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Content

GENETIC ASPECTS OF BETA-THALASEMIA DISEASE IN THE POPULATION OF AZERBAIJAN

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Abstract: Beta-thalassemia represents an inherited blood disorder typified by diminished hemoglobin production, the vital protein facilitating oxygen transport in red blood cells. This condition arises from mutations within the beta-globin gene, culminating in a spectrum of clinical presentations, spanning from mild anemia to grave, life-threatening complications. Particularly prevalent in regions characterized by high rates of consanguineous unions, such as Azerbaijan, beta-thalassemia poses a significant public health concern. This article delves into the genetic dimensions of beta-thalassemia within the Azerbaijani populace, exploring its prevalence, molecular genetic underpinnings, and endeavors in genetic counseling aimed at mitigating its impact.
Keywords: thalassemia, hemoglobin, disease, genetics, blood cells

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İntroduction:

Beta-thalassemia is prevalent across various global regions, particularly in areas where consanguineous unions are frequent. Azerbaijan, situated in the South Caucasus region, exhibits a relatively elevated rate of consanguinity, consequently heightening the prevalence of beta-thalassemia within its population.

Although the precise prevalence of beta-thalassemia in Azerbaijan lacks sufficient documentation, it is deemed relatively high. Estimates suggest a carrier frequency of beta-thalassemia in Azerbaijan ranging from 5% to 8%, implying a substantial portion of the populace carries a single mutated beta-globin gene without manifesting symptoms of the ailment. Pinpointing the exact count of individuals with beta-thalassemia major, the most severe manifestation of the disorder, proves challenging due to data limitations and scarcity.

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Table 1. Prevalence of β-thalassemia and HbS in the regions of the Republic of Azerbaijan

Regions	Number of examinees	β-thalassemia frequency, %	Frequency of HbS, %
Ağdaş	581	0.0751	0.0013
Ağsu	411	0.0385	0.0019
Astara	502	0.0393	0.0016
Babək	418	0.0423	0.0035
Qəbələ	847	0.0841	0.0173
Gədəbəy	540	0.0043	0
Göyçay	330	0.0415	0.0023

Xanlar	421	0.0338	0
Xaçmaz	599	0.0291	0.0089
Xınalıq	365	0	0
İmişli	319	0.0425	0
Culfa	77	0.0455	0
Qazax	288	0.0550	0
Quba	555	0.0322	0.0015
Qusar	394	0.0261	0.0019
Laçın	122	0	0
Lerik	103	0.0149	0
Oğuz	338	0.0580	0.0080
Ordubad	152	0.0526	0
Sabirabad	263	0.0645	0
Sədərək	271	0.0429	0.0031
Şahbuz	75	0.0208	0.0208
Şəki	473	0.0559	0.0017
Tərtər	217	0.0333	0
Ucar	463	0.0515	0.0083
Zaqatala	420	0.0336	0
Total	9552	0.0433	0.0040

Source: Akhundova A. Thalassemia in Azerbaijan SSR (prevalence, clinic, treatment). Problems of Hematology 1965;7:10–8.

One of the primary reasons for the elevated prevalence of beta-thalassemia in Azerbaijan is consanguineous marriages, wherein individuals marry close relatives, such as cousins. Consanguinity heightens the probability that both partners will bear the same mutated beta-globin gene, consequently raising the risk of producing affected offspring. Estimates suggest that more than half of all marriages in Azerbaijan involve some degree of consanguinity, thereby substantially augmenting the prevalence of beta-thalassemia within the population.

Beta-thalassemia constitutes a genetically heterogeneous disorder triggered by mutations in the HBB gene, responsible for encoding the beta-globin subunit of hemoglobin. These mutations may yield diminished or absent production of functional beta-globin chains, thereby inducing aberrant hemoglobin synthesis and manifesting clinical symptoms of the disease.

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Various mutations in the HBB gene can precipitate beta-thalassemia, categorized broadly into two main groups [3. s,102].

These mutations directly impact the synthesis of beta-globin chains, leading to diminished or absent beta-globin production. They can be categorized into two main groups:

a) Beta-thalassemia major (β0-thalassemia): This severe form of the disease results in a complete absence of beta-globin production.

b) Beta-Thalassemia Intermedia (β+-thalassemia): This less severe form of the disease is characterized by reduced, but not absent, beta-globin production.

These mutations cause reduced beta-globin production but do not induce the severe clinical manifestations observed in beta-thalassemia major or intermedia. Individuals with beta-thalassemia trait are carriers of one mutated beta-globin gene and one normal gene

Table 2: Common β-thalassemia Mutations in Azerbaijan

Mutation	Frequency in Azerbaijan

IVS-I-1 (G->A)	High
IVS-I-110 (G->A)	Medium
CD 39 (C->T)	Medium
IVS-II-1 (G->A)	Low
CD 8/9 (+G)	Low

Source: Guliyev AM, Rasulov IM, Dadashova T, Schwarz EI, Rosatelli C, Saba L, Meloni A, Gemidjioglu E, Petrou M, Modell B. Thalassemia in Azerbaijan. J Med Genet. 1994; 31 :209–212. [PMC free article] [PubMed] [Google Scholar]

The molecular mechanisms underlying beta-thalassemia are diverse and may involve various genetic alterations, including point mutations, deletions, and insertions in the HBB gene. These mutations disrupt normal splicing, transcription, or translation of the beta-globin gene, resulting in a deficiency of functional beta-globin chains.

The HBB gene exhibits allelic diversity, with hundreds of different mutations identified worldwide. Several common beta-thalassemia mutations (IVS-I-5 (G>C), IVS-I-110 (G>A), and IVS-I-1 (G>T)) have been documented in the Azerbaijani population. These mutations are associated with varying degrees of disease severity and can cause beta-thalassemia major or intermedia.

Given the high prevalence of beta-thalassemia and the potential for serious health consequences, genetic counseling and carrier screening programs have been initiated in Azerbaijan to reduce the incidence of affected individuals and support affected families.

Genetic counseling plays a crucial role in beta-thalassemia management in Azerbaijan. Genetic counselors collaborate with couples at risk of having a child with beta-thalassemia to provide information, assess genetic risk, and discuss reproductive options. Couples carrying both beta-thalassemia traits can choose from various options, including prenatal diagnosis and preimplantation genetic diagnosis (PGD), to have a healthy child without the disease [1. s,34].

Carrier screening programs aim to identify individuals who carry a single mutated beta-globin gene, enabling them to make informed reproductive decisions. These programs have been implemented targeting both related and unrelated couples in Azerbaijan. Screening typically involves blood tests to identify carriers of beta-thalassemia traits. Education and awareness campaigns have also been launched to inform the public about the importance of carrier screening, especially before marriage [4. s,229].

For couples at known risk of having a child with beta-thalassemia, prenatal diagnosis is an option. Prenatal tests such as chorionic villus sampling (CVS) or amniocentesis can detect the presence of beta-thalassemia in the fetus. Couples diagnosed with prenatal beta-thalassemia in the fetus can then make informed decisions about continuing the pregnancy or consider treatment options [6. s,12-16].

In cases where both partners are carriers of the beta-thalassemia trait, preimplantation genetic diagnosis (PGD) offers the option to select unaffected embryos for implantation during in vitro fertilization (IVF). This technique enables couples to have a child free from beta-thalassemia.

Despite efforts to combat beta-thalassemia in Azerbaijan, several challenges persist, necessitating ongoing initiatives to further diminish the prevalence and impact of the disease.

Cultural norms and traditions such as consanguineous marriage can pose difficulties in terms of change. To address this issue, public health campaigns and educational programs must continue to raise awareness of the risks associated with beta-thalassemia and promote the benefits of genetic counseling and carrier screening.

Improving access to health services, including genetic testing and counseling, is crucial, particularly in rural areas. Making these services widely accessible and affordable can help reach a broader population.

Advancements in research and treatment options for beta-thalassemia, such as gene therapy and stem cell transplants, provide hope for those affected. Continued investment in research and the development of new treatments can enhance the quality of life for individuals with beta-thalassemia.

Beta-thalassemia poses a significant health challenge in Azerbaijan due to a combination of genetic factors, including a high carrier frequency and consanguineous marriages. Efforts to tackle this issue encompass genetic counseling, carrier screening, and reproductive options to diminish the incidence of affected individuals. While challenges persist, ongoing initiatives and research offer hope for a brighter future for individuals and families impacted by beta-thalassemia in Azerbaijan. By raising awareness, enhancing access to healthcare, and investing in research, Azerbaijan can make strides in combating this inherited blood disorder.

Beta-thalassemia is inherited in an autosomal recessive manner, meaning both parents must carry a copy of the mutated gene for a child to be affected. If both parents are carriers (each having one mutated gene), their children have:

25% chance of neither being affected nor carrying the mutation.

50% chance of being carriers like their parents.

25% chance of inheriting beta-thalassemia.

In some instances, individuals receive two different mutations of the HBB gene from each parent. This condition, known as compound heterozygosity, can lead to a diverse range of clinical manifestations depending on the combination of mutations.

In some instances, individuals inherit two different mutations of the HBB gene from each parent. This condition, known as compound heterozygosity, can lead to a wide range of clinical manifestations depending on the combination of mutations.

To comprehend the protein foundation of beta-thalassemia, investigating the structural and functional aspects of hemoglobin is crucial. Hemoglobin is a globular protein consisting of four polypeptide chains: two alpha-globin chains and two beta-globin chains. Each globin chain is associated with a heme group containing iron, which binds to oxygen. The binding of oxygen to heme groups is vital for transporting oxygen from the lungs to tissues and organs.

In individuals with beta-thalassemia, mutations in the HBB gene disrupt the production of functional beta-globin chains. This disruption can occur at different levels. Consequently, there is an imbalance between alpha-globin and beta-globin chains, resulting in various structural and functional abnormalities in hemoglobin and red blood cells.

The hemoglobin molecule comprises two components: heme and globin. In a healthy individual, the globin protein consists of two pairs of polypeptide chains. Within the erythrocytes of an adult, there are three distinct types of hemoglobin based on their polypeptide chains:

1. Hemoglobin A: The globin component comprises 2 alpha and 2 beta polypeptide chains, constituting 96-98% of total hemoglobin.

2. Hemoglobin F: The globin component comprises 2 alpha and 2 gamma polypeptide chains, representing less than 1% of total hemoglobin.

3. Hemoglobin A2: The globin portion comprises 2 alpha and 2 delta polypeptide chains, accounting for less than 2-3% of total hemoglobin.

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CHARACTERIZATION OF THE GENETIC SIGNIFICANCE OF BIRD SPECIES WINTERING IN THE CASPIAN SEA

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Abstract: The Caspian Sea represents a critical aquatic ecosystem, serving as a significant migratory corridor and wintering habitat for numerous avian species throughout the year. The taxonomic diversity of bird populations wintering along the Caspian coastline, their physiological adaptations, and resilience to climatic fluctuations have garnered considerable scientific interest. Genetic diversity is a fundamental determinant in evolutionary selection and ecological adaptation mechanisms. Molecular analyses of the DNA of avian species overwintering in the Caspian region reveal a remarkably high degree of genetic variation. This genetic heterogeneity plays a pivotal role in facilitating adaptation to diverse climatic conditions and enhancing ecological plasticity. This study aims to investigate the genetic diversity of wintering bird species in the Caspian Sea region and assess the genetic significance of molecular markers in avian population dynamics.
Keywords: birds, genetic diversity, DNA, molecular markers, SSR, ISSR

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Introduction:

The class *Aves* originated approximately 80–100 million years ago, undergoing extensive evolutionary diversification. The high basal metabolic rate of birds, coupled with the locomotor versatility of many species-enabling both flight and aquatic adaptation-has facilitated their extensive biogeographical distribution. Avian species exhibit pronounced migratory behavior in response to adverse climatic conditions, allowing them to exploit seasonally favorable habitats for survival and reproduction. (I. Babayev, F. Asgarov, F. Ahmadov, *Biological Diversity: Waterfowl of the Azerbaijani Part of the Caspian*).

The Caspian Sea represents the largest enclosed inland water body globally, bordered by Russia, Kazakhstan, Turkmenistan, Iran, and Azerbaijan. This distinctive hydrological basin is characterized by both marine and lacustrine features, with its ecological system being influenced by factors such as salinity gradients, climatic conditions, and adjacent terrestrial biomes. Spanning an area of approximately 371,000 square kilometers, the Caspian Sea reaches depths exceeding 1,000 meters in certain regions. Its endorheic nature—lacking a natural outflow—results in variable salinity levels, which play a crucial role in shaping the basin's biological diversity (Kosarev & Yablonskaya, 1994).

The Caspian Sea is a vestige of the ancient Paratethys Sea, and its distinctive hydrochemical properties have facilitated the evolutionary processes of various endemic species. The water salinity exhibits a significant gradient, transitioning from nearly freshwater conditions in the northern regions to more saline waters in the central and southern areas. These dynamic salinity variations regulate the distribution and abundance of aquatic organisms, thereby influencing the ecological dynamics and foraging behaviors of

avian species that depend on this ecosystem (Zonn et al., 2010).

The climate surrounding the Caspian Sea exhibits a gradient from temperate to arid, with winter temperatures being comparatively milder than those at higher latitudes. The wetlands, deltas, and shallow coastal zones are ecologically rich, providing abundant food resources such as fish, mollusks, and plant matter. These ecological conditions facilitate foraging, resting, and nesting for numerous avian species. Notably, the extensive reed beds and wetlands in the Volga Delta and other coastal regions serve as critical refuges for migratory birds, offering shelter from both predation and adverse climatic conditions (Cramp & Simmons, 1977).

Wintering Bird Species of the Caspian Sea:

Wintering birds are migratory species that relocate to more temperate regions during the winter months to avoid extreme climatic conditions and food shortages in their breeding habitats. The primary objective of these birds is to mitigate the challenges posed by adverse environmental factors, such as low temperatures and limited food availability, thereby enhancing their chances of survival during harsh seasonal conditions (Greenlight Environmental Consultancy LTD).

The wintering period for bird species begins in October and lasts until March (www.arthian.com). In Azerbaijan, however, the arrival of birds migrating to the Caspian Sea coast for wintering coincides with the month of January.

A number of avian species utilize the Caspian Sea as a wintering habitat. The most frequently observed species in this region include the following:

Dalmatian Pelican (*Pelecanus crispus*) – This large pelagic bird species is characterized by its distinctive curved cervical plumage and a pronounced preference for wetland ecosystems. It primarily exhibits piscivorous feeding behavior, foraging in shallow aquatic environments. Dalmatian pelicans are highly social, forming small, cohesive colonies and typically establishing nests in floating macrophytes or on remote islands. The loss of suitable habitat, primarily due to anthropogenic influences, has resulted in a significant decline in their population, highlighting the necessity for targeted conservation strategies to prevent further population decline (BirdLife International, 2018).

Common Pochard (*Aythya ferina*) – This diving duck species is frequently encountered in the shallow waters of the Caspian Sea. It preferentially inhabits freshwater lakes, wetlands, and estuarine areas with abundant aquatic vegetation. Males are distinguishable by their chestnut-colored head and red eyes, while females exhibit a more cryptic coloration. In terms of foraging, *Aythya ferina* is omnivorous, consuming a diet consisting primarily of plant material, small invertebrates, and seeds, thus demonstrating ecological plasticity and the ability to adapt to varying environmental conditions (Fox et al., 2016).

Greater Flamingo (*Phoenicopterus roseus*) – This species is primarily observed in the southern parts of the Caspian Sea and feeds predominantly on small invertebrates and algae. It employs a specialized filter-feeding mechanism using its bill, enabling it to extract food from shallow waters, a process facilitated by its elongated legs and neck. *Phoenicopterus roseus* forms large colonies, which provide enhanced protection from predators. The species' characteristic pink coloration is derived from carotenoid pigments, which are bioaccumulated through its diet, particularly from crustaceans and plankton (Johnson & Cézilly, 2007).

Red-breasted Goose (*Branta ruficollis*) – This critically endangered species utilizes the Caspian Sea as a primary wintering site. It is characterized by its distinctive plumage, which includes red, black, and white patterns. The species primarily feeds on grasses, roots, and seeds, foraging in coastal meadows and wetland habitats. Habitat degradation and climate change have significantly impacted its population dynamics, necessitating the implementation of conservation strategies to ensure its persistence

(Wetlands International, 2019).

Percentage distribution of wintering bird species

Azerbaijan, due to its diverse regional characteristics, serves as an advantageous site for studying the distribution of Caucasian endemics. It is also a critical location for monitoring avian migration patterns. In particular, the Beşbarmaq Mountain gorge offers a vantage point for observing migratory bird species. Along the coastline, the Kura Delta and the extensive lagoons of Qızılağac provide wintering grounds for various bird species, with a notable concentration of waterfowl, making these areas of significant ornithological interest (Ornithological Society of the Middle East, the Caucasus, and Central Asia).

In the 2022 winter bird census conducted in Azerbaijan, a total of 820,086 individuals from 118 species were recorded. Subsequent research on January 25, 2023, indicated an increase to approximately 960,000 individuals across 157 species. A significant proportion of the recorded avifauna consists of Anatidae, which represent 76% of the total count. Within this group, 51% are dabbling ducks, 5% remain unidentified, and 20% are diving ducks. Among the species, *Anas penelope* (Wigeon) dominates with 20% of the total, followed by *Anas crecca* (Common Teal) at 14%, and *Aythya ferina* (Pochard) at 3%. The census data reveals that 95% of the recorded birds are waterfowl, 35% are grassland species, 2.3% are flamingos, and 0.3% are cormorants (Sultanov et al., 2023).

Nine species have been included in the IUCN Red List and the Red Book of the Republic of Azerbaijan. The smallest species in Group I include the bustards (*Otis tarda*) with 29,770 individuals, the black-tailed godwit (*Limosa limosa*) with 370 individuals, the ferruginous duck (*Aythya nyroca*) with 353 individuals, and the Dalmatian pelican (*Pelecanus crispus*) with 347 individuals. In Group II, notable species include the flamingo (*Phoenicopterus roseus*) with 21,932 individuals, the mute swan (*Cygnus olor*) with 268 individuals, and tundra birds (*Calidris alpina*) with 190 individuals. In Gobustan National Park, the total number of bird species is approximately 0.5 million. Furthermore, 152,137 individuals were recorded in the Absheron National Park, with additional species counts observed in the Pirallahi Island aquatic zone. In the Alat and Gobustan bays, as well as Ağgöl AES, the bird populations ranged between 40,000-60,000 individuals, while approximately 30,000 individuals were recorded near the Baku Deepwater Jackets Plant, and more than 10,000 birds were reported in other regions, typically through monitoring via leased territories (Sultanov et al., 2023).

Materials and Methods

The diversity and abundance of bird species wintering in the Caspian Sea have garnered significant interest, not only from other countries but also from Azerbaijan. DNA analysis and genetic passporting of bird species play a pivotal role in understanding their systematics and phylogeny. The discovery of the DNA structure has heralded a new era in ornithology. The application of DNA analysis to determine the familial relationships and classification of avian species, as well as the specific role of genetic markers, is crucial for advancing the understanding of avian taxonomy and evolutionary processes (Wink, M. *DNA Analyses Have Revolutionized Studies on the Taxonomy and Evolution of Birds*).

The Role of SSR and ISSR Markers

Genetic markers are pivotal in genetic mapping, playing an essential role in identifying the loci of closely linked alleles on chromosomes (The Editors of Encyclopaedia Britannica, Article History). The application of molecular markers has expanded significantly in research due to their ability to localize quantitative trait loci (QTLs), which in turn facilitates the identification of genes, making them invaluable tools for genetic enhancement studies (SSR and ISSR markers in assessing genetic diversity in *Gallus gallus domesticus*: A quantitative analysis of scientific production).

SSR (Simple Sequence Repeats) and ISSR (Inter-Simple Sequence Repeats) markers are extensively employed in molecular genetics and genomics, offering comprehensive insights into the genetic diversity, population structure, phylogenetic relationships, and evolutionary processes of avian species (Zhan et al., 2010; Dawson et al., 2013). These markers are instrumental in evaluating both the quantitative and qualitative aspects of genetic variation, as well as in assessing gene flow and genetic differentiation driven by natural selection (O'Brien et al., 2006).

SSR markers consist of short tandem repeat sequences that are widely distributed within the genome, exhibit high mutation rates, and can be amplified using specific primers (Primmer et al., 2005). Their codominant inheritance model enables accurate genotyping of both heterozygous and homozygous individuals. The primary applications of SSR markers in genetic studies of avian populations include the following:

Analysis of population genetics and genetic structuring: SSR markers enable the assessment of genetic variation within and between populations, the calculation of genetic differentiation indices (such as Fst and AMOVA), and the evaluation of gene flow direction, providing valuable insights into the evolutionary dynamics of species (Küpper et al., 2012).

Evaluation of phylogenetic and evolutionary relationships: The high degree of polymorphism and extensive genomic distribution of SSR markers facilitate their application in reconstructing phylogenetic relationships within species and among closely related species. These markers provide valuable insights into evolutionary processes, genetic divergence, and the identification of distinct evolutionary lineages (Bensch & Åkesson, 2005).

Parentage analysis and kinship determination: SSR markers, characterized by a codominant inheritance model, facilitate the accurate genotyping of individuals, thereby providing a reliable method for investigating parent-offspring relationships and analyzing pedigree structures (Jensen et al., 2003).

Conservation genetics and protection of endangered species: Through the use of SSR markers, the assessment of genetic diversity loss, population bottlenecks, and inbreeding levels can be conducted, providing critical insights for the development of effective conservation strategies (Oyler-McCance et al., 2010).

ISSR markers amplify intermicrosatellite regions within the genome using primers based on non-specific simple sequence repeats (Bornet & Branchard, 2001). These markers exhibit a dominant inheritance model and serve as an efficient and cost-effective tool for analyzing genetic polymorphism. The applications of ISSR markers in avian species include:

Assessment of Genetic Variation and Population Structure: ISSR markers enable the quantification of genetic diversity indices (He, Na, Ne), facilitating the evaluation of genetic variation within and among populations (Hale et al., 2012).

Evolutionary and Phylogeographic Analyses: Through the examination of genetic clustering patterns and allele distribution, ISSR markers provide insights into avian evolutionary trajectories and migratory routes (Zink & Barrowclough, 2008).

Investigation of Hybridization and Speciation Processes: ISSR markers serve as a robust molecular tool for detecting hybrid individuals and assessing interspecific gene flow, thereby contributing to the elucidation of speciation mechanisms (Mosaad et al., 2019).

Leg Bands in Birds and Their Role in Scientific Research: Leg bands constitute a fundamental methodological approach in ornithological studies, facilitating biometric assessments and ecological analyses (Sutherland et al., 2004). When systematically applied, this technique serves as a critical tool in population dynamics research, conservation biology, and climate change modeling (Canadian Wildlife Service, 2018). Leg bands, also referred to as identification rings, represent one of the most extensively utilized marking techniques in avian research. This method enables the precise identification of individual birds, thereby contributing to longitudinal ecological and

behavioral investigations.

The selection of band material, design, and application strategy is contingent upon the target species, research objectives, and prevailing environmental conditions.

The primary classifications of leg bands are as follows:

Taxonomic and Structural Differentiation of Leg Bands: Metal leg bands are provided by national and international bird banding programs, with each band assigned a unique identification code for individual recognition (USGS Bird Banding Laboratory, 2020).

Stainless steel bands, which demonstrate high resistance to corrosion, are typically favored for long-term monitoring studies due to their durability (Bairlein, 2001).

Aluminum bands, characterized by their aerodynamic lightness, are predominantly utilized in smaller passerine species, offering minimal weight impact on the birds (Baillie & Peach, 1992).

Colored Plastic Bands: Colored plastic bands are encoded using various color combination systems to expedite the process of individual identification (Sutherland et al., 2004).

Composed of lightweight polymer composites, they are specifically designed for small to medium-sized avian species (Canadian Wildlife Service, 2018).

High-visibility spectral colors are employed to generate optical contrast, enhancing visual recognition (Newton, 2010).

Anodized or Protective Coated Metal Bands: These bands are fabricated using advanced anodization technology, which provides superior resistance to both chemical and mechanical abrasion (USGS Bird Banding Laboratory, 2020).

They are particularly suited for use in oceanic bird species and environments characterized by elevated salinity levels (Bairlein, 2001).

Biometrically Designed Locking and Pinning Bands: These bands are engineered with a specialized mechanical fixation mechanism to prevent detachment, especially in raptorial and large avian species with powerful beaks (Canadian Wildlife Service, 2018).

They are utilized in long-term monitoring protocols, with a design that minimizes the risk of unintended opening (Baillie & Peach, 1992).

Application of Leg Bands in Biometric and Ecological Analyses

Migration and Navigation Analysis: The recapture and observation of banded individuals enable the study of their migration trajectories, direction changes, and adaptation mechanisms in response to ecological barriers (Newton, 2010).

When combined with geo-mechanical tracking technologies, migration modifications related to ecotone boundaries and climatic changes can be analyzed with precision (Bairlein, 2001).

Demographic and Population Dynamics Studies: Long-term monitoring of banded individuals allows for the quantitative analysis of changes in population density, dispersion patterns, and mortality rates (Baillie & Peach, 1992). Reproductive success and generation growth rates can be accurately measured through the individual tracking of banded individuals (Sutherland et al., 2004).

Ecological and Ethological Studies: The color-coding systems of leg bands facilitate the identification of social structure, dominance hierarchies, and inter-individual interactions within bird flocks (Canadian Wildlife Service, 2018). Leg bands are applied as an effective visual marking method for studying mating strategies, territorial behaviors, and reproductive selection mechanisms (Newton, 2010).

Application of Leg Bands and Safety Standards. Methodology of the Banding Process: Birds are meticulously handled to minimize stress, with biometric measurements, including wing length, body mass, and tarsus size, recorded for subsequent analysis (USGS Bird Banding Laboratory, 2020).

The size of the band is selected according to the specific species to avoid any restriction in movement or potential tissue damage (Baillie & Peach, 1992).

The band is applied to the tarsus or metatarsus using specialized, certified banding tools to ensure secure placement and minimize

injury (Sutherland et al., 2004).

Potential Risks and Their Minimization

Band Loss or Deformation: Bands with inadequate durability may suffer mechanical damage or detachment, leading to the loss of valuable data (Bairlein, 2001).

Mechanical Injuries: Improperly sized bands may lead to tissue compression, resulting in hematomas or necrosis (USGS Bird Banding Laboratory, 2020).

Results and Discussion

The Caspian Sea serves as a critical wintering habitat for numerous avian species, providing essential resources such as food, shelter, and favorable climatic conditions. The genetic adaptations of these birds enable them to thrive in this environment, thereby underscoring the importance of implementing effective conservation strategies to ensure their long-term survival. Given the ongoing impacts of climate change and anthropogenic activities on the Caspian Sea ecosystem, investigating the genetic and ecological dimensions of wintering bird populations is crucial for their conservation.

SSR and ISSR markers represent powerful molecular tools for assessing genetic diversity, lineage relationships, ecological interactions, and selection processes in wildlife populations. SSR and ISSR markers play an integral role in avian genetic studies. The co-dominant inheritance pattern of SSR markers enhances their utility in precise genetic mapping, population structure analysis, and parentage determination (Garza & Freimer, 1996, Sevin Teoman Duran, Saltanat Aghayeva). In contrast, ISSR markers, which do not require genomic resources and function as dominant markers, are particularly advantageous for detecting widespread genetic polymorphisms, making them invaluable in phylogenetic and population genetic research (Bhargava; Fuentes, 2010). Thus, the selection of an appropriate marker type is contingent upon the specific objectives of the research, the desired accuracy, and the availability of resources.

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CASPIAN GOLDFISH (SALMONIDAE) MODERN SITUATION AND PERSPECTIVES OF AQUACULTURE

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Abstract: Declines in many fish species, including the critically important salmon, and declines in industrial fishing have been recorded. On the other hand, the change of habitat affects the biology of individual fish species formed over many years, it also causes changes in the biological indicators of populations. Currently, the fish stock in the Caspian, Kura, Araz rivers and other water bodies of Azerbaijan has decreased significantly, and it is natural that the population's demand for fresh fish meat is not met at the required level.
Keywords: Caspian Sea, Karabakh, pollution, salmon.

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Introduction:

Fish and seafood are an important ingredient in human nutrition. They have minerals such as calcium, calcium, magnesium, iron, phosphorus, and vitamins that are important to the human body. Despite the growing demand for fish products, while almost all countries are involved in fishing and fishing production, these resources are still being used improperly and highly unproductively. Referring to the more efficient use of fish and other products during the release of fish products, it is important not only to implement new technological production schemes and high-tech equipment but also to follow transportation, storage, fish food preparation regulations, etc. Therefore, the most important issue in the fish industry is to both acquire high-quality raw materials and fish products and to keep them without loss. Fish cultivation is the most common form of aquaculture. This usually involves commercial fishing in tanks, fish ponds or ocean covers for food. An object that releases juvenile fish into the wild for recreational purposes to increase the natural number of fish or species is generally called fish culture. The world's most important fish are fish, goldfish, tongues, and summer fish.

In the Mediterranean, a young blue tuna fish is netted at sea and slowly pulled towards the shore. They are later isolated in the sea pens where they are grown for the market (sometimes made from floating HDPE pipes). In 2009, Australian researchers were able to first get southern blue-faced orkinos to grow in tanks with no access to the sea. Southern blue-faced orkinos are also caught in the wild and are rooted in sea cages growing up in southern South Australia, Spencer Bay.

A similar process is used in the goldfish section of the industry; Underage people are taken from incubation facilities and used in a variety of ways to help them grow. For example, as mentioned earlier, goldfish can be grown with a cage system that is some of the most significant fish species in the industry. This is done by having net cages, better in open water with a strong current, and feeding the goldfish with a

special food mix that helps them grow. This process allows fish to grow year-round, thus producing higher yields during the right seasons. An additional technique, sometimes known as marine farming, has also been used within the industry. The marine farm refers to the fish being grown at an incubation plant in a short period of time and then released into seawater for further development, after which the fish are caught again once they mature.

Fishing in Azerbaijan:

In 1991 Azerbaijan's independence was rebuilt in the fishing sector, fishing, and aquaculture. This also serves as a resumption of water resources. Nevertheless, commercial aquaculture practices have developed since the 1980's.—Nadirov and others, 2013; Mohammadov and others, 2017.

Much of the fishing activity took place on the shores of the Caspian Sea, with the main objective of acquiring a sphere of sturgeon *species (Acipenseridae*), which in the early days appeared to have no impact on fish stocks. But the findings from the research have shown otherwise. Between 1935 and 1940, the number of fish in the country began to decline. As a result, stocks started to decline rapidly and began to decline somewhat after those dates. For example; Production of 4220 tons from 1931 to 1935, 4070 tons from 1936 to 1940, 1640 tons from 1941 to 1945, and 2,600 tons from 1946 to 1950. There are several reasons for this decline. These are:

(1) excessive fish and illegal, unknown or unregulated fishing;

(2) Failure to manage fish supplies;

(3) Deteriorating environmental conditions;

(4) Built on these migration routes of fish that migrate from the Caspian Sea to their natural growth.

All of this resulted in annual fishing from about 5,000 tonnes at the beginning of the 20th century to less than 108 tonnes in 1991. In addition to the species of noise, there are some species of *Cyprinidae* and *salmonidae* for Azerbaijani fishing in the Caspian Sea - Abdurrahmanov, 1966; Abbasov &Hajiyev 2001; 2013).

These stocks also showed a decline for the same reasons as illegal fishing. As a result, Acipenseridae, Cyprinidae, and Salmonidae amounted to 33,000 tons from 1931 to 1935, and some 1,570 tons from 1986 to 1990.

Until 1991, fishing activity in the inner waters was concentrated mainly in larger rivers (Aras and Cork rivers) and in reservoirs (Mingachir and Shamkir). Valuable fish species: *Cyrpinus carpio*, *Chalkalburnus chalkoides*, *Abramis brama* and *Sander lucioperca* (Abdurrahmanov, 1966; Abbasov &Hajiyev, 2001;).

In an effort to increase the hunting of these fish, various stocking programs have been developed in the Caspian Sea and inland waters. Millions of species of infant fish produced in 12 aquaculture have been released into water resources, but they have not succeeded. Since the late 1980's, they have been active in Azerbaijan to increase fish production. Until Azerbaijan's independence in 1991, 3 commercial lands was a major fishing activity. There were commercial fish farms in two lakes across the country. The main fish species grown on these farms are carp (*Cyprinidae*), others *Silurus glanis* and *Abramisbrama* (Nadirov and others, 2013); Mustafayev, 2015).

Potential for natural water supplies for fishing and aquaculture in Azerbaijan

From the north to the south, the Caspian Sea is some 1,200 miles (1,200 km) long and some 320 miles (320 km) across at its widest distance. Altogether, 6,500 km of coastline is 713 km in Azerbaijan. The water level in the Caspian Sea is 28 feet [28 m] below sea level and is about 50 large and small islands. There are 130 rivers of various sizes flowing into the sea. The average water level in the Caspian Sea has decreased by 190 feet [190 m] and the water depth has decreased by 3.2 m in the last 100 years. The salt is about 12 ‰. The Caspian Sea is known for its extensive variety of fish because of geographical, climate, and hydrological factors. Because of the large level of coastline in the sea, high primary production and therefore more fish production are caused by the excesses of nutrient mixtures. Five

countries bordering the Caspian Sea benefit from it in three ways:
1. The Xerxes Sea has great resources of natural oil and gas. These resources are extracted, exploited and exported;
(2) It is an important fishing area for species and spheres;
3. The Sea of Caspian; Along the Volga River, the Russian Federation has only one way to reach international waters along various water channels. -Axundov and others, 2013; Ibrahimov & Mustafayev, 2015.

Most of the physical, chemical, and biological parameters of the Caspian Sea have a distinctive characteristic. These parameters create high productivity for valuable fish such as roar species and goldfish. In the 1980 ' s, more than 90 percent of black balls and fish production were extracted from fish caught in the Caspian Sea. (Axundov and others, 2013; Nadirov and others, 2013.

Rivers: Araz and Kurd are the largest rivers in Azerbaijan. These areas are used for commercial fishing. There are some 8,000 large, small rivers and canals in Azerbaijan, some 3,000 of which flow directly into the Caspian Sea. The two largest rivers are Araz and Kurdish, which are more than 300 miles [500 km] long. Fishing is mainly concentrated in the Araz and Kurdish rivers. The Kura River forms in Turkey and flows through Georgia to Azerbaijan. The total length of the river is about 1515 miles [1515 km]. It is located some 906 miles [906 km] across at its borders. In addition to these two large rivers, Azerbaijan is 100 to 500 km long and 22 miles [51 to 100 km] long. There are 107 water sources that are 40 miles [40 km] long and 26 to 50 miles [26 to 50 km] long. The remaining water sources are less than 26 miles [26 km] long and form rivers that are larger. - Axundov and others, 2013.

Commercial fishing in Azerbaijan's rivers is mainly carried out in the Cork River. A significant portion of the fish caught in the cork river was migratory fish. There are many species of fish caught in the Kurdish world (Abdurrahmanov, 1966; Abbasov &Hadjiev, 2001; Ibrahimov &Mustafayev, 2015).

Lakes and reservoirs: The country's largest lake is Lake Sarajevo. There are more than 450 large and small natural lakes in Azerbaijan. The total area of all lakes in Azerbaijan is 394 square miles [394 sq km]. Lake Sarajevo is the only lake used for commercial fishing. There are more than 50 water tanks in Azerbaijan with various water volumes. Most reservoirs are used for irrigation and hydroelectric purposes in the country. There are currently only 2 reservoirs used for commercial fishing. These are the reservoirs of Mingxevir and Shamkir. The Sarajevo Water Reservoir, located on the Tartarus River, has been an important part of the past and has been used for fishing purposes. The Giantbatan water tank on the Absheron Peninsula is used as a drinking water tank for Baku and Sumatra. Therefore, fishing is not allowed to be used.—Quliyev, 2006.

Mingechevir and Shamkir are lakes with hydrobiological conditions that are ideal for fishing. Fish caught in these reservoirs are Abramis brama, Sander lucioperca, Rutiles rutiles, and Cyrpinus carpio (Axundov and others, 2013). Small reservoirs are too small for commercial fishing and serve recreational activities for sports fishing. Fish caught, on the other hand, are often used as food in local villages. Lake Sarajevo is the only lake that provides support for commercial fishing. But the annual catch rate from this lake is very low. Fish caught in this lake *include Esox lucius*, *Rutiles rutiles* , and *Cyrpinus carpio* (Axundov and others, 2013; Nadirov and others, 2013.

Work to be done:

The importance of scientific and technological advances in addressing ecological problems is essential to the development of an ecological worldview for the development of human relationships with nature. Every member of the community in which we live should recognize the environmental well-being. If the use of nature is not planned and efficient, manufacturing will damage the unity and integrity of nature. Environmental well-being is world-round, and all nations need to oversee the development of life. In our liberated areas, there is a very flexible environment for the

development of fishing, and if work is carried out, we are satisfied with the increase in fish in Cambodia after 2-3 years. The water of rivers in our other regions is declining because of the season. However, rivers in the region of Canaan are abundant. Because the rivers contain abundant, oxygen-rich and cool water, there is a flexible environment for increasing goldfish and other fish species. To prevent the decline in fish production in Azerbaijan year after year, the fishing potential of the occupied territories should have been developed. To that end, studies in areas liberated from invasion also show that fishing can indeed be developed at a high level in those areas. Except for the archery. Oxchuchai is a river that comes from Armenia and is most polluted. But other major rivers can increase as much fish as possible because they are abundantly watery year-round. The Ministry of Ecology and Natural Resources had to release some fish babies into those rivers and continue the process in the future. Because those areas have been unsupervised for a long time, it is impossible to say what species of fish remain without research, but any species of fish that live in rivers can be increased.

The result:

First, referring to the experiences of Europe, Asia, Scandinavia, and other countries, the republic's demand for valuable fresh fish meat can be met at the right level. In this regard, businessmen and enthusiastic fishermen are offered to educate them by explaining that the area is very profitable.

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SPECIES OF THE DAPHNIA GENUS AND THEIR AQUACULTURE POTENTIAL IN LAKE AMIRJAN (BULBULA)

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Abstract
This study analyzes the species diversity of Cladocera in Lake Amirjan (Bulbula), located on the Absheron Peninsula, and evaluates their aquaculture potential. The research determined the diversity and abundance of Cladocera species in the lake, revealing that some species could serve as valuable resources for aquaculture. The findings indicate the presence of various Cladocera species, with *Daphnia pulex* being the dominant species in terms of both abundance and biomass. Additionally, the study examines the ecological role of these species, their impact on the lake ecosystem, and their relationship with ecological conditions. The results highlight the importance of Cladocera in maintaining biodiversity, supporting the trophic chain, and serving as a key food source for fish in the region. The high nutritional value and rapid reproductive capacity of certain Cladocera species make them well-suited for aquaculture. Furthermore, the study evaluates seasonal variations in species composition and the influence of anthropogenic factors on the lake ecosystem.
Keywords: Cladocera, Lake Amirjan, species diversity, aquaculture, anthropogenic impact

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Introduction:

There are about 250 lakes within the borders of the Republic of Azerbaijan and the majority of these lakes are small in terms of surface area. The lakes in the country are divided into three groups according to their location and origin of formation:

- Kur-Araz Plain Lakes
- Absheron Peninsula Lakes
- Mountain Lakes

There are about 150 lakes in the Absheron Peninsula. Only 6 of these lakes differ from the others in terms of surface area. Large lakes with a surface area of 1 to 13 km² are: Böyükşor, Masazır, Binəqədi, Kurdəxanı, Xoca-Həsən and Krasnoe lakes. These lakes belong to the group of relict (relict) lakes in terms of formation.

All lakes on the peninsula are salty. This is mainly due to the high content of sodium (Na^+) and chlorine (Cl-) ions in the water of these lakes. Many lakes in Absheron were used in the past as natural reservoirs for salt production. Until 1960, lake water levels dropped as temperatures rose, and some lakes could dry up completely. During cold periods, the water level would rise again. However, in the 21st century, especially with the rapid development of the oil industry and agricultural activities, the discharge of industrial and domestic wastewater into the lakes has increased, leading to serious pollution of the lake waters.

The lake ecosystem in Absheron is divided into three groups according to the salinity of the water:

- Saline lakes
- Hypersaline lakes

- Slightly saline lakes

Today, the number of saline and hypersaline lakes is smaller than the number of lightly saline lakes. These lakes also vary in depth. Therefore, although water levels decrease as temperatures rise in summer, these lakes do not dry up completely. Lake Amirjan (Bulbula) is one of the shallow water basins located in the centre of Absheron peninsula. Over time, this lake has become one of the saltwater lakes of Azerbaijan [1]. Located on the Absheron Peninsula, between the settlements of Bakyxanov and Izmirjan, at an altitude of 8 meters above sea level, this lake is one of the most important natural features of the region, notable for its ecological and hydrological characteristics. Like other lakes, in the past it was recognized as one of the saline lakes of the Absheron Peninsula.The area of the lake is about 3 km², the maximum depth is 4 meters and the average depth is 1.1 meters. Its water is slightly salty, with salinity ranging from 0.8-0.96% (8-9.6 ‰) in summer and 0.15-0.4% (1.5-4 ‰) in winter. The water level and other physicochemical properties of Lake Emircən vary depending on seasonal changes:

In summer, the water level of the lake decreases due to high evaporation rate, and salinity increases accordingly.

In winter, the water level rises and salinity decreases relatively due to increased precipitation and decreased evaporation.

Temperature values:

In summer: 28-33 °C in summer.

In winter: 6-7 °C in winter.

The amount of dissolved oxygen in the water is quite low - in the range of 6.5-9 mg/L. This is due to the high salinity level in the lake, which limits oxygen solubility.

pH value: The pH of the water ranges between 7.24-7.58.

The ecological balance of the lake is threatened by pollution and environmental pressures, especially from industrial activities. In this context, the protection of Lake Emircən is of great importance for the sustainability of the biodiversity and ecosystem integrity of the region.The lake is inhabited by various zooplankton organisms, including Cladocera. These small organisms are zooplankton organisms that play an important role in the biodiversity of the lake [4]. They act as the main link of the food chain and are considered as indicators of the ecological status of water bodies. Cladocera feed on bacteria, algae and debris and serve as food sources for fish and other predatory organisms, respectively. These creatures are the food objects of fish living in other lakes of the peninsula. Cladocerans are important live food found in seas and lakes. Due to their small size, they are used as live food in the later stages of fish development. In addition, omega-3 fatty acids, which are essential amino acids obtained from unsaturated fatty acids, which are important for the growth and development of fish, are also present in cladocera.

Since these crustaceans are resistant to a wide range of changes in abiotic factors, they can be found in almost all water bodies of the world. In recent years, the increase of ecological problems in the lake, especially in the modern era, has had a great impact on biodiversity. As a result of the intense ecological situation in Lake Amirjan, blue-green algae (cyanobacteria) intensively developed in spring and autumn seasons. Therefore, a decrease in the species composition of Cladocera living in the lake was observed. Thanks to this research study, it is important to investigate these organisms, to evaluate their effects on the ecosystem and to make some suggestions for determining the potential of aquaculture.

Main section:

In this chapter, the species composition and ecological importance of Cladocera in Lake Amirjan, located in the centre of Absheron Peninsula, were investigated. Three species and one subspecies of Cladocera were recorded in Lake Amirjan [2,3]. The main habitat of *D. Pulex*, one of the species recorded here, is plant-rich water layers. In the lake, *D. pulex* species dominate in spring (March-April) and *D. magna* species dominate in May. In June, there is an increase in warm species. Cladocera reach their maximum amount in the lake in late spring and early summer. However, the number of crabs starts to decrease as a result of the increase in temperature in July-August in the summer

season. In autumn (September), as a result of the temperature drop, the most favourable conditions for the development of cladocerans are created. The main plankton composition in autumn is formed due to Cladocera - *D.magna, D.Pulex, D.middendorfiana* [6]. In 2013, the annual average number of cladocera in Lake Amirjan was 738 individuals/m3. In April, a large part of the number of crabs consists of their larvae (nauplii). The period from the end of May to the beginning of July is considered to be the peak period of cladocera development [3].

1.Daphnia Pulex [14]. *2.Daphnia Magna [15].* *3.Daphnia middendorfiana [16]*

In 2014, the annual average number of cladocera was 3500 individuals/m3. The number decreased in April and October and reached a maximum in June. The total number in spring and early summer was due to nauplii and metanauplii. In both years, *D. pulex* was the dominant species among the cladocera in Lake Amirjan (Bulbula). The main biomass producing species was *D. magna* [3].

In 2015, the average annual number of cladocera was 4900 individuals/m3 [6]. In the winter season, 15 individuals were studied and this was due to the low temperature in the water basin. With the increase in temperature, the number of cladocera increased to 9820 individuals/m3 in spring. A high increase in cancer development was recorded in May [2,3].

According to the results of the research, the highest diversity of cladocera species in Lake Amirjan was recorded in April-May. Among the dominant species, species belonging to the genera *Daphnia magna and Daphnia pulex* were found. The number of cladocera increased in spring and summer due to high temperatures and abundance of food sources. According to the seasonal changes, the number of cladocera increased significantly in spring (April-May) due to the proliferation of phytoplankton, while the decrease of some species in summer (July-August) was attributed to high temperature and oxygen depletion. However, anthropogenic impacts (pollution, discharge of waste (domestic) water and decrease in water level) caused a decrease in the number of some species. As a result of these effects, the population of more sensitive species has decreased and tolerant species have become dominant. The high nutritional value and rapid reproduction of some cladocera species make them suitable for aquaculture. Especially *D. magna and D. pulex* (water flea) species recorded in Lake Amirjan are considered as an ideal source of live feed for fish nauplii, metanauplii and fry. The presence of natural populations of these species in Lake Amirjan in the peninsula creates potential for their utilisation in aquaculture [6].

Materials and Methods:

The research work was carried out in the laboratory of Western Caspian University in spring and summer. In the spring season, samples were collected from different depths and coastal areas of the lake using a plankton

net. Samples were taken from each point twice a month. The collection and processing of materials was carried out in 2 stages: 1st stage samples were collected and 2nd stage samples were analysed in the laboratory. The collected samples were fixed in 4% formalin or 70% alcohol and analysed in the laboratory to determine the species composition and abundance of cladocera. The study of species composition was mainly carried out using a binocular microscope. Samples were added in pieces to a Petri dish and analysed under a microscope. In this way, species composition and morphology were analysed based on specific reference books. Standard plankton analysis methodology was applied to calculate the quantity. At that time, various instruments designed for plankton were in use. Quantification was carried out under a microscope. Bogorov camera was used for counting. Mathematical analysis formulas were used for statistical processing and comparison of the data, seasonal variations and correlation between species were analysed.

Results and Discussions:

The high species diversity of cladocerans in Lake Amirjan (Bulbula) confirms their importance for this ecosystem. The highest amount of *D. pulex* cancer was recorded from the beginning of April to the end of June. It was determined that they play an important role in preserving biodiversity and maintaining ecological balance. Species such as *D. pulex and D. magna* were found to be potential resources for aquaculture. Anthropogenic impacts were found to have a negative impact on species diversity and cause species decline. . It is therefore recommended that appropriate environmental measures be taken to ensure the conservation of the Lake Amirjan ecosystem. One of my recommendations is to conserve the species in Lake Amirjan, where *D. pulex* grows intensively, and to organise its use as a main resource for crab farming.

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BİOLOGY AND ECONOMİC POTENTİAL OF *ARTEMİA SALİNA* İN EXTREMELY SALİNE ECOSYSTEMS

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Abstract: Extreme saline ecosystems are water bodies formed under the influence of climatic and geological conditions, characterized by high salinity and unique physico-chemical properties. In these environments, the *"Artemia salina"* brine shrimp adapts to harsh conditions through its adaptation mechanisms. In addition to maintaining the balance of the ecosystem, the *"Artemia salina"* brine shrimp holds significant economic value as live feed in the aquaculture sector. Its remarkable ability to withstand fluctuations in temperature, salinity, and oxygen levels makes it exceptionally suited for survival in extreme environments. Due to its high resilience and nutritional profile, *Artemia* is widely used in marine hatcheries across the globe. Its role in supporting early larval development of commercial fish species underscores its importance in sustainable aquaculture. This article provides an in-depth exploration of the various functions of ecosystems and the biological adaptations of the *"Artemia salina"* brine shrimp.
Keywords: *"Artemia salina",* aquaculture, breeding, hypersaline environments.

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İntroduction:

Extreme saline ecosystems are water bodies with high salinity and unique physicochemical properties, formed by the influence of climatic and geological conditions. In these environments, the brine shrimp *Artemia salina* adapts to harsh conditions thanks to its adaptive mechanisms. In addition to ensuring the balance of the ecosystem, *Artemia salina* has great economic value as live feed in the aquaculture sector. This article provides an in-depth study of the various functions of ecosystems and the biological adaptations of *Artemia salina* in general.

Zoogeographic Distribution of Artemia Salina Crustacean:

Artemia, also known as brine shrimp, are small *crustaceans* that live in high-salinity environments worldwide. Their unique morphological and biological properties, especially their potential applications in the treatment of cancer, have made them the focus of extensive scientific research. Since the 1930s, newly hatched *Artemia* nauplii (larvae) have become the most widely used live food source in fish and shrimp farms worldwide, as they play an important role in the development of marine fish larvae.

These *crustaceans,* which belong to the genus *Artemia,* are capable of both sexual and asexual reproduction. Sexual reproduction occurs when males and females mate, while asexual reproduction occurs when females fertilize eggs without the participation of males in parthenogenetic populations. In both modes of reproduction, *Artemia* can reproduce either ovoviviparously or oviparously, depending on environmental conditions. Under favorable conditions, females produce thin-shelled eggs, which develop fully within the uterus and are

born as nauplii larvae. Under unfavorable conditions, females produce thick-shelled resting eggs (cysts). These cysts can float on the surface of the water, be carried ashore by wind and waves, and survive for long periods of time as long as they remain dry (Bossier & Sorgeloos, 2020).

Figure 1. Brine shrimp *"Artemia salina"*

Artemia crustaceans have a distinctive morphology adapted to their saltwater habitats. Adults are approximately 15 mm long and have a segmented body divided into three main parts: the head, thorax, and abdomen (Lee & Nam, 2019):

• Head: Contains a pair of compound eyes, a middle eye (nauplii eye), and a pair of antennae. The compound eyes provide a wide field of vision, while the middle eye plays a role in phototaxis. The antennae help them sense movement and their surroundings.

• Thorax: Consisting of the second through eighth segments, this segment has paired appendages called thoracopods. These appendages are used for filter feeding and serve to capture microscopic algae, bacteria, and organic debris from the water.

• Abdomen: Consisting of the ninth through eleventh segments, it ends in a forked tail called the furca. The abdomen is involved in locomotion and the furca helps it move quickly through the water.

In terms of internal structure, *Artemia* has a simple digestive system, a heart that provides blood circulation, and a ventral nerve cord consisting of segmental ganglia. The excretory system consists of a pair of green glands located near the base of the antennae. The genus *Artemia* consists of both hermaphroditic species and parthenogenetic (asexually reproducing) populations. Genetic differences such as ecological isolation, variations in heterochromatin composition, different ploidy forms, and reproductive isolation are observed in the genus *Artemia.* Of the hermaphroditic species distributed in North, Central, and South America, *Artemia franciscana* has been the most studied and is considered a "superspecies" due to the reproductive isolation of some populations in nature. *Artemia* persimilis has been found in hypersaline environments of Argentina, southern Chile, and occasionally in the Mediterranean basin. Of the hermaphroditic species distributed in Europe and Asia, *Artemia salina* was once distributed in the Lymington area of England (now extinct) and in the Mediterranean region. *Artemia urmiana* is found in Lake Urmia in Iran, *Artemia sinica* in Central and East Asia, and *Artemia tibetiana* in the Tibetan Plateau of China. Several parthenogenetic populations with different ploidy levels exist in Europe, Africa, Asia, and Australia. In some saline environments, these populations coexist with bisexual populations. *Artemia* brine shrimp are widely distributed in brackish and saline water bodies worldwide, except Antarctica (Hagiwara & Yoshinaga,

2017).

Structure and Biology of the brine shrimp *"Artemia salina"*

Artemia salina is a small crustacean that lives in environments with high salinity. They live mainly in chloride, sulfate or carbonate waters, as well as in compounds of these anions. The ability to adapt to low oxygen levels in high salinity conditions and the ability to form immobile cysts (cysts) in unfavorable environments ensure their adaptation to extreme environments. The genetic diversity of *Artemia salina* is due to the duration of isolation and the effect of natural selection. Their high plasticity leads to morphological variability, which makes their systematic classification difficult. Changes in water mineralization lead to high variability in morphology. In addition, reproductive characteristics and sex ratio can also vary (Lee & Nam, 2019).

Artemia salina belongs to the thermophilic species and is particularly sensitive to heat during the reproductive period. Although adults can tolerate a wide range of temperatures, a narrow temperature range of 20-300C is required for reproduction. Their mass development is observed in water bodies with high salinity (>70 g/l), which limits the development of natural predators. In such conditions, *Artemia salina* develops practically in monoculture due to its high osmoregulation capacity, and its density depends mainly on the nutritional factor (Ogata & Morioka, 2020).

The method of reproduction has a different effect on the quantitative parameters of the life cycle of *Artemia salina,* the sex ratio and the types of egg laying. Reproduction can be carried out by live birth or by egg laying. Two types of eggs are distinguished: thin-shelled (spring) and thick-shelled, diapausing (cysts). Nauplii hatch from thin-shelled eggs immediately after their release by the mother. Thick-shelled eggs contain embryos in the gastrula stage, are covered with a thick shell and remain in diapause. The shell of the cysts consists of three well-defined layers: two chitin layers and an inner embryonic cuticle. The total shell mass of diapausing eggs is approximately 30% of their total mass (Zhou & Li, 2015).

Artemia salina cysts are usually found on the surface and in the depths of the water, accumulate on the shore and dry up. As a result of this dehydration process, the diapause mechanism is inactivated and the cysts begin to continue embryonic development when they come into contact with water under optimal conditions. The transition of diapause eggs to metabolic activity and the breaking of their shells is possible only during full hydration and under sufficient lighting conditions. The newly hatched larvae molt 7 times within 10-16 days and turn into young crabs. After 20-30 days after birth, they molt an additional 4-5 times and reach sexual maturity. The fertility of adult female *Artemia salina* and the viability of nauplii depend on the salinity of the water and the abundance of food. An individual can lay up to 200 eggs at an average interval of 3-11 days. Under unfavorable conditions, the population remains in the diapause egg (cyst) stage. Dehydrated cysts are more resistant to unfavorable conditions than hydrated cysts. Dry cysts can remain in diapause for years, but continue to develop when released into water.

The distinctive morphological features and exceptional biological properties of *Artemia salina* make them an interesting object of study. Their resistance to extreme environmental conditions and potential anticancer properties highlight the importance of continued research into the biology and applications of these organisms (Boyd & Tucker, 2012).

Reproductive Characteristics of the *Artemia salina* Crustacean:

Artemia salina populations, especially in isolated high-salinity lakes, exhibit significant genetic diversity. Geographic and ecological isolation leads to the formation of different *Artemia* species or strains, which ensure their adaptation to specific environmental conditions. For example, populations living in permanent water bodies may have a stable reproduction cycle throughout the year, while those living in seasonal or temporary water bodies produce cysts that are resistant to unfavorable conditions. In addition to sexual and parthenogenetic reproduction, the ability to form cysts also plays an important role among

the reproductive strategies of *Artemia salina*. When environmental conditions deteriorate, for example, when salinity or temperature changes, females produce thick-shelled cysts. These cysts are resistant to desiccation and can remain dormant for years. When favorable conditions are restored, new individuals develop from these cysts, thus ensuring the continuity of the population (Sugumar & Philip, 2011).

The ability of *Artemia salina* to survive in extreme environments is related to their physiological resilience and versatile reproductive strategies. Their ecological role, scientific and industrial importance make it important to study and conserve these organisms in greater depth. In particular, as human impacts on hypersaline ecosystems increase, the conservation of *Artemia* populations is important to maintain their ecological and scientific value. As environmental changes and human activities affect hypersaline ecosystems, the conservation of *Artemia salina* populations is important to maintain their ecological and scientific value. These *crustaceans,* with their ability to survive in extreme conditions and their diverse reproductive strategies, are valuable model organisms for evolutionary and ecological studies (Boyd & Tucker, 2012).

The Economic and Biological Importance of *Artemia salina* brine shrimp:

Artemia salina is a unique group of *crustaceans* that have developed unique survival strategies in environments with extreme environmental conditions. These creatures form special egg forms called diapause in order to ensure the continuity of life. Diapause eggs can be stored in a dry state for a long time, preventing population decline in difficult and variable conditions. When these eggs enter water, they develop rapidly and appear as nauplii. Thus, *Artemia salina* is of great importance both biologically and economically. Diapause eggs of these crustaceans are formed in response to seasonal changes in the environment. During high salinity, temperature and other stress factors, the egg-forming mechanism is activated for the survival of the population. Diapause eggs have great commercial potential, as they can be stored in dry conditions for a long time. Keeping them in a dry state reduces transportation and storage costs, as well as allows them to be traded in accordance with market conditions. Additionally, the hatching process is extremely rapid: eggs begin to hatch within the first 15-20 hours, and this rate reaches 90% within 24-30 hours, making a significant contribution to increasing productivity in the aquaculture industry (Food and Agriculture Organization of the United Nations, 2021).

Artemia salina is also widely used as live food. After their eggs develop into nauplius stage in a short period of time, they create conditions for rapid growth and early sexual maturity of marine fish and other aquatic organisms due to their rich protein and fatty acid content. Thus, this living organism prevails as live food in aquaculture farms and has high value in terms of nutritional quality. In addition, the production of *Artemia salina* is also of great economic importance. Large-scale cultivation activities are carried out in salt basins in regions such as America and Asia. For example, production carried out in 100-hectare salt ponds with qualified and additional labor allows for an annual income of one hundred thousand dollars. This not only contributes to the regional economy, but also increases employment opportunities. From an ecological point of view, *Artemia salina* populations support the effective filtration of phytoplankton and bacteria by accumulating calcium and other ions present in the water in their bodies. In addition, *Artemia salina* populations play the role of the main food source and habitat for many bird species. Flamingos and migratory birds in particular benefit from the rich nutritional value of these creatures, thus contributing to the biodiversity of the natural environment. At the same time, *Artemia salina* has also found its place in research laboratories, being among the model organisms widely used in toxicity tests (Ogata & Morioka, 2020).

Conclusion:

The brine shrimp *"Artemia salina"* stands out with its special adaptation mechanisms in extreme saline ecosystems. Its diapause eggs

ensure the continuation of the population in harsh conditions and are widely used as high-quality live feed in the aquaculture industry. This organism maintains the balance of the ecosystem by supporting the natural filtration processes of water bodies and adds significant value to the regional economy. At the same time, the biological characteristics and economic potential of *"Artemia salina"* create broad prospects for future research. Its commercial value, meeting the growing demand in local and international markets, expands development and investment opportunities in the field and contributes to the protection of the ecosystem.

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