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# Preliminary Results from Shrimp Trawl Calibration Experiments off West Greenland (2004, 2005) with notes on Encountered Experiment Design/Analyses Problems

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## Abstract

In 2005 the old survey "Skjervoy 3000" trawl used since 1988 in the yearly northern shrimp survey in West Greenland waters was substituted with a new one ("Cosmos 2000"). This paper gives preliminary results from trawl calibration experiments performed with the aim of determining size-class specific conversion factors for northern shrimp in order to ascertain continuity in the time series. We carried out trawl calibration experiments during the 2004 and 2005 field seasons following an experimental design proposed by Lewy *et al*., 2004. Conversion factors for 0.5 mm length classes at the 95% level of confidence are given graphically and in Appendix 1. However obtained conversion factors should be viewed as conversion factors for hauls, not density conversion factors. The reason for that distinction is that the different trawls have different wingspreads and therefore differ in the swept area for the same trawled distance. The results of the performed preliminary analyses also indicate problems in the design/analyses of the trawl calibration experiment. This will prompt further evaluation of the results since the continuity of the survey data time series depends on methodological consistency. Meanwhile we feel forced to use the estimated conversion factors however with the above mentioned reservations.

## Introduction

The fishery for the Northern shrimp *Pandalus borealis* constitutes a major source of income for the Greenland community and therefore the size, age structure and distribution of the shrimp stock is monitored regularly for assessment purposes. Monitoring are based both on information from the commercial fishery (log book data) (e.g Kingsley and Hvingel, 2005) and from an annual fishery-independent stratified trawl survey covering the waters off West Greenland. This survey, which has been carried out since 1988, covers West Greenland waters from 60°-73°N within NAFO Subarea 1 and a small part of Div. 0A in Canadian waters (e.g. Wieland and Bergstrøm, 2005). Since the beginning of the survey series a "Skjervoy 3000" trawl with bobbins on the ground rope has been used, but in 2005 a new trawl a "Cosmos 2000" with "rock-hopper" ground rope was taken into use in order to allow trawling on rougher bottom and with the hope to give a more representative catch composition. The decision to change trawls was founded in part on the observation that the commercial fishery was venturing into areas were it was impossible to use the old survey trawl but also on reported good experiences from the use of rock hopper gear in commercial operations.

Against this brief background, calibration experiments with the old and the new trawl were performed during the 2004 and 2005 field seasons. The objective of these experiments was to determine conversion factors, over relevant size intervals, between catches of shrimp and fish taken with the old and the new trawl. These conversion factors will be applied to the time series of survey results that has been collected by the Greenland Institute for Natural Resources since 1988 in order to ascertain methodological continuity in the time series (Wieland, 2005). In Wieland's 2005 study results concerning *Pandalus borealis* acquired by the old trawl are recalculated in order to harmonize with results obtained with the new trawl.

According to Pelletier (1998) trawl calibration studies can be classified in two different groups each building on different philosophies and assumptions. One approach is the "paired hauls method" where stations close in time and space are assumed to have similar densities of the target species. A second group comprises area-based methods that build on the assumption that density and size structure of the target species are homogenous within a chosen stratum.

Our study represents a special case of the paired haul approach where successive hauls are made on the same track line within a very short period of time. The experimental design largely follows principles reported by Lewy *et al*., 2004. These authors reported results from calibration experiments performed in the Baltic Sea during the period 1999-2002 targeted towards cod and cod surveying with two different types of trawls.

In this paper we describe trawl calibration experiments carried out in 2004 and 2005 and provide conversion factors between the old and the new trawl for Northern Shrimp, *P. borealis*. We also briefly discuss some concerns regarding the design of the experiment and/or the analyses of the data. This is the first instance the method developed by Lewy *et al*., 2004 has been applied on shrimp.

## Material and Methods

*Experimental design*

The experimental design of the present study essentially follows the protocol reported by Lewy *et al*. in 2004. As in that study, we used four different types of paired haul combinations:

0. old-old (contributes to the estimation of the depletion factor of the Sk30)
1. old-new and
2. new-old ( both combinations contribute to the estimation of the conversion factor between Sk30 and Co20)
3. new-new (contributes to the estimation of the depletion factor of the Co20)

In total 68 pairs of hauls were performed (40 in 2004 and 28 in 2005) (Table 1) at depths of between 166 and 597 meters within NAFO Subarea 1C and 1B.

Table 1. Number of paired hauls of different types performed during trawl calibration experiments in 2004 and 2005

| Type of pair | 0 | 1 | 2 | 3 | All types |
|---|---|---|---|---|---|
| 2004 | 8 | 13 | 14 | 5 | 40 |
| 2005 | 9 | 6 | 6 | 7 | 28 |
| Total both years | 17 | 19 | 20 | 12 | 68 |

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*Treatment of the catch*

From each catch a sample of between 2 and 4 kg of shrimp was taken and sorted to species. Oblique carapace length (CL) of *P. borealis* was measured to the nearest 0.1 mm with the aid of slide callipers (e.g. Bergstrøm, 2000). Based on these measurements we calculated length frequency distributions for all experimental hauls and used these for the further analysis.

*Analytical Methods*

In each type of paired haul the probability that a sampled individual is found in the sub-sample of the first haul, on the condition that it is sampled, in any of the two hauls, is given by:

| | First Haul | Second Haul |
|---|---|---|
| Type 0 | $E(U_0^1) = q_{old} D$ | $E(U_0^2) = q_{old} \alpha D$ |
| Type 1 | $E(U_1^1) = q_{old} D$ | $E(U_1^2) = q_{new} \alpha D$ |

| | | |
|---|---|---|
| Type 2 | $E(U_2^1) = q_{new} D$ | $E(U_2^2) = q_{old} \beta D$ |
| Type 3 | $E(U_3^1) = q_{new} D$ | $E(U_3^2) = q_{new} \beta D$ |

where $U$ denotes the CPUE estimated at the location where the double haul took place. The symbol α denotes the depletion factor of the old trawl (in this study the SK30), $\beta$ denotes the depletion factor of the new trawl (Co 20 in this study). If we change the object of interest from the total catch U to the sub-sample $S$ and assume that each catch has a known sampling fraction $sf$ ($sf$, is in pragmatic terms the ratio between the weight of the sub-sample and total catch) we end up with the following expressions.

| | First Haul | Second Haul |
|---|---|---|
| Type 0 | $E(S_0^1) = q_{old} \cdot D \cdot sf_1$ | $E(S_0^2) = q_{old} \cdot \alpha \cdot D \cdot sf_2$ |
| Type 1 | $E(S_1^1) = q_{old} \cdot D \cdot sf_1$ | $E(S_1^2) = q_{new} \cdot \alpha \cdot D \cdot sf_2$ |
| Type 2 | $E(S_2^1) = q_{new} \cdot D \cdot sf_1$ | $E(S_2^2) = q_{old} \cdot \beta \cdot D \cdot sf_2$ |
| Type 3 | $E(S_3^1) = q_{new} \cdot D \cdot sf_1$ | $E(S_3^2) = q_{new} \cdot \beta \cdot D \cdot sf_2$ |

Now we can find $S^1 \mid S$ (the conditional probability that a sampled individual came from haul 1 given that it was sampled) for each experiment type

$$S_0^1 \mid S_0 = \frac{q_{old} \cdot D \cdot sf_1}{q_{old} \cdot \alpha \cdot D \cdot sf_2 + q_{old} D \cdot sf_1} = \frac{sf_1}{sf_1 + sf_2 \cdot \alpha}$$

$$S_1^1 \mid S_1 = \frac{q_{old} \cdot D \cdot sf_1}{q_{old} \cdot D \cdot sf_1 + q_{new} \cdot \alpha \cdot D \cdot sf_2} = \frac{sf_1}{sf_1 + sf_2 \cdot \alpha \cdot \gamma}$$

$$S_2^1 \mid S_2 = \frac{q_{new} \cdot D \cdot sf_1}{q_{new} \cdot D \cdot sf_1 + q_{old} \cdot \beta \cdot D \cdot sf_2} = \frac{sf_1}{sf_1 + sf_2 \cdot \beta / \gamma}$$

$$S_3^1 \mid S_3 = \frac{q_{new} \cdot D \cdot sf_1}{q_{new} \cdot D \cdot sf_1 + q_{new} \cdot \beta \cdot D \cdot sf_2} = \frac{sf_1}{sf_1 + sf_2 \cdot \beta}$$

where $\gamma$, the conversion factor from old to new trawl, is given by:

$$\gamma = q_{new} / q_{old}$$

Then the conditional distribution of $S_0^1 \mid S$ has a binomial distribution. Since the effort is the same for each haul in a pair an alternative interpretation is the conditional probability of a given individual being measured in the first sample, given that it is measured in either of the catches. This is equivalent to the Millar and Walsh method for paired trawl selection studies (Millar and Walsh, 1992).

In order to smooth the data, a running mean over +/- 5 length bins, each length bin 0.5 mm was applied to the number of individuals in each size category in each haul. The parameters $\alpha$, $\beta$, $\gamma$ were then found by maximizing the sum of likely-hoods over all paired hauls. Instead of a parametric variance we used a bootstrap method (Manly, 1997) in which paired hauls with replacement are picked in 500 replicates. The middle value of $\gamma$ from these replicates was then used as the average.

The dataset includes some outliers where the catch ratio between paired hauls is rather large. Those paired hauls were not omitted in the analysis but simply contribute to the overall variance in the experiment.

The rationale for using a bootstrap rather than a parametric variance is that $\gamma$ is a ratio and determination of variances for ratios are less problematic using bootstrap methods than parametric methods.

It is worth noticing that the result of the experiment is a conversion factor for hauls, not a density conversion factor. The reason for that distinction is that the different trawls have different wingspreads and therefore differ in the swept area for the same trawled distance.

*Evaluation of the experiment design.*

The general experimental design allows estimation of $\alpha$, and $\beta$ from experiment types 0 and 1, and $\alpha$ and $\gamma$ from experiment types 2 and 3 i.e. the factor $\beta$ may be estimated independently based on two different experiment types. If the method works properly estimates of $\beta$ should be similar or very close to each other, independent of on which experiment group the estimates were performed. Since we performed all four of the experiment types it is therefore possible from our data to test this hypothesis. As a preliminary analysis we calculated the conversion factor $\gamma$ for each length group using experiment types 0 and 1, 2 and 3 and all 4.

A significance test evaluating whether experiment types 2 and 3 gives a smaller $\gamma$ value than experiments of types 0 and 1 was also performed. The test was performed on the carapace length group 22 mm since this group showed the largest difference in $\gamma$ estimate between experiment groups.

## Results

*Conversion factors*

Estimated conversion factors for 0.5 mm length bins at the 95% level of confidence are illustrated in Fig. 1 and tabulated in Appendix 1.

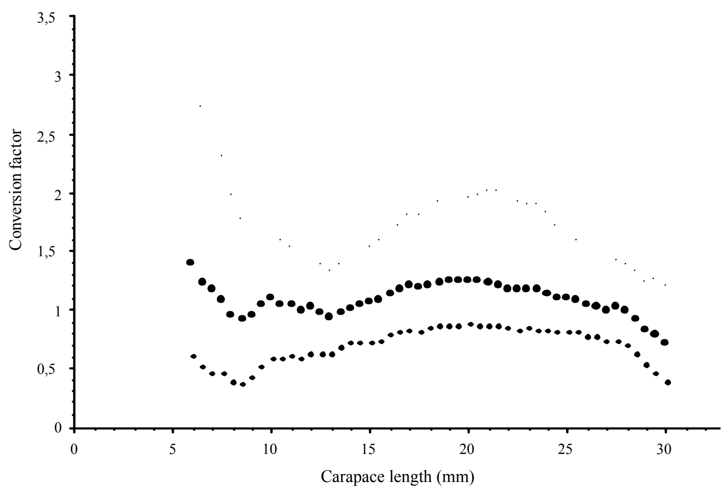


Fig. 1. Plot showing estimated conversions factors for 0.5 mm length bins at the 95% level of confidence.

*Evaluation of the experiment design*

Contrary to our expectation a fairly large discrepancy between estimates of $\gamma$ based the different methods was found (Fig. 2). This discrepancy is largest in the length-classes where the sample size is largest (15-25 mm).

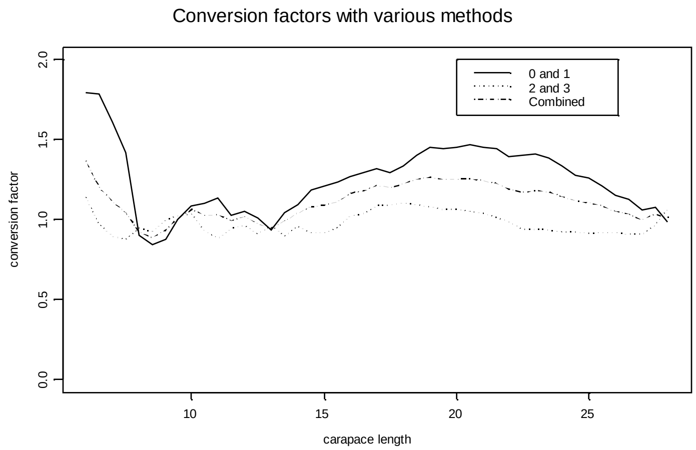


Fig. 2. Graph showing the conversion factor $\gamma$ estimated based on paired haul combinations 0 and 1, 2 and 3, and all paired haul combinations.

A significance test evaluating whether experiment types 2 and 3 gives a smaller $\gamma$ value than experiments of types 0 and 1 gave a p value of 0.22. This indicates a difference in estimates of $\gamma$ at only the 78% level of confidence. This test was performed on the carapace length group of 22 mm since this group showed the largest difference in $\gamma$ estimate between experiment groups.

## Discussion and Conclusions

As we understand the results of the performed preliminary analyses there seem to be a problem in the design/analyses of the trawl calibration experiment. This is disconcerting since the continuity of the survey data time series depends on methodological consistency.

We will continue to explore alternative ways of analyzing our data and report the results of these explorations. Meanwhile we feel forced to use the estimated conversion factors however with the above mentioned reservations.

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**APPENDIX 1.**

| Length group | 5% level of confidence | Mean conversion factor | 95% level of confidence |
|---|---|---|---|
| 6 | 0.602577 | 1.375598 | 3.168576 |
| 6.5 | 0.514104 | 1.224493 | 2.717414 |
| 7 | 0.467735 | 1.151913 | 2.543684 |
| 7.5 | 0.459669 | 1.070977 | 2.287454 |
| 8 | 0.387577 | 0.941319 | 1.952647 |
| 8.5 | 0.378293 | 0.906089 | 1.757326 |
| 9 | 0.424936 | 0.955476 | 1.788548 |
| 9.5 | 0.513632 | 1.045759 | 1.775735 |
| 10 | 0.58824 | 1.092576 | 1.746343 |
| 10.5 | 0.58711 | 1.046447 | 1.572743 |
| 11 | 0.60454 | 1.04246 | 1.532774 |
| 11.5 | 0.59528 | 0.99171 | 1.435779 |
| 12 | 0.631954 | 1.019013 | 1.455503 |
| 12.5 | 0.63641 | 0.960159 | 1.371356 |
| 13 | 0.628293 | 0.928206 | 1.318678 |
| 13.5 | 0.675848 | 0.967927 | 1.371578 |
| 14 | 0.715069 | 1.009857 | 1.446976 |
| 14.5 | 0.726471 | 1.043003 | 1.508633 |
| 15 | 0.718326 | 1.054343 | 1.532425 |
| 15.5 | 0.737492 | 1.077197 | 1.57433 |
| 16 | 0.778966 | 1.136781 | 1.639242 |
| 16.5 | 0.793915 | 1.156209 | 1.708528 |
| 17 | 0.822053 | 1.193683 | 1.798294 |
| 17.5 | 0.808415 | 1.182045 | 1.799449 |
| 18 | 0.835536 | 1.196675 | 1.841922 |
| 18.5 | 0.858211 | 1.228564 | 1.900252 |
| 19 | 0.868035 | 1.248024 | 1.927375 |
| 19.5 | 0.856463 | 1.239688 | 1.932481 |
| 20 | 0.869477 | 1.239098 | 1.948907 |
| 20.5 | 0.867843 | 1.234976 | 1.96116 |
| 21 | 0.861482 | 1.218359 | 1.988991 |
| 21.5 | 0.858744 | 1.199575 | 1.990499 |
| 22 | 0.83969 | 1.175146 | 1.93239 |
| 22.5 | 0.827389 | 1.164613 | 1.914176 |
| 23 | 0.835974 | 1.169528 | 1.894766 |
| 23.5 | 0.825813 | 1.15441 | 1.887186 |
| 24 | 0.818828 | 1.128442 | 1.815331 |
| 24.5 | 0.809052 | 1.09956 | 1.694102 |
| 25 | 0.805881 | 1.089933 | 1.629472 |
| 25.5 | 0.797379 | 1.076427 | 1.564208 |
| 26 | 0.767123 | 1.041292 | 1.505814 |
| 26.5 | 0.769382 | 1.022535 | 1.439265 |
| 27 | 0.728339 | 0.986109 | 1.361475 |
| 27.5 | 0.737346 | 1.015321 | 1.416223 |
| 28 | 0.698664 | 0.98884 | 1.376474 |
| 28.5 | 0.61354 | 0.903031 | 1.313686 |
| 29 | 0.522854 | 0.808164 | 1.226559 |
| 29.5 | 0.450169 | 0.771023 | 1.254105 |
| 30 | 0.379889 | 0.702986 | 1.185551 |