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Diversity and Adaptations of Immature Diptera in Semiaquatic Habitats at Shorelines of Hypersaline Lakes in the Crimea, with a Brief Review of Diptera in Mineralized Bodies of Water

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The order Diptera (Insecta) is one of animal groups most successful in the colonization of mineralized shallow aquatic and semiaquatic environments. At the same time, the taxonomic composition of Diptera, their role in communities and adaptations to extreme conditions of hypersaline lakes and other mineralized bodies of water are still insufficiently known. Semiaquatic biotopes at shorelinesare of particular interest as poorly known habitats of various Dipteraimmatures.

In 2005–2013, the author investigated Diptera that develop in shoreline habitats (water margin zone) of two hypersaline lakes, Koyashskoe and Kirkoyashskoe situated in eastern part the Crimean Peninsula, near or at the Black Sea coast. These habitats are affected by a combination of extreme environmental factors (high salinity, H_2S, hypoxia, strong variations in the water level and temperature). In total, 16 sites of water margin zone were sampled.Sites strongly differed in the substrate, vegetation and water mineralization (20–430 g/l); the diversity of conditions is illustrated in Figures 1. The study combined quantitative assessment of macroinvertebrates (numbers and biomasses) and rearing of dipteran immatures to adults (about 3000 specimens reared). The tendencies in the composition and structure of dipteran immature assemblages are reviewed.

Species in 18 dipteran families develop at shorelines of two lakes (e.g. see Przhiboro &Brodskaya, 2006; Garbuz et al., 2008; Przhiboro &Shadrin, 2012; Grichanov et al., 2012). Diptera comprise 65–90% of macroinvertebrates' biomass in all habitats. Taxonomical and ecological (e.g. trophic) diversity of Diptera in the shoreline zone of study lakes is not low as compared to many freshwater lakes of European Russia but is concentrated in few habitats. More than 30 species in 10 families can develop in the same

Fig. 1. The examples of study sites at shorelines of salt lakes Koyashskoe and Kirkoyashskoein the Crimea.

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semiaquatic habitat and site. Apparently, major factors limiting the abundance and diversity of Diptera are strong influence of waves and wind, deficiency in plant remains and strong changes in the water level.

Most species recorded are halophilous; Ceratopogonidae, Stratiomyidae and Ephydridae were represented by more than five species. Surprisingly, many closely-related species (in the genera *Nemotelus*, *Stratiomys*, *Culicoides*, and *Dasyhelea*) inhabit the same extreme habitats and sites. The taxonomic structure of

Diptera at the generic and familial levels is similar to that in other extreme semiaquatic habitats (sea intertidal zone, hot and sulfuric springs, shores of strongly polluted waterbodies) suggesting that adaptations to a wide spectrum of extreme (semi)aquatic conditions appeared independently in several widely-distributed but not closely-related groups of Diptera (Limoniidae, Ceratopogonidae, Stratiomyidae, Tabanidae, Ephydridae). The halophilous life mode occurring in many species of these of other families seems to be a particular result of these adaptations.

Some adaptations of six halophilous species inStratiomyidae, Tabanidae and Ceratopogonidae were examined in comparison with related species confined to cold freshwaters. In halophilous species, larvae display the higher thermotolerance and maintain higher concentrations of heat shock proteins (HSP70) both before and after heat shock (Garbuz et al., 2008, 2010). In Stratiomyidae, halophilous species differ from those living in cold freshwaters in the organization of HSP70 and HSP83 genes and in the regulatory mechanisms of expression of these genes (Garbuz et al., 2008, 2011; Astakhova et al., 2013).

An attempt is made also to briefly review and analyze the tendencies in colonization of mineralized bodies of water by different groups of Diptera, based on the original and published data on taxa that develop in shallow aquatic and semiaquatic habitats. In particular, the original data were used on 15 mineralized inland bodies of water in the Palaearctic Region as well as on the intertidal zone of two northern seas (e.g. see Glukhova& Przhiboro, 1995; Przhiboro, 1997, 2005; Przhiboro & Buhl, 2004).

Species in more than half of dipteran families associated with freshwaters occur in saline waters as well. Species in no less than 25 families develop in hypersalinewaters but their larvae are confined mostly to semiaquatic habitats at the shorelines. At the same time, the taxonomic richness of Diptera in aquatic saline (meso)habitats (littoral and sublittoral zones) is very low: species of only four families (about 40 species in 15 genera) live in aquatic hypersalinemesohabitats, almost all feeding as detritivores. Dipteran larvae belong to dominants by the biomassboth in aquatic and semiaquatic communities. Larvae of several species in five families colonize habitats in extremely wide range of salinity, from freshwater to hypersaline.

Key words: salt lakes, mineralized bodies of water, aquatic habitats, shoreline semiaquatic habitats, Diptera, larvae, biodiversity, community, taxonomic richness, adaptations, heat shock proteins.

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