Influence of hydrological regimes on the ecological balance of the environment: case study of the Republic of Ingushetia

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Abstract. Dragonflies are amphibious insects whose existence is associated with water bodies that are necessary for the development of larvae. Different types of dragonflies differ in the requirements for the choice of habitats. In mountain species, preferences depend on the height of the habitat. The analysis of the existing flow of literary information on dragonflies indicates that there are still problems that require close attention. First and foremost, this is insufficient study of Caucasian regional odonata faunas. Of all the unique Caucasian regions, the territories of the Dagestan and Chechen Republics were the least studied with regard to dragonflies. This is caused by the acute shortage of specialists and the difficulties of studying the group of animals of this original and unique region, which is located at the biogeographic crossroads of various faunas. Siberian, European, Mediterranean, Ethiopian, Central and East Asian dragonfly species fly together within these territories. A significant number of scientific articles are devoted to Caucasian dragonflies, testifying to the unique fauna of dragonflies in the region. At the same time, there are many unresolved issues of the taxonomic nature of some dragonfly species, their propagation, distribution over high-altitude zones, life cycles of ontogenesis, and some environmental issues, in particular, the phenology of the group in the peculiar and unique physical, geographical and landscape conditions of the Republic of Ingushetia. There is a relatively extensive literature on the dragonflies of the Caucasus, while there is no purposeful summary of the ecological-faunal, ecological-geographical and zoogeographic features of this group of insects in the Republic of Ingushetia. Another problem that has not yet been solved is the establishment of patterns of dragonfly propagation along the altitude gradient, as well as the peculiarities of the formation of odonatocomplexes in various high-altitude zones of the Republic of Ingushetia.

1. Introduction

Odonata is a unique order of the insect class, whose age dates back several hundred million years. They are characterized by high morphophysiological specialization, due to which they belong to a separate infraclass.

Dragonflies are characterized by biological progress: they have an all-world distribution, a large variety of species abundantly represented in terrestrial and aquatic ecosystems. This group of insects occupies an ecological niche of flying predators. Due to the alternation of the terrestrial and aquatic phases of ontogenesis, having large biomass the dragonflies play a significant role in the cycle of matter within ecosystems.

Dragonflies have important biocenotic and practical significance. They exterminate mosquitoes, midges, pests of forestry and agriculture, cause harm, in particular, exterminate entomophilic insects.
and entomophages, cause significant damage to beekeeping, and serve as the carriers of animal helminths. But this harm is insignificant compared to the useful value of dragonflies in biogeocenoses.

The purpose was to study ecological-geographical features and adaptive strategies for the high-rise-belt distribution of the feed base of dragonfly larvae (odonata) in the Republic of Ingushetia.

To achieve the purpose of research and qualification work, the following task was set: to study in detail the fauna of dragonflies in the Republic of Ingushetia.

2. Results
The waters of the Republic of Ingushetia study area are of different origin: moraine, karst, oxbow and artificial reservoirs. Dragonflies are amphibious insects which existence is associated with reservoirs that are necessary for the development of larvae. Different types of dragonflies differ in the requirements for choosing habitats. The preferences of mountain species depend on the height of habitat.

The analysis of the height distribution of nymphs indicates the influence of some limiting factors on their distribution. The studied group of animals is euribionts, the larval stage, of which more than other phases of ontogenesis depend on changes in environmental conditions, and the egg stage is able to resist changes in environmental conditions [1].

According to environmental features, dragonflies are divided into two groups – rheophilic and limnophilic [8]. Preimaginal phases of the reophilic develop in watercourses. In the Republic of Ingushetia, reobiont species live in flowing reservoirs and are stenotopic. Most limnophilic dragonflies can be attributed to euritope.

With an increase in absolute height in the mountains, the role of flowing reservoirs decreases. Euritope species live in non-flowing and semi-flowing reservoirs at an altitude of 800–1300 m. [2]. Climatic features, which are optimal conditions, are associated with the flow of water. The entire complex of abiotic habitat conditions of nymphs affects euritope species [3, 4, 7].

One of the main factors determining the possibility of nymph habitat is the temperature regime of water bodies. High temperature can be harmful to dragonflies.

The principle of habitat change is clearly manifested in the mountainous part and on the plain in the Republic of Ingushetia.

On the flat part of the Republic of Ingushetia the hydrological regime of reservoirs is characterized by high production processes. In the spring-summer period, the water temperature varies within 16–28 °C [6]. The feed base of the nymphs is zooplankton and benthos. As part of the zooplankton, the main role belongs to the vetvistous (moins and daphnia). Rotifers, which are the representatives of the Brachionidae family, make the main contribution to nutrition in spring and early summer. Copepods, which are also the foraging base of larvae, are represented by the only species Cyclops strenius. The role of round and small-leaved worms contributing to the general biomass of zoobenthos is important.

The studied water bodies of the Republic of Ingushetia within the heurigyphid zone are arranged on pebbles. The temperature of water bodies in the warmest period varies between 20 and 28 °C. Such a hydrological regime of heurigyphid reservoirs leads to poor development of zooplankton and zoobenthos [6]. The zooplankton includes the following eurigypses: rotifers, copepods and cladocerans, and zoobenthos – larvae of secondary water insects, round and oligochaete. The biomass of dipteran larvae is low, and the biomass of small-leaved and roundworms found in biotopes with silty deposits does not exceed 0.3 g/m³ [6].

Mountain reservoirs in the study area are formed by basins filled with spring and river waters. The water temperature does not exceed 16–20 °C. In the horizontal aspect, the difference in surface water temperature in mid-July is 1.7–3.5 °C.

By the middle of the day, in shallow water bodies, water warms up to 25 °C. The low temperature regime of the reservoir determines the low qualitative and quantitative composition of zooplankton and zoobenthos. Rotifers form the basis of zooplankton, the biomass of which is 0.01–0.03 g/m³.
Biomass of cladocerans (Bosmina longirostris, Chydorus sphaericus) in warm-water biotopes is 0.05–0.06 g/m³ [6].

The study of the composition of the stern base of nymphs in the mountains indicates the influence of the hydrological regime of the mountains on the folding structure of hydrobionts – stern objects, which is sufficient for the successful development cycles of 4 species: Aeschna cyanea, Libellula depressa, Orthetrum brunneum Coenagrion pulchellum (Table 1).

13 species of dragonfly larvae were found in the eurygipsa zone: Libellula depressa, Sympretrum meridionale, S. danae, S. striolatum, Anax imperator, Crocothemis erythraea, Platycnemis pennipes, Coenagrion puellas.

14 species of dragonfly larvae were found in the plain zone – Libellula depressa, Sympretrum danae, S. vulgarum, S. depressiusculum, S. striolatum, Anax imperator, Gomphus vulgarissimus, Crocothemis erythraea, Platycnemis pennipes, Coenagrion puella, C. pulchellum, Erythromma viridulum, Lestes sponsa, Calopteryx splendens (Table 1).

Table 1. Distribution of dragonfly larvae by high-rise belts of the republic

| Species                     | Plain (50–450 m ASL) | Eurygipsa (450–900 m ASL) | Mountains (900–3000 m ASL) |
|-----------------------------|----------------------|----------------------------|-----------------------------|
| Gomphus vulgarissimus       | +                    | –                          | –                           |
| Aeschna cyanea              | –                    | –                          | +                           |
| Anax imperator              | +                    | +                          | –                           |
| Sympretrum danae            | +                    | +                          | –                           |
| Sympretrum depressiusculum  | +                    | –                          | –                           |
| Sympretrum striolatum       | +                    | +                          | –                           |
| Sympretrum vulgarum         | +                    | –                          | –                           |
| Sympretrum meridionale      | +                    | +                          | –                           |
| Crocothemis erythraea       | +                    | +                          | –                           |
| Libellula depressa          | –                    | +                          | +                           |
| O. brunneum                 | +                    | +                          | –                           |
| Platycnemis pennipes        | +                    | +                          | –                           |
| Coenagrion puella           | +                    | +                          | –                           |
| Coenagrion pulchellum       | +                    | +                          | +                           |
| Erythromma viridulum        | +                    | +                          | –                           |
| Lestes sponsa               | +                    | +                          | –                           |
| Lestes dryas                | –                    | +                          | –                           |
| Calopteryx splendens        | +                    | +                          | –                           |

The distribution of nymphs over the altitude vector is associated with the number and “quality” of biotopes suitable for settlement. When dragonflies choose places suitable for habitation, the degree of the reservoir flow is of paramount importance, because it sets the temperature regime and aeration. There is a confluence of various types of dragonflies with certain types of reservoirs. Table 2 shows that larvae of 9 species live in standing and low-flow reservoirs, i.e. they are eurytopic; larval phase of 5 species is characteristic of flowing waters (rheophiles); distribution of the representatives of four species – limnophilic.

The colonization of standing reservoirs is traced to initially reophilic species, which, in particular, is observed among Calopteryx splendens.

The composition of the feed base of dragonfly larvae is affected by the temperature of habitats. Vegetation has a significant impact on the distribution of dragonfly larvae, which affects the species to a greater extent – phytophiles. Sharp depletion of vegetation in the reservoirs of mountains and eurygipsa reduces the biodiversity of nymphs [5, 6].
Table 2. Confinement of morpho-ecologic groups of dragonfly larvae to types of biotopes in the republic

| Species                  | Morpho-ecologic groups | Biotope (type of reservoir)                  |
|--------------------------|------------------------|---------------------------------------------|
| Gomphus vulgatissimus    | R                      | shall depth                                 |
| Aeshna cyanea            | R                      | circulating water reservoir                 |
| Anax imperator           | E                      | stagnant and low flow                       |
| Sympetrum danae          | E                      | stagnant and low flow                       |
| Sympetrum meridionale    | E                      | stagnant and low flow                       |
| Sympetrum vulgatum       | E                      | various reservoirs                          |
| Sympetrum striolatum     | E                      | various reservoirs                          |
| Sympetrum depressiusculum| L                      | various stagnant reservoirs, including temporary |
| Crocothemis erythraea    | R                      | circulating water reservoir                 |
| Libellula depressa       | E                      | stagnant and low flow                       |
| Orthetrum brunneum       | E                      | stagnant and semi flow                      |
| Platycnemis pennipes     | E                      | water circulation does not prevent distribution |
| Coenagriion puella       | L                      | stagnant, often in swamps                   |
| Coenagriion pulchellum   | L                      | stagnant, often in swamps                   |
| Erythromma viridulum     | E                      | various stagnant reservoirs and circulating water reservoir |
| Lestes sponsa            | L                      | standing                                    |
| Lestes dryas             | L                      | various stagnant reservoirs, often in swamps |
| Calopteryx splendens     | R                      | circulating, representatives adapt to stagnant reservoirs |

P – rheophilic, L – limnophilic, E – eurythopic.

The most favorable for the habitat of dragonfly larvae are warm-water reservoirs and their biotopes, combining areas of wetland with semi-flowing or standing water, where shrub, rigid semi-submerged and submerged vegetation grows on sludge-detritus soil. Such stations are the most suitable for the entire life cycle of dragonflies.

The analysis of the biotopic distribution of nymphs along the high-rise gradient indicates heterogeneity of placement, due to the fact that for water bodies of the plain and eurygipsa, biotopes with the necessary optimal living conditions are characteristic. This cannot be said in relation to mountains where there are practically no biotopes suitable for the development of the larval phase of dragonflies. A decrease in the temperature in water bodies and a decrease in the biomass of the feed base is a factor limiting the resettlement of dragonflies in the mountains. For example, Zygoptera taxa, which feed diet consists of zooplankton, are almost not found in eurygipsa and mountain reservoirs. The biomass of cladocerans in the mountains is low. This trend is also characteristic of rotifers. The feed diet of Anizoptera is sufficient for the successful development cycles of four species: L. depressa and Ae. suapea, Ort. brunneum, Coenagriion pulchellum.

The analysis of the distribution of the larval phase at various heights showed that when climbing mountains, the number and quality of feed deteriorates, being the reason for the distribution of dragonflies over heights [6].

Temperature is one of the main factors limiting the spread of dragonflies in the mountains, which affects all aspects of the ecology and biology of dragonflies. Besides, temperature, as already noted, affects the imago breeding.

Thus, it can be assumed that the complex of larvae consists of species living on the plain, eurygipsa and in the mountains. According to our data, the community of larvae on the plain includes (Anizoptera – 11 species, Zygoptera – 5 species, Caloptera – 2 species). Most species of larvae disappear in the mountains. The eurygipsa zone is characterized by larvae of 14 species (Anizoptera – 8, Zygoptera – 6 species), and in the mountains – only 4 species of larvae (heteropterous – 3, homopterous – 1 species).

The distribution of species by heights is associated with energy features that are associated with the temperature of aquatic biogeocenoses of different heights, the mode of which affects the composition
of the feed base of the larval phase. Vegetation affects more the distribution of nymph species – phytophiles.

3. Conclusion

Ae. Suapea larvae are characteristic of oligosaprobic reservoirs of the mountainous part, acting as an indicator of environmental pollution. They are found only in the mountain belt and live in oligosaprobic reservoirs. Nymphs L. depressa, S. meridionale, O. cancellatum, O. albistylum are confined to aquatic biogeocenoses, they are characterized by a significant concentration of organics. The first species is also distributed in the mountainous part of the republic, where it lives in polysaprobic reservoirs. Other species of the nymph community gravitate to mesosaprobic reservoirs. Thus, the listed species can be recommended as model objects of environment biomonitoring.

The above shows that the distribution pattern of the larval phase is related to the contamination of biogeocenoses with organic and their oxidation substances. The degree of influence on the nymph community and its distribution depends more on the different characteristics of the species and its ecological characteristics, while it is clear that none of the factors is the main one in determining the structure of the nymphs. Only the entire complex of factors affects the community of dragonfly larvae.

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