Research Article

Genetic evaluation of native and non-native shrimp species of Iran with aquaculture potential; An overview of protection and exploitation recommendations

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Abstract

Efficient management of aquatic resources and development of aquaculture rely on the identification of genetic resources of native species and populations in each region. Studying the geographical distribution, biological characteristics, and ecological status of species can provide the foundation for planning the protection and sustainable exploitation of genetic resources. In this study, we focus on the population distribution of shrimps in the aquaculture industry of Iran and evaluate the current state of stocks and genetic diversity of commercially farmed shrimps. The Persian Gulf is home to two groups of shrimps, Penaeidae and Caridean, with 16 species of Penaeidae family shrimps identified in its waters. However, only five species are commercially exploited in Iran, namely Green tiger prawn (*Penaeus semisulcatus*), Banana prawn (*Fenneropenaeus merguiensis*), white shrimp (*Litopenaeus setiferus*), kiddi shrimp (*Parapenaeopsis stylifera*), and small white shrimp. Recent studies indicate that the amount of shrimp catch in Iran has decreased by half in recent years, mainly due to the loss of broodstock resulting from overfishing or fishing during the spawning season, as well as the destruction of habitats.

Key words: Crustaceans, Shrimp, Genetic resources, Genetic diversity, Protection, Exploitation

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Introduction

Meeting the food needs of the growing global population is crucial and requires careful management and planning. Aquaculture has

become one of the most important sectors for food production and protein supply for human societies. The growth of this industry has led to economic development, job creation, and poverty reduction, particularly in developing countries. The increasing demand for fishery products and the limited marine resources have made aquaculture the most viable way to supply protein for the growing world population, decrease pressure on wild fish stocks, and increase the income of coastal communities, particularly in low-income countries. Shrimp farming is expanding at a faster rate than other aquaculture sectors worldwide. Global production of farmed shrimp exceeded 4.5 million tons in 2021 and is expected to surpass 5 million tons by 2022 (Chris Chase, 2022). Despite the progress made in the fisheries and aquaculture sector, it is important to manage living aquatic resources appropriately to ensure the sustainability of their contribution to the food, economic, and social well-being of the growing global population. Although aquatic resources are renewable, they have limitations and require effective management.

Evolutionary processes have led to severe changes in aquatic ecosystems, resulting in the destruction of different populations and species. Moreover, the global climate crisis and the lack of information on the compatibility of different genetic traits have doubled the importance of preserving aquatic genetic resources. Cases like overfishing, extensive manipulation of riverbeds, and domestication of wild species through aquaculture have highlighted the need to protect aquatic genetic resources, which has been the focus of researchers in the fisheries sector (Tol-Gilani *et al.*, 2014). The aquatic species in a country's water resources have high diversity, and their identification and classification are of significant importance for science and the economy. The exploitation of aquatic resources should be based on the biological and ecological indicators of different species. Therefore, knowing the distribution and diversity of populations of each aquatic species is a strategic key to the principled exploitation and protection of genetic resources. Studying the biological traits, geographical distribution, species diversity, ecological status, and abundance of species groups in marine ecosystems, inland water resources, and aquaculture systems can provide the basis for planning the protection and sustainable exploitation of aquatic genetic resources (Seyedmortezaei *et al.*, 2017).

In recent years, the shrimp breeding industry in developing countries has emerged as a significant source of national income, playing a valuable role in their growth and prosperity. The increase in global demand due to the rise in per capita income in developed and developing countries, the improvement of breeding methods, the creation of diversity in species breeding, and the limitation of natural resources in the seas are effective factors in the development of shrimp farming.

It is projected that by 2026, shrimp will generate a revenue of 23.4 billion dollars from the global share of aquatic trade (Renub research site).

Shrimp exhibit great biological diversity and have a wide geographical distribution. They inhabit fresh, brackish, and very salty waters, from tropical regions to cold waters, and can be found from coastal to deep waters with a depth of about 5700 meters. However, most economically valuable species live in waters of the continental plateau with a depth of less than 100 meters. For centuries, shrimp of the Penaeidae family have been used as a suitable food source.

In Iran, various types of shrimp are found in inland waters, the Caspian Sea, the Persian Gulf, and the Oman Sea. However, the saltwater species with the ability to breed are Green tiger shrimp (*P. semisulcatus*), Banana prawn (*Fp. indicus*), Indian white shrimp (*P. indicus*), red tail shrimp (*Fp penisulcatus*), Japanese shrimp (*M japonicus*), and white shrimp (*Mp affinis*). Among these species, red tail shrimp and Japanese shrimp are very rare, and white shrimp has not been considered a cultured species in Iran due to its very small size. In addition to these species, the black tiger prawn is present in Gwadar Gulf (Sistan and Baluchistan province). About 16 species of shrimp have been identified in the waters of the Persian Gulf and the Oman Sea, but only five species with larger sizes and more abundance are economically exploited. The most important economic species in fishing is the Green tiger shrimp (*P semisulcatus*), which is found in most habitats of the Persian Gulf and the Oman Sea, but is mainly caught in the coastal waters of Bushehr province. Banana prawn (*Fp mergueinsis*), the second most commercially important species, is mostly caught in the waters of Hormozgan province. Other species, such as Indian white shrimp (*Fp indicus*), Japanese shrimp (*Mp japonicus*), and black tiger shrimp (Penaeus monodon), despite their large size, are not economically exploited due to their low abundance and limited habitat. Species of Caridean shrimp have also been identified in the Persian Gulf region, but they are not commercially viable due to their small size and non-commercial nature.

This study investigates the population distribution of shrimps in Iran's aquaculture industry, evaluates the current status of stocks and genetic diversity of commercially farmed shrimps, and explores conservation and exploitation methods. The review is retrospective and covers all the studies and plans implemented in the fields of aquaculture, distribution, and abundance of shrimp in the Persian Gulf, the Oman Sea, and the inland waters of the country. The biological and ecological characteristics of the species are investigated, and using the available information and scattered studies in the field of species identification and diversity in the water ecosystems of the country, endangered species are identified and categorized. The study also determines

the priorities of sustainable exploitation to protect these species.

Introduction of farmed shrimps of Iran

In the waters of the Persian Gulf and the Oman Sea, five species with larger sizes and more abundance are economically exploited. The most important economic species in fishing is the green or pink tiger shrimp (*P. semisulcatus*), which is widely distributed in the Persian Gulf and the Oman Sea but is mostly caught in the coastal waters of Bushehr province. The banana prawn (*P. merguensis*), which ranks second commercially, is mostly caught in the waters of Hormozgan province. Other species, such as Indian white shrimp (*Fp indicus*), Japanese shrimp (*P. japonicus*), and black tiger shrimp (*P. monodon*), despite their large size, are not economically exploited due to their small abundance and limited habitat (Moslemi and Bavand, 2018). Three species of Kiddi shrimp (*P. stylifer*), white shrimp (*Mp affinis*), and small white shrimp are distributed throughout the Persian Gulf and the Oman Sea, but they have no export value. These three species are mostly exploited for local and regional markets. Table 1 presents the classification of commercially important shrimps, while Table 2 provides the production statistics of Iran's saltwater shrimp breeding species by province.

Table 1. Classification of Iran's important commercial shrimps (salt water)

row	scientific name	Native	Non-native	natural distribution	production method
1	*P. semisulcatus*		*	the Persian Gulf and the Oman Sea	Catch
2	*P. merguensis*		*	the Persian Gulf and the Oman Sea	Catch
3	*M. affinis*		*	the Persian Gulf and the Oman Sea	Catch
4	*P. stylifera*		*	the Persian Gulf and the Oman Sea	Catch
5	*Fp. indicus*		*	the Oman Sea	Breeding
6	*P. monodon*	*		Indo-Pacific	Breeding
7	*P. vannamei*	*		South America	Breeding

Table 2. Iran's farmed shrimp production statistics by province (tons) (Statistical Yearbook of Iran Fisheries Organization, 2021)

Province	2013	2014	2015	2016	2017	2018	2019	2020
Bushehr	8488	14500	8205	9012	13434	21000	21767	23608
Khouzestan	771	1362	1348	724	854	528	208	227
Sistan and Baluchistan	0	210	303	570	1025	1565	1650	834
Golestan	304	481	714	1124	1690	2585	405	410
Hormozgan	3135	5922	7225	9901	15329	22181	22084	23776
Total	12698	22475	17795	21331	32332	47859	46114	48855

Biology and ecology of shrimp species in Persian Gulf and Iranian waters with emphasis on previous researches

Iran has various types of shrimps in inland water resources, Caspian Sea, Persian Gulf, and Oman Sea. However, the saltwater species that have the ability to breed include Green tiger shrimp, Banana prawn, Indian white shrimp, red tail shrimp (Fenneropenaeu penisulatus), Japanese shrimp, and white shrimp (Metapenaeus affinis). Among these species, red tail shrimp and Japanese shrimp have a very low abundance, and white shrimp has not been considered as a cultured species in Iran due to its very small size. Additionally, there is a small number of black tiger shrimp in the waters of the Gwadar Gulf in Sistan and Baluchistan province.

Niameymandi (2006) conducted studies on Green tiger shrimp in the Persian Gulf during 2003-2006 and reported that the growth parameter for males was 1.6 and for females was 2.2 per year. The infinite length for males was 38 mm and for females was observed to be 50.4 mm. Natural mortality (M), fishing (F), and total (Z) parameters for Green tiger shrimp in the Persian Gulf were estimated in Azimi (1985), Niameymandi (2006), and Khorshidian (2005) studies. The results estimated natural mortality to be about 3, fishing mortality to be 4-7, and total mortality to be 7-9 per year. Overall, regarding this species, which is considered the main species of the Persian Gulf, the exploitation coefficient (E) indicates overfishing.

Kamrani (1993) investigated the dynamic parameters of the Banana prawn population, whose main hunting grounds are the waters of Hormozgan. He analyzed and reported that the coefficient K was estimated as 1.9 and 2.2 in males and females, respectively, and the infinite length was 37 cm in males and 49 cm in females. Male and female catch mortality is 8.4 and 5.4, while overall mortality is 10.8 and 7.3, respectively. The exploitation coefficient in both males and females was more than the allowed limit ($E \leq 0.5$), estimated to be 0.77 in males and 0.73 in females.

Spawning and reproduction

The spawning period of female shrimp is observed in five stages: immature, early maturing, late maturing, mature, and spent-recovering. These stages are observed in five species of commercial shrimp in Iranian waters. Studies have shown that all Persian Gulf shrimps have two spawning periods (Khorshidian, 2013; Niameymandi, 2015; Zarshenas, 2015). The Green tiger shrimp spawns in winter and early spring, while the Banana prawn spawns in spring.

Population distribution of the most important commercial shrimp species in Iran's aquaculture industry

The Green tiger shrimp (*P. semisulcatus*), also known as pink shrimp, is widely distributed in the western Indo-Pacific region, ranging from

the east coast of Africa to the Red Sea, Persian Gulf, India, Japan, Korea, Thailand, northern Australia, and the northern Mediterranean coast of Egypt, Palestine, and Syria. This species can be found in depths up to 120 meters, but it is more abundant in waters with a depth of less than 60 meters, particularly in mud, mud-sand, sand, or sand-pebble beds. Juvenile shrimps prefer estuary areas while adult shrimps live in the sea. This species requires saltwater with a high salinity range during its growth stage. (Table 3). The spawning season of White shrimp is in summer and autumn. Green tiger shrimp mainly spawns in the Bahrkan region, and some specimens also spawn near Bushehr waters. Banana prawn spawns in the waters of Hormozgan and shallow coastal areas. White and Kiddi shrimp spawn throughout the Iranian region of the Persian Gulf, and due to their wide distribution, they do not have a specific area for spawning. In general, all commercial species spawn in waters that are far from the coast, and the larvae that are on the surface are carried by sea currents along the coast and estuaries.

Table 3. Some biological characteristics of *Penaeus semisulcatus*

Scientific name	depth (meters)	salinity range (ppt)	preferred temperature (C°)	Carapace length of adult female (mm)	Carapace length of adult male (mm)	Source
Penaeus semisulcatus (De Haan 1844)	2 to 130	40-45	25-28	50.4	38	Dalirpour, 1997 Niameymandi, 2002

Movement and migration

Among the shrimp species in the Persian Gulf, only the migration of the Green tiger shrimp has been studied. The results of this research, which was conducted in the waters of Bushehr province, observed the movement of both males and females to far waters from the coast. This migration was generally in the direction of moving from coastal waters to deep waters (Niameymandi, 2014). The maximum distance traveled was 127 km in 95 days, although one sample of the marked shrimp had traveled only 20 km after 138 days. This shrimp was caught in the spawning area, and it confirms the theory that the Green tiger shrimp does not leave the waters of Iran at the maturity stage. Instead, it spends its life in the same place once it reaches a specific area for spawning. Most of the samples had moved about 20 kilometers. The movement direction of the marked and captured shrimps was from the southern region (Deir and Bushehr) to the northwest of the Persian Gulf (Bahrkan).

In general, research on other species that migrated in different regions of the world shows that this aquatic animal is less mobile. It has been reported that the Green tiger

shrimp has moved up to 100 meters in the waters of the Oman Sea. The maximum recorded distance for Banana prawn in the Papua Gulf was 190 km. Regarding other Persian Gulf species, no research has been conducted regarding their migration and movement characteristics (Matinfar *et al.*, 2012).

Habitats of juveniles

The habitats of juvenile shrimps in the Persian Gulf have been determined to some extent. Research conducted on Banana prawn in the waters of Hormozgan shows the accumulation of juveniles of this species on beaches and areas covered by mangrove trees, which are known as the nursery of this species. Fishermen catch Banana prawn juveniles in areas covered by mangrove trees (Ebrahimi, 2013; Staples *et al.*, 1985).

Regarding the Green tiger shrimp, research conducted in the waters of Bushehr province concluded that the nursery of this species is located in the vegetation, such as algae and seaweed. The accumulation of newborns, especially in areas that have certain species of seaweed, is reported in this research (Niameymandi, 2014). The protection of these areas, which are located on the coasts of the sea and are exposed to pollution, trawler fishing, and industrial development, has been emphasized.

The vegetation cover of the coastal areas has not been studied extensively, and the distribution and living mass of these areas are not completely known. However, the reduction of sea shrimp reserves can be partly attributed to the loss of this cover, which serves as a shelter and habitat for post-larvae to young shrimp of the two types of Banana prawn and Green tiger shrimp. This conclusion has also been made in Australian waters, where it has been reported that the reduction of coastal vegetation directly affects the sea shrimp stocks (Staples *et al.*, 1985). In the conclusions of the research conducted in Australian waters, the most important determining factor in the survival of the Green tiger shrimp has been mentioned as the seagrass cover (Jackson *et al.*, 2001).

Kiddi and White shrimp nurseries have also been identified in the waters of Bushehr province and Khuzestan province. In the waters of Bushehr province, White shrimp juveniles have been observed in ponds near the sea during low tide. In Khoor Mousa waters, the larvae of White, Kiddi, and Young White shrimps are commercially caught by fishermen in the streams branching from Khoor Mousa, which also leads to the reduction of sea reserves (Niameymandi, 1994; Mohsenizadeh and Nourinejad, 2000; Dehghan, 2007).

Population distribution of the most important commercial shrimp species in Iran's aquaculture industry

The Green tiger shrimp (*P. semisulcatus*), also known as Pink shrimp, is distributed in the western Indo-Pacific region, from the east coast of Africa to the Red Sea and the

Persian Gulf to India, Japan, Korea, Thailand, northern Australia, the northern Mediterranean coast of Egypt, Palestine, and Syria. It can be found from coastal waters to depths above 120 meters, but its abundance is greater in waters with a depth of less than 60 meters, primarily in mud, mud-sand, or sand-silt beds. Adults live in the sea, while juvenile shrimps live in estuary areas. This shrimp requires saltwater with a high salinity range during its growth stage (Table 3).

Banana prawn (*Penaeus merguensis)*:

The Banana prawn (*Penaeus merguensis*) belongs to the Penaeidae family and is distributed from East Asia, the Philippines to Sri Lanka and the coasts of India and Pakistan to the Persian Gulf (FAO, 1984). In Iran, it is known as banana or pink shrimp and is the most abundant among other shrimps in Hormozgan province. Its distribution depends on estuaries with mangrove vegetation, including estuaries in the east and west of Jask, Sirik Estuary, Kolahi and Tiab estuaries, Kolaghan and Khamir estuaries. This species can be found in depths of 10-45 meters, primarily in mud beds, estuary, and sea areas. Banana prawn is an important commercial species (Table 4) in the Persian Gulf and the coast of Pakistan (Momeni, 2014).

Table 4. Some biological characteristics of *Penaeus merguiensis*

Scientific name	Habitat	salinity range (ppt)	preferred temperature (C°)	Carapace length of adult female (mm)	Carapace length of adult male (mm)	Source
Penaeus merguiensis (De Man, 1888)	mud beds at a depth of 10-55 meters	20-30	30	24	19.5	Dalirpour, 2019

Black tiger shrimp (*Penaeus monodon)*

The species under discussion is widely distributed in the western Indo-Pacific region, ranging from east and southeast of Africa and Pakistan to Japan, south to Indonesia, and northern Australia. It is native to the Indian Ocean and the Southwest Pacific Ocean and is considered one of the Eurasian species. This species can be found in depths of 10 to 100 meters and beds up to 27 meters deep. Most adults live in the sea while juveniles reside in estuaries. This species is cultivated in many Asian countries due to its high growth rate under breeding conditions, where growth rates of up to 5.5 grams per week have been observed under suitable conditions. However, breeding this shrimp in captivity is difficult and survival rates are low (Table 5).

Table 5. Some biological characteristics of *Penaeus monodon*

Scientific name	Habitat	salinity range (ppt)	preferred temperature (C °)	Carapace length of adult female (mm)	Carapace length of adult male (mm)	Source
Penaeus monodon (Fabricius, 1798)	Sea shores and mangrove estuaries, waters down to about 160 m	5-35	26-33°C	47-81 mm	37-71 mm	Motoh, H., 1985

Indian white shrimp (*Fenneropenaeus indicus)*

The species under discussion is widely distributed in the West Indo-Pacific region, ranging from East and Southeast Africa to South China, Indonesia, New Guinea, North, and Northeast Australia. They mostly inhabit depths of 20 to 90 meters and prefer sandy or muddy beds. Adult shrimps reside in estuaries. This species can tolerate water of lower quality, higher salinity, and higher densities than many other species of cultured shrimps. It matures well in captivity, but its size is typically small when grown in culture (Table 6).

Table 6. Some biological characteristics of *Fenneropenaeus indicus*

Scientific name	Habitat	salinity range (ppt)	preferred temperature (C °)	Carapace length of adult female (mm)	Carapace length of adult male (mm)	Source
Fenneropenaeus indicus (H. Milne Edwards, 1837)	muddy and soft beds, up to a depth of 90 meters	5-50	18-34.5	27-35	28-34	Zarshenas *et al.*, 2007 FAO, 2023

Western white shrimp (*Litopenaeus vannamei)*

This species is primarily distributed in the eastern Pacific region, ranging from northern Mexico to southern and northern Peru. This shrimp is native to the American coast in the Pacific Ocean and is typically found in depths of less than 70 meters, particularly in mud beds. Juvenile shrimps reside in estuaries while adults inhabit the sea. Special features of this species include the ability to reproduce and breed in captivity, storage in small sizes, high and uniform growth rate, and relatively lower protein requirements in the diet compared to other cultured species (Table 7).

Table 7. Some biological characteristics of *Litopenaeus vannamei*

Scientific name	Habitat	salinity range (ppt)	preferred temperature (C)	Carapace length of adult female (mm)	Carapace length of adult male (mm)	Source
Litopenaeus vannamei (Boone, 1931)	mud beds up to 70 meters deep	10-40	30-34	28.7-65.8	23.8-65.9	Putra, D.F. *et al.*, 2018

Evaluation of the current status of stocks and genetic diversity of valuable shrimps in the aquaculture industry

In recent years, the global production of crustaceans has been increasing due to the growth of production volume and the diversification of cultivated species. The number of cultured aquatic species has increased from 9 in the 1950s to 62 in the last decade, with the highest number of cultured species belonging to marine shrimps, followed by freshwater crustaceans, crabs, lobsters, and other marine crustaceans (Abdolhay, 2015). In Iran, the imported Vannamei or Western Pacific shrimp is the main species currently cultivated in the shrimp industry, as it was introduced to revive the industry after an epidemic of white spot disease in the farms. The native Green tiger species (*P. semisulcatus*) was the first species used for shrimp breeding, followed by *P. monodon* and other species like *M. affinis* and *P. merguiensis*. However, due to slow growth, vulnerability to pathogenic factors, and high production costs, these species struggled to compete with other farmed shrimp in the country. The introduction of Vannamei shrimp by the Iranian Fisheries Sciences Research in 2005 aimed to increase species diversity and resulted in its acceptance by the producers, replacing Indian white shrimp since 2011 (Matin Far, 2012). Meanwhile, the situation of shrimp fishing and exploitation in the Persian Gulf and the Oman Sea highlights the need for fundamental management to prevent stock reduction, as increasing exploitation is not feasible.

Green tiger shrimp

Breeding of marine shrimps in Iran began in 1984 at the Bushehr Shrimp Research Institute using the green tiger shrimp species. In subsequent years, this species was experimentally bred in some provinces of the country, including Bushehr, Hormozgan, Mazandaran, and Golestan, as one of the suitable representatives for the development program of shrimp breeding in Iran. However, in breeding conditions, this species did not exhibit similar growth and compressibility to other marine shrimps such as Monodon, Indian White shrimp, and Vannamei. Consequently, it is not currently included in Iran's commercial shrimp aquaculture production cycle (Matinfar, 1992).

Indian white shrimp

Reproduction and cultivation of shrimp are remarkable capacit7ies of this species. Its natural distribution is in the waters of eastern Hormozgan province, especially the Jask region. Prior to the introduction of Vannamei shrimp, Indian white shrimp was considered the most important cultured species in Iran and was gradually introduced to the country's shrimp industry in 1997. However, currently, this species does not have a share in Iran's shrimp breeding industry (Matinfar, 2019).

Banana prawn and white shrimp

This species is distributed in the waters of Hormozgan province, with the majority being found in Khuzestan. Despite attempts to reproduce and cultivate them, these species have not been successfully integrated into Iran's aquaculture cycle (Matinfar, 2011).

Western white shrimp

The most prominent non-native species that constitutes the majority of Iran's shrimp production is the western white shrimp (*P. vannamei*). Following significant losses in the shrimp industry due to frostbite in 2001, the occurrence of white spot disease in 2002 at the Choebdeh shrimp breeding site in Abadan, and the slow growth of Indian white shrimp, the Iranian Fisheries Science Research Institute imported 80 pairs of Vannamei shrimp pre-breeders in 2004 and an additional 110 pairs in 2005 from America. Success in post-larvae reproduction in subsequent years and successful breeding in the institute's research farm in 2014, coupled with significant losses in other breeding farms, paved the way for the introduction of Vannamei shrimp as an alternative breeding species. Since then, Vannamei shrimp has become the main and only farmed shrimp species in the country (Matinfar *et al.*, 2009).

The state of the country's different shrimp stocks in terms of genetics

In recent years, several studies have been conducted on the genetic indices of different shrimp stocks in the Persian Gulf and the Sea of Oman. Most of these studies have focused on different regional populations and have aimed to compare the genetic indices of these groups to identify possible separate populations.

Niameymandi et al. (2010) used the RAPD method to study the populations of green tiger shrimp in Bushehr waters in the Persian Gulf, and the results indicated a low level of genetic diversity in 85.2% of the studied sites. The recorded band patterns showed monomorphism, indicating high homogeneity of individuals in the studied populations. The possible reason for this similarity was attributed to the release programs carried out in the waters of Bushehr, which involved a small number of breeders and limited crosses to produce a large number of post-larvae and their release. To protect the genetic diversity of the populations, the researchers proposed releasing according to each region and using breeders from the same regions.

Tamdaonijahormi et al. (2012) studied the populations of two shrimp species, banana shrimp (*P. merguensis*) and Indian white shrimp (*Penaeus indicus*), to maintain genetic diversity and introduce possible genotypes in the main fishing areas. Investigations using 8 pairs of microsatellite primers showed that the amount of observed heterozygosity was lower than the expected heterozygosity in the two species due to reasons such as interbreeding, genetic drift, overfishing, loss of habitats, and reduced adaptation to various environmental conditions due to stress on the population. The population of banana shrimp in the Gowatr region was found to be more differentiated than the other two regions, Jask and Hormuz, due to factors such as sea currents, eddy currents in the Gulf of Oman, brood movement during spawning, and the presence of dense mangrove forests.

Rezvani Gilkolaei et al. (2015) investigated six shrimp species from the waters of the Persian Gulf and the Sea of Oman using the COI gene locus to obtain information about their classification and morphology. The method was able to separate individuals of each species and determine their affinity.

In another study, Tamdani Jahormi et al. (2015) identified the genetic structure of five important shrimp species of the Persian Gulf region using the 16SrRNA and COI gene loci and compared the resulting information with the World Gene Bank (NCBI) database. Mitochondrial DNA analyses showed genetic divergence among different species, and the researchers proposed creating a gene bank of native shrimps and crustaceans of the Persian Gulf and Oman Sea to organize the structure and focus management on genetic resources.

Amini and Mansouri (2008) conducted a karyological study on banana shrimp in the Persian Gulf region, preparing cell extensions from different life stages of shrimp and using different tissues to determine the norm of preparation of chromosomal extension for this species. The researchers obtained the formula 2n=88 and N=44 in haploid testis cells.

The results of studies conducted on the examined species indicate that currently, Vannamei shrimp is the dominant competitor in breeding farms in the brackish water area. While the reliance of the country's shrimp industry on Vannamei shrimp is a positive point, it should not be overlooked that the species is non-indigenous, and imported producers have limitations in providing a sufficient range of genetic diversity necessary to produce healthy and high-efficiency offspring. Therefore, it is crucial to establish a breeding and genetic management program for Vannamei shrimp to ensure biological safety in production. Fortunately, the first steps of this path have been taken in recent years at the country's shrimp research institute in Bushehr. To provide a confidence interval in terms of species diversity in the country's

shrimp industry, focusing on local species with high production potential and implementing new approaches to health issues, as well as breeding programs to produce lines resistant to disease, can be a far-sighted solution for the sustainability of the shrimp farming industry. Among the indigenous species of the country, Indian white shrimp appears to be a suitable candidate for this purpose, given its production history in the country before the entry of Vannamei shrimp into the production cycle.

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