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ENERGY FLOW OF *BELLAMYA AERUGINOSA* IN A SHALLOW ALGAL LAKE, HOUHU LAKE (WUHAN, CHINA) *

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Abstract The energy budget of *Bellamya earuginosa* in a shallow algal lake, Houhu Lake (Wuhan, China) was investigated by the measurement of flesh production (32.8kJ/(m^2·a)), egestion (337.7 kJ/(m^2·a)), metabolism (246.7 kJ/(m^2·a)), and estimation of excretion (21.4kJ/(m^2·a)). The net growth efficiency of the species is about 10.9%, which accords with the generally reported value for gastropods. In addition, the relationships between starvation respiration (*R*, mgO_2/(Ind·d)), body weight (*Wd*, mg in dry wt) and temperature (*T*, °C) were also determined. The regression equation $R = 0.044\ Wd^{0.537}\ e^{0.061T}$ was obtained by the least square method, The measured SDA of the species is 26.51% of its gross metabolism.

Key words: Houhu Lake, energy flow, *Bellamya aeruginosa*

INTRODUCTION

Bellamya aeruginosa is a gastropod species belonging to Viviparidae. Being a detritivore, the species is commonly present in most freshwater bodies. In biomass, this animal is probably the first dominant species of macrozoobenthos, so it plays an important role in material circulation and energy flow in aquatic ecosystem. Besides this essential function, the species is of great importance in fishery in freshwater aquaculture in China, as it is a vital natural food for many kinds of fishes, including and especially carp, black carp, the major products of Chinese fishery. Rational utilization of this natural fish food resource crucially requires investigation on its ecological function, especially its energy flow. But so far, there are few reports on the function of macrozoobenthos in China, let alone that of the studied species, which can adapt to a wide range of water quality, and occurs in very clean water-bodies such as natural unpolluted streams and also in heavily polluted water-bodies such ascertain urban lakes. Population of the species living in different water quality water bodies have obvious difference in production, life cycle, etc., so the species can potentially serve as indicator animal. With the development of aquaculture and deterioration of water environment in China, researches on the ecological function of aquatic animals are becoming more and more urgent, for which reasons, we studied for the first time in China the energy flow of *B. aeruginosa* in two typical shallow freshwater lakes (Yan et al., 1998). This paper presents the results from one typical algal lake, Houhu Lake.

STUDY SITE

Houhu Lake (Fig. 1), a part of Donghu Lake (30°33′N, 114°23′E), is a shallow mesotrophic

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lake in the northeast of Wuchang District, Wuhan City, has area of 3.3 km^2, mean depth of about 2.2 m, maximum depth of 4.25 m. Except for some emergent macrophytes colonizing its shore in summer, the Lake has no macrophytes and is a typical algal lake. The main physical and chemical characteristics of the lake-water were documented by Li et al. (1995).

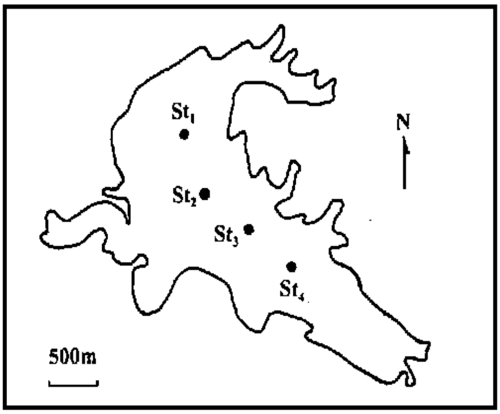

Fig. 1 Houhu Lake and the sampling sites

MATERIALS AND METHOD

Sampling

Quantitative samples were collected from April, 1996 to March, 1997 from each of spaced 500 m apart stations (St_1, St_2, St_3, St_4) along the median transect of the lake (Fig. 1). For each station one sample was collected monthly with a modified Petersen grab (1/16 m^2), and sieved through a 167 μm mesh net. Specimens were sorted manually with naked eye in a white porcelain dish, and preserved in 10 % formalin.

Chemical compositions

Chemical compositions were analyzed by conventional methods. Protein content was measured with an element analyser (PE 24000, CHNS/D), fat with Soxlet extraction method. Ash was obtained by combusting the sample in a muffle stove at 550 ℃ for 24 h. The carbohydrate part was calculated in an indirect way, i.e. the dry weight of a given sample minus the dry weight of protein, fat and ash equals the dry weight of carbohydrate. Energy contents of the flesh and shell were measured using Phillipson microcalorimetry.

Components of the energy budget

In the energy budget equation of Winberg (1956): $C = P + R + F + U$, C is the energy consumed, P is production including somatic and shell production, R represents energy respired, composed of starvation metabolism and SDA, U is energy excreted and F is energy defecated. All these parameters were measured in the following sequence:

Production Production of the population was estimated with the instantaneous growth rate method. Calculating details are presented in another paper (Yan et al., 2000).

Metabolism The metabolism of the animal consists of two parts: starvation metabolism (SM) and specific dynamic action (SDA). SM was determined by a modified Winkler's method; measurement of SDA was conducted by the method of Heiman and Knight (1975).

Egestion Egestion was measured directly. *B. aeruginosa* were collected in the field, placed immediately in jars of clean lake water, and maintained in these jars for periods up to 4 - 5 h (Paine, 1965), Every 15 minutes the fecal matter was collected. At the end of each run the animals were measured, their dry weight established, and the collected fecal matter dried at 70 ℃, and weighed. Three experiments were performed at the mean weather temperature of 18 ℃, 21 ℃, 30 ℃.

Excretion Excretion of the species was estimated at 10 % of the assimilation (Hargrave, 1971; Paine, 1971; Marchant, 1978; Gardners et al., 1983).

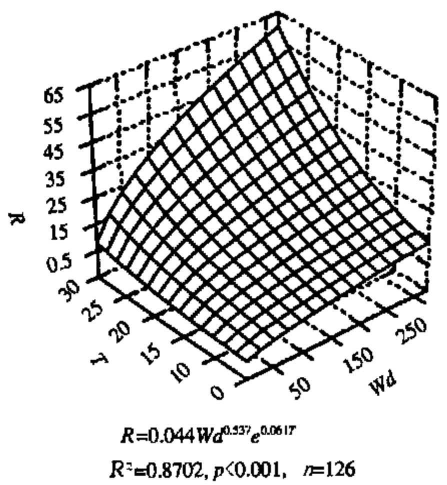

Fig. 2 Relationship between starvation metabolism (*R* , mgO_2/(ind ·d) , dry weight (*Wd* , mg shell-free) and temperature (*T* , °C) of *B. aeruginosa*

RESULTS

Chemical compositions

Chemical compositions of the species are given in Table 1.

Table 1 The chemical compositions of B. aeruginosa **collected from Houhu Lake**

Chemical composition	Content
Protein (%)	57.59
Fat (%)	15.01
Ash (%)	7.80
Carbohydrate (%)	19.60
Energy content (kJ/g dry-wt)	16.97

As Table 1 shows, the species contains high protein and low fat. This might be the reason of its relative low energy content, 16.97 kJ/g dry-wt.

Metabolism

Metabolism of this species was measured from two parts: starvation metabolism and SDA. But so far, there is no report on the SDA of gastropods. Here we made the first try to conduct an experiment to investigate it.

1. Starvation metabolism (*R*)

The relationship between starvation metabolism and body weight were measured under temperature of 5 ℃, 10 ℃, 15 ℃, 20 ℃, 25 ℃, 30 ℃, comparable with the temperature range to which *B. aeruginosa* is exposed under natural conditions. Table 2 shows the regressions.

Table 2 Regressions of starvation metabolism and body weight of B. aeruginosa

Temperature	Regressions of starvation metabolism and body weight
5 ℃	$\lg R = -2.034 + 0.683 \lg Wd$ ($r = 0.7691$, $p < 0.001$, $n = 21$)
10 ℃	$\lg R = -1.222 + 0.6147 \lg Wd$ ($r = 0.9047$, $p < 0.001$, $n = 21$)
15 ℃	$\lg R = -1.052 + 0.635 \lg Wd$ ($r = 0.9885$, $p < 0.001$, $n = 21$)
20 ℃	$\lg R = -1.014 + 0.617 \lg Wd$ ($r = 0.9685$, $p < 0.001$, $n = 21$)
25 ℃	$\lg R = -0.677 + 0.521 \lg Wd$ ($r = 0.9477$, $p < 0.001$, $n = 21$)
30 ℃	$\lg R = -0.827 + 0.672 \lg Wd$ ($r = 0.9597$, $p < 0.001$, $n = 21$)

Based on the above measurements, the relationship of SM and temperature can be calculated. The regression is: $R = -0.05 + 0.09T + 0.0009T^2$ ($r = 0.6994$, $p < 0.0001$, $n = 30$) .

Integrated with the functions of body-weight and temperature, the complex effect is given in the following model: $R = 0.044 Wd\ 0.537\ e^{0.061T}$, ($R_2 = 0.8702$, $P < 0.001$, $n = 126$) (Fig. 2)

2. Specific dynamic action (SDA)

By the method of Heiman and Knight (1975) , the SDA of *B. aeruginosa* was measured at temperature of 10 ℃, 15 ℃, 20 ℃, 25 ℃. The mean O_2 consumptions of the animal under fed and starved conditions are given in Table 3.

Table 3 Mean O_2 consumption of fed and starved *B. aeruginosa*

Temperature	O_2 consumption (mg/(g dry-wt · h))	
	Starved	Fed
10 ℃	0.2065	0.7718
15 ℃	0.4628	2.0208
20 ℃	0.5113	1.8063
25 ℃	0.6752	2.4046

With these data, the calculated percentages of SDA in total metabolism were 26.7 % at 10 ℃; 22.9 % at 15 ℃; 28.31 % at 20 ℃; 28.08 % at 25 ℃, average of 26.5 %.

3. Annual metabolism

Taking the field temperature and the investigated population dynamics into consideration, the annual SM of the population was estimated by substituting the water temperature into the above functions and by extrapolating the experimental data to the field population. The annual SM was calculated to be 181.3 kJ/(m^2 · a). Consequently, the annual SDA was 65.4 kJ/(m^2 · a). Therefore, the total annual metabolism of the animal was 246.7 kJ/(m^2 · a).

Egestion and excretion

The relationship between egestion (*F*, mg dry-wt/h) and body weight (*Wd*, mg dry wt) of *B. aeruginosa* was measured at 18 ℃, 21 ℃, 31 ℃. The regressions were: $\lg F = 2.271 - 0.643 \lg Wd$ (18 ℃); $\lg F = 2.218 - 0.771 \lg Wd$ (21 ℃); $\lg F = 2.565 - 0.761 \lg Wd$ (31 ℃).

With the same method as that for estimation of SM, annual egestion was estimated to be 337.7 kJ/(m^2 · a). Excretion accounts for 7 % of total energy ingested or about 10 % of the assimilated energy for Tegula according to Paine (1971). Therefore, for *B. aeruginosa*, annual excretion was estimated to be 21.4 kJ/(m^2 · a).

Production

Annual production of the species was estimated with the instantaneous growth rate method. The detailed procedures were given in another paper (Yan et al., 2000). Table 4 lists the results.

Table 4 Annual production of year classes of *B. aeruginosa* **in Houhu Lake**

Year class	Production	
	g/(m^2 · dry-wt · a)	kJ/(m^2 · dry-wt · a)
1994 year class	0.436	7.3989
1995 year class	0.824	13.9832
1996 year class	0.672	11.4038
Total production	1.932	32.7860

Energy budget and pattern of energy flow

The complete energy budget for the populution of *B. aeruginosa* in Houhu Lake is shown in Table 5.

Table 5 Energy budget (kJ/(m^2 · a)) for the population of *B. aeruginosa* **in Houhu Lake**

C	*R*	*P*	*F*	*U*
638.6	246.7	32.8	337.7	21.4
(100 %)	38.6 %	5.1 %	52.9 %	3.4 %

C = consumption; *P* = production; *R* = metabolism or respiratory loss; *U* = excretion; *F* = egestion

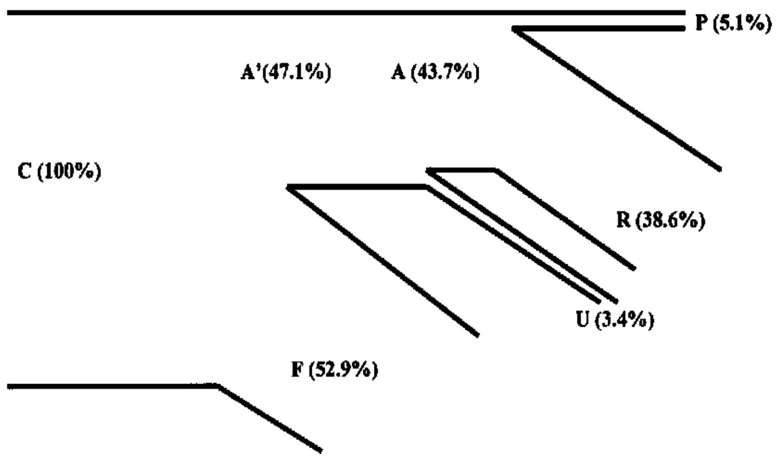

Fig. 3 Pattern of energy flow of *B. aeruginosa* in Houhu Lake

Assuming the annual energy consumption of the gastropod population was equal to 100 % (Fig. 3) , 52. 9 % was rejected as feces , and 47. 1 % was assimilated. 38. 6 % of this energy was partitioned for metabolism and 5. 1 % for production , 3. 4 % for excretion.

DISCUSSION

The bioenergetics for communities of various freshwater and marine animals were published by Odum , 1957 ; Teal , 1962 ; Tilly , 1968 ; for population by Kuenzler , 1961 ; Comita , 1964 ; Paine , 1965 ; Hunter , 1975 ; Riisgard and Randlov , 1981 ; Deslous-Paoli et al. , 1990. Although there are papers on the population dynamics and annual production of *B. aeruginosa* in China (Chen , 1987) , its population energetics has not been reported. Population bioenergetics of freshwater molluscs has received only moderate attention and most materials were published in the period from the 1960s to the 1970s (Apley et al. , 1967 ; Burky , 1968 ; Gillespie , 1969 ; Avolizi , 1970 ; Mattice , 1970 ; Hunter , 1975) . So far , there are no published reports on the energy budget of *B. aeruginosa* , or other species of the genus *Bellamya*. This impedes the evaluation of its ecological function and the rational utilization of its resource , let alone understanding of its bioenergetic strategy for a wide range of freshwater habitats. This study was carried out on the base of these reasons.

A comparison of certain aspects of energy flow in natural populations of *B. aeruginosa* and other gastropods is presented here. Compared with other gastropods , *B. aeruginosa* egested 52. 9 % of its ingestion at almost the same level as *Littorina irrorata* (Odum and Smalley , 1959) in a salt marsh ecosystem , but much higher level than that of *Lymnaea palustris* in upstate New York , which only defecated 32 % - 43 % of its consumption (Hunter , 1975) . *B. aeruginosa* used 5. 1 % of its ingestion , i. e. , about 10. 9 % of its assimilation on growth , which is a low rate among the reported growth efficiency (14 % for *Littorina irrorata* , 40. 8 % - 21. 7 % for *Lymnaea palustris* , 22 % to 52 % for *Laevapex fuscus* (McMahon , 1972) , 65 % for Bithynia. Tentaculata (Mattice , 1970) . This might be partly due to the slow-growing and long life history (3 to 4 years) of *B. aeruginosa*. Moreover , owing to its larger size , its activity metabolism might have been larger than those of the above-mentioned other gastropods characterized by higher respiratory metabolism , roughly 82 % of their assimilation.

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