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Dependence of the Respiration Rate upon Oxygen Concentration in Water for some Rheophilous Mayfly Larvae (Ephemeroptera)

by

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The respiration rate (RR) of five species of mayfly larvae from the Soviet Far East (*Drunella aculea* Allen, *Cincticostella levanidovae* Tshernova, *Ecdyonurus dracon* Kluge, *Siphlonurus lacustris* Eaton, *Ameletus cedrensis* Sinitshenkova) was measured in a closed respirometer and plotted against oxygen concentration (OC). Except *A. cedrensis,* all species were able to maintain RR at a constant level over certain ranges of OC by regulation with respiratory movements. In contrast, the RR of *A. cedrensis* dropped continuously as OC in the water declined, the species being a conformer. These differences are interpreted in the light of microhabitats occupied by the species in the field.

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INTRODUCTION

Most studies on the respiration rate (RR) of Ephemeroptera larvae upon oxygen concentration in the water (OC) were carried out with lenitic species (Polyakova, 1976; Fox et al., 1937; Eriksen, 1963; Nagell, 1973). Lenitic mayflies tolerate an oxygen deficit in the water and are able to maintain a constant level of their RR within a wide range of oxygen concentrations. In the rheophilous Ephemeroptera larvae, this question has hardly been studied. Investigations by Fox (Fox et al., 1937) on the rheophilous larvae of *Baetis* sp. and *Baetis scambus* Eaton revealed considerable differences between these species. Larvae of *B. scambus* tolerated an oxygen deficit in the water well and maintained a constant RR over a wide range of oxygen concentrations. In contrast, the RR of *Baetis* sp. decreased rapidly as OC declined; larvae of this species could not survive at low OC in the water. Unfortunately, both species are only said to live "in streams where the oxygen supply must always be abundant", without data on the specific micro-habitats of the two species.

The present paper presents information on the RR-dependence upon OC in the water for the rheophilous larvae of five mayfly species from three families: *Drunella aculea* Allen, *Cincticostella levanidovae* Tshernova (Ephemerellidae); *Ecdyonurus dracon* Kluge (Heptageniidae); *Siphlonurus lacustris* Eaton, *Ameletus cedrensis* Sinitshenkova (Siphlonuridae). Findings are interpreted in view of the specific microhabitats occupied by the larvae in streams.

MATERIAL AND METHODS

The studies were carried out from April 30 to May 24, 1983 at the Hydrobiological Station of the Institute of Biology and Pedology (Far East Science Center) in the reserve "Kedrovaya Pad" situated along the west coast of Amur Bay, 30 km to the west of Vladivostok. Larvae obtained in the Kedrovaya river near the farmstead of the reserve were used in the experiments.

The Kedrovaya river is of the foothill type (Levanidov, 1965). During the study period it had low water levels, and was about 0.4 m deep in the vicinity of the reserve. The water flows at 0.4-0.5 m s^{-1} over a stony bottom at the sampling site. Water temperature was about 8°C during our experiments. In the summer, the daily temperature amplitude is only 5°C. At the time of the study, oxygen content in the river water was 7.82 ml $O_2 l^{-1}$ (ca. 68% saturation).

The respirometer in which the RR of mayfly larvae was measured had a respiratory chamber of 148 ml. An oxygen electrode with an Pb/Pt-electrode was hermetically mounted in its lid (Klyashtorin, 1978) and connected to a μA-meter. An isolated 8 mm long magnetic stirrer rotated at 200-250 r.p.m. in a secured separate chamber immediately below the sensor membrane. It provided the necessary rate of flow below the membrane and also stirred the water in the respirometer slowly. The oxygen concentration in the respirometer was recorded every ten minutes. RR was calculated for 40-50 min intervals. The initial calibration of the instrument was with Winkler techniques, the sensitivity was 0.05-0.06 ml $O_2 l^{-1}$.

Every experiment lasted for 10 h, on the average. Animal biomass was determined on a torsion balance to an accuracy of 0.1mg. The number of specimens tested, their mean wet weight (g), and the date of the experiments were:

	n	wet weight	date
Drunella aculea	12	0.083	30.4.1983
Cincticostella levanidovae	40	0.0083	3.5.1983
Ecdyonurus dracon	21	0.042	4.5.1983
Siphlonurus lacustris	6	0.136	20.5.1983
Ameletus cedrensis	18	0.089	21.5.1983

RESULTS

The dependence of the RR of the Ephemeroptera larvae studied upon the OC in the water is shown in Fig. 1. Larvae of *Ameletus cedrensis* (Fig. 1a) differed from the others by a continuous decline of its RR as OC dropped from 6.5-0 ml $O_2 l^{-1}$. In the other species (Fig. b-e) the curve had a horizontal section for moderate to high OC. This section is usually called the 'oxygen adaptation zone' (Winberg, 1956), where the RR does not depend on the OC in the water. The oxygen concentration at the lower limit of the oxygen adaptation zone is called the critical concentration. It was 2.9-4.0 ml $O_2 l^{-1}$ for all species, of course except *A. cedrensis*.

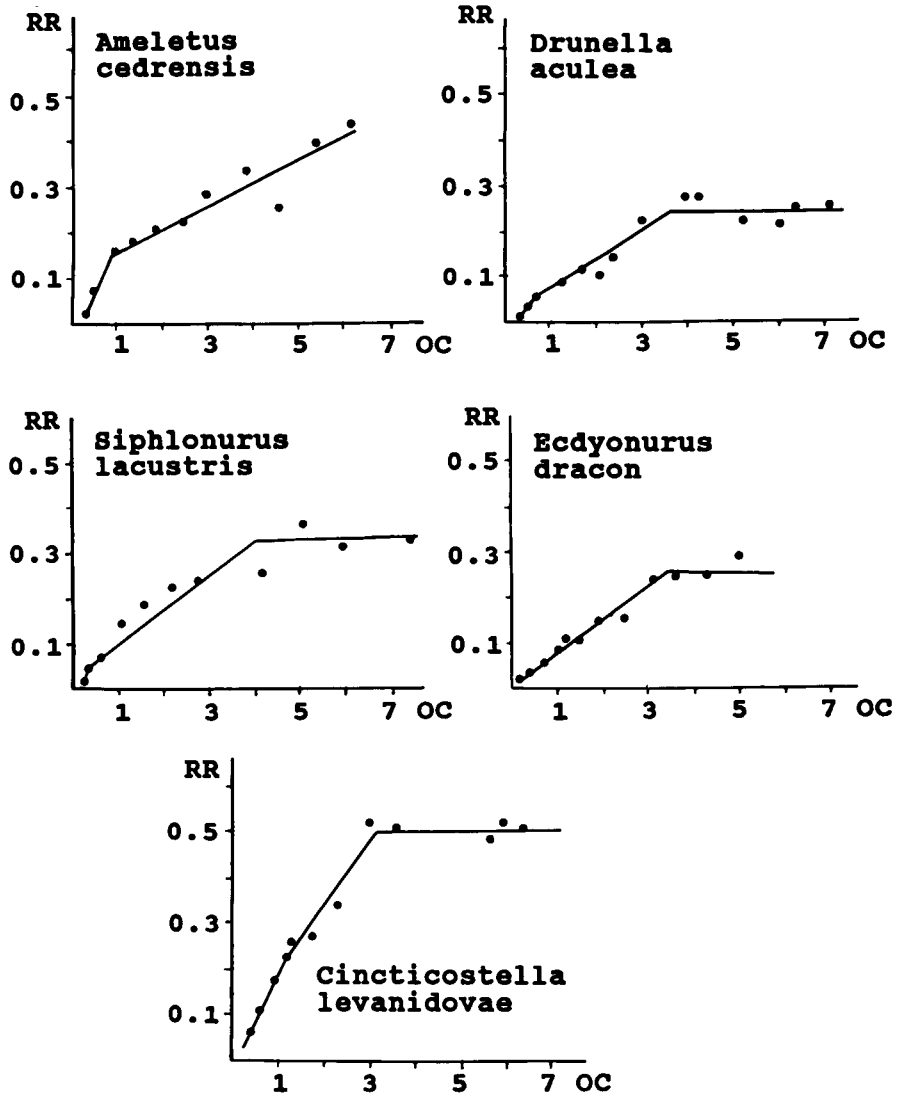

Fig. 1: Respiration rate (RR; ml O_2 $g^{-1}h^{-1}$) of several Ephemeroptera larvae at various oxygen concentrations (OC; ml $O_2 l^{-1}$) in a closed respirometer at 8°C.

DISCUSSION

The 'critical oxygen concentration' measured in a closed respirometer can be regarded as an indicator of the tolerance of an animal species to low concentrations of oxygen in the water. Species which are able to maintain a

constant level of RR within the oxygen adaptation zone due to an increase in the frequency of larval respiratory movements (Eriksen, 1963) are called non-conformers and tolerate low oxygen concentrations in the water.

Larvae of lenitic insect species have, as a rule, wide oxygen adaptation zones. Their critical oxygen concentrations do not usually exceed 2.0-3.0 ml $O_2 l^{-1}$ (Fox et al., 1937; Eriksen, 1963; Nagell, 1973).

In contrast, the few data on rheophilous larvae (mainly of Plecoptera) show that in these species an oxygen adaptation zone may practically be absent (Knight & Gaufin, 1964; Kapoor & Griffiths, 1975). Such animals are known as conformers.

It may be suprising that (except *A. cedrensis*) the Ephemeroptera larvae studied from a fast cool stream have fairly low critical oxygen concentrations and hence, wide oxygen adaptation zones. These larvae appeared to be well adapted to tolerate the rather low oxygen concentrations in the only slightly stirred water in a closed respirometer bottle. However, if one considers specific habitats occupied by these larvae in the river, this phenomenon is easily accounted for:

- Larvae of *Siphlonurus lacustris* and *Ecdyonurus dracon* in the Kedrovaya river are mainly found near the banks of small coves, or in places of slow flow over stone surfaces.
- *Drunella aculea* and *Cincticostella levanidovae* occur in rapid current, but live under stones where stream flow is in fact also low. Before emergence of the subimago, larvae of these species migrate to the calm marginal river areas, which are only 5-7 cm deep and rather warm.

Therefore, the larvae of the species discussed inhabit microhabitats where water flows fairly slowly and habitat conditions are in fact quite comparable to those of lenitic species. Like most lenitic species, the larvae of *C. levanidovae, D. aculea, E. dracon* and *S. lacustris* have well developed gill apparatuses and execute effective respiratory movements with their gills.

Of the species studied, only *A. cedrensis* larvae are conformers. They have practically no oxygen adaptation zone and their RR is directly proportional to the OC in the water over the entire range examined, from 0-75% saturation (Fig. 1a).

Larvae of the genus *Ameletus* swim well. This is favoured by large size, streamlined body form, powerful development of the abdominal segments as compared to the thorax, weak legs and reduced gills (Dodds & Hisaw, 1924). The gills have the form of small oval plates along the sides of the abdomen. Gill surface area is small in relation to total body surface. Therefore, respiratory movements of the gills of *A. cedrensis* would be of low efficiency and unable to maintain a constant level of RR over a wide range of OC. In the Kedrovaya river, these larvae are found in sites with low rates of stream flow, mainly near the banks but occupy upper stone surfaces where they are exposed to the current. In places of near to no flow the larvae are seen swimming constantly

from stone to stone.

In summary, most mayfly larvae studied by us proved to tolerate rather low oxygen concentrations in the water. They are able to maintain a constant level of RR over a relatively wide range of OC. In the Kedrovaya river, these larvae inhabit biotopes with low stream flow, e.g., below stones in marginal river areas. *Ameletus cedrensis* is the only species studied where RR drops over the entire range of OC studied. Apparently, this species cannot maintain a constant RR as OC declines because in connection with adaptations to rapid swimming, its gill apparatus has been reduced in size and efficiency. Evidently, this species should then be more oxyphilic that the others.

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