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# THE GROWTH OF JUVENILE COD, GADUS MORHUA, IN A SCOTTISH SEA LOCH

by

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## Abstract

Cod remain in Loch Torridon, a fjord on the west coast of Scotland, for the first 3 - 4 years of their life. During this time they move very little, holding restricted home ranges and feeding largely on benthic invertebrates. As part of a wider study of the energy budget of these fish, their growth rate has been measured by two independent methods. The first method was based on the determination of mean length and weight of fish of different ages. The second involved the release and recapture of tagged fish.

The measured growth rates were in good agreement, though those obtained with the tag and recapture method were slightly higher. The growth rates are compared with these for older cod entering the commercial fishery, and the differences are discussed in the light of the differing behaviour of the juvenile fish.

## Rèsunè

Au cours de juin et de juillet 1979 on a attaché des émetteurs acoutiques à deux saumons et à cinq grilses pour enregistrer leurs mouvements. Le flux de la marée aussi a été mesuré directement en se servant d'acres flottantes dirigées par le courant.

Au large, les mouvements des poissons étaient complexes, déterminés en grande partie par les courants de la marée. La soustraction des vecteurs de la marée cependant a montre que la route vraie de la nage pour chaque poisson s'est orientée conséquemment dans un sens particulier, et indépendante des courants dans l'eau.

La vitesse moyenne des mouvements à travers l'eau a été établie pour chaque poisson qu'on a suivi, pendant chaque phase de la marée. Ces vitesses étaient approximativement égales à la vitesse de nage ayant le meilleur rendement, c'est à dire, la vitesse à laquelle la consommation d'énergie est la plus basse pour chaque unité de distance parcourue. On discute ce résultat par rapport au temps qu'il faut aux saumons rentrer à la rivière natale des régions lointaines où ils vont pour s'alimenter.

## I Introduction

Tagging experiments have shown that juvenile cod (Gadus morhua L.) remain in Loch Torridon, a sea loch on the west coast of Scotland, for the first 3-4 years of their life. During this time they hold small home ranges and feed largely on benthic organisms. At 3 years old and some 35cm long, the cod leave the loch to join the adult stock, where they feed on more pelagic prey, perhaps adopting a schooling habit.

Most of the juvenile fish in Loch Torridon fall beneath the minimum landing size, and are living in an inshore area where trawling is forbidden. They thus form part of the cod population which is rarely sampled in commercial catches.

As part of a wider investigation of the ecological energetics of the young fish we have monitored their growth rates. In this paper we present these data for comparison with the growth rates obtained from fish sampled from commercial catches.

## II Material and Methods

All fish considered in this study were caught with baited hooks. The fish were caught in all months of the year, sampling being conducted between the years 1974 and 1978. There is evidence from the analysis of length distribution in the total catch that this fishing method is size selective and that smaller fish are under-represented but discussion of this point will be delayed until later.

From the captured fish, two independent methods were used to calculate growth rate. A proportion of all fish caught were tagged at random with respect to size. These fish were returned to the loch after their lengths had been noted. Those individuals subsequently recaptured could be identified by their numbered tags and their gain in length determined. Knowing the number of days between captures, the growth rate of individual fish could then be calculated.

Some cod were sacrificed at various times of the year, their lengths again being noted. Age was determined to the last completed year of growth by counting the annual rings on the saccular otolith. This age was then converted to quarter years and days on the assumption that all fish were born on April the first of the appropriate year. From this data, the mean length at different ages could be calculated for the population, and an average growth rate determined.

Length of the fish was measured while the animal was still alive, or freshly killed. Length was taken as the maximum distance from the snout to the tip of the extended tail, and rounded up to the nearest cm. Gutted weight was also recorded for most sacrificed fish and was taken as the fresh dead weight of the fish measured to the nearest gram, with the entails and gonads removed. The gonads were weighed separately.

## III Results

### The Relationship Between Weight and Length

From the sacrificed fish, a relationship was sought between gutted weight and length. Regression equations were fitted separately for fish captured in each month, each year, and all years together giving 17 separate data sets (there was no information for December).

Two relationships provided good fit to the data.

Weight = a x ln (length) + b .................................... (1)
ln (Weight) = a x ln (length) + b .................................... (2)

From the 17 data sets, equation (2) provided the best fit on 13 occasions while equation (1) provided the best fit on the other 4. All best regressions were highly significant and ranged in F value from 204 to 17 306, (critical value for F at $p = 0.001$ ranges from 7.6 to 14.0). Table 1 provides the statistics for the best regressions on each data set.

### Condition Factor

The condition factor gives an index of the physical condition of a fish by reflecting the relationship between weight and length. It is calculcated as

Condition Factor = $Weight/Length^3$ .................................... (3)

The power to which length is raised reflects the underlying relationship between weight and length under standard conditions. Thus if it could be shown that cod in Torridon grow in a way other than showing a cubing of weight with increase in length, the exponent in equation (3) would have to be altered accordingly.

The 17 sets of data used in Table 1 were fitted with a type (2) equation using least squares regression. The regression coefficient was then compared to a value of 3.0 (Zar, 1974). The results are given in Table 2. Only 4 of the 17 values are significantly different from 3.0, 3 of which are larger and one very much lower. We have therefore employed equation (3) without correction when calculating condition factor.

The values for condition factor ranged from 0.0015 to 0.0195 and were converted, for convenience, to fall between 0 and 1 by the formula

$$\text{Relative Condition Factor} = \frac{\text{Observed CF} - \text{Lowest CF}}{\text{Highest CF} - \text{Lowest CF}} \quad (4)$$

Tables 3 and 4 give the distribution of relative condition factor with time of year and age of fish respectively. Figure 1 was created partly from Table 3, and shows average relative condition factor for fish caught in each month superimposed upon the catch per unit effort and mean water temperature at 10m for each month in Loch Torridon. The correlation between relative condition factor and catch per unit effort is very high ($r = 0.913$, $df = 9$, $p < 0.001$), as is that between temperature and catch per unit effort ($r = 0.801$, $df = 9$, $p < 0.005$).

The catch per unit effort is calculated on the basis of the number of fish caught by baited hook in any month and the number of 'man hours' fished during that month. It is thus an index of fish activity and willingness to take bait at different times of the year. A possible functional relationship between temperature, catch and condition factor will be dicussed later.

## Growth Rates of Juvenile Cod

The two methods described for obtaining data on the growth rates of cod require different methods of analysis. The results will therefore be treated separately.

### Tagging and Recapture of Individual Cod

Two hundred juvenile cod were tagged and subsequently recaptured. They varied in size from 12cm to 42cm on release and were receptured after periods ranging from 1 to 771 days. From the data, two relationships were extracted

growth (cm) v days absent
growth per median fish length (cm) v days absent

The best fit to both sets of data proved to be an equation of the form

$$y = a x + b \qquad (5)$$

Fitted by least squares regression, the fit to both data sets proved highly significant ($F = 514.75$, df = 1,199, $p < 0.001$ for growth per median fish length (cm); $F = 448.73$, df = 1,199, $p < 0.001$ for growth (cm)). There is little to choose between expressing the data as length increment or length increment per median fish length in terms of the predictive value of the resulting equation. To facilitate comparison with growth rate estimated from length and age data, it was decided to simply relate length increment to time. This gives an equation for the growth of cod in Loch Torridon as

$$\text{Length increment (cm)} = 0.0407 \times \text{elapsed time (days)} - 0.108 \qquad (6)$$

The 95% confidence limits for equation (6) are $\pm$ 0.508 when $x = 0$, and thus the y intercept of 0.108 is not significantly different from the expected value of zero growth after zero days.

### The Length of Individual Cod with Age

Between 1974 and 1978, some 1 248 cod ranging in length from 5 to 53cm were caught in Loch Torridon and sacrificed. Length of fish and age in days and quarter years were recorded for each fish on the assumption that all fish were born on April 1st.

Least squares regression gave a growth equation of

$$\text{length (cm)} = 0.029 \times \text{age (days)} + 9.32 \qquad (7)$$

for the data, which is highly significant ($F = 2262.4$, df = 1,1247, $p < 0.001$).

Differences between this growth rate and that estimated by the previous method were found to be significant ($t = 5.77$, $df = 1,444$, $p < 0.001$). Relative biases would thus appear to be at work in the two methods such that tag and recapture data produces a significantly higher estimate for growth rate.

## Growth Rate and Age

From a scatter diagram of the length age data, it was obvious that growth in the fish was not strictly linear. The lengths of very young fish were overestimated by the regression line while those of older fish were underestimated.

The data for mean length with age (in quarter years) was used to investigate whether growth of cod in Loch Torridon could be better explained if the constraints of linearity were removed. Figure 2 shows the mean lengths with 95% confidence limits of fish of all ages caught in Loch Torridon.

As can be seen, lengths of fish at Q13 and Q14 differ markedly from the general trend in the data. Reasons for this will be discussed below, for now however only fish up to the age of Q12 will be included in the analysis.

The von Bertalanffy equation is a prediction of length from age often used in fisheries science (Ricker, 1975). It was fitted to the data on this occasion by Beverton's method outlined in Ricker (1975). For cod of age Q2 to Q12 the parameters of the fitted curve were

$L_\infty = 41.42$cm
$K = 0.17$
$t_o = 0.71$

$L_\infty$ is the asymptotic length towards which the fish will grow given infinite time, K is a constant determining the rate of decrease of length increments, and $t_o$ is the hypothetical time at which fish length is zero.

Table 5 gives the expected lengths at age calculated from the von Bertalanffy curve above, as well as those calculated from regression equation (7). Figure 3 shows the mean length at age of cod up to the age of Q12 with the lines corresponding to equation (7) and the von Bertalanffy curve superimposed. The von Bertalanffy curve clearly gives a better fit to the observed data.

The effect of adding mean lengths of fish at age Q13 and Q14 to the data was investigated by fitting the von Bertalanffy curve again. The new parameters of the equation were

$L_\infty = 89.12$
$K = 0.05$
$t_o = 1.35$

Table 5 gives the predicted lengths at age calculated from this second von Bertalanffy curve. The addition of these older fish changes the fitted curve from a tolerably good fit, to one which is much worse than even the straight line fitted by regression.

Growth of Cod Outside Loch Torridon

Statistics on the mean length at age (years) of cod landed at ports on the west coast of Scotland (Table 6) were used to compare with the growth of the juvenile phase calculated above. A straight line fitted by regression yielded a relationship between age and length of

Length (cm) = 8.93 x age (years) + 36.93 .......................... (8)

The fit to the data was highly significant ($F = 139.88$, $df = 1;6$ $p < 0.001$). Figure 4 gives the observed data and the fitted regression line. A von Bertalanffy curve was also fitted, and as can be seen from Figure 4 again provided better agreement than the straight line. The parameters of this von Bertalanffy curve were

$L_\infty$ = 125.02
K = 0.19
$t_o$ = -0.95

Table 6 gives the lengths predicted by the curve. These lengths far exceed those found for cod of comparable age in Loch Torridon.

## IV Discussion

### Temperature, Catch and Condition Factor

Catch per unit effort can be thought of as a combination of two factors, the probability of the fish encountering bait, and the probability that the bait is then attacked. Given that the population in the loch does not change significantly with time of year (and this proposition is strongly supported by tagging data) changes in the catch throughout the year may be taken as an index of activity and the extent to which fish are feeding.

Differences in the relative densities of bait and preferred natural prey through the year would cause catch per unit effort to vary, the bait and prey competing for the attention of the fish. This however is unlikely to cause the patterns shown in Figure 1, as the time of year when the catch drops is also the time when natural foods might be expected to be scarce and competing less strongly with the bait.

The condition factor provides an indication of the levels of food reserves in the animal. Taken together, the high level of correlation between the two indices provides some picture of cod feeding through the year.

During the coldest months from March to May the condition factor is declining and it seems likely that the fish is not feeding actively. The reserves in the animal are thus depleted by maintenance and other energetic costs. The increase in condition factor in June indicates that feeding activity is on the increase and that the losses in reserves are being replaced.

Changes in energy reserves held by the cod may not be wholly reflected by changes in condition factor, as in many fish the liver acts as a high energy store. Direct weighing and bomb calorimetry of this organ are needed to see how well changes in this potential food store are synchronised with activity patterns.

The low catch rate in early part of year, together with the low condition factor, suggests not only that they are not feeding but that their feeding action is suppressed. Is there a functional explanation for the loss of feeding?

The effect of temperature on digestion and metabolism provides a possible factor. The rate at which food can be digested and the remains evacuated, falls with a decrease in temperature. In March, one of the coldest months in the sea, the fish may be severely limited in the energy intake available to it simply because food can only be processed very slowly.

When feeding, the fish has energy costs above maintenance including the movement associated with capturing and handling prey, and the metabolic costs of digestion and food assimilation. If prey are less available in the winter months, energy costs of searching may increase still further.

At decreasing temperatures, a point may be reached where the costs over maintenance incurred by foraging are greater than the daily energy gain possible at the reduced digestion rate. At this point, the fish should adopt a strategy of greatly reduced foraging activity, allowing previously accummulated food reserves to satisfy maintenance costs. With the summer increase in temperature, feeding again becomes profitable and activity is resumed.

Laboratory experiments are needed to test this hypothesis.

<u>The Calculation of Growth Rates</u>

The two methods employed for calculating growth rates of fish produced significantly different results. Growth rates from the tag and recapture method were significantly higher than those calculated from the length of fish at estimated ages.

We have no evidence on the effect of tagging on subsequent fish growth, but would expect these to be adverse rather than beneficial. However, fish are captured more commonly in the warmer months (June to November) when feeding rates are higher (Figure 1), and growth rates measured by this method may thus be expected to be slightly higher. Tagged fish whose growth was only monitored over these months may thus be found to have a higher growth rate than a similar sacrificed fish whose growth rate is an integration of growth in all seasons up to the day of capture.

The method of fish capture chosen in selective towards the larger representatives of younger age classes. The average growth rate between young (eg Q2) and older fish (eg Q5) will thus be underestimated by the mean length at age method, the selective effects being less on the older age class.

If length rather than age provides the stimulus for fish to leave Loch Torridon and join the adult stock, larger animals in later age classes will be less available for capture than smaller ones. The mean length at age estimate of growth rate will again therefore underestimate the average growth rate of fish in the population.

Thus the tagging of individuals appears to yield estimates of growth rate less open to bias than that calculated from the mean length of fish at different ages. The latter method does however give an insight into the growth of cod unavailable from tagging data. Mean length at different ages of fish outlines the pattern of growth as it changes with the age of the fish (Figure 2), which allows the assumption of linear growth throughout the juvenile phase to be relaxed.

## The Growth of Juvenile Cod

The cod shows a decreasing growth rate with time over the first three years of its life in Loch Torridon (Figure 2). This pattern can be more accurately described by a curve like the von Bertalanffy equation than the straight line of a regression equation. At the age of 3 however, the growth pattern appears to change and growth rate increases over the last half year, when some cod are still found in the loch.

This late change of pattern is based upon only 16 fish caught over the four year study period and, given that it reflects a genuine trend, points to some change in the ecology of the cod as they are about to leave the nursery area. The specific changes in behaviour which result in a sudden increase in growth rate can only be speculated upon, but what is clear is that a simple change in area of occurrence is not sufficient explanation. All the larger fish were caught in areas of the loch where smaller fish were also caught in abundance.

Cod outside the loch also show a decreasing growth rate with time. Predicted lengths from a fitted von Bertalanffy curve however far exceed those found in Torridon for cod of corresponding age.

Such a bias may occur if young fish are rejected before landing as too small, or indeed if the fishing gear is size selective. In this case, only excessively large fish in the first few years of life would be included in the analysis. To test for this, a von Bertalanffy curve was fitted to the length data for cod from 3 to 8 years old. The resulting parameters were

$L_\infty$ = 118.8 cm
K = 0.24
$t_o$ = -0.62

This curve predicts lengths of 38.3 and 55.5 cm for cod aged 1 and 2 years respectively. The curve is thus little different from that obtained from all data (Table 6), suggesting that the effects of selection in fishing are minimal.

If fish attempt to attain a given minimum length before leaving a nursery area, fast growing fish will more rapidly be lost from the nursery length data and become available for landing catch statistics. In this way, growth rate and predicted length at a given age may be increased in the latter as compared to the former.

Finally, conditions in the sea may be such that cod are able to support a higher rate of growth than in nursery areas. Whether this is due to changes in the behaviour of the cod, or changes in the availability, density or quality of the prey is not clear.

V References


Ricker, W.E. 1975 Compilation and Interpretation of Biological Statistics of Fish Population. Bull. J. Fish. Res. Bd Can. No 191.

Zar, J.H. 1974 Biostatistical Analysis. Englewood Cliffs: Prentice Hall 620 pp.

TABLE 1 Statistics of the lines of best fit as determined by least squares regression of gutted weight on length for cod taken from Loch Torridon 1974-1978. All regressions are significant at $p < 0.001$.

| Period over which data was collected | Best form of equation | Regression coefficient | 'Y' intercept | df | 'F' |
|---|---|---|---|---|---|
| January | 2 | 2.81 | -4.06 | 1,171 | 4333 |
| February | 2 | 3.25 | -5.58 | 1,100 | 5191 |
| March | 2 | 2.98 | -4.75 | 1,65 | 1994 |
| April | 2 | 3.31 | -5.87 | 1,18 | 1230 |
| May | 2 | 3.18 | -5.40 | 1,9 | 2246 |
| June | 2 | 2.60 | -3.46 | 1,48 | 339 |
| July | 1 | 0.11 | 2.15 | 1,172 | 2327 |
| August | 2 | 3.16 | -5.31 | 1,136 | 4069 |
| September | 2 | 3.01 | -5.00 | 1,67 | 3825 |
| October | 2 | 3.08 | -5.01 | 1,107 | 2398 |
| November | 1 | 0.11 | 2.29 | 1,316 | 4369 |
| 1974 | 2 | 3.15 | -5.21 | 1,139 | 11659 |
| 1975 | 2 | 3.13 | -5.15 | 1,393 | 17306 |
| 1976 | 1 | 0.11 | 2.18 | 1,481 | 4939 |
| 1977 | 2 | 2.98 | -4.71 | 1,93 | 484 |
| 1978 | 2 | 2.89 | -4.45 | 1,46 | 204 |
| All data 1974-1978 | 1 | 0.12 | 1.96 | 1,1166 | 11645 |

TABLE 2 The test for isometric growth in the cod in Loch Torridon. The regression coefficients in ln (weight) v. ln (length) plots are compared to an expected value of 3.0.

| Period over which data was collected | Regression coefficient | df | 't' | *Significance level |
|---|---|---|---|---|
| January | 2.81 | 172 | 1.89 | |
| February | 3.25 | 101 | 2.10 | $p < 0.05$ |
| March | 2.98 | 66 | 0.14 | |
| April | 3.31 | 19 | 3.81 | $p < 0.001$ |
| May | 3.18 | 9 | 2.40 | $p < 0.05$ |
| June | 2.60 | 49 | 1.94 | |
| July | 2.97 | 173 | 0.19 | |
| August | 3.16 | 137 | 0.94 | |
| September | 3.01 | 68 | 0.72 | |
| October | 3.08 | 108 | 0.47 | |
| November | 1.94 | 313 | 2.98 | $p < 0.005$ |
| 1974 | 3.15 | 140 | 1.88 | |
| 1975 | 3.13 | 394 | 1.06 | |
| 1976 | 2.35 | 482 | 1.88 | |
| 1977 | 2.98 | 94 | 0.10 | |
| 1978 | 2.87 | 47 | 0.45 | |
| All Data | | | | |
| 1974-1978 | 2.64 | 1167 | 1.25 | |

* All significance levels left blank show no significant difference between regression coefficient and 3.0.

TABLE 3 Distribution of Relative Condition Factor of cod in Loch Torridon with time of the year. Figures are given as a percentage of the total number of individuals sampled.

| Relative condition factor | Jan | Feb | Mar | Apr | May | Month June | July | Aug | Sept | Oct | Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.00 | | | | | | | 0.57 | | | 0.91 | |
| 0.06 | | | | | | 1.96 | | 0.67 | | | |
| 0.11 | | | 1.47 | | | | | | | 0.91 | 0.63 |
| 0.17 | | 0.97 | | | | | | 2.68 | | | |
| 0.22 | | 0.97 | 2.94 | | | | 1.14 | 2.01 | 1.43 | | |
| 0.28 | 3.33 | 9.71 | 8.82 | 9.52 | 45.45 | 3.92 | 4.00 | 3.36 | 5.71 | 4.55 | 1.26 |
| 0.33 | 12.22 | 36.89 | 50.00 | 61.90 | 36.36 | 35.29 | 20.57 | 29.53 | 20.00 | 26.36 | 10.69 |
| 0.39 | 43.33 | 41.75 | 26.47 | 23.81 | 18.18 | 43.14 | 35.43 | 45.64 | 38.57 | 47.27 | 37.42 |
| 0.44 | 34.44 | 5.83 | 8.82 | | | 9.80 | 24.59 | 14.77 | 24.29 | 20.00 | 33.96 |
| 0.50 | 5.56 | | 1.47 | 4.76 | | | 9.14 | 0.67 | 8.57 | | 13.84 |
| 0.56 | 1.11 | 2.91 | | | | 3.92 | 2.24 | 0.67 | | | 0.94 |
| 0.61 | | 0.97 | | | | | 1.14 | | | | 0.94 |
| 0.67 | | | | | | | | | 1.43 | | 0.31 |
| 0.72 | | | | | | | 1.14 | | | | |
| 0.78 | | | | | | | | | | | |
| 0.83 | | | | | | | | | | | |
| 0.89 | | | | | | | | | | | |
| 0.94 | | | | | | | | | | | |
| 1.00 | | | | | | 1.96 | | | | | |
| Total No fish sampled | 90 | 103 | 68 | 21 | 11 | 51 | 175 | 149 | 70 | 110 | 318 |
| Average relative condition factor ± S.D. | 0.41 ±0.052 | 0.36 ±0.064 | 0.35 ±0.056 | 0.35 ±0.047 | 0.32 ± 0.041 | 0.37 ±0.071 | 0.40 ±0.073 | 0.37 ±0.069 | 0.39 ±0.065 | 0.37 ±0.052 | 0.42 ±0.063 |

TABLE 4 Distribution of Relative Condition Factor with age of cod in Loch Torridon. Figures are given as a percentage of the total number of individuals sampled.

| Relative condition factor | Age 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| 0.00 | | 0.12 | | |
| 0.06 | | 0 12 | | |
| 0.11 | | 0.50 | | |
| 0.17 | 1.82 | 0.37 | | |
| 0.22 | 4.55 | 0.37 | | 7.14 |
| 0.28 | 19.09 | 3.35 | 0.54 | |
| 0.33 | 38.18 | 23.79 | 16.76 | |
| 0.39 | 27.27 | 39.90 | 42.16 | 28.57 |
| 0.44 | 7.27 | 22.68 | 30.81 | 57.14 |
| 0.50 | 0.91 | 7.06 | 7.57 | 7.14 |
| 0.56 | 0.91 | 1.12 | 0.54 | |
| 0.61 | | 0.36 | 1.08 | |
| 0.67 | | 0.12 | 0.54 | |
| 0.72 | | | | |
| 0.78 | | | | |
| 0.83 | | | | |
| 0.89 | | | | |
| 0.94 | | | | |
| 1.00 | | 0.12 | | |
| Total No fish sampled | 110 | 807 | 185 | 14 |
| Average relative condition factor ± S.D. | 0.34 ± 0.065 | 0.39 ± 0.061 | 0.41 ± 0.063 | 0.36 ± 0.057 |

TABLE 5 Mean length at age of cod in Loch Torridon and the values predicted by a regression equation and two formulations of the von Bertalanffy equation.

| Age (Quarter years) | Mean length caught (cm) | Predicted length a* | b* | c* |
|---|---|---|---|---|
| Q2 | 9.50 | 13.29 | 8.12 | 2.29 |
| Q3 | 15.17 | 15.94 | 13.30 | 5.69 |
| Q4 | 19.19 | 18.58 | 17.67 | 8.96 |
| Q5 | 22.28 | 21.23 | 21.36 | 12.11 |
| Q6 | 24.01 | 23.87 | 24.47 | 15.13 |
| Q7 | 26.58 | 26.52 | 27.09 | 18.03 |
| Q8 | 28.94 | 29.16 | 29.30 | 20.81 |
| Q9 | 33.01 | 31.81 | 31.17 | 23.47 |
| Q10 | 33.72 | 34.45 | 32.75 | 26.07 |
| Q11 | 35.26 | 37.10 | 34.08 | 28.54 |
| Q12 | 35.83 | 39.74 | 35.20 | 30.91 |
| Q13 | 39.80 | 42.39 | | 33.20 |
| Q14 | 45.45 | 45.03 | | 35.39 |

a* regression equation (7) fitted to fish of age Q2 - Q14

b* von Bertalanffy equation fitted to fish of age Q2 - Q12

c* von Bertalanffy equation fitted to fish of age Q2 - Q14

TABLE 6 Mean length at age of cod landed on the West Coast of Scotland, and the predicted lengths using a fitted von Bertalanffy curve.

| Age (Years) | Mean length of catch (cm) | Predicted lengths (cm) |
|---|---|---|
| 1 | 39.8 | 38.7 |
| 2 | 51.3 | 53.6 |
| 3 | 67.1 | 66.0 |
| 4 | 78.7 | 76.2 |
| 5 | 84.0 | 84.6 |
| 6 | 90.6 | 91.6 |
| 7 | 99.4 | 97.4 |
| 8 | 101.8 | 102.2 |

FIGURE 1 Condition factor (bars), and catch per unit effort (broken line) of juvenile cod in Loch Torridon through the year and temperature at 10 m depth in the loch (solid line).

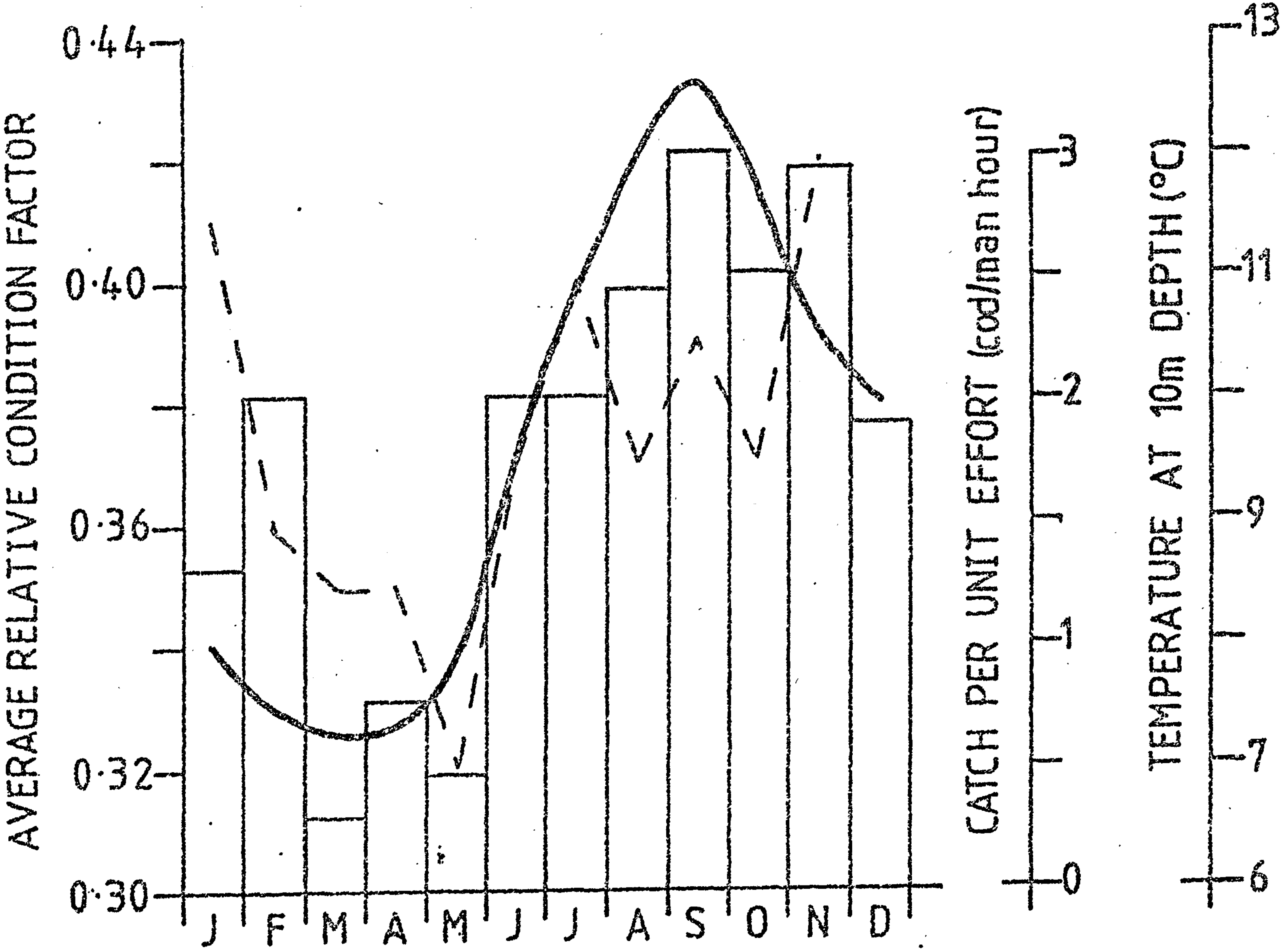

FIGURE 2

The mean length, and 95% confidence limits, of juvenile cod in Loch Torridon aged to the nearest quarter year.

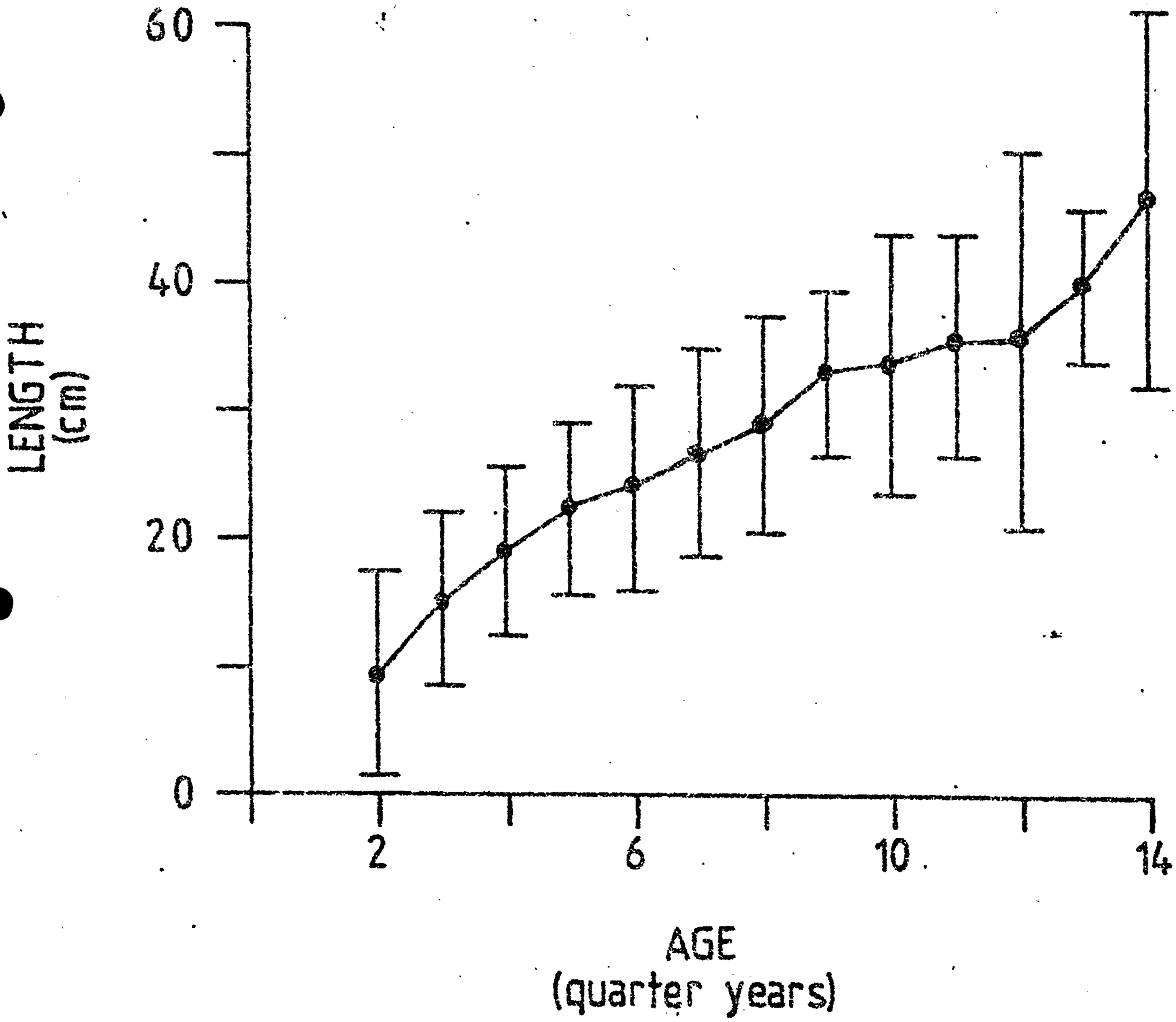

FIGURE 3

Mean length of juvenile cod in Loch Torridon up to the age of 3 years. The broken line is equation (7) in the text, fitted to the data by regression. The solid line is the fitted von Bertalanffy curve.

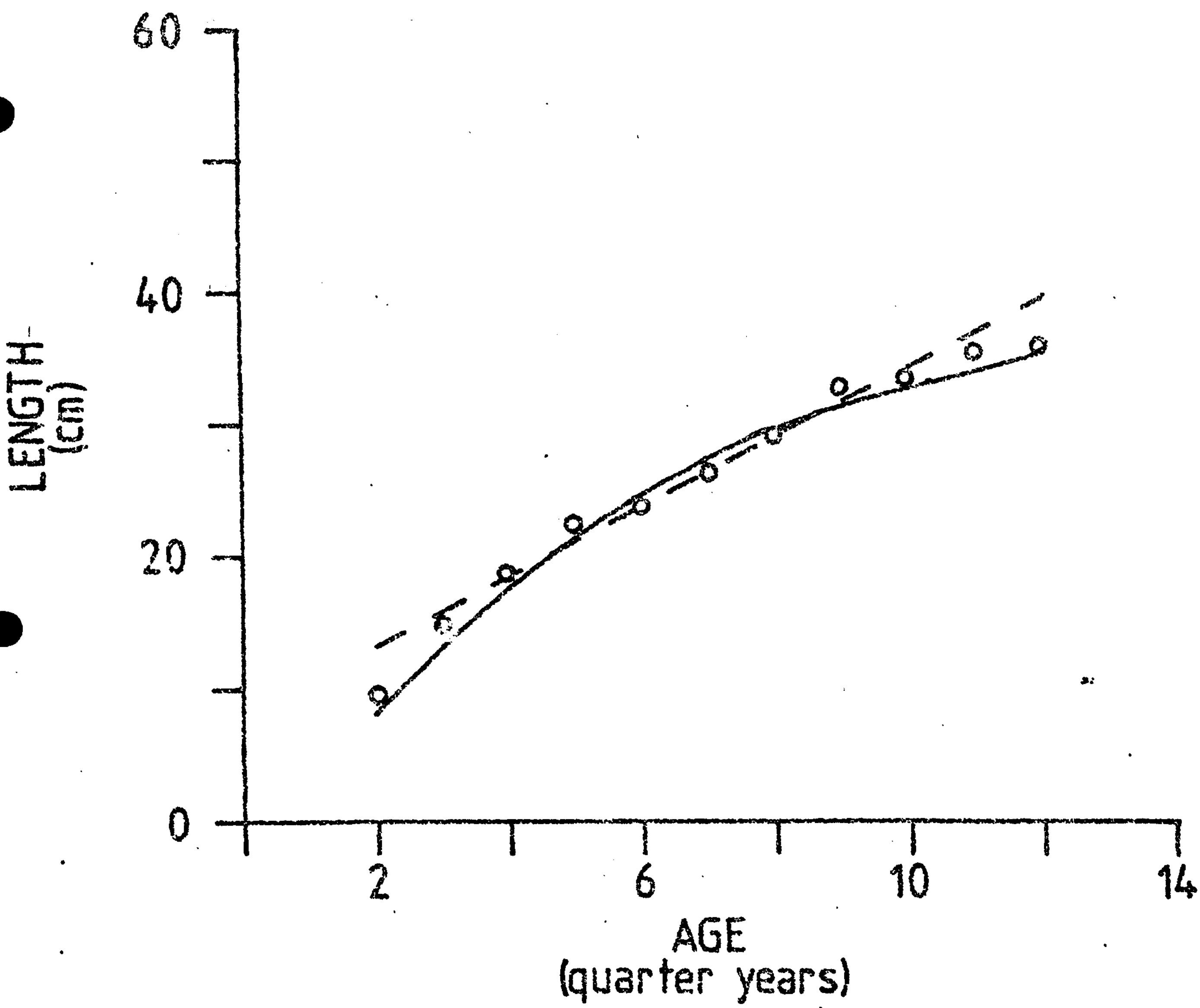

FIGURE 4

The mean length of cod landed at ports in the west coast of Scotland and their estimated ages. The broken line is equation (8) in the text, fitted to the data by regression. The solid line is the fitted von Bertalanffy curve.