SAMPLING GEAR SELECTIVITY AND ITS EFFECT ON ESTIMATES OF MEAN LENGTH AT AGE

by

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ABSTRACT

Using data from the Norwegian bottom trawl surveys in the Barents Sea in February (1989-1996), the International 0-group surveys in the Barents Sea (1985-1996) and previously estimated selectivity for the standard Norwegian sampling gears, effects on estimates of mean length and weight at age are shown. For the younger fish mean lengths at age are biased upwards, the relative bias increasing with decreasing size.

INTRODUCTION

The standard sampling trawl used during the annual Norwegian bottom trawl survey in the Barents Sea in February, has been shown to have a length dependent catching efficiency for cod and haddock (Dickson, 1993b). The obvious effects on the abundance estimates have been studied by several authors (Godø and Sunnanå, 1992; Engås, 1994; Aglen and Nakken, 1997) and it has also been pointed out that a length dependent catching efficiency will give biased estimators of mean length (and weight) at age (Godø and Sunnanå, 1992).

The standard pelagic trawl used in the annual international 0-group survey in the Barents Sea has also been studied by comparing catch length frequencies with those from an experimental juvenile gadoid sampling trawl (Godø *et al.*, 1993; Hylen *et al.*, 1994). Hylen *et al.* (1994) estimated length dependent correction factors for the density estimates from standard trawl assuming that the experimental trawl had no change in efficiency with fish length. These same correction factors can also be used to correct biased estimators of population parameters such as mean length and weight at age.

This paper considers size dependent changes in catching efficiency as estimated in previous works by Dickson (1993b), Aglen and Nakken (1994) for bottom trawls and Hylen *et al.* (1994) for 0-group trawl. The results are derived assuming that the given efficiency curves (selection curves) represent the “truth”. Many other factors than fish size affect the efficiency of sampling gears and there is a range of complex questions demanding investigation in the future. This paper discusses the need for correcting biased estimates of length and weight at age, the magnitude and how to correct such biases.

MATERIALS AND METHODS

The Barents Sea bottom trawl survey data

The data from the Barents Sea surveys from 1989 to 1996 together with the results obtained by Dickson (1993b) are used to show the effects on estimates of mean length and weight at age. The Dickson results for both cod and haddock are presented in Fig. 1 as curves showing the effective fishing width of the trawl in relation to fish length for both species (Dickson, 1993b; Aglen and Nakken, 1994).

The standard bottom sampling trawl is a Campelen 1800 shrimp-trawl with 80 mm mesh size in the front. The codend had 35-40 mm stretched mesh size until 1993, but since 1994 the trawl has been equipped with a codend mesh size of 22 mm. Sweep lengths are 40 m and in the period 1989-1996 both Steinshamn V- and W-doors, 7.1 m^2 (1500 and 2050 kg) and Vaco combi door, 6 m^2 (1500 kg) have been used.

The International 0-group survey data

The data from the international Barents Sea 0-group survey 1985-1996 were analyzed using the correction factors estimated by Hylen *et al.*(1994). This correction factor was derived from experiments with alternate hauls of the standard sampling trawl and an experimental juvenile gadoid sampling trawl (Godø *et al.* 1993).

Only a subset of the 0-group survey data each year was used. Only trawl stations east of 20° E , west of 38° E and south of 75° N were used in the analysis. Other areas of the Barents Sea had a varying degree of coverage during these surveys. The data in the subsets represent regular station grids ranging in number from 70 stations in 1995 to 107 stations in 1986. In 1995 and 1996 the trawl stations were located on equidistant grids, but earlier surveys used north-south course lines with a constant distance between fixed statio~~ns~~ along the course line.

Analysis of bottom trawl survey data

The analysis of the bottom trawl data compares uncorrected estimates of mean length and weight at age with results using corrected estimators of these population parameters. Abundance estimates by length use point observations of fish density (trawl stations):

$$\rho_{s,i} = \frac{f_{s,i} \cdot \dfrac{v_s}{v_s^{(L)}}}{a_{s,i}} \qquad (1)$$

Where effective fishing area $a_{s,i}$ is calculated as:

$$a_{s,i} = \frac{d_s \cdot D_i}{1852} \qquad (2)$$

s,i station number, length in cm

$\rho_{s,i}$ density of fish (number per nautical mile squared) of length i observed at station s

$f_{s,i}$ number of fish measured of length i at station s

$v_s, v_s^{(L)}$ weight of catch, weight of length sample at station s

d_s towed distance at station s

The Dickson corrected effective fishing width in meters D_i for cod is calculated as (from Aglen and Nakken, 1997):

$$D_i = 5.91 \cdot i^{0.43}$$
$$D_i = D_{15} \qquad \text{for } i \leq 15 \text{ cm}$$
$$D_i = D_{62} \qquad \text{for } i \geq 62 \text{ cm}$$

And the Dickson corrected effective fishing width (meters) D_i for haddock is calculated as:

$$D_i = 2.08 \cdot i^{0.75}$$
$$D_i = D_{15} \qquad \text{for } i \leq 15 \text{ cm}$$
$$D_i = D_{48} \qquad \text{for } i \geq 48 \text{ cm}$$

while the traditional estimate for both species uses a constant effective fishing width: $D_i = 25.0$

Point observations of densities are summed up to 5 cm length groups and then used to calculate stratified indices by length groups:

$$I_{p,l}^{(\ )} = \frac{A_p}{N_p} \cdot \sum_{s \text{ in stratum } p} \rho_{s,l} \tag{3}$$

$I_{p,l}^{(U)}$ uncorrected abundance index in stratum p for length group l

$I_{p,l}^{(D)}$ Dickson corrected abundance index in stratum p for length group l

A_p area of stratum p in nautical miles squared

N_p number of stations in stratum p

The Norwegian sampling scheme samples age stratified in 5 cm length groups. For each stratum, length group and age group the following uncorrected proportion can be calculated:

$$P_{p,l,a} = \frac{n_{p,l,a}}{n_{p,l}} \tag{4}$$

$P_{p,l,a}$ proportion of age group a in stratum p and length group l

$n_{p,l,a}$ number of samples with age a in stratum p and length group l

$n_{p,l}$ number of age samples in stratum p and length group l

The Dickson corrected proportion is:

$$P_{p,l,a} = \frac{\sum_j \left(D_{L_{p,l,a,j}}\right)^{-1}}{\sum_{a,j} \left(D_{L_{p,l,a,j}}\right)^{-1}} \tag{5}$$

Both proportions are used together with the corresponding population parameter. Uncorrected mean length in stratum p length group l and age group a is:

$$L_{p,l,a} = \frac{\sum_j L_{p,l,a,j}}{n_{p,l,a}} \tag{6}$$

while the Dickson corrected one is:

$$L_{p,l,a} = \frac{\sum_j L_{p,l,a,j} \cdot \left(D_{L_{p,l,a,j}}\right)^{-1}}{\sum_j \left(D_{L_{p,l,a,j}}\right)^{-1}} \tag{7}$$

The proportions (age-length key) are used to calculate the following indices:

$$I_{p,l,a} = I_{p,l} \cdot P_{p,l,a} \tag{8}$$

using $I_{p,l}^{(U)}$ and (4) for the uncorrected version and $I_{p,l}^{(D)}$ and (5) for the Dickson corrected one. Finally the total indices are calculated by appropriate summation. Population parameters are calculated as weighted means:

$$L_a = \frac{\sum_{p,l} L_{p,l,a} \cdot I_{p,l,a}}{\sum_{p,l} I_{p,l,a}} \tag{9}$$

using (6) for the uncorrected estimate and (7) for the Dickson corrected estimate. Mean weight at age is calculated similarly. Note that the relative change in effective fishing width within a 5 cm length interval is largest for the small fish. The correction had very little effect on the weighting factor for larger fish. The effective fishing width of cod increases 13% from 15 to 20 cm fish length, but only 3.8% from 55 to 60 cm. For haddock the Dickson correction result in a 24% increase in effective fishing width from 15-20 cm and 9.2% increase from 40 to 45 cm.

Analysis of the 0-group survey data

The analysis of the 0-group data is simpler since no age samples are needed. The samples treated are all 0-group fish and there is no age sampling. Hylen *et al.* (1994) gives a correction to be applied directly on each observed length distribution. For each station the frequency at length is given a weight equal to:

$$w_L = 1 + e^{-a-bL} \tag{10}$$

where a=-8.03 and b=0.838 for cod and a=-4.16 and b=0.422 for haddock. This corresponds to the curves presented in Fig. 2 (1992 curves). The length L is in cm. The corrected estimate is the now the weighted estimate of mean length using weights from (10), while the uncorrected estimate is the unweighted estimate of mean length, the original estimator.

For both surveys the percentage bias is calculated as the difference between the uncorrected estimate and the corrected estimate divided by the corrected estimate and multiplied with 100.

$$Bias = \frac{\left(\hat{L}_U - \hat{L}_C\right)}{\hat{L}_C} \cdot 100 \tag{11}$$

Clearly this is only an estimator of bias. The true bias could be calculated from a true (known) length distribution, but the main point remains that the bias is depending on both the shape and position (mean) of the underlying length distribution. The bias in weight is calculated similar to (11). Since both sampling trawls have reduced catching efficiency for smaller fish the uncorrected estimates is always higher than the corrected ones and the bias is positive.

RESULTS

Figs. 3 and 4 show the estimated bias in mean length and mean weight at age for ages 2-5 for cod and haddock.

The bias is shown only for ages 2-5. Age 1 is not included since correction curves for both species flattens out at 15 cm and most of the 1 year old fish are below that limit. If the 1-group was included then the bias would mainly reflect the proportion of 1 year old fish above 15 cm and not be comparable with the other results. Similarly, most fish of ages 6 and older are above 62 cm (48 cm for haddock).

The results from the 0-group surveys are presented in Fig. 5 where the corrected and uncorrected mean length of cod and haddock is shown together with the calculated bias.

DISCUSSION

The bias in estimated mean length (or weight) at age due to size dependent selectivity of sampling gears has been mentioned by other authors. Godø and Sunnanå 1992 studied size dependent changes in catching efficiency by comparing catches in the standard Norwegian bottom sampling trawl applied with Bobbins gear and the Rockhopper gear. Their main concern was that changes in growth (and size) would lead to a varying bias in abundance indices at age, but they also mentioned effects on observed mean length at age 1 for cod and haddock. They also noted that due to mesh selection only the largest 1 year olds were retained in the cod-end and the annual variation in mean length of that age group therefore tended to stabilize. In their discussion on variability of bias in the abundance indices they also pointed out that correction of such time series introduced a reduction in accuracy both through uncertainty in the correction curve itself as well as in the estimation.

For size groups where the trawl samples with very low efficiency the accuracy of the estimates will be particularly low. And of course: For very low catching efficiency the proportion of zero catches for that size class might be drastically increased. Low catching efficiency can thus not be corrected for in the manners used in this paper. A possible solution to this problem is to smooth the observed length distribution, but that will rely heavily on assumptions regarding the underlying true length distribution, and errors in such assumptions are another source of bias.

In the Norwegian bottom trawl surveys the "Dickson" correction has been applied since 1995. This is a simplified correction on the estimated length distribution and there are no correction applied to the age-length keys. This lack of correction has very little effect on the estimates of mean length and weight at age, but could be important for the estimates of abundance. The correction of age-length keys gives larger weight to the small fish so the proportion of younger fish will be higher. If no correction is applied older age groups are overestimated on the cost of younger age groups.

The analysis described in this paper assumes that the given correction curves represent the true selectivity of the sampling gears. This clearly is not the case. As pointed out by Dickson (1993b) the observed change in size dependent catching efficiency is an "overall" mean effect and a result of several factors. He points to otterboard effects, sweep and sand cloud effects which will vary with the visibility. In addition it would be reasonable to address effects of temperature, vertical migration and fish density. Future research should emphasize the quantification of each of these factors on the catching efficiency.

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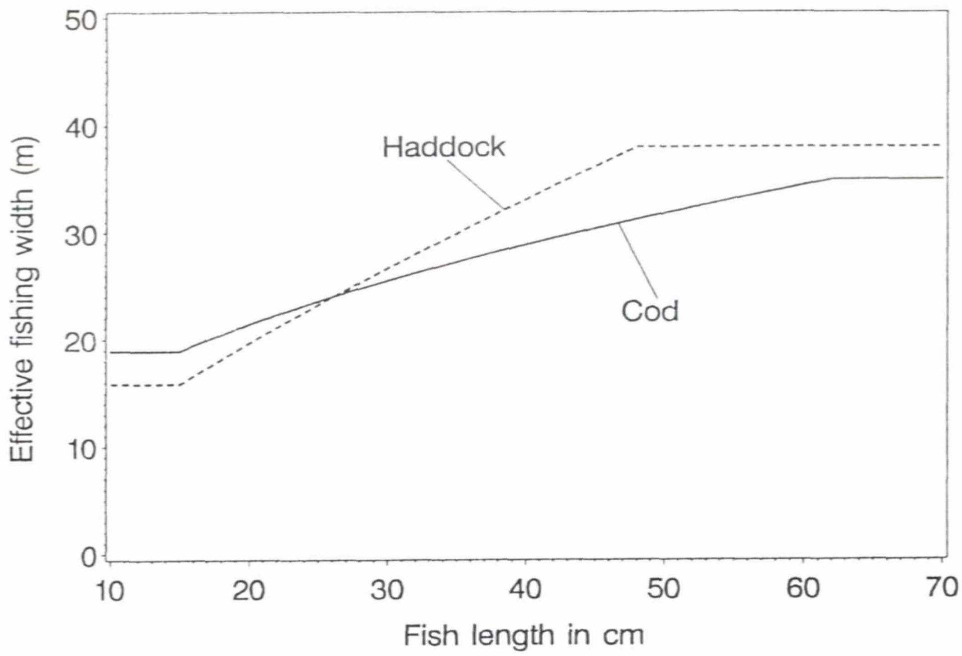

Fig. 1 Effective fishing width of the standard sampling trawl.

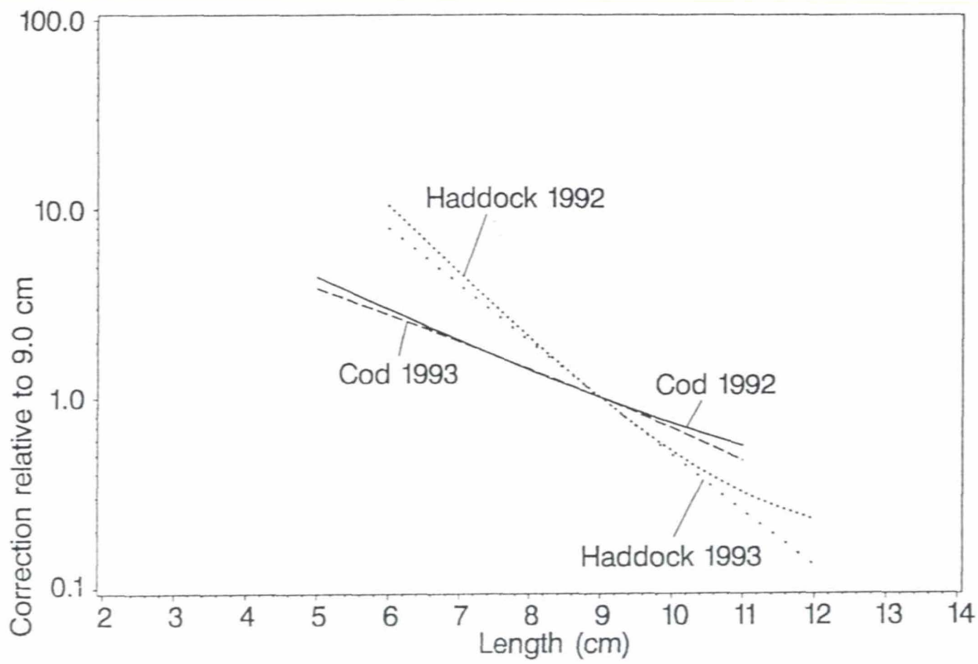

Fig. 2. Correction factors (multipliers) to be used for density estimates based on the standard sampling trawl. From Hylen et al. (1994).

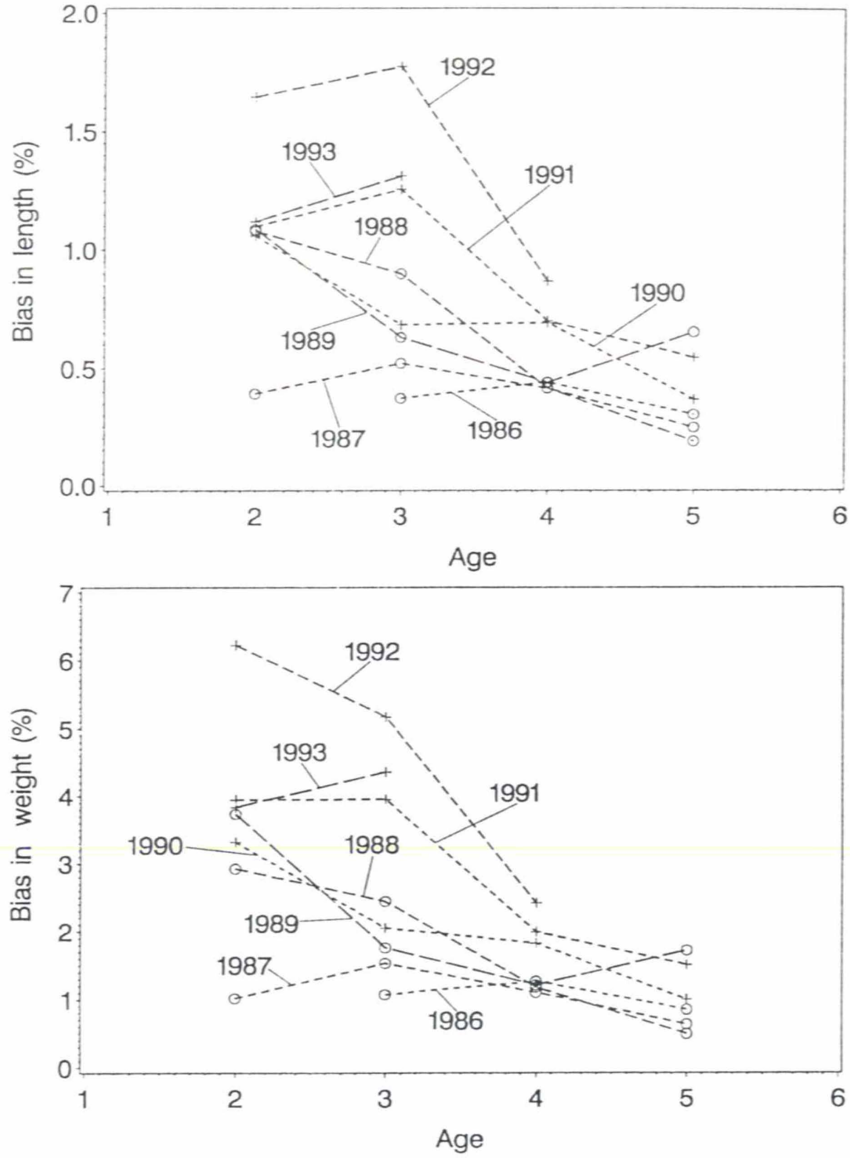

Fig. 3 Estimated bias in length (top) and weight (bottom) of cod for ages 2-5 by cohort.

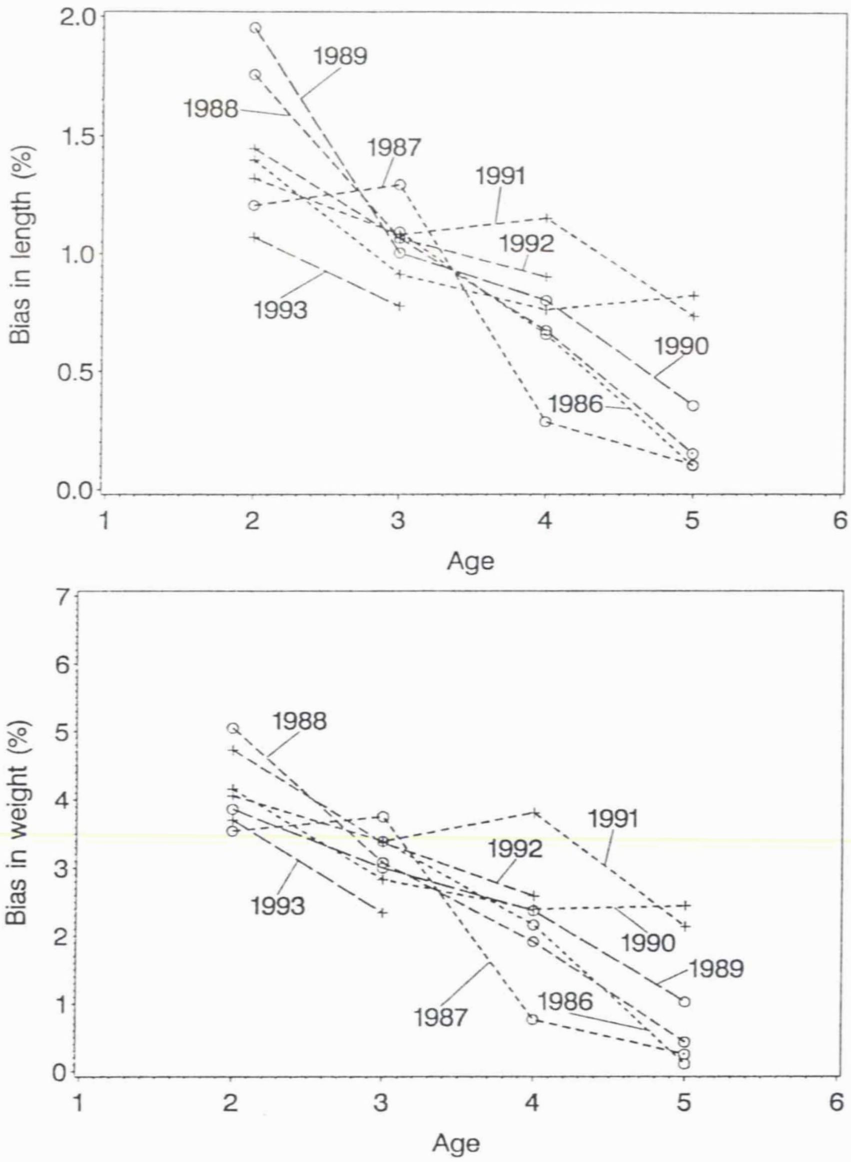

Fig. 4 Estimated bias in length (top) and weight (bottom) of haddock for ages 2-5 by cohort.

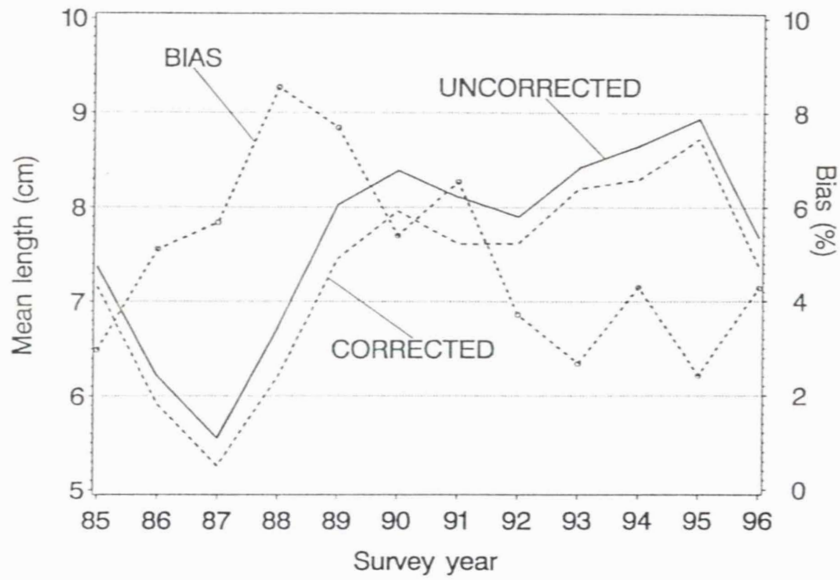

Fig. 5 Corrected and uncorrected estimates of mean length of 0-group Cod (top) and Haddock (bottom) with the estimated bias for the uncorrected estimate given in percent.