REPUBLIC OF AZERBAIJAN

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ABSTRACT

of the dissertation for the degree of Doctor of Science

FAUNA, SYSTEMATICS, ECOLOGY AND PHYLOGENY OF LACEWING (NEUROPTERA) INSECTS (MYRMELEONTİDAE, ASCALAPHİDAE, MANTİSPİDAE, NEMOPTERİDAE) IN AZERBAIJAN

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Field of science: Biology

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INTRODUCTION

Relevance of the topic and level of study. One of the key focus areas in modern biology is the study and conservation of biological diversity. In this context, the study of Neuroptera is of significant interest. The species diversity within this ancient group is relatively small compared to other insect groups. Some members of this group are very rare and are listed in the Red Book of Azerbaijan. The family of thread-winged insects (order Neuroptera) is found only within the Ordubad region, as well as in the Lerik, Zangilan, and Nakhchivan AR. Additionally, as predators, Neuroptera play an important role in the natural regulation of forest and agricultural pest populations. Some species within this group also serve as pollinators, feeding on flowering plants.

The relevance of studying Neuroptera in Azerbaijan is further highlighted by the fact that, prior to our research, only the green lacewing family (Chrysopidae) had been studied, while other families remained unexplored. We identified 5 species and 1 variation from the family Mantispidae, 3 species, 3 subspecies, and 2 morphs from the family Ascalaphidae, 4 species from the family Nemopteridae, and 42 species from the family Myrmeleontidae. DNA barcoding of these species was conducted using molecular genetic methods at the University of Oslo's Natural History Museum of Norway. The nucleotide sequences were submitted to GenBank, where 62 accession numbers were assigned.

Object and Subject of the Study: The object of this study consists of four families within the order Neuroptera: Mantispidae, Ascalaphidae, Myrmeleontidae, and Nemopteridae. The subject of the study encompasses the species diversity, ecology, morphology, fauna, taxonomy, zoogeography, and phylogeny of the Neuroptera order in Azerbaijan.

The purpose and objectives of the study. The aim of the study was to investigate the families Mantispidae, Ascalaphidae, Myrmeleontidae, and Nemopteridae of Azerbaijan from faunistic, systematic, zoogeographic, and phylogenetic perspectives. To achieve this goal, the following aspects were examined:

- Systematic and eco-faunistic analysis of the order Neuroptera (Mantispidae, Ascalaphidae, Myrmeleontidae and Nemopteridae) of Azerbaijan.

- Zoogeographical analysis of Neuroptera (Mantispidae, Ascalaphidae, Myrmeleontidae and Nemopteridae) of Azerbaijan.

- Formation of the fauna of Neuroptera (Mantispidae, Ascalaphidae, Myrmeleontidae and Nemopteridae) of Azerbaijan.

- Factors negatively affecting the fauna of Neuroptera (Mantispidae, Ascalaphidae, Myrmeleontidae and Nemopteridae) in Azerbaijan.

- Phylogeny and DNA barcoding of representatives of Neuroptera (Mantispidae, Ascalaphidae, Myrmeleontidae and Nemopteridae) of Azerbaijan.

Research methods: Various entomological and ecological methods were used in the study. Adults were collected during the day using a hand net, a Japanese umbrella, and at night by using various light traps. Larvae were collected by sifting the soil. The collected material was identified using different identification keys[1].

The similarity index of the Neuroptera fauna of the northern and southern coasts of the Caspian Sea and different natural regions of Azerbaijan was calculated using the Jaccard formula and the BioDiversity professional computer program.

The Qiagen DNeasy Blood, Tissue KitTM was used for DNA extraction, while standard protocols for animal tissues were fully followed.

The optimal partitioning scheme and nucleotide substitution model for phylogenetic analysis were assessed using PartitionFinder v1.1.1, written in Python v2.7.14. The phylogenetic tree was constructed according to the maximum likelihood (ML) GTR+I+G model and visualized in FigTree v1.4.3 (http//github.com;rambaut;figtree;releases) (2018).

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[1] Кривохатский В.А. Муравьиные львы (Neuroptera, Myrmeleontidae) России — биоразнообразие и зоогеография // Проблемы энтомологии в России. - СПб. - 1998. - т. 1, - с. 215-216.

The main provisions submitted for defense:

1. The families Mantispidae, Ascalaphidae, Nemopteridae, and Myrmeleontidae, which belong to the order Neuroptera, were studied in Azerbaijan for the first time. As a result, six taxa were identified within Mantispidae, eight within Ascalaphidae, four within Nemopteridae, and 42 within Myrmeleontidae. Additionally, 11 new species and three new subspecies were recorded for Azerbaijan's lacewing fauna. Furthermore, the larvae of the antlions *Euroleon parvus* Hölzel, 1972, and *Pseudoformicaleo gracilis* (Klug, 1834) were described for the first time.
2. A taxonomic revision of the families Mantispidae, Ascalaphidae, Nemopteridae, and Myrmeleontidae revealed that *Nesoleon ulianini* (Esben-Petersen, 1913) is a synonym of Myrmeleon lineosus (Rambur, 1842), *Cueta anomala* (Navás, 1915) is a synonym of *Myrmeleon grammaticus* (Navás, 1912), and *Lertha palmonii* (Tjeder, 1970) is a synonym of *Nemoptera extensa* (Olivier, 1811). Additionally, an analysis of the distribution of these families across Azerbaijan's natural zones revealed that 39 species inhabit the Greater Caucasus, 21 species are found in the Lesser Caucasus, 20 in Lankaran, 40 in the Middle Araz region, and 31 in the Kura intermountain depression.
3. For the first time, a zoogeographical analysis of the families Mantispidae, Ascalaphidae, Nemopteridae, and Myrmeleontidae in Azerbaijan has been conducted, explaining the formation processes of the lacewing fauna and identifying the negative impacts affecting it, such as urbanization, aridization, salinization, overgrazing, wildfires, and pesticide use. The study reveals that Azerbaijan's lacewing fauna primarily originates from species migrating through the Mediterranean, Iranian, and Turan zoogeographic regions. Additionally, it has been determined that the Hesperian fauna is represented by 16 species, the European nemoral fauna by 3 species, the Scythian plain fauna by 4 species, and the Setian fauna by 17 species.
4. The nucleotide sequences of the COI (cox1) gene, which encodes the first (major) subunit of the cytochrome C oxidase complex,

have been identified in the mitochondrial genomes of Azerbaijani Mantispidae, Ascalaphidae, Nemopteridae, and Myrmeleontidae families and uploaded to GenBank (https://www.ncbi.nlm.nih.gov/genbank/). Analysis of these gene sequences has confirmed the taxonomic status of the Myrmeleontidae and Ascalaphidae families. Additionally, COI gene analysis has verified the identity of the species *Bubopsis hamatus* (Klug, 1834) *and Bubopsis andromache* Aspöck U., Aspöck H., Hölzel, 1979 (Ascalaphidae).

5. Ten rare species from the families *Mantispidae*, *Ascalaphidae*, *Nemopteridae*, and *Myrmeleontidae* in Azerbaijan have been listed in the Red Book of the Republic of Azerbaijan. Additionally, the species *Lertha ledereri* (Sélys-Longchamps, 1866) has been recommended for inclusion in the Red Book.

Scientific novelty. The Neuroptera fauna (Mantispidae, Ascalaphidae, Myrmeleontidae, and Nemopteridae) of Azerbaijan was studied for the first time. Eleven new species ((*Mesonemurus paulus* (McLachlan, 1875), *Macronemurus linearis* (Klug, 1834), *Solter ledereri* Navás, 1912, *Lopezus fedtschenkoi* (McLachlan, 1875), *Myrmecaelurus solaris* Krivokhatsky, 2002, *Nohoveus armenicus* (Krivokhatsky, 1993), *Creoleon remanei* Hölzel, 1972, *Cueta anomala* Navas, 1915, *Distoleon kabulensis* Hölzel, 1972, *Distoleon formosus* Hölzel, 1972, və *Delfimeus morgani* (Navás, 1913)) and three new subspecies (*Neuroleon nemausiensis piryulini* Krivokhatsky, 2011, *Aspoeckiana uralensis jakushenkoi* (Zakharenko, 1983), *Aspoeckiana uralensis curdica* Hölzel, 1972) were recorded for the fauna of Azerbaijan.

A revision of the Neuroptera fauna of the Caucasus was conducted based on the collection of P. Esben-Petersen. Two antlion species (Myrmeleontidae: *Nesoleon ulianini* – Esben-Petersen, 1913 nec McLaclan, 1875 = *Myrmeleon lineosus* Rambur, 1842 syn. nov., və *Cueta anomala* Navás, 1915 =*Myrmeleon grammaticus* Navás, 1912; syn. nov.) and one species of thread tails (Nemopteridae: *Lertha palmonii* Tjeder, 1970: 219 = *Nemoptera extensa* Olivier, 1811(son zamanlarda *Olivierina extensa* (Olivier, 1811)) syn. nov.)) were synonymized.

Ten species of Neuroptera are listed in the Red Book of the Republic of Azerbaijan, with one additional species recommended for inclusion in the next edition. DNA barcoding of the mitochondrial CO1 gene was performed for 56 taxa belonging to the order Neuroptera. The nucleotide sequences were uploaded to NCBI GenBank, obtaining 62 accession numbers.

A zoogeographical analysis of Azerbaijan's Neuroptera fauna was carried out, the formation pathways of the fauna were studied, and the negative impacts affecting the fauna were identified.

Theoretical and practical value of the work. This study plays a crucial role in addressing the gap in knowledge regarding the Neuroptera fauna of Azerbaijan. The DNA barcodes obtained through molecular analysis serve as a significant foundation for future genetic studies on Neuroptera. The discovery of new species through this research has enriched the entomofauna of Azerbaijan. Investigating the lacewing insect families Mantispidae, Ascalaphidae, Myrmeleontidae, and Nemopteridae provides valuable insights into the biodiversity of the region. Understanding the habitats of lacewing insects and their interactions with other species is essential for conserving the ecosystems in which they reside. Antlions and Ascalaphidae are particularly notable for their role in controlling insect pest populations by preying on pests that can harm crops or transmit diseases. Studies of their behavior, predation characteristics, and ecological roles contribute valuable knowledge for developing biological pest control strategies, potentially reducing reliance on chemical pesticides.

Approbation and application. The main findings of the dissertation were presented and discussed at several forums, including a meeting of the "Terrestrial Invertebrates" laboratory at the Institute of Zoology of MSEAR, annual reporting meetings of the Academic Council, a scientific seminar at the Institute, and various national and international scientific and practical conferences listed below:

- International Artvin Symposium, Artvin Choruh University (Artvin, 2018);

- Mountain ecosystems and their components. Proceedings of the VII All-Russian conference with international participation dedicated to the 30th anniversary of the scientific school of the member of the AS of RAS A.K.Tembotov and the 25th anniversary of the A.K.Tembotov Institute of Mountain Ecology of the Russian Academy of Sciences (Nalchik, 2019);

- International Scientific and Practical Conference, Tyumen State University (Tyumen, 2019);

- International Scientific and Practical Conference "Ecology and Nature Management" Maras. Republic of Ingushetia. Ingush State University (Maras, 2020);

- Mountain ecosystems and their components. Proceedings of the VIII All-Russian conference with international participation dedicated to the Year of Science and Technology in the Russian Federation (Nalchik, 2021);

- III international scientific conference. Great Britain (London, 2022);

- Scientific and practical conference "Fundamental and applied scientific research in zoology: current problems, achievements and innovations" dedicated to the 85th anniversary of the Institute of Zoology of ANAS and the 100th anniversary of the birth of academician Musa Musayev (Baku, 2021);

- Biodiversity, land and water resources of Karabakh: past, present and future. Online conference (Baku, 2021);

- Azerbaijan National Academy. Biodiversity, soil and water resources of Shusha and adjacent territories: a look at the future. International conference (Baku, 2022));

- IV Internatıonal Scientific Conference. Italy (Rome, 2023);

- Scientific and practical seminar dedicated to the 100th anniversary of the National Leader H.Aliyev on the topic "Current issues of scientific research: theoretical and practical aspects of zoology". (Baku, 2023)

- International scientific and practical conference "Disturbances in the functioning of ecosystems due to global climate change and ways to eliminate them", organized jointly by the Ministry of Science and Education of the Republic of Azerbaijan, the Institute of

Zoology and the Azerbaijani delegation of the World Wildlife Fund (WWF) (Baku, 2024).

- XII International Scientific Conference "Achievements and Challenges of Biology (AKB)" within the framework of the "Year of Solidarity for a Green World" (Baku, 2024);

- 8th International Congress on Zoology and Technology (Turkiye, 2024);

- International scientific and practical conference "Resilience of natural landscapes and their components to external influences" (Grozny, 2024).

In total, out of 133 published scientific papers 26 ones related to the dissertation topic.

The name of the organization where the dissertation work was completed. The dissertation work was conducted at the Laboratory of Terrestrial Invertebrates at the Institute of Zoology under the Ministry of Science and Education of the Republic of Azerbaijan.

Volume and structure of work. The dissertation comprises 423 pages (349578 characters) and includes the following sections: introduction (9052 characters), six chapters (Chapter I: 23053, Chapter II: 26083, Chapter III: 143774, Chapter IV: 69302, Chapter V: 29080, Chapter VI: 15595), conclusion (22613), recommendations (1382) findings (4205), a list of references, 20 tables, 6 diagrams, and 221 figures. The list of references includes 340 sources (12 in Azerbaijani, 22 in Russian, and 306 in other foreign languages).

CHAPTER I. REVIEW OF THE STUDY OF THE FAUNA OF NEUROPTERA OF THE WORLD AND AZERBAIJAN

This chapter reviews the history of Neuroptera studies in Azerbaijan, beginning with the first recorded specimen of *L. macaronius kolyvanensis*, a female captured by K. Lukyanovich in the village of Jafarhan (now Sabirabad district) in 1886, and extending to the present era, including contributions by researchers such as Bogachev, Gurbanov, and Krivokhatsky. Notable scientists who have contributed to the study of Azerbaijan's lacewing fauna include E. Koenig, K. Satunin, A. Shelkovnikov, B. Uvarov, A. Vasilinin, E. Luppova, R. Schmidt, F. Zaitsev, V. Lukstanov, R. Gnishik, A. Koval, A. Bartenev, D. Znoyko, M. Ryabov, F. Lukyanovich, A. Kirichenko, A. Zagulyaev, I. Radionov, A. Gorokhov, V. Tryapitsyn, G. Gurbanov, D. Kasatkin, M. Volkovich, and I. Shokhin. Most of the specimens in these museums were collected during the early and mid-20th century, particularly during the Nakhchivan expeditions led by Shelkovnikov and organized by the Caucasus Museum. These expeditions gathered various zoological materials, including lacewings. Unfortunately, some of these materials were destroyed before analysis, while others are preserved in the aforementioned museums. Azerbaijani entomologists have not conducted systematic lacewing collections. The first collection effort in this area was by an unnamed individual in 1928. Subsequent work on Neuroptera families in Azerbaijan was undertaken by A. Bogachev, L. Akhundova, N. Yakovleva, and H. Aliyev. Literature on Azerbaijan's Neuroptera fauna reveals gaps in knowledge regarding their fauna, taxonomy, ecology, zoogeography, and phylogeny.

CHAPTER II. MATHERIAL AND METHODS

The dissertation is based on materials collected across all natural regions of Azerbaijan during 2012-2023, as well as on the entomological collections from the Institute of Zoology of the Russian Academy of Sciences, the Zoological Museum of Moscow State University, the Natural History Museum of Georgia, the entomological collections of the Upper Silesian Museum in Poland, and the Kaposvári Rippl-Rónai Museum in Hungary. Research work was personally conducted at the Zoological Museum of the Institute of Zoology of the Russian Academy of Sciences, the Natural History Museum of Georgia, and the Zoological Museum of Moscow State University. Information from the museums in Poland and Hungary was obtained through scientific collaboration with colleagues.

The material was collected during the day, at dusk, and at night using standard entomological methods. Adult lacewings were caught with entomological nets during the day and with light traps at night. Larvae were collected by sifting the soil and selected using soft tweezers. Some of the collected material was treated with ethyl acetate, while others were stored in a 96% ethyl alcohol solution for subsequent molecular genetic studies. All specimens were labeled with the collection location, date, and the name of the collector. During the field studies, the habitats and species of lacewings were photographed using a Sony camera, and the coordinates of the collection sites were determined using GPS.

In the laboratory, the genitals of the species were photographed under an Olympus stereo microscope using the macro mode of a Sony camera. The identification of the collected specimens to the species level was carried out using relevant literature.

The Jaccard coefficient, commonly used in various ecological studies, was calculated to assess the similarity of different landscape-ecological complexes.

The Qiagen DNeasy Blood & Tissue Kit™ was used for DNA analysis of lacewings, following standard Animal Tissue protocols. The COI-5' barcode region was amplified using the forward (LCO1490: 5'-GGTCAACAAATCATAAAGATATTGG-3') and reverse primers (HC02198: 5'-TAAACTTCAGGGTGACCAAAAAATCA-3' or LepF1; LepR1). Nucleotide sequences were assembled and manually edited using CodonCode Aligner v8.0.1 (CodonCode Corporation, Dedham, MA, USA), and consensus sequences (contigs) were generated[2]. The sequences were checked and translated using MEGA v7 to ensure the absence of stop codons and gaps. The contigs were then analyzed using BLAST to identify the closest sequences in GenBank. A total of 62 COI sequences obtained for 56 specimens (33 species, 10 subspecies, 5 variations, 2 larvae, 1 species in ethanol) of Neuroptera were included in the NCBI GenBank. The phylogenetic tree was constructed using the maximum likelihood (ML) method with the GTR+I+G model and visualized in FigTree v1.4.3. For the zoogeographic analysis of the Neuroptera fauna of Azerbaijan, areological classification was performed according to the F.A. Emelyanov system[3].

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[2] Lai, Y., Li, K.-y., Liu, X.-y. Comprehensive DNA barcode reference library and optimization of genetic divergence threshold facilitate the exploration of species diversity of green lacewings (Neuroptera: Chrysopidae) // Insect Science, - 2023. – p. 1-20.

[3] Емельянов, А.Ф. Предположения по классификации и номенклатуре ареалов // Энтомологическое обозрение. –1974, – т. 53, №3, – с. 497-222.

Prior to including some insect species in the Red Book, a national assessment was conducted according to IUCN categories and criteria.

CHAPTER III. SPECIES DIVERSITY AND ECOLOGICAL-FAUINISTIC ANALYSIS OF NEUROPTERA

This chapter gives the taxonomy of the order Neuroptera and the general distribution of the species based on the latest catalogues. Our own collection efforts, which began in 2012, have led to the registration of 60 taxa within the studied families:

Family Mantispidae

1. *Mantispa scabricollis* McLachlan in Fedchenko, 1875
2. *M. styriaca* (Poda, 1761)
3. *M. perla* (Pallas, 1772)
4. *M. perla var. lobata* Navás, 1912
5. *M. adelungi* Navás, 1912
6. *M. aphavexelte* U. Aspöck, H. Aspöck, 1994

Family Ascalaphidae

7. *Nemoptera sinuata* Olivier, 1811
8. *N. coa* (Linnaeus, 1758)
9. *Lertha ledereri* (Sélys Longchamps, 1866)
10. *L. extensa* (Olivier, 1811)
11. *Deleproctophylla variegata* (Klug, 1845)
12. *Libelloides hispanicus ustulatus* (Eversmann, 1850)
13. *L. macaronius kolyvanensis morpha typica* (Laxmann,1842)
14. *L. macaronius kolyvanensis morpha flavum levis*
15. *L. macaronius kolyvanensis morpha alba*
16. *L. macaronius turcestanicus* (Weele, 1909)
17. *Bubopsis hamata* (Klug, 1834)
18. *B. andromache* Aspöck U., Aspöck H., Hölzel, 1979

Family Myrmeleontidae

19. *Palpares libelluloides* (Linnaeus, 1764)
20. *P. turcicus* Koçak, 1976
21. *Dendroleon pantherinus* (Fabricius, 1787)
22. *Gymnocnemia variegata* (Schneider, 1845)
23. *Myrmecaelurus solaris* Krivokhatsky, 2002
24. *M. trigrammus* (Pallas, 1781)

25. *Lopezus fedtschenkoi* McLachlan in Fedchenko, 1875
26. *Acanthaclisis occitanica* (Villers, 1789)
27. *A. occitanica morpha nigrilenta*
28. *Nohoveus zigan* (Aspöck, Aspöck et Hölzel, 1980)
29. *N. armenicus* (Krivokhatsky, 1993)
30. *Creoleon plumbeus* (Olivier, 1811)
31. *C. remanei* Hölzel, 1972
32. *Nedroledon maculatus* Zakharenko, 1990
33. *Nicarinus poecilopterus* (Stein, 1863)
34. *Pseudoformicaleo gracilis* (Klug, 1834)
35. *Delfimeus irroratus* (Olivier, 1811)
36. *D. irroratus iranensis* Hölzel, 1972
37. *D. morgani* (Navás, 1913)
38. *Myrmeleon hyalinus hyalinus* Olivier, 1811
39. *M.hyalinus distinguendus* Rambur, 1842
40. *M. formicarius* Linnaeus, 1767
41. *M. inconspicuus* Rambur, 1842
42. *Solter ledereri* Navás, 1912
43. *Neuroleon (Ganussa) tenellus* (Klug, 1834)
44. *Distoleon tetragrammicus* (Fabricius, 1798)
45. *D. kabulensis* Hölzel, 1972
46. *D. formosus* Hölzel, 1972
47. *Macronemurus bilineatus* Brauer, 1868
48. *M. linearis* (Klug, 1834)
49. *M. persica amoena* Navás, 1915
50. *M. persicus* Navás, 1915
51. *Euroleon nostras* (Geoffroy in Fourcroy, 1785)
52. *E. parvus* Hölzel, 1972
53. *Mesonemurus paulus* (McLachlan, 1875)
54. *Neuroleon nemausiensis piryulini* Krivokhatsky, 2011
55. *N. microstenus microstenus* (McLachlan, 1898)
56. *Megistopus flavicornis* (Rossi, 1790)
57. *Aspoeckiana uralensis jakushenkoi* Zakharenko, 1983
58. *A. uralensis curdica* Hölzel, 1972
59. *Cueta anomala* Navás, 1915
60. *C. lineosa* (Rambur, 1842)

3.1. Mantispidae Leach, 1815

The Mantispidae fauna of Azerbaijan has been studied by us for the first time. As a result of our research, it was determined that 5 species and one variation are widespread in Azerbaijan. These species are found in the Greater Caucasus, Lesser Caucasus, Kura-Araz Plain, Nakhchivan, and Lankaran regions. All of the listed species are present in Nakhchivan. Additionally, *M.aphavexelte*, *M.perla*, *M.styriaca* are also found in the Greater Caucasus, Lankaran, and Kura-Araz Plains. Among these species, *M.styriaca* (EN B2ab(iii); C2a(i, ii)) and *M.aphavexelte* are included in the Red Book of the Republic of Azerbaijan with the status "Data Deficient" (DD).

3.2. Ascalaphdae Rambur, 1842

The earliest information about the Ascalaphidae fauna in Azerbaijan was provided by A.V. Bogachev in his book The Animal World of Azerbaijan[4] . He identified a single subspecies, Ascalaphus macaronius kolyvanensis Laxm, which he recorded only in the foothills and steppes of the republic, specifically in areas ranging from Shamakhi to Samukh and Gazakh, as well as in the mountains of Karabakh. G.G. Kurbanov[5] expanded the list of ascalaphid species to include four: *L.macaronius, L.ustulatus, B.hamatus, and D.variegata.* Unfortunately, the collections gathered by these authors have not survived. However, as a result of our research conducted from 2012 to 2023, we have confirmed the presence of these ascalaphid species in the republic. Additionally, we have determined that the fauna consists of three species, three subspecies, and two morphs.

Two of these species, *B.hamatus* (with EN B2ab(iii)c(iii) status) and *D.variegata* (with EN B2ab(i,ii,iii); C2a(i) status), have been included in the Red Book of the Republic of Azerbaijan.

3.3. Myrmeleontidae Latreille, 1802

We have established for the first time that the Myrmeleontidae family in Azerbaijan is represented by 42 species across 7

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[4] Богачев, A.V. Животный мир Азербайджана. Насекомые. / A.V. Богачев, – Баку: АН АзССР, – 1951, – с. 266-409.

[5] Курбанов, Г.Г. Отряд Сетчатокрылые – Neuroptera. Животный мир Азербайджана Тип Членистоногие. / Г.Г.Курбанов. - Баку: Элм, -1996.- т. 2. - с. 203–208.

subfamilies. As a result of our study on the Myrmeleontidae fauna, 11 new species: *M.paulus* (McLachlan, 1875), *M.linearis* (Klug, 1834), *S.ledereri* Navás, 1912, *L.fedtschenkoi* (McLachlan, 1875), *M.solaris* Krivokhatsky, 2002, *N.armenicus* (Krivokhatsky, 1993), *C.remanei* Hölzel, 1972, *C.anomala* Navas, 1915, *D.kabulensis* Hölzel, 1972, *D.formosus* Hölzel, 1972, and *D.morgani* (Navás, 1913), and additionally, 3 new subspecies of antlions were identified for the fauna of Azerbaijan: *N.nemausiensis piryulini* Krivokhatsky, 2011, *A.uralensis jakushenkoi* (Zakharenko, 1983), and *A.uralensis curdica* Hölzel, 1972.

Four of these species—*P.turcicus* (with CR B2ab(iii)c(iii) status), *M. (Ganussa)tenellus* (with EN B2ab(iii,iv) status), *P. gracilis* (with CR B2ab(iii)c(iii) status), and D. pantherinus (with DD status)—have been included by us in the Red Book of the Republic of Azerbaijan.

For the first time, we described the 2nd instar larvae of the antlions *P. gracilis* and *E. parvus*.

3.4. Nemopteridae Burmeister, 1849

The Nemopteridae fauna of Azerbaijan is limited, represented by 4 species from two genera (Nemoptera and Lertha) within the Nemopterinae subfamily. Our research determined that these insects are found in areas of Azerbaijan bordering Iran and Armenia. Specifically, they are located in the village of Tazakend in the Sharur district of Nakhchivan AR, near the Araz River, the village of Arafsa in the Julfa district, and the village of Gosmalian in the Lerik district, within the Lankaran Natural Province.

In Azerbaijan, *N.sinuata* has the widest range of altitudes, spanning from 466 to 1963 meters. *L.extensa* follows, with an altitude range of 798 to 1598 meters. *N.coa* and *L.ledereri* have been observed at only one altitude point each. There is only literary evidence of *N.coa* being found in areas along the Araz River in Azerbaijan, but we were unable to confirm this with physical specimens. It is believed that this species inhabits the Zangezur and Zangilan regions. *L.ledereri* was recorded by us only in the village of Gosmolyan in Lerik, at an altitude of 1427 meters above sea level.

The genus Lertha primarily inhabits arid regions, xerophytic and mountain-xerophytic meadows, while the genus Nemoptera is found in forest clearings and open meadows, and also flies near river valleys.

L.extensa (with EN B2ab(ii,iv); C2b status), *N.sinuata* (with EN B2ab(ii,iv); C2b status), and *L.ledereri* (with DD status) have been included by us in the Red Book of the Republic of Azerbaijan.

3.5. Revision of the Caucasian Myrmeleontiformia Lacewings Collection of the Georgian National Museum, Identified By P. Esben-Petersen

The Georgian National Museum in Tbilisi houses a collection gathered during expeditions in the Caucasus region by renowned Georgian and Russian zoologists in the 19th and early 20th centuries. The lacewing specimens in this collection were originally identified by the Danish entomologist Peter Esben-Petersen and are preserved in good condition at the museum. After the collapse of the USSR, the whereabouts of the collection remained unknown for a long time. In 2017, we rediscovered and inventoried the collection. Additionally, we compiled a key to the genera of the tribe Myrmecaelurinae of the Caucasus.

As a result of the revision of the Neuroptera fauna of the Caucasus 2 species of antlion and 1 species of Nemopteridae were synonymized.

CHAPTER IV. COMPARATIVE ANALYSIS OF NEUROPTERA SPECIES DIVERSITY IN THE NATURAL AREAS OF AZERBAIJAN

Over the past 60–65 years, several authors have repeatedly developed physical-geographical zoning schemes for the territory of Azerbaijan[6]. The most recent scheme has been refined based on medium-scale landscape maps compiled by B.A. Budagov.

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[6] Azərbaycan Respublikasının coğrafiyası. Fiziki coğrafiya. XII. Azərbaycanın landşaftları / E.K.Əlizadə, M.C.İsmayılov, M.İ.Yunusov, [və b.] – Bakı: – 2014. – 528 s.

4.1.Neuroptera fauna of the Greater Caucasus (GC) natural region

Material was collected from the following areas and surrounding villages of the Azerbaijani territories in the Greater Caucasus: Gobustan, Khizi, Sumgait, Siyazan, Shabran, Guba, Shamakhi, Ismailli, Sheki, Zagatala, Oguz, and Gabala. In total, 3 species from the Mantispidae family, 4 from the Ascalaphidae family, and 32 species from the Myrmeleontidae family were recorded (Figure 1).

In the nival-subnival complexes of mountain landscapes, as well as the alpine and subalpine-meadow complexes of the high-mountain landscapes of the Greater Caucasus, we did not observe any species. This absence is attributed to both the climate and soil conditions. The nival-subnival, mountain-forest, and alpine-subalpine-meadow-rocky landscapes of the highlands are characterized by frequent severe flooding (at least once a year), active landslides, up to five days of hail per year, and avalanches.

Figure 1. Locations of material collection

From the post-forest-steppe and steppe complexes of the lowlands and midlands, the number of lacewing species begins to increase. In the forest-steppe and steppe complexes, 7% of lacewings (9 species) were recorded. In flat semi-desert landscapes 13 species were identified, while 17 species were found in humid desert landscapes, 15 species in dry desert (steppe) landscapes, and 23 species in semi-desert landscapes.

Representatives of the studied Neuroptera families are mainly species that prefer hot and dry climates. More representatives of the studied families were recorded in flat landscapes. Dry desert (steppe), humid desert (forest-steppe) and semi-desert landscapes include 18, 22 and 30% of the registered species, respectively. In the nival-subnival of mountain landscapes, the alpine-subalpine-meadow complex and the mountain-meadow complex of the highlands, neuroptera species were not found at all.

An increase in altitude leads to a decrease in temperature, an increase in the amount of precipitation (rain or snow), a partial decrease in atmospheric gas pressure, an increase in wind speed and turbulence, and the release of extreme radiation. The combined effect of these factors can lead to a change in the structure of the insect habitat, as well as the quality of nutrition.

Neuroptera are poor flyers (with the exception of some ascalaphs), which means that their ability to spread often depends on air currents. In general, Neuroptera species prefer the presence of shelter and food resources that allow them to live in a variety of environments, and also require the presence of complex plant associations that provide them with a variety of niches for survival.

4.2.Neuroptera fauna of the natural region of the Kura Intermountain Depression (KID)

The species composition and characteristics of Neuroptera communities are often linked to the composition of their prey, as well as to microclimate and vegetation structure. The climate, soil, and vegetation of this Natural Region are particularly conducive to the distribution of Neuroptera. This region hosts 31 out of the 60 taxa of the studied families found in Azerbaijan: *M.scabricollis, M.styriaca, M.perla, M. adelungi, M.aphavexelte, D.variegata, L.macaronius* *kolyvanensis morpha typica, L.macaronius turcestanicus B.hamatus, B.andromache, P.libelluloides, D.pantherinus, M.solaris, M.trigrammus, L.fedtschenkoi, A.occitanica, C.plumbeus, C.remanei, M.hyalinus hyalinus, M.parvus, N.(G.) tenellus, D.tetragrammicus, E.nostras, M.paulus, G.variegata, P.gracilis, A.occitanica m.nigrilenta, N.maculatus, N.poecilopterus, D.irroratus, S.ledereri, C.anomala*. Of these 31 species, 27 are found predominantly in the Kura-Araz Lowland. This distribution is not incidental; the Kura-Araz Lowland is the largest lowland in the republic and provides optimal conditions for the habitat and proliferation of the studied species. Specifically, there are 11 species each in the Ajinohur-Jeyranchol and Ganikh-Eyrichay physical-geographical regions, 15 species in the Kudru-Shirvan region, 12 species in the Gazakh-Karabakh region, and 14 species in the Arazboyu plain.

The Kura Intermountain Depression stretches from the shores of the Caspian Sea to the foothills of the Lesser Caucasus. This region encompasses the main sections of the Shirvan, Karabakh, Mil, Mugan, and Salyan plains, as well as the entire southeastern Shirvan area. Southeastern Shirvan is predominantly a lagoon-salt marsh plain, with depressions filled with young deluvial aeolian deposits ranging in depth from 1-2 meters to 3-4 meters. Species such as *C. anomala*, *C. lineosa*, *N. (G.) tenellus*, and *M. paulus* are found in these deposits. These relatively small antlion species utilize such depressions to shield themselves from strong air currents.

The Mugan Plain, an alluvial-deltaic region located between the Araz and Kura rivers, features a gently undulating hilly-lowland relief. This terrain, along with its plant communities, fosters a rich diversity of lacewing species. The primary landscapes are semi-deserts, characterized by wormwood and wormwood-salt marsh vegetation, as well as tamarisk thickets with predominately small shrubs. These conditions are conducive to the distribution of species such as *P. libelluloides*, *E. nostras*, *M. solaris*, *M. trigrammus*, *M. hyalinus hyalinus*, *M. hyalinus distinguendus*, *C. plumbeus*, *A. occitanica*, and *yulgun*. Species of the genus *Cueta* are found in fields, while *N. maculatus* is noted in areas adjacent to the Turyanchay State Nature Reserve.

In the Karabakh-Kazakhstan physical-geographical region, elevation progressively increases, reaching 400-600 meters in the foothills of the Lesser Caucasus. The climate transitions from semi-desert to dry desert as one moves towards the Lesser Caucasus. Within this area, the fauna of lacewings includes diurnal species such as *L.macaronius kolyvanensis*, and ascalaphs and mantispes such as *M. scabricollis* and *M. perla var. lobata*. A comprehensive analysis of the lacewing fauna in the Kura Intermountain Depression reveals a diverse assemblage. This includes two species of ascalaphs, *B. hamatus* and *D. variegata*, and one species of antlion, *N. (Ganussa) tenellus*, which are listed in the Red Book of the Republic of Azerbaijan, along with other rare species such as *N.maculatus* and *A.occitanica morpha nigrilenta*.

The current condition of the natural ecosystems within the Kura Intermountain Depression significantly impacts the species diversity of its Neuroptera fauna. This region encompasses various ecosystems, including forests, xerophytic sparse forests, thickets, swampy areas, floodplain meadows, deserts, semi-deserts, and sandy habitats. Among these, wetlands and floodplain meadows are less favorable for the studied Neuroptera, whereas the other ecosystems provide suitable environments for these insects to thrive and disperse. However, anthropogenic activities have altered the natural region, affecting both soil and vegetation, which in turn influences the composition of the Neuroptera fauna. Key anthropogenic factors include desertification, the flooding of Kura tugai forests due to the Mingachevir hydroelectric power station, the extensive use of Mil, Mugan, and Shirvan plains for cotton cultivation and associated chemical applications, and overgrazing of winter pastures. These factors collectively contribute to the ecological changes in the Kura Intermountain Depression.

Plowing, irrigation, and spraying of fields used for planting create unfavorable conditions for antlions, which construct funnel traps in the soil. The destruction of native plants disrupts the habitat of ascalaphs, which lay their eggs on these plants, as well as antlions, which seek shelter in the branches. Overgrazing during winter leads to the gradual loss of native vegetation, adversely impacting ascalaph populations, as they depend on plant stems for egg-laying.

Conversely, the trampling of soil by sheep flocks enhances soil fertility, creating favorable conditions for antlion larvae, which nest in the soil. This process can facilitate their proliferation.

4.3. Neuroptera fauna of the natural region of the Lesser Caucasus (LC)

The Lesser Caucasus region is categorized into several physical-geographical areas: Ganja, the Karabakh Mountains, the Karabakh Volcanic Plateau, and Hekari. Within this natural province, a total of 21 lacewing species have been identified, including *M.styriaca, M.perla, N.sinuata, D.variegata, L.macaronius kolyvanensis morpha typica, B.hamatus, P.libelluloides, M.solaris, M.trigrammus, C.plumbeus, D.irroratus, M.hyalinus hyalinus, M.formicarius, D.tetragrammicus, M.persicus var amoenus, E.nostras, E.parvus, N.microstenus microstenus, C.anomala, C.lineosa.* Among these 21 species, 20 (or 77%) are commonly found in mountain-steppe landscapes, while only 6 species (or 23%) are present in mountain-forest landscapes.

However, this list does not fully represent the Neuroptera fauna of the natural region. Over half of the Lesser Caucasus territory consists of newly liberated areas that are currently unsuitable for entomological research due to incomplete mine clearance. Consequently, only collection materials from before the occupation were available for analysis, and their limited quantity had minimal impact on the overall results. Information on the remaining regions was obtained through personal research. The areas still not fit for study primarily include mountain-forest and nival landscapes. Although nival landscapes are generally unfavorable for the Neuroptera groups under study, some species might be found in mountain forests. Additionally, the entomological collection at the Institute of Zoology includes the only known damaged specimen of N. sinuata, which was recorded in Zangilan before the occupation. Future research in these areas holds the potential for discovering additional ascalaph species.

4.4. Neuroptera fauna of the Lankaran natural region

20 of the 60 taxa of the studied Neuroptera families were recorded in the Lankaran natural region: *M.styriaca, M.perla, M.aphavexelte, L.ledereri, L. macaronius kolyvanensis morpha typica, P.libelluloides, M.solaris, M.trigrammus, A.occitanica, A.occitanica m.nigrilenta, C.plumbeus, C.remanei, M.hyalinus hyalinus, D.tetragrammicus, D.kabulensis, M.bilineatus, E.nostras, N.m.microstenus, M.flavicornis, A.uralensis curdica, C.lineosa.*

The majority of species (17 species, 38%) are associated with mountain xerophytic landscapes. The Lankaran natural region lies within a subtropical climate zone, where rain frequently falls for 10–15 days without interruption. This climate is unfavorable for the Neuroptera species under study. Additionally, landslides in the Talysh region are most common in the Yardymly depression. The marl-clay composition of the soil-forming rocks (from the Maikop period) and the thickness of the clay layer contribute to frequent, intense landslides along the slopes of nearly all rivers in the depression. These landslides create inhospitable conditions for ant lions, which rely on stable ground to construct their pitfall traps.

In the landscape structures of the Greater and Lesser Caucasus, semi-deserts, mountain steppes, mountain forests, mountain meadows, and nival landscape zones transition from lowlands to highlands. In contrast, the Talysh region exhibits a landscape inversion, where the lowland forest landscape gives way to a mountain xerophytic landscape. Under xerophytic desert conditions, a dry mountain steppe climate prevails, which is favorable for most species of the studied Neuroptera groups. L. ledereri, a species not found elsewhere in Azerbaijan, was discovered in the mountain xerophytic landscape near Gosmolyan village, Lerik district. This rare species is recommended for inclusion in the next edition of the Red Book of the Republic of Azerbaijan. Throughout our research, we recorded only three individuals of this species. An additional specimen was collected from the same area by A. Nekrasov on June 9, 1981, and is now part of the entomological collection at the Zoological Institute of the Russian Academy of Sciences (ZIN).

4.5. Middle Araz (Nakhchivan) (MA) natural region

The Middle Araz natural region is divided into the following physical-geographical areas: Gunnut-Kapychyk (Mountainous Nakhchivan) and Sharur-Ordubad. In terms of Neuroptera diversity, the Middle Araz region surpasses other natural regions. Of the 60 taxa recorded in Azerbaijan from the studied families, 40 have been identified in the Middle Araz region. *M.scabricollis, M.styriaca, M.perla, M. adelungi, M.aphavexelte, N.sinuata, N.coa, L.extensa, D.variegata, L. macaronius kolyvanensis morpha typical, P.libelluloides, P.turcicus, G.variegata, M.solaris, M.trigrammus, A.occitanica, C.plumbeus, C.remanei, P.gracilis, D.irroratus, D.i.iranensis, D.morgani, M.hyalinus hyalinus, S.ledereri, N.(Ganussa) tenellus, D.tetragrammicus, D.kabulensis, D.formosus, M.bilineatus, M.linearis, M.persica amoena, E.nostras, M.paulus, N.nemausiensis piryulini, N. Microstenus microstenus, M.flavicornis, A.uralensis jakushenkoi, A. uralensis curduca, N.armenicus.* Thus, 66.6% of the total taxa are found in the Middle Araz natural region, which is notable for its species diversity. Specifically, 3 out of 4 species from the Nemoptera family, considered the most ancient among the studied groups, are found in this region, with only 1 species identified in the Lankaran region. All 6 species of the Mantispidae family, 8 taxa from the Ascalaphidae family, and 40 out of 42 taxa from the Myrmeleontidae family were also recorded in the Middle Araz. No species were observed in the alpine and subalpine meadows of this region. Among the landscapes, the mountain xerophytic (20 species) and semi-desert (28 species) areas are richer in species than other landscapes.

By comparing the Neuroptera fauna across five natural regions in Azerbaijan, it becomes evident that some species are present in all regions, while others are restricted to specific areas. The following species are found in all natural regions: *M.styriaca, M.perla, P.libelluloides, M.solaris, M.trigrammus, A.occitanica, C.plumbeus, M.hyalinus hyalinus, D.tetragrammicus, E.nostras.* Yalnız Böyük Qafqaz TV-də qeydə aldığımız növlər: *L.hispanicus ustulatus, L.macaronius kolyvanensis morpha flavum levis., L.macaronius kolyvanensis morpha alba, N.zigan.* Yalnız Kür – Dağarası çökəklikdə qeydə alınan növlər: *L.m.turcestanicus və N.maculatus*. Yalnız Orta Araz (Naxçıvan) TV-də qeydə aldığımız növlər: *M.perla var. lobata, L.extensa, D.morgani, M.linearis, A.uralensis curdica*. No species are exclusive to the Lesser Caucasus. The species we observed in the Lesser Caucasus were also found in other natural regions. Among these regions, the Middle Araz is the richest in both species diversity (40) and the number of individuals. In contrast, the Lenkoran region had the fewest species recorded (19).

This is likely due to the climate of the Middle Araz, as the Neuroptera species studied prefer dry desert and semi-desert environments. The species count in the Lesser Caucasus was also similar to that of Lenkoran. This is likely because, in Karabakh, a part of the region recently liberated from occupation, conditions are not yet suitable for conducting modern entomological research.

4.6. Distribution of Neuroptera species in coastal biotopes of the Caspian Sea

Three of the five natural regions in Azerbaijan—the Greater Caucasus, the Kura intermountain depression, and Lankaran—are connected to the Caspian Sea. Only the Middle Araz and Lesser Caucasus lack a direct link to the sea. The Caspian coastal biotopes are particularly favorable for antlions, while mantispids and threadwings are rare in these areas. Of the 60 lacewing taxa recorded in Azerbaijan, 25 have been found in the Caspian coastal biotopes. Among these, 2 are owlflies, and 23 are antlions. *B.hamatus, B.andromache, P.libelluloides, N.nemausiensis piryulini, N.microstenus microstenus, N.(Gabussa) tenellus, M.bilineatus, M.paulus, C.plumbeus, C.remanei, M.hyalinus hyalinus, M.hyalinus distinguendus, E.nostras, E.parvus, S.ledereri, A.uralensis jakushenkoi, A.uralensis curdica, L.fedtschenkoi, C.anomala, M.trigrammus, M.solaris, N.armenicus, N.zigan, A.occitanica, A.occitanica morpha nigrilenta.*

Both owlflies commonly found along the seashore belong to the genus Bubopsis. These species are characteristic of eremial fauna and are widespread in desert, semi-desert, and sandy landscapes. A. occitanica is one of three large species (*P.libelluloides, P.turcicus, A.occitanica*) commonly found along the Caspian Sea coast and in Azerbaijan. It is a nocturnal species whose larvae do not create soil funnels. Zoogeographically, it is an ancient Mediterranean species. *N.zigan, N.armenicus, A.uralensis jakushenkoi, A.uralensis curdica,* and *L.fedtschenoi* inhabit the sandy biotopes along the immediate coastline of the Caspian Sea.

The ancestor of the ant species *C.plumbeus*, which is now widespread in Azerbaijan, particularly in semi-desert, xerophytic, and mountainous xerophytic areas, was once common along the shores of the Tethys Sea until aridification began in the Pliocene. As Caspian waters receded in the Pleistocene, the aridification process freed territories from water. The resulting increase in temperature and intensification of winds facilitated the spread of various lacewing species into arid regions and along the present-day shores of the Caspian Sea. The species within the studied Neuroptera families (excluding daytime ascalaphs) generally do not possess strong flying capabilities. Consequently, air currents, such as winds, significantly influence their distribution. The most powerful winds in the Caspian Sea's coastal region throughout the year are the northerly Khazri winds, which can reach speeds of 40-45 m/sec. Another notable wind is the gilavar, which originates from the south and is predominantly observed in the Absheron Peninsula. These wind types impact the composition of the coastal lacewing fauna.

Additionally, A.uralensis jakushennyi, a species of northern Turanian origin, inhabits the Caspian biotopes. Its southwestern distribution in the Caspian Sea ranges from the mouth of the Kuma River in Russia to Dagestan and extends to Siyazan. The species *A.uralensis curdica*, originating from the Iranian-Kur-Araz region, is separated from *A.uralensis jakushenkoi* along the Caucasian coast of the Caspian Sea.

L.fedtschenkoi, which has its origins in the Sahara-Gobi region, has a wide distribution range, spanning from Tunisia to Mongolia. This species is particularly abundant in the Volga region and north of the Caspian Sea. Its range along the Caspian coast extends through Dagestan to the Beshbarmagh region, which is included into the Siyazan district. We have recorded this species for the first time in Azerbaijan. Although it is common along the northern shores of the Caspian, *L.fedtschenkoi* is rare in Azerbaijan. Among the species found in the

Caspian coastal regions of Azerbaijan, *L.fedtschenkoi* inhabits zones closest to the sea. However, these areas must have dry sand dunes, with low humidity levels. Such biotopes are present within the species' distribution range. It is worth noting that the highest relative humidity on the western coast of the Caspian Sea is observed in the Khachmaz region (77-79%). Additionally, wastewater discharged onto the shores causes beach pollution and leads to the formation of reed beds, creating unfavorable conditions not only for *L.fedtschenkoi* but also for other species. The larvae of *E.nostras*, a species of Western Palaearctic nemoral origin with a broad distribution across Azerbaijan, are typically found on Salsola sp., Orchadenus sp., Artemisia sp., and other plant species that grow along sandy shorelines. The larvae are often located in the shaded areas beneath these plants. Adult individuals are not captured in entomological nets during daytime collection efforts but are attracted to light traps at night. During daylight hours, the adults tend to hide within the branches of shore-growing vegetation. This species is widespread across Azerbaijan, occurring not only along coastal regions but also in various natural habitats throughout the country. *E.nostras* larvae construct their traps in sheltered environments, such as the shaded areas beneath plants, under the overhangs of stones, and near the fences of human dwellings, rather than in open spaces.

According to V.Krivokhatsky, who revised the genus Euroleon, the common ancestor of *E.nostras* and another species from the genus, *E.parvus*, was distributed along the northern coast of the diminishing Tethys Sea during the Miocene epoch[7]. Several species observed in the biotopes along the Azerbaijani coast of the Caspian Sea migrated into Azerbaijan from the northern shores of the Caspian. Their range extended through Dagestan, reaching Shabran, Siyazan, and Absheron. In an analysis of the Caspian antlion fauna, it was found that the dominant group consists of three species: N*.zigan*, *M.hyalinus*, and *P.libelluloides*. Among these, *M.hyalinus* is considered the dominant species, with *N.zigan* as the subdominant. *P.libelluloides* ranks third in

[7] Krivokhatsky, V.A. Antlions (Neuroptera, Myrmeleontidae) along the North Caspian shore; distributional analysis and zoogeographical division of Caspian coast of Russia. / V.A.Krivokhatsky, I.G.Kerimova, V.V.Anikin, [et al.] // Biodiversitas, - 2020. 21(1), - p. 258–281.

terms of frequency of occurrence. This species distribution pattern applies broadly to the entire coastal zone of the Caspian Sea.

4.7. Vertical distribution of Neuroptera species in Azerbaijan

With the exception of a few species, the majority of the studied lacewing families are predominantly xerophilous, thriving mainly in xerophytic and mountain-xerophilous landscapes throughout the country. This trend is also reflected in the analysis of the vertical distribution of the group. The lowest recorded elevation for Mantispidae species is 14 meters above sea level, while the highest reaches 2,109 meters. The highest point of distribution was recorded at the Aghdara Observatory, located approximately 10 km north of Tivi village in the Ordubad district of the Nakhchivan Autonomous Republic. Species within this genus show a preference for xerophytic habitats.

Representatives of the genus Libelloides prefer more humid environments. At sea level (0 m), two subspecies of this genus are commonly found: *L.macaronius kolyvanensis* and *L.macaronius turkestanicus*. However, it is important to note that these are historical records from the collection of the Zoological Institute of the Russian Academy of Sciences (REA ZIN), with specimens collected on the Kura-Araz plain between 1886 and 1933. In our recent surveys, we did not encounter Libelloides in these areas, likely due to the ongoing rapid aridification affecting the region. We observed representatives of the genus at elevations ranging from 300 to 2,500 meters. These species are diurnal, exhibiting an active lifestyle during the day and favoring sun-exposed slopes. Additionally, Bubopsis species are found at elevations between 0 and 500 meters above sea level.

D.variegata, the sole species of the genus Deleproctophylla found in Azerbaijan, exhibits the widest altitudinal range, occurring from sea level (0 m) to elevations of 2,400 meters. Species from both genera are crepuscular, becoming active at dusk, and show a preference for xerophytic and mountainous xerophytic landscapes.

Two species from the subfamily Palparinae of the family Myrmeleontidae (*P.libelluloides* and *P. turcicus*), one species from the subfamily Dendroleontinae (*D.pantherinus*), and 18 species from the subfamily Nemoleontinae (*D.formosus, D.kabulensis, D.tetragrammicus, N.nemausiensis, N.microstenus microstenus, M.linearis, M.perla var. paulus, D.irroratus, D.irroratus iranensis*) were studied, showing that among these species, the widest altitudinal range (0–2500 m) belongs to *C.plumbeus*. The second species with a similarly wide range is *P.libelluloides* (0–2300 m). Eight species (*D.formosus, M.linearis, M.persicus, M.persicus var. amoenus, N.poecilopterus, P.gracilis, D.irroratus iranensis, D.morgani*) exhibit a very narrow altitudinal range, having been recorded at only a single location, predominantly in the Nakhchivan region. An analysis of the vertical distribution of 16 species from the subfamilies Glenurinae, Myrmecaelurinae, and Acanthaclisinae of the family Myrmeleontidae revealed that *M.trigrammus* and *M.solaris* have a broad altitudinal range (0–2400 m), while six species (*M.formicarius, M.hyalinus distinguendus, M.inconspicuus, L.fedtschenkoi, N.zigan, A.occitanica morpha nigrilenta*) are restricted to a narrower range of altitudes.

Among the sixteen species studied, only two (*M.formicarius* and *A.uralensis curduca*) have altitude ranges that do not include 0 m. *M.formicarius* is found at elevations of 1400–1500 meters, while *A.uralensis curduca* occurs between 700 and 1500 meters. Analysis of the vertical distribution of four species from the family *Nemopteridae* indicates that *N.sinuata* has the broadest altitudinal range (466–1963 meters), followed by *L.extensa* (798–1598 meters). *N. coa* and *L. ledereri* were recorded at only a single altitude point. While there is literary evidence of *N. coa* in Azerbaijan[8], we could not verify this with physical specimens. It is believed to inhabit the Zangezur and Zangilan regions. We observed *L.ledereri* only in the village of Gosmolyan in Lerik, at an altitude of 14,270 meters above sea level.

The genus *Lertha* from this family is typically found in arid environments, xerophytic and mountain-xerophytic meadows, whereas *Nemoptera* species are found in forests, open meadows, and near river valleys.

[8] Кожанчиков И.В. Сетчатокрылые – Neuroptera. // В кн. Животный мир СССР . т.V. Горные области Европейской части СССР. Изд.Академии Наук СССР. Москва, - 1958. - 655 с.

4.8. Rare Neuroptera species in Azerbaijan

All genera within the Neuroptera order studied exhibit a mix of both common and rare species. Specifically, the Red Book of the Republic of Azerbaijan includes two species from the Mantispidae family (*M. styriaca* and *M. aphavexelte*), two species from the Ascalaphidae family (*B.hamatus*, and *D.variegata*), four species from the Myrmeleontidae family (*P.turcicus*, *N.(Ganussa) tenellus*, *D.pantherinus*, and *P.gracilis*), and two species from the Nemopteridae family (*N.sinuata* and *L.extensa*). Additionally, *L.ledereri* is recommended for inclusion in the next edition of the Red Book.

According to the IUCN categories and criteria, the national conservation status of *L.ledereri* is classified as Data Deficient (DD). The global distribution of the species indicates an Extent of Occurrence (EOO) of 238,672.395 km² and an Area of Occupancy (AOO) estimated at 16,000 km². In Azerbaijan, *L.ledereri* is found only in the village of Gosmolan, located at an elevation of 1300 meters above sea level in the Lerik region. Only four individuals have been recorded in this area: one by A.V.Nekrasov in 1981, three (one in 2017, and two in 2023) by us. The EOO in the Azerbaijan territory is 4 km², with the AOO also estimated at 4 km².

The reasons for the recommendation to include *L.ledereri* in the Red Book are explained by the fact that the range of *L.ledereri* in Azerbaijan is very small. As mentioned above, the real range (AOO) of the species fully corresponds to the boundaries of the potential range (EOO). The population is small. Only 4 individuals have been registered so far. The time difference between the initial registration and subsequent registrations is very large. The habitats of the species are highly susceptible to anthropogenic impact. This is expressed in the conversion of residential areas into pastures, their use for agricultural purposes, or the conversion of these areas into settlements.

The study of rare species of threadwings is important not only in terms of understanding biological diversity, but also for developing strategies for their conservation. Conservation of these rare insects will serve to maintain the ecological balance and preserve them for future generations.

CHAPTER V. ZOOGEOGRAPHICAL ANALYSIS OF THE NEUROPTERA (MANTISPIDAE LEACH, 1815 ASCALAPHIDAE RAMBUR, 1842, MYRMELEONTIDAE LATREILLE, 1802 AND NEMOPTERIDAE BURMEISTER, 1849)

According to F.A. Yemelyanov's classification, the Republic of Azerbaijan falls within the Sahara-Gobi region of the Palearctic. A.F.Yemelyanov and V.A.Krivokhatsky identify several zoogeographic provinces in Azerbaijan: Samur-Absheron, Kur-Araz, Talysh-Lenkoran, and Ordubad-Nakhchivan. An overview of the Neuroptera fauna in Azerbaijan reveals that it is primarily composed of species that have migrated from the Mediterranean, Iran, and Turan regions. There are no endemic species identified within the fauna. However, *P.turcicus*, of Kur-Araz-Anatolian origin, might be considered subendemic. This species is found exclusively in the mountain steppes of the Ordubad region in Nakhchivan[9].

1. European Nemoral Region: Among the studied Neuroptera families in Azerbaijan, only three species are associated with the European Nemoral Region. However, these species are not exclusively confined to this province. For instance, *D.tetragrammicus* is of Euro-Mediterranean-Saharan-Gobi origin and is distributed across all zoogeographic provinces in Azerbaijan. *M.inconspicuus* is a nemoral-steppe species of Euro-Kazakhstan origin, found specifically in the Samur-Absheron zoogeographic province. *N.microstenus microstenus* is a Euro-Caucasian subspecies of a Mediterranean species, occurring in the Samur-Absheron and Ordubad-Nakhchivan zoogeographic provinces.

2. The Hesperic (Mediterranean-Macaronesian) subtropical region in the fauna of Azerbaijan is represented by two subregions: the Mediterranean and the Eastern Mediterranean. A total of 16 species are of Hesperic origin. Of these, 12 species (*M.aphavexelte, M.scabricollis, M.styriaca, N.sinuata, N.coa, L.macaronius turcestanicus,*

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[9] Керимова, И.Г., Кривохатский, В.А. Современный состав фауны муравьиных львов (Neuroptera: Myrmeleontidae) Азербайджана // Кавказский энтомологический бюллетень. – 2018, 14 (1), – с. 55–66.

P.libelluloides, N.(Ganussa) tenellus, C.plumbeus, M.flavicornis, D.irroratus, S.ledereri) are from the Eastern Mediterranean subregion, while 4 species (*L.hispanicus ustulatus, D.pantherinus, C.remanei, N.maculatus*) belong to the Mediterranean subregion.

3. The Plain Scythian region is represented by four Neuroptera species in the fauna of Azerbaijan: *M.trigrammus, N.zigan, A.uralensis jakushenkoi, L.macaronius kolyvanensis morpha typica, L.macaronius kolyvanensis morpha alba, L.macaronius kolyvanensis morpha flavum levis*. Among these, *A.uralensis jakushenkoi* is a Kazakh-North Turanian species, while *N.zigan* is classified as a South Scythian-North Turanian species. These species are predominantly found in the Samur-Absheron zoogeographic province. However, *M.trigrammus* and *L.macaronius kolyvanensis morpha typica* also occur in other provinces.

4. The Sahara-Gobi desert region is represented by 17 species in the fauna, including *B.andromache, B.hamatus, P.turcicus, C.anomala, D.kabulensis, D.formosus, M. persicus amoena, M.solaris, D.irroratus iranensis, M.paulus, E.parvus, L.fedtschenkoi, P.gracilis, M.perla var. lobata, M.linearis, M.persicus, M.hyalinus distinguendus*. Among these: *B.andromache* and *B.hamatu*s are Eremial species found in the Samur-Absheron and Kur-Araz zoogeographic provinces. *P.turcicus* is specific to the Ordubad-Nakhchivan zoogeographic province. *C.anomala* is part of the Anatolian fauna in the Kur-Araz province of the Iran-Turan subprovince. *D.kabulensis, D.formosus, M.persicus amoena, M.solaris* belong to the Iran-Turan subprovince, with *D.kabulensis* and *D.formosus* limited to the Ordubad-Nakhchivan province, while *M.solaris* is also found in other provinces. *D.irroratus iranensis* is associated with the Iranian province of the Iran-Turan subprovince and is only found in the Ordubad-Nakhchivan province in Azerbaijan. *M.paulus* and *E.parvus* are of Turan-Gobi origin, with *M.paulus* occurring in the Kur-Araz and Ordubad-Nakhchivan provinces, and *E.parvus* found in the Samur-Absheron and Kur-Araz provinces. *L.fedtschenkoi* and *P.gracilis* are of Sahara-Gobi origin, with *L.fedtschenkoi* recorded exclusively in the Samur-Absheron province. *M.perla var. lobata* originates from Central Asia and is present in the

Ordubad-Nakhchivan and Kur-Araz provinces. *M.linearis* is of Kura-Araz-East Mediterranean origin, found in the Ordubad-Nakhchivan province, while *M.persicus* is of Kura-Araz-South Turan origin, distributed in the Kur-Araz province. *M.hyalinus distinguishuendus* is a widespread Saharan-Turanian species found in the Samur-Absheron and Kur-Araz provinces.

The Anatolian subregion is represented by the following species: *L.ledereri*, *L.extensa*, *D.variegata*, *N.armenicus* and *A.uralensis curdica*. Among these, the first three species are of Anatolian origin. *N.armenicus* is a Turanian-Anatolian species, while *A.uralensis curdica* is an Anatolian-Iranian subspecies. *L.ledereri* is found exclusively in the Talysh-Lankaran region.

Species from the ancient Mediterranean subregion include *G.variegata*, *N.poecilopterus*, and *A.occitanica*. Palaearctic fauna species are *M.adelungi*, *D.morgani*, *A.occitanica morpha nigrilenta*, *C.lineosa* and *E.nostras*-dır. Among these, *D.morgani* and *A.occitanica morpha nigrilenta* originate from the Southwest Palaearctic, while *C.lineosa* and *E.nostras* come from the West Palaearctic.

Additional species include *N.nemausiensis*, which is Piryulini-Euxine-Turanian; *M.bilineatus*, which is Nemoral-desert-Mediterranean-Black Sea; *M.hyalinus hyalinus*, which is North African-Arabian; and *M.formicarius*, which is a Transpalearctic-nemoral-boreal species.

Comparing the percentage similarity between natural regions using the Jaccar coefficient reveals a high degree of similarity in the Neuroptera fauna across these regions (Fig. 2). This high similarity can be attributed to the fact that the species within the studied Neuroptera families are predominantly distributed in arid regions. As previously discussed, arid landscapes constitute 58-60 percent of the country's terrain, whereas truly humid areas account for less than 5%.

The majority of the Neuroptera fauna in Azerbaijan originates from Mediterranean regions. Although some species are of Scythian origin, they have adapted to xerophytic-steppe and forest-steppe landscapes as a result of increased aridization, and have also populated semi-desert environments. For instance, *N.zigan* and *M.trigrammus* are examples of such species. *N.zigan* primarily remains in semi-desert areas, whereas *M.trigrammus* migrated from the West Scythian province to Azerbaijan's plains and subsequently spread across extensive territories, including mountain-xerophytic steppes (Nakhchivan) and forest-steppes (Greater Caucasus).

Another species, *M.solaris*, is of Iranian-Turanian origin and entered Azerbaijan from southern Iran and the Turan province via the northern shores of the Caspian Sea. It was first noted in Russia by A.Shelkovnikov in Dagestan in 1910 and was initially identified as *M.trigrammus*. The specimens collected by A.Shelkovnikov, including one male and one damaged individual, are housed in the National Museum of Georgia. These species are sympatric and frequently coexist in the same biotopes in Azerbaijan. The western boundary of their range extends to the eastern part of Turkiye (Van, Kars), the southern boundary reaches Iran, and the northern boundary includes Dagestan.

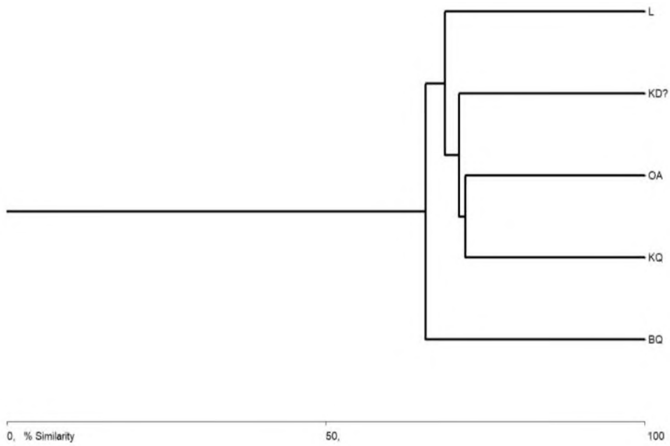

Figure 2. Coefficient of similarity between natural provinces (according to Jaccard)

The true Mediterranean species, from both the Western and Eastern Mediterranean regions, belong to the genera Palpares, Myrmeleon, Cueta, Delfimeus, Myrmecaelurus, Solter, Macronemurus, Creoleon, Distoleon, and Neuroleon. Among these, *M.formicarius* has extended its range into the border areas between the European nemoral region and the Mediterranean, and it is also prevalent in the cooler climatic regions of Azerbaijan. However, this species has not been recorded in semi-desert or xerophytic landscapes. Prior to our research, this antlion had been found in Goygol, but we also identified it in Gadabay.

L.macaronius kolyvanensis entered the mountain meadows of Azerbaijan from the Western Scythian Province, while *C.plumbeus* spread into the semi-desert and steppe regions. Mediterranean species such as *N.nemausiensis, A.occitanica, E.nostras, M.inconspicuus, D.tetragrammicus, M.flavicornis, G.variegata* and *M.bilineatus* are widely distributed across the European nemoral, Scythian desert, and Seto semi-desert provinces.

Among these, *A.occitanica, E.nostras, D.tetragrammicus,* and *P.libelluloides* are found in various landscapes across the country, as previously discussed. The remaining species are primarily associated with semi-desert, xerophytic, and mountain-xerophytic zones. In arid areas, northern semi-desert Seto species are also common, including *A.uralensis, L.fedtschenkoi, C.plumbeus, C.lineosa* and *M.paulus*. These species are detailed further in Chapter 6.

Environmental Factors Influencing Neuroptera Fauna. The larval development of species within the families Ascalaphidae and Myrmeleontidae is closely tied to soil habitats. Certain species of Myrmeleontidae construct conical traps in the soil to capture prey, while others employ a more cryptic hunting strategy by concealing themselves within soil particles, rocks, or vegetation. Neuroptera species generally prey on a variety of small invertebrates, ranging from minute mites to insects and lepidopteran larvae. There have even been instances where antlion larvae attempt to prey on scorpions. Essentially, any organism that inadvertently enters the larval trap becomes a potential food source for the larvae.

The Neuroptera fauna, similar to other organisms, is continuously influenced by various biotic and abiotic factors, with anthropogenic influences being particularly significant. As previously noted, soil plays a crucial role, either directly or indirectly, in the life cycle of Neuroptera species. This is especially apparent in antlions, which rely on soil for constructing their characteristic traps.

The rapid urbanization in Azerbaijan and the increasing use of natural landscapes for economic activities have significantly impacted biodiversity, leading to the acceleration of land aridization processes in various regions, particularly in the Kura-Araz lowland, the plains along the Araz River, and the Nakhchivan Autonomous Republic. In areas like Absheron and Gobustan, soil salinization, coupled with frequent wildfires in the Guba-Khachmaz region after vegetation dries, has directly affected the life cycles of the lacewing families under study. For instance, in the xerophytic steppes near the village of Sitalchay in the Khizi region, fires are common. These areas are home to two of Azerbaijan's largest antlion species, *D.variegata* and *P.libelluloides*. *D.variegata* lays its eggs on dry plant stems, while antlions deposit theirs in the soil. Fires destroy both eggs laid on the ground and dry plants with ascalaphid eggs. Moreover, adult *D.variegata* and antlions have limited flying ranges. Although *P.libelluloides* can cover longer distances, it does so in short bursts, frequently resting on plants. As a result, frequent wildfires also endanger adult lacewings.

As a result of increasing urbanization, natural landscapes are losing their original character, with natural vegetation being replaced by cultivated plants, and dry plains transformed into irrigated areas and vegetable gardens. This shift displaces antlions and ascalaphs, which once thrived in these areas, favoring dry, shallow soils. For instance, species like *M.hyalinus*, *P.libelluloides*, *M. rigrammus* and *M.solaris*, which are adapted to life in arid deserts, are no longer found in populated areas, gardens, or vegetable plots. Instead, species such as *N.nostras*, *D.tetragrammicus*, *A.occitanica* and *D.pantherinus* are more commonly found, as they build their trapping funnels or hunt without funnels in shadier environments.

Chemicals used to combat agricultural pests also lead to the death of larvae in soils located near agrocenoses.

Soil salinization has a significant impact on lacewings, particularly antlions. Adult females lay their eggs in the soil, and increased salinity creates unfavorable conditions for egg development. High salinity induces stress on the developing embryo within the egg. In such soils, the top layer dries and hardens, while water evaporation in the lower layer is slowed, leading to increased soil humidity and temperature. These conditions promote the growth of pathogenic fungi. Additionally, salinized soils suffer from poor aeration, making it difficult for the embryo to breathe.

In highly saline soils, the top layer becomes compacted and hardened, preventing antlion larvae from penetrating the surface and constructing their characteristic funnels. Consequently, antlion eggs may fail to hatch, or the larvae that do emerge often die from starvation. The excess moisture retained in saline soils further complicates funnel-building for antlion larvae, and for species that do not build traps, the increased soil hardness restricts their mobility.

Saline soils also hinder plant growth, forcing herbivores that rely on these plants to migrate elsewhere, indirectly reducing the food available for predatory lacewing larvae. Additionally, the destruction of plant cover leads to the loss of microhabitats for shade-dwelling spiders, further diminishing prey availability for lacewing larvae.

The overall increase in salinity disrupts the balance between plants, herbivores, natural enemies, and their interactions. Antlion larvae benefit from trapping their prey on dry, fine substrates, which not only create optimal feeding conditions but also protect them from entomopathogenic fungi. The lower susceptibility to pathogens in dry environments may explain the higher species diversity of antlions compared to other lacewings in arid regions.

Another threat to antlions is parasitoids, though parasitoid infestations in antlions are relatively rare. Several Diptera genera, including Micomitra Bowden, 1954, Oestranthrax Bezzi, 1923, Villa, Anthrax Scopoli, 1763, Pterobates Bezzi, 1921, Taiwanon Evenhuis, 2018, Chrysanthrax Osten-Sacken, 1886, Dipalta Osten-Sacken, 1877, and Paravilla (Diptera: Bombyliidae), have been documented as parasitoids of antlions.

Infestation of antlions *E.nostras, M.immanis, M.inconspicuus, M.trigrammus, D.tetragrammicus, M.bilineatus* and *C.plumbeus* by

Micomitra stupida, which is widespread in the Palearctic, including Azerbaijan, was noted by V.A. Krivokhatsky et al.[10].

One of the negative impacts of human activity on lacewings is linked to livestock farming. The 30-year occupation of Karabakh deprived livestock breeders of pastures for an extended period, leading to overgrazing in other parts of the country, which has placed additional pressure on these areas. Overgrazing results in the loss of natural habitats for lacewings and insects in general, as lacewings are predatory insects that rely on a stable food source. The destruction of plant cover due to overgrazing reduces the number of phytophagous insects, which serve as prey for lacewings.

Additionally, the movement of cattle across pastures can destroy lacewing funnels, causing the larvae to die. However, this movement can also have a positive effect on antlion species that build funnels. Overgrazing often leads to soil salinization, which creates a hardened surface layer. When cattle walk over this compacted soil, they help break it up and soften it, making it more suitable for antlions to construct their traps.

CHAPTER VI. PHYLOGENETIC ANALYSIS OF NEUROPTERA

For the first time, DNA barcoding of the mitochondrial CO1 gene was conducted for 56 taxa of the order Neuroptera in Azerbaijan. The nucleotide sequences have been uploaded to NCBI GenBank, resulting in 62 accession numbers. This achievement establishes a foundation for future molecular genetic studies of Neuroptera in Azerbaijan and represents a significant step toward advancing research in this field.

6.1. DNT barcoding

DNA analysis has emerged as a crucial tool for studying and conserving lacewing biodiversity, offering insights into taxonomy, phylogeny, genetic diversity, and population structure.

[10] Nartshuk, E.P., Krivokhatsky, V.A., Evenhuis, N.L. First record of a bee fly (Diptera: Bombyliidae) parasitic on antlions (Myrmeleontidae) in Russia // Russian Entomological Journal, - 2019. 28(2). - p. 189 - 191.

In contemporary biological taxonomic studies, DNA barcoding addresses challenges related to precise species identification. Since its introduction by Hebert et al., DNA barcoding has become a widely adopted global method for standardizing the identification of unknown specimens at the species level[11]. In recent years, mitochondrial DNA-based species identification methods have become a viable alternative to traditional morphology-based approaches. Given this advancement, we have performed DNA barcoding on lacewings recorded in Azerbaijan, establishing the foundation for a barcode library of Neuroptera in the region.

The DNA barcode region comprises a 658 bp segment of the COI-5' gene. DNA barcoding enables species identification with a precision of 2% and is widely recognized within the scientific community for its effectiveness in species discrimination.

Over the past 25 years, phylogenetic studies of the three orders within Neuropterida (Raphidioptera, Megaloptera, and Neuroptera) have significantly reshaped our understanding of their evolutionary history. Phylogenetic estimates have diverged due to varied data sources and complex analyses, ranging from adult and larval morphology to comprehensive mitochondrial DNA studies. These insights, combined with data from excavated specimens, have contributed to a revised scientific perspective on the historical evolution and classification of lacewings[12].

Recent advances in DNA sequencing technology have significantly advanced our understanding of insect phylogeny. However, certain parts of the phylogenetic tree of Holometabolans remain unresolved. While the phylogeny of the superorder Neuropterida has been studied in considerable detail, there is still no clear consensus on the phylogenetic relationships within the order Neuroptera.

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[11] Pentinsaari M. DNA barcodes reveal 63 overlooked species of Canadian beetles (Insecta, Coleoptera) / M.Pentinsaari, R.Anderson, L.Borowiec[et al.] // ZooKeys, - 2019. 894, - p. 53-150.

[12] Engel, M.S., Winterton, S.L., Breitkreuz, L.C.V. Phylogeny and evolution of Neuropterida: where have wings of lace taken us? // Annual Review of Entomology, - 2018. 63, -p. 531–551.

The monophyly of the family Nemopteridae was previously questioned, but it was later confirmed by A. Vasilikopoulos et al., who demonstrated that Nemopteridae is indeed monophyletic and related to the clade Ascalaphidae + monophyletic Myrmeleontidae. These findings are consistent with recent cladistic studies on Myrmeleontiformia based on larval analysis. However, a prior phylogenomic analysis of ascalaphids and antlions suggested that Myrmeleontidae were polyphyletic in relation to Ascalaphidae. Based on this, the authors proposed that Ascalaphidae should be included as a subfamily within Myrmeleontidae.

Vasilikopoulos et al. maintain that Ascalaphidae should retain its status as a distinct family, citing differences in larval behavior: while antlions include both trap-setting and free-hunting larvae, Ascalaphidae typically lack trap-setting larvae. The monophyly of Myrmeleontidae is supported by the trap-building abilities of some larvae and the associated behavioral traits.[13]

The monophyletic origin of the families Myrmeleontidae and Ascalaphidae was also confirmed in our molecular genetic studies. The distinction between these two groups is further illustrated by the phylogenetic tree (Fig. 2).

6.2. Description of the phylogenetic tree

First of all, it should be noted that when constructing the phylogenetic tree of lacewing species based on DNA analysis, it was necessary to divide the tree into several parts to facilitate explanation. This was done because the large number of species created overcrowding between the branches (Fig. 3, 4).

[13] Vasilikopoulos, A. An integrative phylogenomic approach to elucidate the evolutionary history and divergence times of Neuropterida (Insecta: holometabola). / A.Vasilikopoulos, Misof, B., Meusemann, K., [et al.] // BMC Evolutionary Biology, - 2020. 20, - p. 1-24.

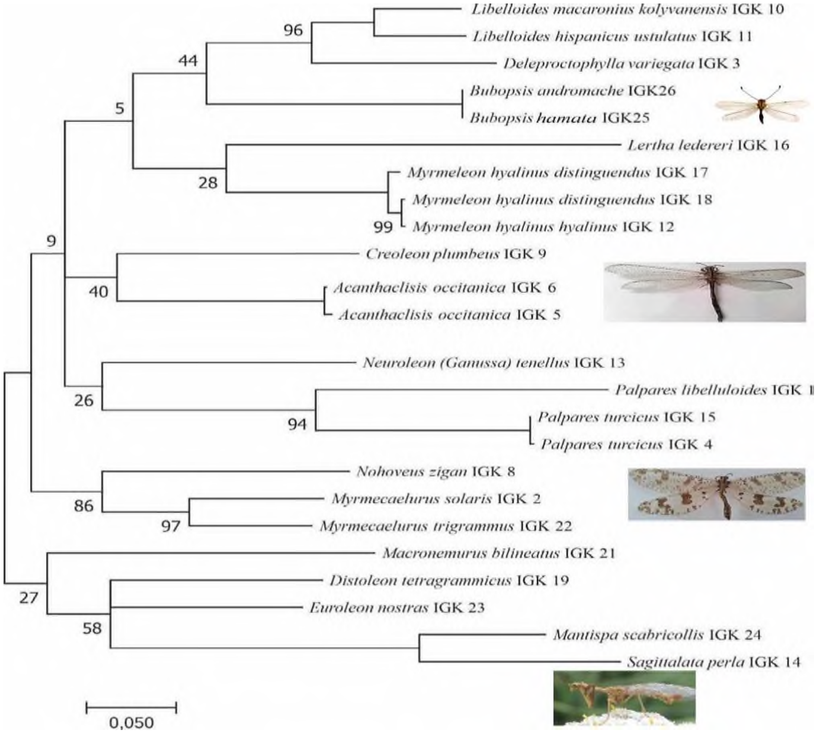

Figure 3. Phylogenetic tree (ML) showing the differences between Myrmeleontidae and Ascalaphidae.

As shown in the figure, the upper branches of the phylogenetic tree have stronger support than the base. All Azerbaijani lacewing specimens are grouped into duplicate clusters. The three alignments obtained for *M.hyalinus* specimens and presented in the ML tree belong to the same species. The genetic difference between the subspecies and their closest relatives is only 5% (0.05). In the phylogenetic tree, the difference between the three sequences does not exceed two percent, and the difference between the dark-colored distinguendus and the light-colored hyalinus is less than one percent. The same result is observed in the NJ tree. The subspecific relationship between *M.hyalinus hyalinus* and *M.hyalinus distinguendus* was established by Hölzel. However, we discussed the geographic subspecies and mixed populations in sympatric zones based on their morphological characteristics, and these findings were confirmed by the genetic results.

In both dendrograms, the close interpopulation relationship between individuals (alignments IGK12 and IGK18) is more clearly expressed than the subspecific relationship. This indicates that the composition of the populations is not uniform.

In the phylogenetic tree, Palpares sp. (IGK 15) is grouped with the unidentified species *P.turcicus*. Both species included in the P. libelluloides species group (*P.libelluloides* and *P.turcicus*) are supported by high percentages, both morphologically and genetically. The value of the node (94) further demonstrates the high reliability of the clustering.

Immature specimens of *P.libelluloides* and *P.turcicus*, which display a temporarily yellow wing background due to residual hemolymph, have similar brown, ring-shaped spots on the last segments of the gills. Another characteristic feature of *P.libelluloides* is the presence of small spots at the fork of the elbow vein in the hind wings. In contrast, the brown spots in *P.turcicus* are larger. Molecular genetic analysis of similar specimens indicated that the species in question (IGK15) belongs to *P.turcicus*. Mitochondrial DNA from both species was analyzed, and the nucleotide sequence obtained by barcoding the CO1 gene was uploaded to NCBI GenBank, where accession numbers were assigned (Table 1).

M.solaris (IGK2) and *M.trigrammus* (IGK22) were included in the cluster with a confidence level of 97% in the ML tree. The difference between them is no more than 10%. The same result was obtained in the NJ tree. In Azerbaijan, these two light yellow species coexist along the shores of the Caspian Sea. In the second dendrogram, which includes *M.major* from GenBank, it is clear that *M.solaris* and *M.major* are more closely related to each other, while the smaller *M.trigrammus* is located at a considerable distance from these two larger species.

As shown in the NJ tree, the genus Myrmecaelurus is supported by 97-100% (with three species: *M.major*, *M.solaris*, and *M.trigrammus*) and is related to another closely related genus, Nohoveus (with the Azerbaijani population *N.zigan* and the Chinese population *N.artifrons* taken from GenBank). In the latest catalog of the world's Myrmeleontidae fauna, these two genera are considered synonymous; however, we regard each as a separate genus within the tribe Myrmecaelurini, which is supported by the distinct morphology of the male genitalia.

As shown in the ML tree, *B.hamatus* and *B.andromache* are identical. The genetic evidence compels us to synonymize these two names: *Ascalaphus hamatus* Klug, 1834 = *B.andromache, syn. n.* However, the two types of nomenclature correspond to the existence of a discrete subspecific rank within the species. We propose that sympatric morphological forms of the only East Mediterranean-Iranian-Arabian species exist in nature and belong to intrasubspecific morphs. Thus, the species B. hamatus includes the morphs *B.hamatus morpha typica* and *B.hamatus morpha andromache*, which occur geographically simultaneously and are genetically indistinguishable by the COI barcode method.

In the phylogenetic tree, the genus Bubopsis, belonging to the subfamily Ascalaphinae, is closely related to the species *D.variegata*. This observation highlights a characteristic branching point of the genus Libelloidin (Pantaleoni) and Libelloides (Schäffer, 1763). Thus, Libelloidini is a sister tribe to the subfamily Ascalaphinae.

It is important to note that although the support between the clades *L.macaronius kolyvanensis*, *L.hispanicus ustulatus*, and *D.variegata* and the clade *B.hamatus* - *B.andromache* is not very high (44), it does allow us to group the traditional family Ascalaphidae into a single cluster.

Figures 3 and 4 show that the families Ascalaphidae and Myrmeleontidae are positioned in separate clusters. Therefore, our studies do not support the proposal to unite the families Myrmeleontidae and Ascalaphidae.

As a result of our DNA analysis, we can address several other controversial issues related to the species belonging to the studied families within the order Neuroptera.

In the cladogram in the Fig. 5 two closely related species of threadwings, *N.coa* and *N.sinuata*, are positioned on adjacent branches, indicating that they share a common ancestor. Although the two species exhibit very similar morphological features, their placement on separate branches-particularly the length of those branches-suggests that they are genetically quite different. The positioning of these species in the cladogram indicates that *N.coa* is on a branch that diverged earlier than the branch leading to the subclade of *N.sinuata*. The fact that the two species are on different branches confirms that they are distinct species.

L.ledereri was located in a completely intermediate branch of the genus Nemoptera and even merged into the cluster of the genus Myrmeleon. This is likely an artifact, as the separation of Nemopteroidae from Myrmeleontidae in the phylogenetic tree was demonstrated with 100% certainty by the presence of three species of filamentous flies.

It is important to note that complex discussions regarding the relationships between the taxa Ascalaphidae and Myrmeleontidae are ongoing.

The inclusion of Nemopteridae in Myrmeleontoidea has been controversial for a long time. This issue has been presented from different perspectives in various studies. Some authors suggest that Nemopteridae is related to Ascalaphidae and Myrmeleontidae, while others propose a closer relationship between Nemopteridae and Psychopsidae. However, recent molecular genetic analyses have provided the most accurate evidence for phylogeny. Such evidence allows us to reach a final consensus on this matter. Thus, molecular genetic results support the relationship of Nemopteridae with Ascalaphidae and Myrmeleontidae. Recently, a clade formed by several extinct families, including Nemopteridae, Ascalaphidae, and Myrmeleontidae, was proposed by Makarkin et al.[14]

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[14] Makarkin, V.N., Wedmann, S., Heads, S.W. A systematic reappraisal of Araripeneuridae (Neuroptera: Myrmeleontoidea), with description of new species from the lower cretaceous Crato formation of Brazil // Cretaceous Research, - London: - 2018. 84, - p. 600–621.

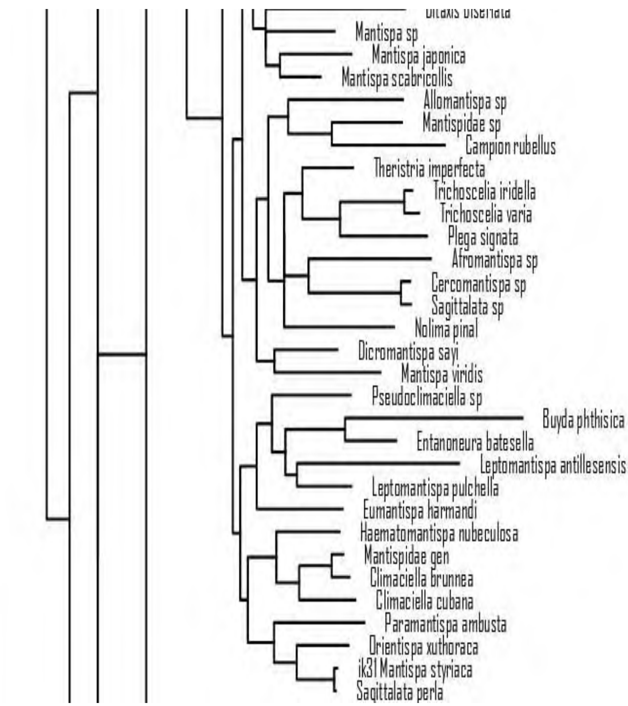

Figure 4. Mantispidae fragment of the phylogenetic tree

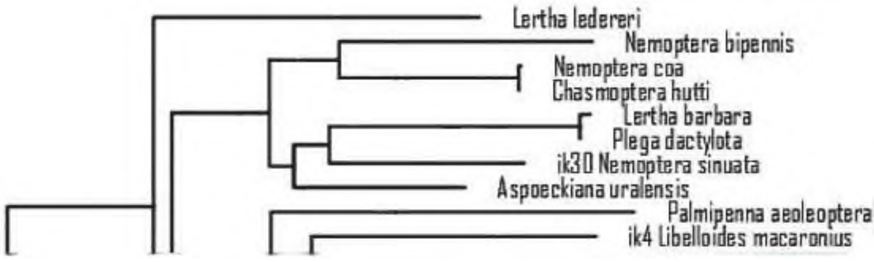

Figure 5. Nemopteridae fragment of the phylogenetic tree

As a result of the DNA analysis, 62 nucleotide sequences were uploaded to the NCBI GenBank. Of these, 3 belong to Mantispidae, 11 to Ascalaphidae, 46 to Myrmeleontidae, and 2 to Nemopteridae.

The analyzed species include those from Turkey, Kazakhstan, Russia, and Kyrgyzstan.

Table 1.

List of species subjected to DNA analysis

Taxons	**GenBank Accession Number**
Mantispidae	
Mantispa perla (Pallas, 1772)	MT621175
Mantispa scabricollis McLachlan, 1875	MT621189
Mantispa styriaca (Poda, 1761)	OR591051
Ascalaphidae	
Deleproctophylla variegata (Klug, 1845)	MT621185
Libelloides hispanicus ustulatus (Eversmann, 1850)	MT621173
L. macaronius kolyvanensis (Laxmann,1842)	MT621183
L.m.kolyvanensis morpha flavum levis. (imaqo)	OR591048
L.m.kolyvanensis_flavum levis. (sürfə)	OR606550
L.m.kolyvanensis morpha alba (imaqo)	OR591049
Bubopsis hamata (Klug, 1834)	MT621192
Bubopsis andromache Aspöck U., Aspöck H., Hölzel, 1979	MT621184
L.m.kolyvanensis morpha typica (Laxmann, 1770) (larva)	OR591030 OR591031
Idricerus sogdianus McLachlan in Fedchenko, 1875	OR591038
Myrmeleontidae	
Palpares libelluloides (Linnaeus, 1764)	MT621181
Palpares turcicus Koçak, 1976	MT621190
Lopezus fedtschenkoi (McLachlan, 1875)	OR606548 OR606549
Lopezus nanus Krivokhatsky 1990	OR606551
Myrmecaelurus solaris Krivokhatsky, 2002	MT621178
Myrmecaelurus trigrammus (Pallas, 1781) imago	MT621179
Myrmecaelurus trigrammus (Pallas, 1781) sürfə	OR591028
Acanthaclisis occitanica (Villers, 1789)	MT621180 MT621193 MT621182
Nohoveus zigan (Aspöck, Aspöck et Hölzel, 1980)	MT621186
Creoleon plumbeus (Olivier, 1811)	MT621187
Creoleon remanei Hölzel, 1972	OR606552
Myrmeleon hyalinus hyalinus Olivier, 1811	MT621174

Continuation of table 1

M.hyalinus distinguendus Rambur, 1842	MT621176
Neuroleon (*Ganussa*) *tenellus* (Klug, 1834)	MT621170
Distoleon tetragrammicus (Fabricius, 1798)	MT621188
Macronemurus bilineatus Brauer, 1868	MT621194
Euroleon nostras (Geoffroy in Fourcroy, 1785)	MT621191
	OR591033
E.coreanus Okamoto, 1924	OR591043
E.parvus Hölzel, 1972	OR591045
Myrmeleon formicarius Linnaeus, 1767 sürfə	OR591029
M.formicarius Linnaeus, 1767	OR591040
M.inconspicuus Rambur, 1842	OR591036
Macronemurus persicus var. graciosa Krivokhatsky, Dobosz et Khabiev, 2015	OR591032
Mesonemurus paulus (McLachlan, 1875)	OR591034
Cueta plexiformia Krivokhatsky, 1996	OR591035
Neuroleon nemausiensis nemausiensis (Borkhausen, 1791)	OR606553 OR606554
Neuroleon nemausiensis nigriventris (Navás, 1913)	OR591037
Neuroleon nemausiensis piryulini Krivokhatsky, 2011	OR591060
Mesonemurus guentheri olgae Krivokhatsky, 2011 (dry)	OR591039
Mesonemurus quenteri olgae Krivokhatsky, 2011 (etanolda)	OR591058
Deutoleon lineatus (Fabricius, 1798)	OR591041
Acanthaclisis curvispura Krivokhatsky 1990	OR591042
Myrmecaelurus major McLachlan, 1875	OR591044
Distonemurus desertus Krivokhatsky, 1992	OR591046
Megistopus flavicornis (Rossi, 1790)	OR591047
Macronemurus persica var. persica (Navás, 1915)	OR591055
M. persica amoena Navás, 1915	OR591056
Holzezus compactus Krivokhatsky, 1992	OR591057
Subgulina talitzkii (Luppova, 1979)	OR591059
Aspoeckiana uralensis jakushenkoi Zakharenko, 1983	OR591061
A.uralensis uralensis (Hölzel, 1969)	OR591062
Nemopteridae	
Lertha ledereri (Sélys-Longchamps, 1866)	MT621172
Nemoptera sinuata Olivier, 1811	OR591050

The obtained results provide a foundation for the creation of a DNA barcode library for the Azerbaijani Neuroptera order. These results will contribute to future molecular genetic studies of Neuroptera species.

RECOMMENDATIONS

1. Since net-wings are predators, they can be used in the biological control of agricultural pests, with antlions being especially effective in this regard. Although it is impossible to artificially reproduce them for release into fields, they can be attracted to agrocenoses in nature. To achieve this, several measures must be taken: Creating favorable habitat conditions: Antlions build their traps in sandy and soft soils. Establishing such conditions near agrocenoses can attract antlions to fields. Reducing the use of chemical pesticides and employing biological control agents will help preserve natural predators like antlions and enhance their role in agrocenoses. Maintaining small areas of natural vegetation within agrocenoses is beneficial for attracting antlions, as these areas draw in small insects that serve as prey. Placing wood chips or stones near agrocenoses can create hiding conditions for antlion larvae that do not construct traps.

2. Among the studied lacewings, there are many small and rare species. Their conservation is beneficial for both biodiversity preservation and ecotourism. The most important issue in protecting rare lacewing species is preserving their habitats from overgrazing, grass cutting, accidental fires, urbanization, agricultural use, and various forms of pollution.

RESULTS

1. For the first time in Azerbaijan, the families Mantispidae, Ascalaphidae, Nemopteridae, and Myrmeleontidae, belonging to the order Neuroptera, have been studied. Six taxa of Mantispidae fauna (five species and one variation), eight taxa of Ascalaphidae fauna (three species, three subspecies, and two morphs), four species of Nemopteridae, and 42 taxa of Myrmeleontidae (33 species, eight subspecies, and one morph) were discovered. [2; 3; 7;14].

2. 11 new species (*Mesonemurus paulus* (McLachlan, 1875), *Macronemurus linearis* (Klug, 1834), *Solter ledereri* Navás, 1912, *Lopezus fedtschenkoi* (McLachlan, 1875), *Myrmecaelurus solaris* Krivokhatsky, 2002, *Nohoveus armenicus* (Krivokhatsky, 1993), *Creoleon remanei* Hölzel, 1972, *Cueta anomala* Navas, 1915, *Distoleon kabulensis* Hölzel, 1972, *Distoleon formosus* Hölzel, 1972, and *Delfimeus morgani* (Navás, 1913)) 3 new subspecies (*Neuroleon nemausiensis piryulini* Krivokhatsky, 2011, *Aspoeckiana uralensis jakushenkoi* (Zakharenko, 1983) and *Aspoeckiana uralensis curdica* Hölzel, 1972 of the Neuroptera fauna were recorded for the Azerbaijan [2; 17].

3. From the family Myrmeleontidae, the 2nd instar larva of *Euroleon parvus* Hölzel, 1972 and the 3rd instar larva of *Pseudoformicaleo gracilis* (Klug, 1834) were described for the first time[11].

4. New sinonim names for some species of Myrmeleontidae and Nemopteridae families were revealed. Myrmeleontidae: *Nesoleon ulianini* – Esben-Petersen, 1913 nec McLaclan, 1875 = *Myrmeleon lineosus* Rambur, 1842 б syn. nov., and Cueta anomala Navás, 1915 =*Myrmeleon grammaticus* Navás, 1912; syn. nov.; Nemopteridae: *Lertha palmonii* Tjeder, 1970: 219 = *Nemoptera extensa* Olivier, 1811(resently *Olivierina extensa* (Olivier, 1811)) syn. nov. [19]

5. The systematic composition of the Mantispidae, Ascalaphidae, Nemopteridae, and Myrmeleontidae families within Azerbaijan's Neuroptera has been identified according to the most recent systematic classification. The fauna of Mantispidae, Ascalaphidae, Nemopteridae and Myrmeleontidae of natural regions was studied and it was found that the Natural Region of the Greater Caucasus is represented by 39 species, the Lesser Caucasus - 21 species, Lankaran - 20 species, the Middle Araz - 40 species, the Kura Intermountain Depression - 31 species [2; 3; 16; 17; 25].

6. A zoogeographical analysis of the families Mantispidae, Ascalaphidae, Nemopteridae, and Myrmeleontidae in Azerbaijan is presented for the first time, demonstrating that the lacewing fauna primarily developed through species migration from the Mediterranean, Iranian, and Turanian zoogeographic regions. This fauna includes 16

species from the Hesperian group, 3 from the European nemoral group, 4 from the Scythian group, and 17 from the Setian group. The study explains the processes shaping the lacewing fauna and highlights the negative impacts affecting it, such as urbanization, aridization, soil salinization, overgrazing, wildfires, and pesticide use [2; 3; 25].

7. The nucleotide sequences of the mitochondrial cytochrome c oxidase I (COI) gene from species belonging to the families Mantispidae, Ascalaphidae, Nemopteridae, and Myrmeleontidae in Azerbaijan have been identified and submitted to GenBank. For the first time, the COI gene sequences of 18 species have been added to GenBank [18; 25].

8. Phylogenetic analysis of the families Mantispidae, Ascalaphidae, Nemopteridae, and Myrmeleontidae in Azerbaijan was conducted, and the status of the families Myrmeleontidae and Ascalaphidae was confirmed through molecular genetic analysis [25].

9. The species identity of *Palpares libelluloides* and *Palpares turcicus* from the genus *Palpares* (*Myrmeleontidae*) was genetically confirmed. Additionally, the identity of *Bubopsis hamatus* (Klug, 1834) and *Bubopsis andromache* (Aspöck U., Aspöck H., Hölzel, 1979) from the family *Ascalaphidae* was verified through COI gene analysis of mitochondrial DNA [18; 25].

10. Genetic analysis confirmed the species status of *Nemoptera coa* (Linnaeus, 1758) and *Nemoptera sinuata* Olivier, 1811, which are similar in morphological characteristics, and established that the first species diverged earlier than the second [18].

11. Two species from the Mantispidae family (*Mantispa styriaca* (Poda, 1761), *Mantispa aphavexelte* U. Aspöck, H. Aspöck, 1994), 2 species from the Ascalaphidae family (*Bubopsis hamatus* (Klug, 1834), *Deleproctophylla variegata* (Klug, 38)), 4 species from the Myrmeleontidae family (*Palpares turcicus* Koçak, 1976, *Neuroleon (Ganussa)tenellus* (Klug in Ehrenberg, 1834), *Dendroleon pantherinus* (Fabricius, 1787), *Pseudoformicaleo gracilis* (Klug, 1834)) and 2 species from the Nemopteridae family (*Nemoptera sinuata* Olivier, 1811, *Lertha extensa* (Olivier, 1811)) included in the Red Book of the Republic of Azerbaijan, Lederer's threadwing (*Lertha ledereri* Sélys-

Longchamps, 1866) is recommended for inclusion in the next edition of the Red Book [21; 22; 25].

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