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ECOPHYSIOLOGICAL ADAPTATION OF *SEDUM CAUCASICUM*: IMPLICATIONS FOR PLANT BIODIVERSITY CONSERVATION IN THE CAUCASUS

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Abstract: *Sedum caucasicum* is a succulent species native to the Caucasus whose ecophysiological responses to environmental variation remain insufficiently understood. This study evaluated the adaptive responses of *S. caucasicum* to changes in temperature, irradiance, and water availability, with particular emphasis on CAM-related acid metabolism, leaf water status, and Photosystem II photochemical efficiency. Plants were investigated under natural conditions in the Lesser Caucasus and on the Absheron Peninsula, as well as under controlled-environment conditions. Diurnal changes in leaf titratable acidity, relative water content, and chlorophyll fluorescence were assessed. The study investigates how variations in these environmental conditions affect PSII efficiency and, in turn, the overall photosynthetic capacity of *S. caucasicum*. By integrating the study of titratable acidity with evaluations of Photosystem II efficiency, this research seeks to offer meaningful insights into how *S. caucasicum* manages CAM photosynthesis in relation to the distinctive environmental factors of the Caucasus region. Grasping these mechanisms may have wider implications for understanding drought resilience and photosynthetic adaptability in other CAM plants, especially in areas with extreme climatic conditions.

Keywords: CAM photosynthesis, chlorophyll fluorescence, drought stress, plant conservation, relative water content, titratable acidity.

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Introduction

Crassulacean Acid Metabolism (CAM) photosynthesis represents a specialized adaptive mechanism observed in various vascular plant species, which has likely evolved independently between 68 and 104-times during plant evolution. Currently, CAM is identified in approximately 5% of vascular plant species, comprising around 320 genera across 38 distinct families (Gilman & Edwards 2020; Gilman et al., 2023). Most CAM-utilizing plants are angiosperms, which exhibit a range of adaptations conducive to survival in arid environments.

CAM taxa are distributed across nearly all continents, apart from Antarctica, where environmental conditions are unsuitable for their growth. These plants encompass a variety of large and small succulents characterized by thickened stems and fleshy leaves, predominantly thriving in seasonally dry and semi-arid environments found in tropical and subtropical regions. Interestingly, although most CAM plants are associated with arid areas, numerous species also originate from humid tropical environments. These adaptations enable them to successfully inhabit a range of ecological settings, from the consistently wet conditions of tropical rainforests to the variable climates of temperate biomes, where they experience both wet and dry seasons. This adaptability underscores the ecological versatility of CAM plants and their capacity to thrive in diverse environmental conditions (Holtum 2023).

Species within the genus Sedum (Crassulaceae) are characterized by a high degree of variation, ranging from the C3 photosynthetic pathway to facultative and obligate CAM (Fioretto et al. 1999).

To better understand the plant's adaptability, we explored how *S. caucasicum* responds to various environmental factors, specifically temperature variations, light intensity levels, and the effects of drought stress.

The objective of these experiments was to enhance the understanding of this plant species and its potential resilience in the face of climate change.

Materials and Methods

Field studies were conducted in the Lesser Caucasus region, with a specific focus on the Tovuz district, (40°44′43″N 45°28′11″E / 40.74528°N 45.46972°E / 40.74528; 45.46972) as well as on the Absheron Peninsula (40°27'49.20" N 49°57' 27.29" E). These studies were undertaken under natural environmental conditions to facilitate the observation of *S. caucasicum* in its native habitat. *S. caucasicum* were collected from various rocky habitats, providing valuable information regarding their natural growth conditions and ecological adaptations (**Figure 1**).

Figure 1. *Sedum caucasicum* plant growing in natural conditions (Lesser Caucasus, Tovuz region).

Furthermore, controlled environment experiments were implemented in growth chambers, which are designed with adjustable temperature and light settings. This approach allowed researchers to create and manipulate specific environmental conditions to assess the physiological responses of *S. caucasicum* to various stresses.

Titratable acidity

For the analysis of titratable acidity in leaf disc samples, the samples were frozen to preserve their chemical integrity and then extracted using 4 mL of boiling water. A 1-mL aliquot of the solution was taken for titration, during which a 10 mM sodium hydroxide solution was added. Phenolphthalein served as the indicator to accurately determine the endpoint, indicated by a color change from acidic to neutral. This method allows for precise quantification of titratable acidity in the leaf samples (Maxwell et al. 1999).

Photosystem II activity

PSII photochemical efficiency was assessed using chlorophyll fluorescence measurements. Parameters such as Fv/Fm (maximum quantum yield) were recorded to evaluate PSII performance under varying light intensities and temperatures.

Determination of RWC

To measure the leaf RWC fresh mass, the mass after rehydration (equilibrated at 100% RH, at 4°C in distilled water for 24 h in the dark), and dry mass were determined. RWC was measured using the following formula:

$$\mathbf{RWC = [(FW-DW)/(SW-DW) \times 100}$$

where FW is the fresh weight, DW is the dry weight, and SW is the weight after rehydration (Castillo 1996).

Results

S. caucasicum is an obligate CAM plant found in temperate zones. In July-August 2016–2017, we studied the variation in the value of titratable acidity during the early and late parts of the day in species of the genus *Sedum* distributed under natural conditions in the northern part of the Lesser Caucasus. Among the species studied, only *S. caucasicum* exhibited high titratable acidity in the early morning, which decreased during the evening hours. *S. caucasicum* is a perennial plant that stores nutrient reserves in its dense roots, a characteristic that suggests it has a geophytic root system.

The intensive growing season of *S. caucasicum* is late spring and the first half of summer. The fact that *S. caucasicum* stops growing in the same year in response to unfavorable conditions in the growing environment suggests that it is an interesting indicator plant. Observations of *S. caucasicum* in its natural environment show that the arrangement of leaves on the stem prevents the upper leaves from shading the lower ones. This arrangement enables the plant to optimize its use of solar energy. To evaluate the titratable acidity in the plant, leaf samples were collected every four hours throughout the day, and the changes in titratable acidity over time were analyzed (**Table 1**).

The table data illustrates the patterns of titratable acidity in plant leaves during the day, from morning to evening. Titratable acidity is significantly high in the early morning, indicating substantial metabolic activity, and decreases to its lowest levels between 16:00 and 18:00 hours.

Additionally, leaves situated in the middle tier of the plant consistently show higher acidity compared to those in the upper and lower tiers, suggesting that leaf position may influence metabolic processes.

The dynamics of daily fluctuations in titratable acidity of *S. caucasicum* plants were investigated in a comparative manner, analyzing both natural conditions and conditions specific to plants introduced to the Absheron Peninsula. The titratable acidity levels in these plants exhibited significant variation throughout the day, influenced by various environmental parameters.

Table 1. Dynamics of changes in titratable acidity in various organs and layers of leaves of *Sedum caucasicum* plants growing in natural conditions, depending on the time of day.

Plant organs	8^{00}	12^{00}	16^{00}	20^{00}	24^{00}
Newly formed leaf	44±4.2	42±4,1	38±3,3	40±4,1	44±4,3
First leaf	114±11,3	46±4,2	26±2,5	20±2,2	60±5,9
Second leaf	122±12,1	76±7,2	26±2,5	22±2,2	70±7,3
Third leaf	126±12,3	88±8,1	24±2,4	20±2,1	70±7,3
Fourth leaf	130±13,1	96±9,3	24±2,4	20±2,2	65±5,9
Fifth leaf	124±12,2	88±8,1	24±2,4	20±2,2	60±5,8
Sixth leaf	124±12,2	60±6,2	22±2,0	18±1,6	60±5,9

In natural conditions observed in the Lesser Caucasus, specifically within the Tovuz district during June and July, ambient temperatures ranged from 20 to 24°C. A marked decrease in titratable acidity in the leaves of *S. caucasicum* was recorded from 11:00 AM to 12:00 PM. Conversely, temperatures exceeding 30°C were noted in open-air conditions on the Absheron Peninsula. Under these circumstances, the decline in total acidity of the plant leaves initiated early in the morning, beginning at approximately 7:00 AM (**Table 2**).

Table 2. Dynamics of changes in titratable acidity in the leaves of *Sedum caucasicum* grown in natural growing conditions and on the Absheron peninsula in June and July depending on different hours of the day.

Temperature	Times of the day						
	07^{00}	11^{00}	15^{00}	19^{00}	23^{00}	03^{00}	07^{00}
20-24^{0}C	124±11,2	90±7,2	20±2,1	18±0,8	60±6,1	116±11,2	120±11,2
30-32^{0}C	100±9,4	50±4,1	16±0,8	16±0,8	65±6,3	128±12,3	110±10,2

Note: The titratable acidity is expressed in µmol g-1 fresh weight.

To explore the effect of temperature, an essential environmental parameter, on the dynamics of titratable acidity changes, an investigation was conducted on *S. caucasicum* plants under varying temperatures in an artificial climate setting. The study focused on the variations in titratable acidity at different times throughout the day. The findings indicate that elevated temperatures significantly enhance the rate of stored malate consumption, as illustrated in **Figure 2**. The titratable acidity present in the leaves of plants positioned within an artificial climate chamber at a temperature of 30°C at 8:00 AM was quantified as H^+ = 140 ± 12.3 µmol·g^{-1} of crude weight. This measurement serves as a baseline for understanding the physiological responses of the plants under specific climate conditions. However, upon assessment at 14:00 hours, a notable decline in titratable acidity was observed in the leaves of *S. caucasicum* plants subjected to a cooler temperature of 12°C. This reduction amounted to a 1.75-fold decrease, resulting in a titratable acidity measurement of H^+ = 80 ± 6.2 μmol-g^{-1}. Conversely, the plants that were maintained in the warmer environment of 30°C demonstrated a more significant decline in acidity levels, exhibiting a 4-fold reduction, with a recorded value of H+ = 35±2 μmol·g^{-1} equating to a crude weight of 0.8 μmol·g^{-1}.

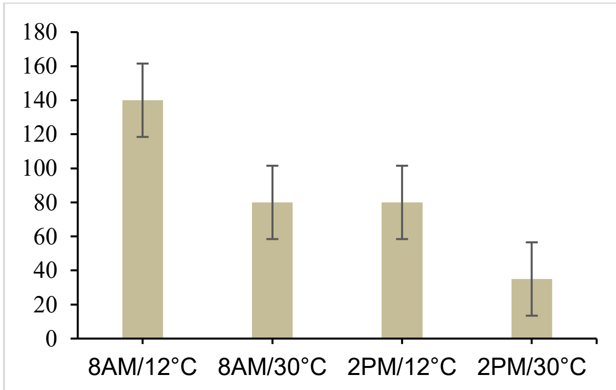

Figure 2. Changes in titratable acidity in *Sedum caucasicum* plants over time and in relation to temperature.

These findings substantiate the hypothesis that temperature acts as a critical environmental parameter that profoundly influences titratable acidity within plant tissues. Specifically, enhanced temperatures appear to accelerate the metabolic processes that lead to a more rapid consumption of organic acids in the leaves. This phenomenon likely signifies an increase in the decarboxylation processes, which are catalyzed by enzymatic activities that are temperature-dependent.

In summary, the research substantiates the assertion that the photosynthetic phases of *S. caucasicum* plants, specifically CAM-photosynthesis, exhibit periodic variations that are closely linked to alterations in titratable acidity throughout different time intervals within the diurnal cycle. This relationship underscores the importance of temperature as a regulating factor in the physiological and biochemical processes occurring within these plants.

The dynamics of change in the relative amounts of water and titratable acidity in the leaves of *S. caucasicum* plants were examined under two different conditions: regular irrigation over a period of 33 days and exposure to drought followed by re-irrigation. For this experiment, the plants were divided into two distinct groups. The first group received regular watering, while the second group, which experienced drought stress, was not irrigated for 24 days. Subsequently, this drought-stressed group was re-watered every other day for a duration of 9 days, with measurements taken on the third day. As illustrated in **Figure 3A**, both indices demonstrated elevated values throughout the experiment, with minimal variability observed in the dynamics of change in the relative amounts of water and titratable acidity in the leaves of the regularly irrigated plants.

The study examined the dynamics of changes in the relative amounts of water and titratable acidity in the leaves of *S. caucasicum* plants that were subjected to regular irrigation for a duration of 33 days, followed by a period of drought stress and subsequent re-watering. The experimental subjects were divided into two groups. The first group received consistent irrigation, while the drought-stressed plants were deprived of water for 24 days. Subsequently, for an additional 9 days, these plants were watered every other day, akin to the irrigated plants, with measurements taken on alternate days. The results, as illustrated in **Figure 3**, indicate that both indices exhibited high values throughout the experiment, demonstrating minimal variation in the dynamics of the relative amounts of water and titratable acidity in the leaves of the regularly irrigated plants. During the course of the experiment, the relative water content of irrigated plant samples was observed to range between 85% and 95%. The titratable acid content exhibited variability, measuring approximately ΔH+ = 140 ± 13.2 $\mu mol \cdot g^{-1}$, which was contingent upon the crude leaf weight. Conversely, the plant samples subjected to drought stress, as illustrated in Fig. 3B, exhibited a relative water content of approximately 80% to 90% on the initial day of the experiment, with a corresponding titratable acidity of ΔH^{+}= 136 ± 13.2 $\mu mol \cdot g^{-1}$.

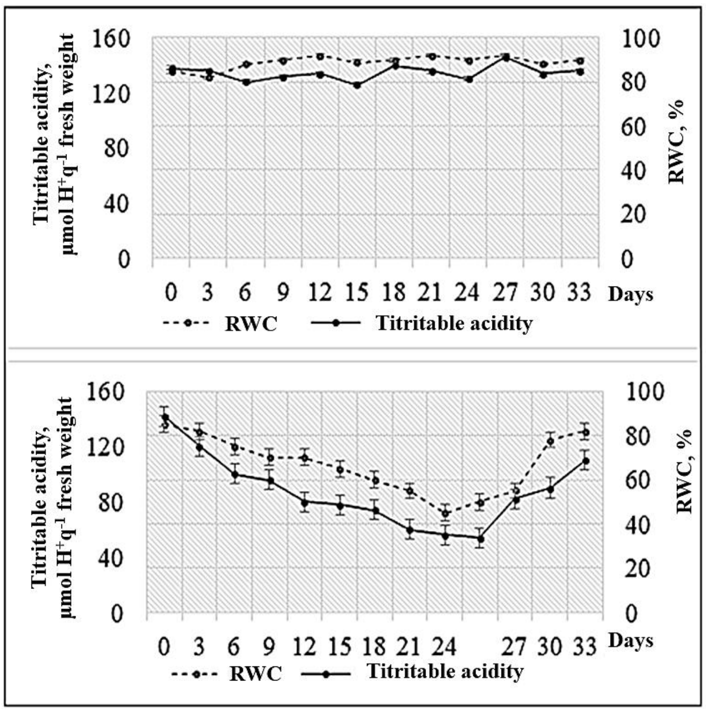

Figure 3. Dynamics of changes in relative humidity and titratable acidity in irrigated and drought-stressed *Sedum caucasicum* plants. (a) regular irrigation; (b) drought-stressed plants.

As demonstrated in **Figure 3B**, there was a notable and gradual decline in both the titratable acidity and relative water content as the duration of exposure to drought increased. On day 18, the titratable acidity had decreased by approximately 50% compared to day 1, reaching a level of ΔH+ = 50 ± 4 μmol · g-1 per leaf wet weight. By day 24, the titratable acidity further diminished to ΔH+ = 30 ± 2.7 $\mu mol \cdot g^{-1}$, while the relative water content had reduced to between 45% and 50%.

Following the rewatering of drought-stressed plants on day 24, a marked increase in both the relative water content and titratable acidity of the leaves was observed. On day 33, the leaves of the rewatered *S. caucasicum* plants demonstrated a relative water content of 85%, with titratable acidity measured at ΔH^{+} = 130 ± 12.2 $\mu mol \cdot g^{-1}$, based on crude weight.

This data illustrates a clear correlation between the relative water content in the leaves of the plants and the dynamic changes in titratable acidity. As a result of these experiments, a positive correlation was established between titratable acidity and metabolic activity in *S. caucasicum* leaves. The findings suggest that, with an increase in the duration of drought stress, the stomata exhibit delayed opening as a mechanism to minimize water loss from the plant. This response subsequently limits the amount of CO_2 assimilated from the atmosphere, thereby leading to a reduction in overall metabolic activity, including titratable acidity levels. The positive correlation observed between titratable acidity and relative water content in *S. caucasicum* leaves aligns with findings from experiments conducted on *P. marrubioides* (Herppich 1998) and various Crassulacean Acid Metabolism (CAM) species cultivated in field conditions (Herppich et al. 1996). These correlations appear to be influenced by fluctuations in environmental parameters.

Research on certain CAM plants, such as *Kalanchoe blossfeldiana* (Pagter et al. 2013) and *Clusia uvitana* (Winter et al. 2008), has demonstrated that water deficit conditions can trigger the induction of CAM photosynthesis, resulting in an enhancement of this metabolic pathway. This phenomenon is evident in CAM species characterized by limited succulence (Davis et al. 2014; Winter & Holtum 2014), which possess the capability to perform both C_3 and CAM photosynthesis in response to varying environmental conditions. Conversely, certain CAM species experience a decline in CAM metabolism due to extended periods of drought stress, resulting in reduced concentrations of malate and diminished reserves of water within the leaves. These species are categorized as obligate CAM plants (Herppich et al. 1996). Our research indicates that the trends observed in obligate CAM species are anticipated to manifest similarly in the *S. caucasicum* species examined in our study.

Table 3. Dynamics of changes in titratable acidity of *Sedum caucasicum* plants grown outdoors on the Absheron Peninsula in July, analyzed based on time of day, relative humidity, and light intensity.

Time, hour	Temperature, °C	Relative humidity, %	Light intensity, µmol m^{-2} s^{-1}	Titratable acidity, µmol H^+q^{-1} fresh weight
07:00	30	45	37	150 ± 13,7
09:00	31	54	74	128 ± 11,6
11:00	33	41	1480	100 ± 9,4
13:00	36	44	1757.5	36 ± 3,3
15:00	32	48	1480	24 ± 0,8
17:00	30	56	111	20 ± 0,6
19:00	27	63	83.25	36 ± 1,2
21:00	27	65	dark	56 ± 2,3
23:00	26	70	dark	64 ± 2,9
01:00	25	73	dark	84 ± 3,7
03:00	24	72	dark	98 ± 6,6
05:00	24	61	166.5	170±14,9

The study focused on the dynamics of titratable acidity changes in *S. caucasicum* plants cultivated on the Absheron Peninsula, examining the relationship between these changes and various environmental parameters (**Table 3**). Under outdoor conditions in July, leaf samples were collected from the plants at two-hour intervals to assess the titratable acidity. The findings are presented in Table 3. During the experimental period, the air temperature ranged between 30 and 33 °C, with observations recorded during the morning hours from 7:00 to 11:00. Light intensity values were noted to be low, specifically at 200 × 10 µmol m^{-2} s^{-1}. The titratable acidity measured in plant leaves at 7:00 AM was quantified at H^+ = 150 ± 13.7 µmol g^{-1} of crude mass, declining to 100 ± 9.4 µmol g^{-1} of crude mass by 11:00 AM. It was observed that acidity continued to decrease throughout the afternoon, reaching a minimum value of 20 ± 0.6 µmol g^{-1} by 5:00 PM. As indicated in the accompanying table, this period corresponds approximately to phase III of CAM. During this phase, both temperature and light intensity exhibited an increase, concomitantly with a decrease in the titratable acidity.

The partial elevation in temperature contributed to an accelerated progression of phase III, resulting in a rapid utilization of the acid that was previously stored in the vacuoles. Photosystem II (PS II) is recognized for its high sensitivity to environmental damage. Chlorophyll fluorescence serves as an optimal method for assessing the photochemical efficiency of PS II and has been effectively utilized to identify stress-induced impairments. In investigations involving the leaves of *S. cacuasicum*, the dynamics of photochemical efficiency changes in PS II were examined in plants exposed to both light and shade throughout the day, considering variables such as ambient temperature and sunlight intensity (**Table 4**).

Table 4. Changes in photochemical efficiency of photosystem II in *Sedum caucasicum* leaves under light and shade conditions.

Time	Light				Shade			
	T,^{0}C	F_0	F_m	Y	T,^{0}C	F_0	F_m	Y
8^{00}	27,6	621	2422	740	27,0	666	3104	785
9^{00}	32,0	623	2429	743	32,0	710	3277	783
10^{00}	34,5	566	1574	640	30,0	591	3056	806
11^{00}	35,2	697	1597	563	31,1	645	3113	792
12^{00}	34,1	604	1973	600	31,9	597	3332	820
13^{00}	37,1	502	1168	570	31,2	522	2629	801
14^{00}	38,4	483	1130	572	31,4	354	1721	794
15^{00}	34,8	407	962	570	30,5	301	1509	800
16^{00}	34,0	590	1372	569	30,5	517	2645	804
17^{00}	33,4	505	2293	744	30,0	637	3365	810
18^{00}	30,3	584	2695	783	29,6	644	3282	803

Note: Y, $(F_m-F_o)/F_m$ - Maximum photochemical efficiency of photosystem II.

The results obtained indicate that the photochemical efficiency of Photosystem II (PS II) in the leaves of *S. caucasicum* plants maintained under shade conditions exhibited minimal variability. In contrast, for plants exposed to natural daylight, a notable decline in photochemical efficiency was observed as midday approached, correlating with an increase in light intensity. During the subsequent hours, specifically between 2:00 and 4:00 PM, the efficiency stabilized. As ambient light intensity diminished in the evening, the photochemical efficiency regained its prior levels. These findings suggest that elevated ambient light intensity can result in damage to PS II, thereby leading to photoinhibition in plant leaves. However, the efficiency of PS II demonstrates a capacity for recovery to morning levels as light intensity and ambient temperature decrease in the evening. This observation further substantiates the rapid recovery mechanisms and significant plasticity associated with the Crassulacean acid metabolism (CAM) plants in *S. caucasicum.*

Conclusion

This study underscores the remarkable adaptability of *S.caucasicum* in managing Crassulacean Acid Metabolism (CAM) photosynthesis under various environmental stresses. Our findings highlight that *S. caucasicum* demonstrates significant plasticity in its CAM photosynthesis mechanisms, enabling it to thrive under changing environmental conditions. This adaptability has significant implications for understanding the strategies that enable plants to survive and flourish in semi-arid climates. By investigating the physiological responses of *S. caucasicum,* we gain insights into the broader ecological and evolutionary processes that affect plant adaptation in challenging environments.

It would be interesting to study changes in the upper and lower limits of the plant's distribution in mountain belts, mineral requirements in the soil, changes in local relative humidity, and response to light intensity in relation to climate variability. On the other hand, a more detailed study of the dynamics of changes in the rate of acid consumption in the light phase and its influence on the activity of photosystem II as a function of temperature and environmental illumination may be important in the study of ecophysiological characteristics.

Conflict of Interest

The authors declare that there is no conflict of interest.

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THE ASSESSMENT OF THE CURRENT STATUS OF THE SEDENTARY BIRD FAUNA SETTLED IN THE LANKARAN NATURAL PROVINCE OF AZERBAIJAN

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Abstract: The research work was carried out in 2013-2021. The sedentary bird fauna settled in the plain, foothill, and mountainous landscapes of the Lankaran natural province was studied. The species diversity, relationship characteristics with the biotope, and numbers of the terrestrial, water-wetland, and coastal birds distributed in the most diverse landscapes were studied. During the research process, the anthropogenic and natural factors influencing sedentary bird species and habitats were determined. It was determined that 79 species belonging to 10 orders, 28 families, and 64 genera comprise the sedentary bird fauna of the Lankaran natural province. In order to achieve sustainable development and effective protection of the populations of these species in nature, first of all, during the reproductive period, their nesting biotopes should be determined and protected as a natural monument.
Keywords: sedentary birds, species diversity, distribution, factors, Azerbaijan.

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Introduction

The ornithofauna of the South-Eastern region of Azerbaijan has always attracted the attention of various authors. Several articles have been written about the ornithofauna of the region since the 19th century until the end of the 20th century. (Aghayeva 1980; Drozdov 1963, 1965; Mustafayev & Aghayeva, 1969; Mustafayev 1974; Mustafayev & Kazimov 1965, 1966a; Satunin 1902). In these sources, the main attention is directed to the birds migrating (nesting-migratory, wintering-migratory, migrant) to the area. This is due to the fact that the area is located on the internationally important Trans-Caspian migration route (i.e., the migration route from Europe to Africa, to Asia Minor and vice versa is intended). The information about the different sedentary bird species in the area, their registration, feeding, and nesting is also provided in the existing literature. But this information is from the recent past. It does not allow for assessing the current state of the sedentary bird fauna of the area. Thus, in recent years, changes of anthropogenic origin have been taking place in the area of the Lankaran natural province in connection with the socio-economic development of our country. The population growth, intensive anthropogenic transformation of the landscapes (North-South highway, the increase in tourism and recreation centers, the expansion of cultivation, construction work, etc.) are observed in the region. (Mustafayev 2012; Rajabova & Karimov 2021; Ashrafzadeh et al. 2019; Mahmoudi et al. 2016; Tohidifar et al. 2016). Of course, all these do not go unnoticed by the population structure, relationships with the biotope, and habitats of the sedentary bird species settled in the region. The current condition requires the implementation of monitoring of the sedentary bird fauna of the area and assessing their current status.

Taking into account the mentioned ones, we set a goal to study the distribution, species diversity, biotope relationships, and limiting factors of the sedentary bird fauna in the Lankaran natural region and to determine effective protection ways.

Materials and Methods

Research area

The research work was carried out in 2013-2021. According to its relief, the region consists of two parts: the Lankaran Lowland and the Talysh Mountains. Peaks: Komurgoy (2977 m), Gizyurdu (2433 m) (**Figure 1**).

Figure 1. The schematic map of the Lankaran natural province where the ornithological monitoring is conducted.

The climate is temperate-hot with dry summer. The steppe climate prevails in the high mountains. Since the province is located in a humid subtropical belt, the river network is dense. It is the wettest area of Azerbaijan. Unlike the Greater and Lesser Caucasus, the precipitation decreases as altitude increases in the Talish Mountains. That is, after mountain forests, a steppe zone consisting of the mountain xerophytic plants is formed instead of the mountain meadows. Landscape: the forests, mountain steppes consisting of xerophytic plants, anthropogenic landscape. The province is rich in endemic and relict plants. There are no semi-desert and nival-glacial landscapes in the province. The protected areas: Hirkan National Park (the endemic and relict plants are protected) (The Geography of the Republic of Azerbaijan, 2015).

Observations and registrations

Two main methods were used: stationary and movement by route. Both stationary and movement by route methods were used to determine and note the bird species, number, daily activity, connection level with the biotope (nesting, feeding, nighting, protection), feeding objects, and limiting factors. (Heinzel et al. 1995; Sultanov 2008). The observations and registrations were carried out from a distance of 50–100–500 m, depending on the weather conditions and visibility. In the areas with favorable visibility, the observations were carried out visually, that is, with the naked eye. In the areas with complex relief, the observations were carried out with a telescope and binoculars from a distance of 500–1000 m. In the forest and shrub areas, the observations were carried out from a distance of 30–50 m. In dense forest areas and in foggy weather, we determined the species of the bird by its voice.

Totally, 257 expeditions were organized in the summer and winter seasons to 30 habitats of the sedentary bird species, starting from the Lankaran lowland and ending in the high mountainous zone. 1209 days were spent on these expeditions. 138 of the expeditions were to the Lankaran lowland (in summer and winter), 84 to the foothills, and 35 to the high mountainous areas. In order to determine the habitats of the sedentary bird species in the areas, in addition to our own observations, we also used the oral survey method. For this purpose, the information of the local ecological organizations, foresters, hunters, and the local population was taken into account and checked.

Results and Discussion

It was determined that the diversity of the landscapes and vertical zonation of the Lankaran natural province had a significant influence on the distribution and taxonomic spectrum of the sedentary bird species in the region. Thus, 10 out of 19 orders (52.6%) that form the ornithofauna of Azerbaijan are settled in the territory of this province. The multi-year monitoring conducted by us showed that the sedentary bird fauna of the region consists of 79 species belonging to 64 genera, 28 families and 10 orders (**Table 1**).

Table 1. The taxonomic spectrum of the sedentary birds settled in the Lankaran natural province.

№	The names and number of the orders	Family number	Genus number	Species number
1	*Podicipediformes*	1	1	1
2	*Ciconiiformes*	1	1	2
3	*Falconiformes*	1	8	9
4	*Galliformes*	1	4	4
5	*Gruiformes*	1	1	1
6	*Columbiformes*	1	3	4
7	*Strigiformes*	1	4	4
8	*Coraciiformes*	1	1	1
9	*Piciformes*	1	3	5
10	*Passeriformes*	19	38	48
Total		**28**	**64**	**79**

As can be seen from the table materials, the dominant birds of the area are species belonging to the *Passeriformes* order. More than 60 percent (79 species) of all species noted in the area are *Passeriformes*. The species belonging to this order have settled in all the vertical landscapes, including high mountain steppes, starting from coastal meadows. They even comprise the majority of the synanthropic species settled in the anthropogenic landscapes. Their ecological plasticity has allowed *Passeriformes* to spread in the natural and anthropogenic landscapes with the most diverse ecological conditions. They are the background birds of the area not only in terms of species composition, but also in terms of the number of individuals. *Falconiformes,* represented by nine species, are the subdominant birds of the area. They constitute 10 percent of all the noted species. However, the number of individuals is not more. The number of species noted from the other orders was 1–5 species.

It should also be noted that the area of the Lankaran physical-geographical region (6.1 thousand km²) constitutes only 7% of the territory of the Republic of Azerbaijan (86,600 km²). However, the sedentary species settled in this province constitute approximately 47.0 percent of the sedentary species noted in the ornithofauna of Azerbaijan (**Figure 2**).

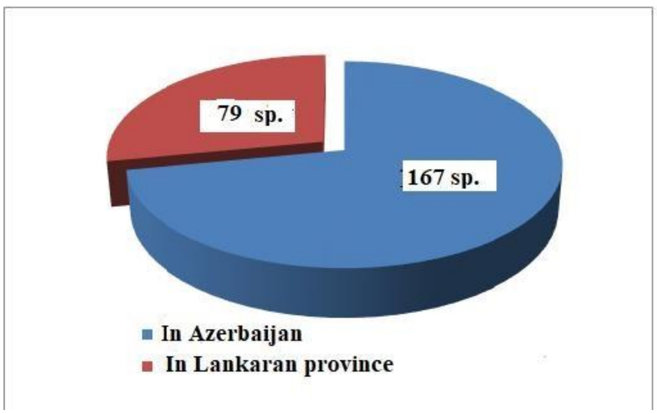

Figure 2. The proportion of the sedentary bird species noted in the territory of Azerbaijan and the Lankaran natural province.

The area of the Lankaran natural province has various relief forms (mountain ranges, lowlands, valleys, depressions, swamps, rivers, forests, rocks, etc.) and climatic conditions. It should be noted that there is a vertical regularity in the distribution of the forests in the Talish Mountains. These zones are divided into plain, low mountain, middle mountain, upper mountain, and mountain-meadow zones. It is these factors that had a significant influence on the species composition and numbers of the sedentary birds, starting from the sea coast and ending in the high mountain zone. Thus, 58 species of sedentary birds were noted in the Lankaran lowland, 54 in the Talish mountain-forest zone and 35 in the Talish high mountain zone. A list of the sedentary species settled in different parts of the province is presented.

It was noted in the Lankaran lowland: *Podiceps nigricollis*, *Ardea alba*, *A.cinerea*, *Haliaeetus albicilla*, *Accipiter gentilis, Buteo rufinus*, *B.buteo*, *Aquila chrysaetos, Aegypius monachus, Gyps fulvus, Circus aeruginosus*, *Francolinus francolinus*, *Porphyrio porphyrio*, *Columba palumbus*, *C.livia*, *Streptopelia decaocto*, *Spilopelia senegalensis* (**Figure 3a**), *Bubo bubo*, *Asio otus*, *Athene noctua*, *Strix aluco*, *Alcedo atthis*, *Picus viridis*, *Dendrocopos major*, *D.syriacus*, *D.minor*, *Galerida cristata*, *Melanocorypha calandra*, *Garrulus glandarius*, *Pica pica*, *Corvus frugilegus*, *C.cornix*, *Coloeus monedula*, *Troglodytes troglodytes*, *Prunella modularis*, *Cettia cetti*, *Regulus regulus*, *Turdus philomelos*, *Erithacus rubecula*, *Panurus biarmicus*, *Aegithalos caudatus*, *Remiz pendulinus*, *Parus major*, *Periparus ater*, *Sitta europaea*, *Tichodroma muraria*, *Certhia familiaris*, *Passer domesticus*, *P.hispaniolensis*, *P.montanus*, *Fringilla coelebs*, *Chloris chloris*, *Spinus spinus*, *Carduelis carduelis, Linaria cannabina, Coccothraustes coccothraustes, Emberiza calandra, E.cia*. The noted species are water-coast, aquatic, herbaceous, tree-shrub, low mountain-forest, and garden birds according to their connection characteristics with the biotope. The species noted (58 species) here constitute 73.4 percent of the sedentary species (79 species) settled in the Lankaran physical-geographical province. According to the species composition and numbers, the dominant birds of this area are species belonging to the *Passeriformes* order. *Passeriformes* (32 species) settled here constitute 40.5 percent of the sedentary species settled in the Lankaran physical-geographical province.

It was noted in the mountain-forest belt of Talish: *Accipiter gentilis, Buteo buteo*, *Aquila chrysaetos*, *Aegypius monachus*, *Gyps fulvus*, *Phasianus colchicus*, *Columba palumbus*, *C.livia*, *Streptopelia decaocto*, *Bubo bubo*, *Asio otus*, *Athene noctua*, *Strix aluco*, *Picus viridis*, *Dryocopus martius*, *Dendrocopos major*, *D.syriacus*, *D.minor*, *Galerida cristata*, *Melanocorypha calandra*, *Lullula arborea*, *Garrulus glandarius*, *Pica pica* (**Figure 3b**), *Corvus cornix*, *C.corax*, *Coloeus monedula*, *Cinclus cinclus*, *Troglodytes troglodytes*, *Prunella modularis*, *Regulus regulus*, *Turdus torquatus*, *T.philomelos*, *T.viscivorus*, *Erithacus rubecula*, *Aegithalos caudatus*, *Parus major*, *Poecile hyrcanus*, *Periparus ater*, *Sitta europaea*, *S.neumayer*, *Tichodroma muraria*, *Certhia familiaris*, *Passer domesticus*, *P.montanus*, *Petronia petronia*, *Fringilla coelebs*, *Chloris chloris*, *Spinus spinus*, *Carduelis carduelis*, *Linaria cannabina*, *Pyrrhula pyrrhula*, *Coccothraustes coccothraustes*, *Emberiza calandra*, *E.cia*. The species (54 species) settled in this zone constitute 68.4 percent of all the species noted in the Lankaran natural province (79 species). The dominant birds of this area are species belonging to the *Passeriformes* order according to the species composition and numbers. *Passeriformes* (36 species) settled here constitute 45.6 percent of the sedentary species settled in the province. The abundance of the dendrophilic species in this zone is due to the widespread distribution of the foothill forests. These forests are distinguished by the richness of the relict and endemic species (*Albizia julibrissin, Parrotia persica, Zelkova, Gleditsia caspica, Ficus hyrcana,* etc.) of the Tertiary period. The limnodophilous species, whose habitat is connected with the aquatic environment, are not met here. The number of the petrophilous species is small.

It was noted in the high mountain belt of Talish: *Accipiter gentilis*, *Buteo rufinus*, *Aquila chrysaetos*, *Gypaetus barbatus*, *Aegypius monachus*, *Gyps fulvus*, *Alectoris chukar*, *Perdix perdix*, *Columba livia*, *Athene noctua*, *Dendrocopos syriacus*, *Melanocorypha calandra*, *Eremophila alpestris*, *Lullula arborea*, *Anthus spino-letta*, *Pyrrhocorax pyrrhocorax*, *Corvus cornix*, *C.corax*, *Coloeus monedula*, *Cinclus cinclus*, *Prunella collaris*, *Turdus torquatus*, *Sitta neumayer* (**Figure 3c**), *Tichodroma* *muraria*, *Passer domesticus*, *Petronia petronia*, *Montifringilla nivalis*, *Fringilla coelebs*, *Serinus pusillus*, *Carduelis carduelis*, *Linaria flavirostris*, *L.cannabina*, *Pyrrhula pyrrhula, Emberiza calandra*, *E.cia.* Burada 35 növ oturaq quş növü qeydə alındı. Bunlar The total of all the sedentary species noted in the Lankaran natural region is 44.3 percent. The background species of the area are birds (24 species) belonging to the *Passeriformes* order. They are 30.4 percent of the sedentary species in the province. The species distributed in this zone are mainly petrophilous, partly dendrophilic birds that prefer the mountain meadows, mountain-forest thickets, rocks, and mountain steppes.

Figure 3. (a) *Spilopelia senegalensis*; (b) *Pica pica*; (c) *Sitta neumayer*.

The results of the monitoring showed that the number of both species and individuals decreases gradually with increasing altitude (**Figure 4**). For comparison, let's note that while 58 species are settled in the Lankaran lowland, 54 species are noted in the Talish mountain-forest belt, and only 35 sedentary species are noted in the high mountain belt (Rajabova 2021).

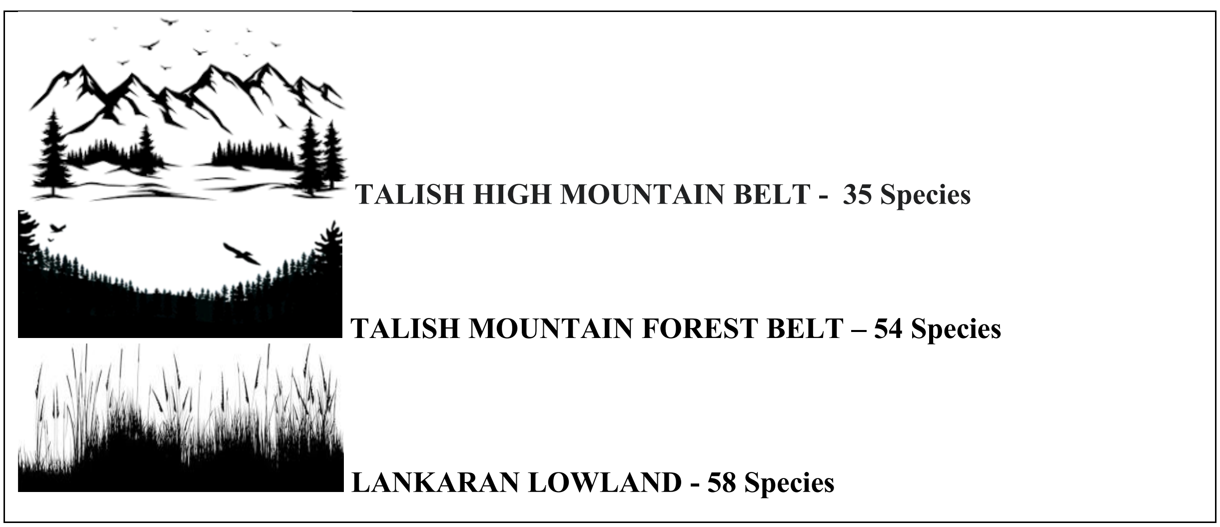

Figure 4. The number of sedentary species settled from the Lankaran lowland to the high mountain belt.

The decrease in the number of species with increasing altitude is due, on the one hand, to the presence of more natural complexes favorable for the birds in the Lankaran lowland, and, on the other hand, to the unique climate of the Talish Mountains (Burovar, Peshtasar ranges). Thus, the interaction of the complex relief with the atmospheric circulation leads to the formation of several climate types by altitude zones. The cold climate types of the steppes with dry summers are widespread for the higher parts of the Talish Mountains. As one rises in altitude, the temperature of the summer and winter months decreases, and the number of frost-free days lasts 120 days. The abundant precipitation falls during the cold period of the year. For this reason, most of the species settled in the high mountainous belt of Talish in the summer season descend to the Lankaran lowland and forest belt, which have more favorable conditions, in the winter months to feed.

As we mentioned above, the population growth, intensive anthropogenic transformation of the natural landscapes, and density of the settlements in the Lankaran province also have a significant influence on the synanthropization level of the birds. This is due to the ecological plasticity of a number of species, their not running away from humans, and the availability of favorable living conditions (i.e., feeding, nesting, absence of enemies and competitors, etc.) in human settlements (mainly in the Lankaran lowland). As can be seen from the materials presented below, 49 species out of 79 sedentary species are noted in the settlements with various statuses (**Figure 5**).

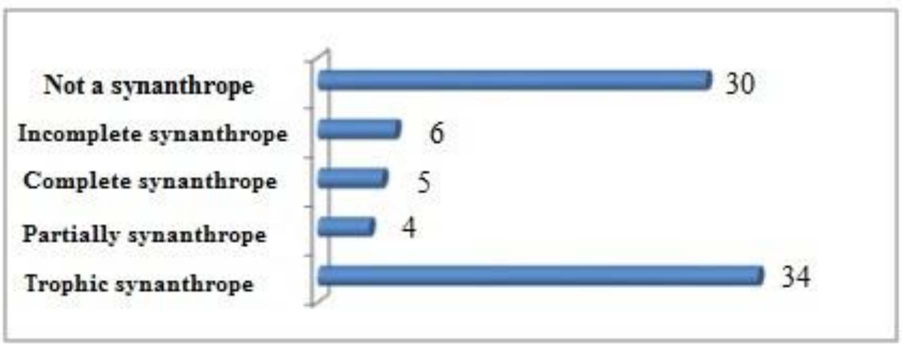

Figure 5. The synanthropization level of the sedentary bird species in the Lankaran natural province.

When talking about the sedentary bird fauna of this province, it is necessary to look at the history of its formation. The ornithofauna of the province (its flora and fauna as a whole) originally consisted of the ancient tropical fauna of Eurasia. As is known, the area of this natural province was not subjected to the glaciation of the III and IV periods. This is also confirmed by the relict and endemic fauna and flora specimens spread in the area. Currently, the endemic sedentary species such as the *Phasianus colchicus talischensis* and *Poecile hyrcanus,* which are representatives of the glaciation period, have settled in the area of the province.

It should be noted that the changes occurred in the ornithofauna of the Palearctic during both the glaciation and post-glaciation periods. That is, the numerous young phylogenetic groups, tolerant of the dry and cold climate of the Palearctic, began to form and spread (Kobishev 1988; Karimov 2024). This process also took place in the area of the Lankaran physical-geographical province located in the South-East of Azerbaijan. Thus, there were faunistic connections with the former fauna of the Afrotropics (including East Africa, the Arabian Peninsula, the Southern areas of Pakistan and Iran, and the islands of the Indian Ocean) and the Indomalayan zoogeographical zones located in the South of itself of the province (not subject to glaciation) (Kobishev 1988).

It is precisely the faunistic relations with the neighboring zoogeographic zones that have a significant impact on the formation of the sedentary bird fauna of the province. The compatibility of the ecological complexes in the province with the ecological complexes in their historical homelands has allowed the sedentary species noted by us today to spend a sedentary lifestyle in the area of the province.

The research work conducted by us showed that the sedentary bird fauna, which is a relic of the periods before and after the last IV glaciation, is exposed to the influence of several anthropogenic factors. Thus, the Lankaran physical-geographical province is one of the regions in the republic where the population is least provided with land. And this creates ecological problems for the sedentary bird fauna in the region where the natural ecosystems are exploited intensively, and the population is increasing. First of all, the reduction of forest and shrub areas, the expansion of recreation and tourism centers, the transport network, and intensive livestock grazing cause the reduction and permanent loss of the reproduction places of the sedentary birds. Illegal hunting and chemicals used in agriculture cause a decrease in numbers and a limitation of the food base. The current situation requires the environmental education of the local population and achieving public mass participation (nature lovers, schoolchildren are meant) in the process of bird protection. When the land plots are given to the farmers and entrepreneurs (tourism, recreation, hotel, catering, etc. centers), they should be informed about the importance of bird protection and compliance with it (fines are provided for non-compliance).

Conclusion

The sedentary bird fauna of the Lankaran natural province is formed from 79 species belonging to 10 orders, 28 families and 64 genera. This sedentary bird fauna consists of various fauna types and endemic species of the Palearctic and is settled in uneven numbers in the area of the province. 58 sedentary species have been noted in the Lankaran lowland, 54 in the Talish mountain-forest belt, and 35 in the Talish high mountain belt. Depending on the climatic factors and the number of ecological complexes, the species composition and number of sedentary birds decrease gradually as the altitude increases. The intensive anthropogenic transformation of the natural landscapes influences the synanthropization level of the sedentary bird species. 62.0 percent of 79 sedentary species settled in the province are related to human settlements with the status of synanthropic species. The factors influencing the habitats and numbers of the sedentary bird fauna of the province are of anthropogenic origin and are related to human economic activity.

The materials collected by us about the sedentary bird fauna of the Lankaran natural province were used in the preparation of the books of the "Red Book" of the Republic of Azerbaijan (III edition, 2023), Information System of the Azerbaijan Fauna (2023), and Taxonomic Spectrum of the Azerbaijan Fauna (2020).

Conflict of Interest

The authors declare that there is no conflict of interest.

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PHYTOPLANKTON DIVERSITY, SEASONAL DYNAMICS, AND TROPHIC LINKAGES TO FISH PRODUCTIVITY IN THE CASPIAN SEA: A REVIEW

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Abstract: As the world's largest enclosed water body, the Caspian Sea possesses a unique ecosystem and significant economic value. Phytoplankton, as primary producers forming the foundation of the pelagic food web, play a fundamental role in shaping the biological productivity and ecological status of this semi-enclosed sea. This review article synthesizes existing scientific knowledge on the species diversity, seasonal dynamics, interactions with key ecological factors, and impacts on fish stocks of phytoplankton communities in the Caspian Sea. The phytoplankton composition is mainly represented by diatoms (Bacillariophyta), dinoflagellates (Dinophyta), cyanobacteria, and green algae (Chlorophyta). Seasonal variability is clearly expressed: diatoms dominate during spring and autumn blooms, while rising temperatures and nutrient enrichment during summer months lead to the massive development of cyanobacteria and dinoflagellates. Recent climate changes, particularly the increase in sea surface temperature (more than 30°C), changes in salinity, and the influence of photosynthetically active radiation, have intensified eutrophication processes and increased the frequency of harmful algal blooms (e.g., *Pseudo-nitzschia seriata, Nodularia spumigena*). These changes exert cascading effects on zooplankton communities and, consequently, on commercially important fish stocks (kilka, sturgeon, and the Caspian seal). Monitoring phytoplankton dynamics is essential for the sustainable management of the Caspian Sea's biological resources and for ecosystem-based conservation strategies.

Keywords: biodiversity, eutrophication, climate change, fish productivity, harmful algal blooms.

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Introduction

With an area of approximately 370,000 km^2 and depths exceeding 1,000 meters, the Caspian Sea is the world's largest enclosed water body. Its distinctive hydrological regime – characterized by a negative water balance, persistent sea-level fluctuations, and a salinity gradient ranging from less than 1% in the north to approximately 13%

in the south – has shaped a biota with high endemism and considerable economic significance (Aladin & Plotnikov 2004; Zonn et al. 2005). The sea's fisheries, particularly sturgeon, which supply over 90% of the world's caviar production, as well as kilka and other commercial species, have played a vital role in the economies of the littoral states for centuries (Dumont 2005; Wootton 1998).

Phytoplankton, as the primary producers, constitutes the foundation of the entire pelagic food web in the Caspian Sea (Falkowski & Raven 2007; Reynolds 2006). These microscopic photosynthetic organisms convert solar energy into organic matter, release oxygen, and create a food base for zooplankton, fish larvae, and higher trophic levels (Kirk 2011; Parsons et al. 1984). The composition, abundance, and seasonal succession of phytoplankton are sensitive indicators of environmental change; they respond rapidly to variations in temperature, light, nutrient availability, and salinity (Harris 1986; Wetzel 2001). For this reason, phytoplankton is widely used as reliable bioindicators in assessing water quality, eutrophication levels, and overall ecosystem health (Anderson et al. 2002; Paerl & Otten 2013).

In recent decades, the Caspian Sea ecosystem has undergone significant transformation under the combined influence of climate change and anthropogenic pressures (Kostianoy & Kosarev 2005; Zonn et al. 2010). Rising global temperatures have elevated sea surface temperatures, altered stratification regimes, and affected the timing and intensity of phytoplankton blooms (Behrenfeld et al. 2006; Fendereski 2025). Concurrently, agricultural runoff, industrial effluents, and domestic wastewater, particularly via the Volga River, which supplies approximately 80% of the sea's freshwater inflow, have increased nutrient loads (nitrogen and phosphorus), accelerating eutrophication processes (Heidari et al. 2018; Smith et al. 1999). Furthermore, the introduction of the invasive ctenophore *Mnemiopsis leidyi* in the 1990s drastically altered zooplankton communities, disrupting trophic dynamics (Dumont 2005; Kideys 2002).

This review aims to characterize the species composition and taxonomic diversity of Caspian Sea phytoplankton; analyze seasonal dynamics and the ecological drivers that regulate them; assess the impacts of anthropogenic and climatic influences on phytoplankton communities; and investigate the linkages between phytoplankton productivity and fish stocks. By integrating satellite observations, field studies, and ecological modeling results (Steele & Henderson 1992; Sverdrup 1953), this work presents the current state of phytoplankton in the Caspian Sea and offers recommendations for ecosystem management (Carpenter et al. 1985; Odum & Barrett 2005).

Ecological characteristics and roles of phytoplankton

Phytoplankton are studied in detail in their ecosystems; they are biologically active, photosynthetic microscopic organic matter (Falkowski & Raven 2007; Reynolds 2006). These organisms, which have an autotrophic nutrition type, convert inorganic carbon into organic compounds using solar energy and release oxygen in the process (Kirk 2011; Wetzel 2001). Globally, phytoplankton produces approximately half of the oxygen entering the Earth's atmosphere and plays a vital role as a carbon sink in the carbon cycle (Behrenfeld et al. 2006; Falkowski & Raven 2007).

The primary productivity of phytoplankton in the Caspian Sea determines the energy base of the ecosystem (Odum & Barrett 2005; Parsons et al. 1984). Organic matter produced by photosynthesis is the main food source for zooplankton, mollusks, crustaceans, and fish larvae (Reynolds 2006; Wootton 1998). Changes in the amount and species composition of phytoplankton spread throughout the trophic chain, directly affecting the formation of fish stocks (Carpenter et al. 1985; Lindeman 1942).

Caspian Sea phytoplankton is represented by various taxonomic groups (Reynolds 2006; Tomas 1997). Each of these groups has unique morphological, physiological, and ecological characteristics. Bacillariophyta (diatoms) is the most widespread and biodiversity-rich group in the Caspian Sea (Bagheri et al. 2011; Heidari et al. 2018). They have a strong cell wall (frustule) made of silica and form mostly single-celled or chain-shaped colonies (Reynolds 2006; Tomas 1997). Diatoms exhibit high abundance in temperate climates and nutrient-rich waters (Sommer et al. 1986; Sverdrup 1953). Among the diatoms that form the basis of spring and autumn blooms, the genera *Cyclotella caspia* (an endemic species), Navicula, Nitzschia, and Coscinodiscus predominate (Bagheri et al. 2011; Heidari et al. 2018). Their high content of protein, lipids, and essential fatty acids make them of high nutritional value for zooplankton and fish larvae (Reynolds 2006; Wootton 1998). In winter, diatoms can constitute 96–99% of total phytoplankton biomass, reaching 4.5-5.0 g/m³ (Vostokov et al. 2023). **Figure 1** depicts a microscopic view of diatoms (Tomas 1997).

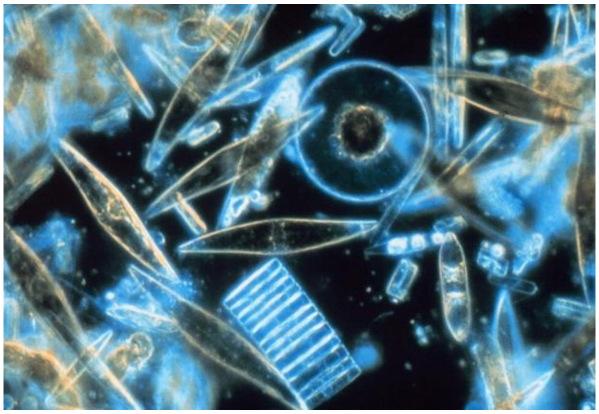

Figure 1. Bacillariophyta (Source: Tomas 1997).

Dinophyta (dinoflagellates) are complex, mostly unicellular, motile organisms (Reynolds 2006; Tomas 1997). They move using specialized flagella, and most species have a covering called theca, which consists of cellulose plates (Hallegraeff 1993; Tomas 1997). Dinoflagellates are mainly distributed in marine and brackish waters, with some species exhibiting mixotrophic nutrition (Reynolds 2006). The genus *Prorocentrum micans* and *Peridinium* are most common in the Caspian Sea (Bagheri et al. 2011; Heidari et al. 2018). Their massive development in the warm season can lead to water "blooming" phenomena (Anderson et al. 2002; Hallegraeff 1993). Some species secrete toxins, creating harmful algal blooms (HABs) (Landsberg 2002; Paerl & Otten 2013). **Figure 2** shows the structure of dinoflagellates (Tomas 1997).

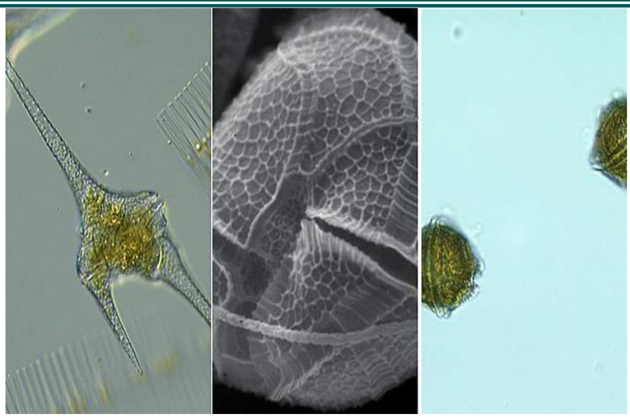

Figure 2. Dinophyta (Source: Tomas 1997).

Chlorophyta (green algae) – although they make up a relatively small portion of phytoplankton, they are mainly distributed near the coast and in areas where rivers flow (Reynolds 2006; Tomas 1997). The presence of chlorophyll "a" and "b" pigments in their cells ensures high photosynthetic activity (Falkowski & Raven 2007; Kirk 2011). Green algae develop more intensively in late summer and autumn (Sommer et al. 1986; Wetzel 2001). Mass reproduction of some species may be an indicator of eutrophication (Smith et al. 1999; Anderson et al. 2002). **Figure 3** depicts a representative of green algae (Leliaert et al. 2012).

Figure 3. Chlorophyta; **A:** Pterosperma (Pyramimonadales), **B:** Nephroselmis (Nephroselmidophyceae), **C:** Palmophyllum (Palmophyllales) **D:** Tetraselmis (Chlorodendrophyceae), **F:** Oocystis (Trebouxiophyceae, Oocystaceae), **G:** Haematococcus (Chlorophyceae, Chlamydomonadales), **H:** Pediastrum (Chlorophyceae, Sphaeropleales), **I:**

Bulbochaete (Chlorophyceae, Oedogoniales), **J:** Chaetophora (Chlorophyceae, Chaetophorales), **K:** Ulothrix (Ulvophyceae, Ulotrichales), **L:** Ulva (Ulvophyceae, Ulvales), **M:** Cladophora (Ulvophyceae, Cladophorales), **N:** Boergesenia (Ulvophyceae, Cladophorales), **O:** Acetabularia (Ulvophyceae, Dasycladales), **P:** Caulerpa (Ulvophyceae, Bryopsidophyceae), **Q:** Klebsormidium (Klebsormidiophyceae), **R:** Spirotaenia, **S:** Nitella (Charophyceae), **T:** Micrasterias (Zygnematophyceae, Desmidiales), **U:** Coleochaete (Coleochaetophyceae). (Source: Leliaert et al. 2012).

Cyanobacteria (cyanobacteria, blue-green algae) are prokaryotic organisms capable of photosynthesis (Paerl & Otten 2013; Reynolds 2006). Their ability to fix atmospheric nitrogen gives them an advantage in conditions where nutrients are limited (Paerl & Otten 2013; Smith et al. 1999). Species such as *Microcystis*, *Oscillatoria*, *Anabaena*, and *Nodularia spumigena* are widespread in the Caspian Sea (Bagheri et al. 2011; Fendereski 2025; Heidari et al. 2018). Their massive growth during high temperatures in the summer months causes water turbidity, oxygen depletion, and the release of toxins (Anderson et al. 2002; Landsberg 2002; Paerl & Otten 2013).

In addition to these four main groups, small amounts of euglenophytes (Euglenophyta) and cryptophytes (Cryptophyta) are also recorded in Caspian waters (Bagheri et al. 2011; Tomas 1997). However, their share in the total phytoplankton biomass is relatively small (Heidari et al. 2018).

Physical and geographical features of the Caspian Sea

The Caspian Sea is located between Europe and Asia, approximately 1,200 km long and 204–466 km wide (Kosarev & Yablonskaya 1994; Zonn et al. 2010). The total length of the coastline is 6,380 km, of which 825 km falls on Azerbaijan (Zonn et al. 2010). The sea covers the coasts of five countries (Azerbaijan, Russia, Kazakhstan, Turkmenistan, Iran) (Kosarev & Yablonskaya 1994). The sea is divided into three main morphometric zones (Kosarev & Yablonskaya 1994; Zonn et al. 2010):

- Northern Caspian: shallow (average depth 5–6 m), characterized by low salinity (under 1%) under the influence of the Volga River.
- Middle Caspian: average depth ~190 m, salinity varies between 8–12%.
- South Caspian: South Caspian: maximum depth is more than 1000 m, salinity reaches 12–13%.

Approximately 130 rivers flow into the Caspian Sea, the largest share being the Volga (~80%), Kura (~6%), and Ural (~5%). Sea level is approximately 28 m below the world ocean level, with long-term variability of 10–20% (Kosarev & Yablonskaya 1994; Zonn et al. 2010).

The climate varies from cold continental in the north to mild subtropical in the south (Kosarev & Yablonskaya 1994; Zonn et al. 2010). In winter, icing is observed in the northern part, while temperatures remain moderate in the south. During the summer months, surface water temperatures can rise above 30°C in the south (Fendereski 2025; Zonn et al. 2005). Water transparency is lower in coastal zones where rivers flow, and higher in the central parts of the sea (Kosarev & Yablonskaya 1994).

The hydrodynamic regime is mainly determined by winds, temperature differences, river currents, and bottom relief (Kosarev & Yablonskaya 1994; Kostianoy & Kosarev 2005). The formation of a thermocline layer during the summer months limits vertical mixing and makes it difficult for nutrients to rise to the surface layers

(Sommer et al. 1986; Sverdrup 1953). These physical characteristics directly affect the spatial distribution and seasonal dynamics of phytoplankton (Kosarev & Yablonskaya 1994; Harris 1986; Reynolds 2006; Zonn et al. 2010).

Phytoplankton species diversity

The species composition of phytoplankton in the Caspian Sea is represented by several algal divisions. According to recent studies (Bagheri et al. 2011; Heidari et al. 2018; Tomas 1997), a total of more than 48 species has been identified. According to observations made in the southwestern Caspian (2020–2021), Bacillariophyta accounts for 80.0%, Cyanophyta for 11.0%, Dinophyta for 4.0%, and Chlorophyta for 3.5%. In the Middle Caspian, *Cyclotella caspia* and *Prorocentrum micans* predominate in spring, and small flagellates and dinoflagellates predominate in summer (Bagheri et al. 2011; Vostokov et al. 2023).

Between 1996 and 2020–2021, the total amount of phytoplankton on the southwestern coast of the Caspian Sea increased 7 times, and the concentration of chlorophyll-a increased 7 times. This increase occurred in parallel with a more than 3-fold increase in nutrients (nitrogen and phosphorus), and the trophic state shifted from oligotrophy to mesotrophy (Bagheri et al. 2011; Heidari et al. 2018; Smith et al. 1999).

New invasive or expanding species have also been recorded in recent years. These include *Pseudo-nitzschia seriata* (a diatom that produces domoic acid), *Ërataulina pelagica*, and *Chaetoceros peruvianus*. The spread of these species is associated with the long-term impact of climate change and warm water conditions (Bagheri et al. 2011; Behrenfeld et al. 2006; Fendereski 2025; Hallegraeff 1993).

The impact of environmental factors on phytoplankton

Temperature is a key factor regulating phytoplankton growth rate, species composition, and bloom phenology (Harris 1986; Reynolds 2006; Sommer et al. 1986). Rising sea surface temperatures lead to a dominance of thermophilic forms (dinoflagellates, cyanobacteria) and a relative decline in diatoms (Paerl & Otten 2013). Satellite data (2003–2021) show that sea surface temperature is the second most important factor influencing chlorophyll-a variability (the first is photosynthetically active radiation) (Behrenfeld et al. 2006; Fendereski 2025).

Light. Photosynthetically active radiation has a dominant effect on chlorophyll-a changes in the Southern Caspian. Reduced water transparency (due to high phytoplankton biomass or suspended particles) limits the transmission of light to deeper layers, concentrating photosynthesis only in the upper layer, which in turn can intensify bloom events (Kirk 2011; Sverdrup 1953; Wetzel 2001).

Food ingredients. Nitrogen and phosphorus compounds are the main limiting factors in the mass development of phytoplankton (Reynolds 2006). Biogenic elements entering the sea through river flows, especially the Volga, have increased significantly over the past 25 years (Heidari et al. 2018; Kosarev & Yablonskaya 1994). This increase has led to eutrophication, elevated chlorophyll-a concentrations, and an increased frequency of harmful blooms (Anderson et al. 2002; Heidari et al. 2018; Paerl & Otten 2013; Smith et al. 1999).

Salinity. The salinity gradient determines the spatial distribution of phytoplankton. Freshwater and brackishwater species predominate in the north, while marine forms predominate towards the south. In recent decades, there has been an increase in salinity, which is due to increased evaporation and a decrease in freshwater inflow (Fendereski 2025; Kosarev & Yablonskaya 1994; Zonn et al. 2010).

Anthropogenic impacts

Eutrophication. Excessive nutrient input from agricultural fertilizers, household and industrial waste has accelerated the eutrophication process. This leads to uncontrolled growth of phytoplankton, decreased water transparency, disruption of the oxygen regime, and the creation of "dead zones" (Landsberg 2002; Smith et al. 1999). Chlorophyll-a levels have increased 7 times in the southwestern Caspian as a result of eutrophication (Anderson et al. 2002; Paerl & Otten 2013; Smith et al. 1999).

Oil and industrial pollution. As the Caspian Sea is one of the ancient centers of the oil and gas industry, oil spills, heavy metals, and organic pollutants have a lasting impact on the aquatic environment (Kostianoy & Kosarev 2005; Neff 2002; Zonn et al. 2005). The oil film reduces the transmission of light to the water, while toxic substances slow down the development of sensitive phytoplankton species and reduce species diversity (Anderson et al. 2002; Neff 2002; Paerl & Otten 2013;).

Invasive species. The introduction of *Mnemiopsis leidyi ctensor* into the Caspian Sea in the 1990s sharply reduced zooplankton populations (Dumont 2005; Kideys 2002). This has weakened grazing pressure on phytoplankton, disrupted the trophic chain, and caused serious damage to stocks of fish species such as kilka (Carpenter et al. 1985; Kideys 2002). At the same time, the introduction of new algae species (e.g. *Pseudo-nitzschia seriata*) is also changing the ecosystem structure (Bagheri et al. 2011; Fendereski 2025; Hallegraeff 1993).

Seasonal dynamics of phytoplankton

Seasonal variability of phytoplankton in the Caspian Sea is clearly expressed and is mainly determined by light, temperature, nutrient availability, and water mixing regime.

The spring season is characterized as "biological spring" or "flowering season". Increased solar radiation, longer daylight hours, and the rise to the surface of nutrient salts (nitrate, phosphate, silicate) accumulated in deep layers in winter create conditions for the rapid development of diatom algae (Harris 1986; Reynolds 2006; Sommer et al. 1986; Wetzel 2001). **Figure 4** shows a schematic representation of spring flowering (Sommer et al. 1986; Sverdrup 1953).

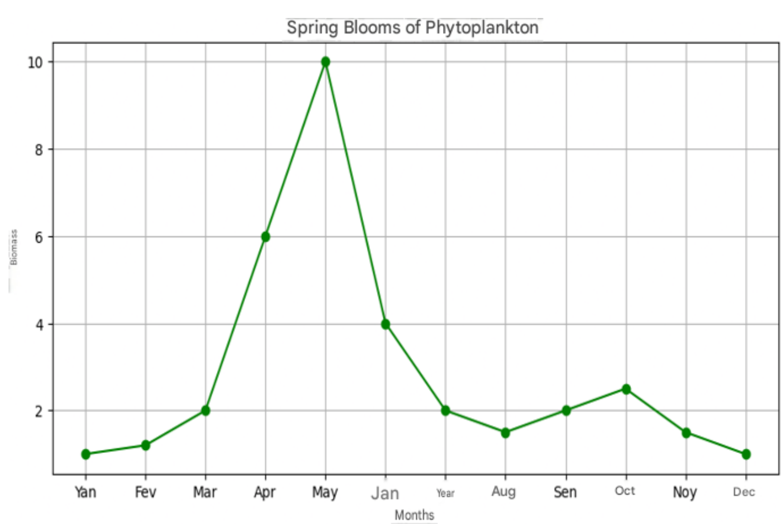

Figure 4. Spring cycle diagram of phytoplankton. (Source: Sommer et al. 1986; Sverdrup 1953)

In summer, due to rising temperatures, the formation of a thermocline layer, and the depletion of nutrients in the surface layers, diatoms decline and are replaced by cyanobacteria and dinoflagellates, which are resistant to heat and low nutrient concentrations (Sommer et al. 1986; Paerl & Otten 2013; Reynolds 2006). **Figure 5** shows the summer cycle diagram (Sommer et al. 1986; Wetzel 2001).

The cyanobacterium *Nodularia spumigena* created a massive bloom in the Anzali region in July 2021, reaching 5,000,000 cells/L (Bagheri et al. 2011; Fendereski 2025). The dominance of these species in eutrophic conditions reduces water clarity, worsens the oxygen regime, and negatively affects fish stocks (Anderson et al. 2002; Landsberg 2002; Paerl & Otten 2013).

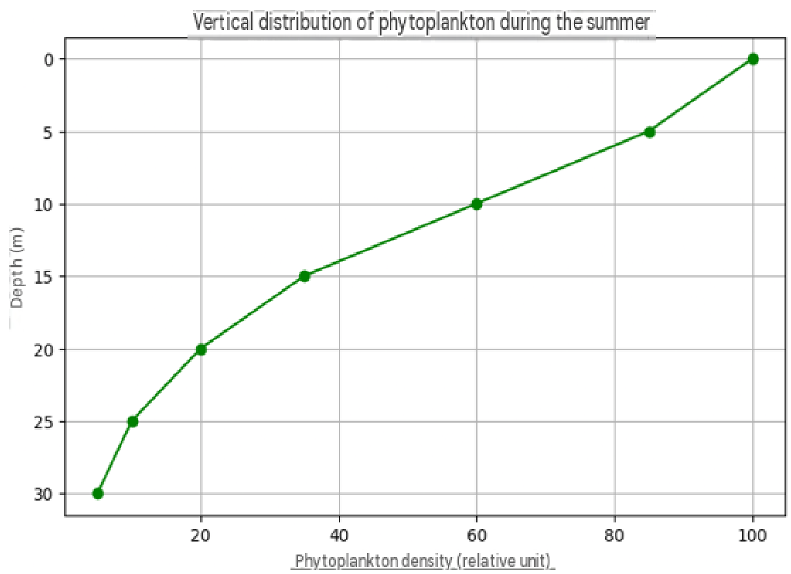

Figure 5. Summer cycle diagram of phytoplankton. (Adapted from Sommer et al. 1986; Wetzel 2001).

In autumn, the gradual decrease in temperature, the strengthening of the wind regime and the intensification of vertical mixing cause the biogenic elements accumulated in the deep layers to rise to the surface (Reynolds 2006; Sommer et al. 1986; Sverdrup 1953). This leads to the second - autumn bloom (Harris 1986; Wetzel 2001). **Figure 6** shows the autumn dynamics (Reynolds 2006; Sommer et al. 1986).

Diatoms again dominate the fall bloom, but this growth is shorter and weaker than the spring bloom (Harris 1986; Sommer et al. 1986). Nevertheless, the fall period plays an important role in the ecosystem's annual productivity and provides an additional resource for zooplankton nutrition (Parsons et al. 1984; Wootton 1998).

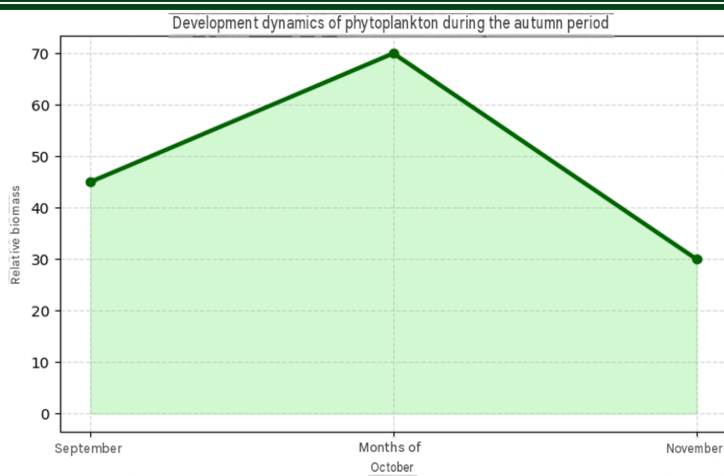

Figure 6. Autumn cycle diagram of phytoplankton
(Adapted from Sommer et al. 1986; Reynolds 2006).

In winter, the weakening of solar radiation, the shortening of daylight hours, and the lowering of water surface temperatures minimize photosynthesis processes (Kirk 2011; Reynolds 2006; Sverdrup 1953). **Figure 7** depicts the winter period (Harris 1986; Sverdrup 1953).

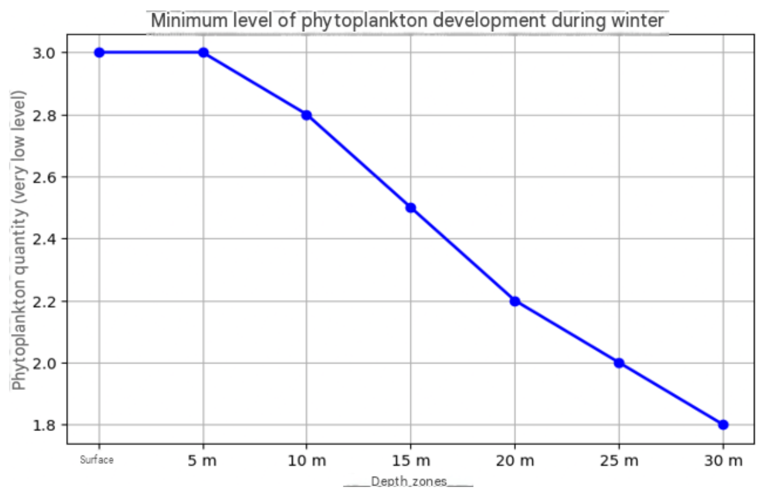

Figure 7. Winter cycle diagram of phytoplankton.
(Adapted from Sverdrup 1953; Harris 1986).

In winter, the number and biomass of phytoplankton decrease sharply (Reynolds 2006; Wetzel 2001). However, winter diatom blooms (January-February) are observed in the Middle Caspian, when the biomass reaches 4.5–5.0 g/m³ and diatoms constitute 96–99% of the total phytoplankton (Vostokov et al. 2023). In addition to traditional diatoms, invasive *Pseudo-nitzschia seriata* and *Cerataulina pelagica* contribute to these blooms (Bagheri et al. 2011; Fendereski 2025). The winter period also creates favorable conditions for the accumulation of nutrients in the water column, which is the basis for the spring bloom (Parsons et al. 1984; Sverdrup 1953).

The role of phytoplankton in the trophic chain and its relationship with fish productivity

Phytoplankton, as primary producers

in aquatic ecosystems, constitute the energy base of the entire trophic system (Falkowski & Raven 2007; Lindeman 1942; Odum & Barrett 2005). The energy flow usually occurs in the sequence Phytoplankton → Zooplankton → Small planktonic fish → Predatory fish (Carpenter et al. 1985; Parsons et al. 1984). **Figure 8** schematically depicts the trophic chain of the Caspian Sea (Carpenter et al. 1985; Odum & Barrett 2005).

According to the 10% rule proposed by Lindeman, approximately 10% of the energy is transferred from each trophic level to the next (Lindeman 1942; Odum & Barrett 2005). Therefore, a decrease in phytoplankton biomass causes a cascading decline in fish stocks (Carpenter et al. 1985; Steele & Henderson 1992). Phytoplankton affects fish stocks in several ways (Falkowski & Raven 2007; Parsons et al. 1984; Wootton 1998):

- Direct feeding: Some fish larvae and microphage species feed on large diatoms and dinoflagellates.
- Indirect effect: Energy is mainly transferred through phytoplankton → zooplankton → fish. The abundance of phytoplankton, which is the food base of zooplankton, has a positive effect on the growth of zooplankton, which in turn has a positive effect on the survival of fish larvae.
- Oxygen regime: Oxygen released during photosynthesis is essential for fish respiration. However, massive decomposition after blooming leads to oxygen depletion (hypoxia).
- Spawning areas: Excessive growth of phytoplankton reduces water transparency, limits the development of underwater plants, and destroys natural spawning substrates for fish.

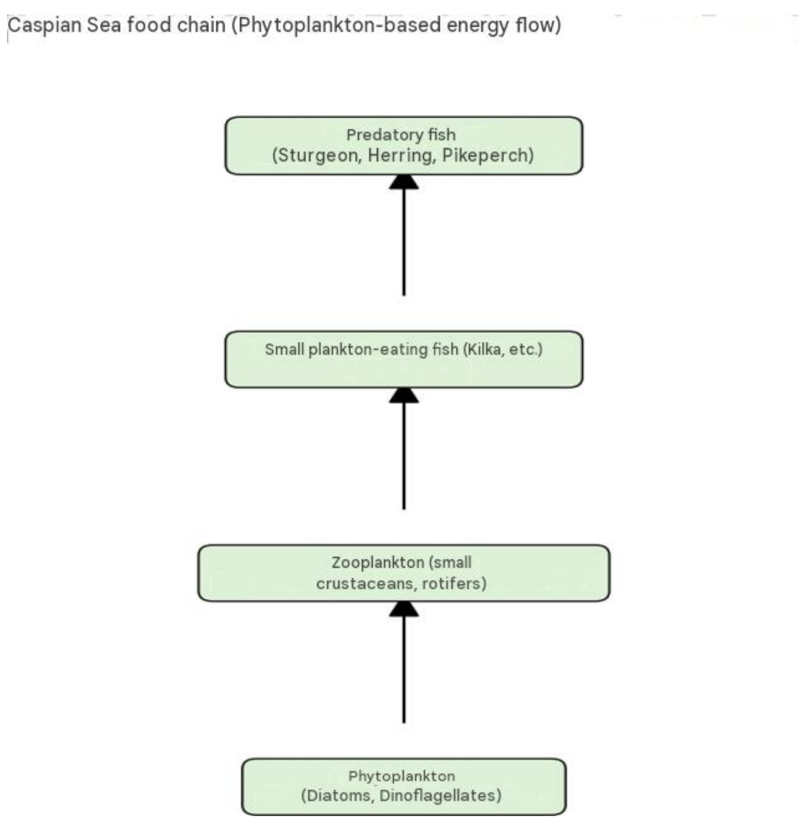

Figure 8. Caspian Sea trophic chain diagram.
(Adapted from Carpenter et al. 1985; Odum & Barrett 2005).

According to the match-mismatch hypothesis (Cushing 1990), the timing of fish larval feeding and phytoplankton blooms determines larval survival (Cushing 1990; Wootton 1998). When climate change alters bloom phenology, this match is disrupted, and fish stocks decline (Behrenfeld et al. 2006; Fendereski 2025).

Figure 9 shows the chain-lag dynamics between phytoplankton (P), zooplankton (Z), and fish (F) biomass (Lindeman 1942; Steele & Henderson 1992). After the phytoplankton peak, zooplankton and fish populations increase a few days later (Carpenter et al. 1985; Steele & Henderson 1992).

In the Caspian Sea, the invasion of *Mnemiopsis leidyi* in the 1990s drastically reduced zooplankton, leading to an overgrowth of phytoplankton, a collapse of kilka stocks, and even the death of sturgeon and Caspian seal (Carpenter et al. 1985; Dumont 2005; Kideys 2002). This event clearly demonstrates the vulnerability of the trophic chain (Carpenter et al. 1985; Kideys 2002).

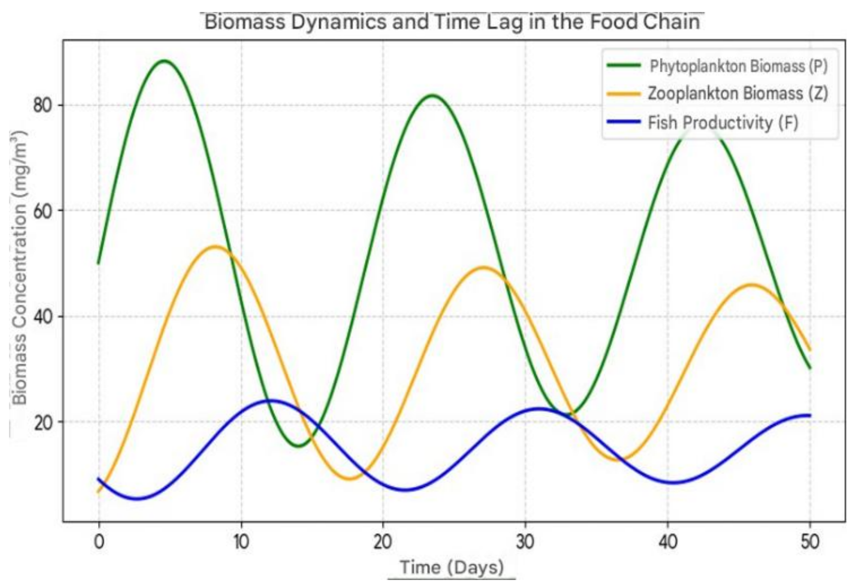

Figure 9. Biomass dynamics and chain lag scheme.
(Adapted from Steele & Henderson 1992; Lindeman 1942).

Negative impacts: Harmful blooms and ecological disturbances

The increase in anthropogenic nutrients causes uncontrolled growth of phytoplankton. After the bloom, bacterial activity increases during the decomposition of biomass, and dissolved oxygen in the water is rapidly depleted (Anderson et al. 2002; Smith et al. 1999). This creates "dead zones" that cause mass fish kills (Andsberg 2002; Paerl & Otten 2013).

Species such as *Nodularia spumigena* (nodularin hepatotoxin) and *Pseudo-nitzschia seriata* (domoic acid – neurotoxin) secrete toxins. These toxins enter the food chain and cause nervous system disorders, gill paralysis, and death in fish. Bioaccumulation of toxins also poses a risk to human health (Anderson et al. 2002; Hallegraeff 1993).

Climate change and pollution are reducing the abundance of high-nutrient diatoms, replacing them with low-nutrient and toxigenic cyanobacteria. This "false productivity" reduces the ecosystem's real fish production potential (Anderson et al. 2002; Carpenter et al. 1985; Smith et al. 1999).

Conclusion and Recommendations

A review of the conducted studies shows that the phytoplankton communities of the Caspian Sea are undergoing rapid transformation under the complex influence of climate change, eutrophication, pollution and biological invasions (Fendereski 2025; Kostianoy & Kosarev 2005; Zonn et al. 2010). The main results are as follows:

1. Species composition: Diatoms, dinoflagellates, cyanobacteria and green algae dominate. The share of invasive and potentially harmful species is increasing (Bagheri et al. 2011; Fendereski 2025).
2. Seasonal dynamics: Spring and autumn diatom blooms are the main productive periods; cyanobacteria and dinoflagellates dominate in summer; biomass is minimized in winter, but diatom blooms are occasionally observed (Reynolds 2006; Vostokov et al. 2023).
3. Ecological factors: Temperature, light, nutrients and salinity are the main regulators of phytoplankton dynamics. Climate change affects each of these factors (Behrenfeld et al. 2006; Fendereski 2025).
4. Anthropogenic impacts: Increased nutrients have led to eutrophication, an increase in the frequency of harmful blooms, and a change in trophic status (Heidari et al. 2018; Smith et al. 1999).
5. Link to fish stocks: The abundance, composition, and phenology of phytoplankton determine the dynamics of zooplankton and fish populations. Harmful blooms pose a direct threat to fish and human health (Landsberg 2002; Paerl & Otten 2013).

Research gaps

- Long-term monitoring: Continuous, coordinated monitoring programs covering all Caspian regions are needed (Fendereski 2025; Kosarev & Yablonskaya 1994; Zonn et al. 2005).
- Mechanism studies: In-depth studies of interspecific competition, regulation of toxin production, and food web dynamics are necessary (Hallegraeff 1993; Reynolds 2006; Sommer et al. 1986).
- Prediction models: Development of ecosystem models integrated with climate change scenarios is essential (Behrenfeld et al. 2006; Fendereski 2025; Steele & Henderson 1992).
- Invasive species management: Strategies to prevent new invasions and mitigate existing impacts should be implemented (Dumont 2005; Kideys 2002).

Management recommendations

- Reducing nutrient inputs (control of agricultural, industrial and domestic waste).
- Monitoring pollution sources and strengthening clean-up measures.
- Sustainable management of fish stocks and implementation of recovery plans.
- Developing climate change adaptation strategies using an ecosystem approach.

Phytoplankton, despite their microscopic size, are a reliable indicator of the health of the Caspian Sea. Monitoring and understanding their dynamics are vital for the conservation of this unique ecosystem and the sustainable use of its biological resources for future generations.

Conflict of Interest

The authors declare that there is no conflict of interest.

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TAXONOMIC COMPOSITION OF RARE WOODY PLANTS DISTRIBUTED IN THE FLORA OF THE REPUBLIC OF AZERBAIJAN, THEIR CURRENT STATUS AND CONSERVATION MEASURES

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Abstract: Among the plant regions of the world, Azerbaijan stands out for the richness and diversity of its flora. Flowering plants native to the republic account for 70% of the higher plant species in the Caucasus region. However, in terms of land area, Azerbaijan covers only 16% of the entire Caucasus region. This rich flora can be explained by the diverse historical, natural, and geographical conditions of the Republic. The flora of Azerbaijan contains a large number of useful plants. More than 1,500 species of flowering plants native to Azerbaijan can be used in various sectors of the country's economy. The main goal is to effectively use this valuable natural resource and pass it on to future generations. Currently, with the accession of the Republic of Azerbaijan to the Convention on Biological Diversity, the Republic's flora is attracting the attention of researchers worldwide. Extensive projects and research are planned in this area. The article discusses the taxonomic composition of rare tree species distributed in the territory of the Republic, their current status, and the importance of conservation measures. The study also assessed the effects of conservation measures on the number of rare tree species. The study mainly notes the current status of 37 species of rare tree species included in the Angiosperms department, which are included in the "Red Book" of the Republic of Azerbaijan published in 2013, their taxonomy, and special conservation measures. As a result, rare tree species found in the territory of the Republic of Azerbaijan have been identified. The current status of these species has been analyzed based on the "Red Book" of the Republic of Azerbaijan. Finally, the positive effects of conservation measures and specially protected state territories on the current status of rare species have been identified.
Keywords: Red Book, Demiraghac, national park, sanctuary, nature reserve, conservation measures, endangered, rare species.

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Introduction

According to various studies, Azerbaijan currently has a large number of rare and endangered plant species in nature. Official measures are being taken to protect and reproduce these plants. These measures include the creation of protected areas, the designation of nature reserves, and the establishment of national parks. One of the most important measures is the creation of the Red Book of Azerbaijan. Published in 1989, this book lists 140 endangered plant species. It should be noted that the "National Strategy and Action Plan for the Conservation and Sustainable Use of Biodiversity in the Republic of Azerbaijan" was adopted by the Decree of the President of the Republic of Azerbaijan dated March 24, 2006, and Article 1.1.3 of the decree provided for the publication of the second edition of the Red Book in 2009. According to current information, 338 rare and endangered plant species are listed in Volume 2 of the Red Book. The latest edition of the Red Book was published in 2013. The book lists 460 plant species, including 383 higher plants, 15 spore plants, 6 mosses, 14 sphagnum mosses, and 5 algae. It also includes 37 fungal species (The Red Book of the Republic of Azerbaijan, 2013). According to the Red Book, there are 37 rare and endangered tree species in the angiosperms section.

In the study, belonging to the Angiosperms (Magnoliophtya) clade: oriental plane (*Platanus orientalis* L.), boxwoods (*Buxus colchica* Pojark., *B. hyrcana* Pojark, *B. sempervirens* L.), sweet chestnut (*Castanea sativa* Mill.), chestnut-leaved oak (*Quercus castaneifolia* C.A.Mey.), Aleppo oak (*Q. infectoria* Olivier), downy oak (*Q. pubescens* Willd.), birch (*Betula raddeana* Trautv), Caucasian alder (*Alnus subcordata* C.A.Mey.), hornbeam (*Carpinus schuschaensis* H.J.P. Winkl.), Hirkan poplar (*Populus hyrcana* Grossh.), Turan poplar (*P.euphratica* Olivier), Persian ironwood (*Parrotia persica* (DC.) CAMey.), *Zelkova carpinifolia* (Pall.) Dippel, Caucasian hackberry (*Celtis caucasica* Willd.), Hyrcan fig (*Ficus carica* L.), mountain-ash (*Sorbus persica* Hedl., *S. roopiana* Bordz., *S. subfusca* Boiss.), pears (*Pyrus boissieriana* Buhse, *P. eldarica* Grossh., *P. georgica* Kuthath., *P. grossheimii* Fed., *P. hyrcana* Fed., *P. medvedevil* Rubtz., *P. addeana* Woronow, *P. salicifolia* Balb., *P. voronovii* Rubtz., *P. vsevolodii* Heideman), thornapples (*Crataegus pontica* C.Koch.), cherry (*Prunus nachichevanica* Kudr., *Pprunus padus* L.), pomegranate (*Punica granatum* L.), Persian silk tree (*Albizia julibrissin* Durazz), Caucasian bladdernut (*Staphylea colchica* Steven), pistachio tree (*Pistacia atlantica* Desf.), holly tree (*llex hyrcana* Pojark.), and Gymnosperms (Pinophyta) clade includes foetid juniper (*Juniperus foetidissima* Willd.) and yew (*Taxus baccata* L.) trees (The Red Book of the Republic of Azerbaijan, 2013).

Information about trees common in the flora of the Republic of Azerbaijan

Trees are woody, evergreen plants with erect trunks and branches. The diversity of their size and appearance makes it difficult to define the morphology of this plant complex precisely. The term "tree" is sometimes used to describe the gradual development of the trunk into thinner branches or the presence of leaves. However, some perennial herbaceous plants, such as palms, do not branch, and giant cacti have lateral branches on their trunks, but they do not form an umbrella-shaped canopy. Some authors state that the minimum height of woody plants is generally 2–6 m. These figures may refer to all trees or to shrubs growing only in high mountains or certain Arctic regions; these plants are simply called "trees". Under suitable conditions, these plants have straight, slender trunks. Some species can reach a height of more than a few centimeters, but in other respects resemble trees. All mature trees naturally grow from seeds or small vegetative buds (Təhməzov et al. 2004).

The geographical structure and location of Azerbaijan, its unique geological history and rich natural environment have led to the creation of numerous magnificent natural heritage sites. With approximately 3,000 natural heritage sites, the territory of this republic reflects almost all genetic and morphological diversity in the fields of biology, paleontology, geology, geomorphology, petrology, hydrology and landscape. According to experts, plant species found in Azerbaijan constitute 64% of the flora of the Caucasus region, 24% of the flora of the former Soviet Union and 11% of the world flora. Endemic and rare flora and fauna, paleontological flora and fauna museums (Binagadi, Eldar and Pila-Kashkur fauna), lakes, springs, waterfalls (Astara, Afurka and Iris), glaciers, natural landscapes and geological and geomorphological heritage make up our republic. The area is rich in relief monuments, including deposits, ores, rock formations, columnar basalt columns, lava flows, Rocky Mountains eruption domes, volcanic cones, craters and calderas, rocky mountains and mountain ranges (Besbarmag, Ilanridag, Goyazan, Khachagaya), avalanches, landslides, layered fractures, structural formations, ophiolite zones, protocave and depression valleys, caves and karst topography (shell karst, pseudokarst), exotic pyramids and wind sculptures formed in rocks and on the ground. In this context, Goyazan Mountain, Duzdag layered junction, Naftalan oil field, Eldar pine forest, ironwood forest and Basicay plain forests are particularly important (Məmmədov 2011; Shahin 2013).

Clade: Angiosperms

Family: Platanaceae

Species: *Platanus orientalis* L. (Oriental plane)

International Assessment (according to IUCN Categories and Criteria): **DD**

National Assessment (according to IUCN Categories and Criteria): **VU A2c+3c**

Description: It is a deciduous tree with a rounded crown, 25–35 m tall (maximum 50 m) and a crown diameter of 1.5–3(–5) m. The leaves are simple, alternate, dense or papery, rounded or elliptical, with 3–5(–7) finger-like lobes. The fruit is a seed. Flowering occurs in April-May, and the fruit ripens in September-October (**Figure 1**). It grows naturally near water. It prefers hot summers but can be cultivated in most temperate regions. It is a very large and broad tree, with large, thick leaves that spread horizontally, making it particularly valuable for providing shade and coolness in hot seasons. It grows well in sunny locations. It grows well in nutrient-rich soil and is drought-resistant (Missouri Botanical Garden). It is also resistant to urban air pollution. Human activities such as grazing and logging are limiting factors.

Distribution: It was previously protected in the Basitchay National Nature Reserve, but private protection and inclusion in botanical gardens inside and outside the reserve are recommended (The Red Book of the Republic of Azerbaijan, 2013).

Figure 1. Oriental plane (*Platanus orientalis* L.).

Family: Fagaceae

Species: *Castanea sativa* Mill. (chestnut)

International Assessment (according to IUCN categories and criteria): **LC**

National Assessment (according to IUCN categories and criteria): **VU A2c+3cd**

Description: This tree can reach a height of 38 m. The mature leaves are glabrous, green on the upper surface, star-shaped on the lower surface, with light green hairy and toothed edges. The male flowers bloom in yellow, spiny clusters. The fruit is a chestnut-like nut with a chestnut-colored shell, long, sharp spiny edges, and a single seed (The Red Book of the Republic of Azerbaijan, 2013). The average lifespan of a chestnut tree is 500–600 years. When cultivated, it can live for over 1,000 years (Barstow & Khela 2018). Flowering occurs in June-July, and fruiting occurs in October-November. This species grows in rocky areas, stony slopes, and dry, sparsely wooded pastures in mid- and high-mountainous regions. It grows well on fertile soils in temperate climates (**Figure 2**). Human influences are limiting factors in its growth. Since wood is a valuable raw material for the furniture industry, wood decay is one of the factors limiting its growth. The presence of pathogens that cause diseases also limits its growth (Hahn 2024).

Distribution: This species is protected in the Zagatala National Nature Reserve and the Ilisu National Nature Reserve. Additional protection is needed in areas where it is more widely distributed (The Red Book of the Republic of Azerbaijan, 2013).

Figure 2. Chestnut (*Castanea sativa* Mill.).

Family: Salicaceae

Species: *Populus euphratica* Oliv. (Turan poplar)

International assessment (according to IUCN categories and criteria): **LC**

National assessment (according to IUCN categories and criteria): **EN B2b(ii, iii)c(v)**

Description: The leaves are leathery, glabrous, blue-gray, lighter on the underside, wedge-shaped at the base, and the stems are 1–2.5 cm long. The fruit is glabrous and forms on a 3–6 mm long stem (**Figure 3**). Flowering and fruiting occur in June. It is usually found in low mountainous areas and along riverbanks (The Red Book of the Republic of Azerbaijan, 2013). In river basins of arid and semi-desert regions, Tugay is an important component of the alluvial plain ecosystem, forming dense thickets mixed with willow, fir, and mulberry trees. This species thrives in saline soil and brackish water and is resistant to seasonal flooding. Once widely used as firewood, this forest has largely disappeared or been fragmented throughout its natural range (Coombes 2012).

Distribution: It is distributed in the mountainous regions of the Nakhchivan Autonomous Republic (Ordubad district, Gilanchay river basin; Julfa district, Alinjachay river basin and Araz river basin), in the coastal plain of the Caspian Sea (Khizi district, Dizarvarchay river basin; Siyazan district, Gilgilchay river basin), in the Bozdag mountain plateau and in the southern mountains of the Lesser Caucasus (Zangilan district, Bartaz mountain). Natural, zoological and anthropogenic factors (agricultural and industrial development in the habitat, use of firewood, etc.) limit its population. The habitat is partially protected in the Ordubad National Nature Reserve and is the subject of conservation efforts (The Red Book of the Republic of Azerbaijan, 2013).

Figure 3. Turan poplar (*Populus euphratica* Oliv.).

Family: Hamamelidaceae

Species: *Parrotia persica* (DC.) C.A.Mey. (Persian ironwood)

International classification based on IUCN categories and criteria: **None**

National classification based on IUCN categories and criteria: **NT**

Description: This species is a branched tree, reaching a height of 16–22(–25) m. The leaves are 4–10(–13) cm long and 3 cm wide, leathery or papery, alternate and lobed with 3–6 oval, obovate or elliptical lobes. The fruit is round to oval. The seeds are pointed, light brown and shiny (**Figure 4**). The species was named by Karl Anton von Meyer in honor of Georg Friedrich Parrott, a German naturalist and founder of Dolpat College, who studied botany in the Alborz Mountains during a mountaineering expedition in the 1830s (San Miguel Ayanz 2016). The flowering period is between February and March and the fruit ripens between August and November. It reproduces by seeds and cuttings. It grows on heavy clay, yellowish silty soils or soils that form podzol. It is widespread in plains, hills and low mountains.

Distribution: It grows wild in the mountainous areas of the Lankaran region (Tangivan village, Khanbulanchay reservoir), in the Lankaran plains (Burjali village in Lankaran region, Mashkhan village in Astara region, Imanli village in Masalli region, Vilashchay valley) and in the Alazan Ayrichay valley (Chukhurgabala village in Gabala region). Human activities such as deforestation limit its spread. It is protected in Hirkan National Park. Some are also planted in Samur-Yarama National Park and the Central Botanical Garden. A protected area has been proposed within the Central Botanical Garden (The Red Book of the Republic of Azerbaijan, 2013).

Figure 4. Ironwood (*Parrotia persica* (DC.) C.A.Mey.).

Family: Rosaceae

Species: *Pyrus eldarica* Grossh. (Eldar pear)

International Assessment (according to IUCN Categories and Criteria): **None**

National Assessment (according to IUCN Categories and Criteria): **CR A2abc+C1**

Description: It is a shrub or tree up to 1 m tall with densely branched umbel-shaped flower clusters. The opposite oblong-lanceolate leaves are 2–3.5 cm long and 0.8–1.3 cm wide. The leaves have fine, finely hairy or glabrous surfaces and sparsely hairy undersides. They are light green (**Figure 5**). The flowering period is April. The fruits ripen in August-September. Reproduction occurs by seeds and shoots. It usually grows on dry, rocky slopes among sparse bushes, at altitudes of 300–600 m, along with Eldar pine and juniper trees.

Distribution: It is widespread in the pasture areas of the Bozdag massif (Samukh district, Eldar Oyun mountains and the right bank basin of the Gabri river). Its growth is limited by natural factors (its fruits are eaten by wild animals and birds). It is included in the Red List of the Azerbaijan SSR and is protected in the Eldar Shamy National Nature Reserve. It is recommended to promote natural regeneration and implement individual protection measures for trees growing outside the reserve (The Red Book of the Republic of Azerbaijan, 2013).

Figure 5. Eldar pear (*Pyrus eldarica* Grossh.).

Family: Rosaceae

Species: *Prunus padus* L. (Wild cherry)

International classification (according to IUCN categories and criteria): **LC**

National classification (according to IUCN categories and criteria): **EN B2b (ii, iii, v)**

Description: A tree or shrub, 2–5(–10) m tall, with a grayish black trunk and branches. The leaves are 4–12 cm long and 2–6 cm wide, oval-lanceolate, elliptical or obovate in shape. The upper surface is wrinkled and dark green, the lower surface is glabrous or hairy. The fruits are spherical, black, 5–7 mm in diameter. The seeds are oval (**Figure 6**). The flowering period is May-June, and the fruiting period is August-September. It grows on riverbanks, in forests and thickets, and is widely distributed from plains to mountain slopes (The Red Book of the Republic of Azerbaijan, 2013).

Distribution: It is native to Northern Europe, Northern Asia and Northeast Asia, and is cultivated as an ornamental plant in North America, and is distributed in the Eastern Greater Caucasus Mountains (Gal Eybugud and Chukhuryurd villages in Shamakhi region, Talistan village and Garanohur Lake basin in Ismayilli region), in the Northern Lesser Caucasus Mountains (Goygol National Park), in the Central Lesser Caucasus Mountains and in the Guba region of the Greater Caucasus Mountains (Geray and Susay villages in Guba region). Their distribution is limited by human activities such as forest fires and deforestation, as well as the impact of the natural environment. There are currently no specific conservation measures. Area management, regular monitoring, and seed collection are recommended (The Red Book of the Republic of Azerbaijan, 2013).

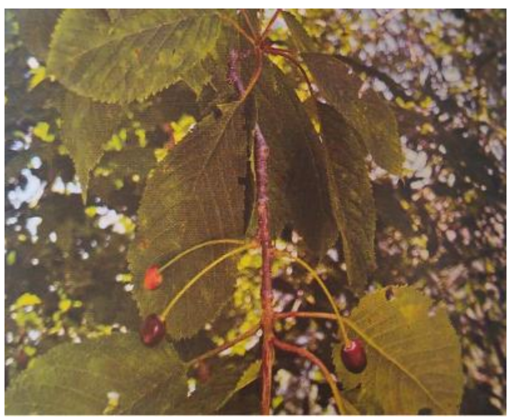

Figure 6. Wild cherry (*Prunus padus* L.).

Family: Lythraceae

Species: *Punica granatum* L. (pomegranate)

International assessment according to IUCN categories and criteria: **LC**

National assessment according to IUCN categories and criteria: **VU Blab (i, ii, iii)**

Description: It is a shrub or small tree, reaching a height of 1.5–5 m. Its leaves are opposite or in groups, oblong or oblong-lanceolate, with a blunt or pointed tip, and leathery (**Figure 7**). The fruit is large and spherical, bright red or yellow in color. It contains numerous seeds and has a leathery surface (The Red Book of the Republic of Azerbaijan, 2013). The flowering period is June-July, and the fruiting period is October. It grows on dry slopes, river basins, and mountain slopes. Pomegranates are drought-resistant and prefer sunny locations. Intermittent irrigation during the summer months can increase yield. In areas with high rainfall, they are susceptible to fungal root rot (Orwa et al. 2009).

Distribution: It is distributed in the Lankaran plains, Samur-Devachi and Kur-Araz lowlands, Mughan plain (Lankaran district), throughout the Greater and Lesser Caucasus mountains, the Gobustan region, the Kur plain, and the plains of the Nakhchivan Autonomous Republic. Its distribution is limited by human factors (deforestation, intensive grazing, land use for agricultural and other purposes, and urbanization) and natural factors (sensitivity to the negative effects of climate change). It is protected in the Turyanchay National Nature Reserve. It has been proposed to conserve the population in situ (The Red Book of the Republic of Azerbaijan, 2013).

Figure 7. Pomegranate (*Punica granatum* L.)

Family: Anacardiaceae

Species: *Pistacia atlantica* Desf. (pistachio tree)

International Assessment (according to IUCN Categories and Criteria): **NT**

National Assessment (according to IUCN Categories and Criteria): **NT**

Description: This plant has a spherical or umbrella shape, reaching a height of 15 m. The leaves are compound, single-petiolate, aromatic, oval, sessile, with a blunt or slightly pointed tip, entire margins, shiny dark green upper surface, light green lower surface (**Figure 8**). The fruit is dry and inverted oval, consisting of green seeds covered with a thick purple-red shell. Flowering occurs in June, and fruit ripening occurs in August-September. It reproduces by seeds and cuttings. It is drought-resistant, prefers sunny places, and requires special soil conditions.

Distribution: It is distributed in the Guba region of the Greater Caucasus Mountains, in the northern, southern, and central parts of the Lesser Caucasus Mountains, in the lowland and mountainous regions of the Nakhchivan Autonomous Republic, in the Kura-Araz plain and the Caspian Sea coastal plain, in the Kura plain, in the Gobustan region, and in the plateau region of the Bozdag Mountains. Its population has declined significantly due to human activities such as grazing and deforestation. It is protected in the Turyanchay National Nature Reserve. A protected area has also been proposed around the Sultanbud Hills in the Karabakh Plain (The Red Book of the Republic of Azerbaijan, 2013).

Figure 8. Pistachio tree (*Pistacia atlantica* Desf.).

Clade: Gymnosperms (Pinophyta)

Family: Cupressaceae

Species: *Juniperus foetidissima* Willd. (foetid juniper)

Description: The tree reaches a height of 5–9 m. It is either dioecious or monoecious, with the upper half of its leaves almost completely separated from the trunk. The cones are flattened and borne on short branches; they are large, spherical or oval, dark brown, reddish-black or black with dark blue spots, and 12–20 mm in diameter. When mature, the tips of the scales become almost invisible (**Figure 9**). The light brown, woody seeds contain 1–3, mostly 2 hemispherical or spherical seeds. This plant is heat-, drought-, and frost-resistant and adapts to a variety of soils. It can live for over 300 years. The root system is branched, dividing into numerous branches in the topsoil. Its roots also extend very deep. The cones ripen between October and December. This plant reproduces by seeds. Its needles and seeds contain volatile oils. Its needles, shoots and seeds contain 5–8% of the inoculant, like those used in heart transplantation, and are useful for this purpose. They also contain 229.7 mg of vitamin C.

Distribution: The tree is widespread in the Crimean Peninsula, the Caucasus, Turkey, Syria, the Balkan Peninsula and the island of Cyprus. In Azerbaijan, it grows in the Lesser Caucasus Mountains, Nakhchivan Mountains, plateaus, plains and mid-altitude mountainous areas, as well as on dry, rocky slopes. It is a rare species included in the Red List of Azerbaijan (Təhməzov et al. 2004).

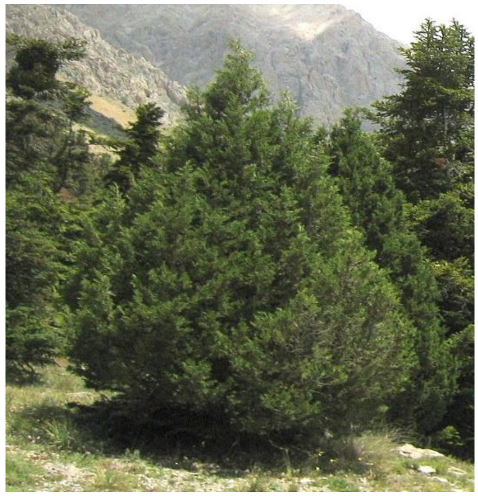

Figure 9. Foetid juniper (*Juniperus foetidissima* Willd.).

Family: Taxaceae

Species: *Taxus baccata* L. (yew)

Description: The berry-bearing blackthorn is a very ancient plant, dating back to the Carboniferous and Cretaceous periods. The berry-bearing blackthorn is an evergreen coniferous tree with dense, umbrella-shaped, dark green leaves, used as an ornamental tree or shrub (**Figure 10**). In Azerbaijan, it is also known as "European blackthorn", "eternal tree" or "red tree". It can still be found in some regions of Azerbaijan, but not in large quantities. The needle-shaped leaves are 3–4 cm long and 1.8–2 mm wide. They have a pointed and scaly, sometimes slightly sickle-shaped, dark green upper surface and a light green lower surface. The seeds are 6–8 mm long and 4–5 mm wide. The fruit is red, juicy, oval-shaped, pointed at the tip, and covered with a fibrous layer. The berry-bearing blackthorn is a shade-tolerant shrub that requires high humidity. It is picky about soil type, resistant to smoke, dust, and gas, but sensitive to direct sunlight. It blooms in April-May, and the fruit ripens in October. It reproduces by seeds, shoots, and cuttings. It is long-lived, sometimes reaching 4000 years.

Distribution: It is found mainly in Europe, Africa, the Far East and the Kuril Islands. In Azerbaijan, blackthorn is widespread in the Ganja, Ismayilli, Shamakhi, Oghuz, Gabala, Sheki, Zagatala, Balaken, Gadabay, Dashkesan, Tovuz, Gusar, Kalbajar, Goygor and Talysh mountains. The coniferous tree is bitter and poisonous due to the presence of toxic glycosides. In traditional medicine, its leaves are used to treat heart diseases. Its wood, which comes in various shades, is used in furniture production, carpentry, and construction materials, especially in submarine and shipbuilding. The greatest advantage of this tree is its slow decomposition. It is on the list of endangered plants and is also included in the Red Book of Azerbaijan (Təhməzov et al. 2004).

Figure 10. Yew (*Taxus baccata* L.).

Specially protected state territories

Below are some examples of specially protected natural areas:

Nature Reserves: The creation of Nature Reserves aims to address some of the most pressing challenges facing the modern world. A Nature Reserve is an area where entire ecosystems are preserved in their natural state. Its main functions are to conserve biodiversity and to create a suitable environment for the study and application of sustainable development approaches at the local level (Mammadov & Khalilov 2005).

National Parks: National parks are a special form of protected area organization aimed at protecting ecosystems and promoting ecotourism. National parks balance the protection of natural, historical, and cultural heritage with the organization of recreational activities. Parks cover relatively large areas and allow the use of ecosystems (Babaşova 2020).

Sanctuaries: Sanctuaries are areas of special importance for the protection, restoration, and maintenance of the ecological balance of natural ecosystems and their components. Sanctuaries can be located on their own territory or on lands belonging to other users (Dolkhanov et al. 2012).

Conclusion

Finally, as a conclusion, we analyzed the number and taxonomic composition of rare and endangered forest plant species in the Republic of Azerbaijan. We also provided information about plant communities based on viability indicators, population size, and influencing factors.

In this study, 467 tree and shrub species were identified in the flora of Azerbaijan. Of these, 43 rare and endangered woody plant species belonging to 24 families and 36 genera demonstrate ecological adaptation; 31 species are sun-tolerant, 12 species are shade-tolerant, 16 species are high-temperature tolerant, 23 species are moderately heat-tolerant, and 4 species are low-temperature tolerant. Depending on the type of aquatic vegetation, various groups were distinguished, including Mesozoic plants (26 species), arid plants (11 species), mesorax plants (2 species), arid Mesozoic plants (2 species), and marsh plants (2 species).

Conflict of Interest

The author declares that there is no conflict of interest.

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FLORISTIC DIVERSITY, DISTRIBUTION AND CONSERVATION OF ENDEMIC PLANT SPECIES IN AZERBAIJAN

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Abstract: The territory of Azerbaijan is distinguished by its rich biodiversity, diverse natural and geographical landscapes, and rare and endemic species of flora and fauna. In order to protect these natural resources, ensure the sustainability of ecosystems, and preserve biological diversity, a system of specially protected natural areas has been formed throughout the country. The article analyzes the stages of development of specially protected natural areas in Azerbaijan, the main goals of the creation of national parks, state nature reserves and state nature sanctuaries, and their role in nature protection. It was noted that the creation of national parks created new opportunities for the protection of biodiversity, protection of rare and relict species, environmental education, scientific research, and development of ecotourism. It has been shown that state nature reserves and sanctuaries are of great importance in the protection and restoration of natural ecosystems and individual flora and fauna components. The study also considered the prospects for measures taken to expand specially protected natural areas, establish biosphere reserves and geological parks, and promote protected areas at the international level. As a result, effective management and scientifically based monitoring of specially protected natural areas have been assessed as one of the main conditions for the long-term protection of Azerbaijan's biological diversity and natural heritage.

Keywords: specially protected natural areas, national parks, state nature reserves, state nature sanctuaries, nature conservation, ecotourism, biosphere reserve.

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Introduction

Plants make up a significant portion of the Earth's surface. It is impossible to imagine the Earth without plants. Because plants are the source of oxygen for all living things - animals, humans, microorganisms, etc. and this oxygen is produced as a result of the process of photosynthesis.

Biodiversity refers to the total variety of life on Earth (plants, animals, fungi, and microorganisms), as well as the communities they form and the habitats they inhabit. The living things that make up biodiversity are: (1) plants; (2) animals; (3) microorganisms; (4) fungi, and other living things (Məmmədov 2011). Biological diversity, or biodiversity, is the term given to the variety of life on Earth and the natural patterns it creates. The biodiversity we see today is the result of billions of years of evolution and is shaped by natural processes and, increasingly, human influence. This forms the web of life of which we are an integral part and upon which we are completely dependent.

This diversity is often understood as a vast array of plants, animals, and microorganisms. Approximately 1.75 million species have been identified so far, most of which are small creatures like insects. Scientists believe that there are about 13 million species, although estimates range from three million to 100 million.

There are 6 floristic regions on the Earth's surface, based on their origin, type, climatic conditions, etc., and other characteristics: (1) Holarctic; (2) Paleotropics; (3) Neotropics; (4) Australia; (5) Cape; (6) Antarctica. The flora of each region has a common historical origin. Each of these floras contains both endemic and relict plants (**Figure 1**).

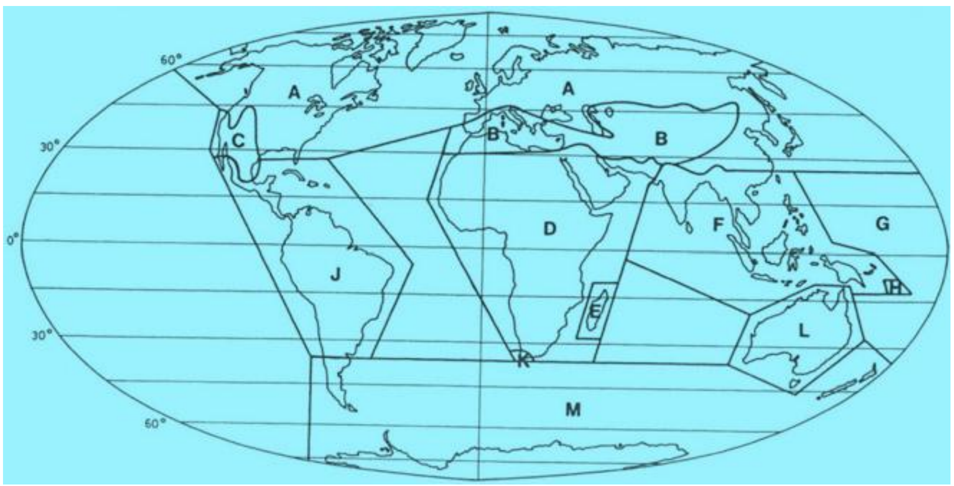

Figure 1. Floristic kingdoms and subkingdoms of the world, after Takhtajan. **A–C:** Holarctic kingdom (**A:** Boreal subkingdom; **B:** Tethyan subkingdom; **C**: Madrean subkingdom); **D–H:** Paleotropical kingdom (**D:** African subkingdom; **E:** Madagascan subkingdom; **F:** Indo-Malaysian subkingdom; **G:** Polynesian subkingdom; **H:** Neocaledonian subkingdom), **J:** Neotropical kingdom; **K:** Cape kingdom; **L:** Australian kingdom; **M:** Antarctic kingdom (Takhtajan 1986).

The Holarctic region is the largest floristic region, encompassing Europe, North America, a large part of Asia, northern Africa, and the Northern Islands. This vast area experiences all climatic conditions except tropical. The same climate during that period led to the emergence of the same type of flora. This floristic region is very rich in plant life. The Holarctic floristic region is divided into subregions such as the Arctic, Europe-Siberia, China-Japan, Caucasus, Mediterranean, North Africa-India, North America, Pacific, etc.

Paleotropical region covers tropical America, subtropical South Africa, southwestern Arabia, India, Indochina, New Zealand, the Philippines, the Malay Archipelago, New Guinea, etc. In terms of area, the Holarctic is second only to the plant world. Despite the highly fragmented terrain, the plant world is very close. Tropical evergreen forests predominate here.

Neotropical regions include Central and South America, the Antilles, and southern Florida. It is called neotropical because it covers the tropical areas of the

New World. The flora of this area is very diverse. Succulent plants, cacti, palms, species of ferns, and milkweeds predominate. It is divided into 3 hemispheres (Central American, tropical, and Andean).

Cape region covers the Cape Province of South Africa. Despite its very small area, it has up to 15,000 plant species, of which up to 3,000 are endemic. It is characteristic that the tree species are somewhat poor. It is very rich in evergreen shrubs and perennial grass species.

Australian floristic area covers Australia and the island of Tasmania. There are up to 10,000 plant species in this area, of which up to 8,000 are endemic plants. Plants from the myrtle, legume, Compositae, and aster families are more widespread. Xerophytic plants are also found in this floristic area. Evergreen, hard-leaved, multi-branched shrubs, mainly consisting of eucalyptus, have formed.

Antarctic floristic region covers the southern part of South America, Tierra del Fuego, and the Antarctic islands. Although the flora is very poor, endemic species make up 75%. The Antarctic islands are mainly inhabited by spore-bearing plants. Of course, just as there are plants in the lithosphere, the water area, i.e., the hydrosphere, also has its own vegetation. Mostly mosses and some flowering plants are common here. Both northern, tropical, and southern aquatic plants are found, each of which has its own unique species and forms.

Relief and distribution of vegetation of the Republic of Azerbaijan

The flora of Azerbaijan also has its own unique biodiversity, and this biodiversity is richer than that of other countries. In general, every region, city, and country has its own unique flora. The territory of the Republic of Azerbaijan is also one of the countries with the richest flora among these countries, with more than 4,500 flowering plant species of various varieties spread here.

In terms of the total number of species, the flora of Azerbaijan is much richer than that of other republics of the South Caucasus. Among these plants, both higher plants and primitive plants are very widespread. The higher plants found in the wild flora of our republic comprise 4,557 species, which constitutes more than 70% of the higher plant species found in the natural flora of the Caucasus as a whole. Although Azerbaijan is approximately 16% of the Caucasus in terms of area. This richness is explained by the diversity of the republic's natural, historical, and physical and geographical conditions. The plant species found in the republic account for 66% of the total number of plant species growing in the Caucasus. Of the 500,000 plant species in the world, 4.3 thousand grow in Azerbaijan. The richness of vegetation in Azerbaijan is primarily due to the diversity of relief and climatic conditions. 370 species of plants are endemic here, meaning they grow only in Azerbaijan. More than 1,500 species of plants found in the Republic of Azerbaijan are used in various fields of the national economy and in the treatment and prevention of various diseases (The Red Book of Azerbaijan, 2013). To date, 146 endemic higher plant species in 28 families and 75 genera, and 402 subendemic higher plant species in 53 families and 191 genera have been identified in the republic. This constitutes approximately 12% of the republic's flora. The natural dendroflora of Azerbaijan includes 435 species of trees and shrubs in 48 families and 135 genera, which constitutes approximately 10 percent of the republic's flora. Of these, 119 species are trees and 316 species are shrubs. Shrubs also include low shrubs commonly found in semi-desert and mountain xerophytic vegetation. Rare and endangered species have been studied. Of the more than 400 higher plant species discovered in the Azerbaijani flora, 140 are included in the "Red Book" of Azerbaijan. They are mainly relict and endemic species and include many plants such as boxwood, blackthorn, mountain ash, hard-branched ivy, wild pear, blackberry, eversmania, species of senna, etc. More than 125 species of rare and endangered plants have been planted in the Central Botanical Garden (The Red Book of the Republic of Azerbaijan, 2013).

The relief of the Republic of Azerbaijan is diverse. The relief of the Republic of Azerbaijan and the plants distributed there. All types of vegetation cover are found in the Republic of Azerbaijan - ancient forest, boreal, desert, xerophyte, steppe, Caucasian, and adventive vegetation (The Red Book of the Republic of Azerbaijan, 2013, 2013; Əsgərov 2005, 2006, 2008). The most abundant examples of ancient forest types are found in Talysh, the boreal type in the mountain zones of the Greater and Lesser Caucasus, and in small quantities in the lower belts, while xerophilous, Caucasian, steppe, and desert types are found in the plain, foothill, and steppe summers of the republic, and most of them are found in the Kura-Araz lowland. The adventive areal type is somewhat less common. Rich and diverse vegetation has also developed in the lakes, ponds, streams, and swamps of the Kura-Araz lowland, Caspian Sea, and other plains (Məmmədov 2016). The reason for the spread of plants in different reliefs in the Republic of Azerbaijan is due to factors such as climatic conditions, soil composition, humidity, temperature, etc. Semi-desert, mountain steppe, and mountain xerophytic plants are widespread in the plains and low mountains (Əsgərov 2005, 2006, 2008).

Semi-desert plants

Semi-desert plants (wormwood, saltwort, davatikani, gavan, kengiz, etc.) are widespread in the Kur-Araz, Shirvan, Mil and Karabakh steppes, as well as in the plains of Jeyranchol, Gobustan and Araz-side Salyan, Mughan, Samur-Devachi lowlands, Araz-side plains of Nakhchivan, Absheron-Gobustan. Semi-desert plants are winter pastures. Due to the increase in cultivated areas and settlements, the natural range of semi-desert plants is sharply decreasing (Əsgərov 2005, 2006, 2008). Dark salinity is widespread in deserts. The branches of the Garashora tree spread out on the ground, creating mounds, and are most common around Lokbatan, in Mughan, and Eastern Shirvan. Small hilly, saribash deserts are commonly found around the Caspian Sea, in the Kura-Araz lowland (Məmmədov 2016). Deserts of self-interest are also widespread in the Republic of Azerbaijan. There are 5–6 species of plants here. The Cheran desert also forms in Eastern Shirvan and some foothill regions (Məmmədov 2016). Semi-desert plants can also be easily seen.

Mountain Steppe Plants

Phytocenoses belonging to this vegetation type are distributed in mountain xerophytic forests and mountain steppe zones at altitudes of 700–900 m, 1500–1800 m, and 1700–2500 m above sea level in arid climates, on mountain gray-brown, mountain chestnut, and grassy mountain meadow soils emerging from the forest floor (Qurbanov 2024). According to researchers, steppe vegetation refers to mountain steppes formed by perennial xerophytic grasses that form dense turf.

Mountain steppe plant groups are formed in the middle mountain belts of the Greater and Lesser Caucasus, Nakhchivan and Talysh, spreading on mountain black soil, gray and chestnut soils. It is found in mountain steppes with cereals, cereals-mixed crops, or mixed grass-cereals. The dominant plants here include thyme (*Thymus* L.), grass (*Poa* L.), fescue (*Festuca* L.), astracantha (*Astracantha* Podlech), wheatgrass (*Agropyron* Gaertn.), germander (*Teucrium* L.), sage (*Salvia* L.), and other genera (Qurbanov 2024).

Mountain steppe plants (velamer, thyme, etc.) are widespread in the northeastern part of the Lesser Caucasus, in the mountainous Shirvan part of the Greater Caucasus, and in the Nakhchivan Autonomous Republic (Əsgərov 2005, 2006, 2008). In the dry and hot regions of the republic (Nakhchivan Autonomous Republic, Jabrayil, Zangilan), on the steppe plateau of the Greater Caucasus, xerophytic vegetation is found, namely, phrygana, shiblak, prickly heath, tistist, and occasionally, stunted juniper and juniper-pistachio. In arid regions, kekotu and its species tumil-kekotu are found. For the Tumil fields, plants such as sedge, meadowsweet, caravan grass, etc. are very typical. Plants such as milkweed, sedge, and barberry are also found in these types of fields (Məmmədov 2016).

In Azerbaijan, the mountain steppes are very similar to the steppes spread across the open gray-brown montane plains, and their species composition consists mainly of xerophytes (Qurbanov & Cabbarov 2017). In the northern part of the Lesser Caucasus, mountain-steppe vegetation spreads at altitudes of 700–1200 m above sea level and has an intrazonal character. In particular, this type of vegetation is found in separate patches in the foothills, lower, middle and upper mountain belts, in areas where forest and subalpine vegetation are formed. Usually, the mountain-steppe vegetation of the high mountainous part includes fescue (*Festuca*) and herbaceous-fescue formations, which are distributed at an altitude of 1900–2400 m above sea level.

Mountain xerophytic plants

Mountain xerophytic plants are distributed in the Talysh Mountains and the Nakhchivan Autonomous Republic. Consists of sparse shrubs and herbs (Əsgərov 2005, 2006, 2008). In the foothill plains of the Greater Caucasus and the Lesser Caucasus, mainly annual and perennial xerophytic plants and shrubs are widespread at altitudes ranging from 200 m to 600–700 m, sometimes up to 1200 meters. Higher up, areas limited to 1800–2200 meters above sea level consist of forests (Əsgərov 2005, 2006, 2008).

Forest plants are also very widespread in the middle mountain regions of the Republic of Azerbaijan. Forests make up 11% of Azerbaijan. The total area of forests is 1.2 million ha. Although the area of Azerbaijani forests is small, their species composition (435 species) is very rich. There are 70 endemic tree and shrub species here. 90% of forests in Azerbaijan are in the mountains (especially in the middle highlands), and 10% are in the plains. Lowland forests are widespread in the Ganikh-Ayrichay valley, the Lankaran lowland, and the Shollar plain of the Samur-Devachi lowland (Əsgərov 2005, 2006, 2008). Azerbaijani forests are divided into several areas:

Broadleaf forests

Broad-leaved forests. Distributed in the low and middle highlands of the Greater and Lesser Caucasus, and the Talysh Mountains. 86% of Azerbaijani forests consist of 3 trees: oak, alder, and beech (Əsgərov 2005, 2006, 2008). These forests are in the mountainous zones of the Greater and Lesser Caucasus at an altitude of approximately 600–1800 m above sea level. The plants growing here are mostly Georgian oak, Eastern pistachio, and in the upper mountain belts, Eastern oak. In general, beech trees are very widespread in these areas and are very productive. At the same time, linden, alder, 5–6 species of birch, especially the Eastern oak, along with the Trautfetter birch, also grow in broadleaf forests. Many plants such as Georgian oak, currant, and gooseberry are also widespread on the slopes of the mountains in broad-leaved forests.

Coniferous forests

Seven species of plants are found in coniferous forests in Azerbaijan. These include the Eldar pine, the hook pine, the multi-fruited, the heavy, the red and the long-stemmed juniper, and the European blackthorn (Əsgərov 2005, 2006, 2008). Locally, it has formed small forests in the Eldar Plain (Eldar pine), in the mountain regions of the Greater and Lesser Caucasus (Kok pine), especially in the Bulannig River basin of the Balakan region, and around Goygol (at an altitude of 1600 m). The Kokh pine, together with the birch, forms large cliffs around Lake Goygol, creating a forest. Among conifers, many species of fir and juniper are widespread in mountain-forest zones. In the northwestern zone of the Greater Caucasus, especially in the subalpine belt of the Zagatala-Balakan regions, small areas of Caucasian rhododendron forests are found.

Tugay forests

Tugay forests extend into a ribbon along riverbeds, especially along the Kura River. Located in semi-deserts, these forests moderate the climate, protect the soil, and strengthen the banks (Əsgərov 2005, 2006, 2008). Along the Kura, Araz, Ganikh, and Gabyrry rivers, there is a local Tugay forest in a ribbon-like form. The basis of these forests is formed by trees and shrubs such as poplar, willow, oak, elm, mulberry, sycamore, and pomegranate (Məmmədov 2016).

Sometimes, mixed, plain, and Talysh forests are found in the territory of the Republic of Azerbaijan. Mixed forests form along mountain rivers or in river valleys. Plants such as sea buckthorn, yyde, willow, sumac, saragan, yulun, mulberry, immortal bush, pomegranate, rose hips, blackberries, etc. are widespread here.

The thorny trees are most common in the valleys of the Shin, Kish, Demiraparag, Turyan, Goychay, Agsu, Velvale, and Tartar rivers (Məmmədov 2016). Plain forests are widespread in the Guba-Khachmaz and Karabakh zones of the Republic of Azerbaijan, as well as in the Alazan-Ayrichay depression. Plants such as oak, elm, hawthorn, elm, etc. are found in these forests. Dozens of different forms of long-stemmed oak also exist in plain forests (Məmmədov 2016). Typical tree species of the Talysh plain forests include ironwood and chestnut oak. In addition to these relict tree species, Hyrcanian-type forests consisting of Caucasian elm, two species of azat tree, elm, cherry poplar, and cherry thorn are also found here. On the sea-facing slopes of these forests, Lankaran acacia, linden, and many others create special mixed forests.

Subalpine and alpine meadows

In the high mountains, subalpine and alpine meadows exist. They are used as summer pastures and hayfields. At an altitude of 1800–3200 m above sea level, subalpine and alpine meadows of various compositions, with steppe and meadow plants prevailing.

True subalpine meadows take on various forms depending on the relief and character of the high mountains. The tall grassland in the subalpine zone also forms a special shape. Most tall grasses and subalpine plants are plants that have emerged from the forest floor. In tall grassy areas, the most common species are celandine, sedge, meadowsweet, soft broom, yarrow, nettle, sedge, and various representatives of the marigold family.

In the subalpine zone, grasslands of various compositions, low-moisture and mesophilous grasslands, dry xerophytes, and steppe grasslands are also widespread. The basis of the subalpine meadow is made up of white moustache, pink tongalotu, Caucasian thin-leaved, purple barley, alpine daisies, wide varieties of lamellar and three-leaf clover, geranium, yarrow, primrose, and yarrow. Up to 1,000 plant species are distributed in the subalpine meadow. Alpine meadows are widespread on the peaks of high mountains, on steep slopes, and in saddle-shaped mountain passes. Although their diversity is less than that of subalpine meadows, their small plant types are very diverse and of great importance. Subnival areas are also widespread on high mountain peaks. The bare cliffs of the high mountain peaks of the Greater and Lesser Caucasus are almost devoid of vegetation.

The Republic of Azerbaijan is considered the homeland of many rare and endemic species of shrubs. Blackthorn is a rare gem of forests as a relict plant. This tree is more common in the southern (Gabala region) and southeastern (Pirgulu, Shamakhi regions) parts of the Greater Caucasus. The late-growing but long-lived black locust has never covered large areas. The homeland of the Eldar pine is Azerbaijan, and its distribution area is the Eldar hollow area of the Jeyranchol foothills. Among the relict and rare trees growing in the Talysh Mountains, ironwood, Lankaran acacia, chestnut-leaved oak, azat, Caucasian date, boxwood, sycamore, Hirkan fig, Hirkan birch, etc. are rare pearls of nature.

Wetlands are widespread in Azerbaijan. They are found in small areas around natural water bodies and in depressions. Swamps are observed in the Kur-Araz plain, the Lankaran plain, and the western regions of the republic.

Marsh plants in Azerbaijan, especially in Talysh, have been well studied. Reeds, Beckmania, paspalum, licorice, frogweed, sedges, lamellar iris, and other plants are common in those swamps. Although these plants grow in water, they are related to the soil. The second group of plants is related only to water conditions. These plants include water lilies, etc. Depending on the growing conditions, these plants form different associations. Wetland plants are of great importance. The importance of reed beds in Azerbaijan is particularly great. They are used as a building material in hunting farms, for fencing, for building sheep pens, as masonry, and as raw materials for making cardboard, paper, and vitamins C and A.

Rare plants of Azerbaijan

The "Red Book" of the Republic of Azerbaijan is an official state document on rare and endangered species of wild animals and plants in the territory of the Republic of Azerbaijan. It provides information on animal and plant species, their distribution, and protection measures throughout the territory of the Republic, including the sector of the Caspian Sea (lake) belonging to the Republic of Azerbaijan. Several measures have been taken to preserve this type of animal and plant world, and sanctuaries, reserves, and national parks have been established for this purpose. Let's look at a few plants that are endangered or rare. These include Hyrcanian evergreen boxwood (*Buxus sempervirens*), Persian ironwood (*Parrotia persica*), Persian silk tree (*Albizia julibrissin*), Eldar pine (*Pinus eldarica*), water lily (*Nymphaea*), *Astragalus caraganae*, Hyrcanian pear (*Pyrus hyrcana*), chestnut-leaved oak (*Quercus castaneifolia*), and velvety euonymus (*Euonymus velutinus*).

Buxus sempervirens, or Hyrcanian boxwood, is a plant species belonging to the evergreen boxwood species (**Figure 2**). They are shrubs that are very common in nature. It can also take the form of a tree, reaching a height of 6–10 m. The bark of the trunk is thin and light grayish-yellow, smooth. It is multi-branched, densely umbellate. The leaf petiole is 2–5 mm long and stiffly hairy. The leaf has entire margins and rounded or slightly toothed tips. Its flowers are located in the axils of the leaves and are greenish. The flower cluster is spike-shaped. It blooms in March-April, and its fruits ripen in July-August. Pollination is entomophilous. It is reproduced by seeds and vegetatively. It is more widespread in moist, shady valleys and in fresh, thick, humus-rich soils. It is distributed at an altitude of 400–800 m above sea level. It grows as a shrub in the second layer or in forests from the lower mountain belt (lowlands) to the middle mountain belt, in oak-oak, mixed hyrcan and beech forests. It is also used for decorative purposes. The evergreen boxwood is relatively drought-resistant and suitable for planting singly or in groups. In the regions, it is distributed in the Lankaran lowland, the mountainous part of Lankaran, etc., and in other regions. Currently, it is protected in the Hirkan National Park (The Red Book of the Republic of Azerbaijan, 2013).

Figure 2. Hyrcanian boxwood (*Buxus sempervirens*).

Parrotia persica, or Persian ironwood, is a plant species belonging to the family Hamamelidaceae. This tree is native to the lower Alborz Mountains of northern Iran. It is widely cultivated in Europe and the United States (**Figure 3**). It is a highly branched tree, 12–22 m tall. The umbel is ovoid or broadly ovate. The shoots are 6–11 mm long. The leaves are 4–10 cm long and 3–6 cm wide. The leaves are alternate, ovate, or elliptical. The flowers are bisexual, have short stalks, and open before the leaves. It blooms in February-March. Its fruits ripen in August-September. Pollination is anemophilous. It is reproduced by seeds and fruit. In the lowlands, in the foothill zone and lower mountain belt, at altitudes of 400–600 m above sea level, it forms mixed forests. Single trees are found at an altitude of 1000–1200 m above sea level. They form both pure and mixed forests consisting of two or three layers (The Red Book of the Republic of Azerbaijan, 2013).

Figure 3. Persian ironwood (*Parrotia persica*).

Albizia julibrissin, or Persian silk tree, is an endemic plant of Azerbaijan. It is also known as "Silk acacia", "Lankaran albissia", "Gulebrishin", and "Silk Flower" (Takhtajan 1986). Widely found in the Lankaran zone. This plant is also found in Europe, around the Mediterranean Sea, in Crimea, and on the Black Sea coast of the Caucasus (**Figure 4**). This plant is used in folk medicine for the treatment and prevention of several diseases. The average height of the tree is 1.2 m, and the diameter of its trunk is 4 cm. In fertile soil, it reaches a height of 10–12 m within 10 years. The plant, which is considered drought-resistant, blooms after 4–5 years of age. It is a woody plant (Məmmədov 2003). In 1989, the this plant was included in the "Red Book" of Azerbaijan (Talışlı & Əhədov 2017). It is advisable to use the silk tree in single and group plantings, in landscaping, as well as in coastal areas, to reduce heat in the summer months, and as an ornamental plant in Absheron conditions. The seeds of the plant are fully resistant to the soil and climatic conditions of Absheron (Mehdiyeva 2011).

Figure 4. Persian silk tree (*Albizia julibrissin*).

Pinus eldarica or Eldar pine is a coniferous tree species belonging to the Pinaceae family. It is a relict plant of the III period of Azerbaijan and is a rare tree species that is naturally distributed only in the western part of the Eldar plain, on the right bank of the Gabyrrichay River, as well as in the Ellar hollow in Ganja. In 2004, nearly 2,000 hectares of Eldar pine forest were removed from the Goygol reserve, and the Eldar Pine Reserve was established on its basis. The Eldar pine reaches a height of 20 meters and has a straight trunk and a wide canopy. Its leaves contain vitamin C and carotene. It is also a good building material. Eldar pine has high forestry potential in dry regions. Its rate of biomass accumulation rivals the fastest-growing conifer species. According to this feature in this article, we studied plantation possibilities in new areas based on the data obtained by geoinformational technologies about the ecological limits of *Pinus brutia* var. *eldarica*. Eldar pine (**Figure 5**) is also used for landscaping purposes in regions where many other types of pine trees do not grow. The flowers are pollinated in April-May. Its cones ripen in the second year, in August-September. However, it reproduces by seeds. Pollination is anemophilous. It is xerophytic. It is resistant to drought and heat (Məmmədov 2008; Mammadov et al. 2022; Farzaliyev & Afonin 2016).

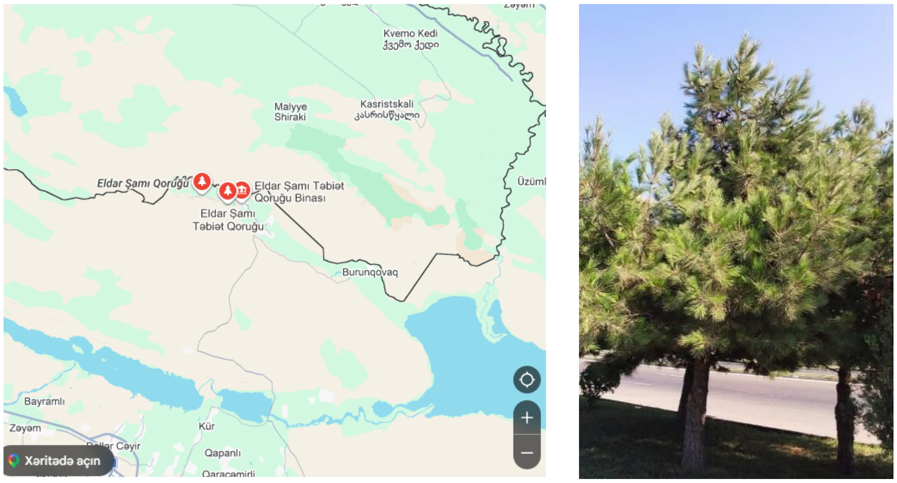

Figure 5. Eldar pine (*Pinus eldarica*).

Nymphaea, or water lily or Egyptian lotus, is a genus of plants from the lily family. It is a perennial aquatic plant with a strong root. The leaves are very large, solitary, on long, dense stalks; the leaf margins are heart-shaped to oval, sometimes rounded, and 10–25 cm wide. Its flowers are arranged singly, large, and 10–15 cm in diameter. The petals are numerous, white, oval-oblong. The fruit is spherical and green in color. The flowering and fruiting period occurs in May, August, and September. It is a water- and moisture-loving (hydrophilic) and light-loving plant. It is reproduced by seeds and vegetatively. In some water bodies, they have disappeared altogether. This plant is used as a food, medicine, and ornamental plant. The Kur-Araz lowland (Zardab district - around the Garasuchay River), the Lankaran lowland (Lankaran district - Liman settlement, in the northern part of Lake Mortso) are very widespread. It is protected in the Qizilaghac reserve (Flora Azerbaidjana, 1950-1961).

Astragalus caraganae, or Nakhchivan gavan, is a plant species from the legume family. It is a perennial plant with numerous erect stems, 20–50 cm tall. The leaflets are 16–27 pairs, oblong-oval, and covered with dense velvety hairs on the underside. The ovary is oblong and pedicelled. The raceme is short, with 4–6 sparse flowers (**Figure 6**). Flowering occurs in May, and fruiting occurs in June-July. It is a xerophytic plant. It is found in the middle mountain belt, on dry stony slopes, and in rocky areas. It is found in the mountainous part of Nakhchivan (Shahbuz region - around the villages of Garababa, Badamli, Kuku and Kechaldagh) and is widely distributed. As a species whose status in the wild has reached a critical point and is likely to become extinct, its distribution areas in Zangezur National Park and Arpachay State Nature Reserve should be placed under special control and its natural populations should be protected (Habel et al. 2010).

Figure 6. *Astragalus caragana*.

Pyrus hyrcana, or Hyrcanian pear, is a species of plant of the family Rosaceae. It is a tree up to 25 m tall. The leaves are ovate, with small margins. They are white, felty on the underside, and hairless on the upper side. The stem is long, thin, equal to the length of the leaf blade, and covered with fine hair. The fruits are cinnamon-colored, flattened, and spherical, and are found singly or in clusters on one-year-old shoots. It blooms in April-May. Its fruits ripen in August-September (**Figure 7**). Pollination is entomophilous. They reproduce by seeds and root suckers. It is distributed mixedly in the foothill forests and forest glades of the mountain massif. It has a natural range in Azerbaijan and Iran. It is distributed in the Astara and Lankaran regions of Azerbaijan. Lankaran lowland (Astara-Shuvi, Anbabu, Duriya, Istisu, Astara villages; Lankaran district-Dashdatuk and Khanbulag villages) and the mountainous part of Lankaran (Yardımlı district - Pirembel village; Lerik district - Lerik village). It is widespread in the villages of Khanbulan and Dashdatuk in the Lankaran region and Anbabu village in the Astara region (Celka & Drapikowska 2008).

Figure 7. Hyrcanian pear (*Pyrus hyrcana*).

Quercus castaneifolia, or chestnut-leaved oak, reaches a height of 40–45 m, a trunk diameter of 100–150 cm, and has a tent-like or broad-pyramidal canopy. The bark of the branches is gray, and the bark of the trunk is dark gray. The stems are densely covered with hair, and the buds are small and egg-shaped. Its leaves are falling. The leaves are 19–20 cm long, 4–8 cm wide, with a toothed or lobed edge and a leathery surface. The upper side is shiny, dark green, and bare, while the lower side is light green and covered with hair. The leaf veins are 9–13 pairs. The flowers are unisexual. The male flowers are up to 10 cm long and are located singly in drooping earrings. The female flowers are arranged in clusters on the stem, 2–3 together. The stem is densely covered with hair and is 10 cm long. It blooms in April-May and is pollinated by the wind. The fruit is a seeded cone. The cone is 2.5–3.5 cm long, oblong, obovate, elliptical, or lanceolate. The cones ripen in September-October. It is warm, light-loving, very demanding on soil fertility, and has little resistance to frost and drought. It is found in the Ismayilli, Guba, Tartar, Shamkir, Shamakhi, and Barda regions of Azerbaijan, and in the Talysh zone. It is intended for use in single plantings and in the furniture industry. Its cones contain starch, and its bark and leaves contain antioxidants and tannins (The Red Book of the Republic of Azerbaijan, 2013; Əsgərov 2005, 2006, 2008).

Euonymus velutinus, or Velvet spindle, is a plant species belonging to the family Celastraceae. It is a shrub 1.5–4 m tall. Shoots are ovate, 3–5 mm long. The leaves are oblong-elliptical or obovate, 2–8 mm long and 1–3.5 cm wide, blunt or acuminate, finely toothed along the edges, covered with small hairs along the veins; the petiole is short (1–6 mm) and hairy. The flower cluster is simple or umbel-shaped, located on a short axillary flower axis. The flowers are 4-membered, greenish, and small. The petals are oblong, rounded at the tip, and about 3 mm long. It blooms in May-June, and its fruits ripen in August. It is pollinated by entomophiles. Being a microphanerophyte, it reproduces through seeds and vegetatively. It grows in light forests, on mountain slopes and along valleys, up to 1800 m above sea level, rising to the middle mountain belts. It is more commonly found scattered in sparse forests, on forest edges, among bushes, on mountain slopes, and in valleys. It is both an ornamental plant and used in landscaping. It is widely distributed in the Kur-Araz lowland, the central and southern part of the Lesser Caucasus (Khojavand), the western (Zagatala State Nature Reserve) and eastern part of the Greater Caucasus (Ismayilli region - Talistan village), the Lankaran Mugan, and the mountainous part of Lankaran.

Relict plants of Azerbaijan

Relict lat. *relictum* - remnant - relict plants and animals - plant and animal species of past geological periods that are part of the modern biocenosis, can occupy a small or large area (Mirzəyev 2019).

Azerbaijan is also rich in relict genera belonging to the Tertiary period, whose representatives are found more frequently in all zones, especially in the Talysh zone. Examples include ironwood, Persian silk tree, chestnut-leaved oak, bigavar, boxwood, etc. In other words, relict organisms are understood as the remnants of populations that inhabited and spread widely in the past. The causes of such changes and the emergence of relict plants may be due to factors such as climate change, competition between organisms, continental drift, or ice ages. Relict plants are used in food, medicine, dyeing, and other fields of application (Maghradze et al. 2015). Relict species are found in all countries of the world. Since the Republic of Azerbaijan has a very rich flora, relict species are widespread here. This includes pomegranate (*Punica granatum*), oriental plane (*Platanus orientalis*), wild grape (*Vitis sylvestris*), Caucasian date palm (*Diospyros lotus*), and mountain thyme (*Thymus collinus*).

Punica granatum, commonly known as pomegranate, is a plant species belonging to the family Lythraceae. Its scientific name in Latin means "Punica" - dark or bright red, and "granatus" - grain. The pomegranate is a multi-stemmed, deciduous shrub or small tree, 3–5 m tall. Young branches are greenish gray, while older branches are brown and have thorns. The leaves are small, oblong or lanceolate, simple, shiny, and have short petioles. The fruit can contain 1000–1200 or more seeds. The seeds are covered in a juicy and edible coating. Pomegranate blooms in April, and its fruits ripen in September-October. The plant is propagated mainly by dividing the bush and cuttings. In Azerbaijan, the common pomegranate is naturally distributed in the Alazan-Ayrichay valley, the Kur-Araz and Lankaran-Astara lowlands, as well as in Absheron. Azerbaijan's favorable climatic conditions allow pomegranates to be grown in various regions of the country. Although pomegranates are mainly cultivated in semi-arid temperate and subtropical climates, they are well adapted to a variety of climatic conditions. Pomegranate, which holds a special place in the national and cultural heritage of Azerbaijan, is widely used in both the food and pharmaceutical industries. Its fruit, juice, and peel are used in the preparation of various food, medicine, cosmetics, and dye products. Pomegranate also has significant symbolic significance in Azerbaijani national culture, art, literature, and cuisine (Akparov et al. 2015).

Platanus orientalis, or oriental plane, is widely distributed in its natural state on the Balkan Peninsula, the Aegean islands, the south and west of Asia Minor, the eastern coast of the Mediterranean Sea, and the islands of Cyprus and Crete. It is a large tree with a wide canopy, reaching a height of 40–50 m and a trunk diameter of 1.5–3 m. The bark of the trunk and branches is greenish, light gray, or yellowish green. The buds are broad-conical, swollen, and arranged alternately on long shoots. The leaves are alternate, round or ovate, 3–7-lobed, long-stalked, shiny green on the upper side, brownish green on the lower side, and glabrous or sparsely hairy (**Figure 8**). It is in the Sharvari flower group, with flowers of various sexes, ranging from 2 to 70 on long drooping stems. The fruit is a drupe, 2–2.5 cm in diameter and 4–7 mm long, with a widened and hairy top. The seed is thin and long. It is propagated by seeds, cuttings, layering, and stem cuttings. The oriental plane tree is a light- and heat-loving, soil-demanding plant. The Eastern plane tree is found naturally on the southern slopes of the Greater Caucasus, including in the regions of the Republic of Azerbaijan - Agstafa, Ganja, Goychay, Barda, Zangilan, Nakhchivan, Ordubad, Yardymli, Zagatala, Agdash, Sheki, Gabala, Baku and other places. Eastern plane trees are planted in parks, gardens, and orchards, singly or in groups, for landscaping purposes. Eastern plane trees are naturally planted along riverbanks, along with trees such as alder, willow, and poplar. The leaves and bark have been used for medicinal purposes. The branches and roots have also been used to make fabric dye (Huseynov et al. 2022; Mirzəyev 2019).

Figure 8. *Platanus orientalis.*

Vitis sylvestris, or wild grape, is widespread in the Caucasus, considered the center of origin of viticulture and included in the Vavilov Triangle (**Figure 9**). Although the phytogenetic resources of this species have been studied, research on micropropagation of wild grape forms of Caucasian origin is a new direction (Maghradze et al. 2020). The plant is a bushy liana with gray-brown bark. Its leaves have 3–5 lobes, its flowers are dioecious, and its fruits are blackish berries. It blooms in May-June and bears fruit in August-September. It reproduces by seed and vegetatively and is distributed in the lowland and mid-mountain zones, mainly around wetlands. It grows in open forests in the South Caucasus, climbing various trees and shrubs (Ocete et al. 2018). It is important in medicine, agriculture, and the food industry. It is used to pollinate female grape varieties; the male flowers are used to flavor wines in Azerbaijan, and the unripe fruits are used to prepare marinades and special sauces (verjuice) (Maghradze et al. 2015).

Figure 9. Wild grape (*Vitis sylvestris*).

Thymus collinus is a plant species belonging to the family Lamiaceae. It is widespread in the Caucasus. It is a rare and relict species of Azerbaijan. Its range is narrow and it is found in the mountainous areas of Guba and Nakhchivan Autonomous Republic in Azerbaijan. It grows more often in the middle and subalpine regions, on dry rocky slopes (**Figure 10**). It is a perennial plant with a branched stem at the bottom and hairy at the top. The height of the flower stalks is 7–12 cm. The leaves are petiolate, oblong-ovate to ovate, 7–11 cm long, 3–5 mm wide, and dotted-veined. Its flowers are pink and clustered in small clusters. The fruit is a cone. In nature, it reproduces mainly by seeds. It is widely used in ornamental gardening (Ganbarov et al. 2015).

Figure 10. Hill thyme (*Thymus collinus*).

Diospyros lotus L., or the Caucasian persimmon, is a plant species belonging to the Ebenaceae family. It is a tree 15–25 m tall, and up to 40 m in favorable conditions, with a diameter of up to 80 cm (**Figure 11**). Only one species, the Caucasian date palm, grows naturally in Azerbaijan. In Azerbaijan, this plant is widespread in the Lankaran region, in the Guba-Khachmaz zone, at an altitude of approximately 500 m above sea level. Currently, this plant is cultivated in almost all regions of Azerbaijan and is used for various purposes (Bakhshaliyeva 2023). Its lateral roots have penetrated deep into the soil, and the root system is divided into sections. The mild climate of the Lankaran-Astara region, the abundance of rain and sunny days, and the presence of humid air masses allow the Caucasian date palm to spread in different ecosystems. This species is distributed in mountainous and foothill areas up to 1500 m above sea level, mainly in mixed forests with oak (*Quercus* L.), ironwood (*Parrotia persica*), and hornbeam (*Carpinus* L.) trees. It is a straight-stemmed tree, 15–20 m tall, and sometimes up to 30 m in forests, depending on its ecological conditions. It is a light-requiring plant (Huseynov et al. 2022). The Caucasian palm loves moist soils. It is used as an ornamental and medicinal plant. It can also be widely used in landscaping and afforestation. The common date palm or Caucasian date palm belongs to the ancient Mediterranean group of the Asia Minor - Mediterranean class of the ancient forest geographical type. It is distributed in the Mediterranean, the Balkans, Asia Minor, Iran, India, the Himalayas, Japan, China, Ukraine, Central Asia, and the Caucasus. In Azerbaijan, it is widespread in the eastern and western regions of the Greater Caucasus, the northern regions of the Lesser Caucasus, the mountainous part of Talysh, the Lankaran and Kur-Araz lowlands, the Alazan-Ayrichay valley, and the Bozgir plateau. It grows from the lowlands to the middle mountain belt (up to 1800 m above sea level).

Figure 11. Stem, leaf and fruit of the Caucasian date palm (*Diospyros lotus*).

Specially protected natural areas and national parks of Azerbaijan

Azerbaijan is a country distinguished by its rich biodiversity, diverse landscapes and climate zones, and rare and endemic flora and fauna. Especially protected natural areas have been established throughout the country to protect these natural resources, ensure the sustainability of ecosystems, and protect rare species. These areas include natural complexes of special ecological, scientific, cultural, aesthetic, and health-improving importance, as well as areas where rare and endangered plant and animal species are distributed.

Specially protected natural areas in Azerbaijan are divided into categories such as state nature reserves, national parks, nature and ecological parks, state nature reserves, natural monuments, zoological parks, botanical and dendrological parks, health resorts, and geological parks, depending on their purpose and protection regime.

The creation of protected areas is conventionally divided into three stages. The first stage began in 1910 with the creation of the Eldar Pine Botanical Reserve. In the second stage, especially in 1925–1936, the Goygol, Gizilaghac, Zagatala, and Hirkan state nature reserves were established. The third stage is characterized by the establishment of national parks since 2003. This stage, in addition to protecting biodiversity, has created opportunities for the development of ecological tourism, scientific research, and environmental education.

National parks

National parks are specially protected areas created for the protection of natural complexes of special ecological, historical, and aesthetic importance, for environmental education, scientific research, and nature tourism. The first national parks in Azerbaijan were established in 2003. Currently, 12 national parks are operating in the country: Zangezur, Aggol, Shirvan, Hirkan, Altyaghaj, Absheron, Shahdag, Goygol, Samur-Yalama, Gizilaghaj, Ilisu, and Akhar-Bakhar national parks named after Academician Hasan Aliyev.

National parks make an important contribution to the preservation of biodiversity in various natural and geographical regions. Hirkan National Park plays an important role in protecting the Hirkan forests rich in relict and endemic plants, Gizilaghac National Park protects the Caspian coast and wetland ecosystems, Shahdag and Ilisu national parks protect the mountain ecosystems of the Greater Caucasus, and Zangezur National Park protects the rich natural complexes of Nakhchivan.

State Nature Reserves

State nature reserves are created to protect rare and characteristic natural complexes in their natural state, as well as to study natural processes. Maximum protection of natural ecosystems is the main principle in reserves, and economic activity is strictly restricted. The first state nature reserve in Azerbaijan is considered to be the Goygol State Nature Reserve, established in 1925. In subsequent years, the Qizilaghaj, Zagatala and Hirkan reserves were established. The reserves operating in the country include Zagatala, Turyanchay, Shirvan, Basitchay, Garayazi, Garagol, Eldar Shamy, Mud Volcanoes Group and Korchay state nature reserves. (https://www.eco.gov.az/az/tebii-servetlerimiz/qoruglar)

State Nature Sanctuaries

State nature reserves are established to protect and restore natural complexes and their individual components, as well as to maintain ecological balance. Their main task is to ensure the protection of certain plant and animal species, habitats, and natural complexes. Sanctuaries can be established without taking land from owners and users. Activities that could harm nature are restricted or prohibited in these areas. The first state nature reserves in Azerbaijan began to be created in 1961. Korchay, Bandovan, Lachin, Garayazi-Aghstafa, Sheki, Shamkir, Gusar, Gubadli, Zuvand, Ordubad, Ismayilli, Dashalti, Gabala, Arazboyu, Hirkan, Zagatala, Arpachay and other state nature reserves operate in various regions of the country. (https://www.eco.gov.az/az/tebii-servetlerimiz/yasaqliqlar)

Development prospects of specially protected natural areas

The development of specially protected natural areas is of great importance for the protection of biodiversity as well as for the socio-economic development of regions. The creation of new protected areas and the development of existing ones allow for strengthening ecological security, developing ecotourism, increasing employment, and sustainable use of natural resources. The creation of a biosphere reserve in the Zagatala-Balakan region, as well as the organization of geological parks, are promising directions in terms of protecting Azerbaijan's natural and geological heritage. The international recognition and protection of the Hyrcanian forests is also of particular importance. The inclusion of the Hyrcanian National Park on the UNESCO World Heritage List could make a significant contribution to the international recognition and protection of the biodiversity of this area. Thus, Azerbaijan's specially protected natural areas play an important role in preserving biodiversity and genetic resources, and in protecting rare and endangered species. National parks, state nature reserves, and sanctuaries are complementary protection mechanisms. Effective management of these areas, strengthening scientific monitoring, and applying ecotourism principles create important opportunities to preserve Azerbaijan's natural heritage for future generations.

Conclusion

Azerbaijan's specially protected natural areas are of great importance in preserving the country's rich biodiversity, rare and endemic species of flora and fauna, and valuable natural landscapes and ecosystems. The historical development of the system of protected areas in the country shows that measures taken to protect nature have become more extensive and complex over time, and the organization of national parks, along with the creation of reserves and sanctuaries, has become one of the priority areas.

The establishment of national parks, in addition to protecting natural ecosystems, has created new opportunities for environmental education, scientific research, ecotourism, and sustainable regional development. State nature reserves serve to preserve natural complexes in their original state, while state nature reserves serve to protect and restore individual natural components and their habitats. The joint activity of these protection categories is one of the important guarantees of the country's ecological security and biodiversity protection.

In the future, it is of great importance to expand the scope of specially protected natural areas, improve their management based on modern scientific approaches, conduct regular monitoring of biodiversity, and create databases using digital technologies. In addition, involving local communities in the process, developing ecotourism based on sustainable principles, and strengthening environmental education among the population can contribute to the effective management of protected areas.

In particular, the work carried out towards the creation of biosphere reserves and geological parks, as well as the international promotion of Azerbaijan's natural areas, are considered promising directions in terms of protecting the country's natural heritage. In general, the development of specially protected natural areas serves not only to protect individual species and ecosystems, but also to maintain ecological balance, sustainable use of natural resources, and the preservation of Azerbaijan's rich natural heritage for future generations.

Conflict of Interest

The author declares that there is no conflict of interest.

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