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OXYGEN CONSUMPTION OF THE LARVAE OF PIKE *(ESOX LUCIUS* L.) AND SHEAT-FISH *(SILURUS GLANIS* L.) AT TEMPERATURES OF 0,5 TO 28° C

ELEK WOYNÁROVICH

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The consumption of oxygen by the larvae of two predatory fishes, the pike and the sheat-fish, from hatching, then during feeding from the yolk sac, till the beginning of feeding through the mouth, has been investigated.

Oxygen consumption by the larvae increases considerably during this phase of larval development. According to SAMARDINA (1954) the pike larvae, when beginning to feed, consume almost five times more oxygen than when freshly hatched. LINDROT (1942), LOSINOV (1952), MARCKMAN (1958) and PRIVOLNEV (1957) observed an increase in oxygen consumption of salmon and other fish. MENDES (1953) reports the same of larvae of Rana pipiens. On the other hand, it is known that the oxygen consumption of the poikilothermic organisms increases considerably with a rise in temperature. Few of the earlier investigators kept this fact in mind and the consumption of oxygen was never measured in the same stages of development at the same temperatures. The study of the oxygen consumption of fish larvae at these stages of development is also of interest because the fish then pass from diffuse consumption of oxygen to respiration through the gills. As the larvae develop, the proportion of organs participating actively in respiration to the inactive ones changes very considerably. We may assume that at the end of the pre-larval development, before the larva begins to feed, most of the tissues participating in respiration are present in the animal. SAMARDINA (1954) explains the increase of oxygen consumption in the developmental stages of fish by the change in the proportion of active and inactive respiratory organs.

In the literature no particulars on this subject are to be found, although various authors discuss the oxygen consumption of fish at various stages of development.

Methods and Matherials

The larvae of pike and sheat-fish, artificially bred, freshly hatched (I) then in mid-development (II) as well as larvae past the larval stage and able to feed, but which have not yet started to feed (III) were studied. In the course of these investigations other larvae were also examined, at intermediate stages of development.

At each stage of development the investigations were made within 1 hour, at various temperatures at 7 intervals between 0,5 and 28° C, *i.e.* at 0,5; 5, 10, 15, 20, 25 and 28° C. For description of method and apparatus see WOYNÁROVICH (1959). In each case the incubation lasted for 2 hours. The separation of the larvae from the water at the end of the experiment took place without difficulty. In each experiment there were larvae in 3 vessels and two other vessels were similary incubated but without fish, for control purposes. The initial oxygen content was strictly ascertained by means of the controls.

3 to 30 pike larvae or 5 to 15 sheat-fish larvae were put into each vessel. At higher temperatures fewer larvae were put into the vessels to avoid a drop in oxygen concentration to below 50%. Variation in the number of animals caused no difference in the results of the experiment.

The animals were previously kept for one to two hours at the experimental temperature, this period having proved to be sufficient for their adaptation. For trial purposes experiments in adaptation times were also made, for 10 minutes and 2 hours, but there were no significant differences in the results. We kept the pike larvae — which fish spawns in cool water — in water at about 10 to 20° C and those of the sheat-fish (which spawns in warm water) in water at 20° C before the experiment. The oxygen content was tested by the method of WINKLER—MAUCHA using n/200 $Na_2S_2O_3$.

The experiments were repeated several times in 1958 and 1959 but there were no substantial differences in the results.

The live weight of the larvae was not taken because of the lack of precision in measuring. The full length of the animals was measured as well as the dry weight (dried at 105° C to constant weight).

The respiration of fish larvae

BALON (1958) discusses the periods and phases of fish development According to his denominations the fish investigated by us were in the "pre-larval phase" (protopterygiolarval phase). MONTEN et AL. (1948) discuss the development of pike larvae. GIHR (1957) writes about their development and detailed anatomy; LINDROTH (1942) about the development and respiration and, finally, ZIĘBA (1956) about the vascular system.

The freshly hatched pike larva respires in a diffuse way by means of a network of veins on the surface of the yolk sac. In the course of its development there appear the primordia of gills which enter gradually into the process of respiration. After having consumed the total contens of the yolk sac, the larva, at the end of the pre-larval phase, respires through its gills.

During the three stages of development the larva takes in oxygen in the following three ways:

1. in a diffuse way on the surface of the yolk sac.
2. In this diffuse way and also through the gills.
3. Breathing entirely through the gills.

At the beginning of the stages of development investigated by us the larva lies on the ground; afterwards it attaches itself to different objects and at the end of the pre-larval phase drifts freely in the water.

The pike is a predatory fish which spawns in cool Water. The best temperature for the development of the larva seems, according to our experiments, to be 10 to 15° C.

The sheat-fish is also a predatory fish and spawns in warm water, over 20° C. For the development of its larvae the most favourable temperatures are 20 to 25° C.

(See information and data on freshly hatched sheatfish larva and its development, WOYNÁROVICH 1952). The freshly hatched sheat-fish larva moves its tail regulary to and fro and ever faster as it develops. Respiration takes place in a diffuse way. The tail movements are closely connected with respiration. At this stage the larva, by means of a secretion from a gland in its head, attaches itself to different objects. As development progresses the primordia of gills appear, the larvae become photophobic and gather together in groups with their heads all pointing toward the same direction. The strokes of the tail are now rapid sideways movements, in which the fore-part of the body takes no part. With the development of the gills this rhythmic movement ceases, the photophobia of the animals decreases and the groups disperse.

The sensitivity of fish larvae to temperature

The two kinds of fish larvae investigated show contrasting trends in respect to their sensitivity to low temperatures.

The larvae of the pike in the beginning bear a low temperature of 5° C without any damage. Later on in their development they expire when kept 4 to 6 hours at this temperature. The heart of the freshly hatched larva ceases to beat at 4° C but starts again, even after several days, if the environment becomes gradually warmer.

The larva of the sheat-fish at the beginning of its development is very sensitive to temperature and can endure a low temperature of about 5° C no longer than 4 to 5 hours at the most. The fully developed larva remains alive without demage at this temperature. According to our observations, the larvae of the sheat-fish develop very slowly and finally die when kept continually at a temperature below 15° C.

Results of oxygen-consumption measurements

The results of the oxygen-consumption measurements of the larvae in question are presented in 4 Tables and 2 Figures.

Table 1 shows the consumption of oxygen by 100 pike and sheat-fish larvae respectively at different temperatures in the three phases of development, in mg oxygen per hour. This *Table* also contains the data on dry weight (each 100) and length of larvae.

The body of the pike larva is bigger, the dry weight of 100 freshly hatched pike larvae being 30,8% higher than that of 100 sheat-fish larvae. As the larvae develop the yolk substance is gradually used up. Before they begin to take up food the dry weight of 100 pike larvae is 17,6%, the dry weight of 100 sheat-fish larvae 16,9% less than at the beginning of development. In the body weight of these two larvae, differing in size and weight in the first stage of development there is an almost parallel decrease until the yolk substance is consumed.

Table 1 — 1. táblázat

Oxygen consumption of 100 larva mg/hr

100 drb lárva oxigénfogyasztása mg/óra

	Esox lucius praelárva			Silurus glanis praelárva		
C°	I. Freshly-hatched frissen kelt	II. In mid development közepesen fejlett	III. Ready to feed Táplálkozásra kész	I. Freshly-hatched frissen kelt	II. In mid development közepesen fejlett	III. Ready to feed táplálkozásra kész
28	0,286	0,790	1,504	0,202	0,626	1,000
25	0,253	0,722	1,253	0,173	0,534	0,814
20	0,204	0,534	0,902	0,122	0,383	0,618
15	0,148	0,349	0,594	0,056	0,213	0,331
10	0,081	0,203	0,357	0,024	0,101	0,148
5	0,044	0,126	0,189	0,017	0,064	0,105
0,5	0,022	0,070	0,096	0,007	0,035	0,065
Dry weight of 100 db szárazsúlya g	0,205	0,175	0,169	0,142	0,138	0,118
Full length teljes hosszúság mm	8,55	11,05	12,7	8,5	9,25	12,00

The oxygen consumption of the pike larva increases from hatching until the intake of food (at the end of the pre-larval phase) on an average by 4,48 times. That of the sheat-fish larva increases by 6,03 times in the same interval.

From the time of hatching till the mid-development stage the oxygen consumption of the pike larvae increases to 2,75 time while that of the sheat-fish larvae 3,73 times the original value.

Table 2 contains the data on oxygen consumption calculated to 1 g dry weight, in mg per hour. From this *Table* it is apparent that the oxygen consumption increases considerably in the three stages of development of the larvae, at temperatures from 0,5 to 28° C. Since the 0,5 as well as the 28° C temperatures are extreme values, these two limit were disregarded and calculations were made as to how many times the amount of oxygen consumed at 5° C will consumed at 25° C. These data are shown in *Table 3.*

Table 3 also shows that the quotient of oxygen consumption (Q 20) of the two larvae changes as their development advances, in an opposite sense. The pike larva (which spawns in cool water) reacts to a change in temperature with a decrease in oxygen consumption. Its oxygen consumption is more balanced over a wider temperature scale. In the middle and at the end of its

Table 2 — 2. táblázat

Oxygen consumption of 1 g dry weight, mg/hr

Oxigénfogyasztás 1 g szárazanyag mg/óra

C°	Esox lucius praelárva			Silurus glanis praelárva		
	I.	II.	III.	I.	II.	III.
28	1,40	4,52	8,89	1,42	4,53	8,47
25	1,23	4,13	7,41	1,22	3,87	6,90
20	1,00	3,05	5,33	0,86	2,77	5,24
15	0,72	2,00	3,51	0,39	1,54	2,81
10	0,39	1,16	2,11	0,17	0,73	1,26
5	0,22	0,72	1,12	0,12	0,46	0,86
0,5	0,11	0,40	0,57	0,05	0,24	0,41

Table 3 — 3. táblázat

Increase in oxygen consumption at 25 C° over that at 5 C° as calculated to 1 g dry substance (Q_{20})

25 C°-on az oxigénfogyasztás hányszorosa az 5 C°-on fogyasztott 1 g szárazanyagra számított oxigénmennyiségnek (Q_{20})

Stage of larval development — Fejlődési állapot	Pike larva Csuka lárva	Sheat-fish larva Harcsa lárva
Freshly-hatched I. — Frissen kikelt	5,6	10,2
In mid-development II — Közepesen fejlett	5,7	8,4
Before beginning to feed III — Táplálkozás megkezdésére érett	6,6	7,7

development the pike larva becomes more sensitive to a change of temperature and the quotient of oxygen consumption increases in the same temperature range.

The sheat-fish larva (which spawns in warm water) is at first highly sensitive to temperature, but adapts itself, as it develops, to wider fluctuations. This is shown by a decrease in the oxygen consumption quotient.

There is a manifold increase in oxygen consumption in the course of larval development when measured at identical temperatures. The quotients were obtained by dividing the data on oxygen consumption in the course of development (II. and III stages) as related to 1 g dry substance by the figure for freshly-hatched larvae (I stage). The quotient therefore shows how many times the oxygen consumption increases, at the course of development in comparison with the consumption of a freshly-hatched larva. The quotient, *i.e.* the degree of the increase in oxygen consumption, is determined by the lower initial oxygen consumption or by the gradually more intensive

consumption later on, or both. The smallest quotient indicates the smallest change in respiration in the life of the organism in question and shows the degree of temperature at which the larva develops with greatest stability. Quotient values surpassing the average mean more intensive changes in respiration during development, which may be unfavourable to the animal at that phase.

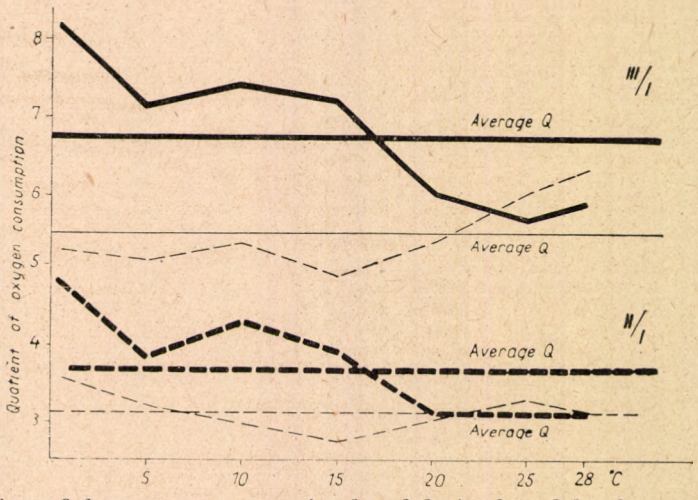

Fig. 1 Quotient of the oxygen consumption found during larval development (III/I, II/I) at the various degrees of temperature investigated. Average: Quotient of oxygen consumption. Temperature ---------- and ———— pike praelarva ▪▪▪▪▪▪▪ and ▬▬▬▬ sheat-fish praelarva

1. ábra. Oxigényfogyasztás hányadosa a lárvafejlődés során (III/I II/I) különböző vizsgált hőmérsékleten. Középérték: oxigénfogyasztás hányadosa — — — — és ———— csuka praelárva, ▪▪▪▪▪▪▪ és ▬▬▬▬ harcsa praelárva

Fig. 1 graphs the data in *Table 4* and explains them more explicitly. The changes in respiration of the pike larva are the smallest at 15° C, while higher temperatures (over 21° C) indicate more intensive changes in respiration and therefore a disadvantageous environment. The graph also shows periodical sensitiveness to changes in temperature during development.

The change in respiration of the sheat-fish larva is least at 25° C and temperatures below 15° C are unfavourable. Both these findigs have been confirmed by experiences in paratical fish breeding.

In *Fig. 2* the values for oxygen consumption calculated to 1 g dry substance are shown in mg per hour. It is also to be seen that the oxygen consumption of the pike and sheat-fish larvae as calculated to 1 g dry substance at 25 to 28° C is the same in the first and second stages and nearly the same in the third stage. At lower temperatures the larva of the sheat-fish consumes considerably less oxygen. This proves that the fish larvae developing in warmer water reacts to a cooler environment with a decrease in oxygen consumption.

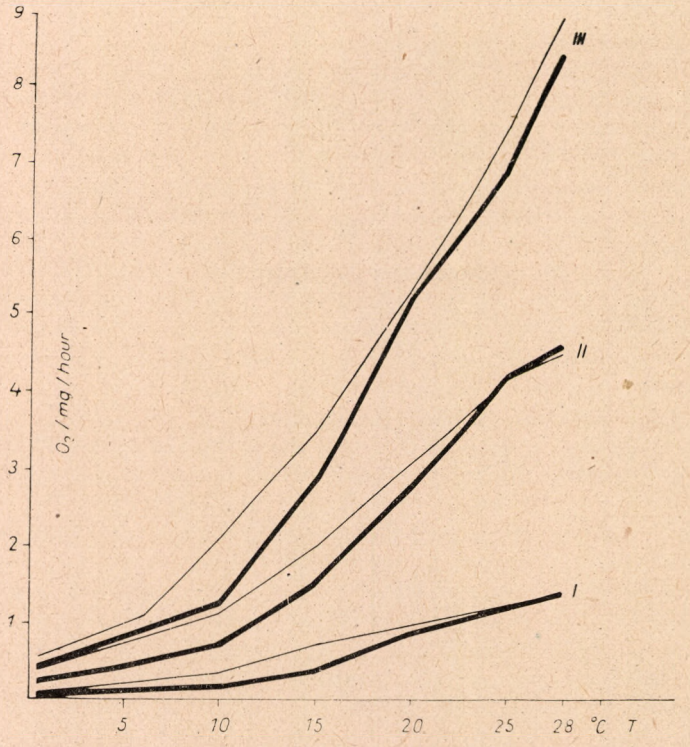

Fig. 2 Oxygen consumption mg/hour, calculated to 1 g of dry substance at three different stages of the pre-larval phase (I, II and III) of the pike and sheat-fish larva. Oxygen mg per hour (mg/h) ——— Pike prae-larva ▬▬ Sheat-fish prae-larva.

2. ábra. Csuka és harcsa praelárva oxigénfogyasztása mg/óra, 1 g SzA.-ra számítva három különböző fejlődési stádiumban. Oxigén mg/óra —— csuka, ▬▬ harcsa.

Table 4 — 4. táblázat

Temperature Hőmérséklet C°	Esox		Silurus	
	II/I	III/I	II/I	III/I
28	3,23	6,35	3,19	5,96
25	3,36	6,02	3,17	5,65
20	3,05	5,33	3,22	6,09
15	2,77	4,87	3,94	7,20
10	2,97	5,34	4,29	7,41
5	3,27	5,09	3,83	7,16
0,5	3,63	5,18	4,80	8,20
Mean V. Átlag	3,18	5,45	3,78	6,81

Quotient of the rise in oxygen consumption in comparison with the first stage of development
Az oxigénfogyasztás emelkedés hányadosa az I. stádiumhoz viszonyítva

Summary

Investigations were made to ascertain the oxygen consumption of the larvae of a fish spawning in cool water *(Esox)* and of one spawning in warm water *(Silurus)* at seven different temperatures between 0,5 and 28° C.

The oxygen consumption of 100 larvae is shown in *Table 1*, and the values (in mg/hour) of oxygen consumption as calculated to 1 g dry substance are given in *Table 2*.

The oxygen consumption was measured at these given temperatures in three different stages of development: 1. in freshly-hatched larvae (I); 2. larvae in mid-development (II); and 3. larvae respiring through the gills, the yolk substance already consumed but before they begin to food (III).

Larval oxygen consumption changes considerably with changes in temperature and as development progresses.

At the different degrees of temperature the quotient of the increase in oxygen consumption between two stages of development is not the same. The lowest quotient is found in the pike larva at 15° C and in the sheat-fish larva at 25° C. Values surpassing the mean of the quotients are for the pike (which spawns in cool water) at 25 to 28° C and for the sheat-fish (which spawns in warm water) at 15—10—5 and 0,5° C. (See *Table 4* and *Fig. 1)*.

The quotients for the oxygen consumption of the larvae in mid-development also change but in this phase of development the value of the quotient of the pike larva rises above the average at 5 and 0,5° C. This is explained by the fact that the pike larva in this stage of development is exceptionally sensitive to cold.

The oxygen consumption of the sheat-fish larva as calculated to 1 g dry substance equals that of a pike larva in the same stage and differs only at low temperatures, in which case it is considerably smaller in absolute values.

I should like to express here my gratitude to Mr. István Tölg and Mrs. Brigitte Szabó for their painstaking and valuable help during this work.

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A CSUKA *(ESOX LUCIUS* L.) ÉS HARCSA *(SILURUS GLANIS* L.) LÁRVÁK OXIGÉNFOGYASZTÁSA 0,5—28 C° KÖZÖTT

Woynárovich Elek

Összefoglalás

A vizsgálatok egy hűvös vízben ívó *(Esox)* és egy meleg vízben ívó hal *(Silurus)* praelárva fázisának oxigénfogyasztására terjedtek ki 0,5—28 °C között, hét hőmérsékleti ponton.

A 100 db lárva oxigénfogyasztását az *1. táblázat,* az 1 g szárazanyagra vonatkoztatott oxigénfogyasztás értékét (mg/óra) a *2. táblázat* tartalmazza.

A lárvák oxigénfogyasztását az adott hőmérsékleten, három különböző fejlődési stádiumban (I. frissen kikelt, II. közepesen fejlett, III. kopoltyúval lélegző, felszívódott szikzacskójú, de még nem táplálkozott) mérte meg a szerző.

A lárvák oxigénfogyasztása jelentősen változik a hőmérséklettel és a fejlődés előrehaladásával.

A különböző hőmérsékleti pontokon két fejlődési állapot közötti oxigénfogyasztás-emelkedés hányadosa nem egyforma. A legkisebb hányados a csukánál 15 C°-ra, a harcsánál 25 C°-ra esik. A hányadosok átlagánál nagyobb értékek a hűvös vízben ívó csukánál 25—28 C°, a melegvízben ívó harcsánál 15—10—5 és 0,5 C°-on voltak *(4. táblázat)* és *(1. ábra).*

A közepesen fejlett lárvák oxigénfogyasztási hányadosai is hasonlóan változnak azzal a különbséggel, hogy a csukalárvánál ebben a fejlődési állapotban az 5 és 0,5 C°-on átlag fölé emelkedik a hányados értéke. Ez magyarázatot nyer azzal, hogy a csukalárva ebben a fejlődési állapotban különösképpen hidegérzékeny.

A melegvízben ívó harcsa lárváinak az 1 g szárazanyagra vonatkoztatott oxigénfogyasztása magas hőmérsékleten megegyezik a hasonló fejlődésű csukalárva oxigénfogyasztásával, alacsony hőmérsékleten azonban ennél abszolút értékben lényegesen kisebb.