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# The Fishery for Northern Shrimp (*Pandalus borealis*) in the Barents Sea

by

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## Abstract

The resource of northern shrimp (*Pandalus borealis*) in the Barents Sea is assessed as one stock. The fishery is multinational. Norway accounts for 70-90% of the landings. The fishery is managed by effort control.

Catches have declined from 83 ktons in 2000 to 41 ktons in 2005. Discard of small shrimp is believed to be low. A standardised catch-per-unit-effort series indicate an increase in stock density since 2004. A standardised effort series indicate a declining trend in fishing mortality since 2000.

## Introduction

The resource of northern shrimp (*Pandalus borealis*) in the Barents Sea (Fig 1) within the Norwegian EEZ and in the Svalbard zone (ICES Div I and II) is for assessment purposes considered as one stock. Norwegian and Russian vessels exploit the stock in the entire area while vessels from other nations are restricted to the Svaldbard fisheries zone.

The fishery was initiated in 1970 by Norwegian vessels. While the fishery developed, vessels from several nations joined and catches reached some 128 ktons in 1984 (Fig. 2). During the recent decade annual yields have varied between 35 and 85 ktons. Norwegian vessels accounted for 70-90% of the total catches and vessels from Russia, Iceland, Greenland and the EU for the rest.

The fishery is regulated by effort control: licences are required for the Russian and Norwegian vessels and the fleets operating in the Svaldbard zone is regulated by number of effective fishing days and number of vessels by country. Minimum mesh size is 35mm. Other species and small shrimp are protected by mandatory sorting grids and by temporary closing of areas where excessive by-catch of juvenile cod, haddock, Greenland halibut, redfish and shrimp<15mm carapace length.(measured in catch samples taken by independent observers).

A major restructuring of the fleet towards fewer and larger vessels has taken place since the mid 1990s. In 2006 the fleet is largely composed of a group of large freeze or factory trawlers (>2000HP (HP=engine horsepower)) and a smaller group of smaller (<500HP) vessels (Fig. 3).

The present paper updates available information derived from catch statistics, logbooks and catch sampling from the Norwegian trawl fishery for shrimp in the Barents Sea (ICES Div. I and II).

## Materials and Methods

Logbook data were analysed to show the spatial and temporal distribution of the fishery and fleet composition. Catch-per-unit-effort (CPUE) data from Norwegian vessels were used in multiplicative models to calculate

standardised annual catch rate indices (Hvingel *et al*., 2000). A Standardised effort series was derived by dividing total catch by the standardised CPUE.

The CPUE indices included the following variables: (1) vessel fishing power grouped by engine size, (2) seasonal availability of shrimp, (3) spatial availability of shrimp, (4) gear type (single, double or triple trawl) and (5) annual mean CPUE. The calculations were done using the SAS statistical software (Anon., 1988). The area definition used is similar to the stratification used in the survey. The multiplicative model was represented in logarithmic form as:

$$\ln\left(CPUE_{kjmhi}\right) = \ln\left(u\right) + \ln\left(V_k\right) + \ln\left(S_j\right) + \ln\left(A_m\right) + \ln(G_h) + \ln\left(Y_i\right) + e_{kjmhi}$$

where $CPUE_{kjmhi}$ is the mean CPUE for vessel-group k, fishing in area m in month j during year i with geartype h (k = 1,...,n; m = 1,…,a; j = 1,…,s; i = 1,…,y; h=1,2,3); ln($u$) is overall mean ln(*CPUE*); $V_k$ is the effect of the k$^{th}$ vessel-group; $S_j$ is the effect of the j$^{th}$ month; $A_m$ is effect of the m$^{th}$ area; $G_h$ is the effect of grar type h; $Y_i$ is the effect of the i$^{th}$ year; $e_{kjmhi}$ is the error term assumed to be normally distributed N(0,$\sigma^2$/n) where n is the number of observations in the cell. The standardised CPUE indices are the antilog of the year coefficient.

Data on catch compositions are available from observers since 1995 and a reference vessel since 2002. The carapace length is measured on 300 individuals of shrimp in each sample.

## Results

*Fleet composition and gear*

A major restructuring of the fleet towards fewer and larger vessels has taken place since the mid 1990s. In 1995 6% of the catches reported in logbooks were taken by large factory trawlers (>2000 HP) whereas this fleet component accounted for more than 95% in 2006 (Fig. 4).

Since 2000 the number of vessels participating have been reduced from 150 to 34 in 2006 (Fig. 3). The large vessel component (>2000HP) consists of 18 vessels with varying amounts of effort allocated to shrimp fishery: individual vessels catch span from 0.5% to 12% of the total (Fig.5).

Until 1996 the fishery was conducted by using single trawls only. Double trawls were introduced in 1996 and in 2002 approximately 50% of the total effort spent was by using two trawls simultaneously (Fig. 6). In 2000 a few vessels started to experiment with triple trawls: 10% of the effort in 2006 is accounted for by this method.

*Spatial and seasonal distribution*

The fishery is conducted mainly in the Hopen area (central Barents Sea) which, along with the Svaldbard shelf, is considered the most important fishing ground (Fig. 1). The fishery takes place in all months but may in certain years be restricted by ice conditions. The lowest intensity is generally seen in October through March, the highest in May to August (Fig. 7). In 2005 more effort than usual was spent in the beginning of year (January–Mars).

*Landings*

Since the early 1980s annual landings have varied in a cyclic manner with local minima and maxima separated by periods of 4-5 years (Fig. 2). Overall catches have ranged from 28 to 128 ktons. The most recent peak was seen in 2000 at approximately 83 ktons. Catches thereafter declined to 40 ktons in 2005. Based on data until August (logbooks and information from the industry) the total catch of 2006 is estimated to remain at this level.

*Discards an by-catch*

Discard of shrimp is believed to be small as the fishery is not catch regulated. Small cod, haddock, Greenland halibut and redfish in the size range of 5-25 cm are caught as by-catch. The by-catch of small cod ranged between 2 and 67 million individuals/yr since 1997, while 1-9 million haddock/yr and 0.5 to 14 million Greenland halibut/yr was registered since 2000. There are no estimates of by-catch of redfish. Details on by-catch are reported to AFWG (ICES 2006).

*Standardised CPUE*

The fishery dependent index of stock biomass – the standardised CPUE – is indicative shrimp greater than 16 mm cpl., i.e. of the older male and the female stock combined.

The standardised CPUE declined by 60% from a maximum in 1984 to the lowest value of the time series in 1987 (Fig. 8). After that it showed an overall increasing trend until 2000 and then remained stable close to the mean of the series until 2003. Following a decline from 2003 to 2004 the std. CPUE increased significantly reaching values comparable to the 1984-maximum in 2006.

Some vessels may have failed to report the use of multiple trawls resulting in effort mistakenly being registered as of single trawls. The recent changes in the CPUE indices could therefore be due to changes in fishing efficiency rather than changes in stock density. However, a similar index series based on the same data but excluding all hauls reported as single trawls showed similar trend as the over all index (Fig. 8).

Changes (improvements) of the fishing efficiency of the vessel groups may also be a source of bias particularly in the recent years where many vessels have left the fishery. Presumably the vessels now remaining are the most effective of their respective vessel groups. A model based on individual vessels as the unit of fishing power was constructed using available data since 2000. This series also showed an increase since 2004 however somewhat smaller than that seen in the two other series (Fig. 8). Further the difference of the 2006 value to the level around 2000 was less pronounced indicating that the vessel group efficiency indeed had improved and that the series based on vessel groups are overestimating the recent improvement in stock density.

In general the std. CPUE and the survey series have been well correlated (corr. coeff.= 0.8) (Fig. 9).

*Effort*

Standardised effort has shown a declining trend since 2000 (Fig. 10).

*Catch composition*

Has not been analysed.

**Acknowledgements**

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**References**

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ICES 2006. Report of the Arctic Fisheries Working Group 2006. ICES CM 2006/ACFM:25.

**Table 1.** Nominal landings, catch-per-unit-effort (CPUE) and effort standardised and unstandardised. Norwegian data. (*2006 catch is estimated based on data until August).

| | | Absolute | | Standardised | |
|---|---|---|---|---|---|
| year | Catch ('000 tons) | CPUE (kg/hr) | Effort ('000 hrs) | CPUE (index) | Effort (index) |
| 1980 | 35.061 | 184 | 190.783 | 1.00 | 1.00 |
| 1981 | 32.713 | 215 | 152.112 | 1.16 | 0.83 |
| 1982 | 43.451 | 198 | 219.098 | 1.10 | 1.23 |
| 1983 | 70.798 | 229 | 308.768 | 1.26 | 1.80 |
| 1984 | 76.636 | 245 | 312.218 | 1.31 | 2.11 |
| 1985 | 82.123 | 227 | 361.692 | 1.04 | 2.58 |
| 1986 | 48.569 | 154 | 315.078 | 0.63 | 2.25 |
| 1987 | 31.353 | 110 | 283.900 | 0.48 | 1.97 |
| 1988 | 32.021 | 111 | 289.674 | 0.52 | 2.02 |
| 1989 | 47.064 | 139 | 338.394 | 0.68 | 1.99 |
| 1990 | 54.182 | 149 | 364.772 | 0.68 | 2.57 |
| 1991 | 39.272 | 170 | 230.495 | 0.72 | 2.25 |
| 1992 | 39.603 | 211 | 188.083 | 0.83 | 1.79 |
| 1993 | 33.109 | 209 | 158.621 | 0.88 | 1.38 |
| 1994 | 20.116 | 165 | 122.166 | 0.70 | 0.87 |
| 1995 | 19.337 | 145 | 132.968 | 0.62 | 0.89 |
| 1996 | 25.445 | 181 | 140.323 | 0.79 | 0.94 |
| 1997 | 29.079 | 212 | 137.044 | 0.78 | 1.00 |
| 1998 | 44.792 | 289 | 155.010 | 0.93 | 1.29 |
| 1999 | 52.612 | 290 | 181.466 | 0.95 | 1.71 |
| 2000 | 55.333 | 280 | 197.830 | 0.86 | 2.10 |
| 2001 | 43.021 | 351 | 122.496 | 0.86 | 1.43 |
| 2002 | 48.799 | 409 | 119.196 | 0.85 | 1.55 |
| 2003 | 34.652 | 380 | 91.253 | 0.84 | 1.02 |
| 2004 | 36.188 | 333 | 108.756 | 0.75 | 1.25 |
| 2005 | 36.456 | 371 | 98.173 | 1.10 | 0.80 |
| 2006* | 45 | 543 | 82.821 | 1.30 | 0.84 |

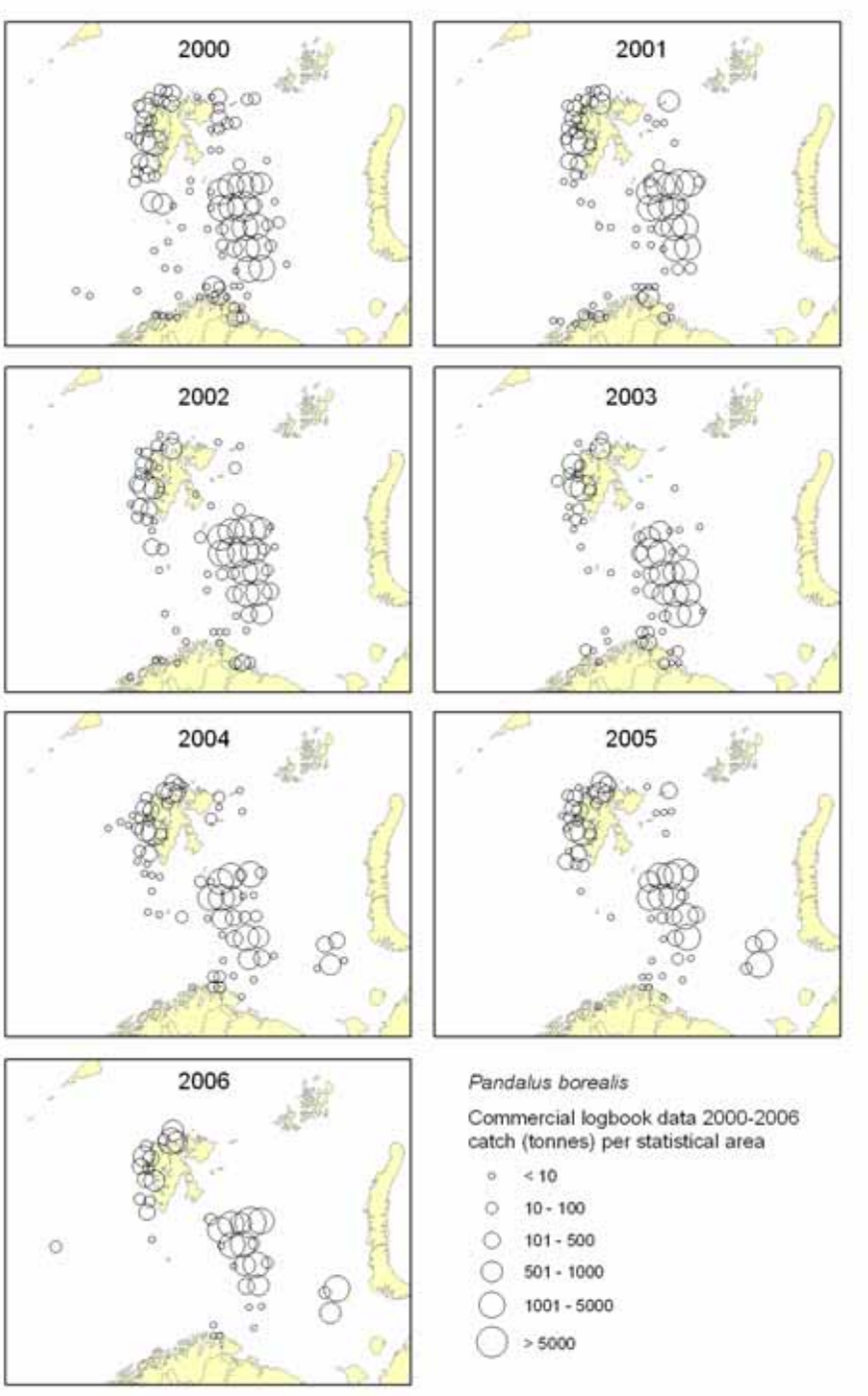


**Fig. 1.** Distribution of catches by Norwegian vessels 2000-2006 based on logbook information.

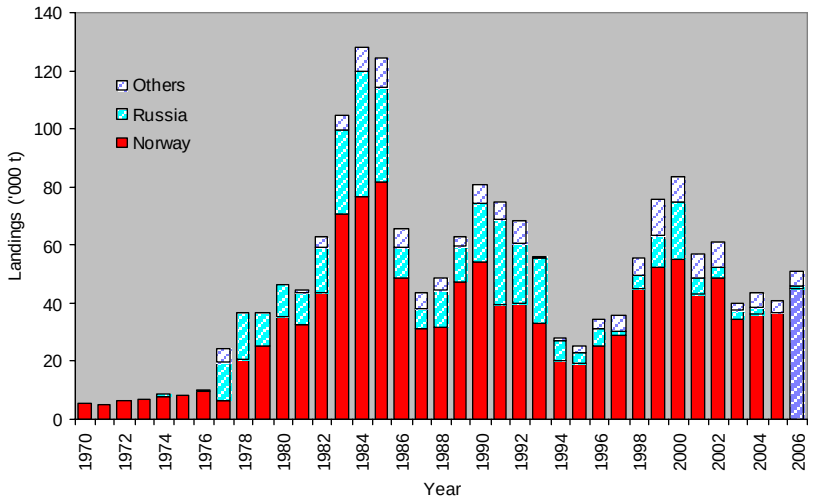


**Fig. 2.** Shrimp in the Barents Sea: Total landings. The 2006 value is estimated based on data until August.

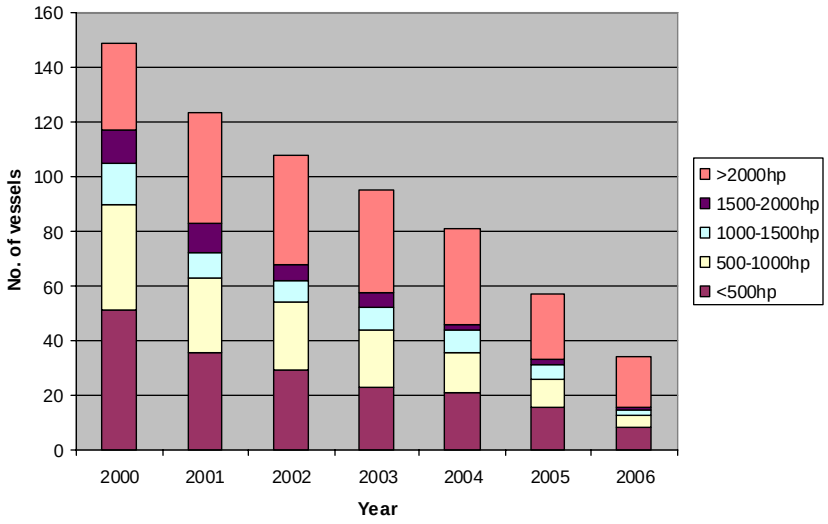


**Fig. 3.** Shrimp in the Barents Sea: Number of vessels participating in the fishery 2000-2006. The 5 fleet components are separated by engine size (HP= horse-powers). Norwegian data.

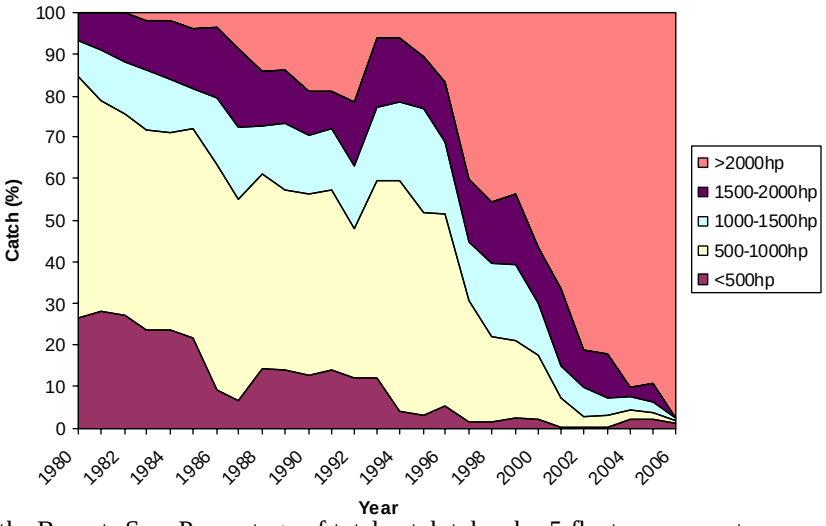


**Fig. 4.** Shrimp in the Barents Sea: Percentage of total catch taken by 5 fleet components separated by engine size (HP= horse-powers) 1980-2006.

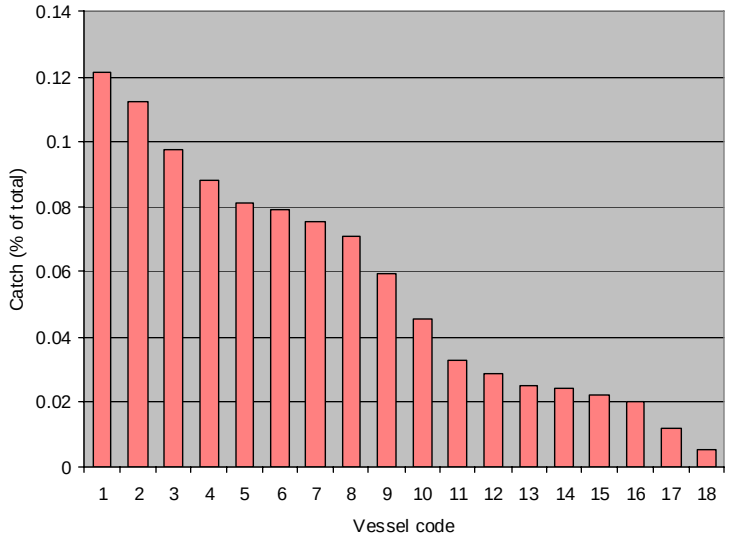


**Fig. 5.** Shrimp in the Barents Sea: Percentage of total catch taken by individual vessels >2000HP (engine horsepower) in 2006. Norwegian data.

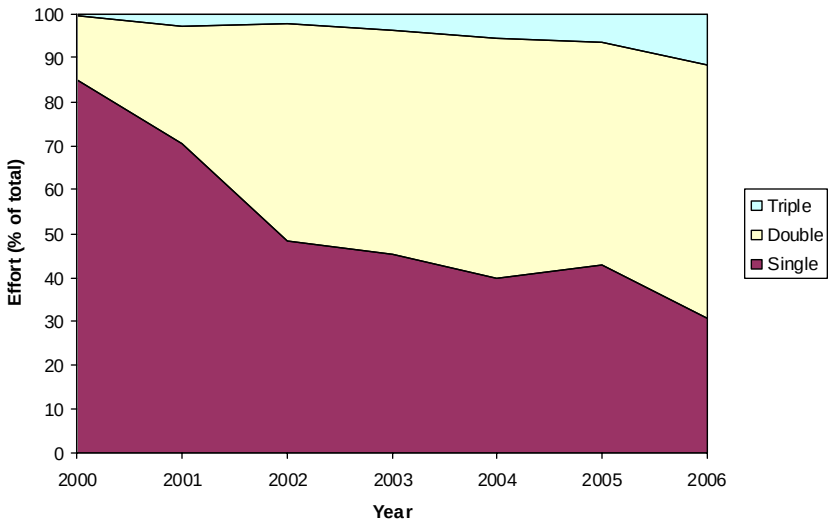


**Fig. 6.** Shrimp in the Barents Sea: Percentage of total fishing effort spent by using single, double or triple trawls 2000-2006. Norwegian data.

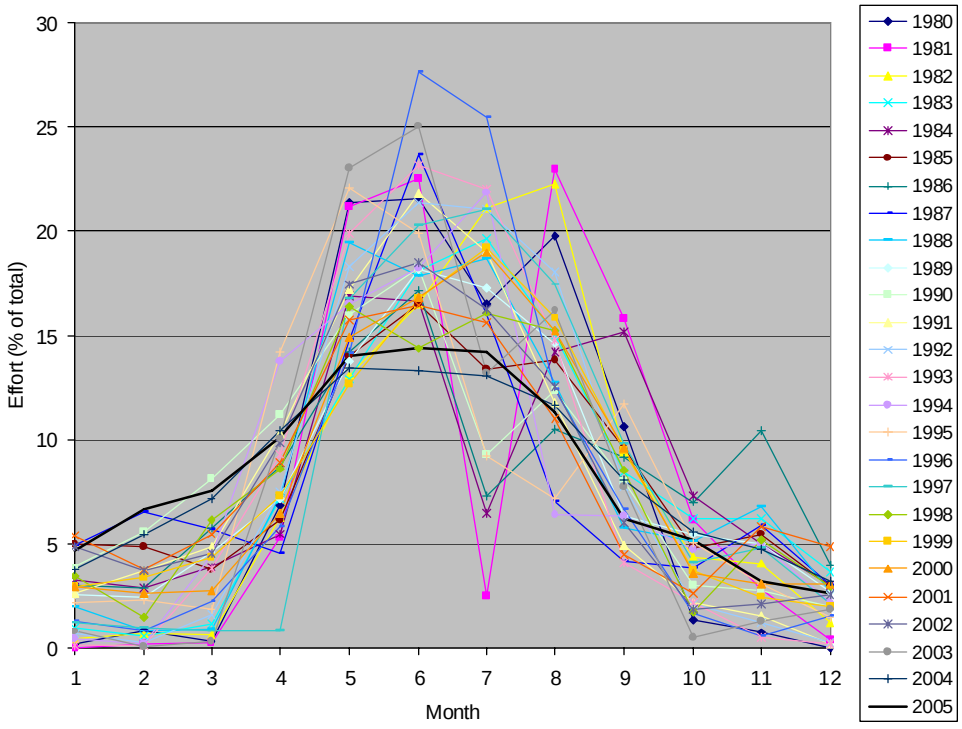


**Fig. 7.** Shrimp in the Barents Sea: Seasonal distribution of fishing effort 1980-2005. Hours trawled in a month as a percentage of total effort of the year. Norwegian data.

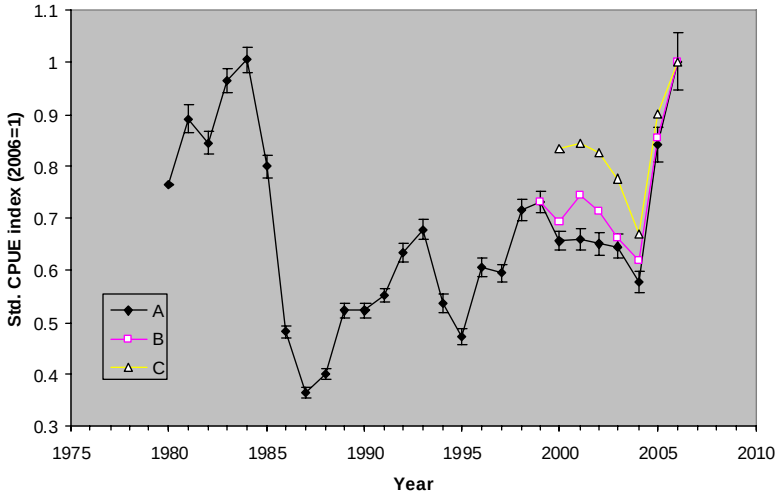


**Fig 8.** Shrimp in the Barents Sea: Standardised CPUE based on (A) vessels grouped by engine size, (B) only hauls positively reported as double and triple trawls, (C) individual vessels as the unit of fishing power. Norwegian data.

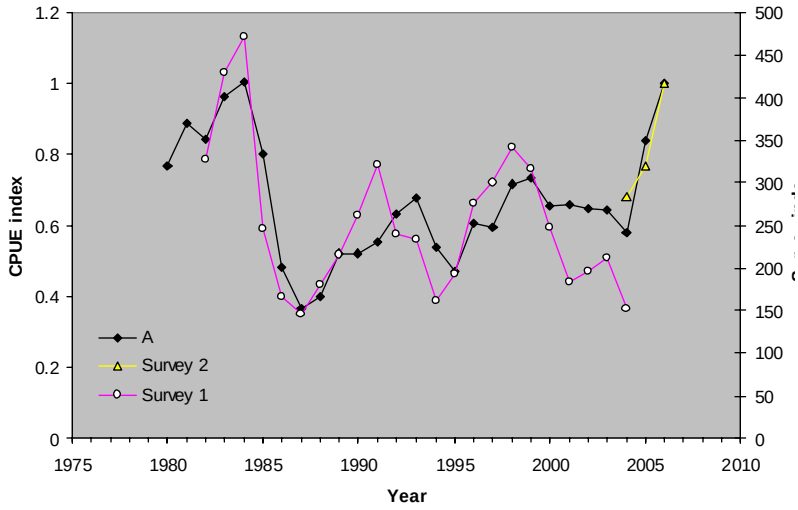


**Fig 9.** Shrimp in the Barents Sea: Standardised CPUE (A) and survey indices.

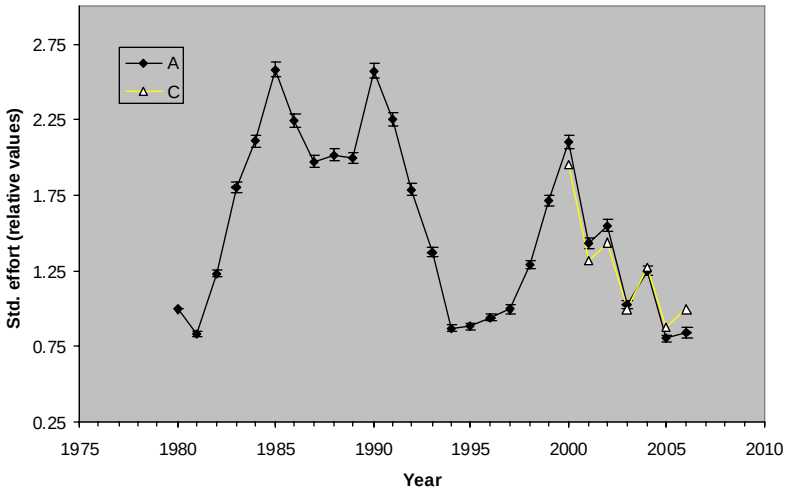


**Fig 10.** Shrimp in the Barents Sea: Standardised effort. (A) vessels grouped by engine size, (C) individual vessels as the unit of fishing power Norwegian data.

**Appendix 1.** Diagnostical output from GLM-run of the Barents Sea index.

Class Level Information

| | | |
|---|---|---|
| strata | 8 | A B C D E F G H |
| gear | 4 | 56 58 59 |
| vessel | 5 | 1 2 3 4 5 |
| year | 27 | 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2080 |
| month | 12 | 1 2 3 4 5 6 7 8 9 10 11 12 |

Number of Observations Read 102199

Dependent Variable: lncpue
Weight: effort

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 51 | 933529.251 | 18304.495 | 2800.27 | <.0001 |
| Error | 102147 | 667703.485 | 6.537 | | |
| Corrected Total | 102198 | 1601232.736 | | | |

| R-Square | Coeff Var | Root MSE | lncpue Mean |
|---|---|---|---|
| 0.583007 | 49.19762 | 2.556696 | 5.196787 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| strata | 7 | 42368.0532 | 6052.5790 | 925.94 | <.0001 |
| year | 26 | 252950.5354 | 9728.8667 | 1488.35 | <.0001 |
| gear | 3 | 13975.4669 | 4658.4890 | 712.67 | <.0001 |
| vessel | 4 | 138083.6933 | 34520.9233 | 5281.10 | <.0001 |
| month | 11 | 71194.5110 | 6472.2283 | 990.14 | <.0001 |

| Parameter | | Estimate | | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|---|---|
| Intercept | | 6.326655153 | B | 0.02338514 | 270.54 | <.0001 |
| strata | A | -0.251067943 | B | 0.00606917 | -41.37 | <.0001 |
| strata | B | 0.012218334 | B | 0.00574204 | 2.13 | 0.0333 |
| strata | C | 0.040330532 | B | 0.00530358 | 7.60 | <.0001 |
| strata | D | -0.009844988 | B | 0.01166893 | -0.84 | 0.3988 |
| strata | E | 0.201295824 | B | 0.00459196 | 43.84 | <.0001 |
| strata | F | 0.008176321 | B | 0.01209506 | 0.68 | 0.4990 |
| strata | G | 0.044747559 | B | 0.00776449 | 5.76 | <.0001 |
| strata | H | 0.000000000 | B | . | . | . |
| year | 1980 | 0.000000000 | B | . | . | . |
| year | 1981 | 0.149247398 | B | 0.01124972 | 13.27 | <.0001 |
| year | 1982 | 0.096950782 | B | 0.01014355 | 9.56 | <.0001 |
| year | 1983 | 0.228422415 | B | 0.00956961 | 23.87 | <.0001 |
| year | 1984 | 0.271421201 | B | 0.00951833 | 28.52 | <.0001 |
| year | 1985 | 0.042076072 | B | 0.00950852 | 4.43 | <.0001 |
| year | 1986 | -0.464296735 | B | 0.00990470 | -46.88 | <.0001 |
| year | 1987 | -0.742404395 | B | 0.01036677 | -71.61 | <.0001 |
| year | 1988 | -0.649905464 | B | 0.00990724 | -65.60 | <.0001 |
| year | 1989 | -0.384170105 | B | 0.00943101 | -40.73 | <.0001 |
| year | 1990 | -0.383356755 | B | 0.00929539 | -41.24 | <.0001 |
| year | 1991 | -0.330320303 | B | 0.00986410 | -33.49 | <.0001 |
| year | 1992 | -0.189433851 | B | 0.01024030 | -18.50 | <.0001 |
| year | 1993 | -0.123246494 | B | 0.01071767 | -11.50 | <.0001 |
| year | 1994 | -0.357998850 | B | 0.01266810 | -28.26 | <.0001 |
| year | 1995 | -0.484921675 | B | 0.01258929 | -38.52 | <.0001 |
| year | 1996 | -0.234220915 | B | 0.01191677 | -19.65 | <.0001 |
| year | 1997 | -0.254541930 | B | 0.01146584 | -22.20 | <.0001 |
| year | 1998 | -0.068252675 | B | 0.01116122 | -6.12 | <.0001 |
| year | 1999 | -0.047729120 | B | 0.01059848 | -4.50 | <.0001 |
| year | 2000 | -0.154951186 | B | 0.01040602 | -14.89 | <.0001 |
| year | 2001 | -0.151204574 | B | 0.01157185 | -13.07 | <.0001 |
| year | 2002 | -0.165473302 | B | 0.01224237 | -13.52 | <.0001 |
| year | 2003 | -0.172100986 | B | 0.01314694 | -13.09 | <.0001 |
| year | 2004 | -0.283894332 | B | 0.01375437 | -20.64 | <.0001 |
| year | 2005 | 0.093086266 | B | 0.01533251 | 6.07 | <.0001 |
| year | 2006 | 0.265889626 | B | 0.02073750 | 12.82 | <.0001 |
| gear | 55 | -0.605608932 | B | 0.02067037 | -29.30 | <.0001 |
| gear | 58 | -0.285525368 | B | 0.01986077 | -14.38 | <.0001 |
| gear | 59 | 0.000000000 | B | . | . | . |
| vessel | 1 | -0.846979077 | B | 0.00604913 | -140.02 | <.0001 |
| vessel | 2 | -0.575085185 | B | 0.00500824 | -114.83 | <.0001 |
| vessel | 3 | -0.480810061 | B | 0.00548374 | -87.68 | <.0001 |
| vessel | 4 | -0.291487164 | B | 0.00564354 | -51.65 | <.0001 |
| vessel | 5 | 0.000000000 | B | . | . | . |
| month | 1 | 0.203015669 | B | 0.01195718 | 16.98 | <.0001 |
| month | 2 | 0.166884809 | B | 0.01228286 | 13.59 | <.0001 |
| month | 3 | 0.283084984 | B | 0.01145947 | 24.70 | <.0001 |
| month | 4 | 0.223265149 | B | 0.01043425 | 21.40 | <.0001 |
| month | 5 | 0.141068361 | B | 0.00993332 | 14.20 | <.0001 |
| month | 6 | 0.152473116 | B | 0.00987514 | 15.44 | <.0001 |
| month | 7 | 0.078641262 | B | 0.00993303 | 7.92 | <.0001 |

| | | | | | |
|---|---|---|---|---|---|
| month | 8 | 0.012358811 B | 0.00998108 | 1.24 | 0.2156 |
| month | 9 | -0.175842015 B | 0.01025003 | -17.16 | <.0001 |
| month | 10 | -0.409265435 B | 0.01115980 | -36.67 | <.0001 |
| month | 11 | -0.172084533 B | 0.01088923 | -15.80 | <.0001 |
| month | 12 | 0.000000000 B | . | . | . |