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The Norwegian 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. Catches have ranged between 25 and 128 ktons. Norway accounts for 70-90% of the landings. The fishery is managed by effort control. Discard of small shrimp and by-catch of other species is believed to be low.

Overall catches have declined from 83 ktons in 2000 to 30 ktons in 2006 and a major restructuring of the fleet has taken place, mainly due to reduced market prices for shrimp products. A standardised catch-per-unit-effort series indicate a slight decline in stock density from 2000 to 2004 and a large increase thereafter. However, the index for 2007 is down approx. 18% as compared to 2006. 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 Svalbard fisheries zone.

The fishery was initiated in 1970 by Norwegian vessels. As the fishery developed, vessels from several nations joined and catches reached some 128 ktons in 1984 (Fig. 3). During the recent decade annual yields have varied between 29 and 83 ktons. Norwegian vessels accounted for around 70-90% of the total catches and vessels from Russia, Iceland, Greenland and the EU for the rest (Tab. 1).

The fishery is regulated by effort control: licences are required for the Russian and Norwegian vessels and the fleets operating in the Svalbard 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. The fleet is now largely composed of a group of large freeze or factory trawlers (>2000HP (HP=engine horsepower)) and a smaller group of <500HP vessels. Trawling is mainly performed using two or three trawls simultaneously.

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 (Hvingel, 2007). 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

Spatial and seasonal distribution

The fishery is conducted mainly in the Hopen area (central Barents Sea) which, along with the Svalbard 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. 2). In 2005 more effort than usual was spent in the beginning of year (January–March).

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. 3). Overall catches have ranged from 25 to 128 ktons. The most recent peak was seen in 2000 at approximately 83 ktons. Catches thereafter declined to 30 ktons in 2006. Based on data until August (logbooks and information from the industry) the total catch of 2007 is estimated to remain at this level.

Discards and 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, 2007).

Fleet composition and gear

A major restructuring of the fleet towards fewer and larger vessels has taken place since the mid 1990s. In 1994 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 2007 (Fig. 4).

Since 2000 the number of vessels participating have been reduced from 150 to 21 in 2007 (Fig. 5). The large vessel component (>2000HP) consists of 12 vessels.

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: 22% of the effort in 2007 is accounted for by this fishing method.

Standardised CPUE
The fishery dependent index of stock biomass – the standardised CPUE – is indicative of 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. 7) (Tab. 2). 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. The 2007 mean value is 18% lower than that of 2006, but is still well above the average of the series.

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 dataset but excluding all hauls registered as single trawls showed similar trend as the overall index (Fig. 7).

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. 7). Further the increase from the early 2000 values to the most recent values as seen in the original series could not be seen here indicating that the vessel group efficiency had improved and that the series based on vessel groups may overestimate the recent improvement in stock density. However, in general, the std. CPUE and the survey series have been well correlated (corr. coeff.= 0.8) (Fig. 8).

Effort
Standardised effort has shown a declining trend since 2000 (Fig. 9).

Catch composition
Has not been analysed.

References

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Table 1. Nominal landings (‘000 tons) by nation (*2007 catch is estimated based on data until August).

Year	Norway	Russia	Others	total
1970	5.508	0	0	5.508
1971	5.116	0	0	5.116
1972	6.772	0	0	6.772
1973	6.921	0	0	6.921
1974	8.008	0.992	0	9.000
1975	8.197	0	0.002	8.199
1976	9.752	0.548	0	10.300
1977	6.78	12.774	4.854	24.408
1978	20.484	15.859	0	36.343
1979	25.435	10.864	0.39	36.689
1980	35.061	11.219	0	46.280
1981	32.713	10.897	1.011	44.621
1982	43.451	15.552	3.835	62.838
1983	70.798	29.105	4.903	104.806
1984	76.636	43.180	8.246	128.062
1985	82.123	32.104	10.262	124.489
1986	48.569	10.216	6.538	65.323
1987	31.353	6.690	5.324	43.367
1988	32.021	12.32	4.348	48.689
1989	47.064	12.252	3.432	62.748
1990	54.182	20.295	6.687	81.164
1991	39.272	29.434	6.156	74.862
1992	39.603	20.944	8.021	68.568
1993	33.109	22.397	0.806	56.312
1994	20.116	7.108	1.063	28.287
1995	19.337	3.564	2.319	25.220
1996	25.445	5.747	3.320	34.512
1997	29.079	1.493	5.164	35.736
1998	44.792	4.895	6.1031	55.790
1999	52.612	10.765	12.292	75.669
2000	55.333	19.596	8.2413	83.170
2001	43.031	5.846	8.659	57.536
2002	48.799	3.790	8.899	61.488
2003	34.172	2.776	2.277	39.225
2004	35.918	2.410	2.373	40.701
2005	37.253	0.435	3.010	40.698
2006	27.413	0.004	2.271	29.688
*2007	26.000	0.004	2.000	28.004

Table 2. Nominal landings, catch-per-unit-effort (CPUE) and effort standardised and unstandardised. Norwegian data. (*2007 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	43.031	351	122.524	0.86	1.45
2002	48.799	409	119.196	0.85	1.57
2003	34.172	380	89.989	0.84	1.01
2004	35.918	333	107.945	0.75	1.17
2005	37.253	365	102.063	1.10	0.80
2006	27.413	401	68.362	1.25	0.51
2007*	26.000	532	48.872	1.03	0.54

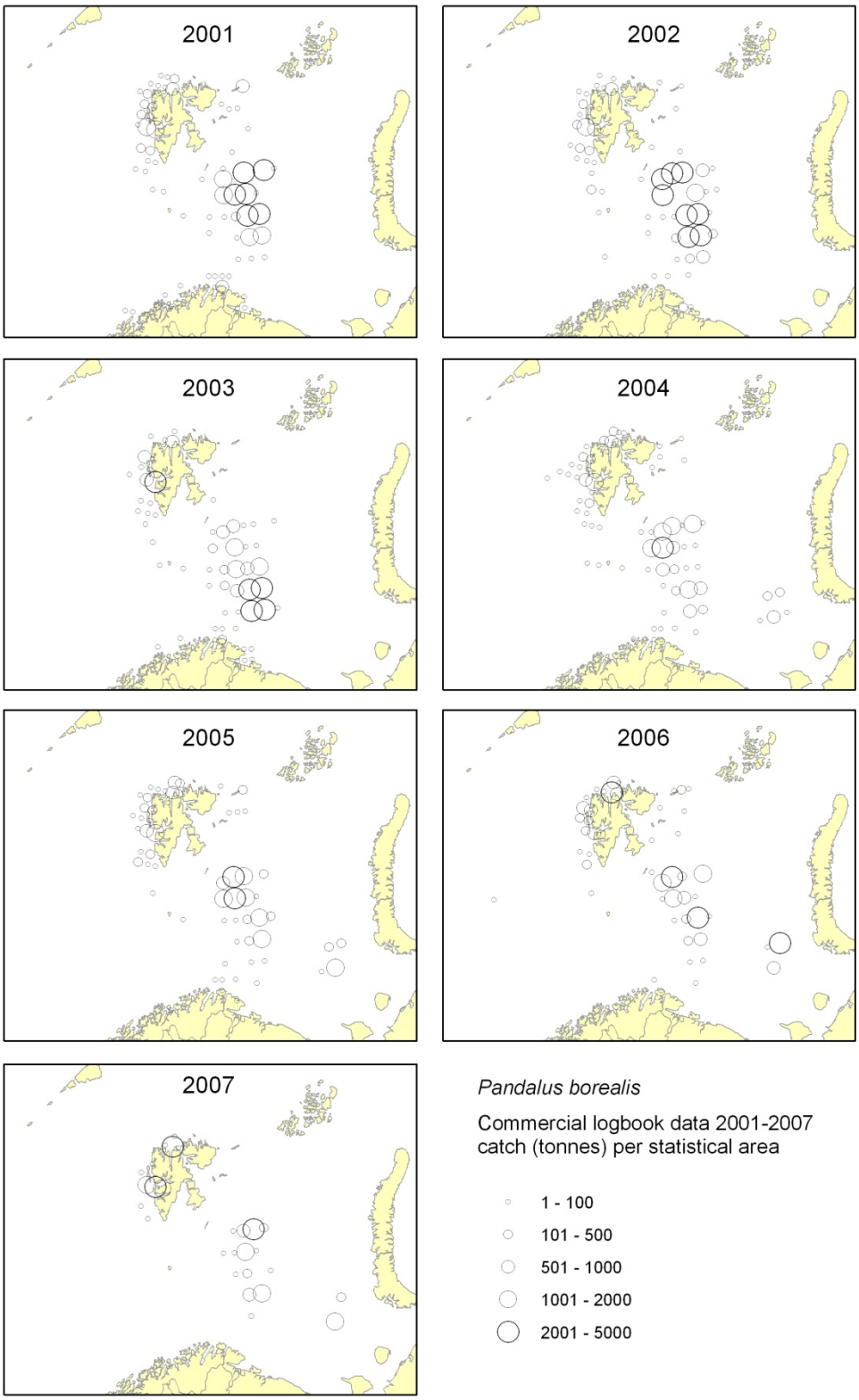

Fig. 1. Distribution of catches by Norwegian vessels 2001-2007 based on logbook information.

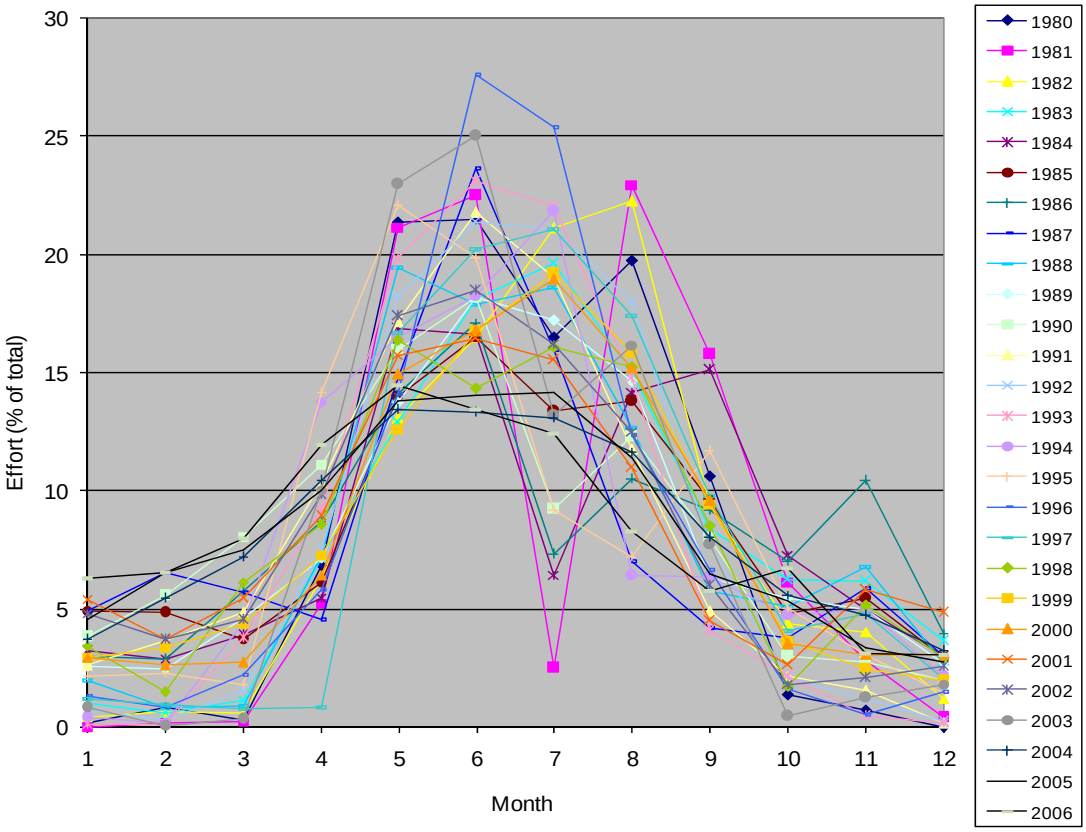

Fig. 2. Shrimp in the Barents Sea: Seasonal distribution of fishing effort 1980-2006. Hours trawled in a month as a percentage of total effort of the year. Norwegian data.

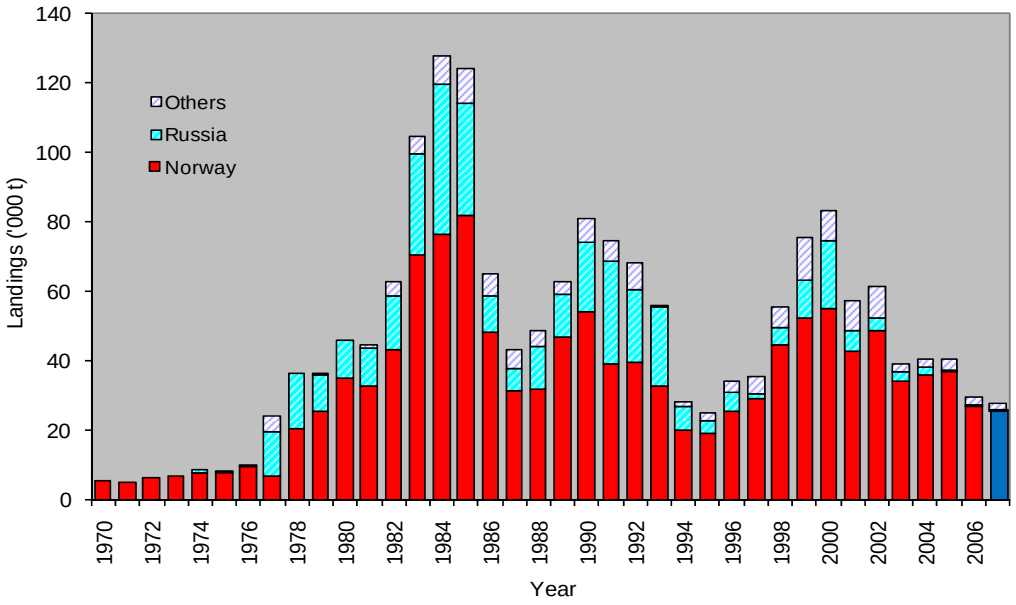

Fig. 3. Shrimp in the Barents Sea: Total landings. The 2007 value is estimated based on data until August.

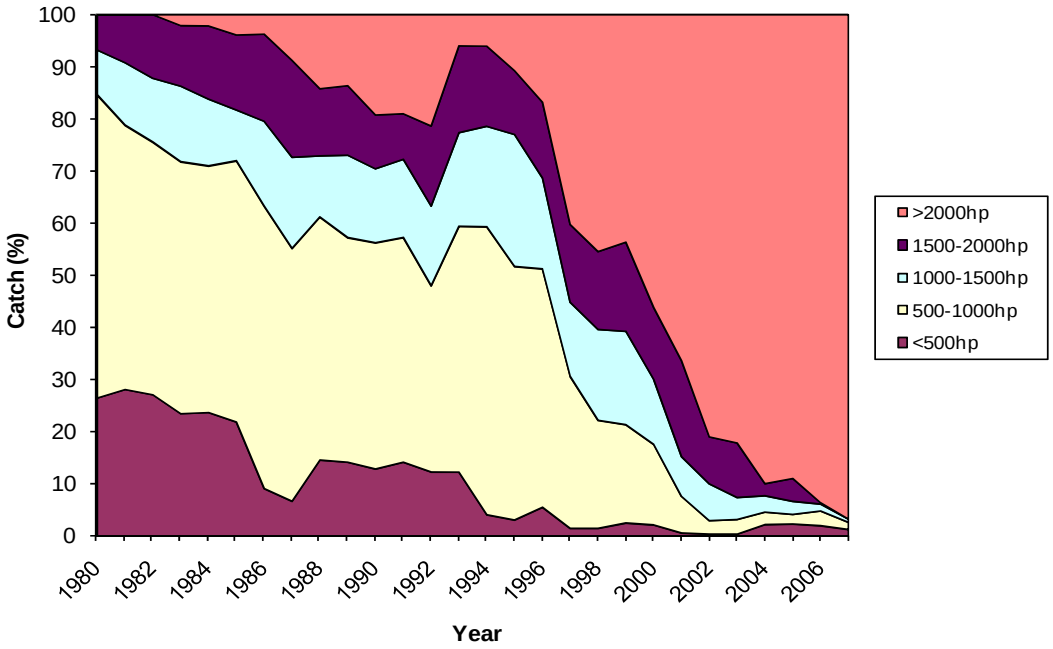

Fig. 4. Shrimp in the Barents Sea: Percentage of total catch taken by 5 fleet components separated by engine size (HP= horse-powers) 1980-2007.

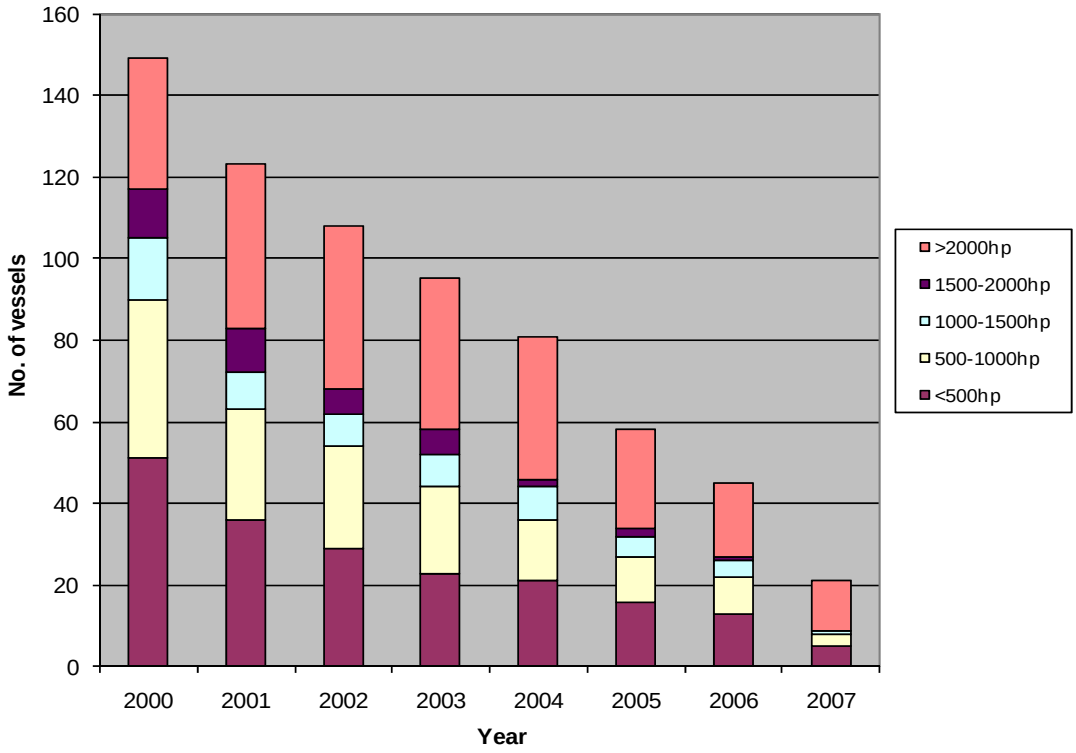

Fig. 5. Shrimp in the Barents Sea: Number of vessels participating in the fishery 2000-2007. The 5 fleet components are separated by engine size (HP= horse-powers). Norwegian data.

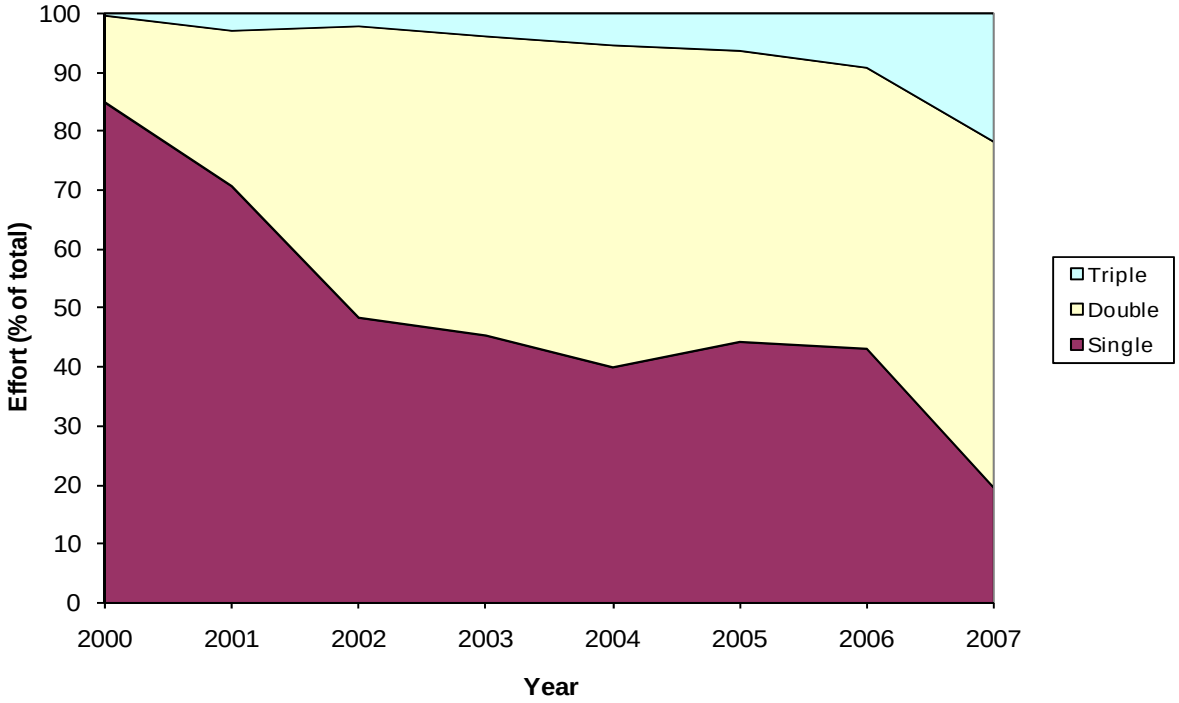

Fig. 6. Shrimp in the Barents Sea: Percentage of total fishing effort spent by using single, double or triple trawls 2000-2007. Norwegian data.

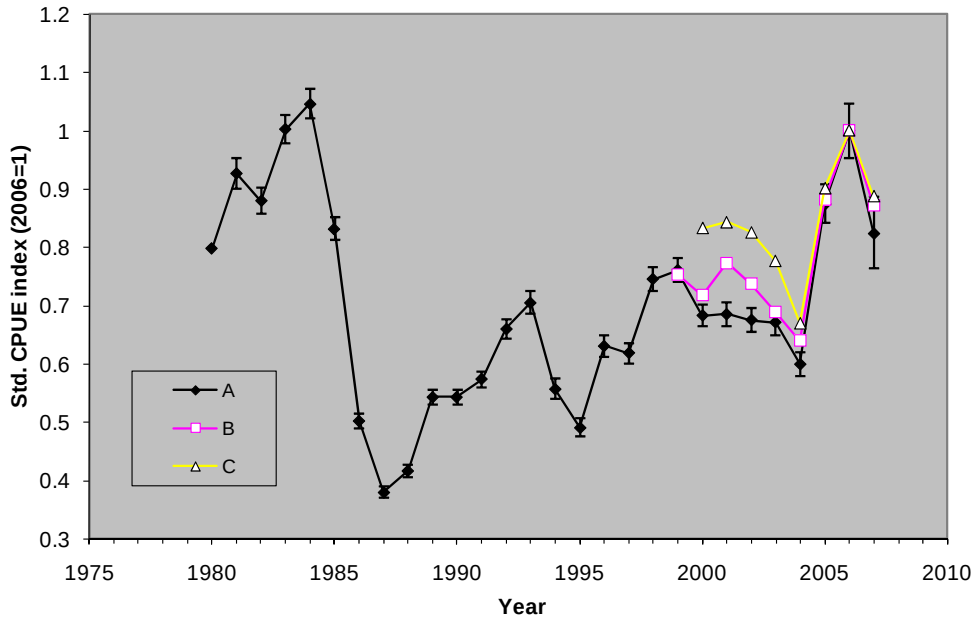

Fig 7. Shrimp in the Barents Sea: Standardised CPUE based on (A) vessels grouped by engine size, (B) only hauls positively reported as double and triple trawls, (C) individual vessels as the unit of fishing power. Norwegian data.

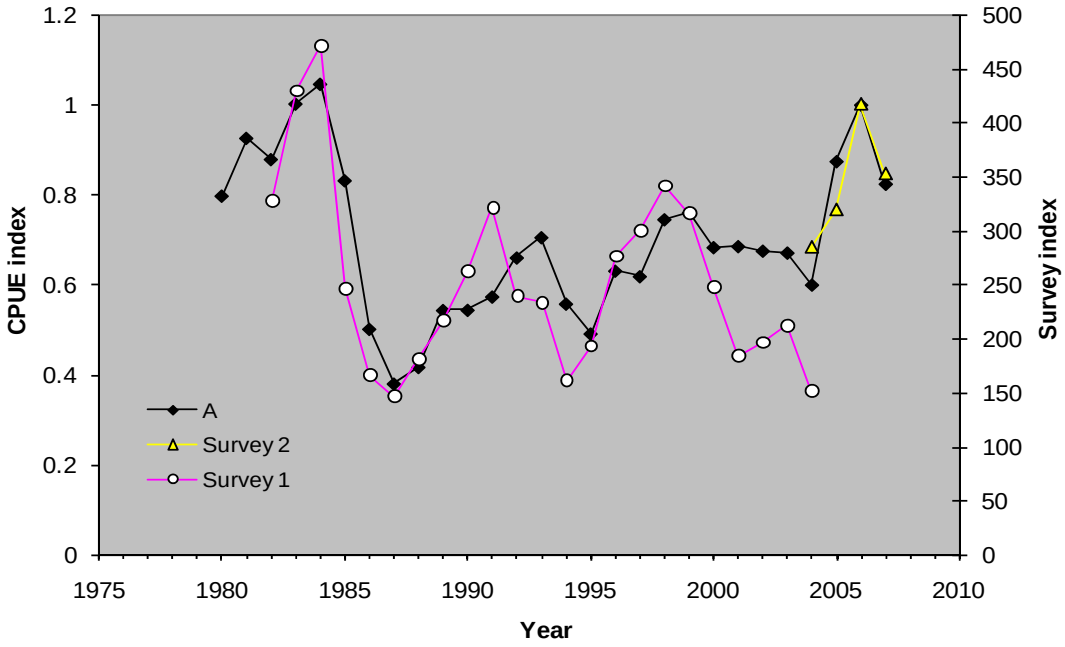

Fig 8. Shrimp in the Barents Sea: Standardised CPUE (A) and survey indices.

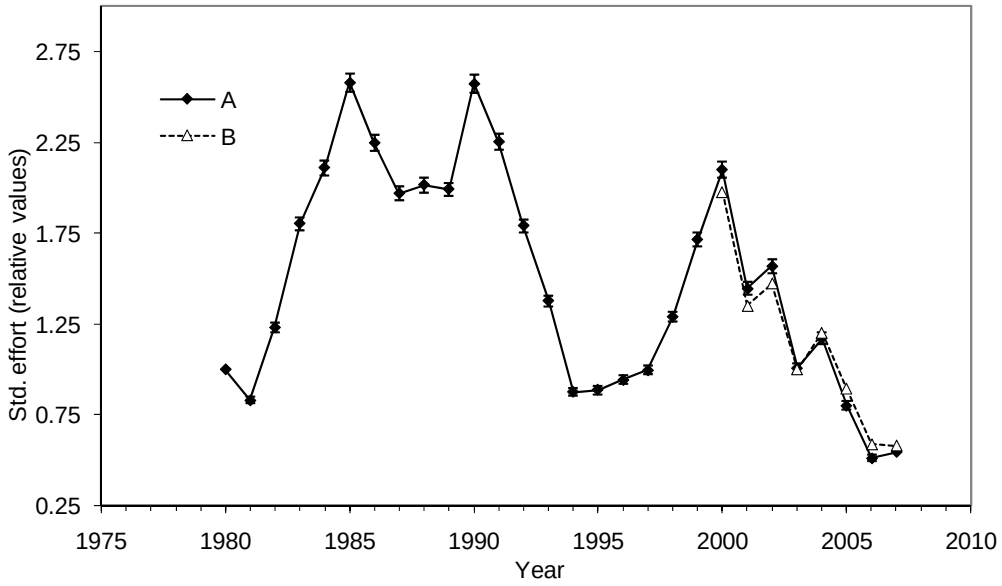

Fig 9. Shrimp in the Barents Sea: Standardised effort. (A) vessels grouped by engine size, (B) individual vessels as the unit of fishing power Norwegian data.

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             3  55 58 59
vessel           5  1 2 3 4 5
year            28  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 2007 2080
month           12  1 2 3 4 5 6 7 8 9 10 11 12
                         Number of Observations Read      102882
Dependent Variable: lncpue
Weight: effort
```

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	51	953720.624	18700.404	2861.06	<.0001
Error	102830	672114.867	6.536		
Corrected Total	102881	1625835.491			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.586603	49.15270	2.556594	5.201331

Source	DF	Type III SS	Mean Square	F Value	Pr > F
strata	7	42379.6756	6054.2394	926.27	<.0001
year	27	253724.1185	9397.1896	1437.72	<.0001
gear	2	14343.7114	7171.8557	1097.26	<.0001
vessel	4	138393.2128	34598.3032	5293.36	<.0001
month	11	72308.6627	6573.5148	1005.71	<.0001

Parameter		Estimate		Standard Error	t Value	Pr > |t|
Intercept		6.320116283	B	0.02228619	283.59	<.0001
strata	A	-0.252613760	B	0.00606434	-41.66	<.0001
strata	B	0.010502265	B	0.00573669	1.83	0.0671
strata	C	0.038547519	B	0.00529242	7.28	<.0001
strata	D	-0.011319191	B	0.01166646	-0.97	0.3319
strata	E	0.199475551	B	0.00457436	43.61	<.0001
strata	F	0.006690562	B	0.01209237	0.55	0.5801
strata	G	0.043240389	B	0.00775811	5.57	<.0001
strata	H	0.000000000	B	.	.	.
year	1981	0.149496867	B	0.01124913	13.29	<.0001
year	1982	0.097162192	B	0.01014309	9.58	<.0001
year	1983	0.228704933	B	0.00956895	23.90	<.0001
year	1984	0.271577553	B	0.00951765	28.53	<.0001
year	1985	0.042067047	B	0.00950750	4.42	<.0001
year	1986	-0.464331378	B	0.00990341	-46.89	<.0001
year	1987	-0.742815963	B	0.01036571	-71.66	<.0001
year	1988	-0.649920553	B	0.00990671	-65.60	<.0001
year	1989	-0.384204666	B	0.00943047	-40.74	<.0001
year	1990	-0.383435702	B	0.00929484	-41.25	<.0001
year	1991	-0.330450818	B	0.00986309	-33.50	<.0001
year	1992	-0.189246428	B	0.01023785	-18.48	<.0001
year	1993	-0.123137638	B	0.01071604	-11.49	<.0001
year	1994	-0.358519040	B	0.01266670	-28.30	<.0001
year	1995	-0.485415934	B	0.01258806	-38.56	<.0001
year	1996	-0.234691362	B	0.01191567	-19.70	<.0001
year	1997	-0.254491464	B	0.01146386	-22.20	<.0001
year	1998	-0.068056723	B	0.01115801	-6.10	<.0001
year	1999	-0.047747157	B	0.01059658	-4.51	<.0001
year	2000	-0.155123760	B	0.01040369	-14.91	<.0001
year	2001	-0.151603842	B	0.01156761	-13.11	<.0001
year	2002	-0.166604919	B	0.01223165	-13.62	<.0001
year	2003	-0.173042863	B	0.01313773	-13.17	<.0001
year	2004	-0.285078688	B	0.01373875	-20.75	<.0001
year	2005	0.091983629	B	0.01530796	6.01	<.0001
year	2006	0.226273067	B	0.01867583	12.12	<.0001
year	2007	0.032896211	B	0.02970062	1.11	0.2680
year	2080	0.000000000	B	.	.	.
gear	55	-0.599854460	B	0.01939819	-30.92	<.0001
gear	58	-0.278444606	B	0.01848984	-15.06	<.0001

gear	59	0.000000000 B	.	.	.
vessel	1	-0.847721036 B	0.00604551	-140.22	<.0001
vessel	2	-0.575945180 B	0.00500477	-115.08	<.0001
vessel	3	-0.482277733 B	0.00547838	-88.03	<.0001
vessel	4	-0.293029882 B	0.00563938	-51.96	<.0001
vessel	5	0.000000000 B	.	.	.
month	1	0.205952158 B	0.01189556	17.31	<.0001
month	2	0.170771333 B	0.01223800	13.95	<.0001
month	3	0.288017245 B	0.01140931	25.24	<.0001
month	4	0.226367551 B	0.01038524	21.80	<.0001
month	5	0.144529217 B	0.00988936	14.61	<.0001
month	6	0.155366605 B	0.00983029	15.80	<.0001
month	7	0.082091935 B	0.00988983	8.30	<.0001
month	8	0.015331106 B	0.00993841	1.54	0.1229
month	9	-0.173032665 B	0.01020907	-16.95	<.0001
month	10	-0.408343920 B	0.01109486	-36.80	<.0001
month	11	-0.172054686 B	0.01085199	-15.85	<.0001
month	12	0.000000000 B	.	.	.