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Standardization of Fishing Power in the Norwegian Shrimp Trawler Fleet

by

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Introduction

Differences in fishing power between vessels in a fleet are an imortant error source when commercial cpue is used as an index of abundance (Gulland 1983). In this paper a model for standardisation of fishing power for individual vessels is described. The model is applied on the logbook data base from the Norwegian shrimp trawler fleet.

Material and Methods

Model

The model is based on methods in Gulland (1956) and Beverton and Holt (1957) who compared CPUE from pairs of vessels when they were fishing at the same time and place. For a given fleet and for a given species or sub-group, the relative differences in fishing power are estimated between as many vessel pairs as possible. These estimates are then used to calculate each vessel's fishing power relative to a chosen standard vessel. The relative fishing power between two arbitrary individual vessels are termed local power factors, and the fishing power between the standard vessel and other vessels, relative to the standard vessel, are termed global power factors. Using a vessel's global power factor, the applied effort can be converted to effort units of the standard vessel.

When two vessels have recorded catches close in time from the same area the probability that they were fishing on the same density of fish under equal environmental conditions is assumed to be high. A single estimate of relative fishing power between the vessels can then be made by taking the ratio of their CPUEs, and this is defined as a comparison. A time-space cell for a comparison has to be defined, i.e. a maximum difference in time and distance between the two vessels when their CPUEs are compared. Some catch composition criteria can also be made to increase the probability that the vessels were trying to catch the same species. The expression for local power factor, relative to one of the two vessels, is given by

$$P_{ik} = median\left[\frac{CPUE_{ij}}{CPUE_{kj}}\right] \qquad \text{for } j = 1, \ldots, n \text{ and } n \geq l \qquad (1)$$

where P_{ik} is the local power factor of vessel i relative to vessel k, $CPUE_{ij}$ and $CPUE_{kj}$ are their respective catch per unit effort during comparison j, n is the number of comparisons used and l is the minimum number of comparisons required to estimate a local power factor between the two vessels.

The standard vessel should be a particularly active vessel during the whole analysed time period with a high number of comparisons with the other vessels in the fleet. It is important not to choose a vessel which has undergone significant changes, e.g. rebuilding. This may change the vessels fishing power, and an important assumption concerning the standard vessel is that its fishing power remains constant throughout the analysed period. When calculating the global power factors vessel are grouped into 2 different levels according to the possibility to estimate local power factors directly or indirectly in relation to the standard vessel. Figure 1 gives a precise definition of what the different levels imply. The calculation of the global power factor $F_j^{(2)}$ is done by averaging products of local power factors:

$$F_j^{(2)} = \frac{1}{n}\sum_{i=1}^{n} P_i \cdot P_{ij} \qquad (2)$$

where n is the number of vessels at level l with estimated local power factors in relation to vessel j (at level 2), P_i is the local power factor of vessel i relative to the standard vessel and P_{ij} is the local power factor of vessel j relative to vessel i.

Since the relative fishing power between vessels in a fleet changes with time, it is important to divide longer time periods into shorter ones and to estimate local and global power factors within each of these shorter periods.

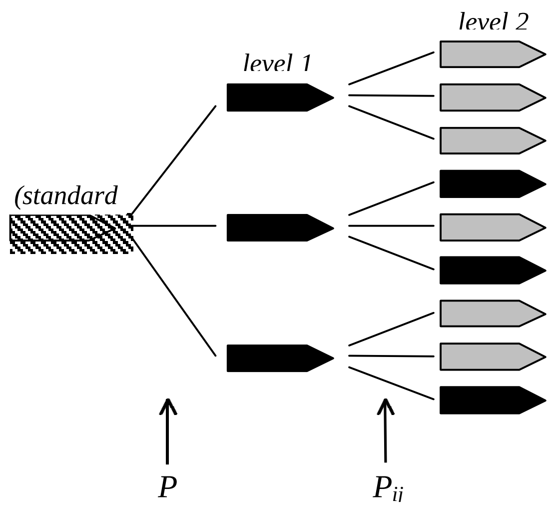

Fig. 1. The principle of how the local power factors between individual vessels (showed as lines) are used to estimate their global power factors in relation to a standard vessel using Equation 2. Vessels at level 1 have obtained a local power factor (P_i) directly in relation to the standard vessel, vessels at level 2 have obtained a local power factor (P_{ij}) in relation to vessels at level 1 The grey colored vessel did not obtain a local power factor directly in relation to the standard vessel and had to be related indirectly to the standard vessel, through ships at level 1.

Application

Each individual record in the logbook data base includes vessel, date, species, catch (in kilograms), summarised duration (in hours) of all the trawl hauls the recorded date, position according to the area-location scheme used by the Directorate of Fisheries (Appendix), length of the vessel (in meters) and engine size (in horsepower). The size of the geographical locations varies between 1° and 2° in longitude and 0.5° and 1° in latitude. If a vessel operates in different locations on the same day, the location with the largest trawl catch is recorded. CPUE is expressed in kilograms per hour.

A comparison of two vessels CPUE is done when the same statistical location (see Appendix) is recorded on the same day (time-space cell). The standard vessel is set to be the vessel having the highest number of comparisons with other vessels during the analysed time period. Standardisation of the fleet is done in two separate time periods, and the same standard vessel is used for the whole period. The few vessels that were rebuilt or given a new registration number during the period are removed.

Earlier works (e.g. Beverton and Holt, 1957) show that vessel and engine size explain much of the variation in fishing power, the larger and more powerful vessels being more efficient. To evaluate the global power factors in this work, linear regression analysis between vessel length and power factor and between engine size and power factor are carried out. The measurement procedures for gross tonnage changed gradually during the the analysed period and is thus not used. The frequency distribution of a randomly chosen vessel's CPUE ratios from comparisons with the standard vessel is explored to evaluate the method used for estimation of local power factors and to give a visual impression of the uncertainty in these.

Results

In both the two periods the length and engine size of the vessels are correlated with the estimated global power factors (Fig. 2). Four large vessels seem to be extremely efficient in the last period causing them to appear as outliers in the plots.

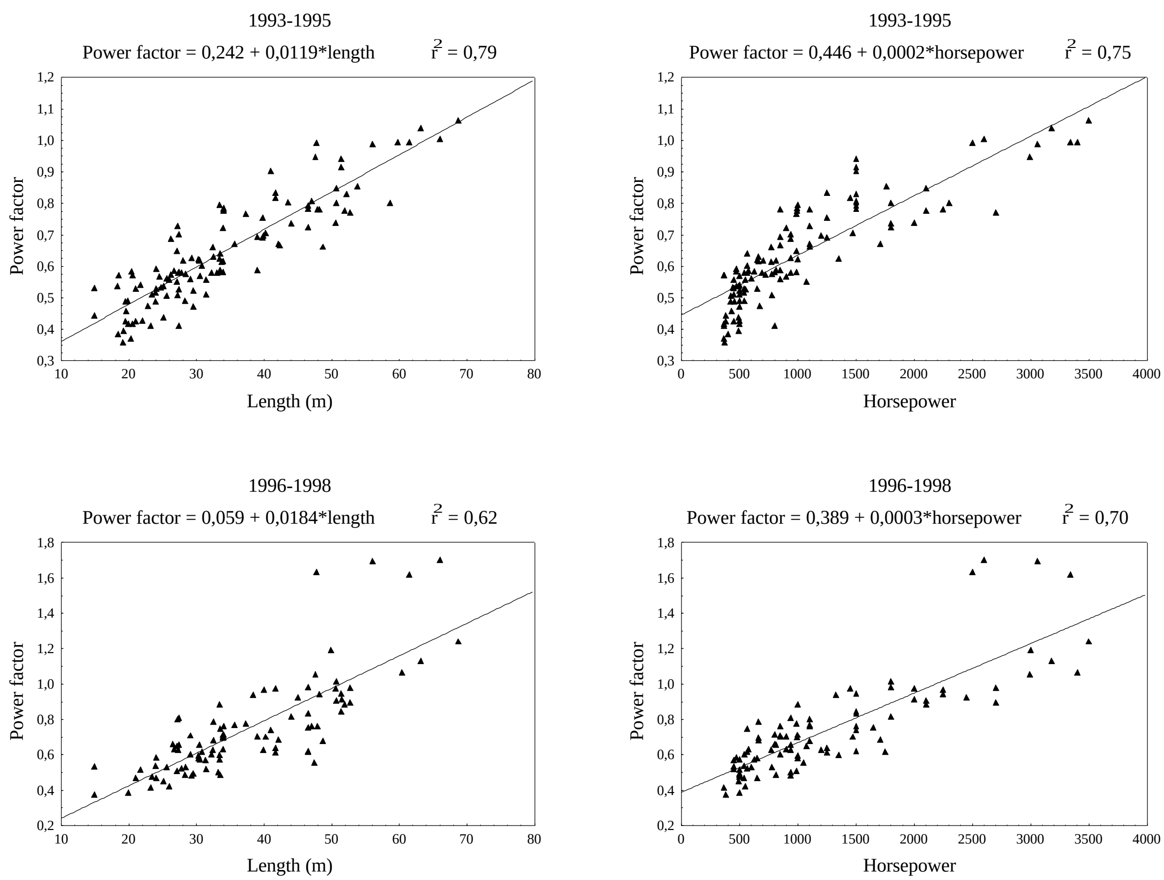

Fig. 2. Global power factors (Power factor) in relation to the standard vessel and length/engine power of all the standardised vessels in the two analysed time periods. Linear regression lines are shown together with their equation and correlation coefficient.

The distribution of the CPUE ratios (from Equation 1) between the investigated vessel and the standard vessel show one large value of the ratio and some ratios close to zero (Fig. 3).

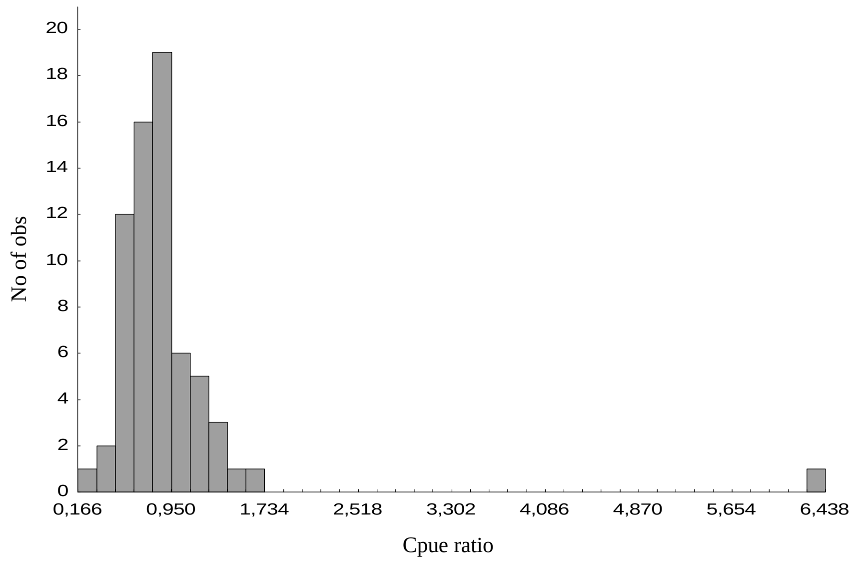

Fig. 3. Frequency plot of the CPUE ratios relative to the standard vessel from a randomly chosen vessel in the period 1996-1998.

Discussion

The results of regressions between global power factors and engine power/length of the vessels show that these characteristics probably explain much of the differences in relative fishing power, and this may indicate that our model for estimation of relative fishing power works well. Factors which most likely cause differences in fishing power between vessels are size, engine power, skipper, age of vessel and differences in fishing technology (Gulland, 1983). The outliers in the plot from the last period in Figure 2 are probably from vessels with double trawl. The effects these points have on the regression lines and correlations are not important since the only intention with the regressions is to evaluate the model.

Because of the resolution of the analysed data set, the smallest time-space cell for a comparison is not very precise. Vessels can be far apart in time and distance when their CPUEs are compared. Still the resolution is high enough for many comparisons to be made during a time period of four years.

The CPUE ratios between the analysed vessel and the standard vessel in this work (Fig. 3) seems to be fairly normally distributed but with occasionally very large and very small (near zero) values. If estimators for differences in fishing power which make use of all the CPUE ratios are applied (as in e.g. Beverton and Holt, 1957; Gulland, 1956; Wilderbuer *et al*. 1998), occasionally very large and very small values could have a large effect on the estimator. Therefore the median of the ratios is considered to be the most appropriate estimator of the relative fishing power between two fishing vessels.

A critical assumption in this model is that the fishing power of the standard vessel remains constant throughout the analysed time period. Another simplifying assumption is that the local power factors between pairs of vessels remain constant within the time period. These two assumptions are probably always violated to a certain extent. Fishing vessels normally increase their efficiency with time due to technological improvements, and the rate of improvement may differ among vessels. Current differences in fishing power between two vessels may also be dependent on conditions such as water depth, type of ground and weather conditions.

Conclusion

Instead of trying to analyse the complex set of factors causing differences in catching efficiency, the actual fishing power of the vessels can be estimated by direct comparisons of the vessels on the fishing grounds. The model also tracks differences in efficiency between vessels with new and old technology. A certain amount of spatial and temporal information about the vessels catching operations are however required.

References

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Appendix

Original statistical area-location scheme for the Barents Sea used by the Norwegian Directorate of Fisheries. The North-east Atlantic are similarily divided with areas.