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# Notes on the energy metabolism of the cod *(Gadus callarias L.)* and the coalfish *(Gadus virens L.)* in relation to body size

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## *Introduction*

The energy metabolism or oxygen consumption in fish has been worked out for many species. Leiner (1938) and Black (1951) have given good reviews of the literature.

There seems to be no investigation on the oxygen consumption of the cod and the coalfish after the larval stage. Some physiological data have been gathered on these two species and the present paper considers some results from these experiments.

The work on which this paper is based was carried out at Fiskeridirektoratets Havforskningsinstitutt in Bergen.

## *Materials and methods*

The fish which were used in the experiments were all caught off the west coast of Norway. The size range was from 2.8—1750 grams.

The coalfish is by no means an experimental animal. The epidermis is easily damaged and lethal infections follow. The cod, however, is a good experimental animal. Adaptation to the experimental conditions is good, making the fish easy to work with.

All fish were starved 3 to 4 days before they were placed in the experimental aquarium. The experimental period lasted up to 10 days. After the experiments the fish were transferred to large storage aquariums. Their survival, food intake and behaviour in the following weeks were used as an indication that conditions had been normal during the measurement of the energy metabolism. Data from fish which seemed to have been under abnormal conditions were omitted.

Winkler's method, with the modification introduced by Krogh (1935), was used in estimating the oxygen consumed. The «respiration» of the seawater was measured, but the value stayed inside the error limit of the analyses. The oxygen consumption of the fish was measured in closed aquariums.

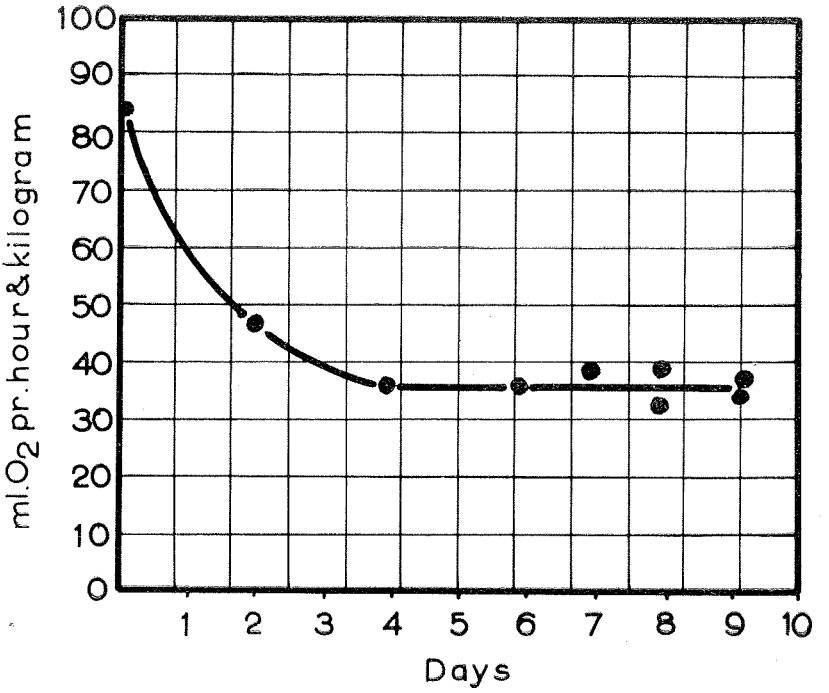


Fig. 1. Oxygen consumption of a cod of 1750 gr.

*Energy- metabolism under standard conditions*

The term «basal metabolism» is used in medicine, but it is impossible to keep a fish in basal conditions according to such a definition. In most works about fish the external data have been standardised, but the measured metabolic rate has not always been a standard metabolism. The physiological conditions of the fish are very imbortant. *The energy metabolism of fish under standard conditions may be defined as a steady energy metabolic rate (inside the biological variation) over long time intervals, which can be defined as a normal rate by the chemical and physical characteristics of the environment.*

The experimental conditions were far different from normal conditions, and therefore the oxygen consumption of the fish was very high just after transfer to the experimental aquarium. Winterstein (1908) mentioned this fact, which he considered himself able to show by experiments.

The cod and the coalfish have a significantly increased energy

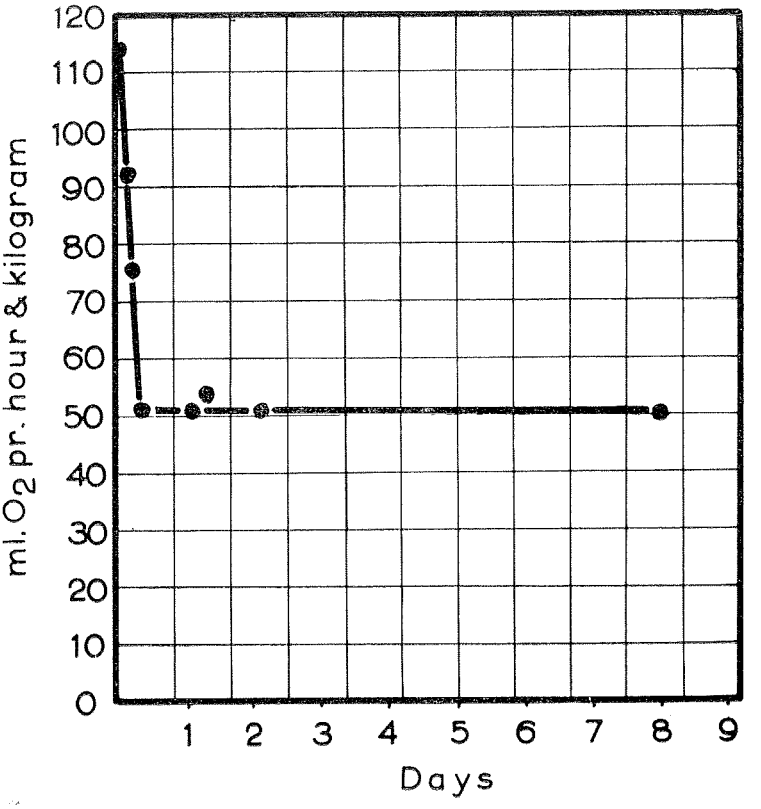


Fig. 2. Oxygen consumption of a cod of 280 gr.

metabolism after being transferred to the experimental aquarium. (Figs. 1, 2, 3 and 4).

It seems that the acclimation time is different for small and large cod. The same was found on cod which were investigated in different aquariums. This phenomenon is valid for the coalfish as well. (Figs. 3 and 4).

The difference in the acclimation time between large and small specimens may have a connection with body size in relation to the volume of the experimental aquarium. However, measurements on small specimens in a small aquarium do not confirm this. Their acclimation time is as short as it would be in a large aquarium. It is not possible to give a general acclimation time for cod and coalfish in the same way as Keys (1930 a) and Wells (1932) have done for *Fundulis parvipinnis*. Wells (1932 p. 585) writes:

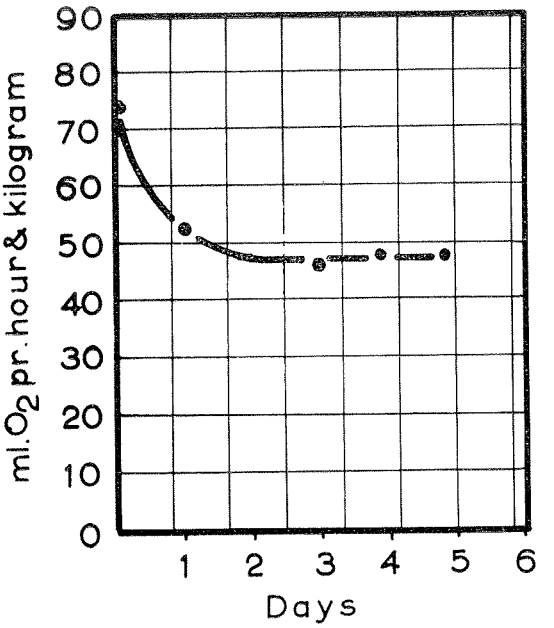


Fig. 3. Oxygen consumption of a coalfish of 1020 gr.

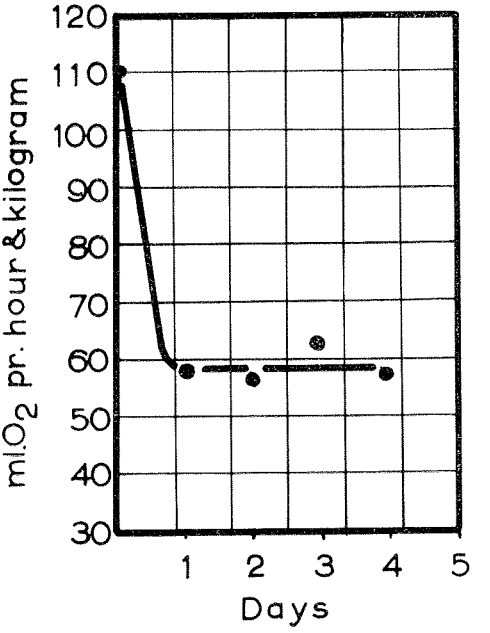


Fig. 4. Oxygen consumption of a coalfish of 230 gr.

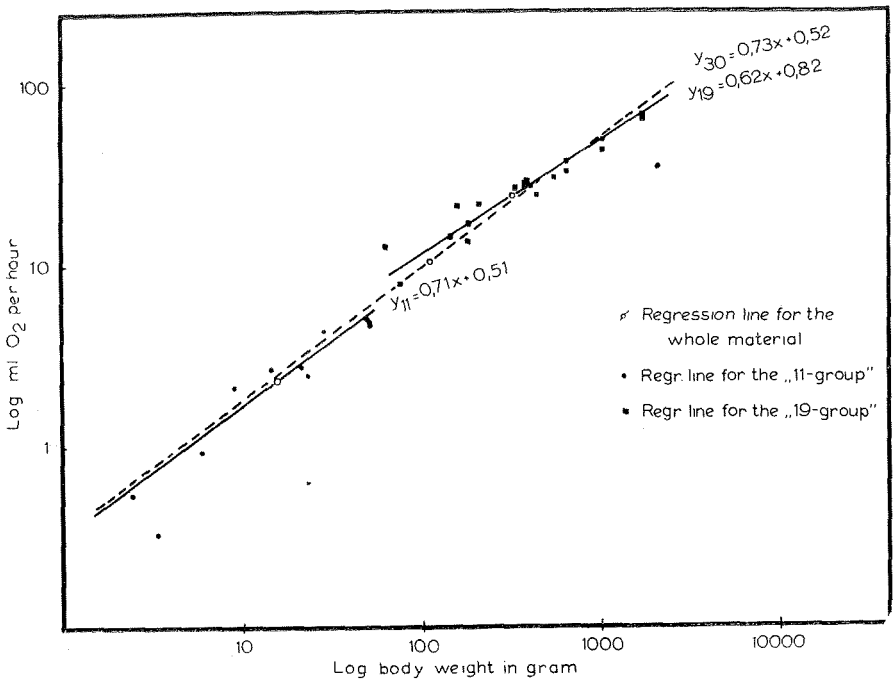


Fig. 5. Energy-metabolism of cod and coalfish in relation to body weight. (Both species lumped together).

«Indeed I should expect that with very active, nervous fishes several days would be required for them to reach a normal level of metabolism, while on the other hand, quiet, sedentary fishes may do so in a few hours.»

The results in the present work show that the acclimation time is not species specific. The phenomenon is more complicated, and contributing factors must be sought in each single individual and among the external stimuli.

The high oxygen consumption in the cod and the coalfish just after being transferred to another aquarium is known. Sundnes (1956) outlines the situation when these species are transported alive in well-boats.

### *Energy-metabolism in relation to body size*

Oxygen consumption in relation to body size has long been discussed. One of the difficulties is the unit of body size, because this is important in the comparison of different animals. Zeuthen (1947)

finds that $N_2$-content and body weight give good comparative units.

There is little of this work on fish. Cronheim (1911) writes that he finds from the experiments of Knauthe (1898) that the oxygen consumption in *Cyprinus* sp. is proportional to the surface of the body. Lindstedt (1914) reaches the same results on *Tinca vulgaris*. Punt and Jongbloed (1946) emphasize that the oxygen consumption in fish is proportional to the body surface. Keys (1930 a), Viswanathan and Tampi (1952), and Wells (1935), have made investigations on fish in relation to body weight for almost the whole size-range of the species.

In the present work the conditions have been standardized. The results are plotted (fig. 5). Keys (1930 b) has found a three phase curve for *Fundulus parvipinnis*. Eliassen (1952) has found the same for *Artemia salina* and Zeuthen (1947) the same for *Mytilus edulis*. In a later work Zeuthen (1953) believes he finds the same phenomenon in other groups of the animal kingdom from the results of other authors and his own experiments.

### *Statistics*

When the values originally found in the present investigation are transferred to a logarithmic scale, there seems to be a clear linear regression between the weight of the fish and the oxygen consumption. The correlation-coefficient was found to be 0.99 for the whole material (30 fish). This significant coefficient dose not exclude the possibility of a difference i oxygen-consumption in relation to the weight between small fish and the bigger ones.

The parameter found, can not prove that the oxygen consumption increases in linear proportion to increasing weight. As a hypothesis the 11 smallest fish were tested as one group and the 19 biggest fish as another group. (From the diagram there seems to be a natural gap between these two groups). The correlation coefficients found were 0.97 and 0.94 respectively.

Testing three different correlation coefficients against each other has not been done, as no simple criterion is known. On account of the small amount of material no further statistical methods have been involved, and it would in any case have been difficult to get significant answers to the problems.

The regression-lines for the three mentioned groups have, however, been calculated, and, as will be seen from the diagram, there is

a slight difference between the rise of the 11-group and the 19-group. This might imply that the oxygen consumption by increasing weight, dose noe increase to the same extent among big fish as among small ones.

*Summary.*

The present work on the oxygen consumption in the cod and the coalfish shows that there is a connection between the body size and the acclimation time required for reaching a «normal» level of metabolism after being transferred to anoher aquarium. (Figs. 1, 2, 3 and 4). The oxygen consumption under standard condition shows that there is a clear linear regression between the two variables used. However, the significant coefficient does not exclude the possibility of a difference in oxygen-consumption in relation to the weight between small fish and bigger ones. (Fig. 5).

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# CORRIGENDA

*Vol. 11, No. 9.*

Page 7, Fig. 5, on the abcissa for *Log ml $O_2$ per hour* read *Log ml $O_2$ per hour* $(+ 1)$.

*Vol. 13, No. 5.*

Page 3, line 5, for *Schonlander* read *Scholander.*