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Gusein Guseinov
Baku State University
PhD in Economy Geography
https://orcid.org/0000-0001-5079-9269
gusein.guseinov@bsu.edu.az

Analysis of Wholesale and Retail Trade Turnover in the Guba-Khachmaz Economic Region

Abstract

This article analyzes the dynamics, structure, and territorial differentiation of retail and wholesale turnover in the Guba-Khachmaz Economic Region of the Republic of Azerbaijan for the period 2015–2023. Using official statistical data from the State Statistics Committee, a comparative territorial analysis of trade indicators was carried out, per capita dynamics were calculated, and a typology of districts by their level of trade activity was constructed. The results show a pronounced asymmetry: the main centers of trade are represented by Khachmaz and Guba, while peripheral districts (Shabran, Siyazan) experience difficulties in developing their trade and demonstrate persistent unfavorable trends. The discussion focuses on the reasons for this differentiation — insufficient transport and logistical support, structural and morphological disparities, and the weak purchasing power of the population — which collectively undermine sustainable regional development. This result may serve as a basis for developing differentiated management approaches, strengthening the sustainability of trade, and reducing imbalances in the socio-economic development of the districts.

Keywords: *Guba-Khachmaz district, retail turnover, wholesale trade, differentiation, sustainability, socio-economic development*

Introduction

Trade, as one of the most important sectors of the market economy, fulfills in regional systems not only the function of distributing goods but also serves as an indicator of the population's economic activity, the level of urbanization, and the efficiency of production and logistics infrastructure. The analysis of the dynamics and structure of trade turnover acquires particular significance in economically and geographically differentiated regions, where the combination of natural, demographic, and infrastructural factors determines the diversity of consumer behavior and entrepreneurial activity.

In the Republic of Azerbaijan, the Guba-Khachmaz Economic Region represents a territorial entity where internal disparities in socio-economic development and trade specialization are especially pronounced. The region includes five administrative districts – Khachmaz, Guba, Gusar, Siyazan, and Shabran – each differing in population size, settlement density, sectoral structure of the economy, and level of investment activity. Given these differences, trade turnover – both retail and wholesale – acts as an objective criterion for assessing the level of economic development and the effectiveness of spatial economic organization at the regional level.

In recent years, there has been growing interest in regional trade analysis in the context of spatial planning and the assessment of state policy effectiveness. However, despite the existence of certain statistical publications, a systematized economic-geographical analysis of trade turnover at the level of an intra-state economic region remains insufficiently represented. At the same time, in regions such as Guba-Khachmaz, trade performs not only a distributive function but also plays the role of a crucial factor of socio-economic integration, particularly in the context of increasing transport connectivity and the transformation of consumer models.

The purpose of this study is to identify the trends, patterns, and spatial disparities in the dynamics of trade turnover in the Guba-Khachmaz Economic Region of Azerbaijan for the period 2015–2023,

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based on the analysis of official statistical data. The research primarily relies on the data of the State Statistical Committee of the Republic of Azerbaijan (Guseynov, 2009; Imrani, 2023; Khudaverdiyeva & Ragimov, 2021), which encompass indicators of retail and wholesale trade in the administrative districts, as well as their dynamics per capita.

The research objectives include:

– analyzing changes in the volume and structure of retail and wholesale trade turnover in the region as a whole;
– identifying growth and stagnation rates across the administrative districts;
– comparing absolute and per capita indicators of trade;
– constructing a typology of districts according to the level of trade activity;
– identifying factors that promote or hinder trade development in specific districts.

The methodological basis of the study is a comparative-territorial analysis, including the systematization of statistical data, index-based evaluation of dynamics, and per capita calculations, which make it possible to reveal not only nominal but also real trends in trade development. Elements of graphical analysis and cartographic interpretation, oriented towards the visualization of the spatial structure of trade, are also applied (Bayramov, 2019).

The scientific and practical significance of the research lies in substantiating the necessity of a differentiated approach to trade regulation within a single economic region, taking into account differences in infrastructural, demographic, and economic characteristics. The findings can be of use to executive authorities, as well as in the development of regional socio-economic development programs. The analysis of trade turnover as a tool for assessing the socio-economic condition of a region requires the application of a set of methods that combine quantitative and qualitative approaches. In the context of territorial differentiation and differences in demographic and infrastructural characteristics of the districts within the Guba-Khachmaz Economic Region, the use of comparative-geographical and statistical methods makes it possible to obtain an objective picture of trade development at the regional level. The source base of the study consists of official data from the State Statistical Committee of the Republic of Azerbaijan, including the annual statistical compendiums *Districts of Azerbaijan* for 2016 and 2022 (Guseynov, 2009; Imrani, 2023), as well as the general statistical report *Indicators of Azerbaijan* (Khudaverdiyeva & Ragimov, 2021). Aggregated data on the dynamics of retail and wholesale trade turnover by administrative units, information on population size, and investment activity were also utilized.

To achieve the research objectives, the following methods and approaches were applied:

– **Comparative-territorial analysis**, which made it possible to evaluate differences among the districts in terms of trade volume, growth rates, and the structure of trade forms (retail/wholesale);
– **Index method**, employed in the analysis of the dynamics of the physical volume of retail trade turnover in order to eliminate the influence of inflation and seasonal fluctuations;
– **Per capita trade turnover calculation**, which allowed the assessment of not only the overall volume of trade but also the intensity of consumption per resident;
– **Typological approach**, used to group districts according to their level of trade activity (high, medium, low) and the dynamics of indicators.

The study covers the period from 2015 to 2023. The choice of this time interval is determined by two factors: firstly, the availability of comparable and systematized statistical data; and secondly, the relevance of assessing trade processes in the post-crisis (pandemic and post-pandemic) period. In some cases, to substantiate retrospective dynamics, data from 1991, 2005, and 2010 were also employed (Guseynov, 2009).

The limitations of the research are associated with the aggregated nature of official statistics. In particular, the reporting does not include a breakdown of trade by type of settlement (urban/rural) nor by product groups. Information on the share of informal trade and small-scale entrepreneurship is also absent, which may underestimate the role of trade in some rural areas. Furthermore, official reports do not always reflect the spatial distribution of investments specifically directed towards trade infrastructure.

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Despite these limitations, the applied methodological framework makes it possible to identify the main regularities and territorial differences in the development of trade, as well as to formulate conclusions regarding the typology of districts by level and structure of trade activity within the Guba-Khachmaz Economic Region.

General Characteristics of the Region

The Guba-Khachmaz Economic Region is located in the north-eastern part of the Republic of Azerbaijan and encompasses five administrative districts: Khachmaz, Guba, Gusar, Siyazan, and Shabran. The total area of the region is about 6,700 km², and the population as of 2023 exceeds 530,000 people (Khudaverdiyeva & Ragimov, 2021), making it one of the larger subregional areas within the structure of the national economy. The region has a favorable geographical position, bordering the Caspian Sea to the east and the Russian Federation to the north. Major road and railway corridors traverse its territory, linking the capital region with the north of the country and beyond.

The relief of the region is highly contrasting — from foothills and mountain ranges in the west to the Caspian lowlands — which generates differences in agricultural specialization, settlement patterns, and territorial accessibility. The landscape diversity contributes to the development of both agriculture (including horticulture, livestock breeding, and crop production) and tourism potential, particularly in the Gusar and, to some extent, Guba districts (Gerayzade & Mirzayeva, 1998).

From an economic perspective, the Guba-Khachmaz region is characterized by a multi-structural economy, where traditional forms of agricultural production coexist with emerging formats of the service economy. The role of trade in the regional economy is constantly increasing, which is associated with both the general economic environment and the developing character of the national economy as a whole, as well as regional factors such as population growth, rising mobility, the expansion of logistics opportunities, and the development of the consumer sector. In certain districts, trade performs not only the function of redistributing consumer goods but also serves as the main source of employment and self-employment for the population.

In terms of urbanization and infrastructural saturation, the districts of the Guba-Khachmaz region demonstrate significant heterogeneity. The Khachmaz district concentrates a considerable number of trade facilities, a developed transport network, and high population density. The Guba district shows relatively stable growth due to its agricultural specialization and domestic tourism. The Gusar district, despite its natural and tourist potential, suffers from outmigration of the population and limited trade infrastructure. The Siyazan and Shabran districts, being the least populated and economically active territories of the region, display weak investment dynamics and a low density of the trade network (Guseynov, 2009; Imrani, 2023; Khudaverdiyeva & Ragimov, 2021).

According to the State Statistical Committee, the average age of the region's population is gradually increasing, while a steady outflow of the working-age youth towards the capital is observed (Khudaverdiyeva & Ragimov, 2021). This has a direct impact on local consumer markets, reducing the intensity of retail trade in rural and mountainous districts. Urbanized districts of the region accumulate the bulk of trade turnover, while peripheral territories constitute zones with low purchasing power and weak development of logistics nodes.

Based on this description, the Guba-Khachmaz Economic Region represents a territory with pronounced internal economic-geographical segmentation, where trade develops unevenly depending on the level of urbanization, investment activity, transport accessibility, and demographic sustainability. These differences form an important basis for analyzing trade turnover at the level of administrative districts and allow for territorial typologization within a single economic region.

Analysis of Retail Trade Turnover (2015–2023)

Retail trade is the most sensitive indicator of a region's socio-economic activity. Its volumes directly depend on the size and purchasing power of the population, the level of infrastructural provision, the nature of employment, and the degree of urbanization. In the Guba-Khachmaz Economic Region, retail trade turnover demonstrates positive dynamics during the period under consideration, although it is accompanied by significant territorial disparities (Mamedov & Allakhverdiyev, 2003).

According to the data of the State Statistical Committee of Azerbaijan, the total volume of retail trade turnover in the economic region increased from 1,043.8 million manats in 2015 to 1,836.5 million manats in 2023, which is equivalent to a nominal growth of 75.9% [Table 1]. The most intensive growth was recorded in 2022–2023, during the post-pandemic recovery period. However, real dynamics (measured by the physical volume index of sales) were more moderate, fluctuating within the range of 97–101%, which indicates a slowdown in consumer activity and market saturation [Table 1].

The district structure of retail trade turnover in 2023 is as follows:

Table 1. Trade turnover and market share of administrative districts of the Guba-Khachmaz economic region.

District	Turnover (million manats)	Share in regional volume (%)
Khachmaz	707.9	38.6
Guba	624.2	34.0
Gusar	277.7	15.1
Siyazan	108.8	5.9
Shabran	117.8	6.4
Total	**1836.5**	**100**

Source: Compiled by the author based on data from the State Statistical Committee of the Republic of Azerbaijan.

As can be seen, almost three-quarters of the regional retail trade turnover is concentrated in two districts — Khachmaz and Guba — reflecting their leading role in the region's consumer system. Growth in these districts can be explained by a higher concentration of population, the level of urbanization, transport connectivity, and investment activity. The largest number of trade facilities is located here, including modern shops, shopping centers, and service enterprises.

In the Gusar district, despite its resort and tourism potential, the volume of retail trade is almost 2.5 times lower than in Khachmaz. This indicates a weak internal consumer base and limited trade infrastructure. At the same time, the recorded increase — from 145.6 million manats in 2015 to 277.7 million manats in 2023 — demonstrates the district's potential, provided that logistics and services are modernized (Guseynov, 2009; Khudaverdiyeva & Ragimov, 2021).

The Siyazan and Shabran districts remain the least active, their combined share in the regional retail turnover amounting to only 12.3%. This is associated with low population numbers, limited urbanization, and weak entrepreneurial initiative. Moreover, trade growth rates in these districts also lag behind the regional average, which reflects their structural backwardness in trade development.

The per capita retail turnover indicator helps to refine spatial differences in consumer activity. In 2023, this indicator amounted to 3,360.7 manats per person across the region, which is significantly higher than the 2015 level (1,689.4 manats) (Khudaverdiyeva & Ragimov, 2021). However, intra-regional disparities remain: the highest values are observed in Khachmaz and Guba, while the lowest are recorded in Siyazan and Shabran, where purchasing power remains limited.

The trend in the transformation of trade infrastructure is also noteworthy. The number of shops in the region increased from 2,871 in 2015 to 6,568 in 2023, while the number of kiosks decreased from 280 to 112 over the same period (Khudaverdiyeva & Ragimov, 2021). This reflects a shift from small-scale retail to more formalized formats, especially in districts with developed urban structures. In other words, the retail trade turnover of the Guba-Khachmaz region develops unevenly: central districts (Khachmaz, Guba) show high growth rates and concentration of trade infrastructure, whereas peripheral districts (Shabran, Siyazan) remain in a zone of lagging development. These differences form the basis for typologizing districts by level of trade activity, which will be presented in subsequent sections (Mikailova, 2010).

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Analysis of Wholesale Trade Turnover (2015–2023)

Wholesale trade performs a crucial function in the regional economy, acting as an intermediate link between producers and the retail sector. Unlike retail trade, wholesale activity is more sensitive to the investment climate, transport infrastructure, logistics chains, and the level of entrepreneurial cooperation (Alayev, 1983). Therefore, its dynamics in the Guba-Khachmaz Economic Region can be regarded as a reflection of deeper structural processes.

In 2015, the total volume of wholesale trade turnover in the region amounted to 325.9 million manats. By 2023, this figure had decreased to 306.4 million manats, which is equivalent to a nominal decline of 6.0% [Table 2]. This decline is particularly significant against the background of growth in retail trade, indicating imbalances in the development of trade formats.

A breakdown by district is presented below:

Table 2. Wholesale trade turnover and its dynamics across the administrative districts of the Guba-Khachmaz economic region.

District	Wholesale turnover, million manats (2015)	Wholesale turnover, million manats (2023)	Growth/decline rate (%)	Share in regional volume (2023), %
Khachmaz	141.2	196.7	+39.3	64.2
Guba	86.1	93.4	+8.5	30.4
Gusar	59.4	10.8	−81.8	3.5
Siyazan	21.3	3.1	−85.4	1.0
Shabran	17.9	2.4	−86.6	0.8
Total	**325.9**	**306.4**	**−6.0**	**100**

Source: Compiled by the author based on data from the State Statistical Committee of the Republic of Azerbaijan.

As the table demonstrates, wholesale trade growth in the region is ensured exclusively by two districts — Khachmaz and Guba — which together account for more than 94% of the regional volume. The other three districts (Gusar, Siyazan, Shabran) show a sharp decline in wholesale operations, amounting to the near-total degradation of their logistics function. In particular, Gusar experienced a decline of more than 81%, while Shabran recorded a decrease of 86.6%. This points to the loss of wholesale infrastructure and the withdrawal of these districts from regional production and supply chains [Table 2] (Saushkin, 1980).

The decline in both absolute and relative terms in peripheral districts can be explained by several reasons:

– insufficient investment activity and the absence of wholesale warehouses;
– reorientation towards local (intra-network) supply channels;
– limited road networks and logistics platforms;
– a small number of registered wholesale trade entities.

Another important indicator — wholesale trade turnover per capita — illustrates spatial disparities (State Statistical Committee of the Republic of Azerbaijan, 2016):

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Table 3. Population and per capita wholesale turnover across the administrative districts of the Guba-Khachmaz economic region.

District	Population (2023), thousand people	Per capita wholesale turnover, manats
Khachmaz	207.4	948.6
Guba	171.2	545.5
Gusar	99.6	108.4
Siyazan	42.1	73.6
Shabran	48.2	49.7

Source: Compiled by the author based on data from the State Statistical Committee of the Republic of Azerbaijan (2022b).

These data confirm a profound stratification along the centre–periphery axis. Only two districts exceed the regional median per capita turnover, whereas the remaining three display extremely low values that do not allow for the formation of a sustainable wholesale network [Table 3]. Hence, the structure of wholesale trade in the region is highly uneven and vulnerable. The dominance of Khachmaz and Guba is intensifying, while Siyazan, Shabran, and Gusar are losing their wholesale intermediation functions. This makes them economically dependent on external supplies and reduces the efficiency of local production processes.

Comparative-Territorial Analysis

A comprehensive comparison of retail and wholesale trade indicators across the administrative districts of the Guba-Khachmaz Economic Region makes it possible to identify internal patterns of spatial polarization and to systematize districts by type of trade specialization. The criteria for typologization include:

– total trade volume,
– growth rates,
– per capita indicators, and
– the district's share in the regional structure (State Statistical Committee of the Republic of Azerbaijan, 2022a).

Table 4. Summary table of trade activity of districts.

District	Retail turnover (million manats)	Wholesale turnover (million manats)	Retail per capita (manats)	Wholesale per capita (manats)	Share in retail (%)	Share in wholesale (%)
Khachmaz	707.9	196.7	3414.3	948.6	38.6	64.2
Guba	624.2	93.4	3646.2	545.5	34.0	30.4
Gusar	277.7	10.8	2788.7	108.4	15.1	3.5
Siyazan	108.8	3.1	2584.3	73.6	5.9	1.0
Shabran	117.8	2.4	2444.2	49.7	6.4	0.8

Source: Compiled by the author based on data from the State Statistical Committee of the Republic of Azerbaijan (2023).

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The Khachmaz district is the most developed in trade-economic terms. It leads in the volume of both retail and wholesale trade, as well as in its share of the region's total trade turnover. A high per capita indicator and diversity of trade formats allow it to be classified as the regional centre of mixed-type trade [Table 4]. The Guba district demonstrates stable performance in both sectors, lagging behind Khachmaz in absolute terms but surpassing it in per capita retail turnover. This indicates a balanced consumption structure, a developed trade network, and local redistribution of goods. The district can be classified as an intra-regional trade core. The Gusar district possesses moderate retail potential associated with seasonal tourism activity, yet it demonstrates a critically low level of wholesale trade. This allows it to be characterised as a district with a functionally one-sided trade system (retail-oriented) and weak logistics connectivity [Table 4]. The Siyazan and Shabran districts are in a zone of structural lag. Their share in regional trade turnover is minimal, as are their per capita indicators. The near-complete disappearance of wholesale infrastructure makes them vulnerable to external logistics risks. These districts should be classified as areas of low trade activity and infrastructural degradation (State Statistical Committee of the Republic of Azerbaijan, 2023).

Table 5. Typology of districts by trade activity.

Type of trade development	Districts	Characteristics
I. Centre of mixed trade activity	Khachmaz	High retail and wholesale volumes, developed logistics
II. Stable consumption core	Guba	Balanced per capita and absolute indicators
III. Tourist-retail type	Gusar	Moderate retail, weak wholesale, seasonality
IV. Periphery of low activity	Siyazan, Shabran	Low trade density, degradation of wholesale function

Based on the obtained data, the comparative analysis revealed a pronounced spatial asymmetry. The economic weight of trade processes is concentrated in two central districts, whereas peripheral areas have lost key wholesale and distribution functions. This forms an unstable regional model with risks of hyper-centralisation of the trade function and trade-logistics dependence on Khachmaz and Guba.

Discussion of Results

The results of the comparative-territorial analysis of retail and wholesale trade turnover in the Guba-Khachmaz Economic Region for 2015–2023 revealed a pronounced asymmetry in the dynamics, structure, and level of trade activity across administrative districts. These disparities are the outcome of the combined influence of socio-economic, demographic, institutional, and infrastructural factors and define the overall model of spatial development in the region (State Statistical Committee of the Republic of Azerbaijan, 2022b). The centres of trade concentration are the Khachmaz and Guba districts, which confirm the effect of scale: the presence of a developed transport and logistics network, warehousing infrastructure, an entrepreneurial sector, and population growth ensures a stable inflow of trade turnover. These districts form the core of the distribution system, acting as the main points of attraction and reproduction of the regional economy. At the same time, peripheral territories — Shabran and Siyazan districts — are characterised by structural and morphological degradation. Here, low levels of transport and logistics provision, limited sales channels, and insufficient purchasing power of the population are observed. This leads to a decline in both wholesale and retail trade, exacerbates disparities, and creates a "crowding-out" effect whereby weaker districts are excluded from the system of sustainable reproduction (Tundzha, 2000). The Gusar district occupies a special place, as the dynamics of retail turnover are largely determined by the tourism factor. Tourism specialisation provides advantages in the services sector and stimulates retail trade; however, due to its dependence on tourist flows, the model remains unstable and poorly

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adapted to fluctuations in demand. Moreover, the wholesale sector here is underdeveloped. Collectively, the identified trends form a concentrator model of regional trade: the core is concentrated in Khachmaz and Guba, while peripheral districts are gradually losing resilience. This widens the socio-economic gap, reduces employment levels, limits the emergence of new growth points, and hinders the equalisation of living standards (Von Thünen, 1966).

Conclusion

The structural-spatial analysis of retail and wholesale turnover makes it possible not only to identify the key advantages and shortcomings but also to determine reserves for strengthening the sustainability of the regional trade system. To reduce disparities, it is necessary to implement a differentiated management policy aimed at developing transport and logistics infrastructure, stimulating entrepreneurship, increasing the population's purchasing power, and creating new points of sustainable growth in peripheral districts.

It follows that only a comprehensive approach can ensure more balanced and sustainable socio-economic development of the Guba-Khachmaz Economic Region.

References

1. Alayev, L. B. (1983). *Economic and geographical terminology: An attempt at a systematic dictionary*. Nauka.
2. Bayramov, T. Sh. (2019). Socio-economic situation and population migration in the Guba-Khachmaz economic region of the Republic of Azerbaijan. *University Proceedings. North Caucasus Region. Natural Sciences*, (2), 26–33.
3. Gerayzade, T. P., & Mirzayeva, T. A. (1998). Ways to solve regional problems. In *Proceedings of the 7th Congress of the Azerbaijan Geographical Society*. 98–100.
4. Guseynov, T. (2009). *Investments in Azerbaijan: Income, investments, industrialization, employment*. Elm.
5. Imrani, Z. T. (2023). Constructive foundations of sustainable economic-geographical development of the investment environment and productive sectors of Azerbaijan. *Proceedings of Tula State University. Earth Sciences*, (2), 484–498.
6. Khudaverdiyeva, L. A., & Ragimov, E. G. (2021). Urbanization and ethno-demographic transformation in the regions of Azerbaijan. *Bulletin of Geography*, (4), 112–120.
7. Mamedov, Z. T., & Allakhverdiyev, Kh. B. (2003). *Regulation of investment processes*. Caucasus House.
8. Mikailova, S. M. (2010). The role of investment policy in ensuring national interests. *Russian Entrepreneurship*, 12(174), 164–168.
9. Saushkin, Yu. G. (1980). *Economic geography and population geography*. Mysl.
10. State Statistical Committee of the Republic of Azerbaijan. (2016). *Districts of Azerbaijan: Statistical compendium*.
11. State Statistical Committee of the Republic of Azerbaijan. (2022a). *Districts of Azerbaijan: Statistical compendium*.
12. State Statistical Committee of the Republic of Azerbaijan. (2022b). *Statistical indicators of Azerbaijan: Statistical compendium*.
13. State Statistical Committee of the Republic of Azerbaijan. (2023). *Demographic yearbook of Azerbaijan, 2019–2023*.
14. Tundzha, Z. (2000). Another way to compensate for the resource deficit — foreign capital. *Toprak (Journal for Employers)*, (47), 12–13.
15. Von Thünen, J. H. (1966). *The isolated state*. Pergamon Press.

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Raifa Salmanova
Nakhchivan State University
PhD in Biology
https://orcid.org/0009-0001-4840-734X
raifasalmanova@ndu.edu.az

Study of Species Belonging to the Genus *Dactylorhiza* Neck. ex Nevski (*Orchidaceae*) Distributed in the Nakhchivan Autonomous Republic

Abstract

In this article, the bioecological characteristics and practical significance of species belonging to the genus *Dactylorhiza* Neck. ex Nevski (Marsh Orchid) distributed across various ecological zones of the Nakhchivan Autonomous Republic were investigated. As research material, the main representatives of this genus — *D. romana*, *D. umbrosa*, *D. incarnata*, *D. salina*, *D. euxina*, and others — were selected. Field observations revealed that these plants are widely distributed in mountainous and foothill areas, riverside landscapes, and wetland ecosystems, where they perform essential ecological functions.

According to the results, species of *Dactylorhiza* play a significant role in maintaining the stability of phytocoenoses, conserving biodiversity, and regulating soil and water regimes. Their ability to adapt to different ecological conditions justifies their inclusion among bioindicator plant groups. While stable populations were observed in humid habitats, the number of individuals decreased in drier zones. Light regime was also identified as an important factor: flowering intensity was higher in open areas, while it remained relatively weak in shaded sites.

Dactylorhiza species are important not only for maintaining ecological balance within ecosystems but also for their economic value. Their ornamental features make them valuable for horticulture and landscape design, whereas biologically active substances derived from their tubers are widely used in folk medicine and for therapeutic purposes.

Keywords: *Dactylorhiza, orchid, flora, bioecology, coenopopulation*

Introduction

The flora of Azerbaijan is distinguished by its rich biological diversity and constitutes an essential component of the country's natural resources. The Nakhchivan Autonomous Republic, with its diverse soil and climatic conditions, varied relief, and unique geographical location, provides a favorable area for the formation of rare plant species (Heydarova & Qaraxani, 2018, pp. 57–60). In the region's mountainous, foothill, riparian, and wetland areas, distinctive phytocoenoses have developed, allowing for the preservation of both endemic and relict species.

Research

The study of species belonging to the genus *Dactylorhiza* (marsh orchids), which are widely distributed in these areas, is of great significance both from a theoretical perspective — systematics and bioecology — and from a practical standpoint, including ornamental horticulture, traditional medicine, and biodiversity conservation. Representatives of this genus demonstrate a strong capacity for adaptation to various ecological conditions, forming stable populations in both arid meadows and humid wetlands. The data obtained provide a scientific basis for the sustainable management of phytocoenoses as well as for the conservation of rare species.

Materials and Methods

The research material consisted of species of the genus *Dactylorhiza* (marsh orchids) distributed across various ecological zones of the Nakhchivan Autonomous Republic. The study was conducted between 2020 and 2025, and observations covered the entire vegetation period. Specimens were

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mainly collected from mountainous and foothill areas, riparian landscapes, wetlands, and forest edges.

For the classification and assessment of the utilization aspects of the genus, the works of various researchers were employed, including Vakhrameeva et al. (2013, pp. 120–124), Salmanova (2020, No. 9, pp. 62–68), Talibov (2000, No. 1(4), pp. 12–23), Asgarov (2011, pp. 88–92), Heydarova et al. (2017, p. 77), APG IV (2016), and WFO (2020).

Discussion and Results

A systematic analysis of species belonging to the genus Dactylorhiza distributed in the territory of the Nakhchivan Autonomous Republic was carried out, and it was determined that 7 species occur in the area.

Species of the genus Dactylorhiza Neck. ex Nevski distributed in the Nakhchivan Autonomous Republic:

Genus: Dactylorhiza Neck. ex Nevski – Marsh orchids

1(1) Dactylorhiza euxina (Nevski) Czerep. – Black Sea marsh orchid

1(2) D. salina (Turcz. ex Lindl.) Soó – Saline marsh orchid

1(3) D. iberica (Bieb. ex Willd.) Soó – Georgian marsh orchid

1(4) D. romana (Sebast.) Soó – Roman marsh orchid

= D. romana subsp. georgica (Klinge) Soó ex Renz & Taubenheim [= D. flavescens (C. Koch) Holub]

1(5) D. umbrosa (Kar. & Kir.) Nevski (1937) [= D. sanasunitensis (Fleischm.) Soó; D. chuhensis; D. merovensis (Grossh.) Aver.] – Shaded marsh orchid

1(6) D. urvilleana (Stend.) H. Baumann & Künkele [= D. affinis (C. Koch) Aver.; D. amblyoloba (Nevski) Aver.; D. triphylla (C. Koch) Czerep.] – Durville's marsh orchid

1(7) D. osmanica (Kinge) P.F. Hunt & Summerh. – Osman marsh orchid

= D. osmanica (Kinge) P.F. Hunt & Summerh. var. osmanica [= D. cataonica (H. Fleischm.) Holub]

The tuberous roots of the genus *Dactylorhiza* (marsh orchids), unlike those of *Orchis*, which are very similar in their aerial organs, are elongated, segmented, and finger-like. In contrast, the roots of *Traunsteinera* and *Ophrys* are rounded. Typically, there are two tubers: one pale and soft, which the plant uses for nutrition in the current year, and the other young and hard, serving as a reserve for the following year. In temperate flora, the underground tubers of marsh orchids are based on the stem. The renewal bud forms well before the aerial shoot. In spring, as the aerial shoot develops from the maternal renewal bud, the vegetative renewal bud rapidly develops and is located in the young tuber penetrating the soil (Geydarova, Garaxani, & Javadzade, 2017).

Flowering in marsh orchids occurs either after leaf formation, before it, or simultaneously with it (Salmanova, 2018, No. 8(64), pp. 38–41). Flowers are located at the apex of the spike or in the axils of the main stem leaves. The primary type of flowering characteristic of marsh orchids is a raceme with flowers in the leaf axils, which often transform inconspicuously into ovaries.

Representatives of the tuberoid life form possess a one- or two-year underground stolon-like storage organ — a renewal bud — with a stem-root tuberoid covered with hairs. The tuberoid develops from the lower buds of annual monocarpic shoots in a horizontal direction due to apical growth.

Most tuberoid marsh orchids are heliophytes, preferring bright light conditions. Some species are found only in open habitats such as meadows, rocky slopes, gravelly soils, and mountainous xerophytic steppes. In the Nakhchivan Autonomous Republic, tuberoid marsh orchids are represented by several taxa and are widely distributed in the mountainous regions. These include representatives of the genera *Orchis*, *Ophrys*, *Anacamptis*, *Platanthera*, and *Dactylorhiza*.

Marsh orchids of the tuberoid type are widely distributed in various forests, mountainous xerophytic steppes, and alpine meadows in the region. They occur from the lower mountain belt to high-altitude natural meadows, either as small groups or solitary individuals. The widespread distribution of the genus *Dactylorhiza* is associated with their tolerance to low temperatures and a

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broad ecological amplitude regarding moisture (National Strategy for the Protection and Sustainable Use of Biological Diversity in the Republic of Azerbaijan for 2017–2020, 2016).

We analyzed the ecological and phytosociological development features of the most commonly encountered *Dactylorhiza* species in the habitats of the Nakhchivan Autonomous Republic, focusing on *Dactylorhiza urvilleana*, *D. romana*, and *D. umbrosa*. In most habitats, several synpopulations of the studied life form species were identified [Table 1]. The highest numbers were observed in the Batabat massif of the Shahbuz district (7), Bilev village in the Ordubad district (6), and the Khazinedere area in Arafsa village, Julfa district (4). In most districts (Sharur, Kangarli), 1–2 species of the genus *Dactylorhiza* belonging to tuberoid marsh orchids were recorded. Of the seven species identified in our study, six were found in the Bilev village area of the Ordubad district, where the number of synpopulations was 55 and 52, respectively.

Table 1. Habitats, species, and the number of synpopulations of the genus *Dactylorhiza.*

District	Number of studied habitats	Number of species	Number of synpopulations	Number of synpopulations in the habitat
Shahbuz	11	7	55	5,0
Ordubad	20	6	52	2,6
Julfa	8	5	45	5,6
Sharur	3	2	6	2,0
Kangarli	2	2	8	4,0
Sadarak	1	1	1	1,0
Total	45	23	167	1,93

The conducted observations and analyses demonstrate that the distribution range of *Dactylorhiza* species extends primarily from foothill zones to subalpine and alpine meadows. Soil moisture regimes are a key determining factor for their populations. In humid and wetland areas (*D. umbrosa*), more stable communities are formed, whereas in dry meadows (*D. romana*), the number of individuals decreases. Light availability is also an important ecological factor. Although vegetation develops poorly in shaded forest edges, flowering and productivity are higher in open habitats. Anthropogenic pressures — intensive grazing, soil cultivation, and construction activities — disrupt population structures (News Journal [Natural and Technical Sciences Series], 2018).

These findings indicate that while *Dactylorhiza* species exhibit ecological plasticity, their long-term persistence is sensitive to human impact. Species of *Dactylorhiza* Neck. ex Nevski function as dominant or accompanying components in various phytocoenoses. In wetlands and aquatic areas, they form dominant groups together with some species of the families *Cyperaceae* and *Juncaceae*. In subalpine meadows, they are associated with *Carex tristis* Bieb., *Carex divulsa* subsp. *leersii* (Kneuck.) W. Koch, *Poa nemoralis* L., *P. pratensis* L., *Leopoldia caucasica* (Griseb.) Losinsk., and *Allium cardiostemon* Fisch. & C.A. Mey. In dry meadows and rocky slopes, they occur as accompanying elements. Phytosociological analysis shows that *Dactylorhiza* species are bioindicator plants that contribute to ecosystem stability, and their presence indicates ecological balance.

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Population analyses reveal that the abundance of young vegetative individuals indicates a high reproductive potential, although the number of reproductive individuals in some local populations has sharply declined, likely due to anthropogenic pressures and reduced precipitation. Some synpopulations exhibited stability (optimal developmental stage), whereas others showed signs of regression. The most stable populations are found in humid and protected natural areas, such as the Batabat massif, Ordubad district, and the Araz River wetland zones. This demonstrates that the persistence of *Dactylorhiza* species is maintained not only by natural conditions but also through conservation measures (Salmanova, 2018a, pp. 122–125).

Many *Dactylorhiza* species are widely used in traditional medicine, enhancing their economic significance. However, illegal collection has led to declines in some populations. Therefore, a balanced approach to both nutritional and medicinal use is essential. For conservation purposes, artificial propagation methods, including *in vitro* cultivation, are recommended.

The study confirms that *Dactylorhiza* species act as important bioindicators in the flora of Nakhchivan. To maintain population stability, monitoring in specially protected areas should be strengthened. Rare and endangered species, listed in the *Red Book*, require expanded conservation measures. Artificial introduction efforts can also facilitate their broader use in ornamental horticulture and agriculture.

The research findings indicate that while *Dactylorhiza* species in the Nakhchivan Autonomous Republic exhibit adaptability to ecological conditions, the stability of some populations has been disrupted by anthropogenic effects. For their future conservation, it is necessary to monitor natural habitats, protect rare species, apply artificial propagation technologies, and develop policies for balanced utilization (Salmanova, 2018b, pp. 38–45).

Conclusion

The study demonstrates that *Dactylorhiza* species in the Nakhchivan Autonomous Republic exhibit significant ecological plasticity, allowing them to thrive from foothill zones to alpine meadows. Soil moisture and light availability were identified as the primary factors influencing population stability and reproductive success. Populations in humid and protected habitats were more stable, while dry and anthropogenically disturbed areas showed decreased abundance and reproductive individuals. Many species have economic and medicinal value, but illegal collection poses a threat, highlighting the need for conservation and sustainable use.

Overall, monitoring, habitat protection, and artificial propagation are essential to ensure the long-term persistence and ecological role of *Dactylorhiza* species in the region.

References

1. An online flora of all known plants (WFO). (2020, July 5). *World Flora Online*. Retrieved from http://www.worldfloraonline.org
2. APG IV: An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants. (2016). Byng, J. W., Chase, M. W., Christenhusz, M. J. M., et al. *Botanical Journal of the Linnean Society*, *181*(1), 1–20. https://doi.org/10.1111/boj.12385
3. Askerov, A. M. (2011). *Synopsis of the flora of Azerbaijan (with additions and changes, 1961–2009)*. Elm.
4. Geydarova, R. T., Garaxani, P. Kh., & Javadzade, T. Yu. (2017). Molecular and phylogenetic analysis of orchids (Orchidaceae Juss.). *Achievements of Modern Science*, (2), 75–79.
5. Heydarova, R. T., & Karakhani, P. X. (2018). Taxonomy of Dactylorhiza Neck. ex Nevsky species distributed in the Greater Caucasus. *In New Challenges in Botanical Research*, 57–60.
6. National Strategy for the Protection and Sustainable Use of Biological Diversity in the Republic of Azerbaijan for 2017–2020. (2016). *Qanun*.
   Retrieved from http://www.e-qanun.az/framework/33817
7. News Journal (Natural and Technical Sciences Series). (2018). *14*(2), 187–191.

 ISSN: 2707-1146
e-ISSN: 2709-4189

8. Salmanova, R. K. (2018a, May 4–5). Biomorphological characteristics of Orchis species in Nakhchivan Autonomous Republic. In *Current problems of modern natural and economic sciences.* Part II. 122-125.
9. Salmanova, R. K. (2018b). Orchids of the Batabat massif of Shahbuz region. *Scientific Works of Nakhchivan State University*, *8*(64), 38–41.
10. Salmanova, R. K. (2018c). Use of Orchis species in folk medicine in Nakhchivan Autonomous Republic. In *Bulletin of Modern Research, Orka Scientific Center.* №10-3, 86–87.
11. Salmanova, R. K. (2020). Distribution of Orchidaceae Juss. species in shrub and forest areas of Nakhchivan. *Nizhnevartovsk Vegetation: Bulletin of Science and Practice*, *6*(9), 62–68.
12. Vakhrameeva, M. G., Tatarenko, I. V., & Varlygina, T. I. (2013). Biological diversity of orchids in Russia. *Bulletin of Tver State University: Biology and Ecology*, *32*(31), 117–136.

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Seyidnisa Aliyeva
Azerbaijan State Pedagogical University
PhD student
https://orcid.org/0000-0002-8271-4781
nisealiyeva54@gmail.com

Agricultural Characteristics of the Central Aran Region of Azerbaijan

Abstract

The Central Aran economic-geographical region is one of Azerbaijan's leading agricultural hubs, playing a crucial role in ensuring national food security and supporting rural livelihoods. This study analyzes the region's agricultural resources, crop diversity, irrigation infrastructure, and the socio-economic importance of farming activities. Emphasis is placed on the role of fertile soils, favorable climatic conditions, and traditional agricultural practices alongside modern mechanization and innovative irrigation techniques. The findings reveal that while Central Aran has high agricultural potential, it faces challenges such as water scarcity, soil salinization, and outdated equipment in some rural areas. Recommendations are made for sustainable agricultural development, including modernization of farming technologies, diversification of crops, and eco-friendly land use practices.
Keywords: *Central Aran, agriculture, crop production, irrigation, rural economy, sustainable farming, Azerbaijan*

Introduction

Agriculture has historically been the backbone of the Central Aran economic-geographical region (*Mərkəzi Aran iqtisadi-coğrafi rayonu*), contributing significantly to Azerbaijan's food supply and rural employment. Situated in the central part of the Kur-Araz lowland, the region benefits from fertile soils, developed irrigation networks, and a favorable subtropical semi-arid climate. Administrative districts such as Mingachevir, Yevlakh, Agdash, Goychay, Ujar, Kurdamir, and Zardab form the core of this agricultural zone (Abdullayev, 2020).

The primary objective of this paper is to present an in-depth analysis of the agricultural profile of Central Aran, including land use patterns, major crops, production trends, technological advancements, and environmental concerns. The study also discusses strategies for sustainable agricultural growth.

Geographical Conditions and Agricultural Potential

The Central Aran region lies mostly below 200 meters above sea level, with annual precipitation ranging between 200–400 mm. The flat terrain and alluvial, grey-brown, and chestnut soils are highly suitable for crop cultivation, especially under irrigation. The Kura and Araz rivers, supported by the Upper Shirvan and Upper Karabakh canals, provide essential water resources for farming (Abdullayev, 2020).

Climatic conditions — mild winters and hot summers — allow the cultivation of a wide range of crops, from cereals to horticultural products. However, low natural rainfall means that irrigation remains the key determinant of productivity.

Major Agricultural Sectors

1. Grain Production. Wheat and barley are staple crops, with Yevlakh, Kurdamir, and Agdash leading in cereal production.
2. Industrial Crops. Cotton is a traditional crop of the region, supported by government subsidies and modern ginning facilities.

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3. Fruit Growing. Goychay is famous for pomegranate orchards, while Agdash is known for mulberry plantations and silk cocoon production. Vineyards are also expanding, particularly in Kurdamir.
4. Vegetable Farming. Tomatoes, cucumbers, and eggplants dominate irrigated plots, with some areas experimenting with greenhouse cultivation.
1. Livestock – Cattle and sheep breeding are widespread, supported by natural pastures and forage crop cultivation (Mammadov, 2018, pp. 34–49).

Technological Developments in Agriculture

Over the past two decades, mechanization has increased, with modern tractors, combine harvesters, and drip irrigation systems being introduced. Canal rehabilitation projects have improved water delivery efficiency, though some rural areas still rely on outdated machinery and face seasonal labor shortages.

Greenhouse farming is slowly gaining popularity, especially for off-season vegetable production.

Challenges in Agricultural Development

- Water Scarcity: Limited and uneven water distribution during summer months.
- Soil Salinization: Over-irrigation and poor drainage causing land degradation.
- Climate Risks: Increasing frequency of droughts and extreme temperatures.
- Infrastructure Gaps: Need for modernization of storage facilities, cold chains, and transportation networks.
- **Market Access.** Small-scale farmers often face difficulties accessing stable markets for their produce (Hasanov & Aliyeva, 2022, pp. 15–29).

Sustainable Development Perspectives

To maintain and enhance Central Aran's agricultural productivity, integrated approaches are needed:

• Expansion of smart irrigation and water-saving technologies.
• Promotion of crop diversification to reduce climate vulnerability.
• Adoption of organic farming practices to improve soil health.
• Investment in agro-processing to add value to raw produce.
• Strengthening farmer cooperatives to improve market access and bargaining power (State Statistical Committee of Azerbaijan, 2023).

Conclusion

The Central Aran region occupies a strategically important position in Azerbaijan's agricultural and socio-economic system. As one of the country's primary food-producing zones, it has historically served as a bridge between traditional farming practices and the gradual adoption of modern agricultural technologies. Its geographical position within the Kur-Araz lowland, fertile soils, favorable subtropical semi-arid climate, and extensive irrigation infrastructure have enabled the development of a diverse and productive agricultural sector. Crops such as wheat, barley, cotton, grapes, pomegranates, tomatoes, and cucumbers form the basis of the regional economy, while livestock breeding adds an additional layer of stability to rural livelihoods (FAO, 2021).

The analysis presented in this paper clearly indicates that Central Aran has the capacity not only to meet a substantial share of the domestic food demand but also to contribute to the country's export potential. This dual role — ensuring national food security while participating in international agricultural markets — provides both opportunities and responsibilities. The sustainability of this role depends on the region's ability to address persistent challenges while maximizing its strengths (Ibrahimli, 2017, pp. 112–125).

One of the most pressing issues is water scarcity. Although the region benefits from the Kura and Araz rivers and major irrigation canals, the current distribution system often suffers from inefficiencies, leakages, and unequal allocation. Climate change has intensified this problem by reducing the predictability of precipitation and increasing evaporation rates during hotter summers (UNEP, 2020).

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Soil salinization represents another critical environmental threat. Poor drainage systems and excessive irrigation with mineral-rich water have already degraded certain tracts of arable land, particularly in low-lying areas. If not addressed through systematic reclamation measures — including improved drainage, crop rotation with salt-tolerant species, and organic soil amendments — this process could lead to irreversible productivity losses (Aliyev, 2022, pp. 20–31).

From a socio-economic perspective, the region's demographic potential is both an asset and a challenge. A relatively young and active population can support labor-intensive agricultural practices, but mechanization and technological shifts risk creating underemployment if alternative rural income sources are not developed. This underlines the importance of agro-industrial diversification — developing processing plants, storage facilities, and value-added production chains that can absorb labor and enhance the profitability of farming (Aliyev, 2022, pp. 20–31).

Another dimension is market integration. While Central Aran produces significant volumes of agricultural products, small-scale farmers often face barriers in accessing larger markets due to limited transportation infrastructure, insufficient storage capacity, and lack of cooperative networks. Strengthening regional logistics hubs, particularly in cities such as Yevlakh and Mingachevir, could transform the efficiency of product distribution, reduce post-harvest losses, and open new trade opportunities.

Policy interventions will be crucial to this transformation. Targeted subsidies for modern equipment, preferential credit lines for smallholders, and training programs on sustainable farming can accelerate the adoption of innovative practices. Moreover, collaboration between state institutions, private investors, and research organizations will create a foundation for evidence-based decision-making. Agricultural research stations in the region should focus on developing drought-resistant crop varieties, optimizing irrigation schedules, and promoting integrated pest management (Aliyev, 2022, pp. 20–31).

References

1. Aliyev, N. (2022). Cotton farming and modernization in Central Aran. *Journal of Agricultural Innovations*, 5(2), 20–31.
2. Abdullayev, A. (2020). Geographical problems of Central Aran. Elm Publishing.
3. FAO. (2021). Irrigation systems in the South Caucasus: Challenges and opportunities. Food and Agriculture Organization.
4. Hasanov, R., & Aliyeva, G. (2022). Agricultural potential of Central Aran: Analysis and prospects. *Azerbaijan Geographical Review*, 28(1), 15–29.
5. Huseynov, T. (2019). Water resource management in Central Aran. *Water Policy Journal*, 15(1), 55–68.
6. Ibrahimli, E. (2017). Environmental risks in semi-arid zones of Azerbaijan. *Caspian Environmental Journal*, 9(3), 112–125.
7. Mammadov, S. (2018). Economic development of Azerbaijan's lowland regions. *Journal of Regional Studies*, 12(2), 34–49.
8. State Statistical Committee of Azerbaijan. (2023). Agricultural indicators by economic regions.
9. UNEP. (2020). Environmental assessment of the Kura-Araz Basin. Geneva: United Nations Environment Programme.

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Jeyhuna Hamidova
Baku State University
https://orcid.org/0000-0002-9107-8545
hamidovaceyhuna@gmail.com

The Effect of Hypokinesia on the Reproductive Outcomes of Pregnant Rabbits and the Biometric Parameters of Their Offspring

Abstract

The effect of hypokinesia on blood parameters during various stages of pregnancy in pregnant rabbits was investigated. Hypokinesia acts as an adverse extreme factor negatively affecting the course and outcome of pregnancy in pregnant rabbits, leading to resorption of the fertilized egg or embryo, as well as the birth of offspring with reduced viability and miscarriage. Pregnant rabbits subjected to hypokinesia during different prenatal developmental stages (embryonic, fetal, and late fetal periods) experienced stress conditions that impacted the blood parameters, body weight, and survival rates of their offspring. Hypokinesia during pregnancy results in fetal developmental delay and causes a 47% reduction in reproductive capacity when imposed during the embryonic stage. Movement restriction negatively influences the quality of life of both the mother and the fetus, weakening oxygen transport systems and potentially impairing placental blood circulation. Therefore, investigating prenatal hypokinesia is highly relevant. The main objective of this study is to examine the reproductive capacity and dynamic changes in biometric indicators before and after hypokinesia exposure in both intact and hypokinesia-exposed pregnant rabbits at various prenatal developmental stages.

Keywords: *ontogenesis, hypokinesia, reproduction, biometric indicators*

Introduction

Restriction of physical activity leads to morphofunctional alterations in vital systems and affects cellular genetics (Zaripova et al., 2014). In the 20th century, among various ecological factors emerging due to scientific and technological progress, reduced physical activity in humans — *hypokinesia* — and muscle function weakening — *hypodynamia* — have become prominent. Their negative effects manifest throughout all stages of ontogenesis, including the embryonic development period (Kovalenko & Gurovski, 1980; Shchedrina, 1989).

Evidence in the literature indicates that hypokinesia, particularly when prolonged, manifests in the functioning of the central nervous system as well as in the mechanisms involved in the formation and regulation of its fundamental processes (Mahmudova, 2018). Studying the impact of limited physical activity (*hypokinesia*) on the organism remains a pressing issue in physiology. Movement restriction induces morphofunctional changes in vital systems and affects the genetic apparatus of cells (Dolganova, 2008; Kozlovskaya, 2003; Tkachenko, 2011).

The most pronounced changes during hypokinesia occur in the musculoskeletal system, with restricted muscle activity being a key feature of hypokinetic syndrome. Research shows that 15 days of hypokinesia in mice reduces motor activity by 66.7%, 30 days by 78.9%, and 45 days by 91.4%.

Research

Hypokinesia during pregnancy disrupts mother–fetus interactions, resulting in changes in the number and survival dynamics of the offspring. Although predicting the future child's health is challenging, it is possible to prevent negative influences of some external and internal factors on the developing fetus and mitigate their consequences (Shirochenko, 2003).

Long-term studies conducted under the supervision of A. G. Gaziyev in the "Environmental Factors and Development of Analyzers" Laboratory at the Institute of Physiology named after academician A. Garayev have shown that the impact of factors such as chronic hypoxia, hypokinesia,

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and electromagnetic radiation during critical periods of embryonic development leads to significant developmental delays and increased mortality rates among newborn rats.

The findings of this study can be used for direct and indirect analysis of functional changes in the brain of offspring born to mothers exposed to hypokinesia during pregnancy, especially during later postnatal developmental stages. Given that prolonged maternal hypokinesia during gestation can affect the formation of fetal or embryonic brain structures and its effects may persist postnatally, these factors must be considered in the study of the neurophysiological and neurobiochemical aspects of hypokinesia.

The results obtained are of considerable clinical and biomedical importance in analyzing functional changes arising from prolonged limited movement conditions in sedentary pregnant women and their offspring.

Materials and Methods

Experiments were conducted using pregnant rabbits of the *Chinchilla* breed, newborn kits, and 30-day-old kits. The effects of hypokinesia on the biometric parameters of newborn and 30-day-old kits, as well as on the reproductive capacity of pregnant rabbits and the survival rate of offspring, were studied. For each stage of pregnancy, 8–10 female rabbits were used.

The gestation period for rabbits lasts 28–30 days. Adult rabbits measure 43–58 cm in length and weigh between 950 and 1350 grams. Animals were kept in dry, heated rooms with good natural and artificial lighting. Male and female rabbits were housed separately during pregnancy.

All pregnant rabbits were divided into two groups: control and experimental. The control group was maintained under normal vivarium conditions, while the experimental group was subjected to hypokinesia at different stages of pregnancy. To create hypokinesia conditions, specially sized cages were designed to allow the pregnant rabbits to sit only, restricting movement.

According to E. A. Kovalenko and N. N. Gurovski (1980), one of the methods to induce hypokinesia in experimental studies is housing small animals in spatially and volumetrically reduced cages. Blood samples (1–1.5 ml) were collected from the ear veins of pregnant rabbits in both control and experimental groups for analysis. This procedure is considered non-invasive and minimally traumatic, complying with bioethical standards.

All experiments were conducted in accordance with the European Union International Convention (November 13, 1987, Strasbourg) and animal welfare principles.

Conclusion

In the initial phase of the study, reproductive capacity was assessed in control and experimental groups exposed to prenatal hypokinesia at all three stages of pregnancy. In the control group, one rabbit produced an average of 7–8 offspring, with 67 kits born from 10 rabbits, of which 3 died. In contrast, hypokinetic rabbits produced an average of 4–5 kits each. During the embryonic stage, 10 rabbits were mated, 7 gave birth, yielding 32 kits, with 11 mortalities. This indicates a 47% reduction in reproductive capacity due to hypokinesia during the embryonic stage. During the fetal and late fetal stages, 7–8 rabbits out of 10 gave birth, producing 49 kits with 13 mortalities and 52 kits with 7 mortalities, respectively. Body weights of newborn kits were as follows: control group — 67 ± 9.544 g; kits born to mothers subjected to hypokinesia during the embryonic stage — 49.8 ± 2.867 g; fetal stage — 51.6 ± 4.05 g; late fetal stage — 46.2 ± 3.19 g. For 30-day-old kits, weights were: control — 651.2 ± 40 g; embryonic stage hypokinesia — 421.6 ± 76.0 g; fetal stage — 527.8 ± 81 g; late fetal stage — 302.4 ± 30 g

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Table 1. Biometric parameters of newborn and 30-day-old rabbits under conditions of hypokinesia during various periods of prenatal development.

№	Kontrol (gr)	Embrionic period (gr)	Pre-fetal period (gr)	Fetal period (gr)
New born	67±9,544	49,8±2,867	51,6±4,05	46,2±3,19
30 days	651,2±40,0	421,6±76,0	527,8±81,6	302,4±30,0

Discussion of Results

The changes in hemoglobin and platelet counts during various stages of pregnancy caused by the influence of the *hypokinesia* factor exert a negative impact on pregnancy and its progression. These alterations contribute to the disruption of reproductive functions (Hamidova, 2025).

Based on the obtained results, it can be concluded that the number of offspring significantly decreased during the early stages of pregnancy (E0–E10, embryonic period) in pregnant rabbits exposed to *hypokinesia*. The overall data from the experimental groups demonstrated a 47% reduction in offspring number compared to the control groups.

Specifically, the several-fold increase in platelet count during this period adversely affects the course of pregnancy, leading to resorption of the fertilized egg or embryo and the birth of offspring with reduced viability. Additionally, the research revealed that among the critical periods of pregnancy, the fetal period (E10–E20) is the most resilient to the destructive effects of the *hypokinesia* factor. During this stage, significant changes in hemoglobin and platelet levels were not observed.

Regarding the changes occurring during the late fetal period, an increase in platelet count may raise the risk of infarction and stroke in the heart and cerebral vessels.

Based on our study, it can be asserted that *hypokinesia* negatively influences the reproductive capacity of pregnant rabbits. Evidence from previous studies investigating the effects of prenatal *hypokinesia* demonstrated significant deviations in physiological indicators of the newborn offspring as a consequence of maternal *hypokinesia* during pregnancy (Ağayeva, 2019).

References

1. Aghayeva, E. N. (2019). A review of the history of hypokinesia as a current problem. In *International Scientific Conference on Current Problems of Natural and Economic Sciences*. GDUY, 134.
2. Dolganova, T. H., Luneva, S. H., Kolcherpina, V. V., Tkachuk, E. A., Romanenko, S. A., & Gasanova, A. G. (2008). Functional state and metabolism of major electrolytes in humans under hypokinesia (literature review). *Modern High-Tech Technologies*, *11*, 6–10.
3. Drozdov, D. N., & Kravtsov, A. V. (2015). The effect of physical activity on peripheral blood parameters in humans. *Vestnik MGPU named after I.P. Shamyakin*, *4*, 23–28.
4. Grigoryev, A. N., Kozlovskaya, N. B., & Shenkman, B. S. (2004). The role of support afferentation in the organization of the tonic muscular system. *Russian Physiological Journal named after I.M. Sechenov*, *90*(5), 508–521.
5. Hamidova, J. (2025). Primary quantitative changes in hemoglobin and platelets under the influence of hypokinesis at different stages of prenatal development. *Scientific Research International Scientific Journal*, *5*(2), 139–143.
6. Hamidova, J. (2025). *Study of hematological parameters of rabbit offspring subjected to prenatal hypokinesia.* (3), 156-157
7. Kovalenko, A. E., & Gurovski, N. N. (1980). *Hypokinesia*. Medicina.

8. Kozlovskaya, N. B., & Kirenskaya, A. V. (2003). Mechanisms of disruption of precise movement characteristics during prolonged hypokinesia. *Russian Physiological Journal named after I.M. Sechenov*, *89*(3), 247–258.
9. Shirochenko, N. D., Rykhlikova, G. G., Aksenova, N. P., & Bondar, N. N. (2003). Influence of hypokinesia and some climatic factors on embryogenesis. *Scientific Bulletin*, 196.
10. Shchedrina, A. G. (1989). *Ontogenesis and the theory of health: Methodological aspects*. Nauka.
11. Tkachenko, A. V. (2011). Metabolic processes in the heart and liver of rats during experimental hypokinesia and their correction with phytosyrup "Valeoton". *Bulletin of Kharkiv National University named after V. N. Karazin*, *14*(971), 177–184.
12. Zaripova, R. I., Andrianov, V. V., Yafarova, G. G., Gaytundinov, Kh. L., Khabibrakhtanov, I. I., & Zefirov, T. L. (2014). Influence of different durations of hypokinesia on the dynamics of nitric oxide production in the heart, spinal cord, and liver of rats. *Russian Journal of Physiology*, *100*(8), 926.
13. Mahmudova, N. Sh. (2018). *Dynamics of electroencephalogram formation in the cerebral cortex of rats exposed to hypokinesia during the perinatal period (Author's abstract).*

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Elnura Safarova
Azerbaijan State Pedagogical University
https://orcid.org/0000-0002-4151-1750
seferovaelnure@mail.ru
Konul Mahmudova
Azerbaijan State Pedagogical University
https://orcid.org/0000-0001-7042-9257
mahmudova.konul@adpu.edu.az

Absheron Region Garden and Forest Plant Pests and Their Integrated Entomophage Complexes

Abstract

Various pest species cause extensive damage to garden plants, trees, and shrubs in the Absheron region, resulting in annual yield reductions of 30–50%, which can escalate to 80–90% during periods of intensive plant growth. Scientific foundations have been developed in Azerbaijan aiming at the biological control of major pest species through the use of effective entomophages. These foundations focus on the species composition and bioecological characteristics of six insect species that damage garden and forest vegetation, as well as their natural enemies, including parasites and predators that regulate their populations. The investigation of pest and entomophage species diversity, their bioecological traits, and distribution patterns across green spaces in the Absheron natural zone was carried out using classical entomological techniques, specialized methodological tools, and authoritative identification references. These include works by N. F. Meyer (1933–1936), N. A. Telenga (1936), and I. A. Rubchov (1948).
Keywords: *Absheron region, garden, entomophages, insect, plant, forest, integrated*

Introduction

Like all areas of socio-economic and cultural life of Azerbaijan, the ecological situation of our republic is also in the focus of attention of the President of the country, and a consistent plan of targeted measures is being implemented in this area. The *Comprehensive Action Plan for Improving the Ecological Situation in the Republic of Azerbaijan*, approved by the 2006 decree of the President of the Republic of Azerbaijan, is aimed at improving the environment in the country, including Baku and the Absheron Peninsula.

Research

The study of pest and entomophage species composition, their bioecological features, and distribution patterns in the green areas of the Absheron natural region was conducted using standard entomological methods, tools, and reference materials (Meyer, 1933–1936; Telenga, 1936; Rubchov, 1948). In addition, to determine the species composition and morphological features of pests and entomophages, MBS-1 and MBS-9 microscope magnifiers, a *Biolom* microscope, a *Canon* digital camera, and a luxometer were used to determine the degree of light irradiation. As a result, complex entomophages of several insects that cause serious harm were discovered (Mirzoeva, 2001).

1. **Complex entomophages of the willow moth (*Pandemis heperani* Den. et Schiff.)**

The entomophages of the willow moth are represented by polyphagous parasites and predatory insects (four-spotted carrion beetle, ladybird). In this context, the entomophage complex of the willow moth warrants thorough study, as information on it remains very limited (Muradova, 2015).

According to studies, it would be more interesting to examine the entomophages of the willow moth in places where it is most abundant — in cities, streams, and various geographical areas. We found that the infection of young caterpillars with entomophages by arthropods is 20%, and of older

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caterpillars by dipterans — 37%. Among the entomophages, *Apanteles solitarius* Ratz., *A. inclusus* Ratz., tachin flies — *Complisura concinnata* Mg., *Zenilla libathrix* Panz., *Exorista larvarium* L., and sarcophagus — *Pseudosarcophaga offinis* Flln. are widespread (Aslan & Warchalowski, 2001).

2. Complex entomophages of the silver butterfly (*Cacoecia lecheana* L.)

The entomophage complex of the silver butterfly was examined between 2010 and 2015 during periods of mass oak tree growth in open fields. Infection of the caterpillar stage of the butterfly by entomophages takes the second place. They consist of six hymenopteran and three dipteran species in a complex.

Among them, the parasite that infects eggs, *Telenomus brevis* Thoms., is of greater importance. It destroys 24.2–32.3% of eggs in different years. A number of authors have named the species *Telenomus laeviusculus* Ratz., *Telenomus mayri* Kieff., *Anastatus bifasciatus* Fons., and *Teleas punctatissimus* Ratz. as egg parasites. Such a large number of egg-eaters is due to the correct location of eggs in the bark of oak trees. In some cases, even 84–94% infection was noted.

In 2012–2014, the mass reproduction of the silver butterfly in the egg stage in oak forests in the Sheki–Zagatala region was completely suppressed by the parasite *Trichogramma evanescens* Westw. In 2013–2014, during the repeated mass reproduction, infection of the caterpillar and pupal stages with the parasite *Barylypa longicornus* Brauns. was noted. In some foci of infection, the rate of infection reached 35–40%. In 2015, the role of this parasite was more significant during mass reproduction (Toth, Schmera, & Imrei, 2004).

Dusona falcator F., *Coclichneumon cingulars* Bert., and *Enicospilus rossicus* Kok. parasites were less frequently recorded. In recent years, no silver butterfly caterpillars were found on the parasite. The decrease in the number of the pest was due to the presence of tachinids — *Drino inconspicua* Mg., *Exorista fallax* Mg., *Exorista unicolor* Stein., *Tachina magna* Giglio Tos., *Compsilura concinnata* Meig., and *Zenillia libatrix* Panz.

The species *Meteorus fragilis* Wesm., recorded in St. Petersburg by I. A. Porchinsky (1911), has not been found in Azerbaijan. According to the conducted studies, 10.6% of silver butterfly pupae were infected by the parasite *Cyclogastrella deplanata* Nees in 2014 and 27.4% in 2015. These species are highly developed and effective among the complex parasites of the silver butterfly, and their complex use in biological control was also proposed by I. A. Porchinsky (1911) (Balakhanova, 2024).

3. Complex Entomophages of the Ringed Beetle (*Malacosoma neustria* L.)

The complex entomophages of this pest consist of 93 species, mostly polyphagous. The use of the parasite *Telenomus laeviusculus* Ratz. has been proposed for the biological control of the ringed beetle in forests and orchards. It was found that the ringed beetle is infected with six species of parasites in the egg phase — *Telenomus* spp., mainly *Ooencyrtus tardus* Ratz., and *Anastatus bifasciatus* Fons. Oviparous insects form a common complex and are found at all developmental stages of the pest.

Other parasites are associated with caterpillars — 32 species in total, including 19 species of horseflies and 13 species of tachinids. The composition of the parasite complex also changes depending on the beetle's reproduction conditions in different geographical regions (Valiyeva & Hasanova, 2022).

In all complexes associated with various populations, braconids such as *Apanteles spurius* Wesm. and *Meteorus versicolor*, ichneumonids such as *Pimpla turionella*, *Teronia atalanta*, and representatives of the genera *Casinaria*, *Campoplex*, and *Barylypa* are more common. Among polyphagous taxa, species such as *Carcelia exisa* Fall., *C. gnava* Meig., *Zenillia libatrix* Panz., *Blondelia nigripes* Fll., *Compsilura concinnata* Mg., and *Phryxe vulgaris* Fall. are frequently found.

In the list compiled by V. A. Shapiro (1960), sarcophagid flies were rarely observed, while in our studies, 2–3 species were recorded. Predatory insects that feed on the ringed beetle include mainly carabid beetles and brown ants (Mamedov, 2004). During periods of mass pest reproduction, the population infection rate with complex entomophagous insects reached 70%. In general, the complex entomophagous agents of the ringed beetle are not sufficiently effective, and only specifically designated ovipositors can be used for active biological control (Ben-Yehuda, Assael, & Mendel, 2000).

4. Complex Entomophages of the Green Oak Leaf Beetle (*Tortrix viridana* L.)

Entomophages of the green oak leaf beetle have been studied by many researchers both in Azerbaijan and abroad. The entomophage complex in a single mass breeding site of the host typically includes 12–30 parasite species. According to conducted studies, the impact of complex entomophages on different populations of the green oak leaf beetle is generally limited and not sufficiently effective to significantly reduce the pest's damage.

Among parasites in Absheron, 93% of those collected from caterpillars of the green oak leaf beetle belong to *Phaeogenes invisor* Thunb. In oak groves across other regions of Azerbaijan, this parasite also predominated (Mammadov, 2004). In 2015, infection of leaf beetle pupae with this parasite reached 25%. During mass breeding of the host, *Apechthis resinator* Thunb. and *Apechthis rufata* Gm. were dominant, while *Pimpla turionellae* L., *Pimpla instigator* F., and *Itoplectis alternans* Grav. were also frequently encountered.

In the Lankaran–Astara zone, the main parasite of leaf beetle pupae was *Phaeogenes invisor* Thunb., followed by the tachinid fly *Elodia tragica* and the chalcid *Brachymeria rugulosa* (Safarova, 2024b). The number of *Apechthis* and *Itoplectis* species was relatively small. In 2014–2015, infection of pupae with parasites ranged from 7.2–7.4%, increasing to 28.5–39% in subsequent years.

Parasites of caterpillars were almost insignificant. Although their numbers were approximately double those of pupal parasites, infection rates were only 3%. The main caterpillar and caterpillar–pupal parasites were *Microgaster meridiana* Hal., *Apanteles xanthostigma* Hal., and *Angitia fenestralis* Holmgr (Beibutov, 1965). In Azerbaijan, the leading species in the pupal stage was *Phaeogenes invisor*. Among all parasites found, *Phaeogenes invisor* accounted for 81.5% in the Sheki–Zagatala region and 44.7% in Ganja–Gazakh. Polyphagous parasites also play a significant role in reducing pest infestation levels (Kondo & Watson, 2022).

According to studies, the parasite complex of the green oak leaf beetle in Azerbaijan includes 35 species: 10 ichneumonids, 8 braconids, 11 chalcids, and 6 tachinids (Meyer, 1933–1936).

5. Complex Entomophagous Species of Wood Pests

Extensive research has been conducted on the complex entomophagous species of horntails and long-horned beetles. Entomophagous species of other xylophagous pests have been studied to a lesser extent (Moiseeva & Polyakova, 1970). In our research, the entomophagous species of the pine fiber beetle, tip beetle, large black pine beetle, and typographer beetle were studied in the Absheron region. In all complexes, the main role is played by predatory insects that feed on the root parts of trees (Rubtsov, 1948).

Conclusion

The study focused on identifying major pest species affecting garden and forest plants in the Absheron region of Azerbaijan and analyzing their associated entomophage complexes. Classical entomological methods and diagnostic tools were employed to determine the species composition, bioecological features, and distribution patterns of both pests and their natural enemies.

The willow leafroller (*Pandemis heperana*) was found to be parasitized by hymenopteran and dipteran species, with infection rates reaching 20% in younger larvae and 37% in older ones (Shapiro, 1960). Key parasitoids included *Apanteles solitarius*, *Complisura concinnata*, *Zenillia libatrix*, and *Pseudosarcophaga offinis*. Despite high parasitism rates during outbreaks, only specific egg parasitoids were considered effective for biological control.

These findings highlight the ecological role of entomophages in regulating pest populations and their potential application in integrated pest management strategies. Further research and targeted use of these natural enemies could enhance sustainable pest control in Absheron's forest and garden ecosystems (Safarova, 2024a).

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References

1. Aslan, I., & Warchalowski, A. (2001). New records of the subfamily Galerucinae (Coleoptera: Chrysomelidae) for the Turkish fauna. *Zoology in the Middle East*, 16, 85–87.
2. Balakhanova, G. V. (2024). Ecology and trophic specialization of fungi recorded in the lands of Baku. *Nature and Science*, 6(1), 24–27. https://doi.org/10.36719/2707-1146/40/
3. Beibutov, R. A. (1965). Entomophages and microorganisms in the control of fruit crop pests. *Proceedings of the Scientific Session of Entomologists of Azerbaijan*, 36–37.
4. Ben-Yehuda, S., Assael, F., & Mendel, Z. (2000). Improved chemical control in stone-fruit plantations in Israel. *Phytoparasitica*, 28(1), 1–16.
5. Kondo, T., & Watson, G. W. (2022). A list of scale insect agricultural pests. In *Encyclopedia of Scale Insect Pests*. CABI, 8-37.
6. Valiyeva, L., & Hasanova, G. (2022). AGRIS record. https://agris.fao.org/search/en/providers/124082/records/6474a75b1a9cd02c1d8f9137
7. Mamedov, Z. M. (2004). *Parasites of harmful scale insects of fruit crops in Azerbaijan and methods of their use in biological protection*. Elm, 209.
8. Mammadov, Z. M. (2004). *Parasites of lepidopterans damaging fruit plants in Azerbaijan and ways of their use in biological control*. Elm.
9. Meyer, N. F. (1933–1936). *Parasitic Hymenoptera of the family Ichneumonidae of the USSR and adjacent countries* (Vols. I–IV).
10. Mirzoeva, N. (2001). A study of the eco-faunal complexes of the leaf-eating beetles (Coleoptera: Chrysomelidae) in Azerbaijan. *Turkish Journal of Zoology*, 25, 41–52.
11. Moiseeva, Z. A., & Polyakova, R. V. (1970). *Quarantine pests of orchards and measures for their control*. Gardening.
12. Muradova, E. M. (2015). About biology and entomophages of Ermine moth in Sheki–Zagatala region of Azerbaijan. *Visnyk of Zaporizhzhia National University: Biological Sciences*, (1), 33.
13. Rubtsov, I. A. (1948). *Biological method of pest control*. OGIZ, Selkhozgiz, 411.
14. Safarova, E. F. (2024a). The oriental fruit moth (Grapholitha molesta Busck.) and its natural enemies in the Absheron Peninsula. *AEM. Nature & Science*, 6(9), 29–33.
15. Safarova, E. F. (2024b). Methodology of teaching aesthetic education issues in teaching zoology. *Scientific Works of ARTI*, 91(1), 155–158.
16. Shapiro, V. A. (1960). The role of parasites in reducing the number of ringed silkworms. *Proceedings*, 15, 71–86.
17. Toth, M., Schmera, D., & Imrei, Z. (2004). Optimization of a chemical attractant for Epicometis (Tropinota) hirta Poda. *Zeitschrift für Naturforschung C*, 59, 288–292.

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Gizyetar Shabanova
Azerbaijan State Agrarian University
Master student
https://orcid.org/0009-0006-5725-1101
qizyetersabanova@gmail.com

The Environmental Problems Caused by Industrial Activities in the Ganja Region

Abstract

Ganja city, located in the western part of Azerbaijan, is the country's second-largest industrial center, hosting enterprises in metallurgy, chemistry, machinery, construction materials, food, and light industries. Although industrial activities contribute positively to economic growth and employment, they exert significant anthropogenic pressure on air, soil, and water ecosystems. The study uses monitoring reports of the Ministry of Ecology and Natural Resources for 2023–2024, scientific articles, and laboratory analysis results. Concentrations of $PM_{2.5}$ and PM_{10} particles in the atmosphere, as well as heavy metals (Pb, Zn, Cu, Cd) in soil and water, were evaluated and compared with international standards. The research revealed that industrial enterprises in Ganja cause air pollution, soil fertility decline, changes in the chemical composition of water bodies, loss of biodiversity, and disruption of local climatic conditions. The findings emphasize the necessity of implementing environmental management measures, modern purification technologies, the creation of green zones, and the promotion of public participation. These actions are essential for ensuring sustainable industrial development and ecological stability in Ganja city.

Keywords: *Ganja city, industrial pollution, air quality, soil and water ecosystems, biodiversity, environmental management*

Introduction

Ganja, located in the western part of Azerbaijan, is the country's second-largest industrial center, hosting a diverse range of enterprises in metallurgy, chemical production, machinery, construction materials, food, and light industries. While industrial development contributes significantly to regional economic growth and employment, it also imposes considerable anthropogenic pressure on environmental components, including air, soil, and water ecosystems. Long-term industrial emissions, including particulate matter, heavy metals, and chemical reagents, have resulted in environmental degradation, biodiversity loss, and disruption of local climatic conditions. Monitoring data and research indicate that industrial zones in Ganja, particularly around major plants such as the Ganja Aluminum Plant and chemical facilities, are hotspots of pollution, affecting not only ecosystem health but also human well-being. The complexity of these impacts highlights the urgent need for integrated environmental management, modern purification technologies, green buffer zones, and active public participation. This study aims to analyze the environmental consequences of industrial activities in Ganja, focusing on air, soil, and water quality, as well as biodiversity, and to propose strategies for sustainable industrial development and ecosystem restoration.

Research

Industrial Activities and Sources of Pollution

The industrial infrastructure of Ganja is primarily concentrated in the eastern and southern parts of the city. The operation of metallurgical and chemical enterprises in these areas results in the emission of carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO_x), and particulate matter into the atmosphere. These gases remain in the lower layers of the atmosphere for extended periods, altering air composition and contributing to the formation of acid rain (Aliyev et al., 2024).

Dust waste from the metallurgical industry contains high levels of iron, copper, lead, and zinc compounds, which leads to the contamination of soils and water bodies. Research conducted near the

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Ganja Aluminum Plant revealed that lead concentrations in the topsoil exceeded the norm by 3–4 times, while cadmium concentrations were twice as high (Asgarov, 2022). This situation negatively affects the composition of soil microflora and vegetation. Hydrobiological balance in the Ganjachay basin has been disturbed due to pollution. Aquatic organisms, particularly plankton and benthos species, have decreased in number, and certain fish species (especially carp and catfish) have abandoned polluted zones. The accumulation of heavy metals in soil has led to the degeneration of riparian vegetation and a reduction in biodiversity (Gasimov, 2022).

Soil analyses indicate that in areas along the Ganjachay riverbed, concentrations of Pb and Cu elements exceed normative values by 3–5 times. Crops grown on these soils accumulate toxic substances, indirectly affecting human health (Bayramova, 2023).

In chemical industry facilities, chlorine compounds and catalytic reagents enter the Ganjachay basin, increasing the chemical oxygen demand (COD) and biological oxygen demand (BOD) of the water. Consequently, the self-purification capacity of the water is weakened, and oxygen deficiency occurs in aquatic ecosystems (Mammadli, 2023). Industrial pollution in the Ganjachay area poses serious risks to regional water, soil, and biodiversity. Without strengthened regulatory measures, this pollution may lead to long-term hazards for both the ecosystem and human health. Implementing environmental policies aligned with sustainable development principles, applying modern purification technologies, and enhancing public responsibility are crucial conditions for restoring the ecological balance of the Ganjachay river.

Environmental Restoration and Management Measures

In recent years, the Ministry of Ecology and Natural Resources (MENR) has conducted ecological monitoring programs in the Ganjachay. According to the 2023 report, the discharge of some industrial wastewater has been limited, and local treatment facilities have been installed in some enterprises (MENR, 2023).

For effective ecological restoration, the following measures are essential:

- Industrial facilities should treat wastewater through two-stage biological and chemical purification systems;
- Riparian areas should be restored with protective green belts;
- A digital hydrobiological monitoring system should be established for Ganjachay, enabling real-time tracking;
- Local communities and environmental NGOs should be actively involved in the process.

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Atmospheric Pollution and Its Consequences

According to the 2024 data from the MENR, the annual average concentration of PM_{10} particles in Ganja's industrial zones ranged from 54–68 $\mu g/m^3$, exceeding normative limits by 1.5–2 times (Ministry of Ecology and Natural Resources of the Republic of Azerbaijan, 2024). These values reduce the air quality index (AQI) and pose health risks to the population.

Inhalation of particulate matter can lead to bronchitis, lung diseases, and allergic reactions (Cafarov & Ismayilova, 2023). One direct consequence of atmospheric pollution is the formation of the urban heat island effect. Combined with global warming, this effect alters the local microclimate, increasing air temperatures by 1.2–1.8°C (Gurbanov, 2024).

Ganja, as Azerbaijan's second-largest industrial center, hosts enterprises in metallurgy, machinery, chemical, food, and construction material industries. The activities of these enterprises have long contributed to the emission of various pollutants into the atmosphere. Improper management of industrial waste, outdated purification systems, and insufficient regulatory mechanisms have sometimes caused air quality to exceed normative standards (Ministry of Ecology and Natural Resources of the Republic of Azerbaijan, 2023).

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The main sources of pollution in Ganja's industrial zone include the Ganja Aluminum Plant, Ganja Automobile Plant, chemical enterprises, energy facilities, and, to a lesser extent, domestic waste incineration. These sources emit carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NOx), particulate matter (PM_{10} and $PM_{2.5}$), lead, formaldehyde, phenol, and other harmful substances into the atmosphere. These pollutants remain suspended for long periods, posing serious threats to human health and ecosystems (Aliyev, 2022).

Industrial emissions result in elevated dust and gas concentrations over Ganja, particularly in autumn and winter. During these periods, weakened air circulation, humidity, and temperature inversion lead to the accumulation of pollutants in the lower atmosphere, increasing respiratory diseases. According to MENR monitoring conducted in 2023, the annual average concentration of $PM_{2.5}$ particles in Ganja was 28–30 µg/m^3, twice the safe limit established by the World Health Organization (MENR, 2023).

Atmospheric pollution also affects local climatic conditions. Dust and aerosol particles absorb part of solar radiation, reducing surface warming and altering local heat balance. Sulfur and nitrogen compounds in industrial emissions react with atmospheric water vapor to produce acid rain. These rains increase soil and water acidity, damage urban greenery, reduce soil fertility, and disrupt biodiversity (Gasimov, 2022).

From a human health perspective, industrial air pollution generates serious socio-ecological problems. In recent years, there has been an increase in respiratory diseases in Ganja, particularly bronchitis, asthma, and allergies. $PM_{2.5}$ and PM_{10} particles penetrate deep into the lungs, accelerating chronic respiratory conditions. The presence of heavy metals, especially lead (Pb), in the air negatively affects children's nervous system development (Huseynov, 2024).

At the ecosystem level, atmospheric pollution indirectly impacts soil and water systems. Pollutants deposited by rainwater alter water chemistry and reduce soil microbial activity. Studies conducted in Ganjachay and Hacıkənd indicate that industrial deposition of atmospheric pollutants has increased heavy metal concentrations in soils several times above permissible levels (Bayramova, 2023).

Recent measures for air protection in Ganja include the installation of filtration systems in several industrial enterprises and the application of mechanical and electrostatic devices for gas purification. Additionally, MENR implements an "Annual Monitoring Program of Ganja's Atmospheric Air Quality," with results publicly available (MENR, 2024). Promoting the use of gas- and electric-powered public transport has also contributed to reducing air pollution.

For these measures to be effective, a comprehensive ecological management system is necessary. Each industrial enterprise must implement an emission accountability mechanism and expand real-time air quality monitoring systems. Increasing green areas, establishing protective forest zones around the city, and raising public environmental awareness are also critical steps.

In conclusion, industrial activities in Ganja have a direct negative impact on atmospheric quality, regional ecological stability, and public health. Addressing this problem requires technological modernization, strict enforcement of environmental standards, and strengthened ecological monitoring. Achieving sustainable development in Ganja's industrial zones demands a culture of environmentally responsible production, with air quality preservation recognized as a shared goal by both government and society.

Soil and Water Ecosystem Impacts

Soil pollution in Ganja's industrial zones is primarily observed in the metallurgy and construction materials sectors. Soil mechanical structure is disturbed, humus content decreases, and pH levels drop from 6.5 to 5.8, reducing biological activity (Rustamov, 2021). Crops grown on contaminated soils accumulate heavy metals, which enter the food chain (Huseynov, 2022).

Ganjachay and its tributaries are the primary receivers of industrial wastewater. The discharged waters contain not only chemical pollutants but also biologically active substances. In 2023, analyses showed that the concentration of petroleum products in Ganjachay water was 0.22 mg/L and copper

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0.19 mg/L, exceeding normative limits (Mammadli, 2023). As a result, fish populations have weakened, and certain aquatic organisms' populations have decreased by 40% (Gurbanov, 2024).

Industrial activities alter soil chemistry, reducing fertility and structural quality. Heavy metals such as lead (Pb), copper (Cu), zinc (Zn), and cadmium (Cd) accumulate in soils near industrial facilities, reducing microbial activity and hindering root development, ultimately lowering agricultural productivity (Aliyev & Huseynova, 2022).

Plants growing in heavy-metal-contaminated soils bioaccumulate these elements, introducing them into the food chain, posing risks to both human health and ecosystem stability. Agroecological studies near Ganja indicate that cadmium and lead concentrations exceeding 0.3–0.8 mg/kg cause toxic biochemical changes in plants (Ismayilov, 2021).

Water ecosystems are also affected. Untreated industrial wastewater discharged directly into Ganjachay increases chemical oxygen demand (COD) and biological oxygen demand (BOD), disrupting oxygen balance and reducing aquatic flora and fauna (MENR, 2024).

Excess nitrogen and phosphorus in wastewater accelerate eutrophication, decreasing water self-purification capacity. Fish species have declined, and some local species have disappeared due to ecological stress. Over the past decade, Ganjachay's water conductivity and total salinity increased by 25–30%, indicating industrial and domestic waste impact (Gasimov, 2023).

Groundwater contamination has also been observed. Industrial leachates and filtration processes increase nitrate, sulfate, and ammonium salt concentrations in artesian waters, affecting drinking water quality and agricultural irrigation efficiency (Hasanov et al., 2022).

Conclusions and Ecological Management Measures

The impacts of industrial activities on soil and water ecosystems in Ganja are complex and require long-term remediation. The following measures are recommended:

- Installing modern purification facilities in industrial enterprises and reusing wastewater;
- Reducing heavy metal soil contamination through phytoremediation;
- Establishing continuous water quality monitoring systems in Ganjachay;
- Developing regional ecological management plans with increased public participation.

Implementing these measures will contribute to the restoration of ecosystem resilience and support sustainable industrial development in Ganja.

Biodiversity and Ecosystem Changes

Industrial pollution has caused significant alterations in the structure of vegetation in Ganja's surrounding forests and meadows. Previously dominant species such as poplar, oak, and acacia have declined, replaced by species resistant to dust and gaseous pollutants. Negative trends are also observed in fauna: bird populations have decreased, and abnormalities in amphibians have increased (Hasanova, 2024).

Furthermore, changes in soil cover in the city's surroundings accelerate erosion processes. This disrupts water balance, reduces soil fertility, and weakens agricultural ecosystems (Aliyev et al., 2024).

Ecosystem Degradation and Habitat Reduction

Industrial activities lead to a chain reaction of pollution across soil, air, and water environments. Sulfur dioxide (SO_2), nitrogen oxides (NO_x), hydrocarbons, and heavy-metal-rich dust particles damage vegetation, reducing photosynthesis. Near facilities such as the Ganja Aluminum Plant and chemical enterprises, high dust concentrations have reduced growth rates of trees and herbaceous plants by 20–30% (Hasanov & Aliyeva, 2022).

These changes directly affect fauna habitats. Reduced availability of nests and food sources leads to a decline in populations of birds, reptiles, and small mammals. Biomonitoring in the Ganjachay basin between 2000–2023 indicates that local fish species such as the Goldern-scaled and Ganja river fish are now endangered (Gasımov, 2023).

Toxic Effects on Flora and Fauna

Heavy metals, phenols, petroleum products, and chemical reagents in industrial effluents are among the most hazardous pollutants for biodiversity. They enter plant and animal organisms via soil

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and water, disrupting physiological processes. Laboratory studies indicate that within a 5–7 km radius of Ganja's industrial zone, lead and cadmium levels in soil and plant samples exceed sanitary norms by three times (Aliyev et al., 2021). This reduces photosynthesis, protein synthesis in plants, and causes tissue degeneration.

In fauna, these chemical substances affect the nervous and reproductive systems, causing genetic mutations. Herpetological studies near Ganja show increased developmental abnormalities in frog populations due to soil and water pollution (Mammadov, 2022).

Weakening of Ecosystem Functions

Biodiversity loss reduces the self-regulating capacity of ecosystems. Deforestation and decline of green cover around Ganja accelerate soil erosion, disrupt water cycles, and weaken carbon sequestration processes. Consequently, the atmospheric concentration of greenhouse gases, particularly CO_2, increases, contributing to local climate changes. In aquatic ecosystems, eutrophication and oxygen deficiency limit the survival of fish and other aquatic organisms (Ismayilova, 2023).

Impact on Climate and Weather Conditions

Industrial activities emit greenhouse gases and other pollutants, accelerating climate change and altering local weather conditions (Ministry of Ecology and Natural Resources of the Republic of Azerbaijan, 2023). Carbon dioxide (CO_2), methane (CH_4), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and other substances generate a greenhouse effect, raising temperatures, altering humidity levels, and disrupting local microclimates. The urban heat island effect is particularly pronounced near metallurgy and chemical zones, with temperatures 1–2°C higher than surrounding areas, adversely affecting human health and the environment (Hasanov & Aliyeva, 2022).

Air pollution also modifies the chemical composition of precipitation. Sulfate and nitrate acids formed from industrial emissions lead to acid rain, increasing soil and water acidity, and negatively affecting vegetation and aquatic resources. Research in the Ganjachay basin shows that persistent acid rain has reduced soil pH below normative levels and stressed aquatic organisms (Gasimov, 2023).

Short-and long-term climate impacts result from industrial pollutants. Rising CO_2 and other greenhouse gases can cause local drought trends, changes in humidity and wind regimes, and threaten agricultural productivity, water resources, and ecosystem stability. International experience recommends reducing industrial emissions, adopting green energy, applying air filtration technologies, and establishing environmental monitoring systems (UNEP, 2022). Implementing these measures in Ganja can minimize climate impacts and stabilize local weather conditions.

Environmental Management and Restoration Measures

To mitigate the negative impacts of industrial activities on biodiversity in Ganja, the following environmental management and restoration measures should be implemented:

- Adoption of environmental management systems and strengthened ecological certification in industrial enterprises;
- Restoration of green areas and establishment of ecological corridors;
- Rehabilitation of natural habitats and programs for artificial propagation of rare species;
- Establishment of biomonitoring systems in the Ganjachay basin with regular tracking of biological indicators.

Implementation of these measures can restore ecosystem functionality and ensure sustainable industrial and ecological balance in the region.

Comprehensive actions to improve Ganja's ecological status include: installing modern filtration and wastewater treatment systems in industrial enterprises, reusing and treating wastewater, and creating green buffer zones along industrial areas for phytoremediation (Aliyeva & Mammadov, 2023).

Implementation of ISO 14001 environmental management systems increases efficiency,

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reduces resource losses, and promotes environmental responsibility (Hasanova, 2024). Public environmental education and awareness, along with monitoring mechanisms, support ecosystem restoration.

Industrial enterprises have long impacted air, soil, water, and biodiversity. Therefore, plans to prevent industrial pollution in Ganja have been developed and are being implemented.

Industrial emissions are continuously monitored by the Ministry of Ecology and Natural Resources. Measurements are taken for air quality, water, and soil parameters. If normative limits are exceeded, warnings and fines are applied. Air pollution is monitored via $PM_{2.5}$, PM_{10}, SO_2, NOx, and CO levels, while water bodies are assessed for BOD, COD, and heavy metals. Soil contamination is analyzed annually (Ministry of Ecology and Natural Resources of the Republic of Azerbaijan, 2024). These measures allow early detection of pollution and timely mitigation.

Several industrial enterprises have adopted clean production technologies, reducing waste volumes, optimizing energy use, and preventing air, water, and soil pollution. Metallurgy and chemical plants use filters, electrostatic separators, energy-efficient equipment, wastewater recycling, and circular economy principles for industrial waste processing (UNIDO, 2022).

Green belts have been established around the city and industrial zones to remove airborne dust, reduce urban heat island effects, prevent soil erosion, and protect biodiversity. Public awareness programs, environmental audits, NGO and community participation, and environmental education in schools and universities promote transparency and environmental responsibility (Aarhus Convention, 1998). Legal and institutional measures regulate industrial emissions in Ganja under the Environmental Law, applying taxes and fines, encouraging ISO 14001 certification, and managing waste and recycling systems in industrial parks. Regional ecological strategies include minimizing waste, adopting clean technologies, enhancing monitoring, expanding green zones, creating ecological corridors, implementing restoration and reclamation projects, and publicly sharing environmental information.

The overarching goal of these measures is to minimize industrial pollution impacts, protect ecosystems, and ensure sustainable industrial development. Continuous monitoring, technology modernization, and public participation are essential for effective implementation.

Conclusion

Industrial activities in Ganja have significantly impacted the city's environment, including air quality, soil and water ecosystems, biodiversity, and local climate. Metallurgical, chemical, construction material, and other industrial sectors have led to elevated emissions of carbon monoxide, sulfur dioxide, nitrogen oxides, particulate matter, and heavy metals, which accumulate in the atmosphere, soil, and water bodies. These pollutants disrupt the chemical and biological balance of ecosystems, reduce vegetation cover, degrade soil fertility, harm aquatic organisms, and endanger local fauna. Air pollution has exacerbated respiratory diseases in the population and altered microclimatic conditions, contributing to the urban heat island effect and increasing environmental stress. Soil and water contamination have introduced toxic substances into the food chain, posing direct and indirect risks to human health. Biodiversity loss and ecosystem degradation have weakened the self-regulating functions of natural systems, increasing susceptibility to erosion, eutrophication, and climate-related impacts. Mitigating these effects requires comprehensive environmental management strategies. The adoption of ISO 14001 standards, installation of modern filtration and wastewater treatment systems, restoration of green zones, establishment of ecological corridors, and implementation of continuous biomonitoring are critical steps for sustainable development. Active public participation, environmental education, and strengthened legal and institutional frameworks further support ecological restoration and long-term environmental stability.

In conclusion, achieving sustainable industrial development in Ganja necessitates a balance between economic growth and environmental protection. Only through coordinated technological, regulatory, and community-based measures can the ecological balance of the city and surrounding areas be restored, ensuring the health of both ecosystems and local populations.

References

1. Aliyev, M. (2022). *Industrial activities and atmospheric pollution in Ganja city*. Azerbaijan Journal of Ecology, 15(3), 45–59.
2. Aliyev, M., & Huseynova, L. (2022). *Impact of industrial waste on soil and water ecosystems*. Ecological Research, 8(2), 112–126.
3. Aliyev, M., Huseynova, L., & Mammadli, S. (2024). *Air quality indicators in the industrial zone of Ganja city*. Azerbaijan Air Quality Journal, 10(1), 22–35.
4. Aarhus Convention. (1998). *Convention on Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters*. UNECE.
5. Bayramova, N. (2023). *Heavy metal pollution and agroecological impacts in the Ganjachay river basin*. Azerbaijan Soil and Water Science Journal, 12(4), 78–90.
6. Jafarov, F., & Ismayilova, S. (2023). *Effects of particulate matter on the respiratory system*. Azerbaijan Medical Journal, 29(2), 134–142.
7. Ministry of Ecology and Natural Resources (MENR). (2023). *Annual report on atmospheric air quality in Ganja city*. MENR.
8. Ministry of Ecology and Natural Resources (MENR). (2024). *Air quality monitoring program of Ganja city*. MENR.
9. Huseynov, R. (2024). *Impact of heavy metals on children's nervous system in Ganja city*. Azerbaijan Pediatrics Journal, 31(1), 56–68.
10. Hasanov, V., & Aliyeva, S. (2022). *Effects of industrial pollution on flora and fauna: The case of Ganja*. Ecology and Biology, 14(2), 99–112.
11. Mammadli, S. (2023). *Chemical and biological oxygen demand in the Ganjachay river*. Azerbaijan Hydrobiology Journal, 11(3), 44–56.
12. Gasimov, A. (2022). *Effects of industrial emissions on soil, water, and ecosystems*. Azerbaijan Environmental Studies, 9(1), 12–27.
13. Gurbanov, T. (2024). *Urban heat island effect and microclimate changes: Case of Ganja city*. Azerbaijan Climate and Atmosphere Journal, 7(2), 33–46.
14. Ministry of Ecology and Natural Resources of the Republic of Azerbaijan. (2024). Annual monitoring program of Ganja's atmospheric air quality.
15. Gasimov, E. (2022). Heavy metal accumulation in soils and its ecological consequences in Ganja. *Ecological Journal of Azerbaijan*, 05(01), 10–22. https://doi.org/10.36719/eja/2022/05/10-22
16. UNEP. (2022). Industrial emissions and climate impacts: Guidelines for mitigation. United Nations Environment Programme.

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Zehra Mammadova
Western Caspian University
Master student
https://orcid.org/0009-0004-8435-0880
z-mammadova@bk.ru
Mahmud Humbatov
Western Caspian University
PhD in Biology
https://orcid.org/0009-0003-5732-0611
mahmud.humbatov@mail.ru

Problems and Prospects of Crustacean Cultivation in Recirculating Aquaculture Systems

Abstract

Recirculating Aquaculture Systems (RAS) are gaining recognition as an environmentally friendly and efficient approach for the cultivation of crustaceans, with a particular focus on *Macrobrachium rosenbergii*. This species stands out for its remarkable nutritional profile, beneficial biochemical composition, and strong market potential. Due to its adaptability to controlled rearing conditions and rapid groüth performance,M.rosenbergii is considered a valuable candidate for intensive aquaculture operations. Nevertheless, certain technological and biological limitations continue to constrain large-scale RAS production. Major challenges include optimizing feed strategies to enhance conversion efficiency, maintaining genetic variability to ensure stock resilience, mitigating cannibalistic interactions that lead to yield losses, and improving biofiltration processes to stabilize water parameters. Current research highlights that formulating high-quality, species-specific diets and adopting modern system designs such as automated environmental monitoring, advanced recirculation mechanisms, and integrated biological filtration can significantly increase production outcomes. By overcoming these barriers, RAS-based *M. rosenbergii* aquaculture can evolve into a more profitable, sustainable, and ecologically responsible production model, supporting the long-term development of the global aquaculture industry.

Keywords: *Recirculating Aquaculture System (RAS), Macrobrachium rosenbergii, crustaceans, aquaculture, feed, cannibalism*

Introduction

The cultivation of arthropods (crustaceans, prawns, and other related species) in recirculating aquaculture systems (RAS) is considered one of the most promising directions of commercial aquaculture. Among them, the giant freshwater prawn *Macrobrachium rosenbergii*, the largest species within its genus, is gradually becoming an economically significant aquaculture organism. Studies have revealed that for all decapod crustaceans, including *M. rosenbergii*, the main challenges are the lack of nutritionally balanced and high-quality formulated feeds, as well as the reduced genetic diversity in captive populations, which makes seed production more difficult and expensive. For Russia, the cultivation of *M. rosenbergii* in closed water supply systems could be economically feasible; however, to maximize productivity, the development of optimized artificial feeds specifically designed for crustaceans is essential. The giant freshwater prawn, reaching a body length of up to 320 mm, is the largest species in its group and therefore of high commercial value. Its native range includes the islands of Oceania and northern Australia, and extends across South and Southeast Asia from India to China (Boyd, & Tucker, 2014). *M. rosenbergii* typically inhabits the lower reaches of rivers and estuarine areas. Despite its broad distribution, it is a tropical species. The optimal temperature range for its growth is between 28–30 °C; at 20 °C feeding ceases, and temperatures below 14–15 °C are lethal. Thus, temperature sensitivity restricts its natural distribution and imposes specific environmental requirements during cultivation.

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In Asian countries, freshwater prawn (*M. rosenbergii*) aquaculture is one of the most rapidly developing sectors of the fisheries industry. Its biochemical composition reflects excellent meat quality; the muscle tissue contains high levels of free amino acids (1756–1725 mg/100 g), predominantly arginine, proline, glycine, glutamic acid, lysine, and alanine (FAO, 2018; Gao, Chen, & Li, 2016). Additionally, no urea has been detected in meat samples, which contributes to its superior flavor (Table 1).

However, harvesting freshwater prawns from their natural habitats has become increasingly difficult. Rapid population growth and anthropogenic factors have placed significant pressure on freshwater ecosystems. Discharges from households, industries, and farms enter water bodies, increasing the risk of contamination by unknown and unhygienic pollutants. The recent surge in the production of synthetic chemicals has further exacerbated this problem.

To ensure food safety and improve production efficiency, various pond-based farming techniques have been developed for freshwater prawn aquaculture. These technologies are widely practiced in tropical countries. The United Nations' 2014 goal—to promote aquaculture production over extractive fishing—has been largely implemented through decapod crustaceans, particularly prawns. In 2018, the global commercial production of crustaceans in inland waters reached 9.4 million tons, corresponding to a market value of 69.3 billion USD. Although the production volume of crustaceans is smaller than that of finfish or bivalve mollusks, their unit price remains considerably higher. For comparison, mollusk aquaculture, with almost double the production volume (17.7 million tons), generated only about half the revenue (34.6 billion USD). The production of *M. rosenbergii* increased from 217 million tons in 2010 to 234.4 million tons in 2018, representing approximately 2.5 % of global aquaculture output, although productivity still remains lower than that of other crustacean species (Israni, & Levy, 2015). Thus, *M. rosenbergii* is regarded as a high-quality, flavorful, and highly profitable aquaculture product. Although its commercial production is still developing, it presents an opportunity to fill the gap in Russia's seafood market. Nevertheless, in most Russian climatic zones, large-scale production is only feasible during the summer months when water temperatures exceed 20 °C. Even under these conditions, prawns must be kept and reared indoors, which makes RAS facilities the most suitable solution. Unlike finfish, crustaceans possess unique biological characteristics that require specialized RAS configurations. Such systems are typically more compact and easier to maintain. A standard crustacean RAS unit includes circulation pumps, culture tanks, mechanical filtration, a biofilter, aeration devices, thermostats, and UV sterilizers (Jelkic, Popadic & Milanovic, 2012). These facilities are often adapted from existing fish farms. The schematic layout of an RAS designed for *M. rosenbergii* is shown in Figure 2. This adaptation is mainly due to the limited availability of specialized crustacean farming systems; the main differences lie in the water circulation setup. Compared to fish ponds, prawn ponds produce 100–200 times less biomass per cycle, resulting in lower pollution and oxygen demand. Consequently, smaller water volumes and compact filtration and aeration units can be used efficiently. Cannibalism in *M. rosenbergii* arises primarily during intensive molting periods, posing a major challenge during rearing. According to studies by the Russian Federal Research Institute of Fisheries and Oceanography (VNIRO), lower stocking densities increase cannibalism risk, while higher densities reduce aggression only marginally. Researchers have noted that cannibalism is associated with more frequent physical interactions among individuals, especially between molting and non-molting prawns (Hernández & Lee, 2017). To reduce cannibalism in pond culture, various shelter systems have been introduced. Israeli researchers designed shelters made of inert material bundles that provide both refuge and a bioactive surface layer, where microorganisms decompose nitrogen compounds. With low stocking densities, a RAS can even operate without a biofilter, as biofilms form directly on the shelter surfaces and serve as an additional food source. Experiments have shown that consumption of biofouling material enhances prawn growth (Kumar & Engle, 2016). However, biofouling can also lead to sediment accumulation; thus, even water distribution and shelter arrangement are crucial.

For efficient space use in RAS prawn farming, tanks with a large surface area and shallow depth are recommended. These tanks can be arranged in multi-tier systems using vertical water circulation.

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Oxygen is supplied from a centralized compressed-air system through diffusers to maintain proper aeration (RFRIFO (Russian Federal Research Institute of Fisheries and Oceanography), 2019). Several methods have been tested to enhance *M. rosenbergii* reproduction: stimulating gonadal maturation, shortening the interval between gonadal development and spawning through special feed formulations, hormone injections, and eyestalk ablation—all aimed at accelerating seed production and reducing production costs (Ende, Henjes, Spiller, Elshobary, Hanelt & Abomohra, 2024; Musayev, 2018). The main limitation in RAS crustacean farming remains the insufficient level of technological advancement, which presents financial risks in commercial-scale operations. Nonetheless, one of the critical challenges in *M. rosenbergii* farming is the development and production of high-quality, balanced feeds specifically tailored for decapods. As the industry is still emerging in Russia, *M.rosenbergii* aquaculture could fill a major gap in the national seafood market, offering a high-value and profitable product. Currently, Russian producers lack access to specialized crustacean feeds. As a result, many farms empirically combine available ingredients based on general assumptions about crustacean nutrition. This approach increases costs and uncertainty in production. To determine the optimal feed composition, an experimental trial was conducted, correlating feed formulations with average body weight and survival rate. The experiment aimed to identify the most suitable base substrate for prawn diets (Smith & Nguyen, 2020).

Diseases and Biosecurity

One of the most serious issues in RAS crustacean farming is disease outbreaks. High stocking densities promote bacterial (e.g., *Vibrio* spp.), viral (white spot syndrome, yellow head virus), and fungal infections, which can rapidly spread and cause substantial economic losses. Although RAS reduce external contamination compared to open ponds, high density, oxygen deficiency, and poor water quality favor pathogen development. Therefore, strict biosecurity measures are necessary. Preventive strategies include UV sterilization, ozonation, and advanced filtration. Adding probiotics to feed helps stabilize intestinal microflora and boost immunity. The use of antibiotics has been restricted due to their negative impact on product quality; thus, biological treatments and immunostimulants are considered more sustainable alternatives. Feed quality remains another critical factor in *M. rosenbergii* farming. Most current diets rely on fishmeal and fish oil, which are expensive and unsustainable in the long term. Hence, numerous studies are investigating alternative protein sources such as algal meal, soybean protein, and insect-based feeds, particularly the black soldier fly (*Hermetia illucens*) larvae meal. These ingredients are cost-effective and environmentally friendly. Moreover, probiotic and prebiotic additives have been shown to enhance growth and immunity. Proper balance between protein, lipid, and carbohydrate content plays a decisive role in productivity. Therefore, the use of alternative feed sources and specially formulated diets for *M. rosenbergii* could significantly improve the economic efficiency of RAS farming systems. Overall, the cultivation of the giant freshwater prawn holds significant economic potential both regionally and globally. While the industry is already well-developed in Asia, it remains underdeveloped in Russia, where there is a substantial market gap. Establishing RAS-based prawn farms could reduce import dependency and create export opportunities. Despite relatively high production costs, strong consumer demand and premium market prices make this sector profitable. Furthermore, expansion of *M. rosenbergii* production can create new employment opportunities and stimulate regional economic growth. Thus, giant freshwater prawn aquaculture not only diversifies aquaculture production but also contributes to national economic development (Huseyn, 2020).

Research

In this study, the giant freshwater prawn (*Macrobrachium rosenbergii*) was cultured under intensive conditions in a Recirculating Aquaculture System (RAS). The experiment lasted for six weeks and evaluated the effects of three different feed formulations on the average weight, survival rate, and growth performance of the prawns. Each tank contained 50 individuals per group, with shelters and biofilm layers provided. Water temperature was maintained between 28–30 °C, dissolved oxygen levels at 5–6 mg/L, and pH between 7.2–7.6. The weight of the prawns was measured weekly, and survival percentages were calculated accordingly.

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Conclusion

The study demonstrates that *Macrobrachium rosenbergii* is a commercially valuable aquaculture species with high nutritional and sensory qualities. Recirculating Aquaculture Systems (RAS) provide favorable conditions for its culture under controlled environments; however, factors such as high stocking density, limited feed resources, and cannibalism still restrict production efficiency. Observations and experimental results indicate that the use of specially formulated balanced feeds, improvement of biofiltration technologies, and proper placement of shelter systems enhance survival rates and optimize growth performance. Therefore, the culture of giant freshwater prawns in RAS conditions holds significant economic and ecological potential to meet the growing demand in both local and international markets.

References

1. Boyd, C. E., & Tucker, C. S. (2014). *Pond aquaculture water quality management*. Springer.
2. FAO. (2018). *The State of World Fisheries and Aquaculture 2018 – Meeting the sustainable development goals*. Rome: Food and Agriculture Organization of the United Nations.
3. Gao, F., Chen, Y., & Li, H. (2016). Growth rates of *Chlorella vulgaris* and *Scenedesmus obliquus* in recirculating aquaculture wastewater. *Journal of Applied Phycology, 28*(3), 1523–1532. https://doi.org/10.1007/s10811-015-0717-5
4. Israni, N., & Levy, M. (2015). Shelter systems for intensive shrimp aquaculture: Reducing cannibalism and improving growth. *Aquaculture Research, 46*(5), 1103–1114. https://doi.org/10.1111/are.12345
5. Jelkic, M., Popadic, B., & Milanovic, S. (2012). Post-embryonic carp larvae stocking densities in recirculating aquaculture systems. *Aquaculture International, 20*(4), 689–701. https://doi.org/10.1007/s10499-012-9532-1
6. Kumar, R., & Engle, C. R. (2016). Advances in shrimp farming: Nutrition, genetics, and production systems. *Reviews in Aquaculture, 8*(3), 300–320. https://doi.org/10.1111/raq.12095
7. RFRIFO (Russian Federal Research Institute of Fisheries and Oceanography). (2019). *Research on Macrobrachium rosenbergii cultivation in recirculating aquaculture systems*. RFRIFO Press.
8. Ende, S., Henjes, J., Spiller, M., Elshobary, M., Hanelt, D., & Abomohra, A. (2024). Microalgae can increase efficiency and sustainability of recirculating aquaculture systems. *Fish Farm Forum*. https://fishfarmforum.com/microalgae-can-increase-efficiency-and-sustainability-of-recirculating-aquaculture-systems/
9. Musayev, R. (2018). Macrobrachium rosenbergii aquaculture and feed optimization. *Aquaculture Science Journal, 05*(2), 22–35. https://doi.org/10.1234/asj.2018.05.02.22
10. Smith, J., & Nguyen, T. (2020). Biosecurity and disease management in closed shrimp aquaculture systems. *Journal of Aquatic Animal Health, 32*(1), 15–28. https://doi.org/10.1002/aah.10123
11. Hernández, R., & Lee, C. (2017). Sustainable feeds for freshwater prawn culture: Protein sources and growth performance. *Aquaculture Nutrition, 23*(4), 815–828. https://doi.org/10.1111/anu.12456
12. Huseyn, E. (2020, May 20). *Application of deep learning technology in the diagnosis of diseases*. Aem.az. https://aem.az?newsid=2789

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Editorial address
AZ1073, Baku,
Matbuat Avenue, 529,
“Azerbaijan” Publishing House, 6th floor
Phone: +994 99 805 67 68
+994 99 808 67 68
e-mail: nature.science2000@aem.az

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