

Aquatic Insect Larvae as Indicators of Limiting Minimal Contents of Dissolved Oxygen

by

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ABSTRACT

Minimal concentrations of oxygen are limiting factors for limnic biocenoses. It should therefore be possible to use biocenose structure to infer minimal oxygen concentrations that have occurred, provided the tolerance of the organisms concerned is known. A simple apparatus used to measure LC_{50} of oxygen for aquatic insect larvae with tracheal gills is described. Lethal concentrations found in some Ephemeroptera differ between species. Usually, they are strongly temperature dependent. In the species so far studied, confidence intervals are very small and suggest that such insect larvae could be used as bioindicators of minimal oxygen concentrations (even of short term ones), especially in thermally stable waters.

In terrestrial ecosystems, oxygen content is almost never a limiting ecological factor (Kühnelt 1965, Schwerdtfeger 1978). In aquatic ecosystems this is different because even when saturated a given volume contains 15 to 30 times less oxygen than a similar volume of air, e.g., 14.64 mg/l at 0°C and 7.31 mg/l at 30°C, under normal conditions. Complete saturation or slight oversaturation are characteristic of marine ecosystems, except shelf seas, provided they are little influenced by man (De Lattin 1967). In contrast, the actual oxygen content of inland waters, even if not influenced by man, varies within wide limits, from practically 0% (in, e.g., mud, peat, eutrophic bodies of water covered by ice for long periods of time) to 300% (in algal mats exposed to sun). The variables of the oxygen balance of inland waters are subject to very complex diurnal and annual variations depending on light intensity, photoperiod, convection currents, disintegration processes, and others.

Minimal contents of oxygen are much more limiting for limnic biocenoses than maximal ones. Consequently, it should be possible to infer occurrences even of short term minima from the structure of biocenoses. In doing so it must be taken into account that limnic organisms are more or less strongly adapted to varying contents of oxygen and are able to regulate to some extent, e.g. by adjustable

ventilation movements of gills (Kamler 1971), pumping movements (Benedetto 1970, Knight and Gaufin 1963) or by changing respiratory activities (Schuhmacher & Schremmer 1970, Nagell 1979). Comparatively very few species have so far been tested for minima of oxygen tolerated (in Europe, mainly *Cloeon dipterum*, Ephemeroptera, and *Nemoura cinerea*, Plecoptera), and still much less is known about their possible use as bioindicators.

The following methodological approaches were used in such studies:

- test organisms were exposed to various constant oxygen concentrations and survival time for each of these was determined (e.g., Benedetto 1970).
- test organisms were exposed to a continuously declining oxygen content and ventilation movements (e.g., Knight & Gaufin 1963, 1964) or respiratory activity (e.g., Knight & Gaufin 1964; Nagell 1974) were recorded.

In the present study, we have determined lethal concentrations.

The experimental set-up is shown in Fig. 1. Oxygen content in the test chamber can be reduced continuously by an adjustable nitrogen flow and is measured by a Clarke-electrode, modified by Ardenne, at various constant temperatures. Test organisms were adapted to test temperatures for 24 hrs and tests were run only if none of them had died during this period. Tests were made under the following experimental conditions (for additional data, refer to the table and the figures)

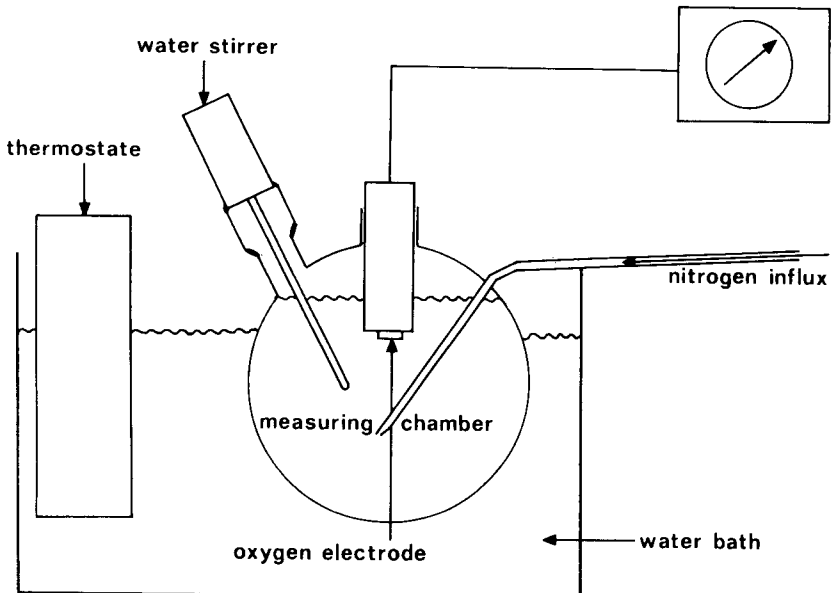


Fig. 1. Scheme of the apparatus used; compare text.

- diffuse daylight (according to Kapoor, 1972, respiratory rates may differ in light or in the dark)
- low to moderate flow of water (Knight & Gaufin 1963, Kamler 1969 and Csoknya & Halasy 1975 showed the importance of this factor)
- suitable substrate, mostly gravel, but glass tubes for the burrowing *Ephemera*, to avoid stress due to abnormal locomotory activity
- tests lasted for 2-5 hrs
- because of the importance of body size (Kapoor & Griffiths 1975), only almost fully grown nymphs were used
- at least 10 specimens were used in every experiment.

It was found difficult to determine accurately the oxygen concentration in the moment of death, because most specimens are drifting lethargically already some time before they die, which appears to be a useful adaptation in running waters. Therefore, LC_{50} , variances, standard deviations and 95 per cent confidence limits were calculated for the mean of small ranges of oxygen concentrations using all animals that had died during these intervals.

Table 1. LC_{50} values of oxygen concentration (x, in per cent saturation), standard deviation and confidence intervals at various constant temperatures for some species of Ephemeroptera and Plecoptera.

	12°C	15°C	20°C	25°C
<i>Rhithrogena iridina</i>	x = 49.5 s = 6.78 ci 43.9 < μ < 55.2			
<i>Baetis vernus</i>	x = 27.8 s = 3.28 ci 25.1 < μ < 30.5			
<i>Nemoura cinerea</i>	x = 10.5 s = 3.23 ci 7.6 < μ < 13.4			
<i>Ephemerella mucronata</i>	s = 6.54	x = 12.2 s = 7.32	x = 19.2 s = 8.4	x = 49.5
ssp. <i>krieghoffi</i>	ci 6.4 < μ < 18.0	ci 12.6 < μ < 25.7	ci 42.0 < μ < 56.9	
<i>Siphonurus aestivalis</i>			x = 5.2 s = 1.39 ci 3.8 < μ < 6.7	x = 6.6 s = 2.8 ci 2.5 < μ < 9.1

Results are summarized in table 1 and figs. 2 and 3. Lethal concentrations of oxygen differ considerably between species and in most cases are strongly dependant on temperature. The following unexpected facts were also noticed:

- confidence intervals are very small for all species studied
- a linear temperature dependence of the LC_{50} of *Cloeon simile* which suggests that below 10°C it enters anaerobiosis
- there is no temperature dependence in *Ephemera vulgata* which dies only when

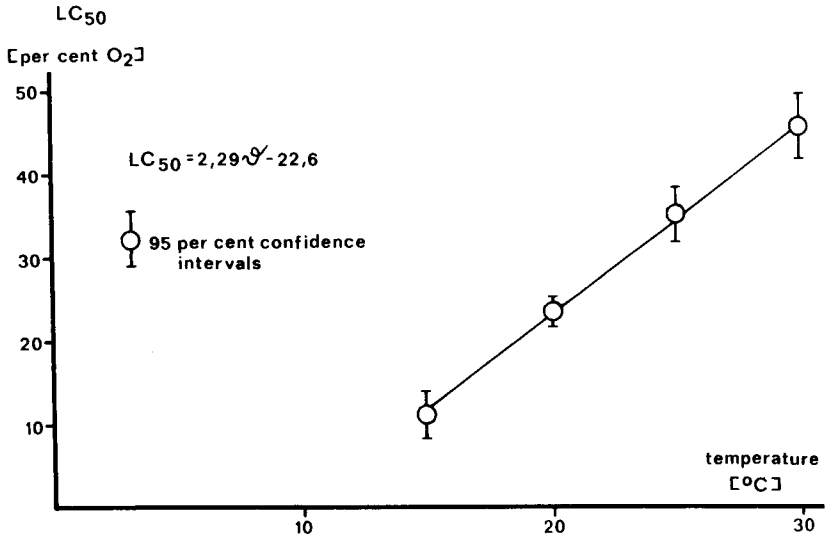


Fig. 2. *Cloeon simile*, temperature dependence of lethal oxygen concentrations (LC₅₀).

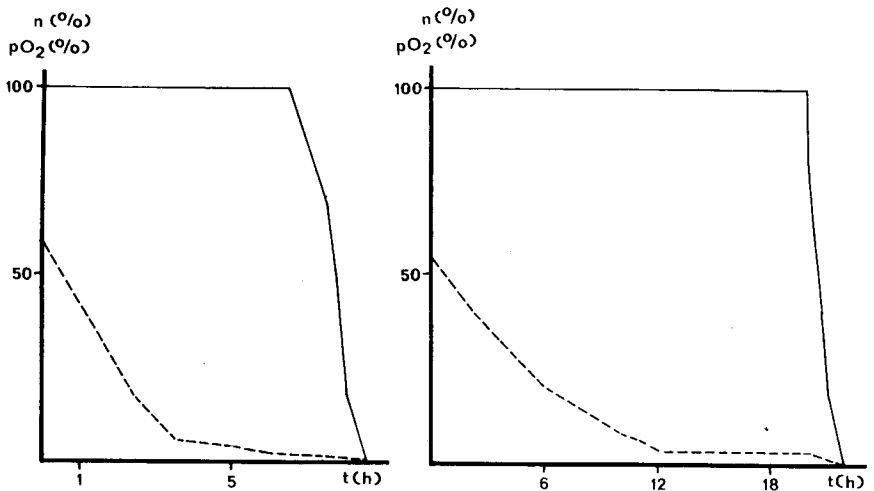


Fig. 3. *Ephemera vulgata*, oxygen content (interrupted line) and percentage of surviving specimens (continuous line) at 25°C (left) and at 15°C (right). LC₅₀ is neither time nor temperature dependent: $x = 0.91$, $s = 0.12$, $ci = 0.83 < \mu < 0.98$.

the environment becomes anoxic, regardless of exposure time and test temperatures, up to 25°C.

The great sensitivity of *Rhithrogena iridina* to reduced oxygen content suggests that of the species listed in table 1 it should be the first to disappear from central European rhithral communities under stress from pollution.

Although standard text books pay little (Uhlmann 1975) or no attention (Breitig 1975) to the possible use of water insect larvae as bioindicators of minimum oxygen levels, a number of them should in fact be valuable. This should be particularly so in waters with relatively small ranges of temperature, e.g. mountain streams or tropical waters.

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