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# Fat Content of Muscle, Gonads and Liver of Silver Hake (*Merluccius bilinearis*) and Red Hake (*Urophycis chuss*) from the Continental Shelf off Southern New England in Late Winter

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## Abstract

Analysis of muscle, gonad and liver tissue from silver hake and red hake, which were caught on the continental shelf off southern New England in March, indicated that the fat content of muscle and gonads is low and relatively constant, whereas the fat content of the liver from these species was much higher and varied greatly. Nevertheless, an indication of the fat content of the entire fish can be determined from the amount of fat in the liver, which is the primary fat depot for these species. Since fat content of the organism is linearly related to liver weight, the latter may be used to estimate the fat content of the organism, this being especially useful in field investigations. Equations are given for estimating the fat reserves of silver hake and red hake.

## Introduction

Among the factors that affect the fatness and physiological condition of fish throughout their yearly cycle is the food supply. Fish belonging to different systematic groups accumulate fat in different organs. Fat accumulates in the hypodermic and muscular tissues and on the intestines of Cyprinidae, Clupeidae and Pleuronectidae, whereas the liver serves as the fat depot in Macrouridae and Gadidae (Podrazhanskaya and Yarzhombek, 1970; Shevchenko, 1971). However, the amount of fat in various parts of the body is subject to considerable fluctuation due to biological condition, age and sex of the fish, state of the food resources, and environmental factors which vary seasonally (Shulman, 1960; Minder and Khobotilova, 1966; Maslennikova, 1966).

The fat reserve in the body of fish varies during the year in relation to the functional peculiarities of the organism, which manifest themselves in one or more phases of the life cycle. Hence, there exists a close relationship between the fat accumulation rate, as one of the major indices of physiological condition of the fish after wintering, and the maturation rate and quality and quantity of sexual products. The present study examines the fat content of liver, gonad and muscle tissue of silver hake and red hake during prespawning migration in the spring. The resultant formulae are suitable for calculating the total fat content of the fish, the method being especially useful for field investigations (Shubnikov, 1962).

## Materials and Methods

Samples of muscle, gonads and liver of silver hake and red hake, and the corresponding morphometric data, were collected from a bottom-trawl catch on the continental shelf in the vicinity of Hudson Canyon off New Jersey, USA, in March 1978 at a depth of 120 m. The samples consisted mainly of maturing individuals but some of the silver hake were immature. The tissues were maintained in a frozen state until analysis in the laboratory.

Batches (2 g each) of the defrosted liver, gonad and muscle tissues (Lapin and Chernova, 1970) were each ground and mixed with anhydrous sodium sulfate, thoroughly washed with ethyl ether on sterile cotton filters, and analyzed by the method of Krivobok and Tarkovskaya (1962). A total of 57 silver hake and 42 red hake specimens were processed. The fat contents of the tissues from the various size-groups of fish are expressed as actual percentages (mean and range) as well as percentages of gutted weight of the fish. The relative weight of the liver multiplied by its fat content gives a value of fat reserve in the liver (percent of gutted fish weight). Standard methods (Plokhinsky, 1970) were used in statistical analysis of the data.

## Results and Discussion

Minder and Khobotilova (1966) reported that the fat content of muscle tissue from silver hake of the Northwest Atlantic averaged 2.6% with a range of 1.2-4.1%. In this paper (Table 1), the fatness of muscle tissue ranged from 0.4 to 1.9%, the overall average being 0.8%. The slightly higher fat content of males than females is probably associated with earlier maturation in males. However, the variation in fatness of muscle tissue from silver hake by size and sex is considered to be insignificant.

According to Minder and Khobotilova (1966) for Northwest Atlantic silver hake and Maslennikova

TABLE 1. Fat content of muscle, gonads and liver of silver hake and red hake from the southern part of Northwest Atlantic by size and sex of fish.

| Length range (cm) | Sex | No. of fish | Fat content of muscle (%) | | Fat content of gonads | | | | Fat content of liver | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Actual (%) | | As % gutted weight | | Actual % | | As % gutted weight | |
| | | | Mean | (Range) | Mean | (Range) | Mean | (Range) | Mean | (Range) | Mean | (Range) |
| **Silver hake** | | | | | | | | | | | | |
| 21-25 | Juvenile | 6 | 0.9 | (0.7-1.4) | — | — | — | — | 8.2 | (4.0-24.6) | 0.10 | (0.02-0.43) |
| 22-25 | Male | 5 | 0.8 | (0.5-1.0) | 7.7 | (2.8-14.3) | 0.012 | (0.006-0.017) | 7.7 | (4.5-13.2) | 0.08 | (0.05-0.13) |
| | Female | 9 | 0.7 | (0.5-1.1) | 4.8 | (1.8-9.1) | 0.020 | (0.006-0.034) | 16.0 | (2.8-78.7) | 0.21 | (0.03-1.11) |
| 26-35 | Male | 11 | 0.8 | (0.5-1.3) | 3.2 | (1.0-13.3) | 0.025 | (0.002-0.096) | 29.8 | (1.7-47.3) | 0.76 | (0.01-1.78) |
| | Female | 9 | 0.7 | (0.5-1.5) | 2.1 | (0.3-4.3) | 0.018 | (0.004-0.036) | 20.7 | (5.0-42.0) | 0.56 | (0.05-2.30) |
| 36-55 | Male | 2 | 1.1 | (0.9-1.3) | 2.0 | (1.4-2.5) | 0.056 | (0.039-0.072) | 40.7 | (36.3-45.1) | 1.45 | (1.07-1.83) |
| | Female | 15 | 0.9 | (0.4-1.9) | 2.6 | (0.9-5.8) | 0.047 | (0.010-0.123) | 38.6 | (19.8-53.8) | 1.56 | (0.40-2.61) |
| | Total | 57 | 0.8 | (0.4-1.9) | 3.5 | (0.3-14.3) | 0.029 | (0.002-0.123) | 24.7 | (1.7-78.7) | 0.75 | (0.01-2.61) |
| **Red hake** | | | | | | | | | | | | |
| 30-35 | Male | 10 | 0.8 | (0.5-1.4) | 2.7 | (0.6-4.6) | 0.030 | (0.006-0.050) | 28.4 | (19.1-39.2) | 0.66 | (0.29-1.36) |
| | Female | 17 | 0.8 | (0.4-1.6) | 1.2 | (0.5-4.1) | 0.011 | (0.003-0.032) | 29.8 | (18.8-47.0) | 0.70 | (0.07-1.14) |
| 36-45 | Male | 1 | 1.7 | — | 2.6 | — | 0.033 | — | 36.3 | — | 1.19 | — |
| | Female | 14 | 0.7 | (0.4-1.4) | 0.9 | (0.3-2.6) | 0.010 | (0.004-0.024) | 31.6 | (8.8-47.0) | 0.89 | (0.09-1.50) |
| | Total | 42 | 0.8 | (0.4-1.7) | 1.5 | (0.3-4.6) | 0.016 | (0.003-0.050) | 30.2 | (8.8-47.0) | 0.77 | (0.07-1.50) |

TABLE 2. Fat content of gonads and liver of silver hake and red hake from the southern part of the Northwest Atlantic, arranged according to the relative weights of the two organs.

| Relative weight of organ (%) | Silver hake | | | | | Red hake | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. of fish | Fat content (%) | | Fat as % gutted weight | | No. of fish | Fat content (%) | | Fat as % gutted weight | |
| | | Mean | (Range) | Mean | (Range) | | Mean | (Range) | Mean | (Range) |
| **Gonads** | | | | | | | | | | |
| 0.09-0.50 | 17 | 5.4 | (1.7-14.3) | 0.013 | (0.020-0.034) | 3 | 3.0 | (1.2-4.6) | 0.008 | (0.003-0.015) |
| 0.51-1.00 | 10 | 3.2 | (1.3-9.1) | 0.022 | (0.008-0.057) | 17 | 1.6 | (0.4-4.1) | 0.012 | (0.004-0.032) |
| 1.01-1.50 | 10 | 2.2 | (0.3-4.0) | 0.027 | (0.004-0.052) | 17 | 1.6 | (0.3-3.9) | 0.020 | (0.004-0.050) |
| 1.51-2.00 | 5 | 2.1 | (1.0-4.5) | 0.038 | (0.017-0.088) | 3 | 2.2 | (0.9-3.3) | 0.034 | (0.014-0.050) |
| 2.01-2.50 | 3 | 2.6 | (1.0-5.8) | 0.057 | (0.022-0.123) | 2 | 1.8 | (1.3-2.2) | 0.038 | (0.032-0.044) |
| 2.51-3.00 | 5 | 2.4 | (1.0-4.2) | 0.068 | (0.025-0.117) | — | — | — | — | — |
| 3.01-3.30 | 1 | 2.9 | — | 0.096 | — | — | — | — | — | — |
| **Liver** | | | | | | | | | | |
| 0.35-1.00 | 8 | 6.4 | (1.7-10.3) | 0.05 | (0.01-0.09) | 1 | 21.0 | — | 0.07 | — |
| 1.01-2.00 | 20 | 15.5 | (2.8-78.7) | 0.22 | (0.03-1.11) | 8 | 24.3 | (8.8-34.1) | 0.42 | (0.09-0.64) |
| 2.01-3.00 | 12 | 28.5 | (5.0-39.4) | 0.59 | (0.12-1.08) | 24 | 31.2 | (18.8-47.0) | 0.75 | (0.41-1.13) |
| 3.01-4.00 | 9 | 36.8 | (21.6-47.3) | 1.32 | (0.65-1.78) | 7 | 38.6 | (32.2-41.6) | 1.18 | (0.98-1.50) |
| 4.01-5.00 | 5 | 47.1 | (40.0-53.8) | 2.10 | (1.82-2.61) | 2 | 28.1 | (22.6-33.5) | 1.22 | (1.09-1.36) |
| 5.01-5.48 | 3 | 45.5 | (42.0-48.7) | 2.37 | (2.30-2.53) | — | — | — | — | — |

(1966) for Baltic cod, the fat content of muscles remains fairly constant throughout the year. Like silver hake, the fat content of red hake muscle tissue ranged from 0.4 to 1.7% with an overall average of 0.8% (Table 1).

The fat content of silver hake gonads ranged from 0.3 to 14.3% with an average of 3.5% (Table 1). The fat content of males (1.0-14.3%) was generally higher than that of females (0.3-9.1%), and, for both sexes, tended to decline with increasing size of fish. In red hake gonads, the fat content was considerably less than in silver hake, averaging only 1.5% with a range of 0.3-4.6%. The average fat content of males (2.7%) was more than double that of females (1.1%), which can be attributed to earlier maturation in males than in females. With increase in relative weight of gonads (Table 2), the fat content consistently declined in silver hake from 5.4 to about 2.5%, but a decline is not so evident for red hake because the highest value (3.0%) is based on only three specimens. However, for both species, the fat content, when expressed as percent of gutted fish weight, consistently increased with the increase in relative weight of gonads, mean values being 0.013-0.057% for silver hake and 0.008-0.038% for red hake in the same relative weight groups. These comparisons indicate that, in all likelihood, the process of slow accumulation of fat in the gonads of both species parallels the process of maturation for which fat requirements are important.

The fat content of the liver in silver hake varied greatly (1.7–78.7%), the average being 24.7% for all fish analyzed (Table 1). In red hake, because only the largest size-groups were represented, the variation in fat content (8.8–47.0%) was less than in silver hake and the average was higher at 30.2%. However, the weighted average for the same size-groups of silver hake was similar at 31.7%. For silver hake, there was a definite increase in fat content of the liver with increasing size of fish, from about 8% in juveniles to about 40% in the largest adults. There is no indication from the available data of a consistent difference between males and females in the fat content of the liver.

The considerable variation in the fat content of the liver is caused by several factors. Apart from individual differences, variations in age, rate of maturation, and feeding conditions in different parts of the sea in winter are very important. Since, in Gadidae, all physiological processes affect the liver more than the other organs (Minder and Minder, 1967), studies are generally focused on the liver. The relative weight of the liver is linearly related to its fat content, and both the absolute and relative fat content values (the latter expressed as percent of gutted fish weight) for silver hake and red hake increased with increasing liver weight (Table 2).

Analysis of the relationships between liver weight and fat reserve and between fat content of liver and fat reserve of silver hake indicated good correlations (r = 0.94 and 0.86 respectively) with small standard errors (Table 3). Slightly lower correlation coefficients ( r = 0.82 and 0.77) were evident in the corresponding relationships for red hake. Regression analyses of fat reserve in the liver (y) relative to the weight of the liver (x) indicated linear relationships ($y = Ax + B$) for silver hake and red hake (Table 3) where A and B are constants. The relationships between liver fat reserve (y) and fat content of liver (x) can best be described by an exponential function ($y = A \times B^x$) for silver hake and by a logarithmic function ($y = A + B \log x$) for red hake.

TABLE 3. Summary of parameters relevant to fat content of liver in silver hake and red hake from the Northwest Atlantic.

| Fat content indices of liver | Silver hake | Red hake |
|---|---|---|
| No. of specimens analyzed | 57 | 42 |
| Weight of liver as % of gutted fish weight | 2.34 (0.43–5.48) | 2.46 (0.35–4.82) |
| Fat content of liver (fatness) (%) | 24.7 (1.7–78.7) | 30.2 (8.8–47.0) |
| Fat content of liver as % of gutted weight (fat reserve) | 0.75 (0.01–2.61) | 0.76 (0.07–1.50) |
| Correlation between liver weight and fat reserve | 0.94 ± 0.01 | 0.82 ± 0.03 |
| Correlation between fat content of liver and fat reserve | 0.86 ± 0.02 | 0.77 ± 0.04 |
| Regression of fat reserve on liver weight | y = 0.54x – 0.50 | y = 0.35x – 0.09 |
| Regression of fat reserve on fat content of liver | $y = 0.05 \times 1.1^x$ | y = 1.9 log(x) – 2.0 |

Because of the low and relatively constant fat content of various organs (except liver) and tissues of silver hake (to 4%) and red hake (to 1%) (Minder and Khobotilova, 1966; Kleimenov, 1971), the fat content of the entire organism can be estimated from the weight of the liver. Although the relative weight of the liver and its fat content are subject to large fluctuations, depending on food and other factors, the correlations and functional relationships noted above indicate that the concept of relative liver weight is useful for characterizing the fatness of these gadoid species. It follows from these analysis that liver weight and its fat content in silver hake and red hake are accurate enough indices for evaluating the fat reserve in these species.

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