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BIOCHEMISTRY, BIOPHYSICS AND MOLECULAR BIOLOGY

Quantitative Estimation of Dragonfly Role in Transfer of Essential Polyunsaturated Fatty Acids from Aquatic to Terrestrial Ecosystems

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The functioning of any ecosystem is based on the flows of matter, energy, and information in trophic chains [1]. As a result of existing division of ecology to the aquatic ecology (hydrobiology) and terrestrial ecology (biogeocenology), ecosystem flows are traditionally studied separately in water and land areas. The transfer of matter and energy between aquatic and terrestrial ecosystems, despite its obvious importance, has been quantitatively investigated rarely so far [2]. However, it is known that the biomass coming from aquatic ecosystems not only forms an additional stream of energy flow that is utilized in trophic chains of terrestrial ecosystems, but also represents a source of essential biochemical components of food for terrestrial animals [3]. These essential biochemical components are long-chain polyunsaturated fatty acids (PUFAs) of the ω3 family, such as eicosapentaenoic acid (EPA, 20: 5ω3) and docosahexaenoic acid (DHA, 22: 6ω3) acids. EPA and DHA are precursors of a number of biochemical endohormones regulating many important physiological and biochemical functions of the body, including the development of the brain, nervous tissue, and organs of vision, as well as the functioning of the cardiovascular system. The vast majority of animals, including humans, must obtain the necessary amount of PUFAs from food [4].

Terrestrial plants are unable to synthesize EPA and DHA. Among all organisms, only a few microalgae can efficiently synthesize long-chain PUFAs [5]. One of the main routes of PUFA export from microalgae to terrestrial ecosystems is the emergence of amphibiotic insects [3]. However, all the estimates of the flow of EPA and DHA to the land through the emergence of insects have been based so far on the averaging of diverse data obtained for entirely different ecosystems [3]. Moreover, the concentrations of EPA and DHA in the biomass are known only for larvae. Data for adult insects are practically absent, and quantitative data on the emergence were obtained in most cases only for the inhabitants of streams—Trichoptera, Ephemeroptera, and Diptera (Simuliidae and some Chironomidae). However, in many landscapes, vast areas are occupied by small lakes, puddles, and other temporary water bodies, which are often dominated by members of another order of amphibiotic insects, namely the Odonata. Dragonflies are components of the diet of many species of birds that are unable to consume smaller adult insects, such as Chironomidae. However, quantitative data of the emergence of dragonflies per unit area are missing in available literature. In view of this, the main aim of our study was to quantify PUFA flow from aquatic to terrestrial ecosystems ensured by dragonfly emergence.

Studies were performed in 1980–2009 at the Chany Expeditionary Station of the Institute of Animal Systematics and Ecology, Siberian Branch, Russian Academy of Sciences, in the central part of Barabinsk forest–steppe (54°32′–54°39′N, 78°06′–78°19′E) in a 272-km^2 area adjacent to the northeastern shore of Lake Malye Chany. One-third of this area (82 km^2) is a water area including temporary ponds, sedge and reed marshes. A large part of this water area (69 km^2) is the habitat of dragonflies. The general description of the environmental study area can be found in the literature [6]. Calculations of flows were made for nine background species of dragonflies, the average annual percentage of which is shown in Table 1.

The abundance of adult dragonflies was determined by the capture–mark–recapture method [7] and counts in transects [8]. To estimate the emergence (i.e., the number of dragonflies that entered the biotope during the season), we used the coefficient

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Table 1. Average annual percentage of dragonfly species at the Chany Expeditionary Station site (1980–2009)

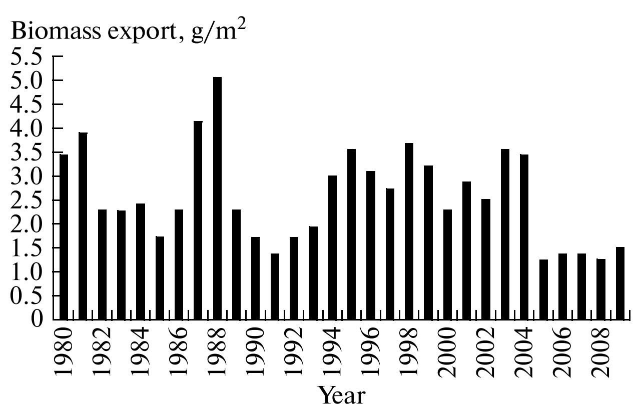
Dragonfly species	Species proportion, %
Sympetrum flaveolum (Linnaeus, 1758)	22.0
Sympetrum vulgatum (Linnaeus, 1758)	20.0
Enallagma cyathigerum (Charpentier, 1840)	18.0
Libellula quadrimaculata Linnaeus, 1758	12.0
Leucorrhinia rubicunda (Linnaeus, 1758)	10.0
Erythromma najas (Hansemann, 1823)	8.0
Sympecma paedisca (Brauer, 1877)	5.0
Lestes dryas (Kirby, 1890)	4.5
Aeshna serrata (Hagen 1856)	0.5
Total	100

Table 2. Content (mg/g wet weight) of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) and their sum in the biomass of dragonflies at the Chany Expeditionary Station site in June–August 2009

Species	EPA	DHA	EPA + DHA
S. paedisca	3.04	0.00	3.04
L. dryas ♂	2.19	0.03	2.22
L. dryas ♀	2.46	0.04	2.50
E. cyathigerum	3.87	0.04	3.91
E. najas	4.33	0.02	4.35
L. rubicunda	2.36	0.02	2.38
L. quadrimaculata	1.92	0.00	1.92
A. serrata	1.74	0.00	1.75
S. vulgatum	2.55	0.03	2.58
S. flaveolum	1.92	0.01	1.93
Average	2.64 ± 0.27	0.02 ± 0.00	2.66 ± 0.27

calculated as the ratio of the emergence period to the mean lifespan of adult dragonflies of each species. This ratio is not constant; it was calculated for each species taking into account the local features of the life cycle and mortality of adults on the basis of the methods used in the population ecology of dragonflies [9]. The content of fatty acids in dragonflies was determined in 2009 using gas chromatography–mass spectrometry as described in detail in [10].

Multiannual data on the emergence of dragonflies per unit area of the studied region are summarized in Fig. 1. The average annual value of dragonfly emergence was 2.6 ± 0.18 t km^{-2} year (season)$^{-1}$ wet weight, or 2.6 g m^{-2} year^{-1} (0.87 g m^{-2} year^{-1} dry weight). The maximum emergence during the study period was observed in 1988 (5.06 t km^{-2} year^{-1} wet weight); the minimum emergence, in 2008 (1.26 t km^{-2} year^{-1}). The levels of long-chain polyunsaturated PUFAs in the dragonfly biomass are listed in Table 2. The average content of EPA + DHA in dragonflies (2.66 ± 0.27 mg g^{-1} in raw biomass or 7.98 mg g^{-1} in dry biomass) was close to the average global estimate of PUFA content in the larvae of amphibiotic insects (9.3 mg g^{-1} dry weight [3]).



Annual total export of the biomass of nine background dragonfly species from water to land at the Chany Expeditionary Station site in 1980–2009.

Thus, PUFA flow from aquatic to terrestrial ecosystems with the dragonfly biomass was 6.9 mg m^{-2} year^{-1} (6.9 kg km^{-2} year^{-1}). The average global estimate of PUFA export to terrestrial ecosystems due to emergence of amphibiotic insects inhabiting primarily watercourses varies from 2.5 to 11.8 mg m^{-2} year^{-1} [3]. Hence, dragonflies, inhabitants of small temporary stagnant water bodies, transfer to terrestrial ecosystems essential biologically active compounds in quantities comparable with the quantities transferred by other amphibiotic insects that are the main study objects of hydrobiology.

Apparently, the flow of matter and energy arriving to terrestrial ecosystems with dragonflies is comparable to the production of populations of many groups of terrestrial insects. However, the biomass of terrestrial insects does not contain essential EPA and DHA [11, 12]. Therefore, dragonflies make not only a significant quantitative but also qualitative contribution to the trophic chains of terrestrial ecosystems in landscapes that are rich in shallow and temporary water bodies.

Thus, this is the first study to determine the concentrations of EPA and DHA in the biomass of adult amphibiotic insects. It is shown that dragonflies transfer to terrestrial ecosystems not only a significant amount of biomass (energy) from aquatic ecosystems but also high quantities of essential PUFAs.

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