ENERGY FLOW OF *BELLAMYA AERUGINOSA* IN A SHALLOW MACROPHYTE-DOMINATED LAKE, LAKE BIANDANTANG

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Abstract The energy flow of *Bellamya aeruginosa* was studied for the first time in China in a shallow macrophytic lake, Lake Biandantang. It was estimated from flesh production(14.6kJ·m^{-2}·a^{-1}), egestion(270.6kJ·m^{-2}·a^{-1}), metabolism (213.5kJ·m^{-2}·a^{-1}), and excretion(17.2kJ·m^{-2}·a^{-1}). The net growth efficiency of the species was about 6.0%, which is slightly lower than the generally reported value for gastropods. In addition, the relationships between starvation respiration(R, mgO_2·ind^{-1}·d^{-1}), body weight (Wd, mg in dry wt) and temperature(T, ℃) were described by a regression function: $R = 0.044Wd^{0.537}e^{0.061T}$. The regressions between egestion(F, mg in dry wt·h^{-1}) and body weight(Wd, mg in dry wt) at 18, 21 and 31℃ were: lgF = 2.271—0.6 1.3lg Wd, lgF = 2.218—0.771lgWd, lgF = 2.565—0.761lgWd, respectively. SDA of *B. aeruginosa* was 26.51% of its gross metabolism.

Key words Lake Biandantang, Energy flow, *Bellamya aeruginosa*

1 Introduction

Bellamya aeruginosa is a species of gastropod, belonging to Viviparidae. Being a detritivore, the species is common in most freshwater bodies. In terms of biomass, this animal is probably the most dominant species of macrozoobenthos (Chen, 1987). Therefore, it plays an important role in material cycle and energy flow in aquatic ecosystem. Additionally, the species is of great importance in freshwater aquaculture of China because it provides food for many fishes such as common carp and black carp. *B. aeruginosa* is able to live in a wide variety of environments. It occurs in very clean streams and also in many heavily polluted lakes (Yan et al., 1999). The obvious difference between these populations in different water bodies is production and life cycle (Yan, 1998). Thus, it possesses the potentiality to be a sentinel animal. This paper is to study the energy flow of *B. aeruginosa* in a macrophytic lake, Lake Biandantang.

2 Study Site

Lake Biandantang (Fig. 1), part of Lake Bao'an (30°15′N, 114°43′E) is a shallow mesotrophic lake in the north-west of Daye City, Hubei Province, covering an area of 3.3km^2. The mean depth is about 2m, with a maximum depth of 4m. Emergent macrophytes (*Nelumbo nucifera*, *Trapa natans*) are abundant in two small bays in summer. Submerged macrophytes (*Myriophyllum spicatum*, *Ceratophyllum demersum*) cover almost all the bottom area (Lu & Ni, 1999). Main physical and chemical characteristics of the lake water are: annual mean water temperature 18.9℃, transparency 148 cm; pH 8.06; conductivity 267.4 $\mu S \cdot cm^{-1}$; DO 9.60 $mg \cdot L^{-1}$; COD 3.60 $mg \cdot L^{-1}$. There have been several papers to report the ecological studies on macrophytes and zooplankton of the lake during the same period (Song & Xie, 1997; Xie & Takamura, 1998; Song et al., 1999; Zhuge, 1999; Lu & Ni, 1999).

3 Material and method

3.1 Sampling

Quantitative samples were collected from April 1996 to March 1997. Eight stations were chosen (Fig. 1), among which four (S_2, S_3, S_4, S_5) were situated at the middle transect of the lake, S_1, S_6 were located in lotus-covered bays, S_7 was in a *Vallisneriaspiralis* covering region, and S_8 in a macrophyte free area. At each station, one sample was collected monthly with a modified Petersen grad ($1/16m^2$), and sieved in a 167-μm-mesh net. Specimens were sorted with naked eye in a white porcelain dish, and preserved in 10% formalin.

3.2 Chemical compositions Protein content was measured with an element analyser(PE 24000, CHNS/D), fat with Soxlet method, ash was detected by combusting in a muffle stove at 550℃ for 24h. Carbonhydrate part was calculated indirectly from the difference between the dry weight and protein fat and ash, energy contents of the flesh and shell were measured using the Phillipson Microcalorimetry.

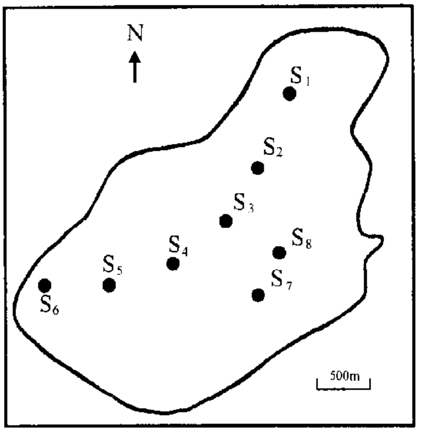

Fig. 1 Distribution of sampling sites in Lake Biandantang

3.3 The energy budget

The energy budget was estimated by the equation of Winberg (1956): $C = P + R + F + U$, where C is the energy consumed, P the production including somatic and shell production, R the energy respired (starvation metabolism and SDA), U the energy excreted and F the energy defecated All these parameters were measured sequentially below:

Production Population production was estimated with instantaneous growth rate method (vide Yan et al, 1999).

Metabolism Metabolism of the animal consists of starvation metabolism (SM) and specific dynamic action (SDA). SM was determined by modified Winkler's method; SDA was measured according to Heiman and Knight (1975).

Egestion Egestion was measured directly at 18, 21 and 30℃. Gastropods from the field were placed in jars with lake water, and feces egested were gathered each 15 minutes successively until 4 ~ 5 hours (Paine, 1971). At the end of each run, height of the animals were measured and converted into dry weight. Fecal matters were dried at 70℃ and weighed.

Excretion Excretion was assumed to be 10% of the assimilation (Hargrave, 1970; Paine, 1971; Marchant, 1978; Gardners et al., 1983).

4 Results

4.1 Chemical compositions

Chemical compositions of the species are given in Tab. 1.

Tab. 1 Chemical compositions of *B. aeruginosa* from Lake Biandantang.

Chemical composition	Content
Protein (%)	57.59
Fat (%)	15.01
Ash (%)	7.80
Carbonhydrate (%)	19.60
Energy content (kJ, g^{-1}. dry-wt)	16.97

4.2 Metabolism

4.2.1 Starvation metabolism The relationship between starvation metabolism and body weight were measured separately at the temperature of 5, 10, 15, 20, 25 and 30℃. The regressions are shown in Fig. 2

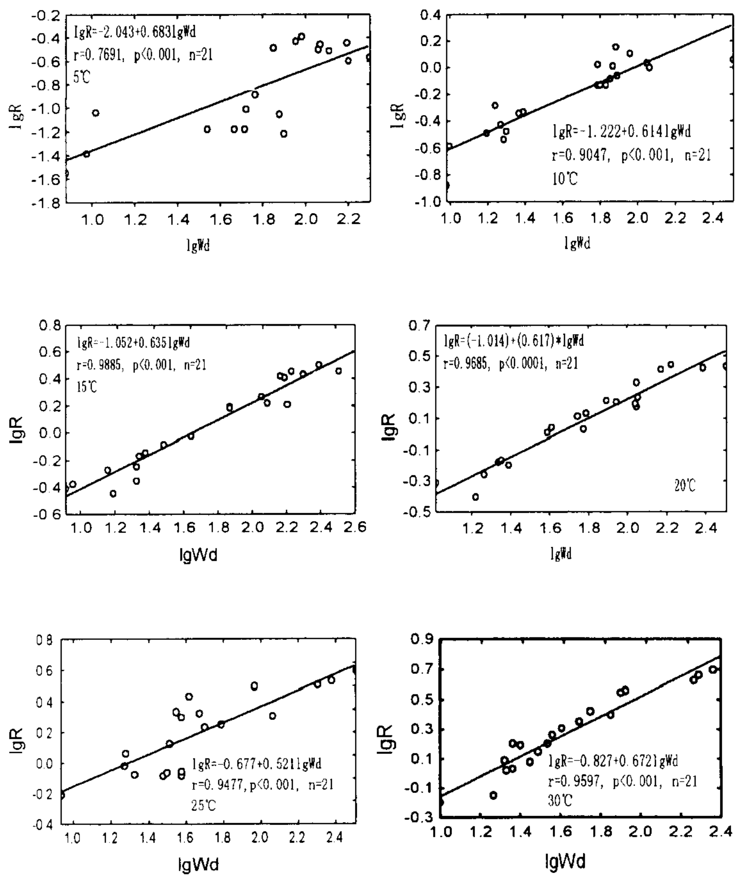

Fig. 2 Relationships between starvation metabolism ($R.\ mgO^2 \cdot Ind^{-1} \cdot d^{-1}$) and dryweight (Wd, mg, shell free) of *B. aeruginosa* at 5, 10, 15, 20, 25 and 30℃.

Coupling the above results, an overall relationship of SM and temperature is developed and expressed as $R = -0.05 + 0.09T + 0.0009T^2$ ($r = 0.6994$, $p < 0.0001$, $n = 30$) (Fig.3). Combining the variables of body-weight and temperature, a three-dimensional function is further obtained. It is described as $R = 0.044Wd^{0.537}e^{0.061T}$, ($R^2 = 0.8702$, $p < 0.001$, $n = 126$), and the resultant diagram is illustrated in Fig. 4.

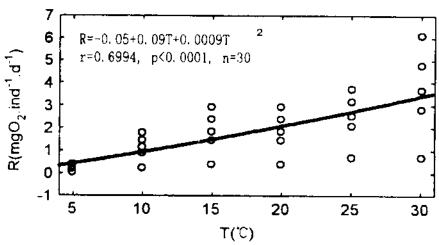

Fig.3　Relationship between starvation metabolism (R, mg $O_2 \cdot ind^{-1} \cdot d^{-1}$) and temperature(T, ℃) of *B. aeruginosa*.

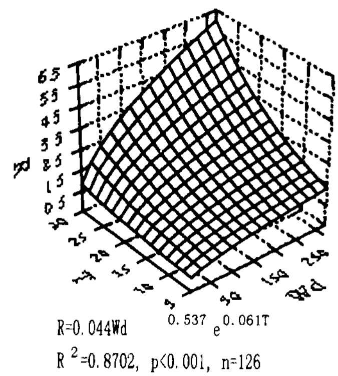

Fig.4　Relationship between starvation metabolism (R, mg $O_2 \cdot ind^{-1} \cdot d^{-1}$), dry weight (Wd, mg shell-free) and temperature (T, ℃) of *B. aeruginosa*.

4.2.2　Specific dynamic action (SDA)　The mean O_2 consumption of *B. aeruginosa* under fed and starved conditions were measured (Fig. 5), and the percentages of SDA in total metabolism were calculated to be 26.7% at 10℃, 22.9% at 15℃, 28.31% at 20℃ and 28.08% at 25℃. The average is 26.5%.

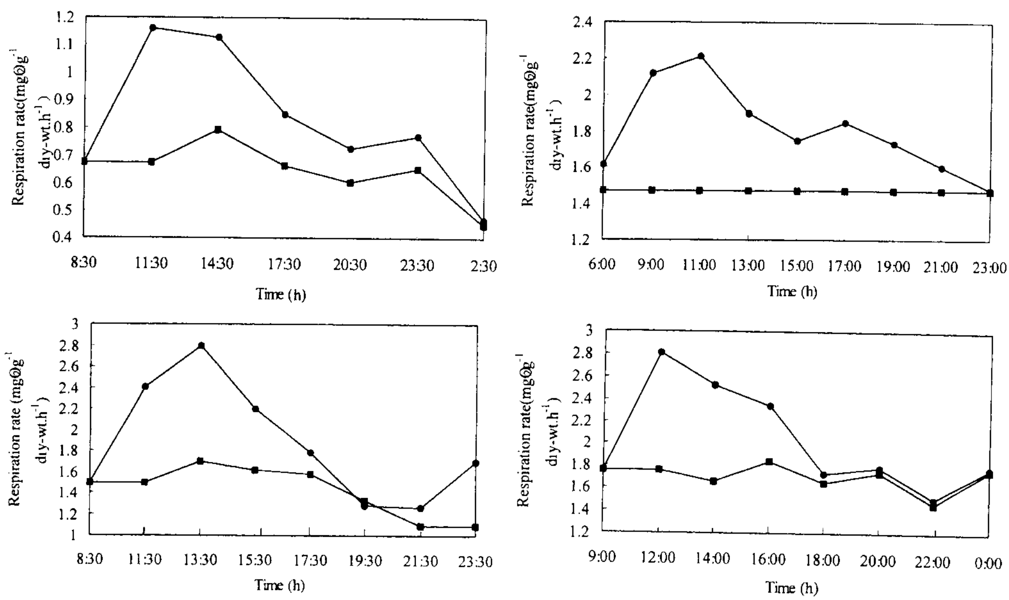

Fig. 5　Mean O_2 consumption ($mgO_2 \cdot g^{-1} \cdot dry\ wt \cdot h^{-1}$) of *B. aeruginosa* using fed and starved animals at 10(a), 15(b), 20(c) and 25℃(d).

4.2.3 Annual metabolism The annual SM of the population was estimated by adjusting the experimental data to field on the basis of corresponding temperature. It was 156.9 kJ. $m^{-2} \cdot a^{-1}$, and the annual SDA was 56.6 kJ·$m^{-2} \cdot a^{-1}$. Hence, the total annual metabolism of the animal was 213.5 kJ·$m^{-2} \cdot a^{-1}$.

4.3 Egestion and excretion

The relationship of egestion (F, mg. dry wt.h^{-1}) and body weight (Wd. mg dry wt) of *B. aerginosa* at 18, 21 and 31℃ were: lgF = 2.271 - 0.643 lgWd, lgF = 2.218 - 0.771lgWd, lgF = 2.565 - 0.761 lgWd, respectively.

Like the calculation of SM, the annual egestion was 270.6 kJ. m^{-2}. a^{-1}, and the annual excretion was 17.2 kJ·$m^{-2} \cdot a^{-1}$.

4.4 Production

The annual production of the species in April, 1996 - March, 1997 is given in Tab. 2.

Tab. 2 Annual production of year classes of *B. aeruginosa* in Lake Biandantang

Year class	Production	
	($g.m^{-2}$.dry-wt.a^{-1})	($kJ.m^{-2}$.dry-wt.a^{-1})
1994 year class	0.085	1.5
1995 year class	0.510	8.6
1996 year class	0.267	4.5
Total production	0.862	14.6

4.5 Energy budget and pattern of energy flow

The energy budget for the populution of *B. aeruginosa* in Lake Biandantang is shown in Tab.3. It means that less than 50% of the annual energy consumption was assimilated, and only 3% or so was transformed into net production (Fig. 6).

Tab. 3 Energy budget (kJ·$m^{-2} \cdot a^{-1}$) for the population of *B. aeruginosa* in Lake Biandantang.
C = consumption; P = production; R = metabolism or respiratory loss; U = excretion; F = egestion.

C	R	P	F	U
515.9	213.5	14.6	270.6	17.2
100%	41.4%	2.8%	52.5%	3.3%

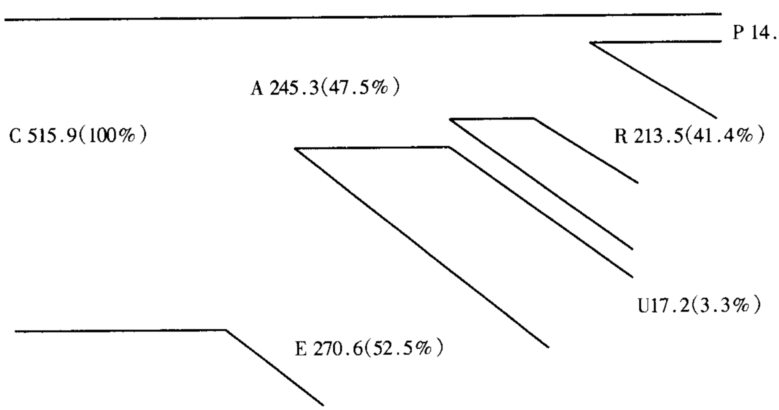

Fig. 6 Pattern of energy flow of *B. aeruginosa* is Lake Biandantang.

5 Discussion

Although population bioenergetics of freshwater molluscs has received moderate attention (Apley 1967, 1970; Burky, 1968, 1971; Gillespie, 1969; Avolizi, 1970; Mattice, 1970; Hunter, 1975). There is no report concerning the energy budget of *B. aeruginosa*, or other species in the genus. The measurement of SDA is still lacking even in the phylum. To evaluate the bioenergetic values of *B. aeruginosa* in the present study, comparisom can only be made with that of other gastropods. In terms of the egestion rate, *B. aeruginosa* was estimated to be 54.5%, which is almost equivalent to that of *Littorina irrorata* (Odum & Smalley, 1959), but obviously higher than that of *Lymnaea palustris* (Hunter, 1975). *B. aeruginosa* used 2.8% of ingestion, or about 6% of assimilation for growth, showing that it has the lowest growth efficiency in comparison with 14% in *Littorina irrorata*, 40.8% ~ 21.7% in *Lymnaea palustris*, 22% to 52% in *Laevapex fuscus* (McMahon, 1972), 65% in *Bithynia tentaculata* (Mattics, 1970). This may partly interpret the slow-growing, elongated life history (3 to 4 years) of *B. aeruginosa*. Moreover, its high respiration rate is in accordance with its size, generally larger than other gastropods.

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