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Oxygen Consumption of Saffron Cod, *Eleginus gracilis* (Tilesius)*

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Abstract

Standard oxygen consumption rates of saffron cod were measured at a temperature between 1 and 16°C in a running sea water system.

The value of Q_{10} was 2.34 for 100-180 g fish, and it fell within normal range reported for other fish. The relationship between oxygen consumption (R) and body weight (W : g) was expressed by the equations: $R=0.150\ W^{0.700}$ at 1-5°C, $R=0.164\ W^{0.782}$ at 6-8°C, and $R=0.217\ W^{0.794}$ at 11-13°C. The adjusted oxygen consumption to 10°C is $R=0.203\ W^{0.774}\times 10^{0.037(T-10)}$.

The exponents of equation fell within a similar range found in Atlantic Gadidae. However, the standard metabolism of saffron cod was maintained at higher levels at low temperatures when compared with that of other boreal or benthic fish species. The higher metabolism at temperatures below zero is probably related to their winter ecological conditions.

Introduction

Saffron cod (*Eleginus gracilis*) are known to be widely distributed in the coast of Alaska in the north Pacific Ocean and Bering Sea, along the coast of Soviet Union including Kamchatka, Sakhalin, and in the eastern shore of Hokkaido. They usually spawn at low temperature below zero in winter (Pokrovskaya, 1960; Kozlov, 1959).

Oxygen consumption of Gadidae in the Atlantic Ocean has been the subject of a number of studies (Sundness, 1957; Saunders, 1963; Edwards et al., 1972; Lipskaya et al., 1972). However little is known about oxygen consumption of the Gadidae in the Pacific Ocean. As a first step to estimate the energy consumption and to clarify the ecological and physiological characters of saffron cod (*Eleginus gracilis*) in the marine environment, the standard respiratory metabolism of the fish was measured at a temperature range from 1 to 16°C. In summer they would be found inshore at a temperature about 12°C.

Materials and methods

Saffron cod were caught by small set net, and hook and line at Usujiri, Funka Bay, Hokkaido from 1982 to 1985. Immediately after catching the fish were

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transported to the laboratory and kept in tanks (1000 l).

Fish were acclimated to laboratory conditions for 1-2 weeks after capture. Obviously injured or unhealthy fish were removed during this period. No food was given to any experimental fish during 72 h period before experiments. Two sizes of respirometers were used. Fish were individually confined in cylindrical respirometers which were placed in a large container at a constant temperature. Care was taken to avoid disturbance from outside.

To eliminate suspended material and bubbles, the seawater was passed through a glasswool filter before using for the experiments. Water was siphoned out of the back of respirometer. The rate of flow of water in a respirometer was 30-120 ml per minute. This rate was controlled depending on the fish size. The total number used for experiment was 32 fish, and 9 fish were measured at different temperature respectively.

Before the start of an experiment, each fish was measured and weighed after anaesthetization by MS 222. Because of the effect of handling, oxygen consumption rates were high at the start of experiments. At least one day was needed before oxygen consumption rates of the fish stabilized. Dissolved oxygen was measured by the Winkler method. The difference between the oxygen level measured in the respirometer and a control combined with the volume of flow through the respirometer and the weight of the fish was used to calculate the oxygen consumption per unit weight of fish. Oxygen measurements were made from 2 to 6 times per day for each fish. External stimuli were eliminated to the greatest extent possible so the fish in the respirometer could be kept in a resting condition.

Results

Metabolic rates did not show any variation due to the time of the day. Therefore the measurements of the oxygen consumption rates were averaged regard-

Table 1. Standard rates of oxygen consumption per unit weight of various sizes and at different temperatures

Temperature range (°C) [*]	Body weight (g)		Oxygen consumption (mlO_2/Kg/h) X ± SD	N
	range	mean		
1-4	100>	41.8	52.88±17.59	4
1-4	100-150	128.6	35.25± 7.22	6
1-4	150-200	173.5	32.05± 9.83	2
6-8	100>	71.0	67.10±22.19	4
6-8	100-150	127.9	67.75± 1.20	2
6-8	150-200	164.9	49.25±12.76	4
6-8	200<	370.0	54.00	1
11-13	100>	63.4	97.62±18.97	5
11-13	100-150	127.0	86.50±10.24	3
11-13	150-200	162.0	70.47±10.86	3
11-13	200<	332.3	63.75±20.72	2

[*] The temperature range was controlled from ±0.2°C for each individual.

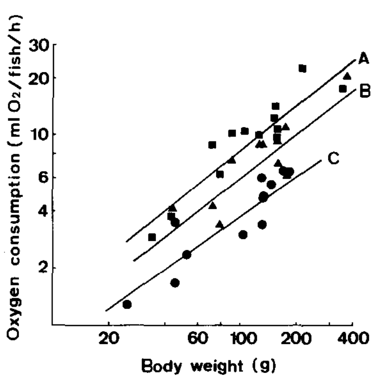

Fig. 1. Relationship between oxygen consumption and body weight of saffron cod.
A : $R=0.217\ W^{0.794}$ $N=13$, $r=0.941$, $P<0.001$, 10-13°C ···· (■)
B : $R=0.164\ W^{0.782}$ $N=11$, $r=0.863$, $P<0.001$, 6-8°C ···· (▲)
C : $R=0.150\ W^{0.700}$ $N=12$, $r=0.879$, $P<0.001$, 1-5°C ···· (●)

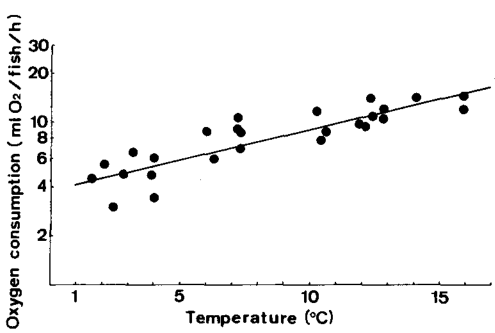

Fig. 2. Relationship between oxygen consumption and temperature of saffron cod of 100-180 g.
$R=3.917 \cdot 10^{0.037T}$ $N=26$, $r=0.868$, $P<0.001$

less of the time of the day.

There is a well-marked effect of size on rate of oxygen consumption. The relationships between body weight and oxygen consumption are shown in Fig. 1. For a given shift in temperature, the proportionate change in oxygen consumption appears to be independent of weight. There was a tendency for small individuals consume oxygen at a greater rate per unit weight than do large fish (Table 1).

The metabolic rates of immature saffron cod (100-180 g, average 140 g) increased linerly on a semilogarithmic scale over wide range (Fig. 2). From the relation between the oxygen consumption rates and temperatures, the Q_{10} value was estimated as 2.34 (1-16°C). To estimate the oxygen consumption at an optional temperature, the Q_{10} value obtained in this study was adopted. If a value of 0.037 is adopted, the temperature correction is obtained as $10^{0.037(T_1-T_2)}$.

This provides an empirical relation for converting oxygen consumption at a temperature T_2°C to a oxygen consumption at T_1°C. Using these relationship the oxygen consumption at 10°C can be shown as follows.

$$R=0.203\ W^{0.774}\times 10^{0.037(T-10)}\ \mathrm{m}l\mathrm{O_2/fish/h}$$

With a value of 1 ml O_2 = 4.83 cal (Ivlev, 1934) the metabolic energy is given by following equations : $R=0.980\ W^{0.774}\times 10^{0.037(T-10)}$ cal/fish/h. The daily maintenance energy is calculated to be $23.52\ W^{0.774}\times 10^{0.037(T-10)}$ cal.

Discussion

In most fish species the Q_{10} value is situated between 2 and 3 (Edwards et al., 1969 ; Edwards et al., 1972 ; Brett & Groves, 1979). The value of saffron cod falls within this range. The exponent of the body weight-oxygen consumption relationship is usually 0.8 in most fish species (Winberg, 1956 ; Paloheimo & Dickie, 1966 ;

Table 2. Comparison of coefficients a and b from respiratory metabolism in Gadidae

Temp. (°C)	species	Range of body weight (g)	a ($R=aW^b$)	b	Source
……	*Gadus callarias*	28-1750	0.520	0.730	Sundness (1957)
	G. virens				
3-5	*G. morhua*	430-6650 (*)	1.633	0.791	Saunders (1963)
10		190-7100 (*)	1.834	0.886	
15		90-3140 (*)	1.890	0.820	
15		140-2200 (**)	0.215	0.796	
12	*G. morhua*	15-1000	0.245	0.820	Edwards et al. (1972)
11	*G. callarias*	100-2000	0.388	0.716	Lipskaya et al. (1972)
−1.5	*Boreogadus saida*	0.665-122 (*)	0.089	0.830	Holeton (1974)
10	*E. gracilis*	25-370	0.203	0.774	this paper

[*] routine rate.
[**] standard rate (recalculated from the data of Saunders, 1963).

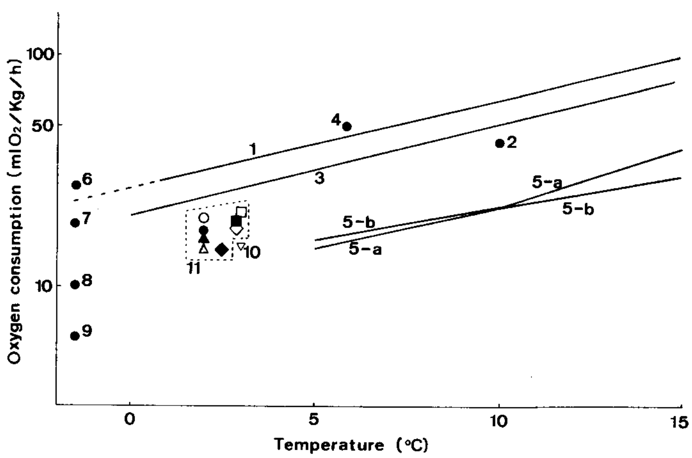

Fig. 3. A comparison of standard rates of oxygen consumption of various species with saffron cod. All data are either applicable to or have been corrected to values representative of 100-200 g fish.
1 : this paper 2 : haddock (Tytler, 1969) 3 : Atlantic cod (recalculated from Saunders, 1963) 4 : walleye pollock (Paul, 1986) 5-a : flounders (Duthie, 1982) 5-b : lemon sole (Duthie, 1982) 6 : polar cod (Holenton, 1974) 7 : arctic cottids (Holeton, 1974) 8 : arctic zoacids (Holeton, 1974) 9 : arctic liparids (Holeton, 1974) 10 : American plaice (Mackinnon, 1973) 11 : rockfishes (Tamura, 1940) Nos. 6, 7, 8 and 9 are estimated as routine rates.

Fry, 1957 ; Brett & Groves, 1979). The present data falls within a similar range as found in Gadidae (Table 2).

The relation between oxygen consumption rate per unit weight and temperature is given in Fig. 3. The standard rates of saffron cod seem to be nearly the same as that of other gadoid fishes such as Atlantic cod, haddock and walleye pollock. Due to different methods, exact comparison among Gadidae is impossible. Generally, the rates of flatfishes, and rockfishes are lower than that of Gadidae. Especially, the rates of flatfishes and zoacids, liparids in the Arctic Sea are in general considerably lower. This would be due to the difference between benthic or inactive fish and migratory or active fish (Chekunova, 1983).

Saffron cod spawn in shallow coastal waters at quite low temperatures, usually below zero and sometimes beneath the sea ice, and usually feed in the winter period (Pokrovskaya, 1960 ; Kozlov, 1959). From the data obtained in this study, saffron cod could maintain as high a standard metabolism at low temperature environments as compared with other gadoids and higher than some benthic species. This higher metabolism of saffron cod at low temperatures relates to their ecological conditions during the winter. If the regression line of Fig. 3 is extraporated to lower temperatures, the metabolic rate is calculated as $26.9\ ml O_2/Kg/h$ at 0°C. This value is considered to be the estimated metabolism for saffron cod (body weight : 100–180 g) in the winter season.

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