

Oxygen consumption of the estuarine round herring *Gilchristella aestuarius* (Gilchrist & Thompson)

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Routine oxygen consumption of *Gilchristella aestuarius* was determined using a through-flow system. The exponent b and the coefficient a in the relationship $R = a M^b$, where R is the metabolic rate and M is the body mass, were determined for fish ranging from 0,06 to 1,40 g. Experiments were carried out on summer and winter acclimatized fish. The effects of three acclimation temperatures (15, 20 and 25°C) and three salinities 10, 20 and 35‰ were investigated. The results indicate that the mean b value was 0,77 and that the metabolic rate was salinity independent but increased with increasing temperature with a Q_{10} of 2,3. Oxygen consumption over 24 h showed a peak at 08h00 and 15h00 which coincided with feeding peaks found elsewhere.

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Roetinesuurstofverbruik van *Gilchristella aestuarius* is deur middel van 'n deurvloei sisteem bepaal. Die eksponent b en die koëffisient a in die vergelyking $R = a M^b$, waar R die metaboliese tempo en M die liggaamsmassa is, is bepaal vir vis waarvan die massa van 0,06 tot 1,40 g gewissel het.

Bepalings is gedoen op somer- en winter-geakklimatiseerde vis. Die effek van drie akklimatiseringstemperature (15, 20 en 25°C) en drie soutgehaltes (10, 20 en 35‰) is ondersoek. Hiervolgens is 'n gemiddelde b -waarde van 0,77 gevind. Verder was die metaboliese tempo onafhanklik van soutgehalte maar het toegeneem met verhoogde temperatuur met 'n Q_{10} -waarde van 2,3. Oor 'n 24 h-periode het die suurstofverbruik pieke getoon om 08h00 en 15h00 wat ooreenstem met voedingspieke wat elders gevind is.

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The estuarine round herring, *Gilchristella aestuarius* Gilchrist & Thompson, is a clupeid endemic to the east coast of southern Africa where it inhabits estuaries and brackish, as well as freshwater lagoons (Millard & Broekhuysen 1970; Allanson, Bruton & Hart 1974; Wallace 1975; Blaber 1978). This round herring occurs in high densities, feeds primarily on zooplankton (Whitfield 1980; Talbot 1982) and is the major food item of a number of predators in estuaries (Marais 1984). Because of the considerable contribution made by this species to the flow of energy through the food chain, it is important, in estuarine ecological studies, to assess the response of the metabolic rate to changes in environmental factors. In this study, which forms part of a detailed research programme into the biology of *G. aestuarius* in the Swartkops estuary, Port Elizabeth, the effect of temperature and salinity on the metabolic rate as well as the rate of change of metabolism with body mass were investigated.

Materials and Methods

Round herring were caught in the Swartkops estuary using a seine-net and brought to the laboratory where they were fed freshly hatched brine shrimp nauplii. Feeding was discontinued 24 h before the start of each experiment and starvation maintained throughout its duration (ca. 72 h). Newly captured fish were allowed one week to acclimate to laboratory conditions prior to their use in experiments. To prevent thermal history from influencing the data obtained from wild stocks, experiments were carried out in summer and winter. Winter fish were kept at an 11-h photoperiod (07h00 to 18h00) with water temperature kept at 16,0°C in the holding tanks. Water temperature fluctuations were at all times maintained within 0,5°C of the experimental temperature. Summer conditions in the laboratory consisted of a 13-h photoperiod (06h00 to 19h00) and a water temperature of 22,0°C.

A constant flow respirometer was used to determine the rate of oxygen consumption of *G. aestuarius*. The apparatus has been described in detail by Marais, Akers & Van der Ryst (1976). It consisted essentially of a reservoir tank, a thermostatically controlled tank containing ten respiration chambers of 2,5 l capacity. Outflowing water from these chambers was caught in a recipient tank and pumped back to the reservoir. Water in all tanks was kept at the same temperature. The original apparatus (Marais *et al.* 1976) was expanded to include 10 respirometers. Of these, nine contained fish while one was maintained as a control. The oxygen level of the outflow from the respiration chambers was recorded automatically by diverting the outlet of each chamber by means of a three-way valve so that it flowed past an oxygen probe

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(Oxy 39, WTW Welheim) for a period of 6 min every hour. Water flow through the chambers was maintained by gravity and regulated at the rate of 90 to 110 ml min⁻¹. Actual oxygen consumption was represented by the difference between the line drawn by the recorder for the control chamber and that for any other chamber. Bubbling air maintained the oxygen levels in the water of the reservoir tank at, or near, saturation level before it entered the respiration chamber. At no stage did the oxygen level in any chamber decrease to less than 66% of saturation. The number of fish in each chamber depended on individual size. Fish weighing less than 0,06 g each, numbered between eight and ten per chamber, those weighing between 0,06 g and 1,00 g were four per chamber and those weighing more than 1,0 g were two per chamber. All fish in any respiration chamber were of roughly the same size. Oxygen consumption was recorded on fish acclimated to 15, 20 and 25°C in summer and 10, 15 and 20°C in winter. The rate of acclimation to experimental temperature was 2°C per 12 h and never lasted more than five days before fish were placed in the respiration chambers.

The effect of salinity on metabolic rate of fish was also investigated. The size ranges and number per respiration chamber were as described above. Experiments were carried out at 35, 20 and 10‰ for each of the following temperatures, 15, 20 and 25 °C on fish caught in summer. In the holding tanks fish were kept at the salinity at which they were caught and acclimated to the experimental salinity at the rate of 2‰ h⁻¹ prior to each experiment.

In this study, activity was not measured but checked visually approximately every 6 h. If not excited by external disturbances, the fish swam slowly at a steady rate in the respirometer. This low degree of activity was considered to be normal random movement which is acceptable under the definition of routine metabolism according to Fry (1971).

Results and Discussion

Hourly oxygen consumption measured from the time the fish were placed in the respiration chamber is shown in Figure 1. The data represent the average hourly oxygen consumption of three groups of similar-sized fish. Initial results showed

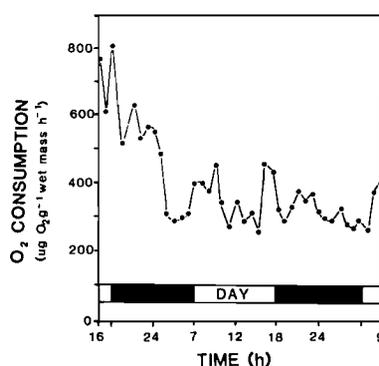


Figure 1 The trend in O₂ consumption from the time of introduction of fish to the respirometer. The data were computed as the average of three sets of recordings.

that stress caused by handling during transfer from the holding tank to the respirometer and the new environment resulted in hyperactivity, raising the oxygen consumption to 800 µg O₂ g⁻¹ wet mass h⁻¹. Activity gradually decreased until routine consumption rate was attained 8 h later. Mann (1965) and Marais (1978) reported similar observations. These high

values were not included in data analysis.

The relationship between rate of oxygen consumption and body mass of *G. aestuarius* fitted the general equation

$$R = a M^b$$

or in its linear form

$$\text{Log } R = \text{Log } a + b \text{ Log } M$$

where R is the metabolic rate measured as µg O₂ h⁻¹ and M is the wet body mass measured in grams.

Regression lines were calculated and the metabolic parameters a and b derived from these are presented in Table 1. The mass exponent b was $0,77 \pm 0,04$ and fell close to the value of 0,8 (limits at 0,71 and 0,81) which is characteristic for fish (Winberg 1956; Mann 1965; Paloheimo & Dickie 1966; Fry 1971; Andrews & Matsuda 1975; Hettler 1976). The value of 0,77 obtained in the present study is close to that of 0,76 found by Lasker (1970) for the Pacific sardine *Sardinops caerulea*, Girard.

Table 1 Parameters of the equation relating metabolism to mass of *Gilchristella aestuarius*

Season	Temp. (°C)	n*	r	a**	b ± SD
Summer	25	4	0,95	483	0,77 ± 0,04
	20	3	0,91	305	
	15	4	0,95	193	
Winter	20	5	0,84	295	0,77 ± 0,03
	15	4	0,93	203	

* Number of oxygen consumption determinations

** µg O₂ h⁻¹

Effect of salinity

Changes in salinity did not appear to affect the metabolic rate of *G. aestuarius*. Analysis of covariance (Snedecor & Cochran 1976) of the data showed no significant difference ($P < 0,05$) among the a and b values in the relationship between O₂ consumption and body mass. Tolerance of a wide salinity range is not unexpected for *G. aestuarius* since it inhabits shallow estuaries where salinities may fluctuate between wide limits within tidal cycles (Talbot 1982) or over longer periods such as that encountered by the population in Lake St Lucia in northern Natal where salinities reach levels of 56,2‰ (Millard & Broekhuysen 1970). In estuaries it is unusual for non-planktonic organisms to remain sufficiently long in any single body of water to allow them to reach a steady state appropriate to a particular salinity. Survival in estuarine conditions, therefore, is dependent upon the ability of an organism to adapt swiftly to the changing saline conditions experienced (Lockwood 1976). It appears that *G. aestuarius* expends very little energy to maintain ionic homeostasis within the salinity range investigated here.

Effect of temperature

Temperature effects on the metabolic rate of *G. aestuarius* were determined by studying the metabolic parameters a (the index of the metabolism) and b (the mass exponent) from the equation $R = a M^b$. The results are shown in Table 1 and were used to construct Figure 2 which represents regressions of oxygen consumption against body mass. Analysis of covariance between b values showed no significant differ-

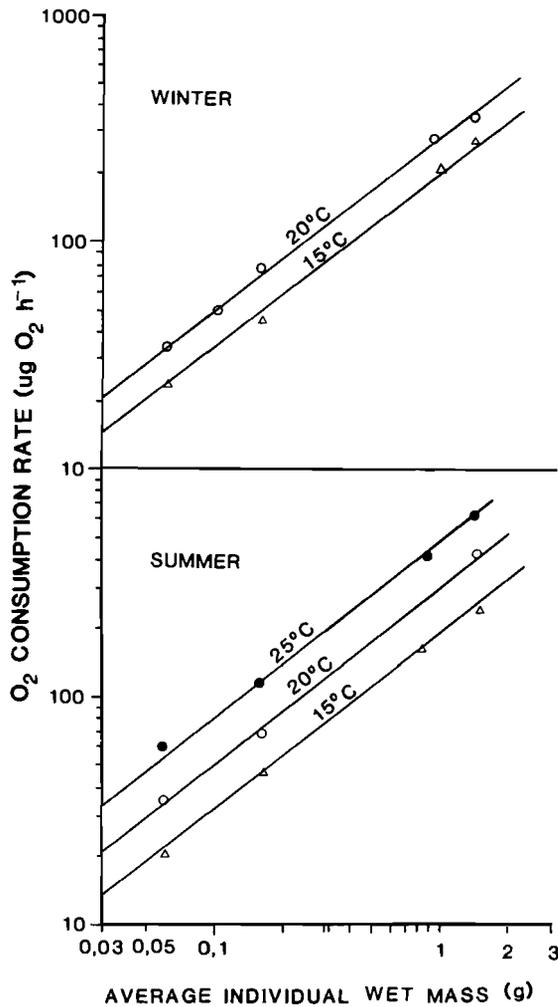


Figure 2 Oxygen consumption in relation to body size at different acclimation temperatures (15, 20 and 25°C on summer-acclimatized fish and 15 and 20°C on winter-acclimatized fish). Each point represents the average oxygen consumption recorded hourly for a minimum of 56 h after allowing an initial 8 h acclimation period in the respiration chambers.

ence at the $P < 0,05$ level between the different acclimation temperatures and between seasons. This temperature independence of the mass exponent is in agreement with the findings of a number of workers (Fry 1971; Hettler 1976; Marais 1978).

Although temperature had no effect on the rate of change of metabolism against body size, the data obtained from summer-acclimatized fish indicate that the metabolic indices (a values) increased linearly over the temperature range. This change fitted the regressed equation $y = 29,90x - 265$ ($r = 0,99$) where y is the metabolic index and x , temperature. Winberg (1956) found that although a is characteristic for a particular species, it is temperature dependent and follows the curve of Krogh (1916). This temperature dependence of a reported here is similar to that reported by many authors (Wieser 1973). Q_{10} was slightly lower in winter (2,1) than in summer (2,5) (t test, $P < 0,05$).

Diurnal rhythms

Mean hourly oxygen consumption of *G. aestuarius* calculated from three sets of three-day continuous records (e.g. Figure 1) is shown in Figure 3. Oxygen consumption rates for the first 8 h, the period of adaptation to the respirometer (see Figure 1), were not included in these calculations of

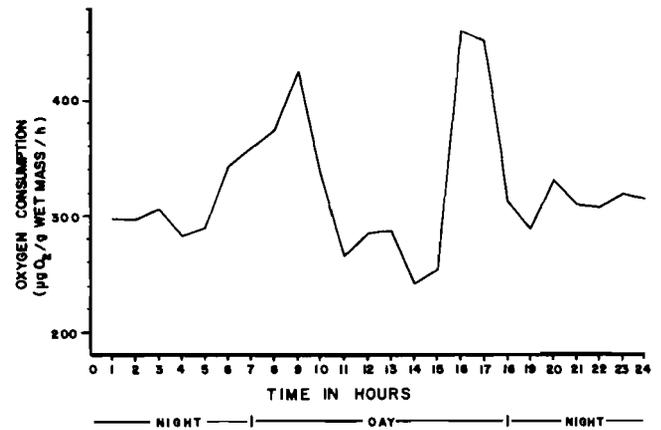


Figure 3 Mean hourly O_2 consumption of *Gilchristella aestuarius* over 24 h. Data was computed as the average hourly values from five sets of three-day continuous recordings. For clarity standard deviation is not shown but ranged between ± 40 and $\pm 70 \mu g O_2 g^{-1}$ wet mass h^{-1} .

mean consumption. The results show a clear pattern in the rate of oxygen consumption with peaks occurring at 08h00 and 16h00. These peaks coincide with times of greatest feeding activity found for *G. aestuarius* (Talbot 1982). In his investigation of the effect of feeding on respiration rate, Hettler (1976) found an initial increase in oxygen consumption owing to increased muscular activity associated with rapid swimming during feeding. This was followed, up to 18 h after feeding, by a subsequent high metabolic rate owing to food utilization, referred to as specific dynamic action (SDA) (Jobling & Spencer Davies 1980). The rhythm shown in Figure 3 could be attributed to an endogenous rhythm triggering the search for food. Clausen (1936) showed similar fluctuations in oxygen consumption of *Micropterus salmoides* Lacépède, kept in total darkness. Fry (1957) warned against recording oxygen consumption over short time intervals because of the presence of diurnal rhythms which could disproportionately influence mean consumption rates.

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