

Metabolism measurements of *Aurelia aurita* planulae larvae, and calculation of maximal survival period of the free swimming stage

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ABSTRACT: Respiration, ammonia and phosphate excretion experiments were performed with planula larvae of *Aurelia aurita* (Scyphozoa) from Kiel Fjord, Baltic Sea, in summer 1983. The mean respiration measured was $3.22 \text{ nl O}_2 \text{ ind}^{-1} \text{ h}^{-1}$ (at $\sim 20^\circ\text{C}$). Excretion experiments revealed average values of $11.41 \text{ pM NH}_4\text{-N ind}^{-1}$, and $0.92 \text{ pM PO}_4\text{-P ind}^{-1} \text{ h}^{-1}$, respectively. The atomic C:N:P ratio of excretion products was 133:10:1. The O:N ratio of 25:1 and O:P ratio of 313:1 point to a lipid-carbohydrate-oriented catabolism of the *Aurelia* larvae. On the basis of experimental results and of biomass determinations, the maximal survival period of the non-feeding free swimming planula stage was calculated. Typically, the value lies in the range of some days to one week.

INTRODUCTION

Respiration and excretion of planktonic animals were investigated by many authors during the last 25 years. While there is a large body of literature dealing with crustacean plankton, only little information is available on the metabolism of other taxa. In summer months, the plankton community of coastal waters is often dominated by larval stages of benthic and planktonic organisms. As invertebrate predation on these larvae is high, the residence time must be relatively short to secure the survival of sufficient individuals in natural populations. Up to now, investigations on the metabolism of invertebrate larvae in the Baltic Sea have not been published. In this paper we present results obtained from respiration and excretion experiments with planulae larvae of the common jellyfish *Aurelia aurita* (Scyphozoa). On the basis of our results we calculated the maximal possible duration of the non-feeding planula stage.

MATERIAL AND METHODS

The planulae larvae for the three sets of experiments were taken from 3 to 5 adult *Aurelia aurita* sampled in Kiel Fjord in August 1983. Experiments started two hours after sampling. Animals were incubated in 1.2-l glass bottles in filtered sea water in the dark for 7 h to 24 h. Respiration was measured using the Winkler method; ammonium and inorganic phosphate excretion were determined according to Grasshoff (1976). Results were calculated as the difference between experimental and control bottles at the end of

experiments. The number of animals per bottle was determined by counting a subsample from each experimental vessel. Total body length was estimated from 50 individuals. Dry weight, organic carbon and nitrogen content was calculated from measuring 6 to 9 replicates, representing 3060 and 4590 individuals, respectively. The carbon and nitrogen analyses were performed using a CHN analyzer (Perkin Elmer Model 240 C). The animals' weight was measured after drying at 60 °C for 24 h.

RESULTS

The results of respiration and excretion measurements of *Aurelia aurita* planulae are given in Table 1.

In the experimental series E 9, negative results were obtained for phosphate excretion and have therefore been omitted. Values reported in brackets are not included in the calculation of means (Table 2). The standard deviation of the mean values is relatively high for all three physiological parameters, whereas the scattering of size and biomass determinations is considerably lower (Table 3). The average carbon content is 39 % of dry weight. Nitrogen contributes to about 9 % of dry weight, and atomic C:N ratio is 5.3. On the basis of these biomass data and of the mean respiration and excretion rates reported in Table 2, daily catabolism and body turnover rates were calculated for carbon, nitrogen, and phosphorus (Table 4). The oxygen measurements were converted to carbon units using a factor of 12/22.4, and a respiratory quotient of 0.85. The daily nitrogen turnover rate (4.8 %) is half the ratio calculated for carbon and phosphate (9.8 %, and 9.5 %, respectively).

Table 1. Summary of respiration and excretion experiments with *Aurelia aurita* planulae larvae.
n = number of individuals studied

| No. | Time (h) | °C | n | Respiration (nl O ₂ ind ⁻¹ h ⁻¹) | PO ₄ (pM ind ⁻¹ h ⁻¹) | NH ₄ (pM ind ⁻¹ h ⁻¹) |
|------|----------|-----------|--------|--------------------------------------------------------------------|---------------------------------------------------------|---------------------------------------------------------|
| E7/1 | 7 | 19.6–20.1 | 15,212 | 1.54 | 0.71 | 30.74 |
| /2 | | | 18,731 | 1.61 | – | 18.85 |
| /3 | | | 29,818 | 1.74 | (0.07) | – |
| /4 | | | 13,963 | 2.28 | 1.08 | 11.62 |
| /5 | | | 17,028 | 3.54 | 0.64 | – |
| /6 | | | 22,818 | 4.48 | 0.76 | 15.48 |
| E8/1 | 7.25 | 20.9–21.3 | 20,220 | 4.75 | 1.56 | 4.09 |
| /2 | | | 16,140 | 4.51 | (0.10) | 10.87 |
| /3 | | | 40,140 | 3.22 | – | 6.19 |
| /4 | | | 28,980 | 3.48 | 1.48 | 14.85 |
| /5 | | | 20,560 | 3.30 | 0.24 | 14.89 |
| /6 | | | 15,030 | 1.87 | (0.11) | 8.26 |
| E9/1 | 24 | 21.1–21.5 | 12,361 | (11.69) | – | 4.27 |
| /2 | | | 23,763 | 5.05 | – | 4.27 |
| /3 | | | 8,418 | (12.12) | – | – |
| /4 | | | 15,132 | 4.33 | – | 4.56 |
| /5 | | | 24,083 | 2.06 | – | – |
| /6 | | | 20,353 | 3.78 | – | 5.28 |

Table 2. Mean values of experimental results. \bar{x} = arithmetic mean; sd = standard deviation; n = number of experiments

| (A) Absolute values | | | |
|----------------------------|-------------------------------------------------------------------------------|-------------------------------------------------------------------------------|---------------------------------|
| | Respiration (nl O ₂ ind ⁻¹ h ⁻¹) | PO ₄ ³⁻ -P (pM ind ⁻¹ h ⁻¹) | NH ₄ ⁺ -N |
| \bar{x} | 3.22 | 0.92 | 11.41 |
| sd | 1.22 | 0.48 | 7.33 |
| n | 16 | 7 | 14 |
| (B) Weight specific values | | | |
| | Respiration (μ l O ₂ mg dw ⁻¹ h ⁻¹) | PO ₄ ³⁻ -P (nM mg dw ⁻¹ h ⁻¹) | NH ₄ ⁺ -N |
| \bar{x} | 3.50 | 1.00 | 12.40 |
| sd | 1.33 | 0.52 | 7.97 |

Table 3. Size, dry weight, carbon and nitrogen content of *Aurelia aurita* planulae larvae

| Parameters | Size (μ m) | DW (μ g ind ⁻¹) | C (μ g ind ⁻¹) | N (μ g ind ⁻¹) | C:N (by weight) | C:N (by atoms) |
|------------|--------------------|-------------------------------------|------------------------------------|------------------------------------|--------------------|-------------------|
| \bar{x} | 255 | 0.92 | 0.36 | 0.08 | 4.5 | 5.3 |
| sd | 26.1 | 0.13 | 0.04 | 0.008 | 0.42 | 0.39 |
| range | 200–320 | 0.8–1.2 | 0.31–0.43 | 0.07–0.09 | | |
| n | 50 | 9 | 6 | 6 | | |

Table 4. Calculated atomic ratios and turnover rates of planula excretion and metabolism

| | |
|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| Excretion | C:N:P = 133.2: 10.4: 1 C:N = 10.7: 1 O:N = 25.2: 1 O:P = 312.5: 1 |
| Daily catabolism | C = 35.28 ng ind ⁻¹ d ⁻¹ N = 3.83 ng ind ⁻¹ d ⁻¹ P = 0.68 ng ind ⁻¹ d ⁻¹ |
| Daily body turnover | C = 9.8% N = 4.8% P = 9.5%* |

* assuming P-content to be similar to planulae investigated in 1984

Assuming these ratios, the whole body carbon would have been respired after 10 days. All organic nitrogen would have been lost as ammonia excretion after 21 days, and phosphate phosphorus after 11 days, respectively.

Table 5. *Aurelia aurita*. Respiration and excretion of adults

| Respiration ($\mu\text{l mg dw}^{-1} \text{h}^{-1}$) | $\text{PO}_4^{3-}\text{-P}$ ($\text{nM mg dw}^{-1} \text{h}^{-1}$) | $\text{NH}_4^+\text{-N}$ ($\text{nM mg dw}^{-1} \text{h}^{-1}$) | Author |
|-----------------------------------------------------------|-------------------------------------------------------------------------|----------------------------------------------------------------------|---------------------|
| 0.090–0.220* | | | Kerstan (1977) |
| 0.095–0.300* | | | Thill (1937) |
| 0.097–0.250** | | | Nicol (1960) |
| 0.100–0.223** | | | Kuz'micheva (1980) |
| | 0.22 | 1.95 | Schneider (unpubl.) |

* assuming dry weight to be 2% of wet weight for Baltic *Aurelia* and
** assuming dry weight to be 3.5% of wet weight for *Aurelia* from other localities (reviewed in Russel, 1970; Kerstan, 1977; Schneider, unpubl.)

DISCUSSION

The mean weight specific respiration and excretion of the planulae larvae are considerably higher than values reported for adult *Aurelia aurita* (Table 5), as expected by the general law of metabolism reduction with increasing body weight (Penzlin, 1977). However, our results are distinctly lower than weight specific rates measured for other smaller zooplankton (rotifers, cladocerans, copepods) under similar experimental conditions in the Baltic (Weisse, in prep.). Since planula larvae do not feed it seems reasonable that their metabolism is relatively lower than that of actively feeding animals like rotifers, cladocerans, and copepods. The specific metabolism of the *Aurelia* larvae is reflected by the atomic ratios reported in Table 4. High O:N and O:P ratios obtained here are caused by a lipid-carbohydrate-oriented metabolism (LeBorgne, 1973; Nival et al., 1974; Ikeda, 1977). The O:P ratio of 313 is higher than previously measured by other authors for different zooplankton groups (reviewed in Ikeda, 1977; see Raymont, 1983). Taking into consideration that not all nitrogen is excreted as ammonia, and a certain amount of phosphorus may be excreted in organic form, the C:N:P ratio of excretion products of 133:10:1 is close to the C:N:P ratio of the larvae's body composition of 139:23:1 which was measured in summer 1984 (Schneider, unpubl. results). It is obvious that the planula larvae catabolize their own body storage products with relatively lower amounts of protein. The maximal maintenance times calculated for carbon, nitrogen, and phosphorus on the basis of the respiration and excretion experiments and of the biomass determinations are unrealistically high. The animals cannot survive until all of their own body products are catabolized. However, lower temperatures in deeper water will reduce metabolic demands, and the maximal survival period will be elongated. Therefore, we assume a maximal duration of the free swimming planula stage between some days and one week, a value consistent with observations by former workers. Lohmann (1908) reported 5 days, Kaestner (1969) 2 days as the typical life span of a planula larva. On the other hand, the larvae can settle down on the substrate within some hours after the release by adult *Aurelia aurita* females (own observations). The actual duration of the free swimming stage is probably mainly determined by environmental factors like bottom depth, turbulence of the water masses and transportation through currents.

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