and fatty acids of two species of North Atlantic krill (Meagnyctiphan and Thysanoessa inermis) and their role in aquatic food. J. Fish. Canada, 27, No. 3, pp. 513-533.
15. Brockerhoff, H.M., R.I. Jurkowski, R.J. Hoyle and R.G. Ackman. 196 acids distribution in lipids of marine plankton. Ibid., 21, No. 6, p
16. Folch, J., M. Lees and G. Sloane-Stanley. 1957. A simple method for th and purification of total lipids from animal tissues. J. Biol. Chem No. 1, pp. 497-509.
17. Vucetic, T., A. Damjanic and A. Cubertovic. 1969. Biochemical studies in Adriatic. Biljeske Inst. Oceanogr. i Ribar., 25, pp. 54-65.

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The Calorific Value of Some Representat of Freshwater Benthos

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The relationships between dry and wet weights, water and ash content and calorific value of dry and organic matter in four species of bivalve mollusks in the course of growth, as well as the calorific value of individual larvae of Trichoptera, Ephemeroptera, Plecopte and Chironomidae and of two species of gastropod mollusks are defined. Equations relating these values with growth are presented.

A widely used technique for study of ecological systems is analysis of ene them. Given this trend, there is a need for accurate evaluation of energy conte organisms. One must distinguished between the energy value (or the energy equ the given organism and its calorific value, which is the energy value per unit of Though the difference between these two concept has been stressed [6], they ar confused.

Among the aquatic invertebrates, we know least about the caloric value of dwelling animals and, particularly, about freshwater bivalve mollusks. Furthe are virtually no data on the changes in caloric value during growth.

We therefore present here our data on the calorific value of the bivalve m tumidus Retz., U. pictorum L., Anodonta piscinalis Nilss. and Sphaerium suec from Lake Naroch' (Belorussian SSR), and also on that of larvae of Trichoptera data with a fairly large weight range), Ephemeroptera, Plecoptera and Chironor vidual measurements) from Lake Zelenetskoye (Barents Sea coast). For the sa made individual measurements of the caloric value of Gastropod mollusks. We Lake Naroch' in June-July 1973, and in Lake Zelenetskoye in July-August 1971.

The wet weight of the animals was determined after drying on filter paper, dry weight after drying to constant weight in a desiccator at 75-82°C for 5 to 6 h (mollusks) and 2 to 3 hours (all other animals). The ash was determined on 80 t batches dried to constant weight and thoroughly ground, and burned for 5 to 6 ho muffle furnace at 550 to 600°C. All determinations were made in 2 to 3 replicat Calorific value was determined by the bichromate oxidation method [6], as the a 3 to 4 measurements. For conversion to calories, an oxycaloric coefficient of 3 0 was used [5]. Where the data were adequate, we defined individual functional ships by the method of least squares.

Correlation Between Dry (W_{dry}) and Wet (W_{wet}) Weight and the Calorific Value of the Bottom-Dwelling Animals of Lake Zelenetskoye

	Number of determinations	W_{dry}/W_{wet}, %	Calorific value	
			cal/mg W_{dry}	cal/mg W_{wet}
Plecoptera	3	24,5	4,9	1,20
Ephemeroptera	3	15,0	4,5	0,70
Chironomidae	5	14,5	5,4	0,81
Lymnaea peregra	3	26,5	2,7*	0,70*
Anisus acronicus	4	31,9	1,5*	0,46*
Trichoptera	14	—	5,7	1,66

*Inclusive of the shell.

In some ecological investigations, it is essential to know the ratio between wet weights of the animals. The lowest ratios were obtained for the larvae of Ch and Ephemeroptera and the highest for mollusks with fairly large shells (Table I basis of 28 measurements of Trichoptera larvae in the 3 to 12 mg weight range, between their dry (W_{dry}) and wet (W_{wet}) weights (mg) is

$$W_{dry} = (0{,}120 \pm 0{,}011)\, W_{wet}^{1.183 \pm 0.020}; \quad r = 0{,}874.$$

Similar equations were derived for Unio (26 determinations for each specie 0.845 to 79.760 g weight range, and for Anodonta (weight of 0.880 to 33.045 g):

for Unio

$$W_{dry} = (0{,}439 \pm 0{,}041)\, W_{wet}^{1.228 \pm 0.018}; \quad r = 0{,}996;$$

for Anodonta

$$W_{dry} = (0{,}203 \pm 0{,}050)\, W_{wet}^{1.070 \pm 0.015}; \quad r = 0{,}901.$$

From Eqs. (1-3) we can see that the ratio between dry and wet weight incr slightly as weight increases with age, especially in Anodonta. In spite of the fac determinations were made in the mollusk Sphaerium suecicum, no systematic ch noted in dry weight as growth proceeded. The dry weight was 19 to 34 (average percent of the wet weight, the variation evidently being connected with the numbe of different age in the marsupia. If this, as well as the irregularity of release of the population are taken into account, then there probably is no defined relation b and wet weight in viviparous mollusks.

The water content in the shells and body of Unionidae did not change with a averaged 3.3 percent (in Unio) and 4.7 percent (in Anodonta) of the weight of the bodies contains an average of 84.2 and 85.6 percent water respectively, while th residue of the cavity fluid accounts for 0.6 and 0.7 percent of the weight of the fl quantity of cavity fluid (W_f) changes with the age of the mollusks and its depender wet weight (W_m) may be approximated by the power-law equations:

for Unio

$$W_f = (0{,}204 \pm 0{,}049)\, W_m^{1.101 \pm 0.042}; \quad r = 0{,}993;$$

for Anodonta

$$W_f = (0{,}303 \pm 0{,}051)\, W_m^{1.069 \pm 0.040}; \quad r = 0{,}984.$$

Shell weight (W_s) also changes similarly:

for Unio

$$W_s = (0{,}317 \pm 0{,}039)\, W_m^{1.065 \pm 0.025}; \quad r = 0{,}993;$$

Since the differences in the exponents in Eqs. (6) and (7) are statistic an average value of 1.074 for the exponent may be used. Naturally, the va constant in the equation also changes. From Eqs. (6) and (7) it can be seer between shell and mollusk weights changes slightly with age, and it is almo Anodonata (32 and 16 percent).

The ash in the shells of Unio, Anodonta and Sphaerium amounted to 8 53.9 percent of dry weight, respectively. In the dry residue of the cavity f (two determinations), ash accounted for 17.1 percent. The ash content in t 5 to 30 g Unionidae was virtually the same in the different species, and inc 15 percent as the weight increased. As growth proceeded in Anodonta, the their body continued to increase (22 to percent 23 percent in mollusks with a 30 to 35 g), while in Unio it remained at the same level (14 to 16 percent). may be connected with the differences in the life span (Anodonta species are more rapidly than Unio and their life span is shorter). The ash content in S suecicum decreases systematically with age:

W_{dry}	4,5	5,4	26,5	29,0	37,0
Ash content, %	74,4	74,0	51,7	55,0	47,4

(The measurements were made on mollusks with shells). In other words, th increase in the organics content, which may be connected with the viviparity of th

We detected no systematic changes in the calorific value of the shells a grew. On the average, it did not exceed 0.22, 0.16 and 0.19 cal/mg dry she Unio, Anodonta and Sphaerium, respectively. The calorific value of the body higher in Unio than in Anodonta (see Table 2). In both animals, at a weight o this value declined from about 4.6 to 4.8 to 3.6 cal/mg dry weight. In Unio over 30 g, it remained at 2.8 to 4.0 cal/mg dry weight.

In elevating the calorific value of the dry matter of the mollusk as a wh with the equation:

$$K_m = \frac{K_s W_s + K_b W_b}{W_m},$$

where K_m, K_s and K_b are the calorific values of the mollusks as a whole and shell and body separately, while W_m, W_s and W_b are the weights of the mollu and the body, respectively.

The calculation showed that the calorific value of the dry matter of moll family Unionidae was virtually the same and that it decreased very slightly wit (Fig. 1). The change in calorific value of mollusks (with their shell) with gro approximated by the linear equation

$$Y = (1,136 \pm 0,041) - (0,010 \pm 0,0016) X,$$

where Y is the calorific value of the dry matter of the mollusk (cal/mg dry wei its wet weight (g). More accurate results can be obtained with separate, equat:

for Unio

$$Y = (0,926 \pm 0,022) - (0,006 \pm 0,001) X,$$

for Anodonta

$$Y = (1,329 \pm 0,169) - (0,015 \pm 0,005) X.$$

The calorific value of the Sphaeriidae is so little dependent on their size t visible data do not indicate only dependence on weight (Table 3). The calorific v mollusks changed irregularly from 1.29 to 0.66 cal/mg dry mollusks weight (inc the shell).

Ash Content and Calorific Value of Mollusks of the Family Unionidae

W_{wet}, g	Ash content, %	Calorific value: cal/mg dry body weight	Calorific value: cal/mg organic matter	W_{wet}, g	Ash content, %	Calorific value: cal/mg dry body wt.	Calorific value: cal/mg ganic r
U. tumidus				*A. piscinalis*			
1,422	48,86	—	—	1,293	46,27	—	—
9,810	6,70	4,81	5,16	1,465	47,78	—	—
13,180	6,10	5,1	5,43	2,453	44,10	—	—
15,070	6,38	4,85	5,18	3,716	46,32	—	—
16,835	8,93	4,22	4,63	4,380	12,54	4,64	5,30
30,505	15,16	3,81	4,51	4,770	9,57	4,70	5,20
25,620	11,50	4,07	4,57	5,095	9,99	5,05	5,60
35,505	15,92	3,70	4,48	8,650	6,31	4,25	4,54
41,785	14,19	3,91	4,56	11,010	9,86	4,29	4,76
45,460	15,91	4,17	4,96	11,365	11,70	4,72	5,32
52,900	14,43	3,85	4,50	12,460	7,89	4,59	4,98
59,040	16,50	4,00	4,96	15,020	15,70	4,17	4,95
79,760	8,69	4,25	4,66	15,075	9,49	4,83	5,34
				15,390	6,77	4,68	5,02
U. pictorum				15,400	11,65	4,30	4,87
0,845	50,67	—	—	16,950	8,49	4,50	4,92
6,650	6,85	4,81	5,17	18,710	13,52	3,88	4,49
6,845	7,00	4,60	4,95	18,960	12,50	4,45	5,05
8,535	6,85	4,80	5,17	19,020	10,62	4,15	4,64
8,600	8,39	4,39	4,76	19,710	10,50	4,69	5,24
9,900	6,85	4,48	4,81	22,155	12,97	4,45	5,12
14,465	12,20	4,65	5,30	22,305	13,07	3,94	4,54
14,950	9,10	5,10	5,60	22,610	24,50	3,57	4,73
18,715	11,10	5,31	5,95	23,210	14,96	3,56	4,20
20,305	8,47	5,10	5,57	23,970	17,40	3,88	4,70
32,860	12,50	4,50	5,19	32,570	20,90	—	—
33,930	16,12	4,40	5,25	33,045	23,40	4,17	5,32

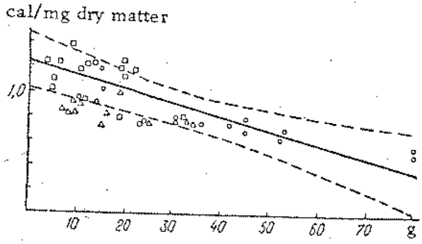

Fig. 1. Calorific value of dry matter of Unionidae mollusks in relation to their wet weight:

O) U. tumidus; △) U. pictorum; □) A. piscinalis. Here and in Fig. 2 wet weight of the mollusks is plotted on the abscissa.

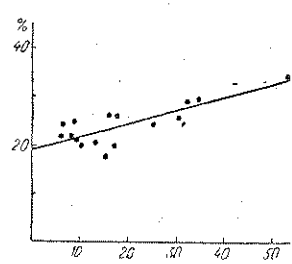

Fig. 2. Fraction of ener the mollusk Unio stored i shell.

Assuming that the calorific value of the shell does not change with age, w the fraction of energy of the whole mollusk stored in the shell. As one might e creases with growth. This increase is linear as can be seen from the example (Fig. 2) and, depending on the weight, can be approximated by a linear function

$\ldots (1\ldots \pm 2,35) + (0,253 \pm 0,028)\, X;$

for Anodonta

$$Y = (8,51 \pm 2,38) + (0,205 \pm 0,069)\, X,$$

where Y is the fraction of the total energy stored in the shell (%), and X is the of the mollusk (g). It follows that the shell stores a higher energy fraction in Anodonta.

The calorific value of the organic matter of Unio and Anodonta is virtual and does not change with age. Its value varied from 4.2 to 5.6 (average 4.9) c organic matter. This fits with literature data [6, 8]. From Table 2, it can b calorific value of the body of the mollusks likewise changes irregularly from 3 cal/mg dry weight. Similar values have been obtained by other authors [1, 2] for (3.22 to 4.78 cal/mg dry body weight), U. tumidus (3.38 to 4.41), A. piscinali 4.78), Sphaerium rivicola, other Sphaeriid species and numbers of marine and mollusks. We can therefore state that the calorific value of the body in most b varies from 3.16 to 5.31 cal/mg dry weight. Among the animals studied, the h calorific values occurred in Trichoptera larvae and the lowest in the Gastropoc (see Table 1).

The power-law relationship between dry and wet weight is systematic, si ships having been defined for the animals of most diverse kinds [3, 12, 16]. N values for the exponents in our equations (1.07 to 1.228) are very close to thos animals, for example, the larvae of Chironomids and Trichoptera [16] and Bla [3]. This means that our relationships have a wider applicability than just to t investigated. They suggest that in animals of different taxonomic positions, dif origins and ecology, the ratios between dry and wet weights increase with growt the same rate.

The calorific values and ash contents of animals studied by us are virtuall as the values given in the literature [1, 6, 8, 10, 11]. One cannot, however, s lower calorific value of organic substances in mollusks as compared, for examp those in insect larvae [11]. One must distinguish between the calorific value of t substance of the body of the mollusk, which, as we and other authors [17, 18] h amounts to about 5 cal/mg organic substance, and the calorific value of the shel extremely low.

It has been stated above that the correlation between calorific value and th the animals can be approximated with good accuracy by the linear function $Y = a$ Similar results have been obtained in studies of the calorific value of Chironomi and crustaceans [9, 12, 14]. This type of equation is the most accurate approxi the experimental data, and the functional relationship between the two values sho sidered as empirical, virtually devoid of any theoretical basis. Naturally, appr the empirical data by a straight lines makes sense in this case only within strict limits, since at $X = 0$ $Y \neq 0$, a proposition devoid of any biological meaning. F rect application of equations of this type, therefore, the thresholds of validity of tions must be stated. Thus, for the mollusks studied, the equation stating the de calorific value on weight can be used only within the 0.8 to 80 g weight range.

Table 3

Caloric Content of Sph. suecium (with Shell)

W_{dry}, mg	Caloric content, cal per dry matter	W_{dry}, mg	Caloric content, cal per dry matter	W_{dry}, mg	Caloric content, cal per dry matter	W_{dry}, mg	Caloric content, cal per dry matter
2,5	1,02	23,0	0,81	5,5	0,87	42,0	0,78
2,5	1,09	23,0	1,02	7,0	0,83	47,5	0,77
3,5	1,19	26,5	1,05	9,5	0,88	52,5	0,96
4,5	0,82	27,0	1,00	11,0	0,96	62,5	0,74
4,5	1,29	29,0	0,67	17,5	0,90	191,1	0,66
4,5	0,90	36,0	0,83	19,0	1,01	—	—
5,5	1,05	37,0	0,76	19,5	0,92	—	—
5,5	1,00	40,70	0,75				

..., this type of correlation gives only an extremely roug relationship involved. Indeed, it is well known that the calorific value of anim the time of the onset of sexual maturity, physiological condition, feeding cond perature, the time of year, etc. [1, 7, 11]. Our equations are adequate for average calorific values of animals during growth. But where greater accura account must be taken of the different kinds of deviations from the average, bro various factors. Still, in ecological investigations it is generally quite suffici mine average calorific values, as per our equations.

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LITERATURE CITED

1. Binger, T. I. 1961. Kormova tsinnost' dlya ryb masovykh form bezkhreb i Dniprovs'ko-Buz'kogo lymanu [The Food Value (for Fishes) of the Invertebrates of the Dnieper-Bug Estuary]. Press of the Ukrainiar Sciences, Kiev.
2. Ivlev, V. S. 1939. The wet combustion method in hydrobiological studies. metodicheskiye zapiski Glavnogo upravleniya po zapovednikam, No.
3. Ivleva, I. V. 1973. The correlation between metabolism and weight in the Palaemon adspersus at different temperatures. In: Energeticheski vodnykh zhivotnykh (Metabolism of Aquatic Animals). Trudy Vses. obshch., 18, pp. 28-41.
4. Konstantinov, A. S. 1973. The respiration rate and biological productivity animals. In: Trofologiya vodnykh zhivotnykh (The Trophology of Aq Moscow, pp. 122-148.
5. Ostapenya, A. P. 1965. The completeness of the oxidation of the organics invertebrates by the bicromate oxidation method. Dokl. Akad. Nauk Minsk, 9, No. 4, pp. 273-276.
6. Ostapenya, A. P. 1968. Biomass and ways of expressing it. In: Metody o produktsii vodnykh zhivotnykh (Methods for Determining the Product Animals). Minsk, pp. 20-44.
7. Ostapenya, A. P., G. A. Pechen', V. A. Babitskiy and A. P. Pavlyutin. 196 rate in Diaptomus graciloides (Lill.) at low temperature. Gidrobiol. No. 5, pp. 121-124.
8. Ostapenya, A. P. and A. I. Sergeyev. 1963. The calorific value of the dry aquatic fodder invertebrates. Vopr. ikhtiologii, 3, No. 1/26, pp. 1
9. Shapunov, V. M. 1973. The calorific value of Idotea baltica basteri (And.) Black Sea. Trudy Vses. gidrobiol. obshch., 18, pp. 62-72.
10. Sherstyukh, V. V. 1971. Calorific value of fodder organisms in the Kreme reservoir. Gidrobiol. zh., 7, No. 6, pp. 99-103.
11. Sherstyuk, V. V. and L. N. Zimbalevskaya. 1973. Calorific value of phytop invertebrates in the Dnieper reservoirs. Gidrobiol. zh., 9, No. 4,
12. Khmeleva, N. N. 1973. Biologiya i energeticheskiy balans morskikh ravnon rakoobraznykh (Biology and Energy Balance of the Marine Isopoda). Dumka Press, Kiev.
13. Comita, G. W., S. M. Marshall and A. B. Orr. 1966. On the biology of Cal finmarchicus. XIII Seasonal Change in weight, calorific value and or matter. J. Marine Biological Association, U.K., 46, No. 1, pp. 1-1
14. Cummins, K. W. and J. C. Wuychecki. 1971. Caloric equivalents for invest ecological energetics. Stuttgart, Schweizerbart.
15. Edwards, R. W. 1958. The relation of O_2 consumption of body size and to t in the larvae of Chironomus riparis Meigen. J. Experimental Biolog pp. 383-395.
16. Geng, H. 1925. Der Futter der naturlichen Fischnährung. Zs. Fischerei, 2 pp. 10-280.
17. Hughes, R. N. 1970. An energy budget for a tidal-flat population of the biva Scrobicularia plana (Da Costa). J. Animal Ecology, 39, No. 2, pp. 3
18. Kuenzler, E. J. 1961. Structure and energy flow of a mussel population in (marsh. Limnology and Oceanography ...