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The effect of twine thickness in cod gill nets

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Abstract

Sea trials were' carried out on a Danish commercial vessel measuring the size selectivity and fishing power of gill nets used to catch Baltic cod (*Gadus morhua*). A comparison was made of two different twine thicknesses at two different times of the year. Nominal mesh sizes of 70-130 mm were used. Method of capture, condition factor and girths were measured for sub-samples of the cod caught. A model of the size selectivity of the gill nets was adapted to the experimental conditions where two gears were fished on the same population and it was fitted to the catch data by set using a model of between-set variance. It was found that twine thickness and trials period had relatively little effect upon the shape of the selectivity curve. Twine thickness had a substantial effect upon the fishing power of the nets.

Keywords: Baltic cod, Gadus morhua, gill nets, selectivity, fishing power

1. Introduction

Baltic cod is a stock which is of considerable commercial importance but has been considered to be both overexploited and subject to an unsatisfactory exploitation pattern with high catches of juveniles. There have in recent years been temporary closures of the fishery, severe quota rationing and an increase in the minimum mesh size for towed gears from 105 mm to 120 mm for standard codends. In recent years the importance of catches in gill nets has increased. The selectivity in trawl codends has been subjected to comprehensive investigations in recent years (Tschemij et al. 1996; Madsen et al. 1998; Madsen et al. 1999a; Tschemij and Holst 1999). There may be a future wish to review the present gill net regulations for fishing Baltic cod. Such a review should be based on knowledge of the selectivity of the gillnets used commercially and consider how the technical parameters of the gill nets can affect their size selectivity and fishing power (ability to retain fish at the optimal modal length). It has been demonstrated that twine thickness has a major effect on catch rates in gill net fisheries (reviewed by Hamley 1975). The effect on the size selectivity of gill nets is, however, not well documented.

An experiment was therefore designed with the objectives of measuring the effects of twine thickness upon the size selectivity and fishing power of gill nets used to catch Baltic cod **and determining** if these effects were dependent upon season.

2. Materials and methods

2.1 Experimental nets

In order to determine the number and range of mesh sizes required, simulations were carried out using a Baltic cod population length frequency distribution obtained by the IMR research vessel Argos during a trawl survey and the selectivity curves reported (Anonymous 1997) for North Sea cod. It was predicted that 6 nominal mesh sizes from 70 mm to 130 mm, increasing in geometric progression, should be sufficient.

A comparison was made of two twines of different thickness giving 12 different experimental nets. Fleets could then be a typical commercial length of 12 nets - one net of each category arranged in random order. Sheet netting were specially produced by a net manufacturer in Finland who was prepared to make sheet netting to order in different mesh sizes. The standard nets were made in 1.5*4 twine, which is the thinnest used by Danish fishermen and the other nets in 1.5*6 twine which is the thickest twine used for mesh sizes up to 130 mm. The designations 1.5*4 and 1.5*6 refer to a Japanese numbering system indicating that there were 4 and 6 threads respectively of number 1.5 monofilament thread which is approximately 0.2 mm in diameter. Twine colour was orange. The full stretched length of each net sheet was 130 m and the stretched depth of the netting was 3.66 m. The nets were rigged in accordance with the trials vessel skipper's normal commercial practice. Hanging ratio was 0.5 on the floatline and 0.57 on the leadline. The floatation was in the form of plastic floats giving a buoyancy of 24 g/m. Each different net category (mesh size and twine thickness) was colour coded on the floatline to simplify identification on hauling and recording of catches.

Inside mesh sizes were measured in the dry state before the first sea trials and at the end of the second trials by inserting a steel ruler and using light hand force to stretch the mesh. Repeated soaking for periods of at least 12 hours increased mesh sizes by approximately 2.7%.

Thickness of the twines used was measured optically by the light extinction method (Ferro 1989). 10 measurements were taken for each twine sample, each at a position midway along a bar. 10 samples were taken for each twine. The measured twine thicknesses were 0.26 mm (std. 0.023) for the 1.5*4 twine and 0.36 mm (standard deviation 0.015) for the 1.5*6 twine. The individual twine filaments were approximately 0.17 mm in diameter for the 1.5*4 twine and 0.19 mm for the 1.5*6 twine.

The length of the floatline and leadline of each net were measured at the end of the trials in the dry state using a 20 kg hanging weight to tension the line. Differences between nets were relatively small with the measured lengths varying by up to 2 m. Mean floatline length of the nets was 68.1 m whereas the original specified length was 65 m. This is equivalent to the hanging ratio increasing from 50% to 52%. Comparison with measurements taken before the trials revealed that this seemed to be partly due to the 20 kg weight giving the line more tension than that applied when the netting was mounted to the line (using a sewing machine) and partly due to the lines stretching with use at sea.

2.2 Sea trials

Sea trials were made in the autumn and in the spring because it was expected that the condition of the cod would differ at these two times of the year. A 10.4 m glass fibre gill net vessel with forward wheelhouse R220 Britta was chartered for both trials. The first trials were carried out in September 1997 in ICES subdivision 25 using the harbour of Nexo, Bornholm, as a base. Only 5 of the 6 available net fleets were used because of bad weather giving a total net length of 3.9 km. The vessel went out to haul, clean and reset the nets each morning, giving soak times of approximately 23 hours. 14 valid sets were completed. The second trials were carried out in April 1998. The same grounds were used. All 6 of the available fleets were used giving a total net length of 4.9 km. 14 valid sets with soak times of just under 24 hours were completed.

2.3 Measurements

The following measurements were made; length of all fish caught by net category (twine and mesh size); numbers of incidental by-catches of mammals and birds by net category; ungutted weight of individuals for a sub-sample of the cod (in g); method of capture (enmeshed behind the gills, enmeshed behind the maxillaries, entangled by the teeth or otherwise entangled) for a sub-sample of the cod. Lengths were measured to the cm below except for the sub-samples where weight and girth were measured. Lengths were measured in mm for these fish. 0.5 cm was added to the length of those fish measured to the cm below in all calculations. The catches in a given net type and mesh size were pooled over all fleets hauled that day to the give the catch taken in a set by that net type and mesh size.

2.4 Modelling

Two aspects are of concern when several sets are made with a series of nets of different design and the catch numbers by length class used for inference on the size selectivity of the nets: 1) random effects such as the between-set variation; 2) the effect of different types of gear upon the size selectivity and the efficiency. It has recently been demonstrated that it is possible to estimate the between-set variation separately from the within-set variance (the binomial error) when modelling gill net selectivity (Madsen et al. 1999b) and hence make proper estimates of the variances. Furthermore the model enables testing for the effect of variables of interest.

To identify the effect of the gear parameters on the selectivity and the fishing power of the nets, the analysis must include all data within a given set simultaneously. Hence the difference behveen the nets with standard 1.5*4 twine and those with the thicker 1.5*6 twine can be modelled as offsets to the individual selectivity curve parameters plus a parameter accounting for the relative efficiency of the thick twine compared to the standard twine. This results, however, in a very high number of parameters (5 for the standard net + 5 offsets for the non-standard net + an efficiency parameter) to be estimated for each set. Estimation in this model is likely to be unstable and may also result in different parameterisations between the sets (different significance patterns). **As** an intermediate step, significant parameters (including offsets and efficiency) were identified by an indirect approach using the Laird-Ware model (Laird and Ware 1982). We call this approach indirect because the differences between the standard and the non-standard nets are not part of the initial model, but only assessed by the subsequent analysis. The advantage of this approach is that significant effects are easily identified. A drawback of the indirect approach is that it fails to recognise the common population contacting the two net types, fished within the same sets. No assumptions are made on the populations contacting the two gear types. This is clearly not valid for nets that were deployed at the same time and on the same fishing grounds. It was a reasonable approach, however, for reducing the dimension of the parameter space, because a ten-parameter model would be practically impossible to estimate. It cannot be used for estimation of the relative efficiency between the nets.

After the number of parameters had been reduced by the method described above, the parameters were estimated by a direct approach, in which the selectivity curves for the two gear types were estimated jointly. The key argument is that the λ_ℓ parameters model the same abundance of fish for both gear types, because they were deployed simultaneously within the same fleet of nets. These parameters are not of direct interest, but are implicitly estimated. The new model was built to perform a joint estimation of the selectivity for both levels of the gear parameters. Differences were specified by offsets to the relevant parameters for the net with standard twine thickness. Several different functional forms for the selectivity curve were fitted to the catch data. A bi-normal form was found to give the most satisfactory fits when referring the deviance to a chi-square distribution with ***dof*** degrees of freedom (McCullagh and Nelder 1989):

$$r_{jk}(\ell;\theta) \propto e^{-\frac{\left(\ell-(\alpha_1+\delta_{\alpha_1}\cdot T_k)\cdot m_j\right)^2}{2\left((\beta_1+\delta_{\beta_1}\cdot T_k)\cdot m_j\right)^2}} + (\omega+\delta_\omega\cdot T_k)\cdot e^{-\frac{\left(\ell-(\alpha_2+\delta_{\alpha_2}\cdot T_k)\cdot m_j\right)^2}{2\left((\beta_2+\delta_{\beta_2}\cdot T_k)m_j\right)^2}}$$

where α_1 and β_1 describe the location and spread of the primary mode and α_2, β_2 and ω describe the location, the spread and the scale (relative to the first mode) of the secondary mode. δ is the difference between the two gear variants and $k=1,2$ indexes the gear type:

$$T_k = \begin{cases} 0 & \text{for } k = 1 \text{ (twine thickness = 5 * 4)} \\ 1 & \text{for } k = 2 \text{ (twine thickness = .5 * 6)} \end{cases}$$

The relative fishing efficiency was introduced by modelling the mean catch a:

$$E_\theta(C_{\ell jk}) = \begin{cases} \lambda_\ell \cdot p_{jk} \cdot r_{jk}(\ell;\theta) & \text{for twine thickness = 1.5 * 4} \\ \lambda_\ell \cdot p_{jk} \cdot q \cdot r_{jk}(\ell;\theta) & \text{for twine thickness = 1.5 * 6} \end{cases}$$

$j=1,$ 6 and $k=1,2$. Here q models the efficiency of the non-standard net relative to that of the standard net.

3. Results

3.1 Catches

Total catch numbers in the second trials were rather low, approximately half those of the first trials despite using one more fleet of nets. The nets in thicker 1.5*6 twine caught only approximately two-thirds the numbers in the standard 1.5*4 nets.

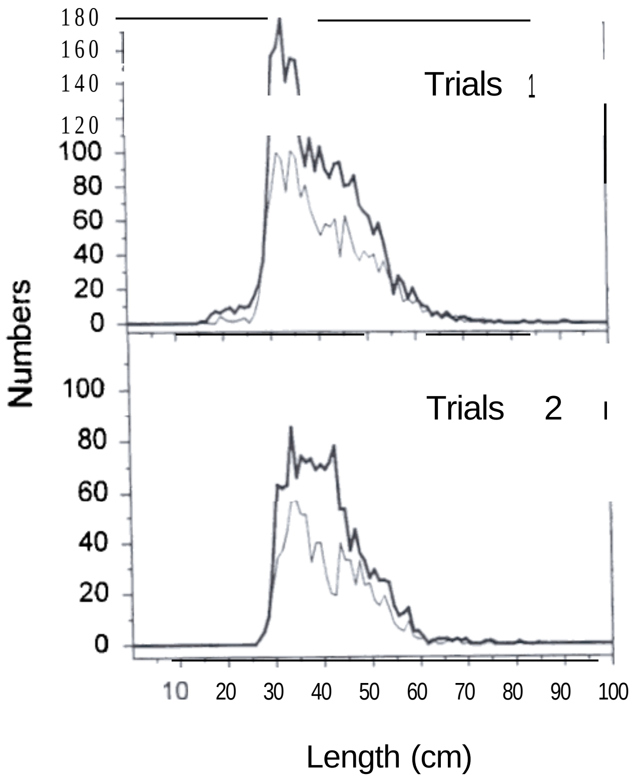

Fig. 1. Length distributions of total catches of cod for each twine and trials period. The thick line indicates the 1.5*4 twine and the thin line the 1.5*6 twine.

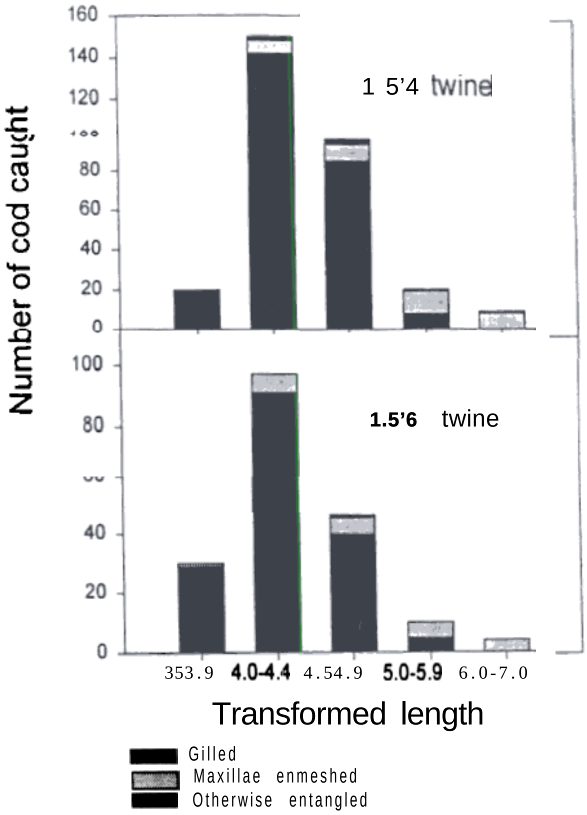

Fig. 2. Numbers of cod caught by method of capture.

The length distributions of the total catches of cod in the standard nets were only slightly different in the two trials periods (Fig. I). The catches peaked at cod of 30 - 35 cm length (1996 year-class) and then decreased steadily with length to a length of 55 cm. There were very few cod below 25 cm or above 60 cm caught in either of the trials.

By-catch numbers were very low in all trials consisting mainly of flounder in the largest mesh sizes and some herring in the first trials. The total incidental by-catch of birds and mammals was just one guillemot (*Uria aalge*).

3.2 Condition factor

The first trials were carried out in September 1997 when cod were well fed and in post-spawning condition with gonad development at a minimum. The second trials were carried out in April 1998 when the cod were in fact found to be in a very similar condition. Very few individuals contained roe. Linear regressions assuming weight was proportional to length cubed gave the following estimates (with standard errors) for the condition factor (Weight (g) / length^3 (cm)) for trials 1: 0.00972 (0.00008); and for trials 2: 0.00975 (0.00007). The condition factor was therefore marginally higher for the second period but not significantly so.

3.3 Method of capture

The data for the two trials periods were pooled since there was little difference between periods (Fig. 2). The majority of the cod were found to be gilled. A much smaller proportion of the total sample were caught by the maxillae. The proportion of maxillae caught fish increased with increasing transformed length (= fish length mm / mesh size mm). Many of the maxillary caught cod were in fact small enough to have been gilled. Few cod were otherwise entangled. The proportion of cod that were otherwise entangled was higher for the thinner twine but in general there was no marked difference between the two twines.

3.4 Effect of twine thickness

The REML (residual maximum likelihood) parameter estimates given by the direct analysis of the effect of twine thickness are given in Table 1 and 2. The results of this analysis revealed significant impacts of twine on the location of the primary mode in the first trials and spread of the second mode in the second trials. The relative efficiency of the thicker 1.5*6 twine was estimated to be 70% of that of the 1.5*4 twine in the first trials period and 64% in the second trials. These figures are slightly higher than those given by simple comparisons of the total catch numbers with the two twines. Twine thickness appeared to have significant effects on different selectivity parameters for the two sets of trials

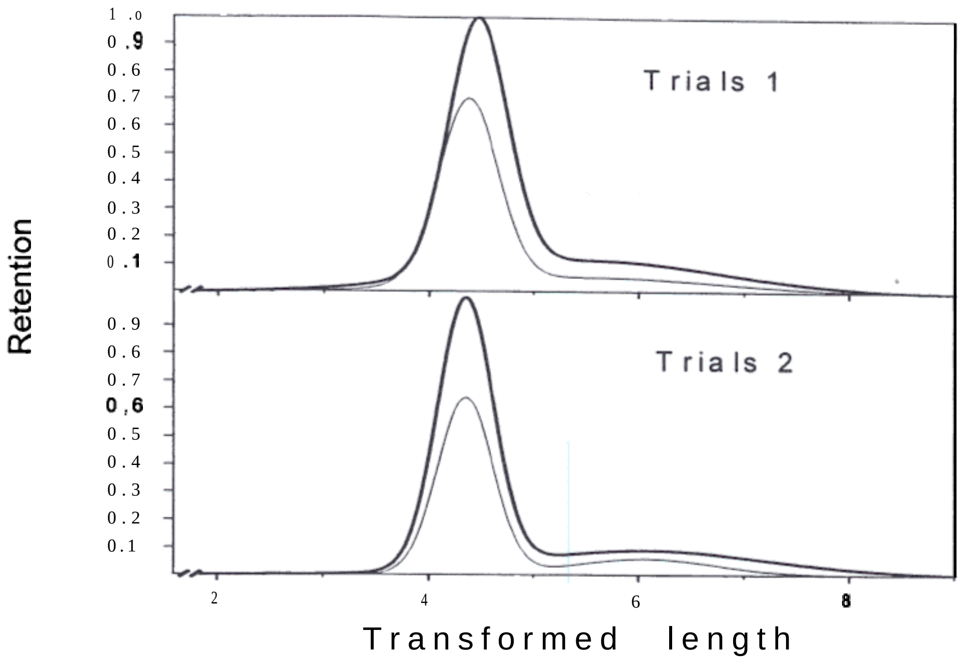

Fig. 3. Selection curves for the two trials. The thick line indicates the 1.5*4 twine and the thin line the 1.5*6 twine.

so the difference in selectivity due to twine thickness was not consistent between the two trials periods.

The locations of the primary mode on a transformed length scale were estimated to be 4.46 and 4.37 for the 1.5*4 and the 1.5*6 nets respectively in the first trials period and 4.35 for both twines in the second trials period. Selectivity curves, taking account of the difference in efficiency between the two twines, are plotted in Fig. 3. The figure demonstrates the substantial difference in fishing power between twines whereas the differences between twines and seasons in the actual form of the selection curves are limited.

Table 1. Parameter estimates for the mean selection curves of the second trials generated by the REML analysis, standard errors (SE) and degrees of freedom (dof).

	α_1	β_1	α_2	β_2	ω	δ_{α_1}	δ_{ω}	4
Estimate	4.46	0.283	5.52	1.27	0.127	-0.0845	-0.0427	0.70541
SE	0.013	0.0069	0.085	0.079	0.0124	0.021	0.012	0.0415
t- Value	339.0	41.1	65.3	16.1	10.2	-4.1	-3.6	16.9784
dof	60	60	60	60	60	60	60	60
p- Value	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	0.000 1	0.0006	0.0000

Table 2. Parameter estimates for the mean selection curves of the second trials generated by the REML analysis, standard errors (SE) and degrees of freedom (dot).

	α_1	β_1	α_2	β_2	ω	δ_{β_2}	4
Estimate	4.35	0.266	6.05	1.14	0.0916	-0.467	0.641
SE	0.01469	0.01062	0.15421	0.14960	0.01108	0.18331	0.03660
t-Value	296.42	25.03	39.24	7.60	8.27	-2.55	17.52
dof	56	56	56	56	56	56	56
p- Value	*0.0000*	*0.0000*	*0.0000*	*0.0000*	*0.0000*	0.0136	0.0000

4. Discussion

The results **support** previous findings (reviewed by Hamley 1975) and fishermen's experience, that nets made of thinner twine catch more fish. It was therefore anticipated that the efficiency of the 1.5*6 twine would be less than that of the 1.5*4 twine but it was somewhat surprising to find the estimated relative efficiency (or fishing power) as low as 0.64-0.70. One wonders how high the absolute selectivity of gill nets for modal length fish actually is and also whether the efficiency of all mesh sizes has in fact been the same when the same twine thickness has been used for each mesh size. In the modelling it was assumed that the efficiency of all mesh sizes had been the same when the same twine thickness was used for each mesh size.

Hamley (1975) suggested that "nets of thinner twine are less visible, easier to stretch, and more flexible; therefore, they should tangle more fish and catch larger fish". The modal length of the selection **curve** for the thin twine was significantly higher for the first trials (in agreement with the supposition that thinner twines catch larger fish). The actual difference was, however, marginal, not found in the second trials and will have no importance for management regulations of mesh sizes. In the **study** of method of capture there were more cod in the "otherwise entangled" category in the thinner twine nets but the catch numbers of this category were too small to make firm conclusions. In general there was no marked difference in the method of capture between the two twines.

The selectivity curves for trials period 1 suggest that escape probabilities for small cod **below** the modal length (which can easily pass through a mesh) were virtually identical for the two twines but that retention rates were far higher for cod above and immediately below the modal length in the thinner twine. This seems a highly plausible concept but unfortunately the same result was not found in the second trials.

There were no significant differences in condition factor or girth measurements between the two trips, which no doubt explains the relatively small differences in the predicted selection curves between seasons. The parameter estimates for the location of the first and second mode are relatively similar to other estimates for bi-model selection curves for cod (Hovgård et al. 1999; Madsen et al. 1999b).

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References

Anonymous. 1997. Selectivity of gill nets in the North Sea, English Channel and Bay of Biscay. Final report of EC AIR Project AIR2-93- 1122. DIFTA.

Baranov. F.I. 1948. Theory and assessment of fishing gear. Chap. 7. Theory of fishing with gillnets. Pishchepromizdat, Moscow. (Translated from Russian by the Ontorio Department of Lands and Forests. Maplc. Ont.).

Ferro R.S.T. 1989. Objective measurement of the thickness of netting twine used in the fishing industry. Fish.Res., 8:103-1 12.

Hamley J.M. 1975. Review of gillnet selectivity. J. Fish. Res. Board Can. 32: 1943-1969.

Hovgård, H., Lassen, H., Madsen, N., Moth-Poulsen, T., Wileman, D., 1999. Gillnet selectivity for North Sea Atlantic cod (*Gadus morhua*): model ambiguity and data quality are related. Can. J. Fish. Aquat. Sci. 56: 1307-13 16.

Laird, N.M. and Ware, J.H. 1982. Random-Effects Models for Longitudinal Data, Biometrics, 38: 963-974.

Madsen, N., Holst, R., and Foldager, L. 1999a. The escape window as a management option to improve the size selectivity of the Baltic cod fishery. ICES CM 1999/R:01.

Madsen, N., Holst, R., Wileman, D., and Moth-Poulsen, T. 1999b. Selectivity of Danish sole (*Solea solea*) gill nets fished in the North Sea. Fish. Res. 44: 59-73.

Madsen, N., Moth-Paulsen, T., and Lowry, N., 1998. Selectivity experiments with window codends fished in the Baltic Sea cod (*Gadus morhua*) fishery. Fish. Res. 36: 1-14.

McCullagh, P. and Nelder, J. A. 1989. Generalized linear models, 2nd edition. Chapman and Hall, London, 5 l I pp.

Tschemij, V., and Holst, R. 1999. Evidence of factors at vessel-level affecting codend selectivity in Baltic cod demersal fishery. ICES CM 1999/R:02.

Tschemij, V., Larsson, P-O., Suuronen, P., and Holst, R., 1996. Swedish trials in the Baltic Sea to improve selectivity in demersal trawls. ICES CM 1996/B:25.