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POLSKIE ARCHIWUM HYDROBIOLOGII (Pol. Arch. Hydrobiol.)	14 (27)	2	1—10	1967

A. DUNCAN*

OSMOTIC BALANCE IN *POTAMOPYRGUS JENKINSI* (SMITH) FROM TWO POLISH POPULATIONS

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ABSTRACT

Both freshwater and brackish *Potamopyrgus jenkinsi* (SMITH) from Polish waters survived for 24 hours direct immersion into environmental salinities up to 18 ‰ but fewer could tolerate higher salinities, 18 ‰ to 34 ‰, although previous acclimatization in a lower salinity doubled the survival rate. The haemolymph of both freshwater and brackish snails was hyperosmotic from freshwater to 4 ‰, apparently is osmotic from 4 ‰ to about 18 ‰ and considerably hyperosmotic in higher salinities up to full sea water as well as showing great individual variation. In a freshwater medium, the haemolymph osmotic concentration was significantly lower in freshwater snails than in brackish ones.

CONTENTS

1. INTRODUCTION

Potamopyrgus jenkinsi (SMITH) has been recorded in Polish brackish waters since 1927 (URBAŃSKI 1935), as *P. crystallinus carinatus*, and recently has been recorded from Zalew Szczeciński and Zatoka Pomorska (WIKTOR 1962), and from Zalew Wiślany (KLIMOWICZ 1958; ŻMUDZIŃSKI 1957) as well as from Zatoka Gdańska and Zatoka Pucka. Inland freshwater records in Polnad are fewer. There are records of its occurrence in the River Odra (in BOETTGER 1951, and URBAŃSKI 1935) found it in Lake Trląg (or Pakoskie), a lake connected to the River Noteć which, in this region has a high chloride content (more than 100 mg/l; STANGENBERG, 1958) due to salt deposits in the area; no living specimens have been found here recently (1962). A new Polish record was made during the 1950 when the University of Toruń established its Limnological Station at Iława on the banks of the Lake Jeziorak. The snail was first found in considerable numbers not only in Lakes Jeziorak and Dauby but also in the nearby Lake Łabędź (GIZIŃSKI 1966). There are no records of *P. jenkinsi* east of Lakes Jeziorak and Łabędź apart from a very isolated

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record on the Rumanian shore of the Black Sea (Grossu 1951). The two populations studied here came from Lake Jeziorak at the island "Rób Co Chcesz" and from Zalew Wiślany off Piaski, where the salinity fluctuates from 3‰ to 6‰ throughout the year (Żmudziński 1957).

The snail is parthenogenetic and is some evidence that it is also polyploid in Great Britain and diploid on the Continent as Sanderson (1940) records and chromosome number of 36—44 in Scottish specimens and Rhein (1935) of 20—22 from a continental population.

2. METHODS

Potamopyrgus jenkinsi collected from lakes Jeziorak and with of a calcium content of 55.7 mg/l and Łabędź with 69 mg/l calcium and Zalew Wiślany were immediately transported back to the laboratory where they were kept in laboratory cultures at around 20°C, either in their own water or in Warsaw tap water (calcium content 100 mg/l, aerated to remove any chlorine) or in a salinity of 3‰ obtained from diluting artificial sea water made up according to Hale's (1958) formula with Warsaw tap water. The experimental solutions ranged from 34.33‰ (= 100% sea water) to freshwater and were also obtained from artificial sea water diluted with Warsaw tap water.

The experiments were all carried out at room temperature (about 20°C); a number of snails, of known length or weight with about five snails per 60 ml medium were placed in covered crystallising dishes containing the various media and left for 24 hours. Some times snails destined for higher salinities (more than 18‰ were acclimatised first for one or two days in 16‰ or 18‰). Apart from one experiment using smaller animals, the snails were all adults about 3.5 mm long and between 5 and 12 mg weights for Jeziorak snails and about 4.5 mm and between 8 and 17 mg weights for Zalew snails. Some of these snails were used for determination of the haemolymph freezing-point depression and others to assess how many survived immersion in various salinities either by observing movement in the experimental medium or by returning them for 24 hours to their normal medium.

The procedure for taking a sample of haemolymph from an individual snails was as follows. A snail was removed from the experimental medium, washed quickly to remove any saline water and, under a binocular microscope, a hole was bored into the third or fourth whorl of the shell with a needle. From this perforation, the haemolymph oozed out; it was transferred by a capillary tube to a glass cavity containing liquid paraffin. From here, samples of haemolymph were sucked up into a capillary tube of Rasotherm glass with a diameter of about 0,2 mm and made in such a way that about ten or so sub-samples of haemolymph were spaced along the tube, separated by paraffin and closed at each end by air. Only those sub-samples whose length was equal to or was twice that of the tube diameter were used for determination of the freezing-point depression (Ramsay, Brown 1955; Klekowski, 1963). Thus, each capillary tube contained a number of sub-samples of haemolymph from one snail. About 25 such capillaries were glued onto a frame together with capillaries containing sub-samples of the experimental media and of twice distilled water. The whole frame was then placed on solid carbon dioxide and frozen immediately; except on two occasions, the determinations were made on the same day.

The freezing-point depression was measured by means of a cryoscope designed by RAMSAY and BROWN (1955) and modified by KLEKOWSKI (1963); the procedure used is described in KLEKOWSKI (1963). The apparatus error determined by repeated measurement of a known salinity several times was ± 0.005°C (KLEKOWSKI: personal communication); repeated freezings of the same set of haemolymph sub-samples revealed that the error for snail haemolymph was greater, being ±0.010°C for haemolymph from media below 18‰ and ±0.020°C from media above 18‰.

3. RESULTS

Potamopyrgus jenkinsi from both brackish water and freshwater populations can live for a long time in all salinities up to and including sea water, providing that before immersion into higher salinities, they have been previously acclimatised in a lower salinity (BOYCCTT 1936; ADAMS 1942; TODD 1964; DUNCAN 1967).

As snails both after direct immersion into various salinities and after previous acclimatisation were used for the measurement of the freezing-point depression, it was necessary to know what proportion of them could survive such treatment. Figure 1 shows the percentage survival after 24 hours of adult snails (more than 3.5 mm long) from the two population either after direct immersion in various salinities or after previous adaptation in 16‰ or 18‰. All snails from both populations survived direct immersion into salinities up to 16‰ or 18‰ but in higher salinities the percentage survival decreased rapidly until it was only 10% in full sea water. Previous acclimatisation in 16‰ or 18‰ almost doubled the percentage survival in each of the higher salinities. Figure 2 shows similar results for snails smaller than 3.5 mm length; again 18‰ was the upper limit for 100% survival of direct immersion into various salinities of snails 1.0, 1.5, 2.0 and 2.5 mm long.

Figure 3 shows the relatin between the osmotic concentration of the haemolymph, as measured by the freezing point depression, of the 194 Jeziorak snails and 194 Zalew snails to the concentration of the experimental medium, after 24 hours immersion, either directly or after previous acclimatisation. Each point represents the mean of up to five snails; those ringed refer to acclimatised snails and the heavily marked points to those means significantly different from the medium (P 0.05), taking into account the error of 0.010°C or 0.020°C involved in determining the freezing-point depression of snail haemolymph.

The curves for both populations are very similar in pattern; from freshwater to about 4‰, the haemolymph is significantly hyperosmotic to the medium (N = 3 to 11 snails, t = 2.6 to 22.4 and P 0.05); from 4‰ to about 18‰, the haemolymph of Jeziorak snails was isoosmotic to the medium but appears to be hyperosmotic in Zalew snails, but not significantly so. Above 18‰, the haemolymph is considerably hyperosmotic to the medium in both populations although less so in acclimatised snails. However, the differences in concentration between the haemolymph and medium was significant in only nine out of 25 Jeziorak snails (N = 3 to 5 snails, t = 2.8 to 19.6 P 0.05) and in only eleven out of twenty Zalew snails (N = 3 to 5 snails, t = 3.2 to 18.4, P 0.05) in the higher sali-mities

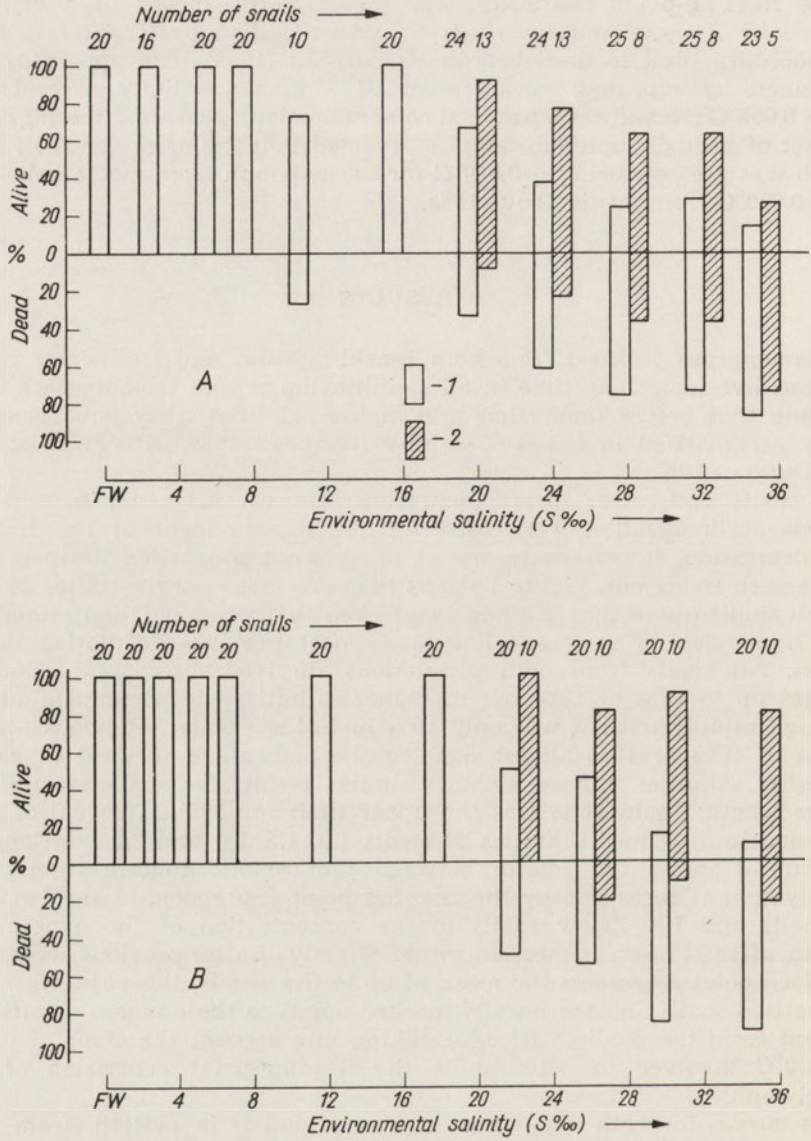

Fig. 1. Survival after 24 hours of adult *Potamopyrgus jenkinsi* in various salinities, either after direct immersion (1) or after more than 24 hours acclimatization (2) in 16 ‰ or 18 ‰ (1 or 2). A. Zalew Wiślany, B. Lake Jeziorak

In these high salinities, the haemolymph osmotic concentrations of individual snails were very variable in any one salinity and particulary among those snails not previously acclimatised. This is to some extent revealed in figure 4 which gives the values for the standard error of the mean for samples of 3 to 5 snails in various salinities. Above about 18 ‰ the standard

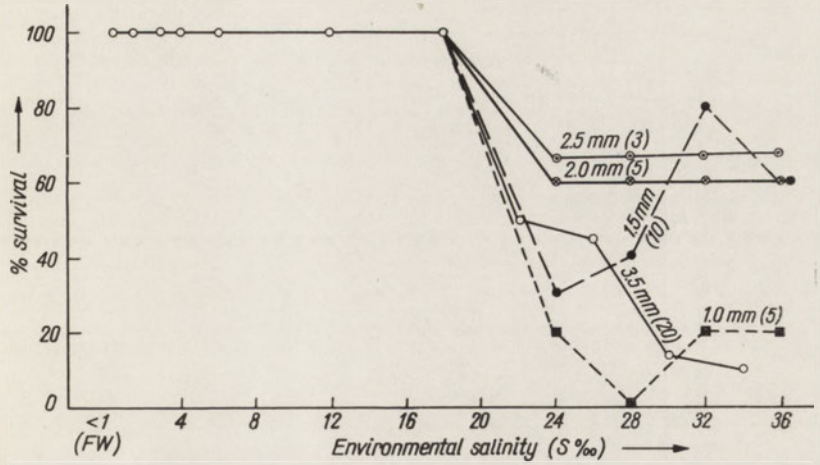

Fig. 2. Survival after 24 hours of different sizes of *Potamopyrgus jenkinsi* from Lake Jeziorak after direct immersion in various salinities

errors are double or treble the values below 18‰. To some extent this is to be expected in higher salinities but in these, many of the sub-samples were not clear and transparent and seemed to contain a certain amount of "debris". This may represent some breakdown of control due to shock of rapid transfer to highly saline media or may be a post-mortum condition (Fig. 1).

Table I

The osmotic concentration of the haemolymph or urine in freshwater of *Potamopyrgus jenkinsi* from various freshwater and brackish water populations

Locality	Δt° Medium	N	Δt° haemolymph urine	SD	SE	Author
Lochend Loch (FW) 1	0,03	20	(0.17) 0.21	0.045	0.010	Todd 1964
Lochend Loch (FW) 2	0.03	16	(0.18) 0.22	0.030	0.007	Todd 1964
Dunbar (BW) 2,4	0.01	11	(0.15) 0.17	0.028	0.008	Todd 1964
Dunbar (BW) 2,5	0.01	14	(0.20) 0.24	0.017	0.005	Todd 1964
Aldeburgh (BW) 2	0.02	3	(0.16) 0.19	0.032	0.018	Todd 1964
Bathesland (FW) 2	0.01	9	(0.15) 0.17	0.030	0.010	Todd 1964
Zalew Wiślany (BW) 3	0.01	15	0.21 (0.25)	0.031	0.008	Duncan
Lake Jeziorak (FW) 3	0.02	11	0.17 (0.21)	0.024	0.007	Duncan
Lake Łabęź (FW) 3	0.02	10	0.17 0.14	0.012	0.004	Duncan
Lochend Loch* 3						
Dunbar snails 2	—		0.18 0.15	—	—	Todd 1964

* A calculated freezing-point depression based on Todd's finding that, in freshwater, the osmotic concentration of the urine of three Dunbar and eight Lochend Loch snails was 83% that of their haemolymph.

1 at temperature 5°C. 2 at temperature 15°C. 3 at temperature 20°C. 4 in Lochend Loch freshwater 5 in Cambridge lap water.

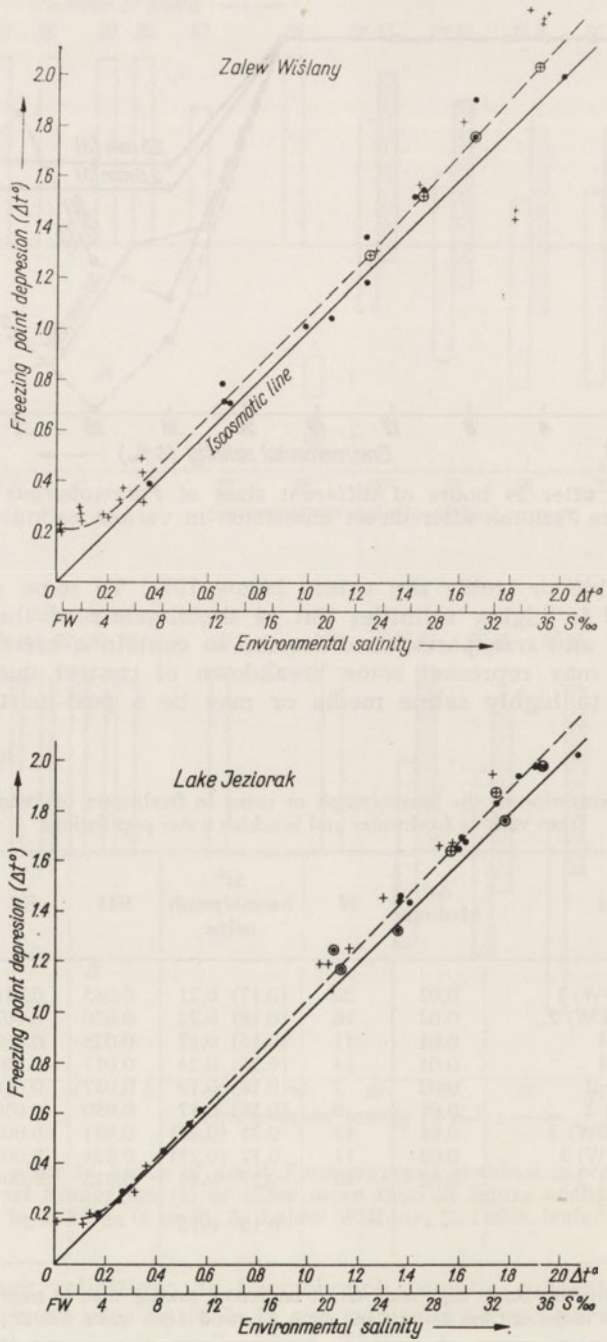

Fig. 3. The relation of the osmotic concentration of the haemolymph to the concentration of the medium in *Potamopyrgus jenkinsi* from Lake Jeziorak and Zalew Wiślany

Table I gives a comparison of the osmotic concentrations of the haemolymph or urine in freshwater of *Potamopyrgus jenkinsi* from various freshwater and brackish water populations as measured by Todd (1964) or Duncan; to the table have been added calculated values for the body fluids not measured directly, namely, haemolymph in the British snails and urine in the Polish snails, based on Todd's finding that, in a freshwater medium, the osmotic concentration of the urine of three Dunbar snails and eight Lochend Loch snails was 83% that of their haemolymph.

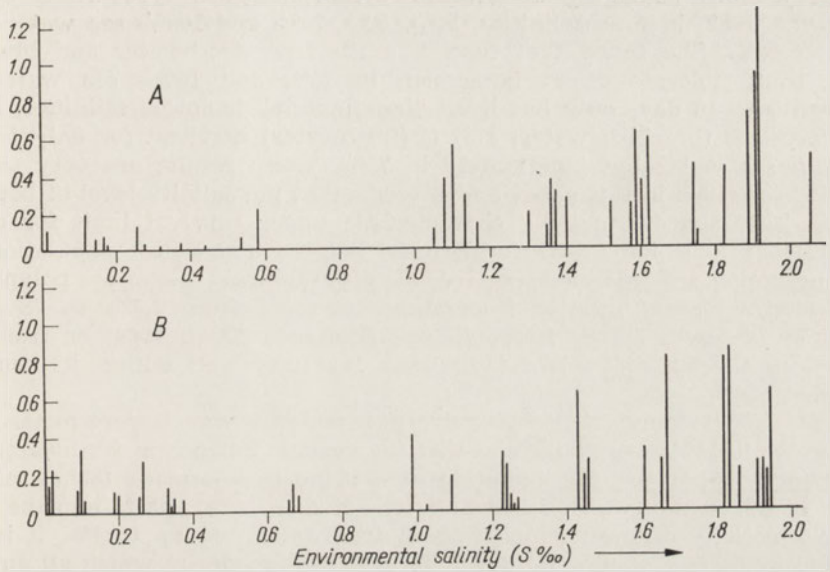

Fig. 4. Values for the standard error of the mean haemolymph osmotic concentration for snail samples in various salinities. A. Zalew Wiślany, B. Lake Jeziorak

The highest values for Δt of either the haemolymph or the urine were found in brackish water populations tested in a freshwater medium with a high calcium content, namely, in Dunbar snails in Cambridge tap water (with 252.8 mg/l total solids, Todd 1964); 51 mg/l calcium (Weil, Pantin, 1931) or in snails from Zalew Wiślany in Warsaw tap water (100 mg/l calcium). The urine freezing-point depression for other British snails was measured in soft water (either 39.6 mg/l calcium or 45 mg/l total solids) and were significantly lower than those for snails kept in Cambridge tap water (Todd 1964). The Polish freshwater snails from Lake Jeziorak, which contains 55.7 mg/l calcium, and from Lake Łabędź, with 69 mg/l calcium, were tested in Warsaw tap water; the osmotic concentration of the haemolymph of these was significantly lower than that of the brackish water Zalew Wiślany, also in freshwater ($N = 15$ and 11, 10; $t = 3.74$, 3.77; $P = 0.002$, 0.001). However, when the osmotic concentration of the haemolymph of Polish freshwater snails was compared with the calculated values of haemolymph concentration of the British freshwater (Lochend Loch, Bathesland) and brackish water (Aldeburgh Dunbar in soft water) populations, the differences were not significant, despite the difference in calcium content of the experimental media.

4. DISCUSSION

Adams (1942) found that all the tested animals from a freshwater Belgian population of *Potamopyrgus jenkinsi* survived for a month the direct transfer from freshwater to salinities from 2‰ to 20‰ but only nine of twenty survived in 22‰ and no snails in 24‰. However, progressive transfer of these snails to higher salinities enabled a few animals to survive up to 32‰ but this was the absolute upper limit. Todd (1964) tested British specimens of *Potamopyrgus jenkinsi* belonging to Warwick's morphological types A, B and C (Warwick 1952) in four salinities, 25%, 50%, 75% and 100% sea water from Millport 32‰. She found that type A snails from freshwater and brackish water could tolerate direct immersion in 75% and 100% sea water for between 7 to 10 days only but lived "indefinately" in lower salinities. However, types B (brackish water) and C (freshwater) survived for only 5 days in 100% sea water but indefinately in 75%. These results are very similar to those described in this paper and it seems that the salinity level of between 18—20—22‰ appears to be a characteristic upper survival limit for direct immersion into saline media for British, Belgian and Polish populations of *Potamopyrgus jenkinsi*, irrespective of geographical range or polyploidy. Thus environmental salinity fluctuations such as from 1.5% to 78% sea water in 24 hours in the River Leven, Scotland, (Todd 1964) or from 3% to 65% in the Randjer Fjord (Johansen 1918) are well within its capacity for tolerance.

Todd (1964) found that *Potamopyrgus jenkinsi* was hyperosmotic from freshwater to 100% sea water and that the osmotic balance in freshwater was maintained in part by the excretion of a urine hypo-osmotic (83%) relative to the blood. In the two Polish populations studied here, apart from the clear hyper-osmoticity of the haemolymph in freshwater and up to 4‰, it is difficult to be certain of this. Between 4‰ and 18‰, media in which all animals survived (Fig. 1) and were fully capable of movement (Duncan 1967), in neither population were any the observed differences between the haemolymph and the medium significant. Above 18‰, where the mean concentrations of the haemolymph were considerably greater than that of the medium, only 36% (Jeziorak) or 55% (Zalew) of them differed significantly due to very wide variations in individual measurements; in these salinities, a high proportion of the animals were already dead.

Todd (1964) found that the osmotic concentration of the urine of Dunbar snails in hard Cambridge tap water (51 mg/l: Weil and Pantin 1931) was significantly higher than that of snails tested in soft water from Lochend Loch water (39 mg/l calcium) and suggested that this was due to decreased permeability in water with more calcium. The urine of the other British snails were measured in soft freshwater and had lower osmotic concentrations than the Dunbar snails in hard freshwater. However, all the Polish snails were measured in freshwater with a high calcium content of 100 mg/l and yet the haemolymph osmotic concentration in freshwater of both Jeziorak and Łabędź snails were significantly lower than that of the brackish Zalew snails whereas there were no differences with the calculated haemolymph values for the British snails other than from Dunbar and in hard freshwater. It appears that some factors in addition to calcium level are involved here, which may be genetic but do not appear to be related to any differences between British-Polish populations.

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5. SUMMARY

1. The osmotic concentration of the haemolymph of *Potamopyrgus jenkinsi* from Polish freshwater and brackish water populations was studied in various environmental salinities, by determination of the freezing-point depression.

2. Both freshwater and brackish water snails survived for 24 hours direct immersion into salinities up to 18‰ but fewer could tolerate higher salinities, 18‰ to 34‰ although previous acclimatization in a lower salinity doubled the survival rate.

3. Both freshwater and brackish water *Potamopyrgus jenkinsi* were hyperosmotic from freshwater to 4‰, apparently isoosmotic from 4‰ to about 18‰ and considerably hyperosmotic in higher salinities up to full sea water, but with great individual variation.

4. When tested in freshwater, the haemolymph osmotic concentration in freshwater snails was significantly lower than in brackish water snails.

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K. STANGENBERG-OPOROWSKA

SODIUM CONTENTS IN CARP-POND WATERS IN POLAND

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ABSTRACT

Sodium content in the waters of ponds examined (83 carp ponds) ranged from 0.5—10.0 mg/1, most frequently 2—6 mg/1, sporadically much more (several tens mg/1 of the geological or pollution origin). No significant differences were found in sodium content between spring and late summer, although a considerable increase in sodium content can be brought about by an intensive evaporation of water. A positive correlation was found between the amounts of potassium and sodium in the pond waters.

CONTENTS

1. INTRODUCTION AND METHODS

It is still very little known about the occurrence, and particularly about metabolism of sodium (RUTTNER 1962). However, studies carried out so far (STILES 1958) suggest that sodium together with aluminium, silicon, chlorine and gallium belongs to fundamental life elements of some plants. As the contents of this component in plants may oscillate within very broad limits, while the contents of potassium are more or less constant, hence the ratio K/Na in plants may be very broad, from 1,15 to 1057 (BERTRAND, PENITZEAU, 1927a, b). The contents of sodium in the dry matter of some halophytes in Neusiedlersee were found to reach even 5% (ZELLNER 1926). Potassium can be replaced by this element, only partially and in particular cases, and the role of sodium in some physiological activities of plants (e.g. transpiration) is very important.

This paper is the first attempt to study the range and frequency of occurring of this cation in pond waters of Poland. The determination of sodium contents was made with Zeiss flame photometer in spring and at the end of the productive season 1962, together with determination of potassium (see OPO-

RCWSKA 1967). Samples of water were collected from 83 carp ponds belonging to 8 administrative units of the Polish Fish Husbandry. In addition sodium contents were examined several times in 17 ponds of the fish-farms at Milicz during the whole vegetation period i.e., from 3 April to 10 September 1962. The materials under discussion (260 determinations altogether) could not, however, take into account the most interesting, though almost unknown, biological rôle of this element in this environment.

2. RESULTS

A. RANGE OF OCCURRENCE

1. Modrzejowice Unit, voivodship Kielce

Sodium content in pond waters of this unit ranged from 1,0 to 2,9 mg/l Na in spring, from 0,5 to 2,6 mg/l Na in late summer. The least quantity of sodium was found in the following ponds; Stary Młyn (1,0 mg/l Na, 4 May 1962 and 5 September 1962) Sycyna (spring 1,5 mg/l Na, late summer 1,2 mg/l Na), Gródki 1 (spring 1,7 mg/l Na, late summer 0,9 mg/l Na) and in some other ponds. In all the 12 investigated ponds (Fig. 1) a diminution of sodium content was clearly noticeable towards the end of the vegetative period to be explained most probably by a pronouncedly rainy weather prevailing at that time.

2. Skępe Unit, voivodship Bydgoszcz

The ponds of the husbandry Chałacie belonging to this complex were characterized by very small oscillations in sodium content both in spring (1,0—1,5 mg/l Na) and in late summer 1962 (1,3—1,5 mg/l Na), except for the pond nr. 8, where the sodium amount was 3.1 mg/l Na (Fig. 1). In feneral, towards the end of the vegetative period the sodium quantity increased slightly, two ponds being exceptions.

3. Charzyków Unit, Kamienica fish farm, voivodship Bydgoszcz

The amount of sodium in the ponds of this unit was from 2.0 to 2.7 mg/l Na, the oscillations being insignificant and similar both in spring and late summer 1962 (Fig. 1).

4. Łyszkowice Unit, voivodship Łódź

At the end of the breeding season, sodium contents were conspicuously smaller in the ponds of Łyszkowice (1.7—1.8 mg/l Na) than in the ponds of Walewice, Przesławice and Psary (2.4—3.4 mg/l Na) where the content was almost twice as high. This seems to be related with the different character of the bottom.

5. Zator Unit, voivodship Katowice

Sodium amounts in the waters of this unit were in spring 2.7—4.5 mg/l Na, reaching in autumn 1,7—3,7 mg/l Na. This conspicuous decrease of sodium (Fig. 1) towards the end of the vegetative period permits including this ponds into a group of ponds rather "poor" in sodium. It was correlated with a decrease in potassium content at this time (OPOROWSKA 1967).

6. Dębowiec Unit, voivodship Katowice

Sodium contents in the waters of this unit were relatively low (1.5—3.0 mg/l Na) in spring but this amount grew up at the end of 1962 (1.9—4.2 mg/l Na, Fig. 1). During 1962, seven ponds of the Milicz Unit, and eight of the Slesin

Unit had the highest amounts of this element (3.2—10.0 mg/l Na and 3.1—76.0 mg/l Na). These last extreme amounts of sodium in pond waters were undoubtedly derived from the bottom (Inowrocław Basin) and from a considerable salt content of tributary waters.

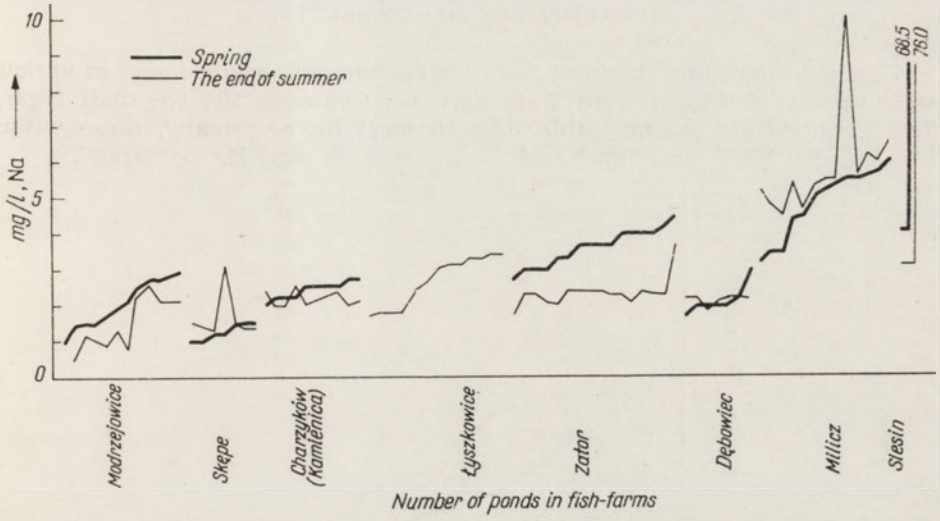

Fig. 1. Occurrence of sodium in Polish carp pond waters in spring and late summer 1962

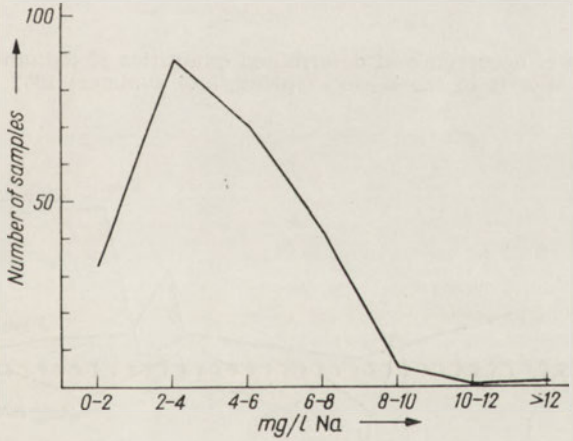

Fig. 2. Frequency of occurrence of determined quantities of sodium in various Polish ponds in 1962

As demonstrated by the above given characteristics the sodium content in Polish pond waters ranged from 0.5 to 76.0 mg/l Na, and there was no one case in which its amount would fall down to analytical zero in litre. Setting aside the results connected with the geological character of the inflowing waters (saltbearing sources of Inowrocław) and the pollutions of

western Pomerania, we can assume the limits of 0.5—10.0 mg/l Na as characteristics amounts of sodium for Polish ponds, with all the higher quantities caused by artificial or natural pollutions.

B. FREQUENCY OF OCCURRENCE

Figure 2 shows that the most frequent amounts of sodium found in various pond waters of Poland were 2—6 mg/l Na. Consequently, we shall regard the quantities of sodium within 0.5—2.0 mg/l Na as "small", those within 2,0—6.0 mg/l Na as "medium" and those above 6.0 mg/l Na as "large".

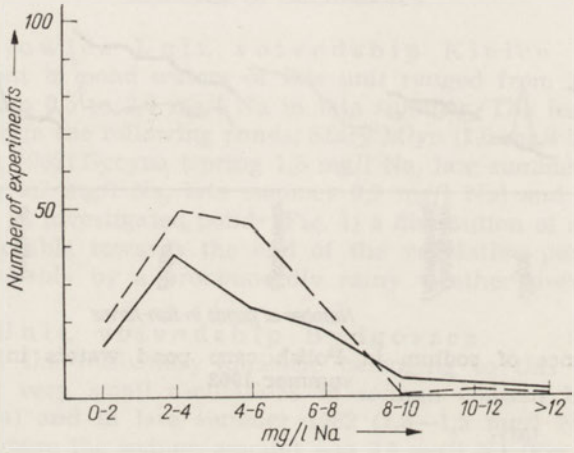

Fig. 3. Frequency of occurrence of determined quantities of sodium in various Polish ponds in the season (spring, late summer) 1962

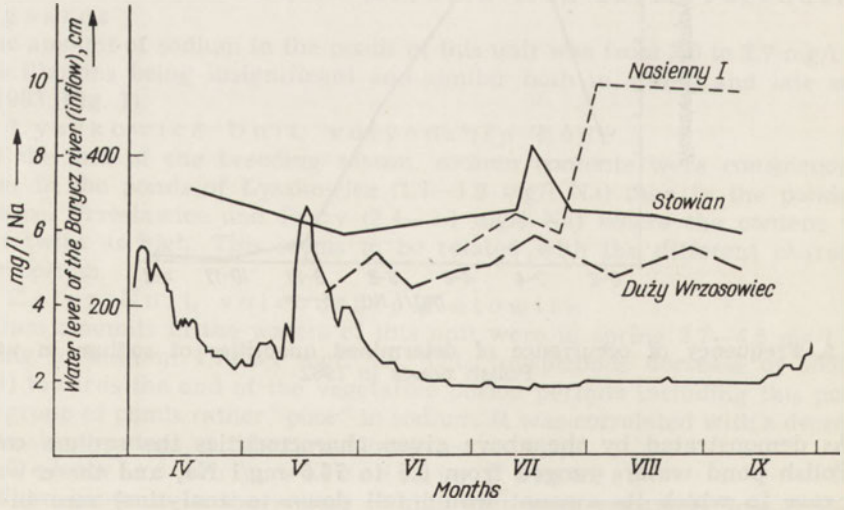

Fig. 4. Changes of sodium contents in pond water during the vegetation period compared with the water level of the river Barycz (inflow)

Figure 3 makes clear that the most frequent amount of sodium found both in spring and autumn was the same; 2—6 mg/l Na with a great deal of samples in this range in autumn. It seems that the climatic conditions have no influence on this cation in this time.

C. SEASONAL CHANGES

Analysis of materials which were collected every month (or more often) during the whole year 1962 from several ponds of the fish-farms Milicz, showed that changes in sodium contents of the separate ponds (Tab. 1) during the productive season were expressed by differences ranging from 1.1 mg/l Na to 4.5 mg/l Na (ponds: Wilczy Mały and Nasienny I).

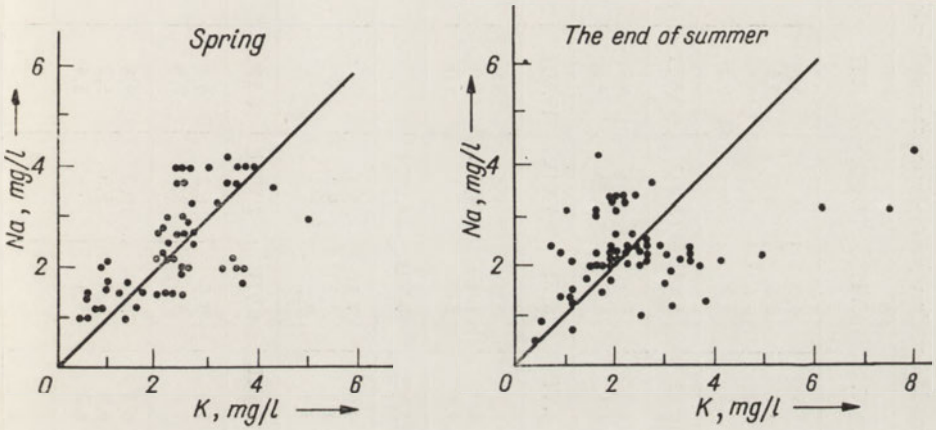

Fig. 5. Correlation between sodium and potassium amounts in the Polish carp-ponds, 1962

In that, thay were approaching the order established for potassium. The data obtained for the ponds Wrzosowiec Duży (Unit Wierzchowice) Słowian (Unit Milicz) and Nasienny I (Unit Radziądz), seem to point to the fact that water level of the river Barycz, did not affect, as might have been supposed, changes found in them (Fig. 4). Most probably intensive evaporation rate caused by higher air — temperature played an important rôle.

3. CORRELATION IN OCCURRENCE OF SODIUM AND POTASSIUM

Mutual relations of potassium and sodium are represented in Fig. 5. As may be seen, a correlation between these two cations proved positive, especially for spring period.

Small sodium contents in pond water may thus indicate its poverty in potassium and vice-versa.

Table I

Sodium contents in the waters of some Milicz Unit ponds during the production period 1962 (mg/l Na)

Fish-farm Milicz	3.IV.	17.IV.	28.V.	13.VII.	17.VII.	26.VII.	16.VIII.	10.IX.		Range of fluctuation
Pond Staś Górny	5,6	7,3	5,5	6,0	6,7	5,5	6,2	5,9		5,5—7,3
Staś Dolny	—	5,8	6,0	6,0	8,0	5,5	6,5	6,3		5,5—8,0
Słowian	—	7,3	6,0	6,6	8,2	6,5	6,3	5,9		5,9—8,2
Wilczy Mały	—	—	5,2	5,5	—	6,3	5,5	5,2		5,2—6,3
Potasznia fish farm	23.V.	6.VI.	16.VI.	5.VII.	12.VII.	19.VII.	24.VII.	10.VIII.	10.IX.	
Pond Władysław	3,5	6,0	4,0	5,0	6,0	6,0	6,0	4,7	4,9	3,5—6,0
Jasny Górny	3,2	5,7	4,5	5,7	6,0	4,5	4,5	5,3	5,3	3,2—6,0
Fish farm Wierzchowice	23.V.	6.VI.	14.VI.	26.VI.	4.VII.	17.VII.	8.VIII.	27.VIII.	10.IX.	
Pond Wrzosowiec Duży	4,4	5,5	4,5	5,0	5,2	5,9	4,8	5,5	5,1	4,4—5,9
Chełm	3,5	4,7	4,0	4,0	7,0	5,9	3,4	4,5	4,2	3,4—7,0
Brzozowy	4,5	6,0	4,0	5,0	7,3	5,0	4,0	4,6	4,3	4,0—7,3
Fish farm Ruda Suł.	23.V.	8.VI.	25.VI.	19.VII.	14.VIII.					
Pond Bliźniaczy Mały	5,0	7,2	9,0	7,5	5,3					5,0—9,0
Bliźniaczy Duży	5,7	7,5	4,5	7,2	6,0					4,5—7,5
Prostokątny	5,5	6,0	5,5	7,2	5,5					5,5—7,2
Fish farm Radziądz	14.VI.	26.VI.	12.VII.	24.VII.	2.VIII.	10.IX.				
Pond Jeleni I	5,5	—	7,0	5,5	6,3	6,1				5,5—7,0
Jeleni II	6,0	—	7,0	5,5	8,0	7,8				5,5—8,0
Nasienny I	—	5,5	6,5	6,0	10,0	9,8				5,5—10,0
Nasienny II	—	5,3	6,0	6,5	5,5	5,2				5,2—6,5
Nasienny III	—	—	6,7	5,8	—	5,4				5,4—6,7
Full range of fluctuation										3,2—10,0

4. SUMMARY

The range of sodium contents in Polish pond waters is 0.5—10.0 mg/l Na, in some single cases (geological character of salt-bearing inflows, pollution) goes to the order of some tens milligrames in a litre (Fig. 1).

The most frequent values in this range of occurrence were lying in the limits 2—6 mg/l Na (Fig. 2). On this basis quantities within 0.5—2.0 mg/l Na may be regarded as "small", those between 2—6 mg/l Na, as "medium" and those exceeding 6.0 mg/l Na, as "large".

A segregation of samples into a spring group and a late sammer group (Fig. 3) has shown no differences in extreme frequenties of sodium, which in both periods kept in limits of 2—6 mg/l Na. Greater oscillations in the content of this element may be brought about, before all, by climatic conditions, among which the chief rôle seems to play the process of evaporation (Fig. 4).

There is a positive correlation between sodium and potassium (Fig. 5).

5. STRESZCZENIE

Zawartości sodu w wodach stawowych Polski leżą w zakresie 0.5—10,0 mg/l Na, a w szczególnych przypadkach (charakter geologiczny zlewni i zanieczyszczenia) sięga kilkudziesięciu miligramów w litrze (rys. 1). Najczęściej napotykane wartości w granicach 2—6 mg/l Na (rys. 2). Na tej podstawie za „małe" ilości sodu przyjęto uważać te, które leżą w granicach 0.5—2.0 mg/l Na, „średnie" — od 2 do 6.0 mg/l Na, zaś jako „duże" — powyżej 6.0 mg/l Na.

Podział prób na grupę okresu wiosennego i późnego lata (rys. 3) nie wykazał różnic w wartościach najczęstszych występowania sodu, które w obu okresach napotykano najliczniej w granicach 2—6 mg/l Na. Większe wahania wywołane być mogą przede wszystkim przyczynami klimatycznymi, wśród których główną rolę wydaje się odgrywać parowanie (rys. 4).

Stwierdzono istnienie pozytywnej korelacji między zawartościami sodu i potasu występującymi w wodach stawowych.

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THE OSMOTIC PRESSURE OF EGGS FROM LAKE WDZYDZE TROUT (*SALMO TRUTTA M. LACUSTRIS* L.) DEVELOPING IN WATER OR PARAFFIN OIL

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ABSTRACT

By measuring the freezing point depression of the perivitelline fluid and of the yolk of trout eggs developing in water ("W-eggs") and in paraffin oil ("P-eggs"), it was found that, whereas in W-eggs a slight hypertony develops in the perivitelline fluid, the increase in hypertony in P-eggs was much greater, especially towards the end of development, when a very violent increase occurred. In contrast, the osmotic pressure of the yolk was approximately constant, similar in both W- and P-eggs and independent of the osmotic conditions in the perivitelline fluid.

CONTENTS

1. INTRODUCTION AND PROBLEM

When ripe salmonid eggs are placed in water, water is taken up and the eggs membranes become separated so that the perivitelline space becomes occupied with a fluid. During embryonic development there is continuous inter-change of water and substances between the egg and its external environment (KROGH, USSING 1937; KALMAN 1959; ZOTIN 1961; POTTS, PARRY 1964). Until now, measurements of the osmotic pressure of the intramembrane fluids (SVELTOV 1928, 1929) suggest that the osmotic pressure is fairly constant and differs little from that of the water surrounding the egg.

Earlier work of one of us (DOMURAT 1956) whose aim was to determine the relationship between changes in the egg's water and the growth of the embryo, shows that eggs placed in an environment of paraffin oil, that is without water, can develop up to just prior to hatching although measurements of the embryos reveal that they are almost twice as small as those of the control, that the mortality rate of eggs during development is very great and that

hatching does not follow (Domurat 1964b). Moreover, the volume of the perivitelline fluid decreased considerably in eggs developing in paraffin oil.

The impossibility of water and dilutal compounds exchange with the external environment in paraffin oil as well as the observed decrease in the perivitelline fluid led us to investigate the changes in osmotic pressure in the perivitelline fluid of eggs as the medium directly in contact with the embryo; both in eggs developing in water and paraffin oil. In addition we tried to check whether in these environments there are any changes in the concentration of osmotically active substances in the yolk of the developing embryos.

2. MATERIAL AND METHODS

Eggs used in these experiments came from female Wdzydze trout (*Salmo trutta m. lacustris* L.) captured from Lake Wdzydze (Kościerzyna district, Gdańsk county). The female was stripped of her eggs at the lakeside on 12 Nov. at 15.00. After fertilisation, the eggs were placed in a litre thermos flask containing iced water and transported to Warsaw. During transport, which lasted 18 hours, the water temperature varied between 4—6°C and the mortality was not greater than 1%. When the experiment began, the embryos consisted of 2—4 blastomeres.

Eggs selected for experimental work on 13 Nov. had their surface water removed by gently rolling them on filter paper by means of a goose feather. A sample of ca. 50 eggs placed in 30 10-cm Petri dishes. To 15 of these dishes was added tap water, previously kept for about two weeks in a large continuously aerated tank. The eggs, lying on the bottom, were covered with 5 to 7 mm of water. In the remaining 15 dishes a similar amount of paraffin oil was added instead of water, also covering the eggs with 5—7 mm layer. All the dishes were covered with lids and placed in a refrigerator, without light and at temperature of 9.6°—9.8°C for 7 days and later kept at $9.0° \pm 0.5°C$; the temperature was continually recorded.

The freezing-point depression was measured by means of a microcryoscope. This apparatus is a modified Ramsay (1955) microcryoscope; the main modification consisted of a frame capable of holding at the same time 30 capillaries (Klekowski 1963); the possibility of moving both the frame and the microscope permitted good observation of all the capillaries. Despite the unfavourable opinion of Ramsay (1955), a polarising filter was used, with a polarisor directly in front of the lamp and an analyzer lying between the microscope objective and the ocular. The polarising greatly improved the differentiating capacity of the microscope and was particularly useful for perceiving the very small crystals of ice, whose final melting it is very important to observe. When the temperature was approaching the expected melting point, its increase was slowed down to about 0.01°C per 2 minutes; the temperature was read to within 0.005°C.

After their removal from the Petri dishes containing either water or paraffin oil, the eggs were again gently rolled on filter paper with a goose feather in order to remove the water or oil. The eggs were placed singly in the hollowed glass plates with paraffin oil; here with the aid of binocular magnification, they were grasped gently with forceps in such a way that the animal pole lies to one side thus ensuring that the perivitelline space lies also on

the side. The yolk membrane was perforated; for this the best instrument is a selected cactus spine fastened with sealing wax to a glass rod. From the opening made in the membrane a drop of perivitelline fluid passes into the surrounding paraffin oil and is then drawn up from under the paraffin into glass capillaries; these glass capillaries had one narrowed and fused end which was broken off just before the fluid samples were taken.

The yolk itself was also collected in this manner, i.e. using capillaries with one narrowed and fused end, also broken until just before use, so that it could be quickly inserted right into the centre of the yolk sphere. The yolk fluid flowed up the capillary until a rapid movement removed it from the egg. Only the yolk from the centre of the sample in the capillary was used for freezing-point determinations.

The perivitelline and yolk fluids collected in this manner were then blown out into a series of oil-filled small depressions in a glass plate. When a series of such samples had been collected on any given day, they were transferred to the measuring capillaries in the following manner. On the end of a bent glass tube with a rubber tube mouthpiece was placed a measuring-capillary (ϕ = 0.1—0.2 mm); by gentle sucking and blowing, about 10 to 20 specimens of the fluid from one sample separated from each other by paraffin oil were drawn up; it was important that length: width ratio of these fluid specimens was about 1—2.

In addition to the yolk and perivitelline fluid, the following fluids were also sampled in order to determine their freezing point depression. Firstly in the neighbourhood of the eggs developing in paraffin oil, some fluid tended to collect which created bridges between eggs lying in contact. This fluid either has been secreted by the developing eggs or consists of remnants of the water on the surface of the eggs left even after drying them on filter paper; however, such bridges were not created immediately after placing the eggs in paraffin oil. Secondly samples of the water from the Petri dishes in which the eggs had developed were taken for freezing-point determination.

It often happened that the perivitelline and yolk fluids became contaminated with each other during collection; such samples were rejected and no determinations made upon them. Also ommitted from the final results were those samples whose freezing-point depression indicated quite clearly that such a mixing of perivitelline and yolk fluids occurred, although not observed during the taking of the samples. The number of utilized determinations of freezing-point depression was 231.

Both in water and in paraffin oil the survival rate was 100% during the first two weeks of development. After this period, only those eggs with embryo in which heartbeat was perceptible were selected for determinations.

The stage of development of individual embryos is given in terms of day degrees that is, the sum of products of number of days of development and temperatures. This way of expressing the age of embryos has often been used (e.g. Embody 1935; Ljubitzki 1934/35; Orska 1956) and is both a simple and comparative expression of the physiological age of fish embryos. The characteristic periods of development were established by analysing all eggs used for freezing-point depression measurements fixed in Bouin's fluid and preserved in 75% alcohol.

3. RESULTS

The results are illustrated in Table I which gives the mean values as well as in Fig. 1 giving individual points for each determination together with the mean values. These suggest the following interpretation.

1. In eggs developing in water, the osmotic pressure of both the perivitelline and the yolk fluids maintained themselves at an approximately constant level throughout the whole period of development. The absolute deviations of values of freezing-point depression were similar in both investigated parts of developing eggs: from 0.010° to 0.050°C for the perivitelline fluid and from 0.545° to 0.580°C for the yolk itself. Thus, the osmotic pressure of the perivitelline fluid is higher than that given by SVETLOV (1929).

Table I

Freezing-point depression of the perivitelline fluid and yolk in trout eggs developing in water and in paraffin oil

Date	Day degrees	Stage of development both in water and in paraffin oil	Freezing-point depression averages $\Delta t° \cdot 10^{-3}$					
			Development in water		Development in paraffin oil			
			Perivitellinum	Yolk	Culture water	Perivitellinum	Yolk	"Bridges"
23.XI	104	3/4 of epibolie	17		25		548	30
26.XI	131	closing of blastopore	27		10	51		40
30.XI	167		23		5	68		40
6.XII	221	beginning of pigmentation	22	554	10	52	545	40
10.XII	257	pigmentation	28	559	15			
15.XII	302		40	572	25			
16.XII	311					89	553	70
18.XII	329		26	556	15	98	554	
22.XII	365		42	555	35	109	554	105
29.XII	428		31	548	25	188	557	
2.I	468	beginning of hatching in water						
4.I	473		30	552	30	263	548	

2. During the closure of the blastopore (after about 130 day degrees after fertilisation) there occurred a period of hypertony of the perivitelline fluid by about 0.020° which lasted until about 300 day degree. Then, the hypertony of this fluid became less and, just before hatching, the fluid was isotonic with the external medium. This period of hypertony (from 130 to 330 day degrees) is quite a clear phenomenon as all the samples of perivitelline fluid were at that time hypertonic to the external medium.

3. The osmotic hypertonic pressure of the perivitelline fluid of eggs developing in paraffin oil was considerably higher than those in water, at least from 130 day degrees onwards (as earlier determinations were not made). In these eggs in paraffin oil the freezing-point depression of the perivitelline fluid increased throughout the developmental period and particularly from 300 day degrees onwards. During the closure of the blastopore, the freezing-point depression of the perivitelline fluid in eggs in oil had a mean value of about

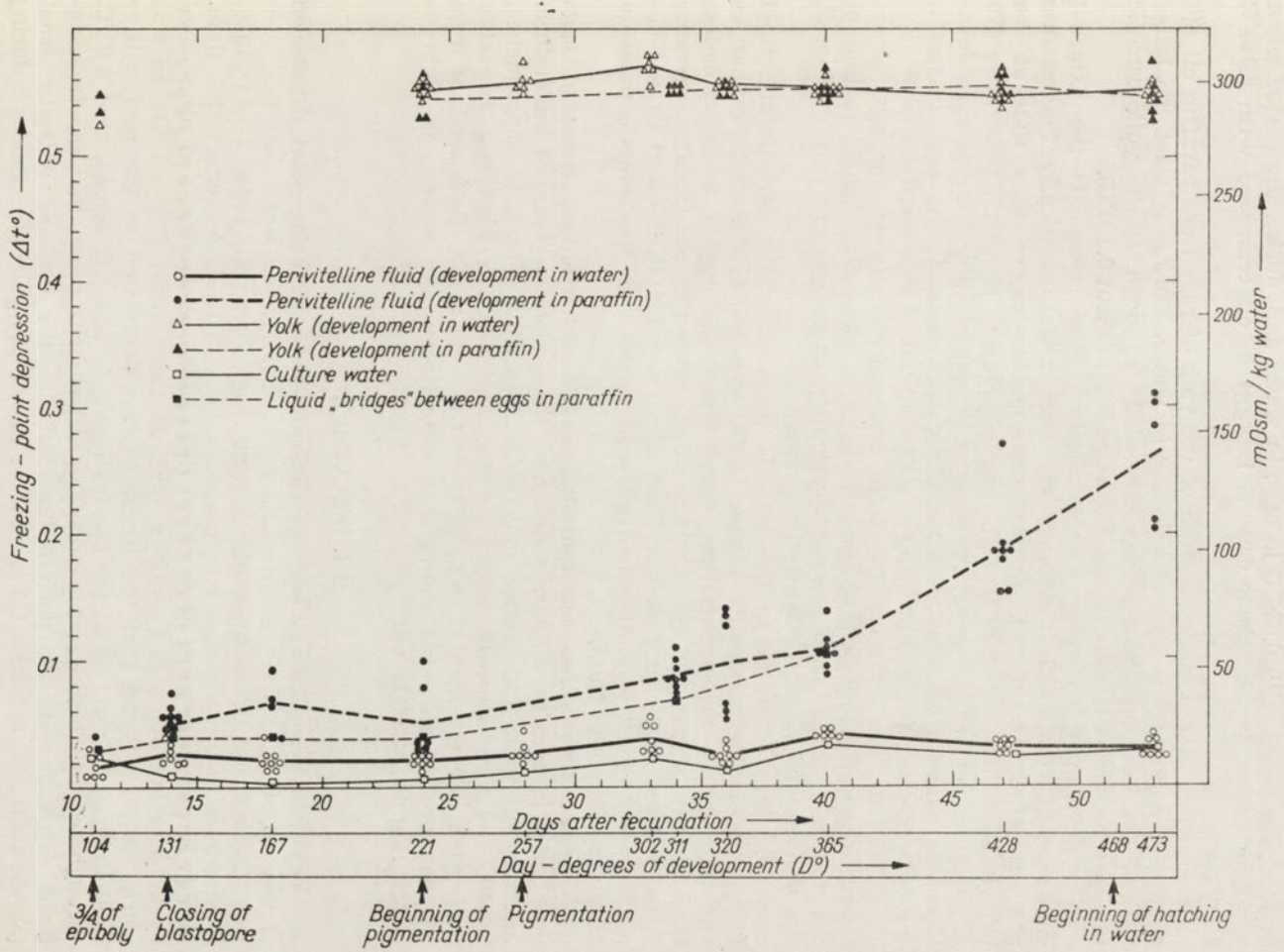

Fig. 1. Freezing-point depression related to day-degrees of development in trout-eggs

0.050°C, compared with 0.030°C in eggs in water and, during the period when hatching began, it was about 0.250°C in eggs in oil compared with 0.030°C in water.

4. However, the osmotic pressure of the yolk of eggs from paraffin oil did not differ from that in eggs developing in water. During at least the latter half of the developmental period (220—470 day degrees) the yolk osmotic pressure remained at more or less the same level (about 0.550°C).

For developing embryos, the perivitelline fluid represents the external environment from which it is completely independent osmotically. The osmotic pressure of the embryo is in fact considerably higher than that of the perivitelline fluid, about 30 times in eggs developing in water. Even after 470 day degrees, when the osmotic pressure of the perivitelline fluid in eggs developing in paraffin oil is about 8 times higher compared with eggs in water, the yolk freezing-point depression is still maintained at a constant level.

5. "The bridges", that is, the fluid connections between the eggs developing in paraffin oil, behave osmotically in a manner analogical to that of the water in which the eggs were developing. In comparison with "bridges", the perivitelline fluid is slightly hypertonic.

6. The great increase in the osmotic pressure of the perivitelline fluid in eggs developing in paraffin oil may be due to products of material exchanges accumulating in the perivitelline space when the egg is in a water-less environment of paraffin oil. On the other hand the considerable decrease in the volume of the perivitelline fluid (Domurat 1964a) (it could be associated with "bridges" formation?) favours an increase in the osmotic pressure of the perivitelline fluid.

Although metabolites accumulating in the perivitelline space of eggs developing in paraffin oil hardly influence the osmotic pressure of the embryo interior, but their toxic action may poison the embryo and, in consequence, weaken its development, reduce its size and cause a high egg mortality during their development (Domurat 1956). Observations of the heart beat from 130 day degrees onwards shows that it is slower and weaker in embryos developing in paraffin oil.

4. DISCUSSION

Very little research has been carried out on the freezing-point depression of the perivitelline fluid of salmonid eggs; usually, the work that has been was carried out on homogenised eggs (e.g. Bcgucki 1930; Gray 1920; Runnström 1920) so that it was probably very difficult to collect this fluid. In this respect, the work of Svetlcv (1928, 1929) is classical and often cited by modern authors (e.g. Prescctt 1955; Kalman 1959; Zctin 1961). In this work, Svetlov found that the freezing-point depression of the perivitelline fluid in eggs of river trout (*Salmo trutta m. fario* L.) is constant, at 0.02°C, throughout the whole development. Our experiment shows that the freezing-point depression of the perivitelline fluid in the eggs of Wdzydze trout (*Salmo trutta m. lacustris* L.) is close to the values given by Svetlov during the first half of the development although always higher than the freezing-point depression of the water in which the eggs developed. (Sveltov states that the freezing-point depression of the perivitelline fluid is always equal to that of the water surrounding the eggs.) However, in our experiment, the value of the freezing-point depression of the perivitelline fluid falls just

before the end of development to attain isotony with the surrounding water. This decline in hypertony of the perivitelline fluid could be associated with increased permeability of the outer egg membrane, a change invoked by the appearance of the enzyme hialuroniddase, which decreases the cohesion of the membrane (Buznikov 1959). These small but nevertheless existing and regular changes in the freezing-point depression of the perivitelline fluid may have been missed in Svetlov's experiments (1929) because of the method used to measure the freezing-point depression and because only a few not very frequent measurements were made. Thus, the demonstration of such changes in the freezing-point depression suggests care in using those results of Svetlov which give the calculated percentage of the perivitelline fluid in relation to the total egg mass at different stages in development, because they are based on the erroneous idea that the freezing-point depression of both the perivitelline and yolk fluids does not change during the development.

The increase in the osmotic pressure of the perivitelline fluid of eggs developing in paraffin oil and its growth during development certainly connected with lack of possibility of water exchanges with the environment. Any accumulation of metabolites in the perivitelline space most probably has the effect of increasing the freezing point depression of the perivitelline fluid. Equally, any reducing of volume of the perivitelline fluid in eggs developing in an environment of paraffin oil (Domurat, 1964a) will increase his osmotic pressure. A great increase in the osmotic pressure of the perivitelline fluid in eggs developing in paraffin oil (about 8 times compared with eggs developing in water) could be one of the factors preventing hatching of salmonid fish embryos in this environment.

5. SUMMARY

The freezing-point depression of the perivitelline fluid and yolk was determined in trout eggs developing in water ("W-eggs") and in paraffin oil ("P-eggs").

The perivitelline fluid of W-eggs were slightly hypertonic in comparison with external environment, during the second half of their development. The perivitelline fluid of P-eggs (at least from ca. 130 day-degrees) had an osmotic pressure which was considerably higher than that of W-eggs. This pressure in the P-eggs increases as the embryo's development advances until it reaches a freezing-point depression of 0.250°C (it is 0.030°C in W-eggs at a comparable stage). The cause of this increase in pressure in P-eggs is certainly the accumulation of metabolites which cannot be passed out into the water-less environment of paraffin oil. These accumulated metabolites poison the embryo, weaken its development and increase mortality.

The osmotic pressure in the yolk is constant throughout (the freezing-point depression is about 0.550°C) and was not different in the W-eggs and P-eggs. The embryo is certainly independent osmotically from the conditions prevailing in the perivitelline fluid.

6. STRESZCZENIE

Oznaczano obniżenie punktu zamarzania płynu okołożółtkowego i żółtka jaj troci rozwijających się w wodzie (jaja „W") i w oleju parafinowym (jaja „P").

Płyn okołożółtkowy jaj „W" był lekko hypertoniczny wobec środowiska zewnętrznego w ciągu drugiej połowy okresu rozwoju. Płyn okołożółtkowy jaj „P" miał co najmniej od ok. 130 stopnio-dni (D°) — ciśnienie osmotyczne znacznie wyższe niż w jajach „W". Ciśnienie to w jajach „P" wzrasta w miarę postępującego rozwoju zarodków aż do $\Delta\ t° \approx 0{,}250°$ (w jajach „W" w tym czasie $\Delta\ t° \approx 0{,}030°$). Powodem tego wzrostu ciśnienia w jajach „P" jest zapewne gromadzenie się metabolitów, które nie mogą być wydalane do bezwodnego środowiska zewnętrznego. Metabolity te zatruwają zarodki powodując słabszy ich rozwój i większą śmiertelność.

Ciśnienie osmotyczne w żółtku było w zasadzie stałe ($\Delta\ t° \approx 0{,}550°$) i nie różniło się u jaj „W" i „P". Zarodek jest zapewne niezależny osmotycznie od warunków w płynie okołożółtkowym.

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DISTRIBUTION OF *PLECOPTERA* AND *EPHEMEROPTERA* IN RELATION TO ALTITUDE ABOVE MEAN SEA LEVEL AND CURRENT SPEED IN MOUNTAIN WATERS

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ABSTRACT

Investigations concerned the distribution (number of species and density of larvae per m^2) of *Plecoptera* and *Ephemeroptera* in the Tatra Mts. and the Bieszczady Mts. (the Carpathian Mts.). It was found that distribution varies with altitude above m.s.l. changes. The distribution of larvae is also variable in different conditions of water current speed.

CONTENTS

1. INTRODUCTION

Data on the vertical range of individual *Plecoptera* and *Ephemeroptera* species in mountain waters are contained in numerous faunistic papers. Recently, the interest of some investigators has been focussed on the problem of species succession along the course of the stream (e.g. ILLIES 1952, BERTHÉLEMY 1964). The classification, by ILLIES (1953) and ILLIES, BOTOSANEANU (1963), of running waters into limnological zones, was based, precisely, on the phenomenon of the *Invertebrata* species, broadly including *Plecoptera* and *Ephemeroptera*.

The present observations on the occurrence of *Plecoptera* and *Ephemeroptera* in relation to the altitude above m.s.l. are based on the material collected from two areas in the Carpathian Mountains. Special attention was devoted to the changes in species number as well as larvae density per m^2 relative to altitude changes. The vertical range of individual species was treated only as the starting point for considerations, while the question of the vertical zonation of species was entirely omitted. Use was also made of additional data provided by recent, fairly numerous publications dealing with the

Carpathian fauna*, excluding, however, as inconsistent with the scope of this work, areas situated outside the Carpathian Mountains.

Some essential changes of the abiotic factors in mountain waters occur together with altitude changes. The influence of thermal conditions on the distribution of *Plecoptera* and *Ephemeroptera* has been discussed in an earlier paper (Kamler 1965). At present, attention was given to the importance of the current speed of water. The opinion as to the importance of water current for stream fauna is shared by numerous authors. Hynes (1941) and Brinck (1949) placed water current first among the factors they enumerated as influencing the stream fauna. Illies (1955) reports that the occurrence of *Plecoptera* shows a close relationship with water flow conditions, and Phillipson (1956), basing on investigations of factors conditioning the distribution of *Simulium ornatum* mg larvae, states that water flow is more important than oxygen concentration.

Among the various problems concerned with the importance of water current speed in relation to water fauna, only one was chosen, viz. the changes of species number and density of *Plecoptera* and *Ephemeroptera* with different current speeds.

2. THE TERRAIN AND METHODS

Investigations covered the Tatra and Bieszczady areas of the Carpathian Mts.

The Tatra Mts. consist of crystal and sedimentary rocks. Their glacier formed relief is typical for high mountains, with glacial cirques, lakes, U-shaped valleys and glacial thresholds, and with moraine ridges heaped at the foot of the mountains. In the Polish region of the Tatra the highest peak Rysy rises 2499 m above m.s.l. Only in some places forests form compact areas. Investigations were performed over the entire Polish area of the Tatra, viz. the High Tatra Mts. (with main attention devoted to the Roztoka stream basin), and the Western Tatra Mts. (with particular consideration given to the Olczyski stream basin).

The Bieszczady Mts. were formed out of sandstone and slate banks. The relief-forming process produced mountain chains with moderately steep slopes and a gentle ridge line. The Quaternary did not essentially affect the Bieszczady relief. The mountains are not high: in the Polish region, their highest peak Tarnica rises 1348 m above m.s.l. Large areas of the Bieszczady are covered with forest. Investigations were centred in three places: the vicinities of Duszatyn (western part of the Polish Bieszczady), Kalnica (central part), and Ustrzyki Górne (eastern part).

In consideration of the above differences between the Tatra and the Bieszczady, the respective differences of their hydrologic conditions are evident. Bieszczady have no high mountain lakes, of which there are many in Tatra. In comparison with Tatra, the streams in Bieszczady form more numerous stagnant waters, of larger surfaces and finer grained bottom. Maximum speeds of water flow at the places of quantitative sampling from stony habitat were found 1.41 m/sec. in Tatry, and 0.50 m/sec. in Bieszczady.

The work was based on material of about 4500 specimens of *Plecoptera*,

* See Table I.

and about 5500 specimens of *Ephemeroptera*, contained in 176 qualitative samples, and 396 quantitative samples taken in Tatra, and in 134 quantitative samples taken in Bieszczady. A part of this material was used by KAMLER (1960, 1962, 1964) for the study of fauna distribution, and (1965), for the study of the importance of temperature conditions. Qualitative sampling was performed in the Tatra, in the months of: January, February, March, May, July, August, September and October, 1954 — 1963. Quantitative studies were carried out in Tatra in July and August 1957, in Bieszczady — in June and September 1963. Investigations covered 40 streams and 11 lakes in Tatra, and 8 streams and 12 pools in Bieszczady.

Quantitative capture of larvae was performed using methods fully described by KAMLER, RIEDEL (1960). In the stony habitat, whole stony material was twice scooped out by pulling a metal-frame sieve the required distance against the current. From detritus, gravel, sandy and muddy bottom, samples were taken using a bottom sampler pushed into the substrate; from moss, 10 x 10 cm pieces were cut out under water; from among macrophytes, larvae were collected over the determined area, using a net. Adult insects were also caught.

Investigations on the species distribution at various altitudes were performed in the 500—2039 m range. The altitude of each sampling was read from the map with up to 50 m difference accuracy.

Water current speed measurements were achieved by means of fivefold surface flow measuring using a float, then mean speeds were calculated for the particular verticals (KLIMASZEWSKI et al. 1954). Use was also made of sodium fluorescein.

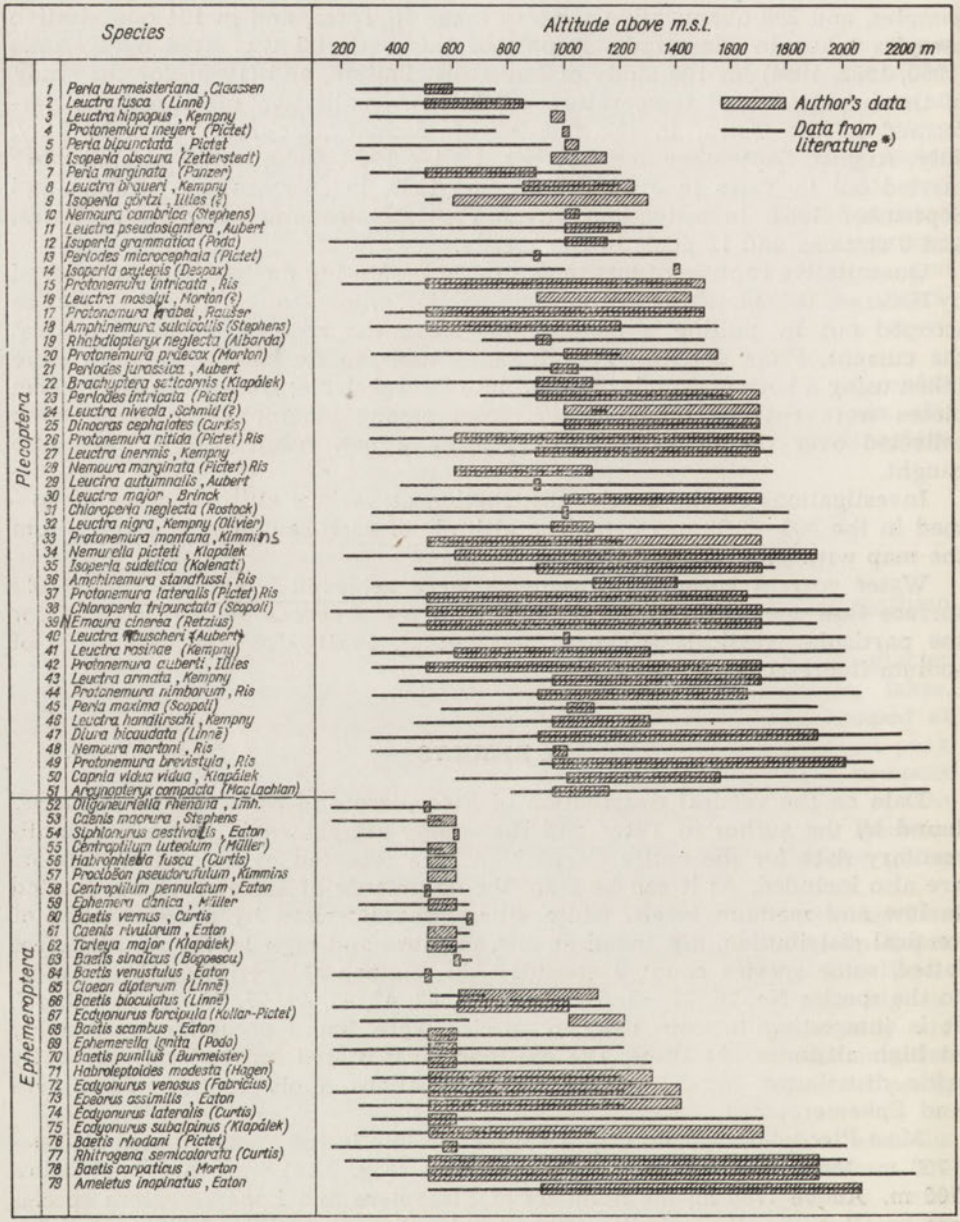
3. RESULTS

Data on the vertical distribution of *Plecoptera* and *Ephemeroptera* species found by the author in Tatra and Bieszczady are shown in Table I. Complimentary data for the entire Carpathian area reported by other investigators are also included. As it can be seen, the occurrence of some species is limited to low and medium levels, while others, characterized by a wide range of vertical distribution, are found at low, medium and high levels. Among these latter, some species count a considerable number of specimens. This refers to the species No. 26, 27, 33, 34, 35, 37, 39, 42, 43, 47, 49, 77, 78, 79, in Table I. It is interesting to note that no species were found occurring exclusively at high altitudes. At these, the existance was stated only of the vertically wide distributed forms. The above observations apply to both *Plecoptera* and *Ephemeroptera*.

Most *Plecoptera* species (Fig. 1Aa) were found in the areas situated at 800—1700 m. Most of the *Ephemeroptera* species (Fig. 2Aa) were observed below 700 m. Above 1700 m, the numbers of *Plecoptera* and *Ephemeroptera* species are small and rather similar. Changes in *Plecoptera* (Fig. 1Ab) and *Ephemeroptera* (Fig. 2Ab) density are highly similar to the changes in the number of species.

Investigations covered the changes in density of larvae per m^2 of various *Plecoptera* and *Ephemeroptera* species inhabiting boulders, stones, gravel, sand, mud and detritus in streams, relative to changes in water current speed. Moss environment was omitted, in consideration of its specific flow condi-

Table I



* Data on the vertical distribution of species, taken from: Bogoescu (1958), Bogoescu, Tabacaru (1957), Botosaneanu, Tabacaru (1963), Ciszek, Sosińska (1965), Despax (1935), Dzięddzielewicz (1917, 1918), Hrabě (1942), Klapálek (1904), Kownacka, Kownacki (1965a, 1965b), Kownacki, Kownacka (1965), Mikulski (1935, 1937), Miron (1964), Mocsary (1899), Nowacka (1965), Obr (1955, 1956, 1963), Pawłowski (1959), Pongrácz (1919), Raušer (1956a, 1956b, 1957a, 1957b), Schoenemund (1930), Sowa (1961a, 1961b, 1962, 1965), Winkler (1957), Wojtas (1964), Zelinka (1953, 1959).

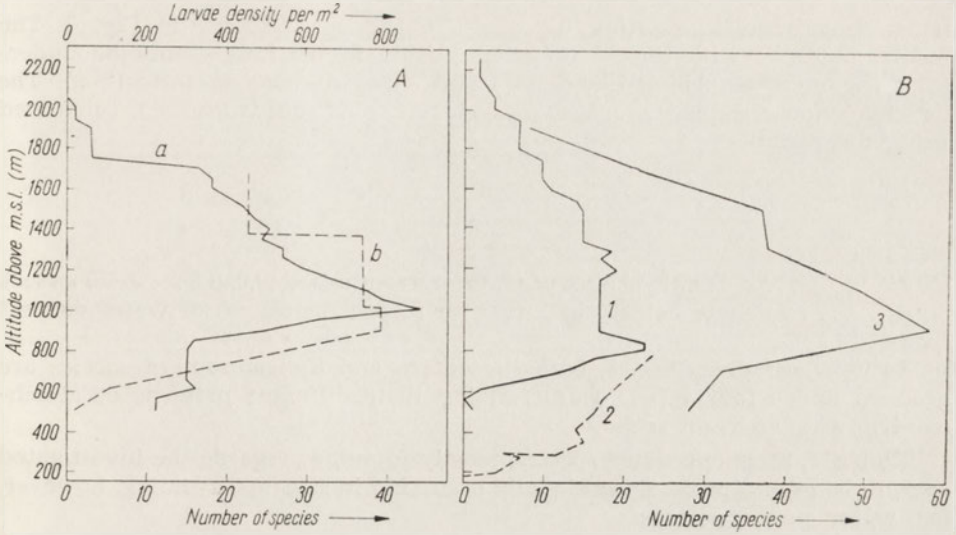


Fig. 1. *Plecoptera* distribution at various altitudes above m. s. 1
A — data based on the present work, from the Tatra and the Bieszczady: number of species (a), larvae density per m² (b), B — number of species in the Carpathian Mts., basing on literature: Botosaneanu, Tabacaru (1963), from the Fagarasch Mts. (1), Nowacka (1965), from the Dunajec River (2), Wojtas (1964), from the Tatra Mts. and Podhale region (3).

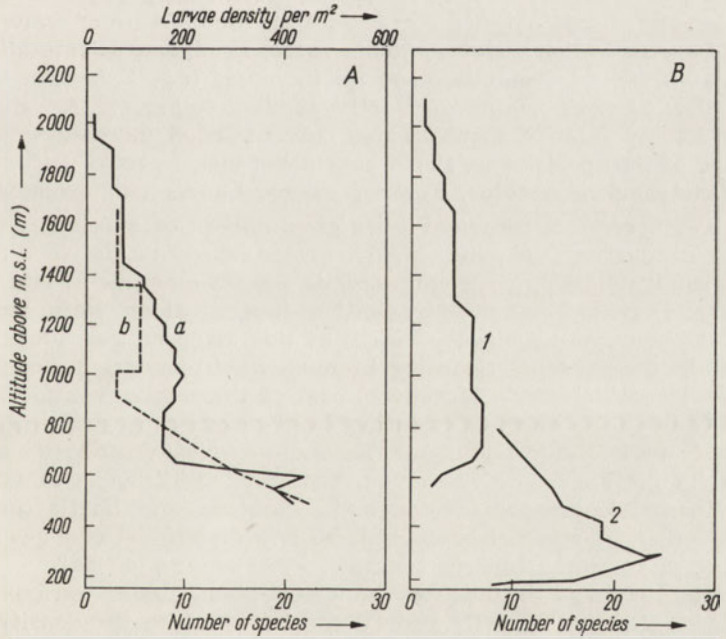


Fig. 2. *Ephemeroptera* distribution at various altitudes above m. s. 1
A — data based on the present work, from the Tatra and the Bieszczady: number of species (a), larvae density per m² (b), B — number of species in the Carpathian Mts., basing on literature: Botosaneanu, Tabacaru (1963), from the Fagarasch Mts. (1), Ciszek, Sosińska (1965), from the Dunajec River (2).

tions. Histograms illustrating the above changes are shown in Fig. 3. The results obtained with regard to species listed in brackets should be understood as uncertain being based on unsufficient number of tests (< 9). The figures denote weighed averages of water current speeds (m/sec.), calculated using the formula:

$$X = \frac{n_1x_1 + n_2x_2 + \ldots + n_sx_s}{n_1 + n_2 + \ldots + n_s}$$

where $x_1, x_2 \ldots x_s$ denote classes of water current speed (0,0, 0,1 ... > 1,0 m/sec), $n_1, n_2 \ldots n_s$ denote density of larvae in respective classes of water current speed.

As it is seen from Fig. 3, both *Plecoptera* and *Ephemeroptera* species are grouped under four types, characterizing their different patterns of attachment to water current speed.

Type I. Stagnant water species, mostly found, as regards the investigated area, in lakes and pools. Exceptionally occurring in streams, avoiding, however, fast water current speeds.

Type II. Species of which a small number of specimens was found in narrow range of slow water current speeds.

Type III. Species inhabiting slow and moderate current speeds. In general, the density of larvae is medium, excepting for the *Habrophlebia fusca* which occurred in great abundance in the current speed class of 0,1 m/sec.

Most of the *Plecoptera* and *Ephemeroptera* species are grouped in the above type. The density of some species decreases with the increase of water current speed (e.g. *Leuctra braueri, Habrophlebia fusca, Ecodyonurus lateralis, Ephemera danica*), while that of other species increases (e.g. *Ephemerella ignita, Baetis scambus, Caenis macrura, Baetis rhodani*) — Fig. 3. No directional changes in density relative to the water current speed increase were observed for some of the species (e.g. *Perla burmeisteriana, Leuctra fusca, Perlodes intricata, Ecodyonurus venosus, Torleya major, Caenis rivulorum, etc.*).

Type IV. Species represented by high numbers of specimens over the wide range of current velocities. Only *Protonemura nitida* was found to comprise a small number of specimens. This species emerges in late autumn. In the summer period, when quantitative investigations were performed, it occurred as very young larvae, which, at this stage of their development, were found in considerable quantity in moss environment unaccounted for in the present considerations. Moreover, part of the larvae, considering their small size, could have escaped attention in the course of sampling. In this type, similarly as in the previous one, for some species, the density of larvae decreased with the increase of water current speed (*Rhitrogena semicolorata*), for some others it increased (*Protonemura montana* and *Baetis carpaticus*), and for still others it was not susceptible to any directional changes (*Leuctra armata, Leuctra inermis, Isoperla sudetica, Protonemura nitida*).

Closer attention was devoted to the distribution, under various current speed conditions, of the Type III and IV species of which the density neither decreased nor increased directionally relative to the increase of current speed. It was observed that for most of these species, the density is lower in the range of moderate current velocity as compared to that encountered in faster and slower current conditions. Thus, e.g. in the case of *Leuctra armata*

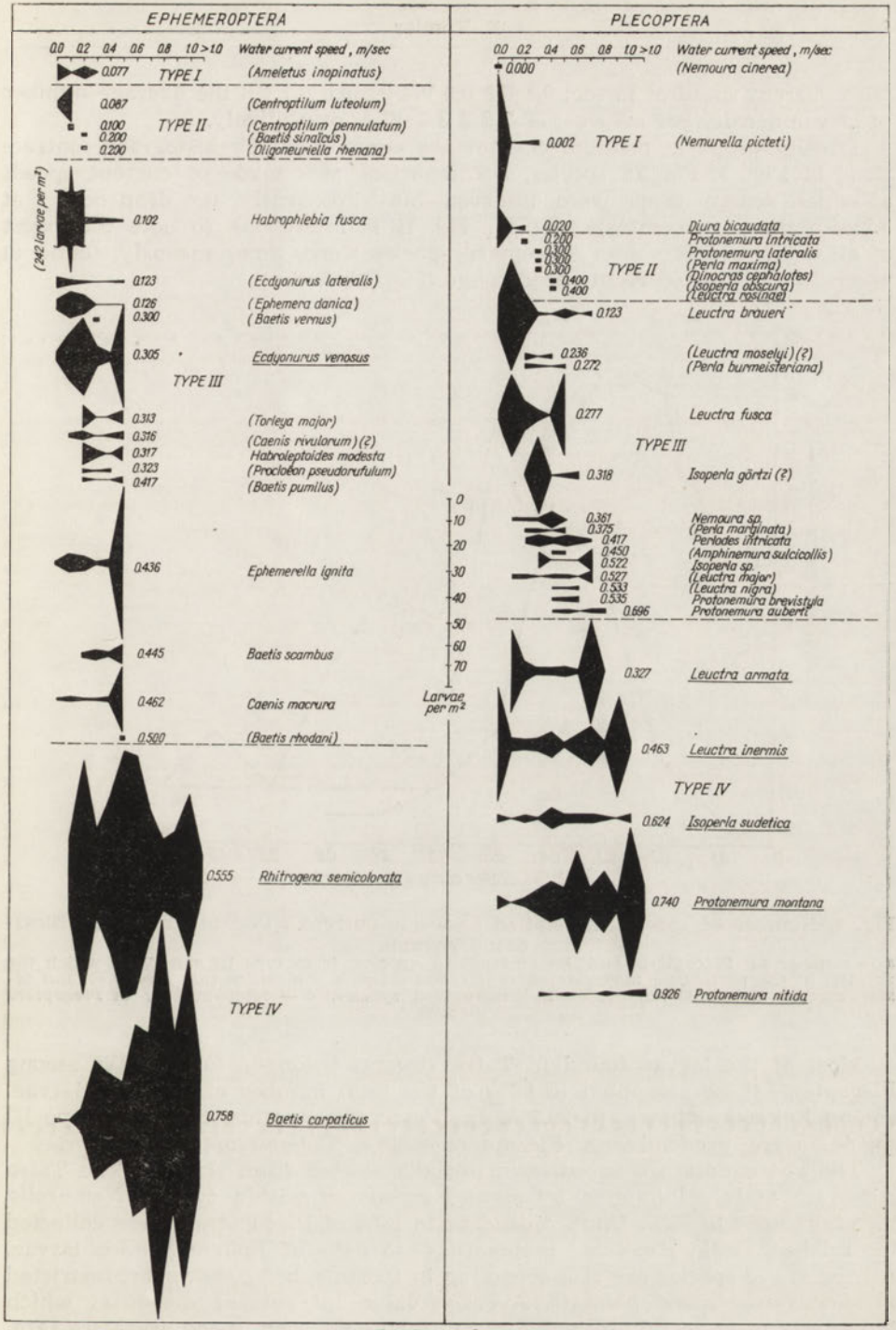


Fig. 3. Density changes of *Plecoptera* and *Ephemeroptera* species, relative to changes in water current speed. The figures denote weighed averages of water current speeds, m/sec. The species listed in brackets were found in < 9 samples. The species found in > 30 samples are underlined

with current speed of m/sec: 0,1 0,2 0,3 0,4 0,5 0,6 0,7 0,8 the average number of larvae density per m^2 was: 32 7 2 3 3 1 40 1, respectively.

Density drops in medium current are exemplified by histogram contractions in Fig. 3. For 16 species, a comparison was made of current speeds at which density drops were observed. Most frequently, the drop occurs at 0.2—0.5 m/sec. current speed (Fig. 4 a). It is interesting to note that most of all *Ephemeroptera* and *Plecoptera* species were, simultaneously, found in precisely the same current speed range (Fig. 4 b and c).

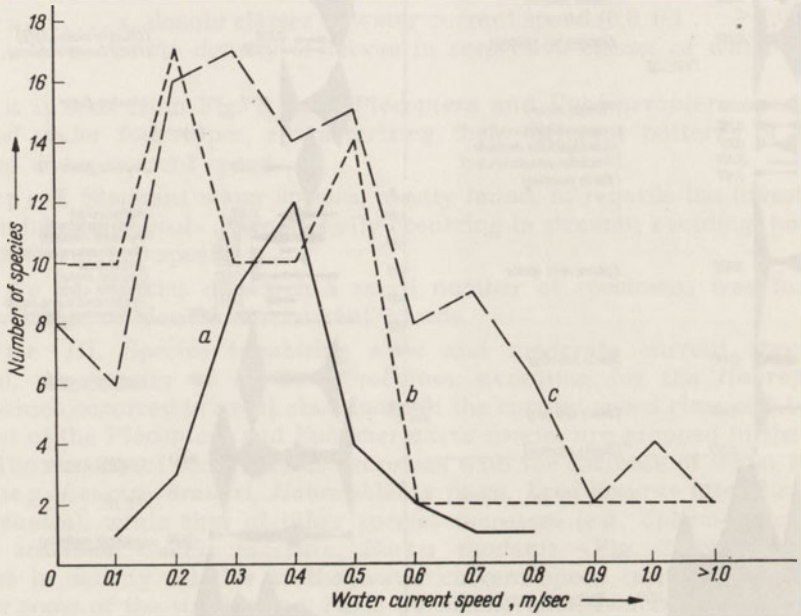


Fig. 4. Number of species in relation to water current speed in Tatra and Bieszczady streams

a — number of *Plecoptera* and *Ephemeroptera* species from type III and IV, of which the density, in the particular, moderate current speed class, is inferior to that in slower and faster current, b — total number of *Ephemeroptera* species, c — total number of *Plecoptera* species.

Most of the larvae found in Tatra streams belonged to type IV: among *Plecoptera*, these amounted to 86% of the total number of collected larvae; among *Ephemeroptera* — to 99.3%. In Bieszczady streams, however, type III species were predominant: *Plecoptera* — 89%, *Ephemeroptera* — 83.5%.

The above data are based on material collected from streams. The Tatra lakes are mainly inhabited by species accounted within type I. *Nemurella picteti* amount to 40%, *Diura bicaudata* to 16% of *Plecoptera* larvae collected from lakes, while *Ameletus inopinatus* — to 84% of *Ephemeroptera* larvae. All the above species are also occurring in streams, being, however, restricted to slow water speed habitats. Average values of current speeds at which the species were found are low (Fig. 3). In streams, slow speed areas are rare. The said species represent a small percentage of the fauna collected from streams which do not outflow from lakes: *Nemurella picteti* 6.9%, *Diura bicaudata* 3.1%, *Ameletus inopinatus* 0.9%.

4. DISCUSSION

The vertical range of species, such, as presented in Table I (dashed rectangles) may be incomplete. It depends on the quantity of the collected material, on the uniformity of sampling at various altitudes and in various seasons and, finally, on the vastness of the area under investigation. For this reason it was considered proper to supplement it with additional data found in 35 papers of other authors, covering the Carpathian area (lines). It is interesting to note the absence in Tatra of species apparently exclusively inhabiting high altitude areas (see also Wojtas 1964). Probably, the lack of typically high mountain forms is characteristic for central and northern European mountains. According to Rauser (1962), these mountains had been, during pleistocene, under a strong glacier influence, and, contrary to the Mediterranean area mountains, the Alps and the Caucasus, include few endemic forms of local origin. Most of the species inhabiting Carpathian Mts. have reached them from the refuges lying in the south, east and west at the time of the glacier's leaving. Some of them, overcoming on their way the lower mountain parts, have reached the high mountain Carpathian area (species occurring over a wide range of altitudes — Tab. I). The post-glacier climate warming up reduced but slightly the occurrence of the most cold-water species in lower situated areas (Tab. I). The fact of the wide range species being the quantitatively predominant element of the fauna seems to speak in favour of the geohistorical interpretation of the lack of typically high mountain forms within the area under investigation. The situation is reversed in Caucasus. Martynov (1928) and Zhiltzova (1956, 1957, 1958, 1960, 1961, 1964) have discussed several *Plecoptera* species being endemic for these mountains. These species occur only in the high mountain area. One may conclude that their vertical occurrence, restricted to high mountain areas, is a characteristic feature of the endemites. The above conclusion represents a development of the theory of Martynov (1922), who, among the *Trichoptera*, distinguished lowland species of geographically broad distribution and mountain species of narrow horizontal distribution. For *Ephemeroptera*, Martynov's conception (1922) was, in broad outline, confirmed by Tschernova (1941). One should not, however, assume the occurrence of all endemites to be limited to the high mountain area. It was reported by Ikonomov (1960), investigating on *Ephemeroptera* of Macedonia, that only some of the endemites showed typically high mountain area occurrence. The vertical distribution of other species was similar to that of the non-endemic forms.

The curves of species number changes at various levels within the presently investigated area (Fig. 1 A a and 2 A a) are, in general, similar to analogical ones basing on material collected in the Carpathian Mts., as reported by other authors (Fig. 1B and 2B). As it is seen, in the Carpathian Mts., maximum occurrence of *Plecoptera* lies above 800 m, of *Ephemeroptera* below 700 m. Sowa (1965), similarly, in the Wielka Puszcza stream (Beskid Mały) flowing at 720—305 m level, observed a preponderance about 2 : 1, or 3 : 2 *Ephemeroptera* to *Plecoptera* per cent ratio, fairly constant throughout the year.

Water current has both direct and indirect effect on freshwater communities, which was stressed e.g. by Macan (1961). The direct influence of water movement is, among other effects, mechanical, by causing fauna displacement, and by affecting fauna respiration and feeding functions. Earliest attention was devoted to the mechanical influence of water movement on

animals. According to STEINMANN (1907), stagnant waters had been the original habitat of stream animals. After immigration into streams, the same species developed morphological adaptations involving their resistance to water movement, and, particularly, body flattening. STEINMANN's opinion was broadly accepted (BRODSKI 1935, STEINBERG, 1935, CZAFIK 1951). The above interpretation of animal resistance to water current was, however, critically evaluated by POPOVICI-BAZNOSANU (1928). It was demonstrated by him that the morphological adaptations, as reported by STEINMANN, do not account for the resistance of animals to water current, and appear as well in organism confined to stagnant waters. POPOVICI-BAZNOSANU suggests that the resistance causes result from physiological adaptations. The latter conclusions found support in the experiments of DORIER, VAILLANT (1954). AMBÜHL (1959) emphasizes on the hiding of animals in places of limited current speed, i.e. layers situated a few millimeters directly above the surface, and the so called dead waters, mainly situated behind an obstacle. Resistance differences of various organism to current speed consist on their different behaviour when penetrating a fast flow water area.

The results of the present work seem to confirm AMBÜHL's theory. The largest number of species were found, precisely, within the range of slow and moderate current (Fig. 3, Fig. 4b, c), while none were reported to inhabit, exclusively, fast current speed areas. The method applied for investigation was, however, in some degree inaccurate. The histograms (Fig. 3) of density relative to water current speed may be incomplete, particularly with respect to the sporadically occurring species. Thus, e.g. *Dinocras cephalotes* (type II) is here reported from a 0.3 m/sec. current speed class, while it was found by SOWA (1965) within the 0.4—0.5 m/sec. range, and, moreover, by KOWNACKA, KOWNACKI (1965 b), from very fast, fast and slow water current. This may suggest a shifting of the above species to type III or even to type IV. Further investigations would, therefore, probably lead to modifying the picture of species distribution in relation to flow conditions, as shown in Fig. 3, particularly in the case of type II accounted species.

Another weakness of the applied method lies in the impossibility to eliminate, from the results, the effect of other factors, as well as the impossibility of an authoritative evaluation of their influence. Thus, e.g., one may only suppose that larvae density drops, occurring in some species only at 0.2—0.5 m/sec. current speeds (Fig. 3, Fig. 4a), are related with the increased competition phenomenon, since, in the above zone, the number of species is the largest (Fig. 4b, c). For this reason, it was considered justified not to endeavour any detailed interpretation of the quantitative distribution of individual species, and to limit the scope of this work to a division of the species under investigation into distinctly differentiated distribution types.

The adopted division seems to be supported by the marked quantitative predominance of species accounted to type III in the slower Bieszczady streams, and that of type IV in the faster Tatry streams.

From a comparison of Fig. 3 and Table I it is evident that all species inhabiting the broad water current range (type IV), simultaneously show a broad vertical distribution. On that basis, however, one may not conclude on the homogeneous influence of the altitude and water current speed relation on fauna distribution: all of the type I species also show a broad vertical distribution range. The above species were found in high elevated Tatra lakes, but, moreover, were also met within lower situated streams, in habitats where conditions were favourable to them.

5. SUMMARY

A total of 530 quantitative and 170 qualitative samples of *Plecoptera* and *Ephemeroptera* were collected from streams, lakes and pools in Tatra and Bieszczady (Carpathian Mts.). Evaluations of altitude and of water current speed were performed simultaneously. Some of the species are occurring at low and medium altitudes. Other species inhabit both low and high altitude areas, a great many of them occurring in considerable quantities. No typically high mountain species were found (Tab. I). Maximum occurrence, both quantitative and qualitative, of *Plecoptera* was reported above 800 m (Fig. 1), of *Ephemeroptera*, however, below 700 m (Fig. 2). The larvae density per m^2 was investigated in habitats of various current speed. Four types of distribution were distinguished: I — stagnant water species, exceptionally occurring in streams, II — species sporadically encountered in slow and little differentiated current speed areas, III — medium numerous species inhabiting slow and moderate current speed ranges, IV — species found in large quantities in slow current, as well as in fast current conditions. No species inhabiting, exclusively, fast flowing waters were found (Fig. 3). Most species were encountered in the zone of 0.2—0.5 m/sec. velocities, in which range the density of some of the type III and IV species is inferior to that found in slower and faster speed areas (Fig. 4). Among the larvae collected in Bieszczady (lower mountains) most belonged to type III, in Tatra-to type IV.

6. STRESZCZENIE

Zebrano 530 prób ilościowych i 170 jakościowych *Plecoptera* i *Ephemeroptera* z potoków, jezior i małych zbiorników w Tatrach i w Bieszczadach (Karpaty). Jednocześnie dokonywano pomiarów wzniesienia i prędkości przepływu wody. Niektóre gatunki występują na wzniesieniach niskich i średnich. Inne gatunki występują zarówno na wzniesieniach niskich, jak i wysokich, wiele z nich występuje bardzo licznie. Gatunków typowo wysokogórskich nie znaleziono (Tab. I). Ilościowe i jakościowe maksimum występowania *Plecoptera* leży powyżej 800 m (Fig. 1), zaś *Ephemeroptera* poniżej 700 m (Fig. 2). Badano zagęszczenie larw/m^2 w potokach w różnej prędkości przepływu. Wyróżniono 4 typy prądolubności: I — gatunki wód stojących, w potokach występujące wyjątkowo, II — gatunki, które sporadycznie spotykano na powolnych i niezbyt zróżnicowanych prędkościach przepływu, III — gatunki średnio licznie zamieszkujące powolne i średnie prędkości przepływu, IV — gatunki bardzo licznie reprezentowane w warunkach zarówno lotycznych, jak i lenitycznych. Nie znaleziono gatunków zamieszkujących wyłącznie wody szybkopłynące (Fig. 3). Najwięcej gatunków spotykano tam, gdzie prędkość przepływu była 0,2—0,5 m/sek, w tej strefie niektóre gatunki z typu III i IV występują w zagęszczeniu mniejszym, niż na przepływach powolniejszych i szybszych (Fig. 4). W Bieszczadach (góry niższe) złowiono najwięcej larw typu III, w Tatrach — typu IV.

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A MODIFIED WATER SAMPLER WITH THERMOMETER AND SOUNDING THERMOMETER

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ABSTRACT

A new instrument (T_2) was built mode of plastic materials to measure temperature of water at a suitable depth. With this instrument one can obtained fast and accurate temperature measurements. The device has a good isolation to prevent the influence of changes in temperature of the surroundings. The water contained in the instrument T_2 can be used for physicochemical analysis by using micro analytical methods. A comparison was given of the two types of apparatus (T_1 and T_2), which showed conspicuous advantages of the second type.

CONTENTS

1. INTRODUCTION

The measurement of the temperature of water of small depths in various water reservoirs is performed usually by means of a water sampler with a thermometer (Fig. 1) which henceforth will be referred to as T_1. Although resistance and thermoelectric thermometers are being more frequently used in water temperature measurement (MORTIMER 1953) this instrument has not gone out of use in spite of the fact that measurements are time consuming *.

The instrument T_1 (Fig. 1) consists of a metal casing which protects a decimal thermometer. To the fastener which is found in the upper part of the casing a line is fastened to manipulate the instrument.

The temperature of the instrument during experimentation is influenced by several factors, namely, the temperature of the instrument before it is sub-

* The discussed water sampler is also used in temperature measurements of running waters (MATUSEWICZ 1953). It however must be relatively heavy.

merged, the temperature of the water just under the surface which fills the vessel as it is submerged, the eventual presence of air in the vessel; thermal stratification of the reservoir; the length of time the instrument was kept under water (which according to several authors should be from 3 to 15 minutes); the poor isolating faculty of the metal walls of the instrument, especially the vessel; the influence of atmosphere on the instrument after it is taken aut of the water. Hence, the final temperature indicated by the instrument must be a resultant and, it would seem to be as a rule, other than that which occurs in the reservoir at the chosen depth.

Such a great difference in the time of measurements is a sound for warning as to their reliability, on the other hand the longer time is not to be accepted because of the slow tempo of the work and the possibility of temperature changes of the water due to atmospheric changes.

Klut and Olszewski (1954) advise moving the instrument under water during the measurement (this must also be done when air is left in the vessel) which is not to be permitted since this disrupts water stratification.

The drawbacks of the discussed instrument were mentioned by Uhle (1925). Bliznjak (1951) has described the adaptation of the water sampler with termometer. It can be filled at any depth by adding load and because of an aperture with a valve in the upper wall of the vessel that can be opened under water by pulling a string on which the devise is hanging. This adaptation is based on the same principle as that of a bottle being opened under water.

2. WATER SAMPLER T_2 WITH THERMOMETER, WITH UNDERWATER FILLING AND EMPTYING OF THE VESSEL

A. CONSTRUCTION

In order to adapt the sampler T_1 to faster and more accurate measurements of water temperature over small depths and small vertical distances, a new instrument was built, henceforth referred to as T_2 (Fig. 2) so that it could not be filled or emptied before it had been placed at the chosen depth.

To improve the isolating faculty of the instrument T_2 it was constructed out of bakelite and vinidur instead of brass. Vessel (A) consist of a lower part (A_1) and of an upper screwed on lid (A_2). There are three apertures in the sampler (namely B_1, B_2, B_3). Water is introduced or removed from the vessel through the lower aperture B_1. A rubber lead (C) is fixed in aperture B_2 serving to deaerate or to bring air into the vessel. On the other hand in aperture B_3, a vinidur pipe (D) is fixed forming the upper casing of the mercury thermometer (E).

The mercury container (H) is placed at half the height of the vessel. Slightly below the upper part of pipe (D) there is an aperture (I) through which the rubber lead deaerating the vessel is introduced into the pipe. Into the upper part of the vinidur pipe (D) a metal barrel (M) is mounted to half its length. It serves to screw on the next segment of the corresponding pipe (N) and further segments. Through the centre of the formed pipe runs the mentioned air lead (C). At the end of this lead, which after leaving the pipe hangs the length of the instrument, there is a vinidur distributor (P) attached to the deaerator (R) closed with the clip (S) and to a rubber pump (U) in which are placed two uni-direction valves (W_1, W_2).

On the outer part of the instrument, starting from half the height of the vessel and further on the vinidur pipe are horizontal marks (Y) every five centimeters and a mobile rubber ring (Z) to mark the depth at which the instrument should be dipped.

The use of bakelite and vinidur in building the instrument decreased the weight and increased the isolating faculty of the sampler walls. Because bakelite is very brittle, only vinidur was used in the building of all subsequent instruments.

B. HANDLING OF THE INSTRUMENT

Before immersing the instrument T_2, we check if the deaerating pipe (R) is closed with the clip (S) by blowing through the rubber lead (C) with the pump (U) to remove the possibly present water. We, then, lower the instrument to the desired depth. At the beginning of this procedure, the vessel and the deaerating lead are filled with air. Increase of hydrostatic pressure during the lowering of the instrument causes a certain amount of water to be forced through the aperture B_1. This water is removed by carefully squeezing the pump (U) until a bubble of air appears at the surface. Then we fill the sampler and the rubber lead with water by opening the deaerating pipe (R). The hydrostatic pressure presses the water into the vessel and the rubber lead through the inlet aperture (B_1) removing the air through the deaerating lead to the limit determined by the depth at which the instrument is immersed. Thus, the thermometer is surrounded with water from the depth at which the measurement is to be performed. The temperature of the water in the vessel, however, may not be close enough to the temperature of the water at the wanted depth. It could have been changed owing to the temperature of the instrument, a certain amount of water forced into the vessel by the hydrostatic pressure, the stratification of water temperature in the reservoir when the instrument was moved from the surface to the desired depth. Therefore, the water from the instrument is removed very carefully by the pump (U) and it is filled again by opening the clip (S). Subsequently after closing this clip, we take the instrument out of the water and read off the temperature.

The vessel is imptied by loosening the clip (S) or more quickly with the help of the pump (U), with the clip closed.

C. CHARACTERISTICS OF FUNCTION

In order to verify the function of the instrument T_2 in compliance with the constructional assumptions, a series of tests were performed:

1. The time of filling and emptying the instrument and taking the reading under field conditions.

The time of filling the vessel with a capacity of 80 ml at the depth of 50 cm, took about five seconds, whereas taking the instrument out of the water and reading the temperature took about ten seconds. On the other hand, the time of emptying the instrument after it has been taken out of the water and after the air lead has been opened took about twenty seconds. Using the pump (U) it took up to 10 seconds.

2. Rate of reaction of the thermometer and the precision of temperature measurements.

Tests were carried out in the laboratory providing specially assumed differences of temperatures between the instrument and the water with, as well as without changing the water in the vessel.

In order to ensure various temperatures to the examined instruments, refrigerators, freezers and passage containers (aquariums) were applied, whereas to observe and compare the functioning of the instruments after they have been submerged into the reservoir, a thermostat filled with water was used.

Decimal mercury thermometers of the same series were fitted in the examined instruments as well as in the thermostat. They were verified at the Office of Measures and Weights. The thermometers chosen for the tests were compared with each other so as to facilitate corrections.

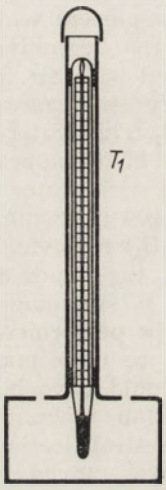

Fig. 1. Water sampler T_1, without the ability of exchanging water

For comparison's sake a sampler T_1 was built of brass according to the previous construction (Fig. 1) and with the same measurements and capacity as the bakelite vessel, its walls being as thin as possible.

The observations were carried out at various temperatures of the instrument and the water in the range of small (about 5°C) average (10°C) and large (15°C) temperature differences. They were chosen so as to correspond to the winter and summer differences in the temperature between the air and the water in a reservoir, and to the winter and summer thermal stratifications which occur in these seasons of the year in small water reservoirs.

In these conditions the functioning of a new sampler T_2 was observed. This sampler was equipped to exchange water in the vessel (Fig. 2) and compared with the functioning of the sampler T_1 which did not have this exchange (Fig. 1). In order to apply temperatures to the instruments which would correspond to the low temperatures of winter air, a refrigerator and a freezer were used. Summer and winter thermal stratifications in small water reservoirs were reconstituted with the help of aquariums and of a thermostat.

In order to apply to the instruments temperatures of the surface layers of the water reservoir and in order to fill the vessel T_1 with water, the in-

struments T_1 and T_2 were submerged in the water in an aquarium with the required temperature. They were held there to the moment, vessel T_1 was filled with water. Within this time, the vessel of the instrument T_2 was in the water filled with air and shut.

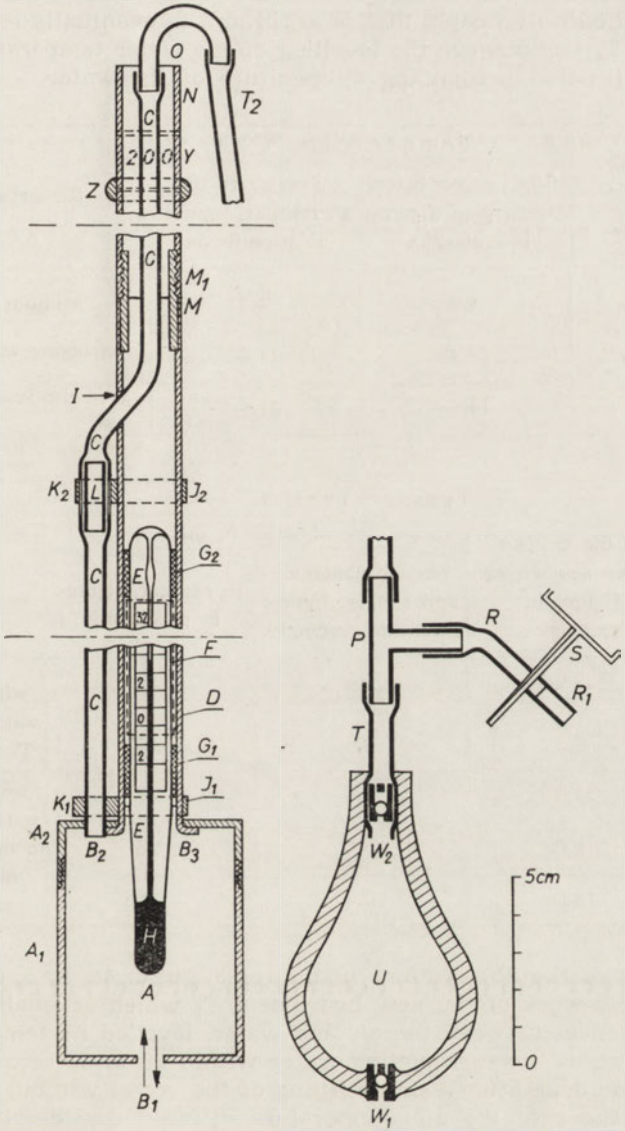

Fig. 2. Water sampler T_2, capable of being filled and emptied at a chosen depth

A. Vessel; A_1.Lower part; A_2. Upper part; B_1, B_2, B_3. Apertures in the vessel; C. Rubber air lead; D. Vinidur pipe thermometer casing; E. Mercury thermometer; F. Window; G_1, G_2. Rubber rings; H. Mercury container; I. Air lead opening to the vinidur pipe; J_1, J_2. Brass rings; K_1, K_2. Holds; L. Metal joint; M. Brass cylinder; M_1. Threaded part of cylinder M; N. Segment of the vinidur pipe; O. Metal joint; P. Vinidur distributor; R. Rubber deaerator; R_1, Metal pipe used to move on the clip in order to open the deaerator; S. Spring clip; T. Rubber joint; U. Rubber pump; W_1, W_2. One way valves; Y. Depth gauge marked every 5 cm; Z. Rubber ring.

After the instruments were taken out of the aquarium, they were submerged immediately into the thermostat, where the instrument T_2 was filled with water and the temperature was recorded as shown by both instruments. Most frequently were the temperatures read in the first minute. The water in the thermostat served to reconstitute the work of the instruments in the reservoir at the desired deph, that is to fill and to eventually exchange water in the vessel T_2 and observe the levelling of the water temperature in vessels T_1 and T_2 with the surrounding temperature of the water.

Experiment (Fig. 3)	Temperature °C		Remarks
	of the sampler before submerging, figures in rectangles	of water in the thermostat, figures in parenthesis	
a	8.9	4.2	without changing water in the vessel
b	18.4	14.4	
c	14.6	21.6	

Experiment (Fig. 4)	Temperature °C			Remarks
	of the sampler before submerging figures in rectangles	of water in the		
		passage container upper layer, figures in dashed rectangles	thermostat, figures in parenthesis	
a	25.2	20.3	15.5	without changing water in the vessel T_2
b	8.2	0.6	3.7	
c	3.0	0.6	3.8	with exchange of water in the vessel T_2 moment of exchange marked with a vertical arrow
d	6.0	0.6	4.5	
e	16.0	0.6	3.65	

The results of the observations in figures 3a, b, c; 4a, b, c, d, e show the fast and precise work of the new instrument T_2 which at small and average thermal differences between the air and water, levelled its temperature with the temperature of the surrounding water within 10 to 60 sec. (Fig. 3a, b, c, 4a, b). This was done after a single filling of the vessel without the exchange of water. In the case the air temperature differed considerably from that of water, temperature differences between the water in the vessel and the water in the thermostat after one minute, amounting from 0.2°C to 0.9°C were eliminated by its exchange (Fig. 4c, d, e).

The functioning of the previous instrument T_1 which was observed at the same time with the new instrument T_2 was considerably slower and less accurate (Fig. 4a—e) on account of the thermic ballast which was carried

together with the surface water in the vessel to the appropriate depth. The influence of the thermal ballast was observed very clearly during the comparison tests (Fig. 4b, T_1). Thermal changes in the instrument T_1 after filling it with water in a passage container (temperature 0.6°C) and later submerging it in a thermostat (temperature 3.7°C) indicate a cooling effect of this water. The recorded temperature of the water in the vessel of the submerged instrument lower than that of the surrounding water, fell even at the beginning and only after 40 seconds began to rise slowly (Fig. 4b, T_1).

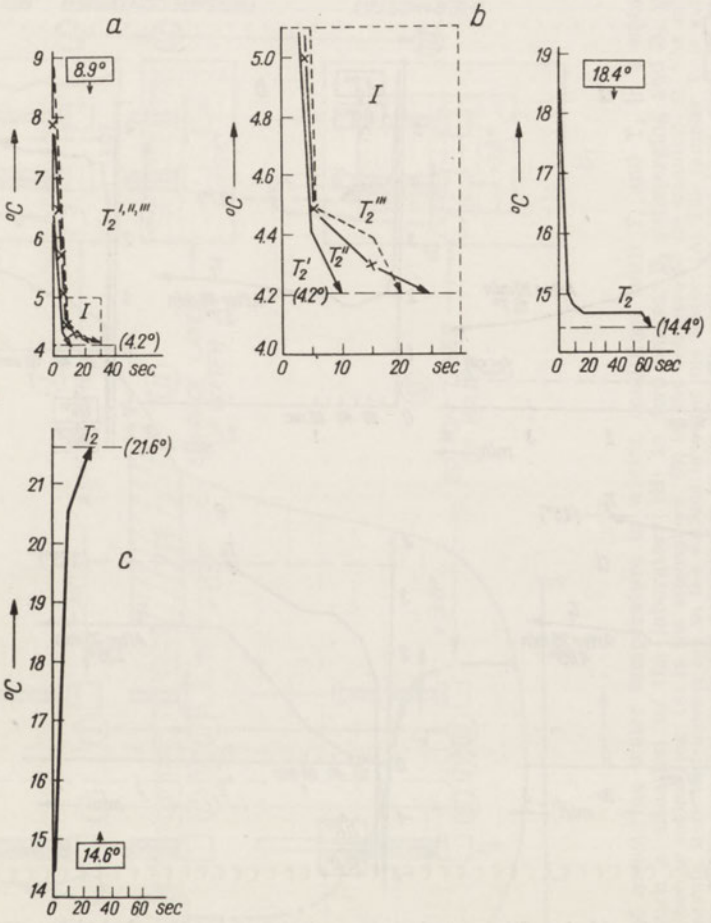

Fig. 3. The rate of levelling the temperature of the water in the bakelite vessel (sampler T_2) with the water temperature in the thermostat

An outline of the work of both compared instruments in the field during winter and the method of reconstituting the natural environment in the laboratory experiment is shown in Fig. 5.

3. Isolating faculty of the vessels.

The isolating faculties of the vessels T_1 and T_2 were observed by filling them with water from the aquarium whose temperature was the same as that

in the natural reservoir at the appropriate depth. One waited then for the temperature of the instruments and the aquarium water to be the same.

The conditions of passing the instruments through layers of water of different temperatures were reproduced by taking the instruments out of the aquarium and immediatelly submerging them into the thermostat.

The temperature of the water in the submerged vessels differed in successive tests in comparison with the water temperature in the thermostat by about 19°, 15°, 9°C.

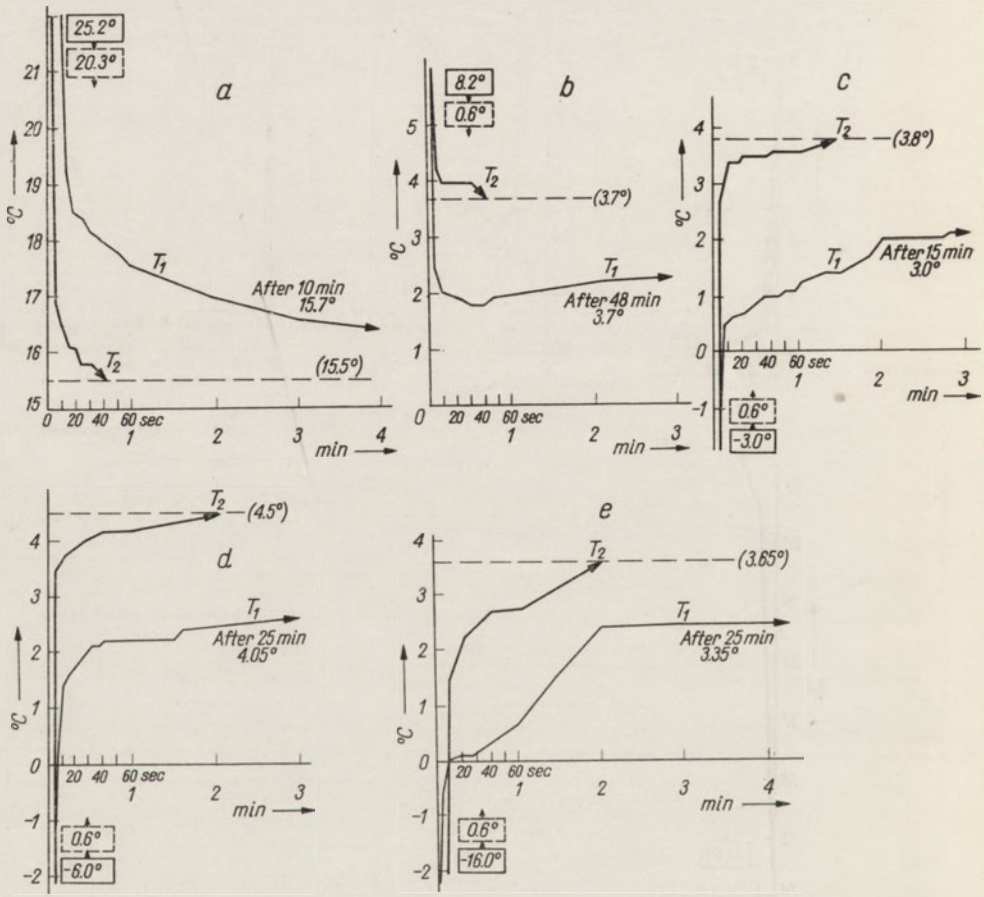

Fig. 4. The rate of levelling water temperature in the bakelite vessel of the sampler T_2 and in the metal vessel of the sampler T_1 with the temperature of water in the thermostat

The observed results presented in Fig. 6 show the positive isolating faculty of the bakelite vessel T_2 and the very poor faculty of the brass vessel T_1. As it was mentioned the instrument T_1 was especially built for comparison, its vessel was smaller and had thinner walls than in the previously used instruments. Comparisons were then made between the functioning of the other instruments of the previous construction of T_1 with the new one T_2.

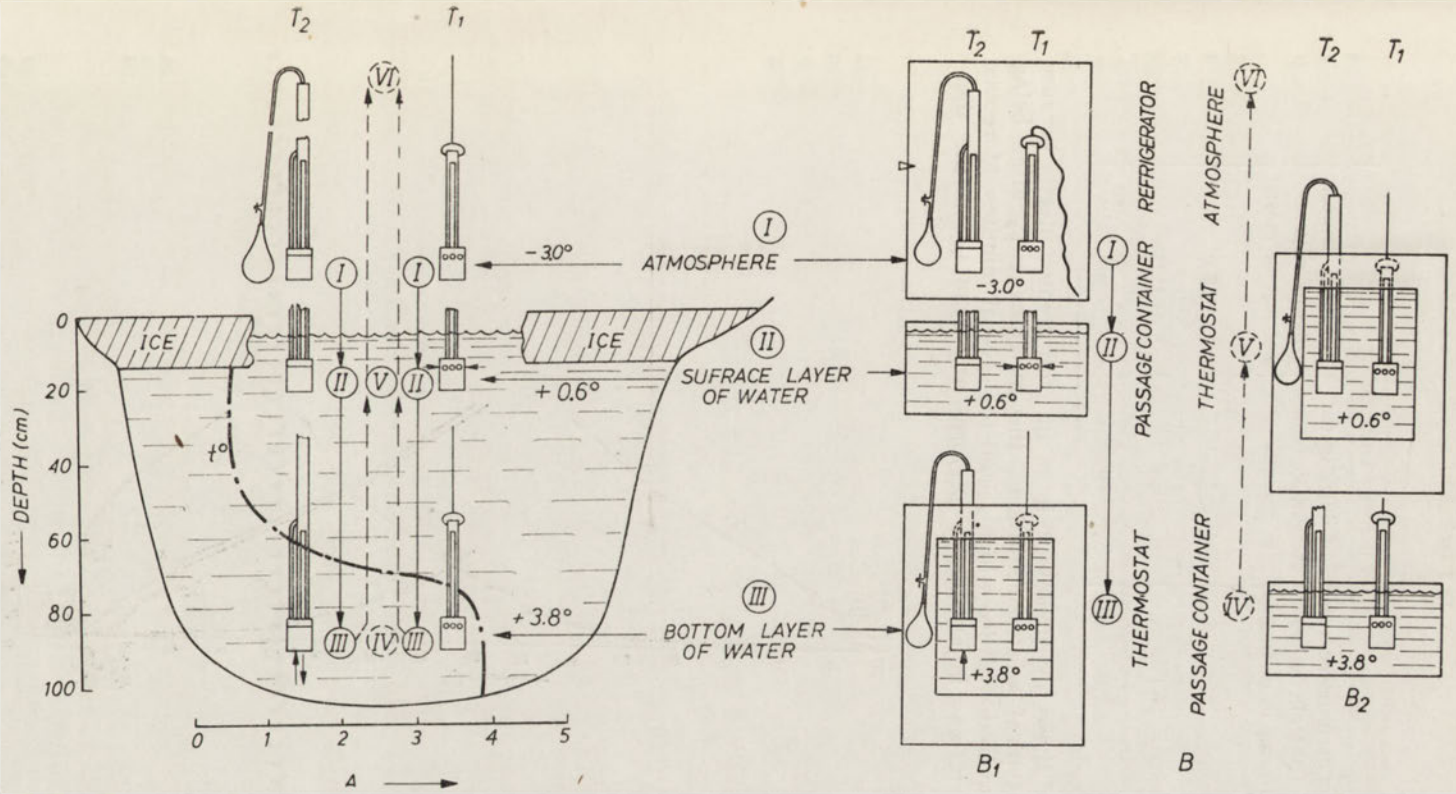

Fig. 5. A scheme of measuring water temperature in winter conditions with T_1 and T_2 in a natural reservoir (A) and the reconstitution of such a situation in the laboratory (B) in two phases: B_1 submerging and B_2, pulling out of the samplers I. Samplers T_1 and T_2 before submerging: (A) in the atmosphere; (B) in the refrigerator (30 minutes). II. The initial phase of submerging the samplers into the reservoir. Both instruments are in the surface layer of the water: (A) The sampler T_1 is automatically filled with water. (B_1) The quick transfer of the samplers from the refrigerator to the passage container and their short (20 sec.) submergence in water in order to fill the sampler T_1. III. Instruments after submergence at the chosen depth: (A) Filling and emptying of the vessel of sampler T_2 at the chosen depth. (B_1) The quick transfer from the passage container, the simultaneous submergence of both samples in the thermostat and filling the vessel of the sampler T_2. Recording the temperature in both samples up to 48 minutes, with or without changing the water in the vessel of sampler T_2 after thirty of sixty seconds. IV. Instruments just before taking them out of the reservoir from the chosen depth. (A) Instruments are thermically influenced by the layer of water, whose temperature is measured. (B_2) The instruments kept in the thermostat with their vessels filled with water are influenced by the chosen layer of water. V. Pulling instruments out of the reservoir: (A) Influence of the layers of water through which both samplers are pulled. (B) Taking the samplers out of the thermostat and very quickly transfering them to the passage container. Observation of the temperature changes. VI. Instruments taken aut of the reservoir to the atmosphere. Observation of the temperature.

Experiment (Fig. 6)	Temperature °C		
	of the instrument and of water in the vessel, figures in rectangles	of water in the thermostat, figures in parenthesis	difference between the instrument and the thermostat
I	4.2	23.2	19.0
II	20.1	4.8	15.3
III	5.8	15.1	9.3

The results showed these instruments to have an even greater inertia because in reconstituting typical winter conditions, the instrument T_2 after being submerged were covered with ice which lasted for several minutes. Moreover during this time, it was impossible to perform any reading on the thermometer.

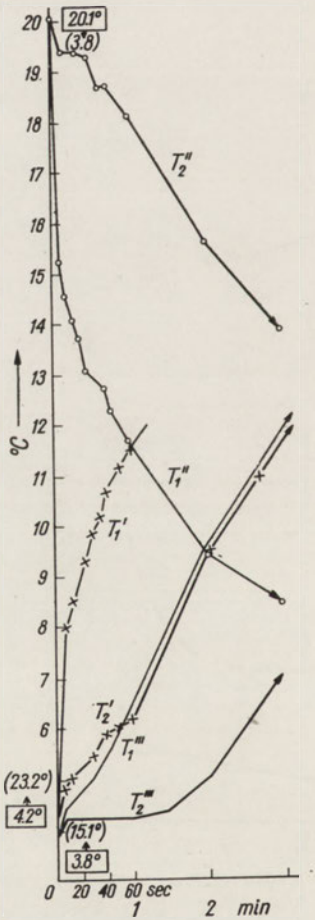

Fig. 6. The isolating faculty of the metal vessel T_1 and the bakelite vessel T_2

The isolating faculty of the instruments T_2 in the atmosphere at various conditions was tested. Even with direct isolation no heating of water in the vessel was observed within 50 seconds, the temperature differences between water and air amounting to 7°C.

Since bakelite presents a lower resistance to mechanical damaging and particularly against crushing than vinidur, further instruments T_2 were made completely of vinidur. A series of comparisons between bakelite and vinidur instruments was performed. The results showed that slightly more time was needed for the temperature to be levelled in the vinidur instrument. The differences 0.05 to 0.2°C must have been mainly caused by the thicker walls of the vinidur samplers. However they could be easily eliminated by changing the water in the sampler.

3. SOUNDING THERMOMETER

A. CONSTRUCTION

In order to avoid walking into a small reservoir or when its shores are inaccessible (Fig. 7) a gear has been constructed which by means of ropes and blocks serves to move the instrument (sounding thermometer, Fig. 8) onto the reservoir, to dip or to lift it and to collect samples of water for physico-chemical analysis (Paschalski 1959).

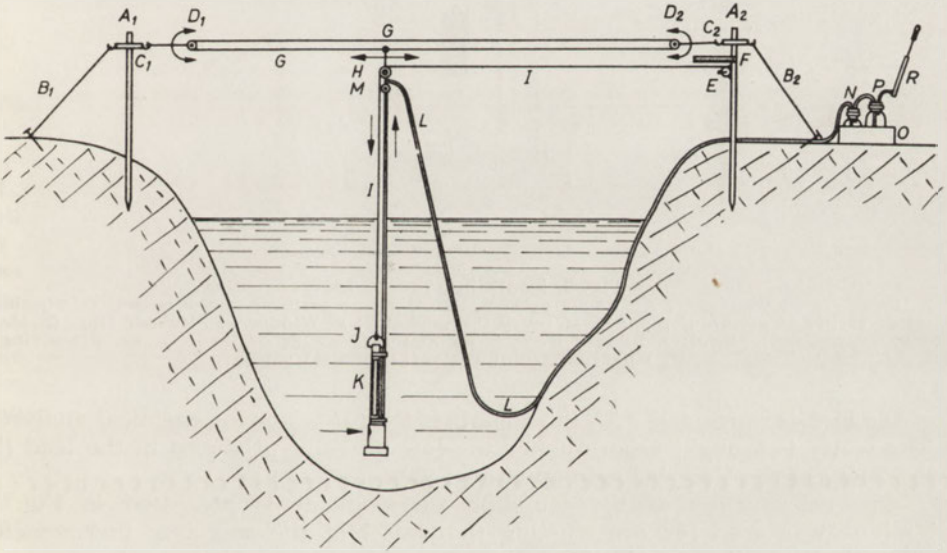

Fig. 7. Field gear for the sounding thermometer
A_1, A_2. Mast; B_1, B_2 etc. Stabilizing lines; C_1, C_2. Holds; $D_{1,2}$. Blocks; E. Wheel; F. Gauge; G. Line; H. Block; I. Nylon line; J. Hold; K. Sounding thermometer; L. Igelite lead; M. Opening in the block; N. Water bottle for chemical analyses; O. Vereshchagin apparatus for filling the bottles with water; P. Vacuum container; R. Pump to reduce the pressure.

The set is composed of two transferable masts (A_1, A_2) which are stabilized with lines (B_1, etc). On the mast are holds (C_1, C_2) which serve to fasten the blocks (D_1, D_2), the wheel (E) with a nylon line and a gauge (F). The blocks support an endless rope (G). On the rope there is a stationary

third block (H) which a nylon line (I) is threaded. At its end a hold (J) is found on which the instrument (K) is fastened. Between the vessel of the sounding thermometer and the shore, an igelite lead (L) is stretched and passed through an opening (M) in the casing of the block (H). The other end

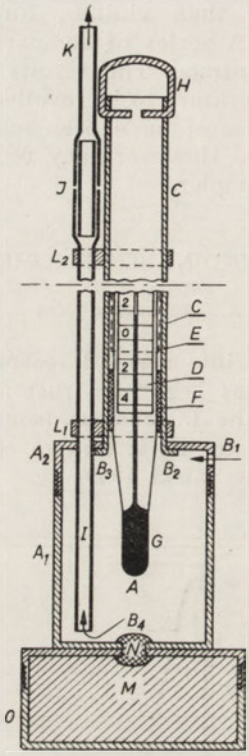

Fig. 8. Sounding thermometer

A. Vessel; A_1. Lower part; A_2. Upper part; B_1, B_2, B_3, B_4. Apertures in the vessel; C. Thermometer casing of a vinidur pipe; D. Mercury thermometer; E. Window; F. Rubber ring, G. Mercury container; H. Hold; I. Rubber lead; J. Metal joint; K. Igelite lead; L_1, L_2. Brass rings; M. Ballast; N. Joining rivet; O. Ballast casing.

of the lead is connected with the container (N) for water for chemical analyses. The water is brought ashore under the low pressure produced in the lead (L) by means of the Vereshchagin apparatus (O).

The construction of the sounding thermometer is presented in Fig. 8. Vinidur was used for constructing the vessel of the sounding thermometer analogically to the sampler T_2.

B. HANDLING OF THE INSTRUMENT

After the described construction has been mounted over the reservoir, the sounding thermometer (K) is moved by means of a rope (G) to the required site. Then with the wheel (E) the instrument is lowered to a desired depth. By producing low pressure in the Vereshchagin apparatus (O), the water is

pumped through the vessel of the sounding thermometer (K) and through the igelite lead (L) to the containers (N). The water which runs through the instrument, equalizes the temperature between the instument and the surrounding layer of water. On account of the necessity for equalizing the temperature between the instrument and the passing water, samples for oxygen determinations must be taken at the end of the series. Then by means of the rope (G) and the wheel (E), the instrument is drawn ashore and the temperature of the water is read. This requires a time of 1 to 2 minutes.

C. CHARACTERISTICS OF FUNCTION

Since the instrument is under the influence of atmospheric factors while it is being pulled to the shore, several laboratory tests were performed regarding changes in temperature readings after the sounding thermometer was taken out of the water and kept in the air under the influence of a fan for three minutes.

Changes in the temperature of the water found in the vessel of the sounding thermometer became evident within 2.5 to 0.5 min. in the temperature difference between the atmosphere and water amounting to 4, 6, 10, 12 and 14°C reached from 0.05°C to 0.6°C with the increasing difference.

4. DISCUSSION

Since the application of the instrument T_1 (Fig. 1) provides results of low precision in spite of an extended time of water temperature measurement, its usefullness can be questioned. The poor isolating faculty of the instrument T_1 indicates furthemore that its usefullness in measuring the temperature of water at great depths, in stratified reservoirs, especially below the epilimnion may not give correct results. The temperature differences can rise to 10°C in lakes (Olszewski, Paschalski 1959) and even to 20°C (Paschalski 1960, 1963, 1965). Under these circumstances large thermal changes will occur very quickly in the metal vessel filled with water when the instrument is pulled towards the surface, and later into the atmosphere. This is why the use of a metal sampler instead of other instruments to measure the water temperature below the epilimnion, particularly when large thermal differences exist in reservoirs, provides results with a considerable error. One must take this into consideration when referring to the data already published, obtained with the use of the sampler with thermometer T_1. The valve used by Bliznjak (1952) das not solve the problem of influence of different temperatures of water masses on the measurement.

Since the functioning of various metal samplers T_1, revealed a considerably greater thermal inertia than of the sampler T_1 especially built for comparison, this indicates that the measurements must be encumbered with even greater errors.

One must pay particular attention to the results of the water temperature measurements used to calculate the amount of dissolved oxygen in the water as percentage of saturation.

Observations of the functioning of the instrument T_2 in comparison with T_1 show an incomparably faster levelling of the temperature between the

instrument T_2 and surrounding water which fills the vessel at the desired depth (Fig. 3a, b, c; 4a, b, c, d, e.) They also show that accurate temperature readings can be obtained by the exchange of water in the vessel and by using in the construction of the instrument good isolating materials such as bakelite or vinidur.

The isolating ability of vessel T_2 appeared clearly within the first 60 to 90 seconds which in comparison with the ten seconds necessary for taking the instrument out of the water and reading the temperature, shows that the application of good isolating material decreases the influence of the thermal stratification of the water reservoir on the measurement. Such errors occur however within that short period of time during the measurement with the metal instrument T_1 (Fig. 6).

The large temperature differences in the experimental conditions between the instrument T_1 and T_2 and the water of about 19° and 15°C, cannot occur in small and shallow water reservoirs and in either surface or shore layers of deep reservoirs. Likewise the difference of 9°C does not occur too often. Hence the occurring small differences under natural conditions cannot influence the instrument T_2 and also the temperature that it indicates. This also concerns atmospheric influences when the instrument is taken out of the water.

5. SUMMARY

Measuring the water temperature of moderate depths may be done by a metal sampler with thermometer T_1 (Fig. 1). This is time consuming and not accurate in spite of an extended time of measurement. (Fig. 4a, b, c, d, e).

In order to do away with these shortcomings a new instrument T_2 was built (Fig. 2) of a new construction and plastic materials (for good isolation) so that it could be filled and emptied at the suitable depth.

This was attained by connecting the vessel to a pump (which produced excess pressure) by means of a lead with valve.

In this manner one can obtain fast and completely accurate temperature measurements, free from the changes caused by pulling the instrument through the superposed water layers and keeping it in the air, because of good isolating walls (Fig. 3a, b, c; 4a, b, c, d, e).

The time of filling an eightly ml. vessel at a depth of 50 cm took five seconds; emptying it in air took twenty seconds, using pressure (Fig. 2) — from 5-to 10 sec. The time for taking it out of the water of a depth of 0.5 m and reading the temperature is about 10 seconds.

The water contained in the instrument T_2 can be used for physico-chemical analysis by using micro analytical methods (Maucha 1945, Donaszy 1955).

The results of the observations and comparisons of the functioning of both instruments show that with the sampler T_2 we can obtain much faster and more accurate water temperature measurements than using the sampler T_1.

In order to avoid a entering small reservoir, or when it is inaccessible, a construction was built (Fig. 7) to move over the reservoir, submerge, lift and pull the sounding thermometer to the shore (Fig. 8). This construction

serves to measure the water temperature and to take samples for physico-chemical analysis with small changes of natural state of the reservoirs.

6. STRESZCZENIE

Pomiar temperatur wód na niewielkich głębokościach dokonywany jest między innymi metalowym termometrem naczyńkowym T_1 (rys. 1). Trwa on jednak zbyt długo i nie jest dokładny (rys. 4a, b, c, d, e).

Celem usunięcia tych wad zbudowano przyrząd T_2 (rys. 2) stosując nową konstrukcję z tworzyw sztucznych, dobrze izolujących, tak aby posługujący się nim mógł napełniać i opróżniać naczyńko na głębokości roboczej. Uzyskano to stosując urządzenie łączące naczyńko przewodem powietrznym, zamykanym szczelnie zaworem z pompką, wytwarzającą nadciśnienie. Tym sposobem uzyskano nieporównywalnie szybszy i zupełnie dokładny pomiar temperatury, zabezpieczony przed zmianami w czasie wyciągania przyrządu z wody i trzymania go w powietrzu (rys. 3a, b, c; 4a, b, c, d, e).

Czas napełniania 80 ml naczyńka na głębokości 50 cm wynosi 5 sek; opróżniania w powietrzu 20 sek, a przy użyciu nadciśnienia 5 do 10 sek. Czas wyjmowania z wody, z głębokości 50 cm i odczytanie temperatury około 10 sek. Zawartą w przyrządzie wodę można wykorzystać do niektórych analiz fizyko-chemicznych przy stosowaniu metod półmikroanalitycznych (Mauch 1945; Donaszy 1955).

Wyniki obserwacji i porównań działania obu przyrządów wskazują, że stosując termometr naczyńkowy T_2 uzyskujemy nieporównywalnie szybsze i bardziej dokładne pomiary temperatur niż przy pomocy termometru T_1. Celem uniknięcia wchodzenia na mały zbiornik, lub gdy jest on niedostępny zbudowano zestaw (rys. 7) do przesuwania nad zbiornik oraz zanurzania, podnoszenia i przyciągania do brzegu termometru-sondy (rys. 8). Stosowanie tego zestawu ogranicza także zmiany w naturalnym stanie zbiornika.

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Z. FISCHER

FOOD COMPOSITION AND FOOD PREFERENCE IN LARVAE OF *LESTES SPONSA* (L.) IN ASTATIC WATER ENVIRONMENT

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ABSTRACT

Studies were made of the food composition of *Lestes sponsa* (L.) larvae and their food preference in various types of astatic reservoirs.

By analyzing the incidence of organisms in the habitat and in the larval intestines, the weed fauna was found to be the most preferable food item as that of a higher calorific value than that of plankton. The numbers of weed fauna eaten formed rather a small percentage of the total numbers consumed, nevertheless they were the main source of energy taken by the *Lestes sponsa* larvae.

In the case when larvae of *Lestes sponsa* occurred in an ephemeral pond there was a high increase in voracity by the end of larval cycle, accompanied by increase in food requirements and by lack of food preference. It was assumed to be a response to indirect stimuli caused by disappearance of water and it can be an important factor accelerating the completion of the larval period.

CONTENTS

1. INTRODUCTION

The species *Lestes sponsa* is typical of astatic environments. It has a short larval stage of two months (May—June) coinciding with the appearance of periodic small ponds, and a long 10-month period of embryonic development, coinciding with the dry or frozen period of these ponds. Further adaptations of *Lestes sponsa* larvae to living in astatic ponds are the following: highly predatory behaviour (BEREZINA 1958, FISCHER 1964) a short period of inhibited metabolism rate preceding metamorphosis (FISCHER 1960), easy moulting (FISCHER 1964), and others. These characteristics suggest very intense metabolic processes, which enable this species to live in ephemeral water bodies. They allow a shortening of the larval period and an acceleration of the time of emergence of adults under extreme conditions when the astatic pond is vanishing. Thus, it can be assumed that the nutritional habits of *Lestes sponsa* larvae will also tend to favour an accelerated growth rate.

The purpose of this paper is to examine the food composition of *Lestes sponsa* larvae and their food preference in various types of astatic ponds, with a special stress laid upon the calorific value of food.

2. MATERIALS AND METHODS

Larvae of *Lestes sponsa* were collected from three different astatic ponds:

1. fish pond Žoldanka was situated at a distance of about 100 km from Prague, with a surface area of 0.75 ha, a maximum depth of 1.3 m, an average depth of 0.5 m; the sampling area was 40 cm deep, with *Glyceria fluitans* and *Eleocharis lacustris* as prepondering plants. The plant cover was 90%. The pond is drained once a year (in October)*.

2. Mansfeldova Tůň, a small astatic pond is located about 60 km from Prague, with a minimum surface of area 1.88 m², a maximum surface area of 209 m², a maximum depth of 1 m, and a plant cover around 40% with *Carex hudsoni* and *Typha latifolia* as predominating species; this is a permanent pond (Oliva 1955).

3. Żmijowa Woda ("Viper Water") is a small astatic pond located about 20 km from Warsaw (in the Kampinos Forest), with a surface area of 450 m², a depth of 30 cm. The plant cover was 80% with no clear dominance of one species, main plant components being *Carex hudsoni*, *Drepanocladus aduncus*, *Iris pseudoacorus palustrae*. The average duration of the pond was about 3 months per year. A detailed description of the terrain and ponds in the Kampinos Forest is given in Chodorowska, Chodorowski 1958, Fischer 1961.

In each pond 25 *Lestes sponsa* larvae were captured at 10 day intervals starting from April 25, 1964 up to the end of the larval stage of this species. In Żoldanka, larvae were captured for the last time on July 20, in the Mansfeldova Tůň, on June 24, and in the Żmijowa Woda as early on May 15, since by the following week this pond had dried up entirely and water did not reappear in it earlier than during the next year. In this pond all the larvae died, their larval development uncompleted. Simultaneously with every capture of larvae were collected samples of plankton, using net No. 13, and of weed fauna, using net with mesh 1.25 mm². The larval alimentary canals as well as the zooplankton and weed faunas were examined in order to identify the animals occurring and to record in what number of individuals were present. Shorygin's index (Shorygin 1939) was used to quantify this relationship between species eaten with species available in the field. This index, K, is obtained from the ratio x_2/x_1 where x_1 represents the percentage of a given food item in the habitat in relation to the total fauna in the habitat and x_2 is the percentage of the component of intestinal contents. This index is burdened with an error resulting from the different speeds at which different kinds of food pass through the alimentary canal. The results concerning organisms which are less digestible may be overestimated, due to the lingering of some parts of these organism in the alimentary canals of the predators. That is why only conspicuous differences in the index value were taken into account when interpreting the results.

* According to data from V. Kořinek, Dep. of Hydrobiology, Faculty of Biology, Karlovy University, Prague.

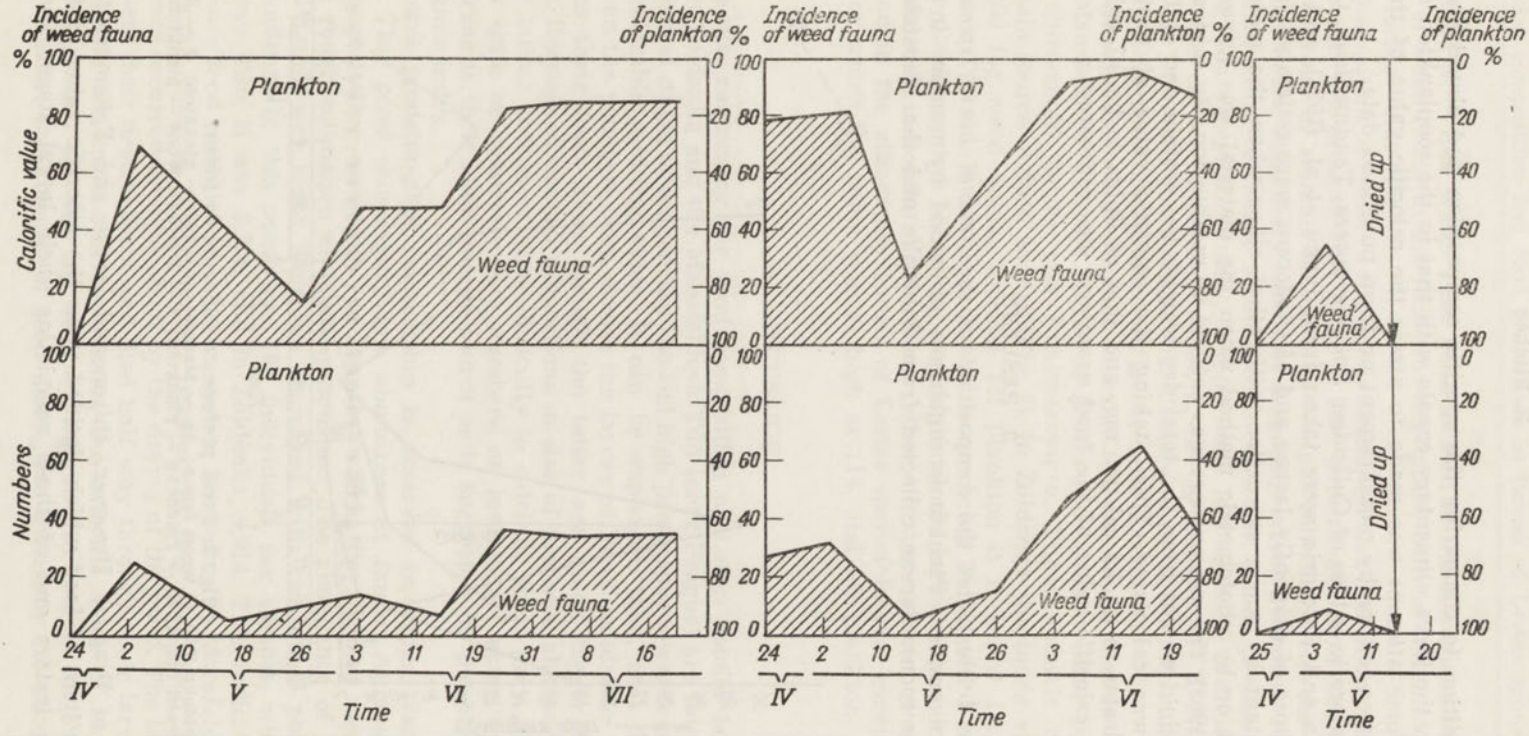

Fig. 1. Food composition of *Lestes sponsa* larvae
A. Zoldanka, B. Mansfeldova Tůň, C. Żmijowa Woda.

In addition to comparing the specific composition and abundance of food species in the larva alimentary canals with that in the zooplankton and weed faunas, some attempt was made to assess the calorific value of the animal species eaten, either by measurement or from published data.

The calorofic values of *Culicidae*, *Ephemeroptera*, *Tendipedidae*, *Copepoda*, *Ostracoda* and *Rotatoria* were taken from IVLEV et al. (1934), and VINBERG (1934). Those of dragonfly larvae and of *Cladocera* were estimated from their lipid content by warm extraction with ethyl ether when the material was abundant or by photometric method when the material was scarce (STERN-SAPIRO 1953). The ash content was defined by combustion. By subtracting the ash and lipid weight from the total dry weight, the protein and carbohydrate content was calculated. Then, taking the calorific value of proteins and carbohydrates to be 4.3 cal per mg, and that of lipids to be 9.1 cal per mg, the total calorific value of the food examined was estimated.

3. RESULTS

Figure 1 illustrates the composition of the food of *Lestes sponsa* in the 3 ponds examined. Planktonic organisms prevailed by number in the food of *Lestes sponsa* larvae collected from Žoldanka and the Mansfeldova Tůň

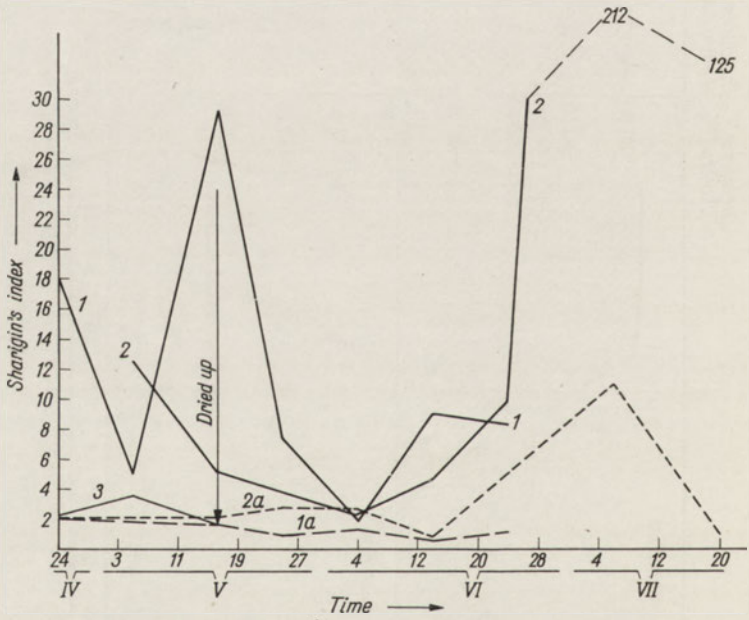

Fig. 2. Food preference (Sharyhin's index)
1 — Mansfeldova Tůň — weed fauna; 1a — Mansfeldova Tůň — plankton; 2 — Žoldanka — weed fauna; 2a — Žoldanka — plankton; 3 — Zmijowa Woda — plankton.

(vicinity of Prague). However, chironomid larvae and *Ephemeroptera* were the main item of food which decided upon the calorific value of food both of young instars and of those completing their larval stage. The reverse

was observed in "Viper Water", the pond located in the Kampinos Forest; the incidence of weed fauna in the food was negligible, both in terms of numbers and of calorific value (Fig. 1).

The composition of fauna in the ponds examined and that of the alimentary canal contents are presented in Table I. The percentages show the incidence of a given group of animals in the total sample collected from the pond, or its incidence in the alimentary canals of dragonfly larvae dissected. To present a rough estimation of faunal abundance in different ponds, 5-class scale of abundance was accepted, namely, 1 represents less than 10 individuals per faunal sample or per alimentary canal, 2, 10—50 individuals, 3, 50—100 individuals, 4, 100—1000 individuals, and 5 more than 1000 individuals. Such a scale can only show conspicuous differences in abundance.

From Sharygin's food preference index (K) it was found that in Żoldanka and the Mansfeldova Tůň the larvae of *Lestes sponsa* show some preference towards chironomid larvae and *Ephemeroptera*. These animals constitute *Lestes'* main source of food energy (Fig. 2). In Żoldanka the index values (K) surpass 200 for weed fauna, whereas for plankton it is below 12. For the Mansfeldova Tůň this index is generally lower being 28 for weed fauna and only 2 for plankton, thus exceeding over 10 times the latter. It was impossible to calculate this index for Viper Water since no specimens of weed fauna were found in the alimentary canals of *Lestes sponsa* larvae, except in one sample, for which the index was as high as 114, and for plankton, below 4.

4. DISCUSSION

The results concerning the food composition of *Lestes sponsa* larvae occurring in Żoldanka and the Mansfeldova Tůň (near Prague) are fairly consisten. All larval stages of dragonflies showed high preference towards organisms of a considerable calorific value. It can be supposed, then, that dragonfly larvae, even the youngest ones, choose the larvae of *Tendipedidae* or *Ephemeroptera* as their food, even though the latter are much bigger than the predators. Because of uneven proportions in size of predator and prey, young dragonfly larvae encounter some difficulty in catching their prey. The weed fauna, in spite of relatively low numbers of individuals eaten by *Lestes sponsa* larvae is their main energy source as is suggested by the high values of Sharygin's index.

A reverse predator-prey relationship is observed in Viper Water (near Warsaw). This pond shows very low abundance of fauna. Although there was no quantitative sampling, the way in which the samples were taken permits a rough estimation of fauna abundance. The abundance of plankton and weed fauna was much lower as compared with two other ponds. The mean abundance in this pond was 196 individuals per sample, whereas in Mansfeldova Tůň, it was 2,311, and in Żoldanka, 4,914. This indicates more advantageous food conditions for *Lestes sponsa* larvae in the Mansfeldova Tůň and Żoldanka than in Viper Water. Besides, in this last pond a special circumstance occurred brought about by the drying of the pond. The larvae did not complete their development and died half way through their larval stage.

To estimate the amount of food eaten, the calorific value of food found in alimentary canal per one mg of body weight was calculated (Fig. 3). In terms of calories, the amount of food eaten was generally 2.5 times higher

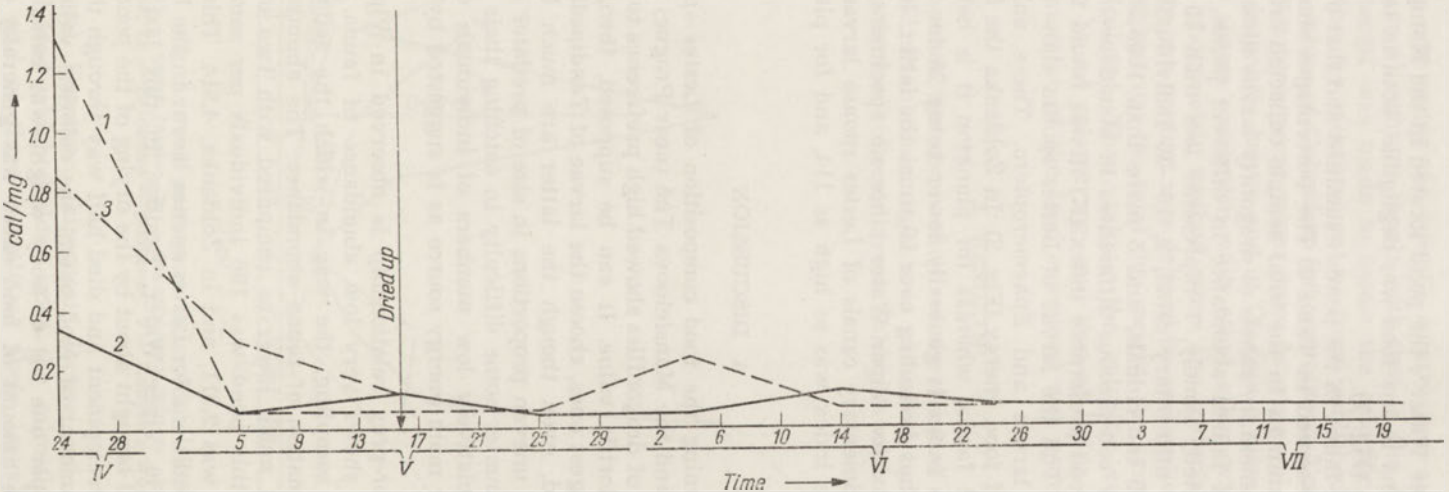

Fig. 3. Food intake in calories per 1 mg of wet weight of *Lestes sponsa* larvae
1 — Mansfeldova Tůň; 2 — Żoldanka; 3 — Żmijowa Woda.

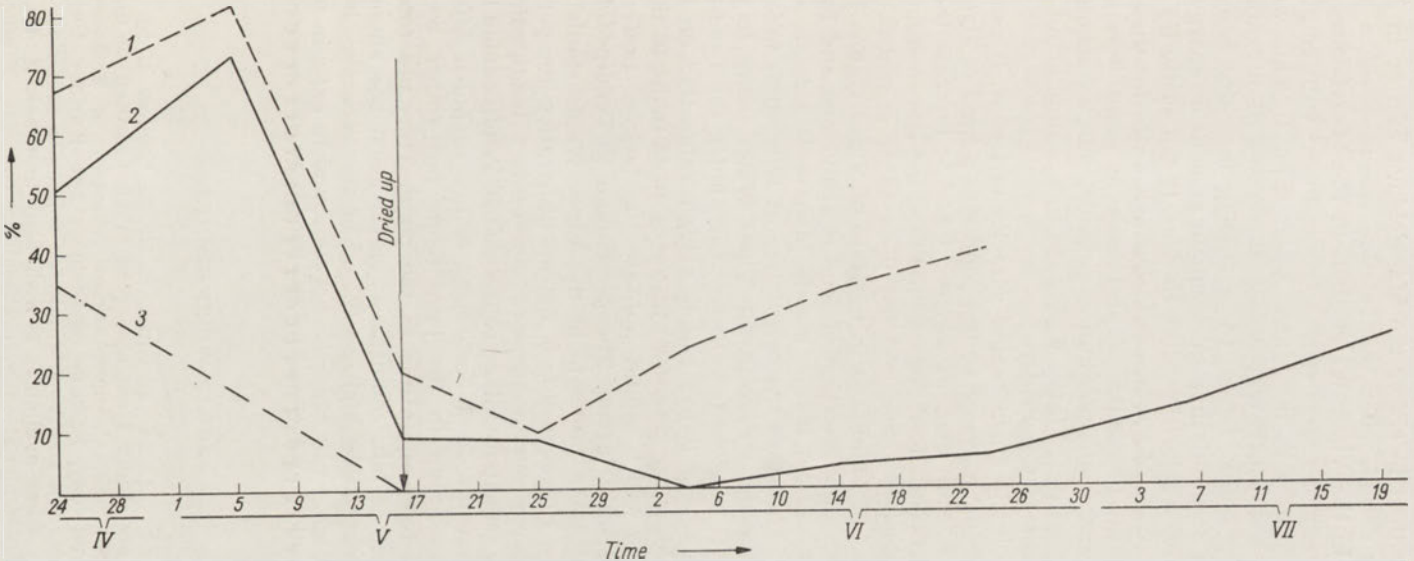

Fig. 4. Percentage of larvae in a sample with no food in the alimentary canals
1 — Mansfeldova Tůň; 2 — Zoldanka; 3 — Zmijowa Woda.

in the Viper Water than in either the Mansfeldova Tůň or in Žoldanka but, during initial 8-day period, when this relation was reversed, a lower amount of food was eaten in the Viper Water than in the Mansfeldova Tůň. At the same time, the number of *Lestes sponsa* larvae found with empty alimentary canals tended to decrease in the Viper Water (Fig. 4). This would indicate that dragonflies in the Viper Water face extremely disadvantageous conditions because of the sparse fauna, their feeding intensity being very high. Yet they succeed in accumulating an adequate amount of energy despite that the food was of a lower calorific value. Besides, it can easily be seen that the larvae in the Viper Water have accumulated more calories than those in the other ponds examined. It should be also born in mind that larvae in the Viper Water fed upon small, planktonic animals, thus to acquire a calorific value equal to one tendipedid larva they have to consume about 7 individuals of *Cladocera* or about 14 *Copepoda*.

All this would point to an increased voracity of larvae. It can be supposed that the rapid vanishing of water in the pond was a kind of signal for *Lestes sponsa* larvae to accelerate their development and to increase their predatory behaviour. Due to this enhanced demand for food the larvae stopped searching for food of high calorific value, and fed upon these organisms which were most abundant, that is on plankton in the case of Viper Water. That is, when the pond begins to dry up, selection of food is abandoned and food consumed is mostly that easily caught, that is mostly planktonic animals and very few weed fauna (Fig. 3). Therefore the calculation of Shorygin's index in relation to the weed fauna for the larvae in the Viper Water seems to be irrelevant (Fig. 4). Although it is possible to calculate such index for *Tendipedidae* from the sample on May 5, and it has rather a high value (112 on the average), the remaining samples show almost no traces of weed fauna in the alimentary canals of the larvae, which would indicate the lack of preference to this food in the *Lestes sponsa* larvae. The percentage of *Tendipedidae* larvae in relation to the total weed fauna is in the Viper Water similar to those in the remaining ponds. However this is not an illustrative comparison since in the Viper Water 6.5 per cent occurrence represents 1 tendipedid larva whereas at Žoldanka the same percentage represents 80 *Tendipedidae* larvae. Hence it seems feasible that the food preference is not so much affected by the incidence of a given group in the total fauna but rather by the general abundance of these food organisms in the pond. Thus the food preference can occur only under certain conditions i.e., (1) when the abundance of the food organisms is adequately high an (2) when the voracious hunger of the predator is not too high. Such conditions were found to exist in the Mansfeldova Tůň and Žoldanka, and those in the Viper Water were beyond these limitations.

ACKNOWLEDGMENTS

I wish to express my sincere gratitude to Dr. R. Klekowski for guidance and help in performing this study. I am also very much indebted to the staff of the Laboratory of Hydrobiology, Czechoslovakian Academy of Sciences and of the Department of Hydrobiology, Faculty of Biology, The Karlovy University, especially to Dr. M. Straškraba and V. Kořinek for collecting materials from Czechoslovakia and making them available. I wish also to thank Z. Kędzierska, who helped me in technical elaboration of material on contents of alimentary canals of the larvae.

Groups of animals	24.IV.												1.V.											
	Żmijowa Woda				Mansfeldova Tůň				Żoldanka				Żmijowa Woda				Mansfeldova Tůň				Żoldanka			
	I		II		I		II		I		II		I		II		I		II		I		II	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Euphyllopoda	0,48	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rotatoria	—	—	—	—	—	—	—	—	0,07	1,3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Copepoda	25,5	3	68	2	60,5	4	31,2	1	64,5	4	50,1	1	15,1	2	35,4	2	71,1	4	33,3	1	33,11	4	22,2	1
Cop. Nauplius	23,2	3	—	—	6,5	2	—	—	3,2	2	6,2	1	53,0	4	—	—	1,2	2	—	—	18,5	4	—	—
Cladocera	32,7	3	32	2	20,5	2	37,6	1	31,0	4	43,6	1	18,2	2	56,9	2	20,7	4	33,3	1	45,2	4	55,6	1
Ostracoda	2,1	1	—	—	4,5	1	—	—	—	—	—	—	11,2	2	—	—	—	—	—	—	1,2	2	—	—
Hydracarina	2,1	1	—	—	—	—	—	—	—	—	—	—	2,0	1	5,0	1	—	—	—	—	—	—	—	—
Ephemeroptera	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1,3	1	1,2	1	—	—	0,6	1	—	—
Odonata	0,8	1	—	—	0,9	1	—	—	—	—	—	—	—	—	—	—	3,6	1	—	—	0,6	1	—	—
Hemiptera	—	—	—	—	—	—	—	—	0,07	1	–	—	—	—	—	—	—	—	—	—	—	—	—	—
Trichoptera	0,8	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Coleoptera	—	—	—	—	0,4	1	—	—	0,9	2	—	—	—	—	—	—	1,2	1	—	—	—	—	—	—
Diptera	7,7	2	3,7	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dip, Tendipedidae	4,7	1	—	—	3,5	2	31,2	1	0,2	1	—	—	0,5	1	—	—	1,2	1	33,3	1	0,8	2	22,22	1

I — Biotope. II — Alimentary canal. A — %. B — Scale: 1 = 10 individuals; 2 = 10 — 50; 3 = 50 — 100; 4 = 100 — 1000; 5 = 1000.

14.V.												25.V.								5.VI.							
Žmijowa Woda				Mansfeldova Tůň				Žoldanka				Mansfeldova Tůň				Žoldanka				Mansfeldova Tůň				Žoldanka			
I		II		I		II		I		II		I		II		I		II		I		II		I		II	
A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
—	—	—	—	8,4	4	1,4	1	—	—	—	—	1,8	2	0,9	1	0,012	1	—	—	3,43	2	0,9	1	1,2	3	—	—
26,9	2	40,3	3	51,5	4	58,1	2	25,0	5	21,0	2	42,3	4	37,2	2	57,4	4	26,7	3	40,2	4	9,0	1	18,9	5	11,9	2
17,7	2	0,5	1	16,8	4	—	—	30,5	5	—	—	3,2	2	—	—	24,6	4	—	—	28,5	4	—	—	34,0	5	—	—
39,8	3	56,9	3	22,4	4	37,6	2	40,1	5	14,0	3	41,4	4	47,3	3	13,5	4	65,9	4	25,0	4	42,2	2	31,6	5	77,4	4
4,3	2	0,5	1	—	—	—	—	2,16	4	—	—	1,6	2	—	—	—	—	—	—	—	—	6,5	1	—	—	—	—
3,7	1	1,2	1	0,1	1	—	—	—	—	—	—	5,6	1	—	—	—	—	5,1	1	—	—	—	—	1,2	3	3	1
—	—	—	—	—	—	—	—	1,08	4	—	—	—	—	—	—	0,5	2	—	—	1,2	2	2,7	1	0,5	2	2,4	1
2,1	1	—	—	0,2	1	—	—	0,27	2	—	—	—	—	—	—	0,018	1	—	—	—	—	—	—	1,2	3	—	—
—	—	—	—	—	—	—	—	—	—	—	—	0,08	1	—	—	—	—	—	—	0,07	1	—	—	—	—	—	—
—	—	—	—	—	—	—	—	0,27	2	—	—	—	—	—	—	0,009	1	—	—	—	—	—	—	—	—	—	—
—	—	—	—	0,2	1	—	—	0,27	2	—	—	0,25	1	—	—	1,95	2	—	—	0,22	1	—	—	2,6	4	—	—
—	—	—	—	—	—	—	—	—	—	—	—	0,08	1	—	—	0,009	1	—	—	0,07	1	—	—	2,1	4	—	—
5,5	1	1,5	1	0,4	1	2,9	1	0,27	2	6,0	1	3,7	2	14,6	2	2,6	2	2,3	1	1,4	2	38,0	2	6,7	4	8,3	2

15.VI.								27.VI.								5.VII.				20.VII.			
Mansfeldova Tůň				Žoldanka				Mansfeldova Tůň				Žoldanka				Mansfeldova Tůň				Žoldanka			
I		II		I		II		I		II		I		II		I		II		I		II	
A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0,83	1	1,2	2	1,3	2	—	—	0,05	1	0,8	1	—	—	—	—	—	—	—	—	0,1	1	—	—
37,0	4	4,8	1	18,2	4	7,2	2	26,3	4	16,7	2	18,4	5	21,8	2	9,3	4	23,7	2	24,8	5	22,5	2
—	—	—	—	18,9	4	—	—	0,1	1	—	—	2,5	4	—	—	3,6	4	—	—	12,02	4	—	—
43,9	4	25,5	2	49,0	4	80,1	4	36,7	4	50,2	3	68,7	5	39,8	3	85,0	5	42,6	4	59,9	5	41,5	3
3,45	2	4,8	1	—	—	—	—	—	—	—	—	2,5	4	—	—	0,6	3	0,5	1	0,8	2	—	—
—	—	1,2	1	1,2	1	1,4	1	—	—	—	—	—	—	—	—	—	—	—	—	0,0	1	—	—
5,7	2	12,0	2	4,1	2	2,2	2	35,4	4	4,3	1	1,1	4	11,1	2	0,6	3	4,9	2	0,8	2	11,5	2
1,72	1	—	—	—	—	—	—	0,7	2	—	—	1,1	4	—	—	—	—	—	—	—	—	—	—
1,15	1	—	—	—	—	—	—	0,2	1	—	—	—	—	—	—	—	—	—	—	0,1	1	—	—
0,28	—	—	—	1,2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
0,57	1	—	—	2,0	2	—	—	0,5	2	—	—	0,7	3	—	—	0,9	3	0,2	1	0,1	1	—	—
0,57	1	—	—	1,2	1	—	—	0,1	1	—	—	2,4	4	—	—	0,005	1	—	—	1,1	3	0,7	1
5,2	2	51,5	2	2,9	2	91,0	3	2,7	3	30,0	2	2,5	4	27,3	2	0,05	2	28,1	2	0,1	1	23,8	2

5. SUMMARY

The paper aimed at studying the food composition of *Lestes sponsa* L. larvae and their food preference in various types of astatic reservoirs. The composition of fauna of habitats in which *Lestes sponsa* larvae occurred as well as the incidence of various groups of animals found in the alimentary canals of the larvae, are presented in Table I. Using Shorygin's index, it was found that the larvae showed much higher preference to weed fauna than to planktonic organisms. Although the weed fauna found in the alimentary canals forms in terms of numbers a low percentage of the total intestinal contents, (20% on the average), but it is a main source of energy supplied to larvae (usually above 50%, sometimes up to 95%). The increased voracity, higher food requirements, and lack of food preference are typical features for larvae *Lestes sponsa* occurring in ephemeral, short-lasting, drying ponds. These features can be considered as a kind of response to direct stimuli brought about by disappearance of water in the pond, which by accelerated growth shortens the larval period.

6. STRESZCZENIE

W różnych typach zbiorników astatycznych przebadano skład pokarmu larw *Lestes sponsa* oraz ich wybiórczość pokarmową.

Analiza udziału grup organizmów napotkanych (fauna naroślinna, plankton) w faunie biotopu, w którym żyły larwy *Lestes sponsa* i w ich przewodach pokarmowych wykazała, że larwy wyraźnie preferują faunę naroślinną (jednostki — współczynnik Shorygina) (Tabela 1, rys. 2) jako pokarm bardziej kaloryczny niż plankton. Ilość osobników fauny naroślinnej stanowi wprawdzie mały procent ogólnej ilości zjadanych organizmów (przeciętnie około 20%), jednakże stanowią one główne źródło energii pobieranej przez larwy w pokarmie (przeciętnie powyżej 50% — dochodzi do 95%).

W przypadku gdy larwy *Lestes sponsa* zasiedlają zbiornik bardzo krótkotrwały, wysychający, przed ukończeniem życia larwalnego stwierdza się wzmożoną żarłoczność, zwiększenie zapotrzebowania pokarmowego oraz brak wybiórczości pokarmowej. Należy przypuszczać, że jest to reakcja na działanie bodźców pośrednich wywołanych zanikiem wody i może mieć znaczenie jako czynnik przyśpieszający zakończenie życia larwalnego.

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The article should be arranged as follows: 1) a brief introduction, 2) a section on methods, 3) the results, 4) discussion, 5) a summary (which is an integral part of the paper), giving the main results, of not more than 200 words in the language of the text, 6) a summary, same text as in point 5 but in the author's native language and 7) a bibliography. Together with the manuscript should be sent 2 copies of an abstract, on separate sheets, of not more, than 150 words in the language of the text, indicating the contents of the manuscript; these abstracts, will be printed on index cards.

The *bibliography* should be given under the heading of "References" and should contain all references cited in the text.

Non-latin references should be transliterated into latin letters according to the ISO-Recomendations (except where there already exists a traditional spelling of names or where the authors themselves prefer another transliteration of their own name).

The list should be arranged in the following form: surname of author (in alphabetical order), initials, date of publication, title of paper, title of journal (abbreviated according to the *World List of Scientific Periodicals*), volume and pages of references (first and last).

Russian references should be arranged at follows (see examples 2, 3): surname and initials of author transliterated into latin characters (ISO — Recomendations); surname and initials of author, date of publication and title of paper in cyrillic; title of paper in the congress languages; abbreviated title of journal in latin characters: etc.

The references in other non-congress languages should be arranged at follows (see example 4): surname and initials of author; date of publication; title of paper in the language of the cited paper; title of paper in the congress language; etc.

In non-Congress language references, the title in a Congress language (and the transliterated name) should be given inside rounded brackets (see example 2) if it has been obtained already translated as a title from, for example the abstract or index, of the original work; or inside square brackets (see examples 3, 4) if has been translated by the author of the manuscript. In the latter case, the title should be translated into the same language as the text of the manuscript.

Printed books should be cited as given examples 5 and 6.

1. Reynoldson, T. B., Young, J. O., Taylor, M. C. 1965. The effect of temperature on the life-cycle of four species of lake-dwelling triclads. *J. anim. Ecol.*, **34**, 23—43.
2. (Shushkina. E. A.) Шушкина, Э. А. 1966. Соотношение продукции и биомассы зоопланктона озер. (Correlation of the production and biomass of the lake zooplankton). *Gidrobiol. Ž.*, **2**, 27—35. Engl. summ.
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4. Luchterowa, A. 1961. Z badań nad biocenozą bakteryjną rzeki Wisły. [Untersuchungen der Bakterien-Biozönose der Weichsel.] *Streszcz. ref., V Zjazd Hydrobiol. Pol. w Gdańsku*, 1961. 77—78. Warszawa, Komitet Hydrobiol. PAN. Polnisch.
5. Ekman, S. 1953. *Zoogeography of the sea.* London, Sidgwick and Jackson.
6. Beeton, A. M., Chandler, D. C. 1963. The St. Lawrance Great Lakes. In: Frey, D. C. (ed.) *Limnology in North America.* 535—558. Madison, The University of Wisconsin Press.

In the text, a reference should be quoted by the author's name and date, such as (Bogucki 1953) or Bogucki (1953); where more than two authors are referred to, the name of the first only should be given followed by "at al".; papers by the same author published in the same year should be distinguished by the suffixes a, b etc. added to the year, e.g. (Ramadan et al. 1963), (Kamler, Riedel 1960a), (Kamler, Riedel 1960 b).

Tables should be typed on separate sheets, numbered with Roman numerals, with a brief title above the table and with the author's name and title paper written on the back; where they are to be inserted in the text should be indicated on the manuscript.

Figures should not contain information already cited in tabular form (or vice versa). All figures, together with the author's name, the title of the paper and the figure number written on the back, should be submitted in their original form, namely, line drawnings in indian ink (jet black and waterproof) and photographs printed on glossy paper for good contrast. Figures (both drawings and photographs) should be numbered with Arabic numerals in the order in which they appear in the text. Where the figures are to be inserted should be indicated on the manuscript.

Manuscripts submitted for publication should be sent to the editor.

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