic invertebrates, larvae and eggs of amphibians, adhesive sticky eggs of fish. It has been reported that aquatic insect larvae are a major component of their stomach contents when other baits are insufficient. At various stages of its growth, larvae tend to be food-eating, and shrimp tend to be more omnivorous or herbivorous. However, when the food is insufficient, the adult also feeds on the animal bait, and even the same kind of disability. It has been reported that crayfish feed on the lumps of fertilized eggs produced by frogs. It has also been observed in the study that crayfish feed on the viscous fertilized eggs attached to the aquatic plants by the economical fish carp and carp. At the same time, it was observed that the biomass of the economical fish carp and carp in the local natural waters showed a downward trend when the biomass of the original crayfish population was the highest in 1985. In Kenya, researchers have observed that crayfish feed on the intermediate host of human schistosomiasis. In Portugal, researchers have also observed that crayfish feed on invertebrates, when other food-deficient invertebrates, it accounts for more than 85% of the crayfish food composition.

1.2.1.4 breeding habits

The breeding strategy of the original prawn is an r-type breeding strategy with a short developmental period. Under conditions of sufficient conditions and sufficient food, it can mature in one month and is a rapidly growing species. In Louisiana, the southern United States of origin of the crayfish, the mating start time is from May to June each year, and the largest spawning population occurs in August-November of each year, with the peak period in October. In the Yangtze River basin where China was introduced, *P. clarkii* generally entered the breeding season from mid-June of that year, and the peak of spawning also appeared in November of each year. In the Dafeng District of Yancheng, Jiangsu, the growth period of the main population of *P. clarkii* is 4, 5, and 3 months per year, and the breeding season is from June to December of the year. *P. clarkii* has the habit of hatching eggs, that is, the abdomen swimming limbs attached to the fertilized eggs are hatched, and the protozoa crayfish also have the breeding habits of the young crayfish, that is, the larvae that have just hatched the membrane adhere to the abdomen of the mother, in the mother Under the protection of the most vulnerable to more than a month. Childcare habits are the habits that most economic shrimps and crabs do not currently have. In addition, the original crayfish began to excavate the cave once they entered the sexual maturity period, and most of the reproductive activities during the breeding period were generally carried out in the cave.

1.2.2 Distribution of *P. clarkii* in Dafeng District

After investigation and literature investigation, the introduction of *P. clarks* in Dafeng District, Yancheng City, Jiangsu Province was mainly through two ways: First, because the meat of the original crayfish is very easy to breed, second, the local residents are introduced for curiosity, viewing and other purposes. Locally, natural stocks are formed in the wild after stocking or abandoning.

Because of its high fertility, rapid growth, early maturity and wide habitat adaptability, *P. clarkii* is currently distributed in various types of aquatic environments in Dafeng District, Yancheng, Jiangsu, such as rivers, ponds, paddy fields, wetlands and other water bodies. As the main flood discharge, drought-resistant, water transport channel in the Yancheng River and its tributaries, there are also some artificial canals found a large number of *P. clarks*, and become a permanent component [3].

2. Potential impact of crayfish on the ecosystem of Dafeng District

2.1 The effect of *P. clarkii* on aquatic environment

P. clarkii is an important consumer in rivers and lakes, and often dominates the biomass of invertebrates in lakes and rivers. They can quickly reach high densities after introduction and change the structure and hierarchy of food chains. . Make available resources quickly reduced. After introduction form Portugal, *P. clarkii* has a great impact on aquatic communities by feeding on all available food resources. The introduction of *P. clarks* also destroys large aquatic plants, transforming these lakes from clear grassy lakes to turbid, eutrophic lakes dominated by phytoplankton, with profound changes in the structure and composition of the food chain. Therefore, *P. clarkii* is a permanent component of various aquatic environments in Dafeng District. Its growth, development and reproduction are bound to be affected by the surrounding environment, and at the same time it will affect the surrounding aquatic environment.

2.2 Effects of *P. clarkii* on biodiversity

Most scholars have studied in the past 10 years that the behavior of the original crayfish through food competition and predation will have an impact on the biodiversity of the indigenous species introduced. In the introduction region, the protozoan crayfish can make the habitat quality of the wetland ecosystem. Declined, directly or indirectly affecting the flora and fauna, and leading to a decline in species diversity. As introduced in 1974, *P. clarkii* has become a dominant species in Spain, directly reducing the availability and refuge of food resources of other species, affecting the reproductive success rate of other animals or plants.

P. clarkii is a serious threat to the survival of indigenous crayfish by competing with local crawfish for food, habitat and other resources (especially habitats) and often at superior locations (Hobbs and Whiteman, 1991). Other studies have shown that *P. clarkii* is easier to adapt to the environment than some indigenous crawfish. In the invasion of the Italian crayfish, the survival area of the Scottish white crayfish, the crayfish are in various biological characteristics. Both show greater flexibility and adaptability than indigenous crawfish and thus often compete with indigenous crawfish.

P. clarkii has strong predation pressure on aquatic plants, aquatic arthropods, gastropods, amphibians and fish in the invaders. Some researchers have found that the stomach of the crayfish has a large amount of plant residues and debris in the stomach, so it is considered to be an omnivorous animal with herbivorous and humic substances as the main food. In the Mediterranean wetlands and southern Europe, the introduction of *P. clarks* has led to the disappearance of certain large plants, both in freshwater wetlands and in low-salinity wetlands.

P. clarks mainly prey on aquatic invertebrates, especially arthropods and gastropods, resulting in a series of effects at lower food levels. Similarly, some researchers have pointed out that although plant foods and organic debris are more likely to appear in the stomach cavity of *P. clarkii*, small arthropods (copepods and ostracods), animals, insect larvae and some small fish can be found in their stomachs.

Some researchers have found that large individuals of *P. clarkii* can directly feed on fish, while small individuals of *P. clarkii* mainly feed on arthropods.

In the introduction of the original crayfish, the effects on amphibians and fish, in addition to directly feeding their fertilized eggs, larvae and part of the adult body, directly lead to their biomass decline, may also be due to the extraction of *P. clarkii* Invertebrates eat less food for amphibians and fish, and indirectly affect the biomass of amphibians and fish. *P. clarkii* is a potential predator of amphibians' eggs and larvae, and therefore has a particularly severe impact on amphibians. .

In summary, *P. clarkii* in Dafeng District may affect the growth of Aboriginal crayfish, amphibians (eg, certain indigenous frogs) and fish (eg, squid and trout), and may also cause the disappearance of some aquatic plants and invertebrates.

When the native crayfish enters various types of aquatic environments in Dafeng District as exotic species, it is bound to overlap with the niche of the same niche. Two species with similar niches will compete for their niche through interspecific competition. Differentiation is happening and a new dynamic balance is reached. The original crayfish has been in China's ecosystem for nearly 90 years and has gradually become one of the important components of China's ecosystem. Therefore, its impact on the ecosystem of Dafeng District needs to be determined through scientific ecological assessment [4].

3. Ecological risk assessment of invasive roots of *P. clarkii* in Dafeng District

3.1 Construction of risk assessment indicator system method

In the risk assessment study of alien species, the risk rating system and the multi-index comprehensive evaluation method are the most widely used and play an important role in the management of alien species. This study uses a combination of the two "risk assessment system methods" based on the basic theories and methods of systems science, bioecology and expert decision-making systems, through a comprehensive analysis of the various factors affecting the invasion of alien species and these influencing factors status, role and their relationship to each other, establish a comprehensive risk assessment system with multiple levels and multiple indicators. When establishing a risk assessment system, the bioecological characteristics, life history characteristics, bio-climatic characteristics, bio-climatic distribution, human disturbance factors of the exotic species of *P. clarkii* are mainly taken into analysis, referring to domestic and international researches. Then we comprehensively analyze of the impacts of intrusion and prevention and control management, comprehensively absorb, summarize, reorganize, add and delete existing evaluation indicators, select evaluation indicators with typical representative significance, and study and analyze the interrelationship between indicators, and then determine the assessments. Coefficient system for alien species invasion risk assessment is established by the method above [5].

3.2 Steps to build a risk assessment indicator system

The specific steps to build a risk assessment system based on qualitative analysis and quantitative estimation are as follows:

(1) Basic research on invasiveness. Conduct basic research on the invasion of alien species, analyze the key factors affecting species invasion, and provide reference for screening and evaluation system indicators.

(2) Screening and evaluation system indicators. Refer to domestic and foreign alien species risk assessment research theories, cases and results, comprehensively absorb, summarize, reorganize, add and delete existing assessment indicators, and combine the natural environment of the study area, the characteristics of ecosystems and the invasion status of alien species, through a complete The main influencing factors of the invasion process of alien species are comprehensively analyzed to screen appropriate evaluation indicators.

(3) Construct an evaluation system framework. According to the construction

principle of the evaluation system and the selected indicators, a risk assessment indicator framework is constructed.

(4) Set the weight of the evaluation system indicators. The analytic hierarchy process (AHP) is used to determine the weighting factors of each indicator.

(5) Quantitative evaluation system indicators. According to the operability of the indicator, the index is usually divided into several levels, and then the corresponding quantized values are taken in turn.

(6) Determine the calculation method of the risk value of the evaluation system. Determine the risk value of each indicator of the risk assessment system and the calculation method of the final total risk value.

(7) Clearly evaluate how the information is missing. During the evaluation process, some assessment information is missing or uncertain, and how such information should be processed.

(8) Divide the risk rating of the assessment system. Based on the existing alien species classification system, combined with the status of alien species invasion in Yancheng, Jiangsu, the risk level is divided, and the corresponding relationship between risk level and risk score is established to determine the prevention and control measures of alien species with different risk levels.

3.3 Construction of risk assessment indicator system

3.3.1 Screening and evaluation system indicators

Based on a complete invasion process of alien species, this study screens and evaluates system indicators with reference to other researchers' research methods and invasive basic research results. This report divides the intrusion process into five phases: the introduction phase, the fitness phase, the diffusion phase, the hazard phase and the prevention phase. Five first-level criteria indicators are determined based on the five phases.

(1) Introduction stage the introduction stage is the first stage in which alien

species begin their invasion process. The introduction of alien species is closely related to human activities. Human activities provide a favorable carrier for the introduction of alien species, even if there is no long distance. Species that spread the ability to spread can also achieve long-distance transmission across regions through human media. The introduction pathways of alien species can be broadly divided into two categories, namely intentional introduction and unintentional introduction. These two types of incoming methods should be taken into account when screening indicators. In addition, the successful invasion of alien species has a certain relationship with the scale of their introduction, and these factors should be considered. On this basis, we should focus on the impact of artificially managed introduction of alien species. That is, the evaluation indicators are selected: 1) the introduction route, including the possibility of intentional introduction and unintentional introduction; 2) the introduction of scale, including the number of species introduction and the number of introductions; 3) the status of the invasion and the management of the introduction route, including the control of relevant local regulations and the effectiveness of quarantine measures. Therefore, in the introduction phase, this criterion layer identifies three indicators, namely, the introduction path, the introduction of scale, and the introduction of management.

(2) Suitable stage Suitable stage is also called the colonization stage. This stage is mainly influenced by external factors (mainly considering the influence of environmental factors) and internal factors (mainly considering the characteristics of the species itself and the characteristics of life history). These two aspects consider the selection of indicators. The suitable stage is whether the new environment is suitable for the survival and reproduction of the species. Climatic conditions have long been recognized as a key factor affecting the geographical distribution of species. In addition, other physical environments such as soil, water environment and biological factors are also important factors in determining the successful colonization of species. Therefore, the indicators considered may include climate suitability, soil suitability, water environment suitability (temperature, salinity, nutrient conditions, etc.). Therefore, in the appropriate stage, this criterion layer sets four assessment

indicators of climate adaptation, stress resistance, adaptability and other environmental constraints.

(3) Diffusion stage In the diffusion process of species, the successful diffusion of species depends on the diffusion mechanism of the species, and can consider its own diffusion ability, its adaptive adaptability and the available media; For the restriction mechanism of species spread, it is possible to consider the number of habitats suitable for its invasion or similar to the invaded area, and whether there are effective natural enemies and competing species in the invasive habitat. Therefore, five indicators of species diffusion, growth rate, diffusion status, control mechanism and diffusion trend were determined during the diffusion phase.

(4) Hazardous stages The damage caused by alien species invasion involves many aspects, including: 1) ecological environmental impacts, including indicators on ecosystem processes, ecosystem factors, community structure, etc.; 2) local organisms The impact of diversity; 3) the impact on local agroforestry; 4) the health and other social impacts of the population, including the impact on human health, reducing the value of leisure and entertainment, changing the aesthetic value of the landscape, the value of tourism and so on. Therefore, four indicators of ecological hazard, social hazard, economic hazard and health hazard were selected in the hazard stage for assessment.

(5) Prevention and control stage Human influence plays an important and even decisive role in the invasion process of alien species. It can be seen that the risk of prevention and control stage significantly affects the comprehensive risk of invasion of alien species. This stage mainly refers to the prevention and control behaviors taken after the invasion of alien species causes certain harms, including: methods and effects of prevention and control, side effects of prevention and control, and cost of prevention. In the process of prevention, it is also necessary to comprehensively consider the prevention force (input of human, material and financial resources), the time spent on prevention, and the side effects caused by prevention, such as the impact on local organisms. Therefore, in the prevention and control stage, three indicators including prevention and control methods, effects, side effects and

prevention costs were selected to construct the indicator system.

3.3.2 Building a risk assessment system framework

The indicator system is divided into three levels: the target layer, the criteria layer and the indicator layer. The first layer is the target layer (R), which is the risk of invasion of typical alien species (R), which is calculated from the next five indicators; the second layer is the criterion layer (first-level indicator Ri), which is introduced by the alien species. (R1), the appropriate phase (R2), the diffusion phase (R3), the hazard phase (R4), and the control phase (R5) are respectively calculated from the corresponding next-level indicators; the third layer is the indicator layer (including the second level indicator Rij and the third level indicator Rijk) are the specificization of the indicators at the criterion level. The norm layer and indicator layer set under the risk of overall alien species invasion follow the basic structure of the indicator framework, with 5 first-level indicators, 17 second-level indicators, and 41 third-level indicators to ensure the scientific and systematic nature of the system. The specific evaluation system framework is shown in Table 3-1.

Table 3-1 Framework of ecological risk assessment system for *P. clarkii*

Target layer	Primary indicator	Secondary indicators	Three-level indicator	Evaluation parameters and criteria
Ecological risk assessment of the Prototype of Crayfish (R)	Introduction phase (R1)	Introduction route (R1.1)	Intentional introduction (R1.1.1)	Consider the introduction of the species, the survival during transportation, and the records introduced.
			Unintentional introduction (R1.1.2)	Consider personnel exchanges, business dealings, ship ballast water discharge status, and historical records, etc.
		Introducing scale (R1.2)	Number of introductions (R1.2.1)	Consider possible introductions and the scale of introduction
			Number of introductions (R1.2.2)	Consider the frequency of introduction of possible introduction methods
		Introduction management (R1.3)	Regulatory control management (R1.3.1)	Consider whether to list the national invasive species, whether there are relevant prevention measures, and whether there are corresponding management and control measures
			Quarantine control management (R1.3.2)	Consider whether it is included in the quarantine control object, the difficulty of quarantine, and the possibility of survival of quarantine avoidance.

	Suitable stage (R2)	Climate adaptation (R2.1)	Climate adaptability (R2.1.1)	The ability of alien species to adapt to local climatic factors, taking into account temperature, humidity, light and precipitation
		Stress resistance (R2.2)	Growth resistance (R2.2.1)	Resistance to adverse environmental conditions during growth, not critical to growing environmental conditions
			Resistant ability during breeding (R2.2.2)	Resistant to adverse environmental conditions during reproduction, not strict with reproductive environmental conditions
		adaptability (R2.3)	Growth adaptability (R2.3.1)	Consider whether the selectivity of species growth is low in the environment, whether the life cycle is short, the speed of adaptation, genetic adaptability, etc.
			Breeding method (R2.3.2)	Considering the diversity of reproductive methods, in addition to sexual reproduction, whether there are multiple ways of vegetative reproduction
			Reproductive capacity (R2.3.3)	Consider seed yield, mode of transmission, stress resistance, germination rate, and survival of vegetative reproduction
		Environmental Factors (R2.4)	Moisture condition (R2.4.1)	Whether moisture conditions are conducive to the growth and reproduction of species

			Soil salinity condition (R2.4.2)	Whether soil salinity conditions are conducive to species growth and reproduction
			Soil nutrient condition (R2.4.3)	Whether soil nutrient conditions are conducive to species growth and reproduction
	Diffusion stage (R3)	Diffusion method (R3.1)	Diffusion diversity (R3.1.1)	Consider whether there are multiple ways of diffusion, such as wind-borne, water-flow, insect-borne, human transport, and self-propagating mechanisms.
			Diffusion distance (R3.1.2)	Consider the survival of different distances
			Diffusion speed (R3.1.3)	Consider the time it takes for the species to spread to a certain extent
		Growth rate (R3.2)	Growth rate (R3.2.1)	The speed of species from larval to adult
		Diffusion status (R3.3)	Diffusion area (R3.3.1)	Consider the absolute value of the existing diffusion area and the number of patches distributed
			Degree of diffusion (R3.3.2)	Consider the existing diffusion severity, the population density of the distribution, etc.

			Proportion of adversely affected areas (R3.3.3)	Consider the proportion of invasive areas affected by local species
		Control mechanism (R3.4)	Natural enemy situation (R3.4.1)	Whether there are effective natural enemies locally
			Control management status (R3.4.2)	Have effective human control measures been taken?
		Diffusion trend (R3.5)	Synchronous situation (R3.5.1)	Consider whether the invaded land has species that compete with the niche
			Free space (R3.5.2)	Whether there is a large area suitable for its habitat (habitat similar to the origin)
	Hazard stage (R4)	Ecological hazard (R4.1)	Harm to local species (R4.1.1)	Consider whether there is a strong competition for local growth factors such as water, light, and nutrition.
			Impact on the ecosystem process (R4.1.2)	Consider whether it affects local ecosystem processes, such as changing local geomorphology (sludge accumulation), changing hydro-hydrodynamic conditions, changing primary productivity, etc.

			The effect on the environment (R4.1.3)	Consider whether it affects the environmental factors of the ecosystem, such as the cycle process affecting nutrients and mineral elements, changing the light intensity of the habitat, p H, the N/P of the water environment, and the dissolved oxygen, whether it has allelopathic effects, etc.
			Impact on the diversity of living things (R4.1.4)	Whether there is an ecosystem substitution effect, whether it will cross the native species and cause genetic diversity effects
		Social hazard (R4.2)	Social production impact (R4.2.1)	Whether it affects the social production mode and production efficiency around the invaded land
			Social life impact (R4.2.2)	Whether it affects the social living conditions around the invaded land
		Economic hazard (R4.3)	Agriculture, forestry and fishery impact (R4.3.1)	Consider negative impacts and extent on agriculture, forestry and fisheries
			Transportation impact (R4.3.2)	Consider the impact and extent of the transportation industry

			Resource utilization impact (R4.3.3)	Whether to change the degradation of available resources and the impact on resource utilization
			Tourism industry impact (R4.3.4)	Consider whether the ecological landscape has been changed and the impact and extent of tourism and other industries
		Health hazard (R4.4)	Animal and plant health hazards (R4.4.1)	Whether it is possible to introduce pathogens (parasites, pathogens, viruses, etc.) to endanger local animal and plant health
			Human health hazard (R4.4.2)	Whether it can cause harm to human health
	Prevention stage (R5)	Prevention management (R5.1)	Control methods and effects (R5.1.1)	Consider whether there are feasible methods and techniques for removing invasive species at the current stage, as well as control effects, etc.
			Prevention and treatment of side effects (R5.1.2)	Consider whether prevention will affect local species and ecological communities, whether it will cause new species invasion, etc.
			Control cost (R5.1.3)	Consider the time, manpower, material and financial resources required to control the hazard to a minimum.

3.3.3 Determining the weight of risk assessment indicators

The weight of each index of the risk assessment system is determined by the Analytic Hierarchy Process (AHP). Analytic Hierarchy Process (AHP) is a multi-criteria decision analysis method proposed by American operations researcher T.L.Saaty in the 1970s. Its core is to quantify the empirical judgment of analysts and provide a quantitative basis for decision-making. And the lack of necessary data is more practical. The method decomposes a complex problem into several components, establishes an ordered hierarchical structure graph, and then judges the importance degree through the pairwise comparison between the components, and uses the obtained judgment results to comprehensively calculate the weight of each coefficient. The specific steps of this analysis method are as follows:

(1) Identify problems and establish an orderly hierarchy

Clarify the question: Ask for a full understanding of the whole issue, clarify the elements it involves and the relationship between the elements. Establish an ordered hierarchical structure: first organize and analyze the problems to be analyzed , and construct an ordered hierarchical structure framework. In this framework, the highest level (target layer) is generally the target or ideal result of the analysis of the problem; the middle layer (the criterion layer) is the intermediate link involved in achieving the goal, which can have multiple levels, mainly the need to consider Guidelines and sub-criteria; the lowest level (strategy layer) is generally the solution to the problem (Figure 3-1).

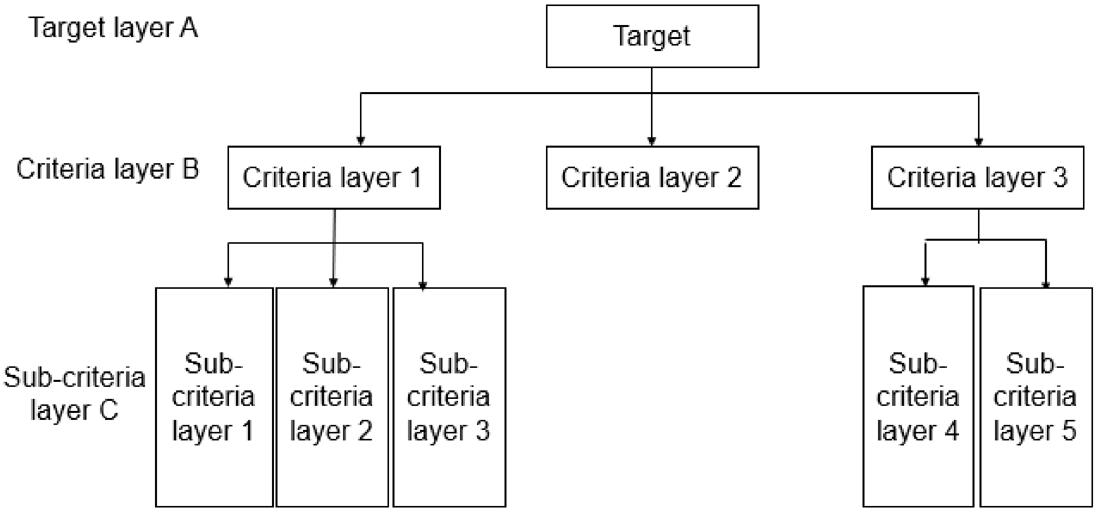

Figure 3-1. AHP hierarchy diagram

(2) Construction judgment matrix

Through a comparison of the components, a judgment matrix C is obtained.

$$C = \begin{array}{c} \\ C_1 \\ C_2 \\ \cdots \\ C_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{pmatrix} c_{11} & c_{12} & \cdots & c_{1n} \\ c_{21} & c_{22} & \cdots & c_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ c_{n1} & c_{n2} & \cdots & c_{nn} \end{pmatrix} \end{array}$$

Among them, c_{ij} is usually determined by the scale 9 graduate of the Saaty design. c_{ij}represents the multiple of the importance of the jth unit (C_j) of the importance of the i-th unit (C_i), so

C_{ij}=C_i importance score/C_j importance score

Table 3-2 Meaning of scale

scale	significance	Description
1	C_i is as important as C_j	C_i and C_j are two factors in the same level
3	C_i is slightly more important than C_j	
5	C_i is more important than C_j	Judging according to a

7	C_i is much more important than C_j	certain standard (ie, relative to a certain factor)
9	C_i is definitely more important than C_j	
2, 4, 6, 8	Median value of two adjacent judgments	Need a compromise between two judgments

(3) Calculation of weights of indicators under the same criterion (hierarchical single ordering).

The calculation steps of the same level indicators C_1, C_2, ..., C_n under the control of the previous level of indicators Wi are as follows:

1) Calculate the product of each row element in the judgment matrix C Xi

$$X_i=c_{i1}\times c_{i2}\times\ldots\times c_{in}$$

2) The product Xi is opened n times

$$X_i'=n\sqrt{X_i}$$

3) The square root vector is normalized, that is, the ranking weight vector $W(C_i)$

$$W_i= X_i'/(X_1'+X_2'+\ldots+X_n')$$

$$\text{Vector } W=\begin{pmatrix} W_1 \\ W_2 \\ \ldots. \\ W_n \end{pmatrix}$$

For example, calculate the judgment matrix $C(c_{ij})$ and weight value W_i of the first-level indicator of the invasive risk system of typical alien species in Dafeng District. The hypothesis is the introduction phase, the appropriate phase, the diffusion phase, the hazard phase and the prevention phase. The risks are C_1, C_2, C_3, C_4, and C_5, respectively. The calculation process and results are shown in Table 3-3.

Table 3-3 Judgment matrix for the intrusion risk value (R) of the first-level indicator $C(c_{ij})$ and weight value W_i

Risk valueR	C_1	C_2	C_3	C_4	C_5	X_i	W_i
C_1	1	1	1	1	1	1	0.18
C_2	1	1	1	1	1	1	0.18
C_3	1	1	1	1	1	1	0.18
C_4	1	1	1	1	2	2	0.36
C_5	1	1	1	1/2	1	1/2	0.10

(4) Calculate the maximum eigenvalue of the judgment matrix λmax

$\lambda max = \sum[(W)_i/n\ W_i]$ (i=1,2,3,,,,n)

Where (W)i represents the ith component of the vector W.

(5) Checking the consistency of the judgment matrix if the inconsistency of a judgment matrix is too serious, it means that the weights obtained are unreasonable. To judge whether the matrix has satisfactory consistency, it is necessary to test the consistency of the judgment matrix:

$$CR=CI/RI$$

Among them, CI is called the judgment matrix consistency index, and its formula is: $CI=(\lambda max-n)/(n-1)$; RI is the average random consistency index of the same level. For the 1st to 9th order matrix, the value of RI is shown in Table 3-4.

Table 3-4 Average Random Consistency Index RI Value

dimension	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45

For the first and second order judgment matrices, RI is only formal. According to our definition of judgment matrix, the first and second order judgment matrices are always completely consistent. When the order is greater than 2, $CR=CI/RI<0.10$, the judgment matrix has satisfactory consistency, otherwise the judgment matrix needs to be adjusted.

For example: Dafeng District alien species invasion risk system for the risk value R judgment matrix C consistency test results:

$$\lambda max= 5.1,\ CI= (\lambda max-n)/(n-1) = 0.025$$

CR = CI / RI = 0.025 / 1.12 = 0.02 < 0.1, and the judgment matrix C has satisfactory consistency. For the same reason, calculate the weights of the secondary and tertiary indicators.

(6) Calculate the comprehensive weight value

The weight value obtained by hierarchical single-order sorting is the separation weight value of each level index relative to the corresponding index of the previous layer. The weight of each level index to the intrusion risk value (R) needs to be solved from top to bottom by the combined weight calculation formula, and the formula is calculated as follows:

$W(R)=W(R_i)W(R_{ij})$

Among them: W(R) is the comprehensive weight value of the third-level index to the first-level index, $W(R_i)$ is the separation weight value of the second-level index to the first-level index, and $W(R_{ij})$ is the separation of the second-level index from the third-level index Weights. In order to facilitate observation and calculation, the total weight of the risk assessment of typical alien species invasion in the coastal waters of the South China Sea is set to 100%, and the weights of the indicators at various levels are shown in Table 3-5.

Table 3-5 Weight of indicators at all levels				
Primary indicator	**Weights (%)**	**Secondary indicators**	**Weights (%)**	**Three-level indicator**
Introduction phase (R1)	18	Introduction route (R1.1)	8	Intentional introduction (R1.1.1)
				Unintentional introduction (R1.1.2)
		Introducing scale (R1.2)	6	Number of introductions (R1.2.1)
				Number of introductions (R1.2.2)
		Introduction management (R1.3)	4	Regulatory control management (R1.3.1)
				Quarantine control management (R1.3.2)
Suitable stage (R2)	18	Climate adaptation (R2.1)	2	Climate adaptability (R2.1.1)
		Stress resistance (R2.2)	4	Growth resistance (R2.2.1)
				Resistant ability during breeding (R2.2.2)
		adaptability (R2.3)	9	Growth adaptability (R2.3.1)

				Breeding method (R2.3.2)
				Reproductive capacity (R2.3.3)
		Environmental Factors (R2.4)	3	Moisture condition (R2.4.1)
				Soil salinity condition (R2.4.2)
				Soil nutrient condition (R2.4.3)
	18	Diffusion method (R3.1)	4.5	Diffusion diversity (R3.1.1)
				Diffusion distance (R3.1.2)
				Diffusion speed (R3.1.3)
		Growth rate (R3.2)	1.5	Growth rate (R3.2.1)
		Diffusion status (R3.3)	6	Diffusion area (R3.3.1)

				Degree of diffusion (R3.3.2)
				Proportion of adversely affected areas (R3.3.3)
		Control mechanism (R3.4)	3	Natural enemy situation (R3.4.1)
				Control management status (R3.4.2)
		Diffusion trend (R3.5)	3	Synchronous situation (R3.5.1)
				Free space (R3.5.2)
Hazard stage (R4)	36	Ecological hazard (R4.1)	10	Harm to local species (R4.1.1)
				Impact on the ecosystem process (R4.1.2)
				The effect on the environment (R4.1.3)

				Whether there is an ecosystem substitution effect, whether it will cross the native species and cause genetic diversity effects (R4.1.4)
		Social hazard (R4.2)	7	Social production impact (R4.2.1)
				Social life impact (R4.2.2)
		Economic hazard (R4.3)	10	Agriculture, forestry and fishery impact (R4.3.1)
				Transportation impact (R4.3.2)
				Resource utilization impact (R4.3.3)
				Tourism industry impact (R4.3.4)
		Health hazard (R4.4)	8	Animal and plant health hazards (R4.4.1)

				Human health hazard (R4.4.2)
Prevention stage (R5)	10	Prevention management (R5.1)	10	Control methods and effects (R5.1.1)
				Prevention and treatment of side effects (R5.1.2)
				Control cost (R5.1.3)
total			100	

3.3.4 Quantitative evaluation system indicators

According to the weight distribution ratio of the ecological risk assessment index of *P. clarkii* in Dafeng District, a hierarchical evaluation system was constructed with 5 first-level indicators, 17 second-level indicators and 41 third-level indicators to quantify each index. In order to facilitate the calculation, the total score of the risk assessment system is set to 100 points, different scores are assigned to each index according to different weights, and then the index is divided into several quantization levels, and the corresponding quantitative values are taken in turn. Specific risk assessment indicators can be analyzed as below:

R1 Introduction phase risk (18 points)

R1.1 Introduction route (8 points)

R1.1.1 Intentional introduction (4 points)

A. Not easily introduced (1 point)

B. There is a certain intentional introduction possibility (2 points)

C. It has been determined that there is intentional introduction of behavior (4 points)

R1.1.2 Unintentional introduction (4 points)

A. The possibility of unintentional introduction is small (1 point)

B. There is a certain possibility of unintentional introduction (2 points)

C. It has been determined that there is unintentional introduction of behavior (4 points)

R1.2 Introduction scale (6 points)

R1.2.1 Number of introductions (3 points)

A. The number of basic non-existent meanings (0 points)

B. A limited number of introduction, and the number of introduction each time is small (1 point)

C. A limited number of introduction, but the number of introduction each time is large (2 points)

D. May be passed in multiple times, and the number of introduction ones is large (3 points)

R1.2.2 Number of introductions (3 points)

A. The frequency and probability of introduction of the above methods are very low (1 point)

B. The frequency and probability of introduction of the above methods are large (2 points)

C. The frequency and probability of introduction of the above methods are very large and very frequent (3 points)

R1.3 Introduction management (4 points)

R1.3.1 Regulatory Control Management (2 points)

A. There are relevant regulations and requirements to prevent and control, and at the same time have attracted attention and attention (0 points)

B. No relevant regulations and requirements to prevent and control, but have attracted attention and attention (1 point)

C. Lack of relevant regulations and requirements, and has not yet received attention and attention (2 points)

R1.3.2 Quarantine Control Management (2 points)

A. It has been listed as quarantine control object and has relatively complete management measures to prevent its introduction (0 points).

B. It has been listed as a quarantine control object, and the current management means may intercept it (1 point)

C. Has not been included in the quarantine control object, but has attracted attention and attention, the current management tools

May intercept it (1 point)

D. Not included in the quarantine control object, it is easier to be introduced (2 points)

R2 At the appropriate stage risk (18 points)

R2.1 Climate Adaptation (2 points)

R2.1.1 Climate Adaptability (2 points)

A. Adaptability to local climate is very poor (0 points)

B. General adaptability to local climate (1 point)

C. Appropriate adaptability to local climate (2 points)

R2.2 Resistance (4 points)

R2.2.1 Resistant ability during growth period (2 points)

A. The tolerance to adverse environment during the growing season is poor (0 points)

B. The growth period is highly resistant to certain adverse environments during growth (1 point)

C. Growth period has strong resistance to various adverse environments during growth (2 points)

R2.2.2 Resistant ability during breeding period (2 points)

A. Breeding period is less tolerant of adversity (0 points)

B. Breeding period has strong resistance to certain stresses during growth (1 point)

C. Breeding period has strong resistance to various stresses during growth (2 points)

R2.3 Adaptability (9 points)

R2.3.1 Growth Adaptability (2 points)

The measurable indicators of species with strong growth adaptability mainly include: (1) low selectivity selection of species for environmental growth; (2) fast growth rate, short growth cycle; (3) strong ability to adapt to the environment, get into the growth stage soon after invasion; (4) strong genetic adaptability. When conducting risk grading evaluation, the above four factors should be considered.

The degree of agreement, so the assessment is as follows:

A. No obvious performance on the above features (0 points)

B. Clearly showing the above 1-2 characteristics (1 point)

C. Clearly showing the above three or more characteristics (2 points)

R2.3.2 Reproduction method (3 points)

A. Mainly rely on asexual way to breed (1 point)

B. Mainly through sexual reproduction (1 point)

C. Both sexual reproduction and asexual reproduction (3 points)

R2.3.3 Reproductive ability (4 points)

1) Sexual reproduction ability (2 points)

A. Almost no sexual reproduction (0 points)

B. Sexual reproduction once a year (1 point)

C. Sexual reproduction multiple times a year (2 points)

(2) Asexual reproduction ability (2 points)

A. Almost no asexual reproduction ability (0 points)

B. Asexual reproduction can only be used to maintain general species (1 point)

C. Asexual reproduction can lead to rapid population growth (2 points)

R2.4 Environmental factor (3 points)

R2.4.1 Moisture condition (1 point)

A. Not suitable (0 points)

B. Generally suitable (0.5 points)

C. More suitable (1 point)

R2.4.2 Salinity conditions (1 point)

A. Not suitable (0 points)

B. Generally suitable (0.5 points)

C. More suitable (1 point)

R2.4.3 Nutritional Conditions (1 point)

A. Not suitable (0 points)

B. Generally suitable (0.5 points)

C. More suitable (1 point)

R3 Diffusion phase risk (36 points)

R3.1 Diffusion method (4.5 points)

R3.1.1 Diversification of Diffusion Modes (1.5 points)

This indicator mainly considers whether there are multiple ways of diffusion. The main modes of diffusion include wind-borne, water-flow, human-transportation, and self-distribution mechanisms. Therefore, the specific assessment should focus on the types of diffusion methods.

A. Have the above-mentioned one type of propagation and diffusion (0.5 points)

B. With the above two modes of propagation and diffusion (1 point)

C. With the above three or more modes of propagation and diffusion (1.5 points)

R3.1.2 Diffusion distance (1.5 points)

A. The diffusion distance is short and spread only near the growth area (0.5 points)

B. Long diffusion distance, can spread in the ecosystem around the growing area (1 point)

C. The diffusion distance is very long and can spread across regions (1.5 points)

R3.1.3 Diffusion speed (1.5 points)

A. The time to spread to colonization is very short, usually less than half a year (1.5 points)

B. The time to spread to colonization is medium, usually half a year to one year (1 point)

C. The time to spread to colonization is long, usually more than one year (0.5 points)

R3.2 Growth rate (1.5 points)

R3.2.1 Growth rate (1.5 points)

A. The rate from maturity to adulthood is fast, far faster than the native species of the same niche (1.5 points)

B. The rate from maturity to adulthood is moderate, and is equivalent to the native species of the same niche (1 point)

C. The rate from maturity to adulthood is slower, slower than the native species of the same niche (0.5 points)

R3.3 Status of proliferation (6 points)

R3.3.1 Diffusion area (2 points)

A. Diffusion or diffusion area in individual administrative areas is less than 5 000 m^2 (0 points)

B. Diffusion or diffusion area in 2-4 administrative regions is greater than 5 000 m^2 and less than 30 000 m^2 (1 point)

C. Diffusion or total diffusion area in more than 4 administrative districts 30 000

m^2

Above (2 points)

R3.3.2 Degree of diffusion (2 points)

A. Sparse individual distribution (0 points)

B. Occasionally high density distribution (1 point)

C. Large area distribution of slices (2 points)

R3.3.3 Proportion of adversely affected areas (2 points)

A. The proportion of the area with negative impact is less than 5% (0.5 points)

B. The proportion of the area with negative impact on the total distribution area is 5-20% (1 point)

C. The proportion of the area with negative impacts on the total distribution area 20-50% (1.5 points)

D. The proportion of the area with negative impacts is greater than 50% (2 points)

R3.4 Control mechanism (3 points)

R3.4.1 Natural enemy status (1.5 points)

A. There are effective natural enemies in the region (0 points)

B. There are natural enemies in this area, but the effect is not obvious (0.5 points)

C. There are no effective natural enemies in the region (1.5 points)

R3.4.2 Control Management Status (1.5 points)

A. Effective control and management measures have been taken, and the effect is obvious (0 points)

B. Control measures have been taken, but the effect is not obvious (0.5 points)

C. No control measures were taken (1.5 points)

R3.5 Diffusion trend (3 points)

R3.5.1 Competing species with niche (1.5 points)

A. There are species with the same niche competition in this region, and the competitive advantage is greater than that of exotic species (0.5 points)

B. There are species that compete with the niche in this region, and the competitive advantage is similar to that of exotic species (1 point)

C. Species with the same niche competition in the region, the competitive advantage is less than the exotic species (1.5 points)

R3.5.2 Free space for diffusion (1.5 points)

A. The area of suitable habitat or possible area of the area is small (0.5 points)

B. There are some habitats in the area that are suitable for their invasion or similar to the invaded areas (1 point)

C. There is still a large area in the area suitable for its invasion or habitat similar to the invaded area (1.5 points)

R4 Hazard Stage Risk (36 points)

R4.1 Ecological Hazard (10 points)

R4.1.1 Hazard to native species (3 points)

A. no threat or threat is not obvious (0 points)

B. There is a certain threat, but the impact is small (1.5 points)

C. Can cause threats (such as habitats that endanger endemic or rare species, affect the growth of native species, cause their degradation, or even disappear) (3 points)

R4.1.2 Impact on ecosystem processes (3 points)

A. The impact on the ecosystem process is not obvious (0 points)

B. A more gradual impact on the ecosystem process, the change can be detected (1.5 points)

C. It has a significant impact on the ecosystem process and may even cause irreversible effects (3 points)

R4.1.3 Impact on the environment (2 points)

A. The impact on ecosystem factors are not obvious (0 points)

B. A more gradual impact on ecosystem factors, the changes can be detected (1 point)

C. Significant impact on ecosystem factors, and may even cause irreversible effects (2 points)

R4.1.4 Impact on biodiversity (2 points)

A. No threat or threat is not obvious (0 points)

B. There is a certain threat, but the impact is not great (1 point)

C. Can cause threats (2 points)

R4.2 Social Hazard (8 points)

R4.2.1 Social Production Impact (4 points)

A. No influence or positive impact on the production mode of the surrounding society, and increase social productivity (0 points)

B. There is no significant impact on the production mode and production efficiency of the surrounding society (2 points)

C. It has an adverse impact on the production methods of the surrounding society and reduces social productivity (4 points)

R4.2.2 Social life impact (4 points)

A. No impact or positive impact on the surrounding social life (0 points)

B. Has little impact on the surrounding social life (2 points)

C. It has an adverse impact on the surrounding social life (4 points)

R4.3 Economic Hazard (10 points)

R4.3.1 Impacts of Agriculture, Forestry and Fisheries (3 points)

A. Basically no impact (0 points)

B. At least one crop, tree species, and aquatic products are affected, and the damage area is not large (1.5 points)

C. It can affect a variety of crops, tree species, and aquatic products, with a large area of damage (3 points)

R4.3.2 Transportation Impact (3 points)

A. Basically no impact (0 points)

B. It can affect the port shipping, but the impact is small (1.5 points)

C. It can have a serious impact on port shipping (such as large-scale encroachment on sea beaches or causing potential channel siltation) (3 points)

R4.3.3 Impact of resource utilization (2 points)

A. Promote better use of resources (0 points)

B. No significant impact on resource utilization (1 point)

C. Hinder the use of resources (2 points)

R4.3.4 Tourism Impact (2 points)

A. Basically no impact on tourism (0 points)

B. A certain impact on the tourism industry (1 point)

C. Significant impact on tourism (2 points)

R4.4 Health hazard (8 points)

R4.4.1 Animal and Plant Health Hazards (4 points)

A. It is not the host of pests or diseases or the environment for pests and diseases (0 points)

B. It is the host of 1 or 2 kinds of pests and diseases or can provide environment for breeding of 1 or 2 kinds of pests and diseases (2 points)

C. It is the host of pests and diseases or can provide environment for pests and diseases breeding (4 points)

R4.4.2 Human Health Hazards (4 points)

A. At this stage, there is no significant impact on the health and living conditions of the population (0 points)

B. 1-3 hazards to the health and living conditions of the population (2 points)

C. Multiple hazards to the health and living conditions of the population (4 points)

R5 Prevention and control stage risk (10 points)

R5.1 Prevention and Control Management (10 points)

R5.1.1 Control methods and effects (3 points)

A. Easy to remove, mature technology, long-term eradication of invasive species (0 points)

B. The removal method is effective, the control effect is good in the short term, but it is easy to repeat (1 point)

C. It is effective only in a small area or at a certain stage of the life history of the species. In the short-term, the control effect is general and easy to repeat (2 points)

D. There is no effective prevention and treatment method (3 points)

R5.1.2 Side effects (3 points)

A. At this stage, there is no negative effect on local biomes or native species (0 points)

B. Effective control methods have a certain impact on local biomes or native species (1.5 points)

C. Effective control methods can cause serious impact on local biomes or native species (3 points)

R5.1.3 Prevention cost (4 points)

A. The control process is fast and the cost is low (0 points)

B. Short-term investment in manpower and capital is required, and the time to control or prevent it below the level of harm is less than 1 year (1 point)

C. It requires a short-term, large amount of manpower and capital investment, and it is less than 5 years (2 points) to control or prevent it below the level of harm.

D. It takes a long-term, large amount of manpower and capital investment, and it takes at least 5 years or more to control or prevent it below the level of damage (3 points)

E. The hazards and adverse effects are irreversible and cannot be recovered (4 points)

3.3.5 Determine the evaluation method of the risk value of the evaluation system

For indicators that can be quantified, measure the score according to the set quantitative range. Indicators that cannot be quantified are assessed using predicted data provided by on-site visiting local fishers and scientific observers. The assessment of a foreign species through five primary indicators, 17 secondary indicators and 41 tertiary indicators, the final score is the combined risk value.

3.3.6 Determine the solution when the evaluation information is missing

In the process of risk assessment, there are sometimes uncertainties in the inability to obtain information about a certain indicator or the information obtained, resulting in the lack of evaluation information. In this case, the “uncertain score” processing method can be adopted, that is, when evaluating a missing information indicator, first exclude the options that can be obviously removed among the listed options, obtain an option interval, and then record the same. The lowest score and the highest score of the interval are used as the scores of the indicator. The final total score will have two results: first, the lowest total score and the highest total score are in the score interval of the same risk level, at which time the risk can be graded. For the risk level of the species; second, the lowest total score and the highest total score are not in the score range of the same risk level, and the risk level of the species is the risk level at which the highest score is located.

3.3.7 Division of the assessment system risk level

The existing laws and regulations on the classification of harmful hazards to human health, animals and plants include: "Infectious Diseases Prevention and Control Law" (1989), "Introduction to Phytosanitary Diseases, Insects, Weeds and Weeds" (1992), Animal Epidemic Prevention Law (1997), "List of Potentially Hazardous Diseases, Insects, Weeds in Entry Plant Quarantine" (1997), "Chinese Weeds", etc. Refer to the current laws and regulations and relevant literature on the classification of risk levels of invasive alien species at home and abroad, and set the risk classification criteria (Table 3-6).

Table 3-6 Risk classification criteria

Risk level	**Risk level description**	**Comprehensive risk value**	**Management strategy**
First level	Highly dangerous, unacceptable	70.5-100	Prohibition of introduction, quarantine
Secondary level	Moderately dangerous, with certain risks	30.5-70	Further research is needed. If introduced, strict risk prevention and control measures should be proposed.
Third level	Low risk, acceptable	0-30	Can be introduced, properly managed

3.4 Risk Assessment of *P. clarkii* in Dafeng District

According to the established ecological risk assessment system of *P. clarkii* in Dafeng District, combined with literature research and field survey results, the risk assessment of *P. clarkii* in Dafeng District was carried out.

Table 4-1 Ecological Risk Assessment Results of *P. clarkii* in Dafeng District

Evaluation index	**Indicator score**	**Doulong River**
R1.1.1	4	4
R1.1.2	4	1
R1.2.1	3	1
R1.2.2	3	1
R1.3.1	2	1
R1.3.2	2	0
R2.1.1	2	2
R2.2.2	3	1
R2.3.1	2	2
R2.3.2	3	1
R2.4.1	1	1
R2.4.2	1	1
R2.4.3	1	1
R3.1.1	1.5	0.5
R3.1.2	1.5	0.5
R3.1.3	1.5	1
R3.2.1	1.5	1.5
R3.3.1	2	2
R3.3.1	2	1
R3.3.2	2	2
R3.3.3	2	0.5
R3.4.1	1.5	0

R3.4.2	1.5	0
R3.5.1	1.5	1.5
R3.5.2	1.5	0.5
R4.1.1	3	1.5
R4.1.2	3	1.5
R4.1.3	2	0
R4.1.4	2	1
R4.2.1	4	1.5
R4.2.2	4	0
R4.3.1	3	1.5
R4.3.2	3	0
R4.3.4	2	0
R4.4.1	4	0
R4.4.2	4	0
R5.1.1	3	1
R5.1.2	3	0
R5.1.3	4	0
Comprehensive risk value	100	33
Risk level		Secondary level

According to Table 4-1, the ecological risk assessment results of *P. clarkii* in Dafeng District are basically consistent with the results of the field investigation. The evaluation system is effective, the risk assessment level is Grade II, and the value is close to Grade III, indicating the introduction of *P. clarkii*. The local ecosystem has a certain degree of impact, but it is still relatively safe. It needs certain protection and prevention measures. If it is not properly managed, it will lead to potential invasion risks and affect local biodiversity [6].

4. The impact of the fishery production model of *P. clarkii* in Dafeng District on the local ecological environment

4.1 Fishery profile of *P. clarkii* in Dafeng District

Dafeng District, Yancheng City, Jiangsu Province is located on the coast of the Yellow Sea and has a good ecological environment. It has always been the main production area for wild caught crayfish. The fishing records of Dafeng District show that the listing volume of the whole district in 2015 was about 12,000 tons, of which Baolong's purchase volume was about 4,000 tons, and the rest were local sales. The crawfish production in Dafeng District comes from the fishing of 500 licensed fishermen in the Douro River and related river courses. About 30% of the crayfish supply in the region has established a supply partnership with Baolong.

4.2 Fishing methods

The crayfish in Dafeng District are caught by fixed cages and shrimp nets (long bag net type), and the fishing regulations clearly stipulate that the minimum mesh size should not be less than 2 cm. The crayfish fishing process does not use bait. The fishing device usually needs to be placed for 24 hours (the water temperature is high in summer, the crayfish are active for feeding, so the placement time is short), and will be placed in the water again after the net is collected. These fishing devices are usually tied to wooden piles on river beds, and fishing is carried out by one or two fishermen on small wooden boats.

4.3 Existing fishery management regulations for *P. clarkii* in Dafeng District

"Fisheries are subject to an effective management system that respects local, national and international laws and standards and incorporate institutional and operational frameworks that require resource accountability and sustainability.”

The crayfish fishery began to be managed in 1993, at that time the market began to demand, but they estimated it was introduced in the 1980s. A receipt of 900 kilograms of crayfish was found in the factory archives in 1993, indicating that the crayfish population in the area is already abundant. 555 licenses were issued in 1997, and this number has not changed since then. There is a license fee of 200 yuan per year, and the licensee is subject to inspection every year.

Management measures were implemented by the Chinese fisheries law enforcement agency (the Dafeng team of respondents during the on-site visit). Economically manage fisheries by giving individuals “rights” to crayfish resources in specific areas, both spatially and temporally. User rights restrict the collection area to licenses (individual/family), and then the licensee is responsible for managing their own collections and complying with regulations established by the regulatory agency. This usually means that right holders (fishers) do not overfish inventory because they will harm their future income. There is no “fish competition” in fisheries or open access managed by TAC. The main management objective is to provide local people with jobs (555 licensed fishermen) and factory jobs (600 Baolong factories). The economy benefits from export processing and its price is higher than other fish products. The permit is issued for the vessel, but in the marshes, the licensee can hire workers, so the employment rate is higher.

The fishery is characterized by the following management, control and enforcement systems:

A) Space, time and catch size limits (permitted area, enclosed area and minimum size)

B) Marketing control (can only be sold through a designated point of sale)

C) Harvest license (licensee)

D) Rights-based management (granting user rights 5 - 7 years)

E) Part of the protected ecosystem (nature reserve)

The official regulatory documents adhere to four management requirements:

1) Size (minimum harvest 5 cm)

2) Season (April to October)

3) License (550 issue)

4) Distribute distribution points for crayfish collection

The local fisheries bureau hopes to maintain stable production and will be fined for illegally catching the original crayfish in the season.

Fishermen are willing to abide by these rules because they can guarantee that their income will be higher next season. There is an annual report on fisheries management that can serve as an indicator of its effectiveness.

4.4 Assess the existing fisheries management practices in the Dafeng District for potential overfishing risks in *P. clarkii* and its bycatch species

4.4.1 Current status of the original crayfish fishery

The need to determine the status of fish is a common problem for fisheries management agencies around the world. Inventory assessments are usually enforced by various national or international laws and often include an assessment of the current biomass and fishing mortality of the stock, comparing the reference levels, usually the maximum sustainable yield (MSY). However, due to the data requirements for assessing stock availability, a large proportion of fisheries managers and scientists in the world lack the capacity to assess reservoir conditions. In the past, many of these data-poor populations have been managed through the use of Harvest Control Rules, which are based on overfishing constraints and biomass in the population. However, due to little knowledge of inventory levels, it is difficult to properly apply preventive management. However, many managers and scientists are turning to risk assessments to better manage inventory in targeted stocks, and risk assessments of data-poor inventory often use some semi-quantitative methods. In the previous semi-quantitative risk assessment example, scientists assessed the risk of extinction of fisheries on bycatch and target species and their impact on ecosystem viability. These methods allow for a smaller amount of information and various factors, and can complement inventory and ecosystem assessments.

Because of the lack of long-term fishery statistics, *P. clarkii* is difficult to assess using standard resource assessment methods, while semi-quantitative evaluation based on population productivity-susceptibility analysis (PSA) is the main method. Complete fishery data, this assessment method has been applied in several offshore fisheries [7].

4.4.2 Evaluation using productivity-easy catch rate analysis method

Through the scientific observers of local fishermen and Dafeng District, the main organisms in the Douron River were learned: *P. clarkii*, crab (mainly *Eriocheir sinensis*), shrimp (mainly grass shrimp), and fish (mainly Squid, scutellaria, , etc.), snail (mainly snail).

The PSA analysis is based on two indices: productivity (P) and susceptibility (S). P index consists of 5 population basic biological parameters (intra-population growth rate, female maximum age, female maximum individual length, female growth coefficient, natural mortality, fecundity, reproductive strategy, supplementary survival rate, female mature age, average nutrition) The productivity scores corresponding to the grades are obtained by weighted averaging. These biological parameters are from the literature [8][9][10][11], and the corresponding productivity scores for each parameter range from 1 to 3, and the weights are assigned as 1 to 4. For example, for the female maximum age parameter, the productivity score corresponding to the maximum age <10 years is 3, the productivity score corresponding to the maximum age of 10 to 30 years is 2, and the productivity score corresponding to the maximum age > 30 years is taken as 1. This classification standard reflects the K-selective ecological countermeasures for the long-lived fish species with low general productivity and slow recovery after population disturbance. The classification of productivity scores corresponding to other biological parameter values is shown in Table 4-1. The S index consists of 11 parameters related to the relationship between population and fishery (the intensity of fishery management measures, the extent of population distribution and horizontal overlap and vertical overlap of fishery operations, population distribution clustering, spawning population biomass and original spawning population) The ratio of biomass, the impact of overlap with fisheries, the impact of fish behavior on the catch rate, the fishing selectivity, the survival rate after capture and release, the economic value of the target, and the impact of fishing on habitats The easy catch rate score is averaged. For example, the vertical overlap parameter of the population distribution range and the scope of fishery operations: if the vertical overlap area between the population and the fishery operation is less than 25% of the vertical distribution range of the population, the corresponding catch rate score of the parameter is 1; greater than 25%. If less than 50%, the easy catch rate score is 2; if it is greater than 50%, the easy catch rate score is 3. The spatial and temporal distribution of the cage fishing operations, the intensity of fishery management measures, the fishing selectivity parameter, and the biomass in the 11 parameters. The information, the temporal and spatial distribution of the population, and the survival rate after capture and release were evaluated from observations by scientific observers of *P. clarkii* in Dafeng District. The criteria for dividing the easy-to-capture rate scores corresponding to each parameter value are shown in Table 4-2. The specific meanings are shown in [12].

Table 4-1 Scores corresponding to each parameter value in the calculation of aquatic animal productivity in the Douro River

	High (3)	Medium (2)	Low (1)	Weights	crab	shrimp	screw	fish	*P. clarkii*
Intrinsic growth rate	＞0.5	0.5～0.16	＜0.16	1	3	3	3	3	3
Female maximum age	＜10	10～30	＞30	1	3	3	3	3	3
Female maximum length	＜30	＜60	＞100	1	2	3	3	2	3
Female growth coefficient	＞0.25	＞0.25	＜0.15	1	3	3	3	3	3
Natural mortality	＞0.4	0.2- 0.4	＜0.2	1	2	2	1	1	1
Fertility	＞10000	100~ 10000	＜100	1	3	2	2	2	2
Reproductive strategy	0	1 ~ 3	≥4	4	2	3	3	2	2
Supplementary survival rate	＞75%	10% ~ 75%	＜10%	4	3	3	3	3	3
Female mature age	＜2	＜2	＜2	4	3	3	3	3	3
Average trophic level	＜2.5	2.5~ 3.5	＞3.5	4	2	3	3	3	2

Table 4-2 Scores corresponding to each parameter value in the calculation of the catch rate of aquatic animals

	High (3)	Medium (2)	Low (1)	Weights	crab	shrimp	screw	fish	*P. clarkii*
Fishery management measures	Limit or close monitoring	Limit or medium level monitoring	No limit or close monitoring	2	2	1	1	2	3
Population level overlap	＜25%	25%～50%	＞50%	2	1	1	3	1	1
Population distribution cluster	50%	25%～50%	25%	2	2	3	2	2	1
Vertical overlap of population	＜25%	25%～50%	＞50%	2	1	2	2	2	2
Spawning population biomass ratio	＞40%	25%～40%	＜25%	2	2	2	2	2	2
The influence of fish behavior on the catch rate	reduce	no effect	increase	2	2	2	2	2	2
Fishing selection rate	low	medium	high	2	2	2	3	2	3
Survival rate after capture release	＞ 67%	33%～67%	＜33%	2	3	2	3	2	3
Economic value of fishing objects	general	Higher	Very high	2	1	1	3	3	3
The negative impact of fishing on habitats	No or very small	Larger	Large and unmonitored	2	3	3	3	2	3

After calculating the P index and the S index, different types of overfishing risks were compared by graphical method (P-S chart). At the same time, the risk index (Vulnerability, V) is calculated based on these two indexes to indicate the risk of overfishing for each species:

$$V = \sqrt{(P - X_0)^2 + (S - Y_0)^2}$$

In the formula, P and S are productivity and easy-to-capture index values respectively. X_0 and Y_0 are PS map origin coordinates. The values of X_0 and Y_0 can be set by themselves (the origin coordinates are different, and the values of various V-values relative to the origin are unchanged). The higher the risk index is, the greater the risk that the population is overfished due to the impact of the fishery will be.

The scores corresponding to the values of the main common biological productivity and easy-to-capture index captured in the rivers such as Doulong River in Dafeng District are shown in Table 4-3. The productivity index of the five organisms is 2.5-2.68, the average value. For 2.58 (Figure 4-1), the low to high productivity index is the original crayfish, crab, shrimp, fish, and snail. The easy catch rate index is 1.9~2.1, the average value is 1.98, and the easy catch rate index is from low to high for *E. sinensis*, grass shrimp, squid, *P. clarkii*, and snail. Populations with low productivity index and high index of easy catching rate have high risk of overfishing; populations with high productivity index and low index of easy catching rate have lower risk of overfishing. Therefore, the snail in Figure 4-1 has a relatively small risk of overfishing. The productivity and easy catch rate of *E. sinensis* and grass shrimp are the same, and the risk index is the same. The risk index V more directly indicates the risk difference of various types of overfishing. The lowest risk index is snail, the highest being *E. sinensis* and grass prawn, indicating that these two populations are most vulnerable to overfishing due to the way cages are caught (Figure 4-2).

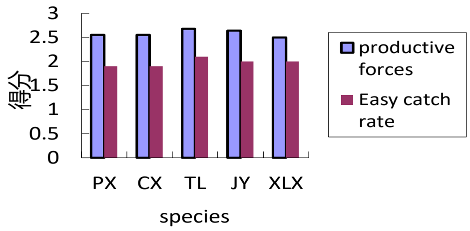

Figure 4-1 Main common biological productivity and easy catch rate index captured by the Doulong River (PX: crab; CX: shrimp; TL: snail; JY: fish; XLX: *P. clarkii*)

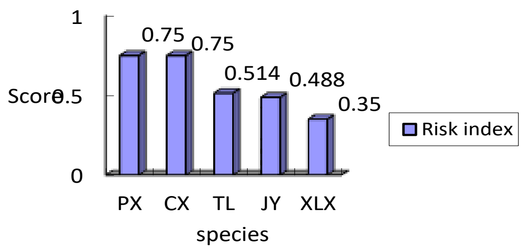

Figure 4-2 Changes in five aquatic organism risk indices in the Douron River

5. Results and recommendations for ecological risk assessment of *P. clarkii* in Douron River

With the reputation of "Spicy Crayfish" being accepted by the general public in all parts of China, its market consumption potential is also expanding. In fact, *P. clarkii* not only has high economic value and edible value, but also is excellent. The scientific model of animals, its huge market potential and scientific research value can not be estimated. The ecological risk assessment of *P. clarkii* showed that its risk assessment level was Grade II. The introduction of *P. clarkii* had a certain degree of impact on local biomes, but the ecosystem was safer and needed protection and prevention measures. If not managed properly, there is a probability that it will lead to potential other risks that affect local biodiversity.

(1) Protecting the ecological environment

According to the living habits of crayfish, the growth environment of crayfish under natural conditions is simulated, and the ecological environment of crayfish in nature is protected and cannot be destroyed.

(2) Establishment of a banned specification and a ban period

Relevant departments should set the minimum specifications for crayfish listing according to the local situation. When fishing crayfish in nature, it is necessary to adhere to the principle of large size retention. For example, crayfish below 6 cm may not be sold on the market. Without market demand, people will not catch this crayfish anymore, which has positive significance for the conservation of crayfish resources.

(3) As in the fishery ban period, the fishery administration should include the protection of crayfish into the scope of fishery services, implement the crayfish ban period and limit the number of cages. Every year from October to February is the stage of crayfish breeding, egg-raising and hatching. This period can be set as the cray-free period of crayfish, during which no crayfish can be caught or sold.

(4) Strengthen publicity and guide correctly

The aquatic products and agriculture departments should strengthen guidance and increase the propaganda and support of crayfish farming methods such as shrimp rice, shrimp and crab polyculture, fish and shrimp polyculture, shrimp aquatic economic crops, etc. The crayfish's forbidden period and forbidden specifications allow people to understand the breeding habits of crayfish, consciously protect the crayfish's broodstock and juvenile shrimp, and enhance the fishermen's awareness of environmental protection of crayfish resources.

(5) Increase investment

The government should increase investment to strengthen the environmental protection of crayfish resources. First of all, the government should support various crayfish breeding projects through the introduction of various preferential policies, and promote the crayfish seed breeding base and crayfish breeding base from project, capital, insurance, credit, etc. through the introduction of industrial policies to promote the industrialization of crayfish. , cooperatives and companies, and the development of crayfish processing companies.

Secondly, strengthen technical training and guidance to accelerate the popularization of crayfish farming and disease prevention technologies. By building a brand and implementing standardized production, it is the fundamental way out for the industrialization of crayfish and an effective measure to protect the environment of crayfish resources. Local governments should take the initiative to attack and plan ahead. The government or enterprise groups organize experts and representatives in breeding, breeding, circulation, processing, etc and prepare standards for crayfish breeding, breeding, processing and packaging, circulation to consumption, and provide them to the market. Standardized, safe and hygienic food.

The environmental protection of crayfish resources is a systematic project. Under this circumstance, government departments, universities, research institutes and leading enterprises should be closely integrated to strengthen the construction of improved breeding and high-quality seed breeding. Protect crayfish resources.

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