HOKKAIDO UNIVERSITY

Title	Oxygen Consumption of Saffron Cod, Eleginus gracilis (Tilesius)
Author(s)	CHEN, Are-lang; MISHIMA, Seikichi
Citation	北海道大學水産學部研究彙報, 37(4), 303-308
Issue Date	1986-11
Doc URL	https://hdl.handle.net/2115/23932
Type	departmental bulletin paper
File Information	37(4)_P303-308.pdf

Hokkaido University Collection of Scholarly and Academic Papers : HUSCAP

Bull. Fac. Fish. Hokkaido Univ.
37(4), 303-308. 1986.

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

Are-lang CHEN** and Seikichi MISHIMA**

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

* *Contribution No. 182 from the Research Institute of North Pacific Fisheries, Faculty of Fisheries, Hokkaido University*
(北海道大学水産学部北洋水産研究施設業績182号)
** *Research Institute of North Pacific Fisheries, Faculty of Fisheries, Hokkaido University*
(北海道大学水産学部北洋水産研究施設)

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.

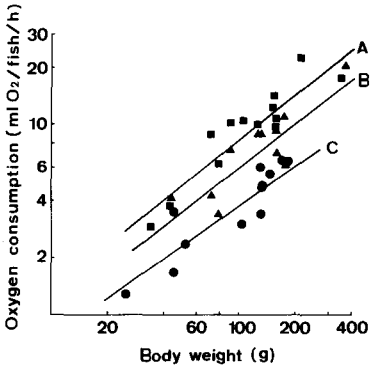

Fig. 1. Relationship between oxygen consumption and body weight of saffron cod.
A: $R=0.217\ W^{0.794}$ N=13, r=0.941, P<0.001, 10-13°C ···· (■)
B: $R=0.164\ W^{0.782}$ N=11, r=0.863, P<0.001, 6-8°C ···· (▲)
C: $R=0.150\ W^{0.700}$ N=12, r=0.879, P<0.001, 1-5°C ···· (●)

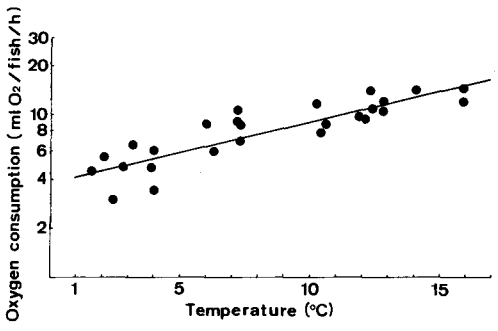

Fig. 2. Relationship between oxygen consumption and temperature of saffron cod of 100-180 g.
$R=3.917 \cdot 10^{0.037T}$ N=26, r=0.868, P<0.001

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.

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

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	b	Source
			$R = aW^b$		
.....	*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).

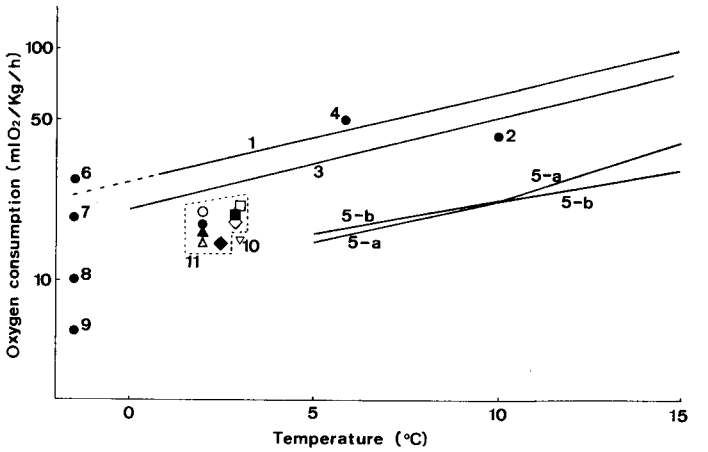

Fig. 3. A comparison of standard rates of oxygen consumption of various species with saffron cod. All data are either applicable to or have been corrected to values representative of 100-200 g fish.
1: this paper 2: haddock (Tytler, 1969) 3: Atlantic cod (recalculated from Saunders, 1963) 4: walleye 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.

Acknowledgements

The authors wish to express their sincere thanks and appreciation to Assistant Professor K. Shimazaki and Dr. H. Ogi of the Faculty of Fisheries Hokkaido University and Professor J.P. Doyle and Mr. A.J. Paul of the University of Alaska. We also wish to express our gratitudes to Mr. Y. Arashida and Mr. K. Nomura of the Usujiri Fisheries Laboratory, who kindly assisted us in collecting the materials.

References

Brett, J.R. and Groves, T.D.D. (1979). Physiological Energetics. p. 280-352. In Hoar, W.S., Randall, D.J. and Brett, J.R. (ed.), *Fish Physiology*. **8**, 786 p. Academic Press, New York and London.

Chekunova, V.I. (1983). Ecological groups of cold-water fishes and their energy metabolism. (Translated from the Russian). *J. Ichthyol.* **23**, 111-121.

Duthie, G.G. (1982). The respiratory metabolism of temperature-adapted flatfish at rest during swimming activity and the use of anaerobic metabolism at moderate swimming speed. *J. Exp. Biol.* **97**, 359-373.

Edwards, R.R.C., Finlayson, D.M. and Steele, J.H. (1969). The ecology of 0-group plaice and common dasin loch ewe: 2. Experimental studies of metabolism. *J. exp. mar. Biol. Ecol.* **3**, 1-17.

Edwards, R.R.C., Finlayson, D.M. and Steele, J.H. (1972). An experimental study of the oxygen consumption, growth, and metabolism of the cod (*Gadus morhua*) *J. exp. mar. Biol. Ecol.* **8**, 249-309.

Fry, F.E.J. (1957). The Aquatic Respiration of Fish. p. 1-63. In Brown, M.E. (ed), *The Physiology of Fishes*. **1**, 447 p. Academic Press, New York.

Holeton, G.F. (1974). Metabolic cold adaptation of polar fish: Fact or artifact. ? *Physiol. Zool.* **47**, 137-152.

Ivlev, B.C. (1934). Eine Mikromethods zur Bestimmung des Kaloriengthalts von nährstoffen. *Biochem. Z.* **275**, 49-55.

Kozlov, B.M. (1959). The biology of the navaga and the navaga fishery in the northern part of the Tatar Strait. *Izv. Tikhookean. nauchnoissled. Inst. ryb. Khoz. Okeanogr.* **47**, 118-144.

Lipskaya, N.Y., Uzarz. D.V., Chekunova, V.I. and Shatunovsky, M.I. (1972). Some aspects of energy metabolism in Baltic cod, *Gadus morhua callarias. Trudy VNIRO.* **75**, 81-85.

Mackinnon, J.C. (1973). Metabolism and its relationship with growth rate of American plaice, *Hippoglossoides platessoides. J. exp. mar. Biol. Ecol.* **11**, 297-310.

Paul, A.J. (1986). Respiration of juvenile pollock, *Theragra chalcogramma* (Pallas), relative to body size and temperature. *J. exp. mar. Biol. Ecol.* **97**, 287-293.

Pokrovskaya, T. (1960). Geographic variability in the biology of the navaga. *Trudy Inst. Okeanol.* **31**, 19-110.

Paloheimo, J.E. and Dickie, L.M. (1966). Food and growth of fish : Effects of food and temperature on the relation between metabolism and body weight. *J. Fish. Res. Bd. Canada* **6**, 869-908.

Saunders, R.L. (1963). Respiration of the Atlantic cod. *J. Fish. Res. Bd. Canada* **20**, 373-386.

Sundness, G. (1957). Notes on the energy metabolism of the cod (*Gadus callarias* L.) and the coalfish (*Gadus virens* L.) in relation to body size. *FiskDir. Skr. Serie Havunderskeser.* **6**, 1-10.

Tamura, T. (1940). The influence of external change to fishes : 2nd report. Respiration of some marine fishes in winter. *J. Fish.* **46**, 56-66.

Tytler, P. (1969). Relationship between oxygen consumption and swimming speed in the haddock, *Melanogrammus aeglefinus. Nature* **227**, 274-275.

Winberg, G.G. (1956). Rate of metabolism and food requirements of fishes. (Translated from the Russian) *Fish. Res. Bd. Canada Trans. Ser.* **194**, 283 p.