

Swimming speed of fish as a factor in gear research

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INTRODUCTION

In fisheries gear research the locomotion of the animal to be caught plays an important role. The swimming speed of fish is of great interest in the development of pelagic trawls and similar active gear where the effect of escape by the fish is a major factor in the efficiency of the gear.

The literature on swimming speeds of fish has been reviewed by Bainbridge (1958) who has carried out further investigations on freshwater species (Bainbridge 1960, 1961, 1962). The only reports dealing with marine species of commercial importance, however, are those of Mangan (1930) and Blaxter & Dickson (1959).

The high swimming speeds of fish which have been mentioned by seagoing people generally have not been verified by the modern investigations. On the other hand, many of the experiments have been performed in aquaria or in traps where the conditions were far from normal. From other investigations (Dragesund & Leivestad 1959, Sundnes 1957a, 1957b) we know that fish behave peculiarly when in aquaria or similar conditions. They are able to set up a very high metabolic rate without locomotion when this is not possible. They seemingly do know that they cannot escape in the real sense of the word but only make "a local escape".

The most commonly used method for measuring the swimming speed in fish is to observe the live fish swimming. Most of the experiments dealing with marine species have been performed in aquaria where the fish swims against a current or where it swims towards the end of a relatively long basin (Mangan 1930 and Blaxter & Dickson 1959). Other measurements have been made in the open sea by piscatometer (Gero 1952) and other devices (Blaxter & Dickson loc. cit.). Another indirect method was used by the author (Sundnes 1957) whereby the resistance of a model of the body in water and the energy metabolism were used in the calculation of swimming speed. In the present investigation the fish itself has been used for dragging measurements. The swimming speeds reported in the present paper are calculations based on hydrodynamic and metabolic measurements.

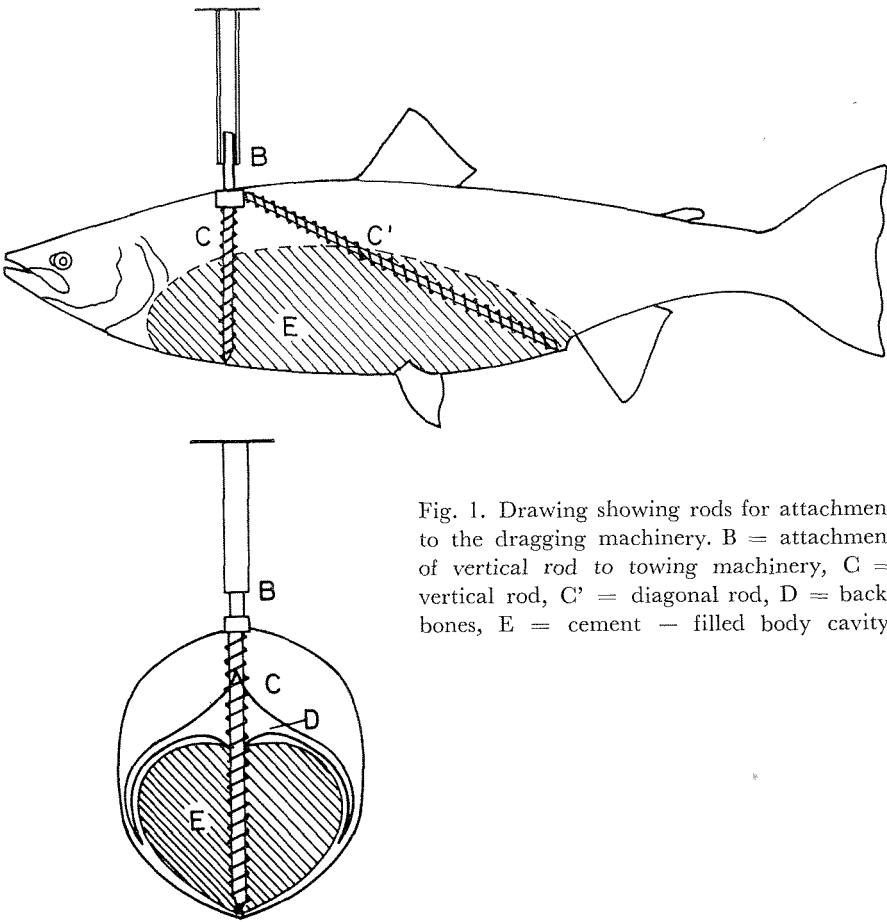


Fig. 1. Drawing showing rods for attachment to the dragging machinery. B = attachment of vertical rod to towing machinery, C = vertical rod, C' = diagonal rod, D = backbones, E = cement - filled body cavity.

MATERIAL AND METHODS

The bodies of the following species were used for dragging measurements:

Cod (*Gadus callarias*), saithe (*Gadus virens*), haddock (*Gadus aeglefinus*), mackerel (*Scomber scombrus*), salmon (*Salmo salar*), herring (*Clupea harengus*) and plaice (*Pleuronectes platessa*).

Immediately after the fish were killed the stomach contents were removed through the mouth and replaced by a rapid hardening cement of identical weight and volume. The body was made rigid for the dragging experiments by a stainless steel rod which was screwed diagonally through the back of the fish. Through this rod a second rod was screwed vertically into the hard stomach cement (Fig. 1). The upper part of the vertical rod extended several centimeters out of the back of the fish and

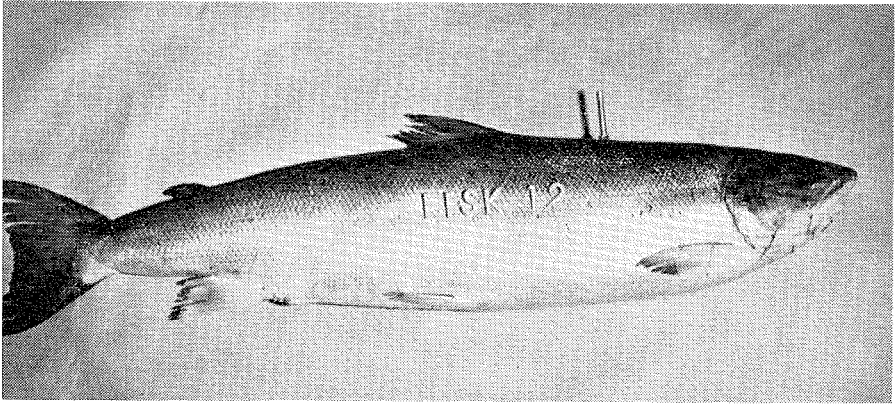


Fig. 2. Photographs of a salmon ready for dragging experiments.

was used as the fixation point for the dragging apparatus (Fig. 2). The resistance data were converted to calories versus distance swum. The dragging experiments were performed at The Norwegian Ship Model Experiment Tank in Trondheim.

The metabolism of live fish was measured in aquaria (Sundnes 1957a). From this data the available energy for locomotion was calculated. The estimation of the oxygen debt was based on the investigations of Leivestad, Andersen & Scholander (1957) and Hochachka (1961). The propulsion effect of the caudal fin was assumed to be 80 % and is used as a constant in the calculations.

RESULTS AND DISCUSSION

The dragging measurements show a hydrodynamic resistance of the fish body similar to other hydrodynamic models (Fig. 3). In the metabolic measurements the energy metabolism will stabilize at a level corresponding to a standard metabolic rate. Metabolic rates 300 % above the standard value in the absence of locomotion have been measured. The connection between swimming speed and the distance swum (Fig. 4) was obtained by making the following assumptions: 25% of the extra energy produced by the body is available for locomotion (Zeuthen 1942) and this amount of energy in one hour can be produced anaerobically.

The hydrodynamic resistance of the fish has been measured as the total drag. The question of laminar and turbulent flow at the surface of the fish body is left open in these experiments but post mortem changes in the surface structure have been kept as small as possible by using freshly killed fish.

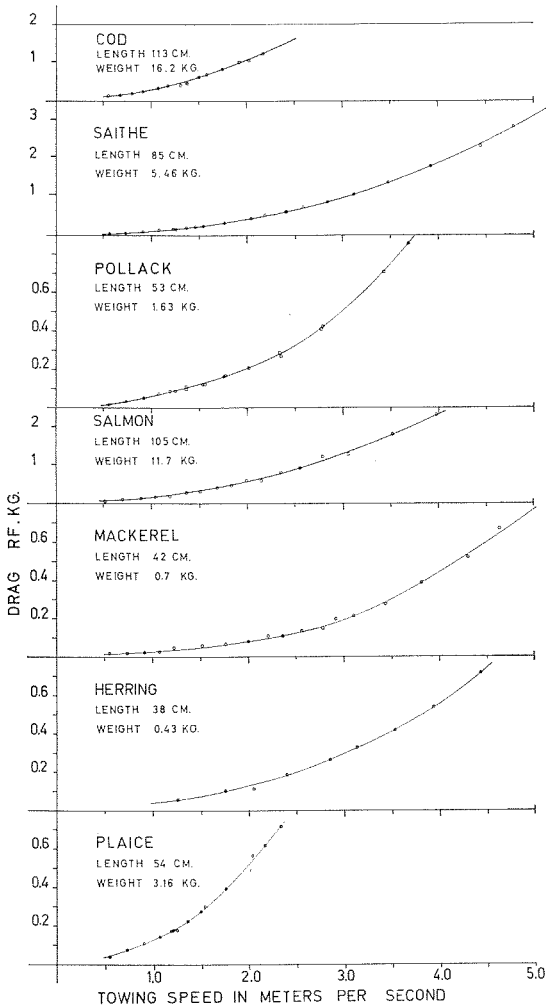


Fig. 3. Curves showing the relationship between drag and towing speed.

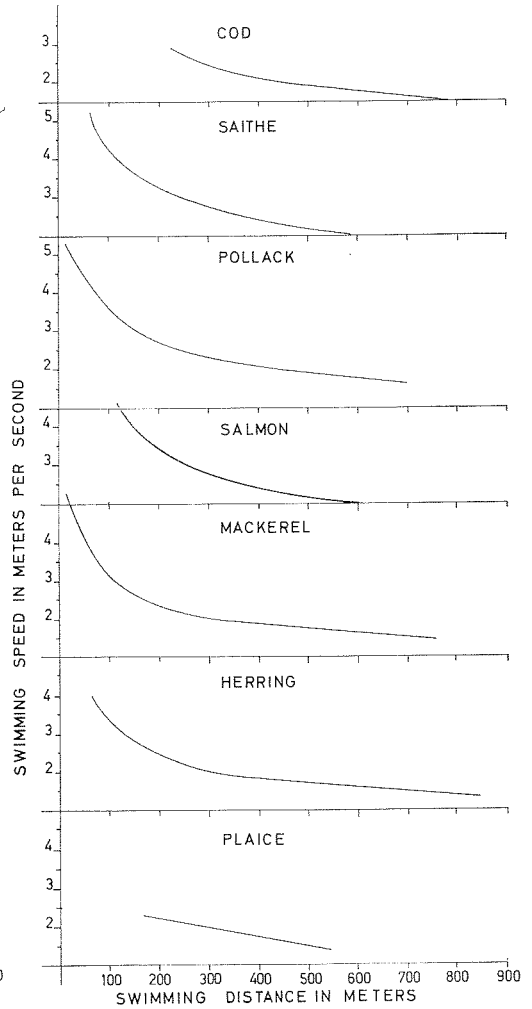


Fig. 4. Curves showing the relationship between swimming speed and distance swum.

The possible difference in the surface currents between the dragged bodies and living fish are mainly due to the swimming movements. Integument structures like those found in the dolphin (Kramer 1961) are not found in fish. However, the drag measured is at least as high as that in a live swimming fish, and the present results may therefore show a lower swimming speed than that actually obtainable since the calculated speeds in the present investigation are based on the energy available and an increased drag will result in a decreased speed.

The shape of the curves in Fig. 4 are based on a constant propelling effect of the caudal fin at all speeds and the curves indicate the limit where the fish are exhausted. The reason for the different result given by the plaice (Fig. 4) is not presently known.

It is of interest that the data show a possibility for the fish to swim relatively fast for short distances. The speeds are higher than those found in aquaria experiments, but they are in accordance with the data recently published by Dow (1962).

Most of the fish towed in the tank in the present investigation showed a theoretical cruising speed of 1 meter per second i. e. 48 nautical miles per day. This is in agreement with the observed speed of 40 nautical miles per day for the "herring front" when the Atlanto-Scandian herring migrate to the coast for spawning (Devold 1961). In addition, tagged salmon have shown an average cruising speed of 53 nautical miles per day for 11 days (Dahl & Sømme 1953).

While the relationship between swimming speed and body size has not been investigated in these experiments, the values in the present data appear high compared with other investigations. On the other hand, the actual speed of the river herring found by Dow (1962) is much higher in relation to body size, a finding which provides evidence for the high-speed swimming possibilities of fish in general. Of greatest interest for gear research is "the shooting effect" of the fish over short distances to escape from or match the speed of a trawl. The possibility for the fish to escape downwards from the pelagic trawl is of special interest.

From pilot experiments in a tank, it was found that cod fish react and try to escape from a fast moving device. By using slower movements, e. g. one-two knots, the fish do not try to escape but let themselves be overtaken by the device. They try to escape, however, when they come into mechanical contact with the gear. This is not so with the salmonids and clupeids as they react and try to escape from the device at all speeds tested. Open sea experiments should be carried out to make this point clear.

For active gear the problem of escape is a complex of factors in fish behavior where swimming speed may play a minor or dominant role according to the species involved. Blaxter, Parrish & Meadows (1960) have shown that the optical sense is of great importance in this connection. For fish which react strongly to active gear as a trawl, gear research probably has to solve problems of gear speeds up to six knots to get a maximum catching effect.

SUMMARY

The hydrodynamic resistance of the bodies of several species of commercially important marine fish has been measured. Based on the hydrodynamic resistance and the energy metabolism of the fish, theoretical swimming speeds and distances have been calculated. It is suggested that gear speeds of up to six knots may be required for species which react strongly to active trawling gear.

ACKNOWLEDGEMENT

I am greatly indebted to Mr. Andreas Eisaissen for preparing the fish bodies and Mr. Nils Helgesen for performing the dragging experiments.

The present work was made possible by grants from Fiskerinæringens Forsøksfond and The Norwegian Working Group for the Evolution of Pelagic Gear (APE).

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