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Inter-calibrations between German demersal gears HG 20/25 and TV3 520 as well as between the gears TV3 520 and TV3 930

by

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Abstract

Since 1985 different attempts were carried out to establish an international co-ordinated demersal trawl survey in the Baltic Sea. An essential precondition for such a survey is the inter-calibration of the different gears used in the national surveys. Schulz and Grygiel (1984, 1987) described the results of the inter-calibration between the gears used by the research vessels „Eisbär" (GDR) and „Dr. Lubecki" (Poland).

New activities started 1995 (ICES 1995) in order to co-ordinate the national demersal trawl surveys. These investigations are funded by the EU in the form of study projects. Besides the establishment of a database for the previous and current data new standard gears were developed and were tested.

During the German national demersal trawl surveys in November 1999 and in March 2000 inter-calibration experiments were carried out between the national gear HG 20/25 and the planned new standard gear TV3 520. In accordance with the proposal of the ICES „Workshop on Baltic trawl experiments,, (ICES 1999) the experiments were realised as paired hauls on the same station. Additional comparisons were carried out between both new standard gears TV3 520 (small) and TV3 930 (large) in March 2000.

The analyses showed which parameters influence the conversion factors between the gears essentially. Furthermore, it was assessed how many inter-calibration experiments must be realised additionally for getting the conversion factors corresponding to a required accuracy.

Key words: gear, inter-calibration, paired stations, cod, flounder, Baltic Sea

Introduction

Only few inter-calibration experiments of demersal gears were carried out in the Baltic Sea. Schulz and Grygiel (1984, 1987) compared the results of the inter-calibration between the research vessels "Eisbär" (GDR) and "Dr. Lubecki" (Poland). These vessels with different size and different power used the same herring ground gear, P 20/25. The analyses showed that the same gear used by different vessels might give different species compositions and different size compositions. Some year later an international co-ordinated inter-calibration experiment (ICES 1987) was carried out under the umbrella of the ICES. Since the catches obtained were not representative due to low catches the results were not used.

An inter-calibration of the gears Ssnderburger ground trawl and herring ground gear, HG 20/25was performed by Oeberst and Friess (1994). The HG 20/25 based on the Polish prototype P 20/25. The analyses of this experiment showed that HG 20/25, the gear with the larger net opening had a higher catch rate regarding the age groups 0 and 1 of cod.

The different gears were used for nation demersal trawl surveys. Such national surveys have been carried out since 1962 (Schulz 1978, Netzel 1979, 1992, Bagge and Steffensen 1984). The surveys of the different countries were planed regarding the special scientific interests of the institutes. During the German surveys the HG 20/25 were used mainly.

The results of the national surveys are used as important VPA independent indices of the year class strength (ICES assessment working group, Schulz and Vaske 1984), for estimating the discards in the commercial fishery (Berner and Schulz 198 1, Bagge 1989), in order to assess the total mortality (Bagge and Steffensen 1984), as estimates of the recruitment (Munch-Petersen and Bay 1991, Anon. 1998, Oeberst and Bleil 1999, 2000), for estimating the food consumption of young cod (Kowalewska-Pahlke 1994), for assessing the maturity ogive (Tomkiewicz et al 1997), and in order to quantify the exchanges between both Baltic cod stocks (Oeberst 1999, 2000).

Since the national surveys have a very heterogeneous distribution in space, time and gears used Sparholt and Tomkiewicz (1998) developed a robust method of compiling trawl survey data for the use in the central Baltic cod stock assessment.

The first attempts to co-ordinate the different national surveys were carried out 1985 (ICES 1985) and were continued in the following years with different intensity (ICES 1986, ICES 1988, ICES 1991,ICES 1992, ICES 1993).

A second attempt for establishing an international co-ordinated demersal trawl survey in the Baltic Sea started in 1995 (ICES 1995). The ICES working group for the "Baltic International Trawl Survey" developed standards for the realization of the surveys documented in the BITS Manual (ICES 2000).
In the circumstance of the EU funded ISDBIT project the new standard gear were developed and tested (Anon. 2000 – Interim Report). The smaller version TV3 520 (520 meshes in circumstance) should be used by research vessels with less than about 600 kW in areas of the Baltic Sea with soft bottom and lower depth. The larger version TV3 930 (930 meshes in circumstance) of the new standard gear should be used by research vessels with more than about 600 kW in the deeper areas and in combination with a special rock hopper ground rope in regions with hard bottom. Both gears are available now for carrying out the inter-calibration experiments. The description of the new gears is given in Anon. 2000.

In order to ensure continuation of the historical and presently conducted surveys conversion factors are necessary for converting the historical catch per unit data for cod and flounder in units of the new standard gears.

Investigations concerning the selection characteristics of the different gear types have been carried out since 1926 (Russel and Edser 1926). The most experiments dealt with the estimation of the selection function of the cod-end. Two technologies were used, the trouser gears or dual cod-end gears (Russel end Edser 1926, Gabriel and Haberstroh 1988, Millar and Walsh 1990) and the covered cod end (Shevtsov 1987, Bohl 1989, Netzel and Zaucha 1989).

Pope et al. 1975 and Fridman (1986) summarized the knowledge of the respective status. Founteyen (1991) compared the results of both technologies and Yoshi et al. 1993 have shown that also other parts of the gear than the cod-end can influence the selection characteristics of the gear.

Sissenwine and Bowman (1978) and Warren (1997) compared two combinations of vessel-gear. Both experiments used paired tows. For the analyses Sissenwine and Bowman (1978) used multiple non-linear models for estimating the conversion factor between the combinations of vessel-gear. Warren (1997) assessed the ratio between the catches of both vessels depending on the length. He developed a special method for excluding outliers. He defined stations as outlier where the differences of both catches compared were very large caused by the patchiness of the different species. The patchiness of the species density observed is the reason for a high variability of the ratio of both vessel and gear combinations compared. Specially if the number of available stations is low the influence of the patchiness can be high and requires a larger number of necessary stations if any defined accuracy is required.

Millar and Walsh (1990) developed a general model to analyse the selection characteristics if trouser hauls, covered cod-end or paired hauls are used, which includes the possibility of the different probability of the encountering of fish in the different trousers or in the alternative hauls. Walsh (1996) analysed possible sources for biased estimations during the demersal trawl which don't correspond with the assumptions of the survey design.

First technical experiments with the full scale gears were carried out during the trawl survey in March 1998. The goal of these investigations was to test the handling and the suitability of the gear TV3 930, the large version of the new standard gears, on board of the R/V "Solea" (engine power of 640 kW). This test showed, however, there are difficulties on board R/V "Solea" in handling the large trawl. There is limited engine power, therefore enormous navigation problems when trawling. On the other hand limited space on the net drums and it is therefore necessary to take off the floats during hauling and put them on again during shooting. This problem takes so long time that it is not always possible to make the usual number of hauls. Beside this problem the handling of the large otter boards which are necessary for the large gear is difficult and very dangers. However it was agreed the comparison between the two sizes should be completed on R/V "Solea", despite the handling difficulties.

First inter-calibration experiments between the German national gear HG 20/25 and the new standard gear TV3 520 were carried out during the German demersal trawls survey in November 1999. The inter-calibration were realized as paired hauls on the same station with an altering sequence of the gears as it was proposed by the ICES " Workshop on Baltic trawl experiments" (ICES 1999a). Since only eleven experiments could be realised determined by the available time additional comparisions between these gears were carried during the German survey in March 2000. During the same March survey inter-calibrations were realized under special test conditions between both new standard gears, the small TV3 520 and the large TV3 930.

The analyses presented here have the following goals:
- development of a model for the inter-calibration of the gears,
- description of the factors which determine the different catches of the gears,
- estimation of preliminary conversion factors and
- estimation of the necessary number of further inter-calibrations experiments in order to estimate the conversion factors according to required level of accuracy.

Material and Methods

Since March 1999 4 German inter-calibration experiments has been carried out. During the trawl survey in March 1999 technical tests were realized with the gear TV3 930, the large version of the new standard gears, for investigating its handling and the suitability on board of R/V "Solea". The tests showed that the handling of this large gear is difficult and problems exist with the velocity of the vessel during the haul. However it was agreed that the comparisons between both new standard gears should be completed on board of R/V "Solea" in 2000 as originally planned, despite the handling difficulties. These experiments showed furthermore, that R/V "Solea" will operate with the small TV3 520 as standard survey gear in the future.

After the German trawl survey in November 1999 inter-calibration experiments were carried out between the gears HG 20/25 and TV3 520 on board of R/V "Solea" in the Arkona Sea, ICES Subdivision 24. On each station a haul with the HG 20/25 as well as, with the TV3 520 were conducted with altering sequence of the gears according to the recommendations of the Workshop on Baltic Trawl Experiment (WKBTE) in Rostock January 1999 (ICES 1999a) and of the Report of the Baltic International Fish Survey Working Group in Tallinn August 1999 (ICES 1999b) (station 1: TV3 — HG, station 2: HG — TV3, station 3: TV3 — HG, ...).
Eleven stations with paired hauls were realized in the Arkona Basin. The depth varied between 45 m and 48 m. The duration of the tows varied between 29 and 31 minutes. The velocities of the hauls were different. The hauls with the gear HG 20/25 were carried out with the same velocity as it was commonly used during the previous German surveys. The values varied between 3.0 kn. and 3.8 kn. R/V "Solea" used between 2.6 kn. and 3.4 kn. during the tows with the TV3 520 as recommended in the BITS Manual (ICES 2000). Table 1 summarizes information, which describe the experiments, as number of measured individuals, length ranges and further parameters. This table also includes the same information for the following German inter-calibration experiments. Figure 1 presents the positions of all stations realised during all inter-calibration experiments. The different experiments are marked with different chars. The measurements of the total length of cod and of flounder were performed in 1 cm length intervals.
Additional to the hauls a CTD memory probe was used after the last 6 stations. The parameters temperature and salinity were recorded in 1 m depth intervals. Figure 2 presents the TS profiles of the different stations. The data show that the experiments were carried out in water layers with relative homogenous conditions concerning the depth and the hydrographic parameters. Each catch was sorted according the species and was measured.

During the German trawl survey in March 2000 comparisons between both TV3 versions were conducted. These experiments were carried out in ICES Sub-division 22 caused by bad weather conditions. Despite the problems during the changes of the otter boards ten paired hauls were realized in water depth between 21 m and 26 m. The haul duration (net on bottom) varied between 29 and 3 1 minutes, the velocity varied between 2.8 kn. and 3.2 kn. Table 1 presents additional information. As required for the inter-calibration the sequence of the gears altered from station to station during the experiment. Since the weather was too bad hydrographical data were not sampled. However because the depth varied only in a small range it can be assumed that the temperature and the salinity was relative constant on all stations.

The inter-calibration between the HG 20/25 and the TV3 520 were continued during the trawl survey in March 2000. Since extra times were not available for special experiments a changed design was used. If the catch of cod and flounder with the German standard gear HG 20/25 was high an additional tow was realised with the TV3 520 on the same station. Using this strategy 7 stations with comparing hauls were executed.
The advantage of this handling was that only a small additional time was necessary and catches with high numbers of cod and flounder were available. As disadvantage it must be pointed out that only the order of the HG 20/25 following by the TV3 520 was realized.
The positions of the 7 stations are shown in Figure 1, too. The depth of the hauls varied between 39 m and 59 m. The duration of the hauls was always 30 minutes. Further information are presented in Table 1. After each station a TS profile was sampled using a CTD-memory probe.

The duration as well as, the velocity of the tows compared varied considerably with partly more than 20%. As consequence the length of the covered area varied significantly, too. In order to reduce the influence of these high differences, which is the source of a higher variability of the conversion factor, the catches were standardized concerning the haul duration of 30 minutes and the velocity of 3.0 kn.

Background of the paired sample strategy used is the assumption that the following equations can be used.

$$\varphi_v(2,k,t) = C(t) * \varphi_v(1,k,t) * \varepsilon_1(k,t) \qquad (1)$$

with

J	index of the sequence of the gears
k	index of the paired station
t	index of the total length
$\varphi_v(j,k,t)$	fish density in number per m^3 during the station, k of gear sequence, j
$C(t)$	$0 < C(t)$, the influence of the first gear regarding the fish density during the second haul.
$\varepsilon_1(k)$	a log-normal distributed stochastic variable with the mean of 1 and the variance of σ^2

The model assumes, that the second haul of a paired station observes the same length distribution as the first gear. Furthermore, it is assumed that the haul of the first gear can produce a significant change of the fish density for the following gear. If the possible influence of the sequence of the gears is not corrected it follows that the variability of the ratio between the CPUE-values of both gears increases. Furthermore the ratio between the CPUE-values is influenced by the number of stations with different sequence of the gears determined by the influence of C(t). The use of C(t) also allows for working with unbalanced numbers of experiments with different sequences.

The catches of the first gear can be described by

$$F_v(i,1,k,t) = \varphi_v(1,k,t) * G(1,t) * S(1,t) * \varepsilon_2(k,t) \quad (2)$$

with

i	index of the gear
t	index of the total length
G(j,t)	the catchability of the net opening – the portion of the individuals in the sphere of the net geometry (net opening, the doors, the warps, the wires, . ..) which was caught
	the selection characteristic of the gear, also including the influence of the all parts of the gear for length, t and gear, i
$F_v(i,j,k,t)$	the standardized CPUE-values in number
$\varepsilon_2(k,t)$	a log-normal distributed stochastic variable with the mean of 1 and the variance of σ^2
FA(i1,i2,t)	conversion factor of the standardized CPUE-values F_v(l,il,k,t) / $F_v(2,i2,k,t)$ depending on the sequence of the gears
	conversion factor of the standardized CPUE-values independing of the sequence of the gears after the correction with C(t)

Both factors used G(j,t) and S(j,t) can be summarized for these analyses because they are not estimated separately. However, since the mesh sizes are different in the first parts of the gears compared this separation into two factors was done to emphasize the possible influence of the first parts of the gears for the comparison. The different selection characteristic can be the reason for a non linear influence of the total length regarding the conversion factor.

The catch of the second gear of a paired station can be described by

$$F_v(i,2,k,t) = \varphi_v(2,k,t) * G(2,t) * S(2,t) * \varepsilon_2(k,t) \quad (3)$$

$$= \varphi_v(1,k,t) * C(t) * G(2,t) * S(2,t) * \varepsilon_2(k,t) \quad (3a)$$

The mean conversion factor of the standardized CPUE-values depending on the sequence of the gears can be described by

$$FA(1,2,t) = \frac{E[\varphi_v(1,k,t) * G(TV,t) * D(TV,t) * \varepsilon_2(k,t)]}{E[\varphi_v(2,k,t) * G(HG,t) * D(HG,t) * \varepsilon_2(k,t)]} \quad (4)$$

$$= \frac{E[\varphi_v(1,k,t) * G(TV,t) * D(TV,t) * \varepsilon_2(k,t)]}{E[\varphi_v(1,k,t) * C(t) * \varepsilon_1(k,t) * G(HG,t) * D(HG,t) * \varepsilon_2(k,t)]} \quad (4a)$$

$$= \frac{E[G(TV,t)] * E[D(TV,t)] * E[\varepsilon_2(k,t)]}{E[C(t)] * E[\varepsilon_1(k,t)] * E[G(HG,t)] * E[D(HG,t)] * E[\varepsilon_2(k,t)]} \quad (4b)$$

For the alternate sequence follows

$$FA(2,1,t) = \frac{E[G(TV,t)] * E[C(t)] * E[\varepsilon_1(k,t)] * E[D(TV,t)] * E[\varepsilon_2(k,t)]}{E[G(HG,t)] * E[D(HG,t)] * E[\varepsilon_2(k,t)]} \quad (5)$$

The factors FA(1,2,t) and FA(2,1 ,t) can be used for estimating C(t) by

$$C^2(t) = FA(2,1,t) / FA(1,2,t) \quad (6)$$

Different model can be used to compare the results of gears compared. As one way a single conversion factor independent of the length and other parameters can be estimated. On the other hand a multiple regression model can be used in order to include factors which influence the differences of the CPUE-values. However, if the influence of a significant parameter, for example the total length, can not be described with sufficient accuracy by a regression model conversion factors for small length ranges must be estimated.

The gear HG 20/25 and the versions of TV3 gears have besides differences in the net opening and net length also different mesh sizes in the first parts of the gears. The construction of the HG 20/25 is described in Schulz and Grygiel (1987). Comparable information regarding the TV3 gears are given in the Interim report of the EU ISDBITS project (Anon 2000) and the Report of the Working group on Baltic international fish surveys (ICES 2000).
The gear TV3 520 uses a mesh size of 40 mm in the part before the cod-end starts. In contrast to this the mesh size of the gear HG 20/25 changes from 60 mm over 40 mm to 20 mm before the cod-end begins. Figure 3 presents the selection curves of the different mesh sizes within the length range from 10 cm to 42 cm using the method described by (Wileman 1991). Matsushita et al. (1992) suggested that besides the cod-end a selection can also occur in the first parts of the gear. Caused by the differences in the mesh sizes it is possible that the conversion factors are dependent on the total length of the fishes. This assumption is supported by the analyses of Warren (1997), who compared the catchability of two combination vessel/gear. He found a significant influence of the total length concerning the ratio of the catches of both vessels for several species.

The description of the possible influence of the total length is important because the length structure of the current cod stocks, which is used for the inter-calibration, is different in comparison to the years between 1978 and 1990. During the inter-calibration the length range from 10 cm to 50 cm was dominant. Between 1978 and 1990 higher catches of cod were observed with a total length of more than 50 cm. In order to convert these data in units of the gear TV3 520 exactly the possible influence of the total length concerning the conversion factor must be taken into account.

For the interpretation of the conversion factor the high differences are important between the stock size of the period between 1978 and 1990 and the current abundance, which is very low. This different stock sizes produce high differences in the CPUE-values of both time periods. Therefore, it is necessary in order to analyse the possible influence of the fish density regarding the conversion factor, too.

During the analyses only those standardized CPUE-values were used where the catch of both tow compared was larger than 3. This way was chosen for reducing the influence of stochastic errors. Furthermore, the CPUE-values of those length intervals were not used in the analyses

where this data were defined as outlier. A data set is defined as outlier where the ratio of this data set is extreme comparing the most other data, if this data set produces unusual studentized residuals during the regression analyses and if a neighboring length interval produces unusual studentized residuals, too. The patchiness of the fish density can be one reason for large unusual differences in the paired CPUE-Values. It can be expected that the probability of outliers is higher for the smaller cods.
The method described by Warren (1997) could not be used because the data base was to small for the different species and length intervals analysed.

Since the new gear TV3 930 is used as standard value for the planned international demersal trawl survey the comparison between the different gears are given by

TV3 520 as function of HG 20/25
and
TV3 930 as function of TV3 520.

The statistical analyses of the different problems were realised with the software Statgraphics (1996).

Results

Data analyses are separated for the species cod and flounder as well as for both inter-calibration experiments between the gears TV3 530 and HG 20/25 and the gears TV3 930 and TV3 520. Since the most available data sets exist for the comparison between TV3 520 and HG 20/25 for the species cod up to now, these data were analyses at first and were used for evaluating the described model as well as, for determining the main factors which influence the conversion factor. The analyses were carried out using the standardized CPUE-values.

Comparison between TV3 520 and HG 20/25 for Cod

Eleven stations were carried out with the sequence HG 20/25 followed by TV3 520. The total length of the cod varied between 5 cm and 79 cm in November 1999 and between 9 cm and 99 cm in March 2000. Since the number of individuals caught were low in many length intervals only the length range from 10 cm to 42 cm could be included in the statistical analyses based on the current stock situation (ICES 2000b). The numbers of cod per standard tow were always lower than 600 individuals.

Statistical analyses showed that data sets exist which can be defined as outlier. In these cases the catches of both gears were very different and the ratio between the standardized CPUE-values was larger than 2.5 or lower than 0.4. In most cases more than one data set came from one station. The total length of these outliers varied between 10 cm and 34 cm. All these data sets were also detected as unusual residuals in the regression CPUE(TV) = f(CPUE(HG)). If these eight data sets are excluded during the regression analysis the following results are available. Figure 4 presents the xy-plott of the data sets and the regression line. Table 2 summarizes the parameter of the regression model.

Comparative analyses showed that the linear model is a suitable description of the relationship between both parameters.

Only few data pairs exist with CPUE-values of more than 200 individuals. The significant influence of these data sets regarding the parameter of the regression models was proved by leverage values of more than 3 times of an average data point. Since the influence of these few data points is so high the analysis was repeated for all data with less the 200 individuals. The analysis shows that the decrease of the data range does not influences the regression parameters significantly. As preliminary result can be concluded from this result that the density of the cod does not influence the relation between the catches of both gears compared. Using the multiple linear regression model

$$VPUE(TV) = a + br * CPUE(HG) + b_2 * Length$$

it was analysed where the total length of cod influences the ratio between the CPU&values of the gears. Figure 5 and Table 3 illustrate together that for the selected data the influence of the total length is not significant. Figure F42.6 also shows that the variability of the residuals of the regression is essential higher within the length rage from 10 cm to 28 cm than for the larger individuals.

Only six stations were realised with the sequence of the gears TV3 520 followed by HG 20/25. The numbers of cod per standard tow were always lower than 200 individuals.
Regression analyses between the stanardized CPUE-values showed that the influence of outliers can be neglected. Only 3 of the total number of 83 data sets are marked as unusual residuals. Since the ratios was not to extreme these values were included in the statistical analyses.
Figure 6 presents the xy-plott of the data in combination with the regression line. Table 4 summarizes the parameter of the model.

The multiple linear regression, as shown in Table 5, demonstrates that the total length influences the ratio between the CPU&values essentially. This result does not correspond with the same analyses of the data from the sequence HG 20/25 followed by TV 3 520.
Figure 7 shows furthermore, that the variability of the paired tows is depending on the total length. The variability of the residuals is relative small for cod with total length of more than 28 cm in contrast to the smaller cods. This different structure of the residuals depending on the different length ranges can not be explained yet. Figure 7 and also Figure 8 suggest that the influence of the total length is not linear. Since the influence of the total length can not be described by a multiple regression model with the required level of accuracy it is necessary to estimate conversion factors for small length ranges.

Multiple regression analyses showed furthermore, that the sequence of the gears influences the conversion factor significantly. Based on this result the factor C(t) of equation (6) was estimated for 2 cm length intervals. Figure 8 illustrates the variability of C(t).
There are some special results. Within the length range from 30 cm to 40 cm the C(t) values are larger than 1. This result suggests that the second gear has a higher catch than the first gear in mean. The reasons for this result are unclear yet. Within the length range from 10 cm to 28 cm the C(t) values are lower than 1.
The distance between the C(t) values and 1 is in the most cases relative low, and the confidence intervals for C(t) includes always 1. This result suggests that the influence of the sequence of the gears is not significant but, the multiple regression model proves the opposite result.

Using the C(t) values for the correction of the CPU&values of the second gear the corrected conversion factors and their confidence intervals can be assessed independent of the gear sequence.

Since the estimation statistical parameters of the corrected conversion factors is depending on the distribution function of these factors it was analysed whether the corrected conversion factors are normal distributed or the log normal distribution must be used. Using the Chi-Square goodness-of-fit statistic, the Shapiro-Wilks W statistic, the Z score for skewness and the Z score for kurtosis it was proved that the corrected conversion factors of the different length intervals are log normal distributed.

Therefore the model of the log normal distribution (Atchison 1969, Müller 1975, Rasch et al. 1981) was used for estimating the corrected conversion factor, its standard deviation and the asymmetric confidence intervals. The corrected conversion factor and their confidence intervals for the different length intervals age shown in Figure 9. The data are given in Table 6.

The estimation of the necessary number of inter-calibration station is depending on two parameters, the error of first kind a and the required level of accuracy. For our estimates it was chosen

a = 0.05 and

that the half of the confidence interval of the log normal transformed data should be less than 0.2.

The required confidence intervals for the conversion factors are presented in Figure 9 presents beside the current confidence intervals also the confidence limits required. The necessary number of stations using the requirements described are given in **Table 6.**

Comparison between TV3 930 and TV3 520 for Cod

During the analyses of the inter-calibrations experiments between both TV3 gears for cod the same steps of the data analyses were carried out as for the comparison between the gears TV3 520 and HG 20/25.

Figure 10 presents the XY-plott of the paired standardized CPUE-values of cod for 2 cm length intervals. With the mark *those data sets were drawn which were sampled during the sequence of the gears TV3 520 followed by HG 20/25. For the opposite sequence of the gears the mark □ was used. Additional the regression lines were given. Figure R.2.1 shows furthermore, that only low densities of cod could be observed. For this analyses the outliers were excluded. For the sequence TV3 930 followed by the TV3 520 two data sets were defined as outliers. For the opposite sequence 4 data sets were defined as outliers.
The parameter of the linear regressions are given in Table 7 and 9. The slopes of both regression models are comparable. In contrast to this the intercepts are significantly different with a p-value of less than 0.01. This result proves that the influence of the sequence of the gears is significant.
The multiple regression analyses proved that the total length of cod influences the relationship between the CPUE-values of both gears significantly. The parameters of the multiple linear regression models are presented in Table 8 and 10 for both sequences of the gears compared.

Especially the direction of influence of the total length is different depending of the sequence of the gears. Figure 11 presents the residual plot in combination with the component length for both sequences. The figure illustrates the different influence of the total length.
Since the regression models did not describe the relationship between both gears compared well and it could be proved that the sequence of the gears has a significant influence (p-value < 0,03) the factor C(t) which describes the influence of the sequence of the gears and the conversion factors for 2cm length intervals were estimated. Figure 12 presents the factor C(t) and the conversion factors depending on the sequence of the gears. The figure shows that the influence of the sequence of the gears is depending on the total length. This observations suggests that the influence of the total length regarding the conversion factors is non linear as it was observed between the gears TV3 520 and HG 20/25. Therefore, the conversion factors were estimated for 2 cm length intervals. The estimates are presented in Table 11. Additional the number of observations, the means of the corrected conversion factors, their standard deviation and the confidence limits are given. Table 11 shows also the number of necessary data sets for 2 cm length intervals if the same level of accuracy is required as for the comparison between the traditional German gear and the TV3 520. Figure 13 illustrates the comparison factors (Mean), the actual confidence intervals (data) as well as the required confidence interval (goal).

Comparison between TV3 520 and HG 20/25 for flounder

Only few data sets could be used for the analyses because the catches of flounder were very low during the comparisons between the gears TV3 520 and TV3 930. Ten paired standardized CPUE values of two cm length intervals were available for the sequence TV3 520 followed by HG 20/25. Table 12 presents the parameter of the regression analysis.

For the sequence HG 20/25 followed by TV 3 520 41 data sets could used in the analyses. Table 13 presents the parameters of the regression analyses.
The estimated regression lines are very similar. Figure 14 illustrates both regression lines in combination with the data sets. The different sequences are marked by different figures. The figure illustrates the comparable results of both regression analyses.
The results suggest that the sequence of the gears does not influence the conversion factor significantly. Furthermore, it could be proved that the influence of the length is not significantly, too. Therefore, a regression analysis were carried out which includes all data sets independent of the sequence of the gears. Table 14 presents the parameters
The analysis proved that the intercept of the regression line is not significantly different from zero. Therefore, a simple conversion factor was estimated, which include all data sets. The analysis showed that this conversion factor is log normal distributed. Using the theory of the log normal distribution the mean conversion factor is 1 .01 with a standard deviation of 0.61.
If the same level of accuracy is required as in the comparisons described before, a necessary number of 26 standardized CPUE-values is necessary. Since the number of observations is higher it can be followed that additional experiments are not necessary.
In contrast to this conclusion additional experiments should be carried out because the length range observed is relative small and also the density observed are low.

Comparison between TV3 930 and TV3 520 for flounder

The number of suitable data sets are also low. Eighteen data sets exist for the sequence of the gears the large TV3 followed by the smaller TV3. The number of data sets for the sequence the small TV3 followed by the large TV3 is 20. The highest standardized CPUE-value was 30. This value demonstrates that only areas with low flounder densities could be covered during the experiments.
Therefore, the results of the analyses are not representative and additional experiments are necessary.

Figure 15 shows all data sets and the different regression lines for both sequences of the gears.

The figure illustrates that the low number of CPUE-values of more than 12 influence the regression lines significantly. The parameters of the regression lines are given in Table 15 and 16. However, these information are only suitable for illustration the current situation , but, they can not be used for estimating trustworthy conversion factors.

Discussion

Different investigations were carried out for detecting the factors which influence the effectivity of the demersal haul. Walsh (1996) summarizes different parameters which influence the use of demersal trawls for estimation of the stock using demersal trawl surveys. For the analyses of the inter-calibration experiments it is important that the different parameters of the gears were relative constant to reduce the variability of the conversion factors.
The analyses of the inter-calibration experiments showed that the realized number of paired stations is too low to get acceptable conversion factors for the gears compared.
Sissenwine and Bowman (1978) analysed 551 hauls for estimating the relationship between two vessels with different gears. Warren (1997) analysed 230 paired tows for a comparable situation. These analyses support the assessment that the realized number of hauls was too low during the experiments described.
The high variability of the standardized CPUE-values of cod especially requires a higher number of data sets. As a minimum number about 20 data sets can be estimated for preliminary analyses. For a more accurate estimation of the conversion factors more than 35 data sets per a length interval are necessary.
The highest numbers of the observations are necessary for cod of the length range from 10 cm to 28 cm. For larger cods the variability of the CPUE-values was lower. These differences are probably determined by the higher patchiness of the younger cods. However, it must be pointed out that the results are representative only for cods with a total length of less than 44 cm. Depending on the current stock situation only some small catches of larger cods were available.

The analyses showed furthermore, that the sequence of the gears influences the conversion factors significantly. Millar (1991) described an algorithm for correcting the different catches in trouser gears and proposed this method also for paired stations. This method uses the catches of larger individuals which are not influenced by the selectivity of the cod-end for the correction. The results of the paired stations during the German inter-calibration experiments described showed that the influence of the sequence of the gears is different for smaller and

described showed that the influence of the sequence of the gears is different for smaller and larger cods. As it was anticipated the parameter C(t) is lower than 1 for the length range between 10 cm and 28 cm. This result suggests that the first tow reduces the density of cod for the following tow of the paired station significantly.
The values of the parameter C(t) are larger than 1 for the cods with a total length of more than 30 cm. That means that the second tow has higher CPU&values in mean. As hypotheses it can be followed that reaction of the larger cods regarding the gear is not so successful since the visibility is reduced determined by sand clouds of the first tow.
The analyses of the CPUE-values of cod showed furthermore, that the influence of the total length regarding the relationship between the gears compared is not linear. The residuals of the multiple linear regression models proved this statement. Depending on these observations it follows that the described method for estimating the conversion factor for small length intervals is suitable to get results with the required level of accuracy. Warren (1997) used a non linear model for describing the relationship between the conversion factors for length intervals and the total length of the species. The correlation between both components was relative high. However, this result is mainly determined by different selection characteristics of the gears. The catchability of the gears especially for the smaller individuals was very different. In contrast to this Sissenwine and Bowman (1978) did not use the length of the species as a parameter for the multiple non linear model.

For reducing the variability of the conversion factors the proposed way by Warren (1997) of excluding the outliers was used. Since the number of observations was low a different method was carried out. The exclusion of the outliers detected is the reason that the variability of the conversion factors decreased and furthermore the necessary number of experiments, too.

The conversion factors for 2 cm length intervals were observed as a log normal distributed. Comparable results were found be Sissenwine and Bowman (1978) and Warren (1997). Using the logarithmic transformation it is possible to estimate unbiased means, variances and the confidence intervals. Depending on the required level of accuracy the necessary number of observations could be estimated.

The analyses also showed that it is useful to estimate the conversion factors for the different species separately since the influence of the total length of the individuals and the sequence of the gears is different. The results illustrate that the variability of the standardized CPUE-values for cod and flounder was different. Furthermore, different methods were used to compare the results of the gears compared.

All results together showed that the model proposed is suitable for estimating the relationship of the CPUE-values between different gears. Furthermore, it was shown that the inter-calibration experiments realized up to now are too low to get conversion factors with high accuracy.

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Tables

Table Overview of the German inter-calibration experiments in November 1000 and March 2000

Time	15 – 17 November 1999	4 – 6 March 2000	19 – 23 February 2000
Inter-calibration	HG 20/25 – TV3 520	TV3 930 – TV3 520	HG 20/25 – TV3 520
Number of stations	11	10	7
ICES Sub-divisions	24	22	24 / 25
Depth range	45 – 48 meter	21 – 26 meter	39 – 59 meter
Duration of the hauls	30 – 31 minutes	29 – 31 minutes	30 minutes
Velocity	2.6 – 3.8 kn	2.8 – 3.2 kn	3.2 - 3.4 kn
Number of sequence 1	6 x TV3 520 – HG 20/25	5 x TV3 520 – 930	7 x HG 20/25 – TV3 520
Number of sequence 2	5 x HG 20/25 – TV3 520	5 x TV3 930 – 520	7 x HG 20/25 – TV3 520
Cod			
Length range	5 – 79 cm	9 – 96 cm	9 – 99 cm
Total number of individuals measured	13 000	3727	8671
Lowest catch	216	45	235
Highest catch	1712	353	1960
Flounder			
Length range	19 – 47 cm	13 – 47 cm	11 – 40 cm
Total number of individuals measured	1155	1009	1401
Lowest catch	2	13	3
Highest catch	385	123	316

Table 2: Parameter of the linear regression between standardized CPUE-values of the gears TV3 520 and HG 20/25 for the sequence HG 20/25 followed by TV3 520
CPUE(TV3 520) = a + b * CPUE(HG 20/25)

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	3.59	1.71	2.10	0.038
Slope	0.700	0.02	32.48	0.000
Number of observations	164			
R-squared	86.7			
Standard Error of Est.	18.8			

Table 3: Parameter of the multiple linear regression between standardized CPUE-values of the gears TV3 520 and HG 20/25 for the sequence HG 20/25 followed by TV3 520
CPUE(TV3 520) = a + b * CPUE(HG 20/25) + c * Length

Parameter	Estimate	Standard Error	T Statistic	P-Value
Constant	1.11	4.67	0.24	0.81
CPUE(HG 20/25)	0.70	0.022	31.86	0.00
Length	0.094	0.16	0.57	0.57
Number of observations	164			
R-squared	86.72			
Standard Error of Est.	18.86			

Table 4: Parameter of the linear regression between standardized CPUE-values of the gears TV3 520 and HG 20/25 for the sequence TV3 520 followed by HG 20/25
CPUE(TV3 520) = a + b * CPUE(HG 20/25)

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	11.14	1.64	6.78	0.00
Slope	0.45	0.033	13.75	0.00
Number of observations	84			
R-squared	69.74			
Standard Error of Est.	11.25			

Table 5: Parameter of the multiple linear regression between standardized CPUE-values of the gears TV3 520 and HG 20/25 for the sequence TV3 520 followed by HG 20/25
CPUE(TV3 520) = a + b * CPUE(HG 20/25) + c * Length

Parameter	Estimate	Standard Error	T Statistic	P-Value
Constant	26.87	3.62	7.42	0.00
CPUE(HG 20/25)	0.43	0.030	14.37	0.00
Length	-0.57	0.120	-4.75	0.00
Number of observations	84			
R-squared	76.33			
Standard Error of Est.	10.01			

Table 6: Parameters of the corrected conversion factors for length intervals and the required number of data sets N* using the log normal distribution

Length interval	Number of data sets	Mean corrected conversion factor	Standard deviation	Confidence limits		Required number of data sets N*
10	8	0.940	0.755	0.573	2.531	34
12	11	1.271	1.297	0.797	3.226	47
14	14	1.076	0.996	0.736	2.301	45
16	16	1.157	0.770	0.871	2.042	30
18	15	1.215	0.819	0.902	2.203	30
20	15	0.891	0.474	0.694	1.470	22
22	15	0.873	0.407	0.696	1.371	18
24	16	0.902	0.499	0.704	1.483	24
26	17	0.922	0.500	0.728	1.480	26
28	17	1.097	0.670	0.847	1.837	26
30	16	1.060	0.552	0.836	1.704	22
32	15	1.143	0.943	0.814	2.256	40
34	16	1.007	0.684	0.755	1.792	28
36	13	0.993	0.679	0.716	1.910	29
38	12	1.055	0.898	0.710	2.331	38
40	9	0.974	0.499	0.698	1.897	19
42	7	1.326	0.516	0.966	2.498	14
>42	4	1.289	0.981	0.571	6.571	36

Table 7: Parameter of the linear regression between standardized cod CPUE-values of cod for the gears TV3 930 and TV3 520 for the sequence TV3 930 followed by TV3 520
CPUE(TV3 930) = a + b * CPUE(TV3 520)

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	6.13	1.73	3.54	0.00
Slope	0.79	0.14	5.85	0.00
Number of observations	70			
R-squared	33.40			
Standard Error of Est.	8.51			

Table 8: Parameter of the linear regression between standardized cod CPUE-values of the gears TV3 930 and TV3 520 for the sequence TV3 520 followed by TV3 930
CPUE(TV3 930) = a + b * CPUE(TV3 520)

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	3.79	1.13	3.36	0.00
Slope	0.73	0.09	7.81	0.00
Number of observations	71			
R-squared	46.93			
Standard Error of Est.	5.82			

Table 9: Parameter of the multiple linear regression between standardized CPUE-values of the gears TV3 930 and TV3 520 for the sequence TV3 930 followed by TV3 520
CPUE(TV3 930) = a + b * CPUE(TV3 520) + c * Length

Parameter	Estimate	Standard Error	T Statistic	P-Value
Constant	-0.90	3.32	-0.27	0.79
CPUE(TV3 520)	0.82	0.13	6.23	0.00
Length	0.20	0.08	2.44	0.02
Number of observations	70			
R-squared	38.90			
Standard Error of Est.	8.21			

Table 10: Parameter of the multiple linear regression between standardized CPUE-values of cod for the gears TV3 930 and TV3 520 for the sequence TV3 930 followed by TV3 520
CPUE(TV3 930) = a + b * CPUE(TV3 520) + c * Length

Parameter	Estimate	Standard Error	T Statistic	P-Value
Constant	8.29	2.26	3.67	0.00
CPUE(TV3 520)	0.68	0.09	7.24	0.00
Length	-0.13	0.06	-2.28	0.03
Number of observations	71			
R-squared	50.70			
Standard Error of Est.	5.64			

Table 11: Parameters of the corrected conversion factors between TV3 930 and TV3 520 for length intervals of cod and the required number of data sets N* using the log normal distribution

Length interval	Number of data sets	Mean corrected conversion factor	Standard deviation	Confidence limits		Required number of data sets N*
10	2	1.567	2.144	1.280	2.352	65
12	4	1.828	3.848	1.494	2.736	95
14	8	1.246	0.953	1.024	1.844	37
16	8	1.603	1.483	1.311	2.398	44
18	7	1.478	1.231	1.211	2.198	40
20	8	1.397	1.332	1.146	2.076	47
22	6	1.782	2.368	1.461	2.651	66
24	6	1.330	1.117	1.089	1.982	40
26	2	1.378	0.040	1.333	1.473	5
28	5	1.918	1.860	1.570	2.861	47
30	4	0.974	0.392	0.797	1.454	15
32	5	1.976	1.536	1.621	2.937	37
34	6	1.692	2.624	1.388	2.518	76
36	8	1.846	1.460	1.511	2.756	37
38	10	1.336	0.484	1.083	2.032	12
40	9	1.119	0.637	0.915	1.675	24
42	10	1.183	0.781	0.966	1.773	29
44	10	1.882	0.806	1.547	2.787	17
46	9	1.143	0.417	0.944	1.679	14
48	5	1.958	2.306	1.604	2.918	58
50	4	1.711	0.366	1.392	2.588	6
52	3	2.576	2.108	2.105	3.857	38
>52	2	1.230	0.262	1.000	1.858	6

Table 12: Parameter of the linear regression between standardized cod CPUE-values of the gears TV3 520 and HG 20/25 for the sequence TV3 520 followed by HG 20/25
CPUE(TV3 520) = a + b * CPUE(HG 20/25)

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	-0.26	2.77	-0.00	0.93
Slope	0.93	0.06	14.89	0.00
Number of observations	10			
R-squared	96.52			
Standard Error of Est.	5.89			

Table 13: Parameter of the linear regression between standardized cod CPUE-values of the gears TV3 520 and HG 20/25 for the sequence HG 20/25 followed by TV3 520 after the excluding of the outliers
CPUE(TV3 520) = a + b * CPUE(HG 20/25)

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	0.07	2.42	0.03	0.98
Slope	0.91	0.11	8.32	0.00
Number of observations	41			
R-squared	63.97			
Standard Error of Est.	10.23			

Table 14: Parameter of the linear regression between standardized cod CPUE-values of the gears TV3 520 and HG 20/25 for the sequence HG 20/25 followed by TV3 520 after the excluding of the outliers
CPUE(TV3 520) = a + b * CPUE(HG 20/25)

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	-0.10	1.87	-0.06	0.96
Slope	0.92	0.07	13.72	0.00
Number of observations	51			
R-squared	79.35			
Standard Error of Est.	9.43			

Table 15: Parameter of the linear regression between standardized cod CPUE-values of the gears TV3 930 and TV3 520 for the sequence TV3 930 followed by TV3 520
CPUE(TV3 930) = a + b * CPUE(TV3 520)

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	4.45	3.50	1.27	0.22
Slope	1.20	0.40	3.00	0.01
Number of observations	18			
R-squared	35.96			
Standard Error of Est.	6.6			

Table 16: Parameter of the linear regression between standardized cod CPUE-values of the gears TV3 930 and TV3 520 for the sequence TV3 520 followed by TV3 930
CPUE(TV3 930) = a + b * CPUE(TV3 520)

Parameter	Estimate	Standard Error	T Statistic	P-Value
Intercept	9.04	2.50	3.61	0.00
Slope	-0.00	0.37	-0.02	0.98
Number of observations	20			
R-squared	-0.00			
Standard Error of Est.	4.33			

Figures

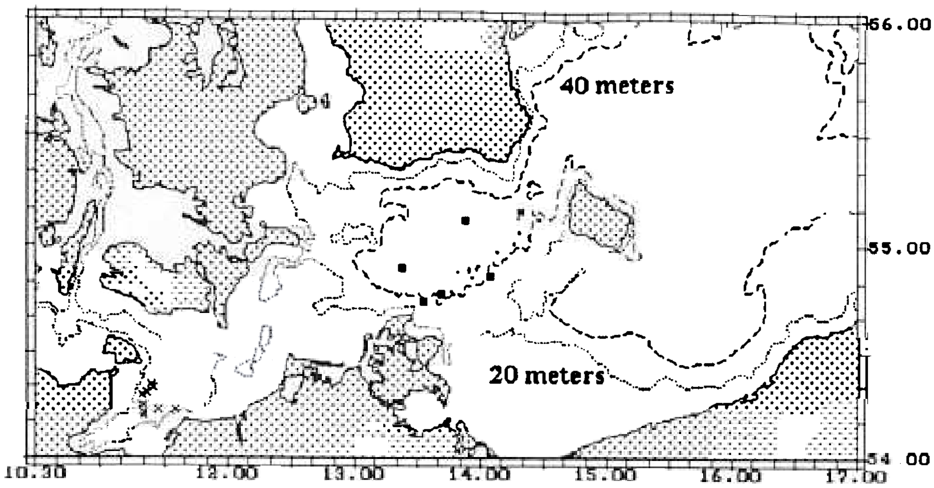

Figure 1: Stations of the inter-calibration experiments in the Baltic Sea between the gears HG 20/25 and TV3 520 in November 1999 (.), between the gears TV3 520 and TV3 930 in March 2000 (x) and between the gears HG 20/25 and TV3 520 in March 2000 (▪)

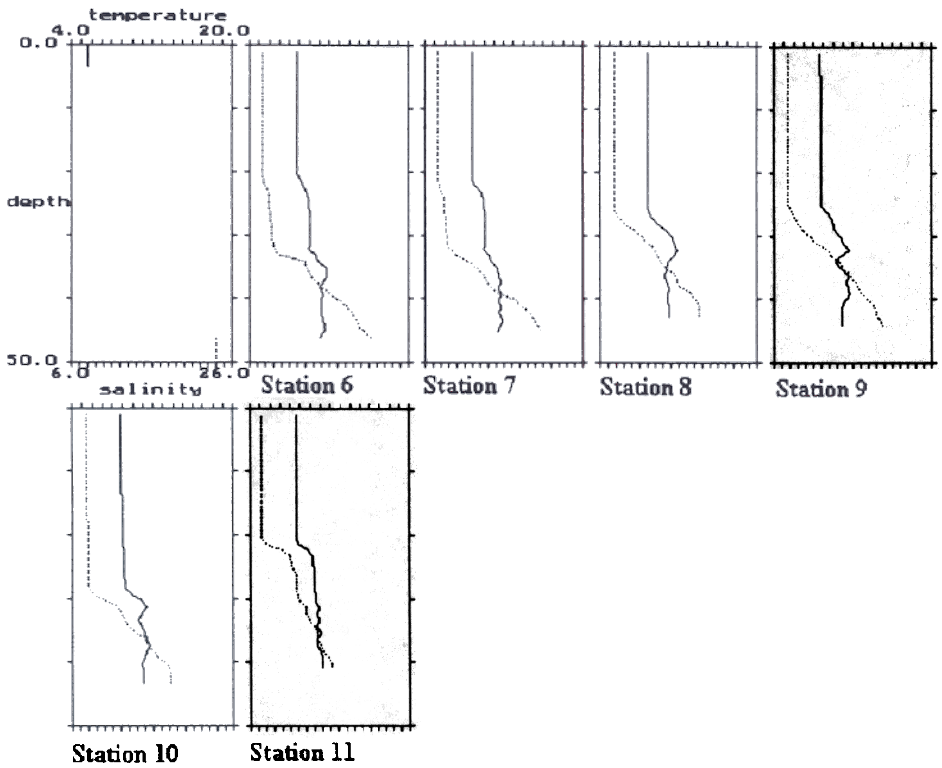

Figure 2: TS profiles from the inter-calibration experiments in November 1999

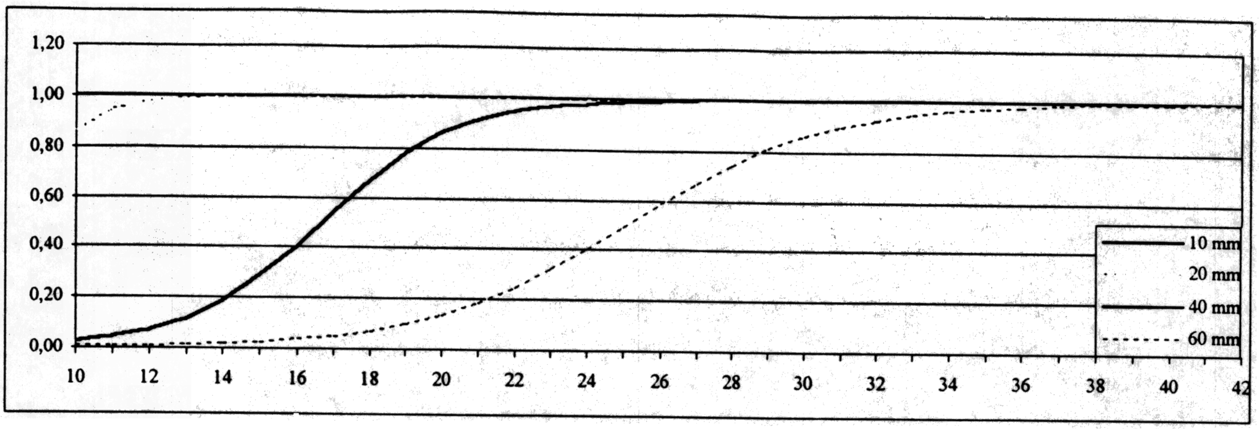

Figure 3 Selection curves of the mesh sizes in the different parts of the gears HG 20/25 (10mm, 20 mm, 40 mm and 60mm) and of the gear TV3 520 (10 mm, 40 mm)

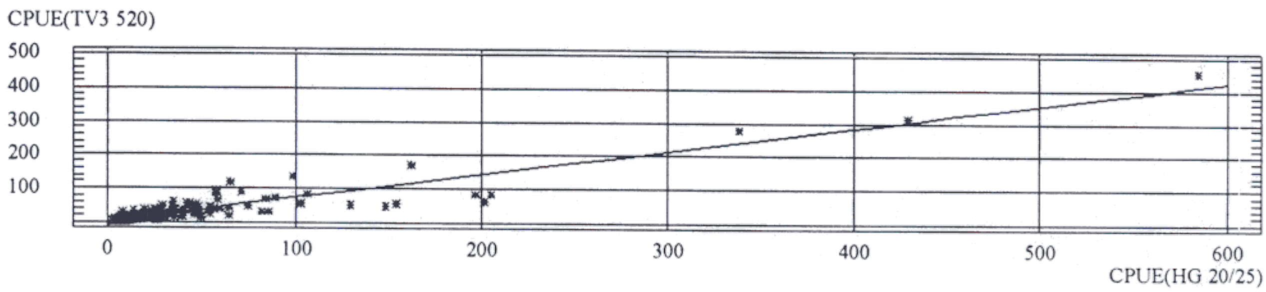

Figure 4: XY plott and regression line of the relation between the standardized catches of TV3 520 and HG 20/25 after the excluding of the outlier

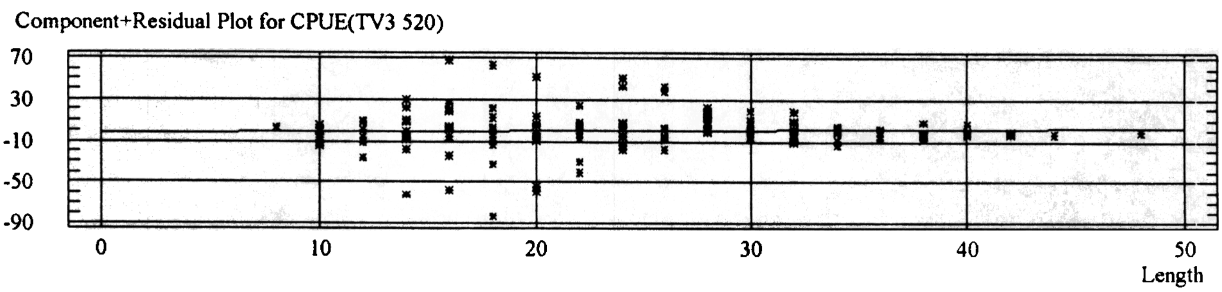

Figure 5: Distribution of the residuals of the multiple linear regression model and the influence of the length component for the sequence of the gears HG 20/25 followed by TV3 520

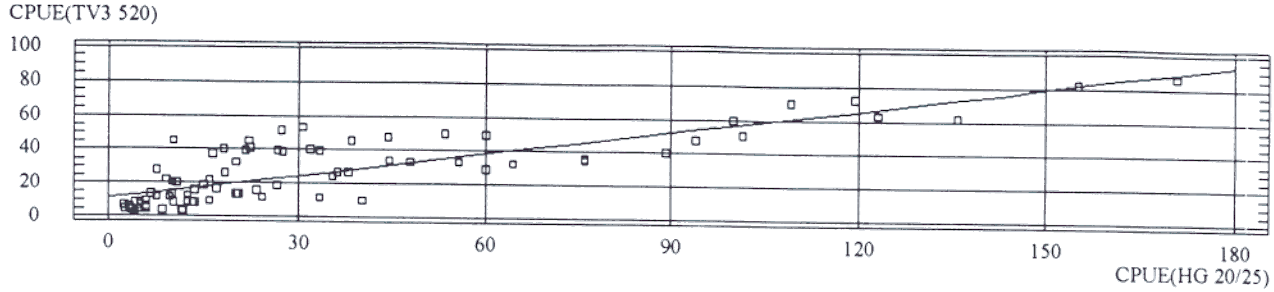

Figure 6: XY plott and regression line of the relation between the standardized catches of TV3 520 and HG 20/25

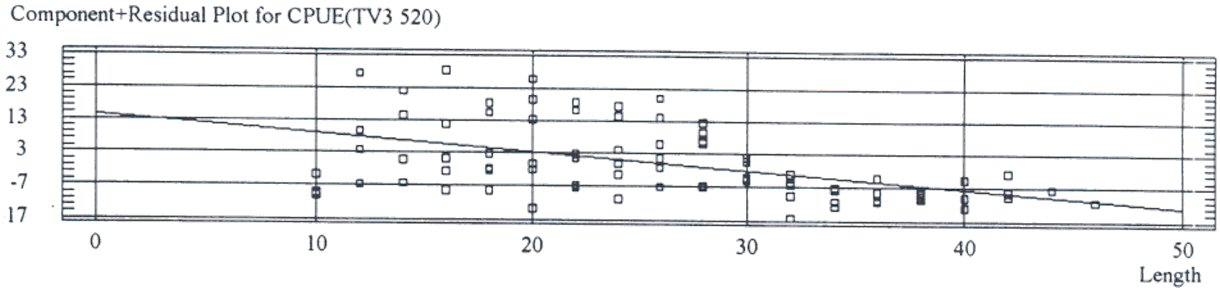

Figure 7: Distribution of the residuals of the multiple linear regression model and the influence of the length component for the sequence of the gears TV3 520 followed by HG 20/25

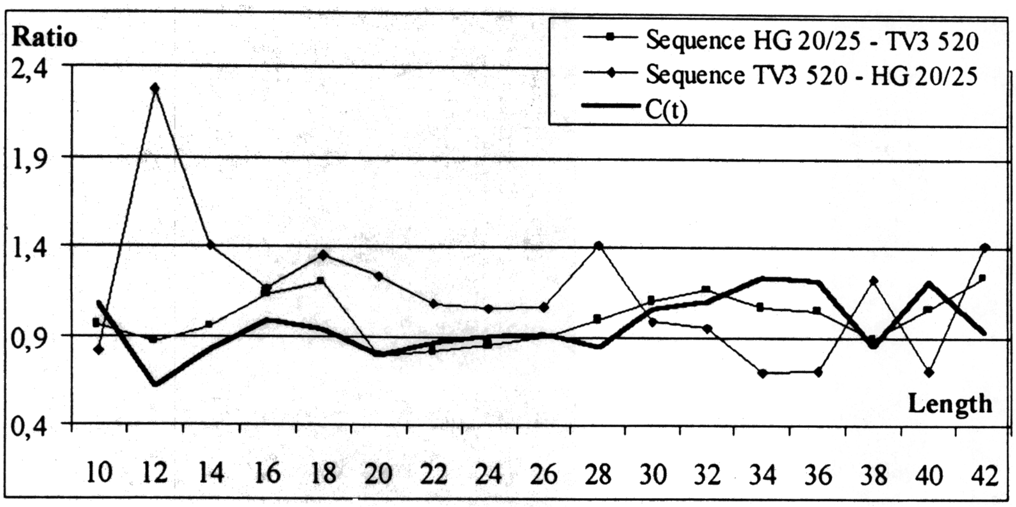

Figure 8: Ratios between TV3 520 and HG 20/25 depending on the sequence of the gears and the variable C(t)

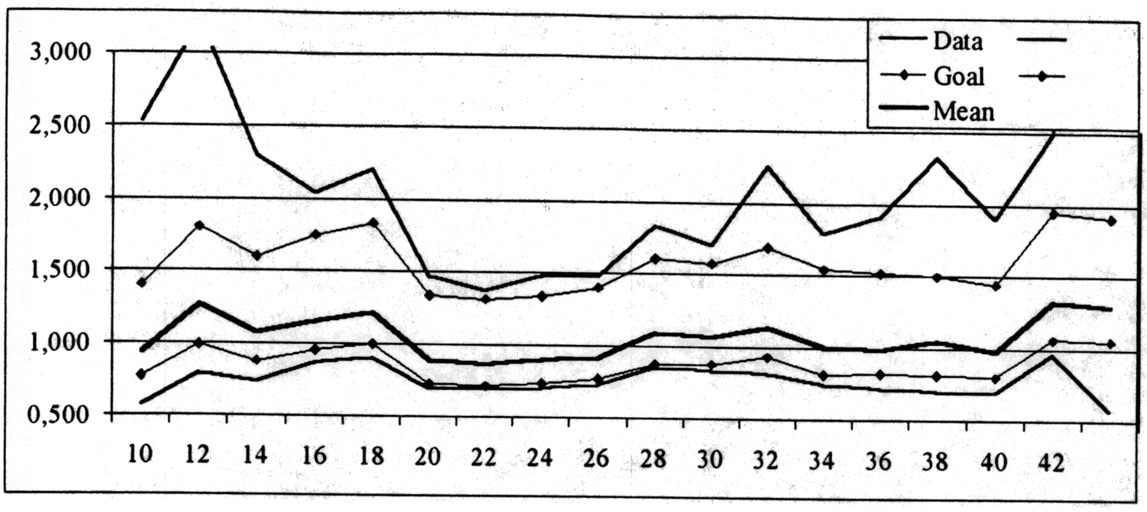

Figure 9: Mean corrected conversion factor (—) with the current (—) and required (-◆-) confidence intervals

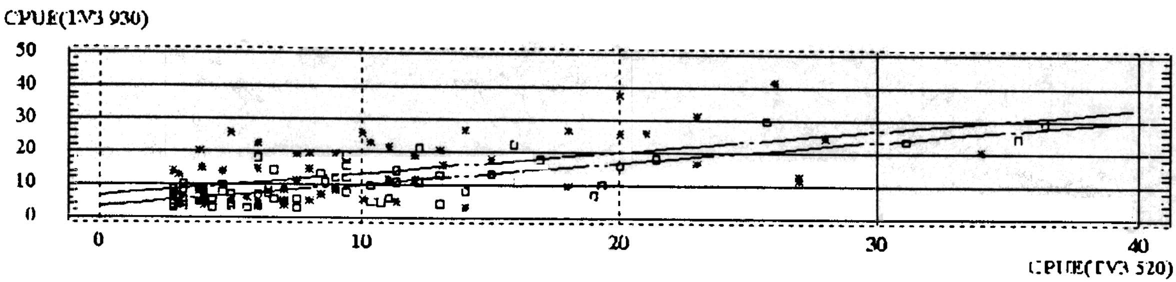

Figure 10: Comparison of the regression lines and the data sets for the standardized CPUE values of cod for the gears TV3 930 (*) and TV3 520 (□) for both sequences

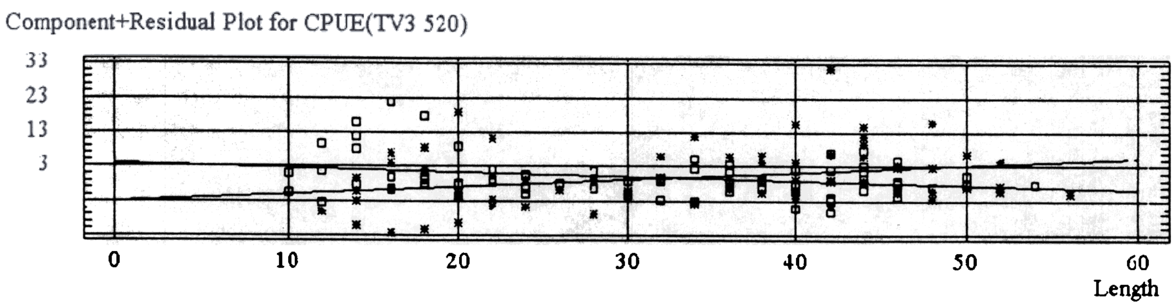

Figure Comparison of the residuals and the length components for the multiple linear regression between TV3 930 and TV3 520 for both sequences of the gears
(*) TV3 930 followed by TV3 520
(□) TV3 520 followed by TV3 930

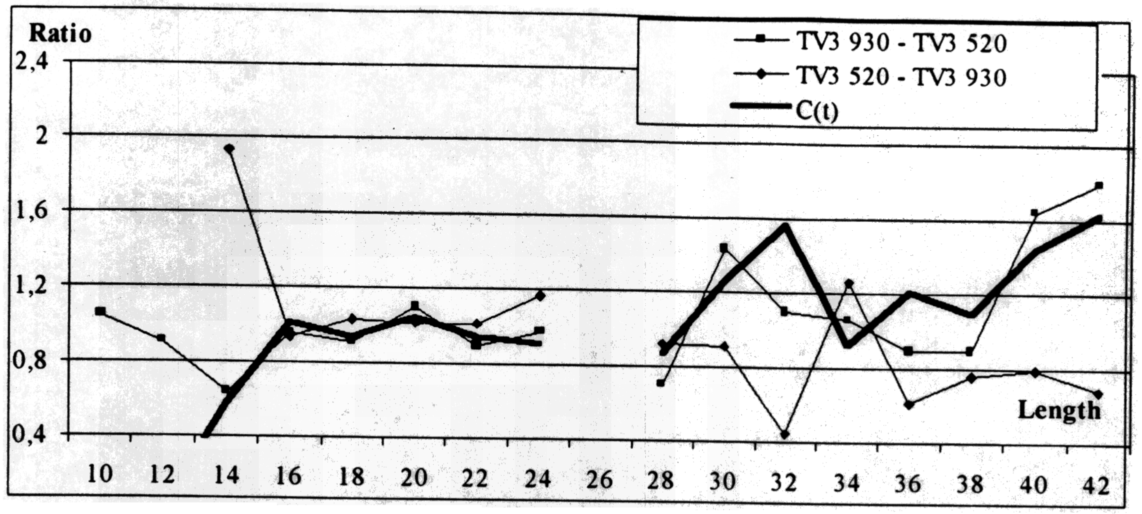

Figure 12: Ratios between TV3 930 and TV3 520 depending on the sequence of the gears and the variable C(t)

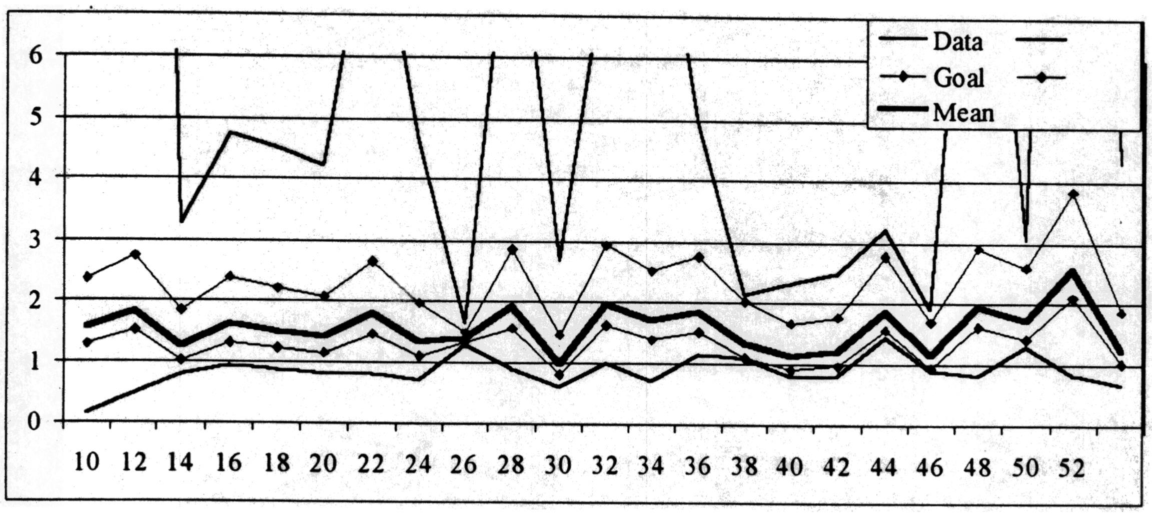

Figure 13: Mean corrected conversion factor (—) with the current (—) and required (-◆-) confidence intervals

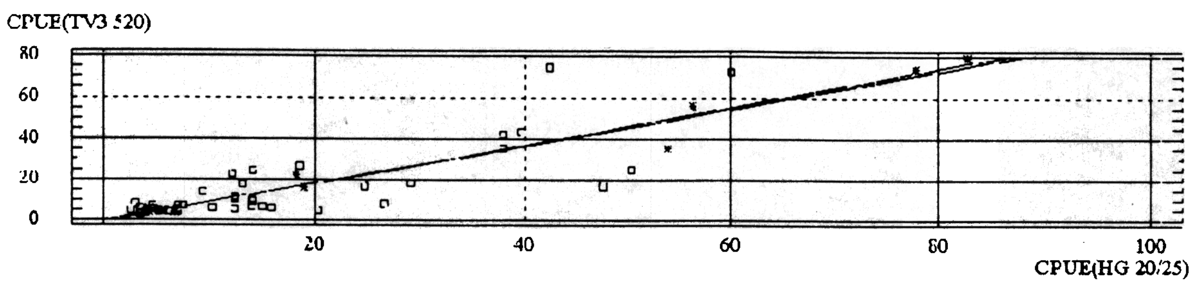

Figure 14: Comparison of the regression lines and the data sets for the standardized CPUE values of TV3 930 and TV3 520 for both sequences (* TV3 520 followed by HG 20/25,

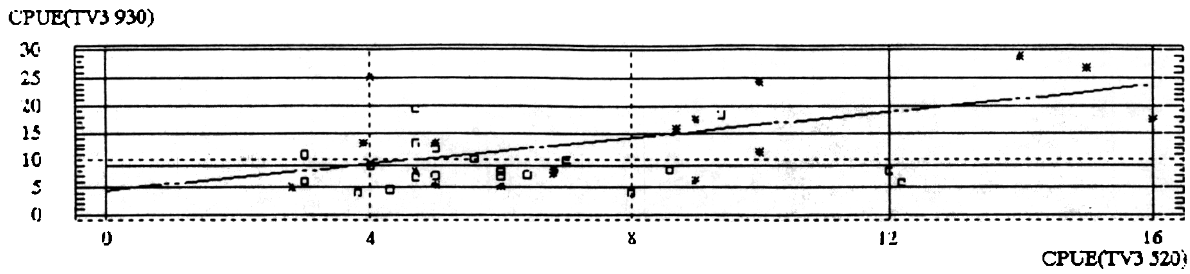

Figure 15 Comparison of the regression lines and the data sets for the standardized CPUE values of TV3 930 and TV3 520 for both sequences (* TV3 930 followed by TV3 520, □ for the opposite sequence of the gears)