Northwest Atlantic Fisheries Organization

Serial No. N5992 **NAFO SCR Doc. 11/66**

NAFO/ICES WG *PANDALUS* ASSESSMENT GROUP – OCTOBER 2011

The Norwegian fishery for northern shrimp (*Pandalus borealis*) in the Barents Sea and round Svalbard 1970-2011

by

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Abstract

The resource of northern shrimp (*Pandalus borealis*) in the Barents Sea is considered as one stock unit. The fishery is multinational. Catches have ranged between 20 and 128 ktons since the mid 1970s. Norway accounts for 75-92% 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 21 ktons in 2010 due to reduced market prices for shrimp products, and a major restructuring of the fleet has taken place. Catches in 2011 are projected at 23 ktons. A standardised catch-per-unit-effort series indicates a decline in stock density from 2000 to 2004 and an increase thereafter to a peak in 2006. The indices for 2007 to 2011 have been fluctuating 5-10% below the 2006 peak. A standardised effort series indicates a declining trend in fishing mortality since 2000.

Introduction

The resource of northern shrimp (*Pandalus borealis*) in the Barents Sea within the Norwegian EEZ and in the Svalbard zone (ICES Div I and II) is for assessment purposes considered as one stock (Fig. 1). 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 128 ktons in 1984 (Fig. 2). During the recent 10-year period annual yields have varied between 21 and 61 ktons. Norwegian vessels accounted for around 75-92% of the total catches and vessels from Russia, Iceland, Greenland and the EU for the rest (Table 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 are regulated by number of effective fishing days and number of vessels by country. Minimum cod-end mesh size is 35 mm. Other species and small shrimp are protected by mandatory sorting grids and by the temporary closing of areas with excessive by-catch of juvenile cod, haddock, Greenland halibut, redfish and shrimp <15 mm 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 few large factory trawlers (>3000HP (HP=engine horsepower)) and a small 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, (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 1980-2004 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 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; 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 gear 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.

Results

Spatial and seasonal distribution

The fishery is mainly conducted in the Hopen area (central Barents Sea) which, along with the Svalbard shelf, is considered the most important fishing ground (Fig. 1 and 3). Logbook data from 2009 and 2011 show decreased activity in the Hopen Deep, coupled with increased effort further east in international waters in the so-called “Loop Hole”. Information from the industry points to high densities of shrimp in this area and area closures in the traditional Hopen Deep due to juvenile redfish bycatch as the main reasons for the change in fishing pattern.

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. 4).

Landings

Since the early 1980s annual landings have fluctuated with local minima and maxima separated by periods of 4-5 years (Fig. 2). Overall catches have ranged from 22 to 128 ktons. The most recent peak was seen in 2000 at approximately 83 ktons. Catches thereafter declined to 21 ktons in 2010. Based on data until August (logbooks and information from the industry) the total catch of 2011 is estimated at 23 ktons.

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 (Table 2). Redfish bycatch have been low (<7 mill/yr) in recent years. Details on by-catch are reported to AFWG (ICES, 2009).

Fleet composition and gear
A major restructuring of the fleet towards fewer and larger vessels has taken place since the mid 1990s. An average vessel had at that time around 1000 HP. 15 years later this value had increased to more than 6000 HP (Fig. 5).

Until 1996 the fishery was conducted by using single trawls only. Double trawls were then introduced and in 2002 approximately 2/3 the total effort spent was by using two trawls simultaneously (Fig. 6). In 2000 a few vessels started to experiment with triple trawls: 58% of the effort in 2010 is accounted for by this fishing method while 35% and 7% of the effort is spent using double and single trawl respectively.

Standardised CPUE
The fishery dependent index of stock density in the fished areas – 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 (Table 3, Fig. 7). Since then it has shown an overall increasing trend. A new peak was reached in 2006. The 2007 to 2011 mean values have fluctuated 5-10% below the 2006-value, but are still above the average of the series.

New methods for the calculation of this index series were introduced in 2008 (see Hvingel and Thangstad (2008)). Details and diagnostics on the GLM model fit are given in appendix 1.

Effort
Standardised effort has shown a declining trend since 2000 (Fig. 8).

References

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Table 1. Nominal landings (‘000 tons) by nation (2011 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	2.186	1.599	37.957
2004	35.918	1.170	4.211	41.299
2005	36.943	0.933	3.519	41.395
2006	27.351	0.000	2.107	29.458
2007	25.509	0.009	3.763	29.281
2008	20.953	0.371	5.130	26.454
2009	19.769	0.000	3.796	23.565
2010	16.779	0.000	4.074	20.853
2011	18.000	0.000	5.000	23.000

Table 2. Estimated bycatch of cod, haddock, Greenland halibut and redfish (no. in millions). No data for 2010-2011.

Year	Cod	Redfish	Haddock	Gr. Halibut
1983	14.57	91		
1984	12.6	167		
1985	92.41	198		
1986	10.91	18		
1987	9.87	110		
1988	5.19	46		
1989	1.5	199		
1990	9.02	94		
1991	22.52	51		
1992	25.43	78		
1993	19.23	22		
1994	4.56	23		
1995	5.92	2		
1996	17.1	25		
1997	28.69	24		
1998	67.11	3		
1999	13.43	11		
2000	7.77	15	3.72	13.94
2001	12.87	14	1.75	7.57
2002	2.46	5	9.19	0.19
2003	15.03	0.61	5.52	0.59
2004	2.66	1.1	1.22	0.33
2005	6.46	2.01		
2006	4.9	5.09		
2007	2.52	6.49		
2008	2.24	5.78		
2009	1.99	5.11		

Table 3. Realised catch-per-unit-effort (CPUE) and effort (hrs trawled), and standardised (se text) CPUE and effort as proxies for fishable biomass and fishing mortality respectively. Based on Norwegian logbook data (2011 values are estimated based on data until August).

year	Absolute		Standardised	
	CPUE	Effort	CPUE	Effort
	kg/hr	'000 hrs	index	index
1980	186	189	1.00	1.00
1981	216	152	1.19	0.81
1982	198	219	1.15	1.18
1983	231	306	1.31	1.73
1984	250	306	1.38	2.00
1985	231	356	1.15	2.35
1986	154	315	0.68	2.08
1987	116	270	0.53	1.76
1988	113	282	0.57	1.84
1989	143	330	0.72	1.88
1990	150	361	0.74	2.38
1991	171	230	0.78	2.08
1992	211	188	0.90	1.64
1993	209	159	0.97	1.25
1994	173	116	0.80	0.76
1995	150	129	0.67	0.81
1996	191	133	0.84	0.89
1997	228	127	0.80	0.97
1998	294	153	0.97	1.24
1999	295	178	1.02	1.60
2000	283	195	0.90	1.99
2001	356	121	0.91	1.37
2002	412	119	0.90	1.48
2003	386	88	0.88	0.93
2004	402	89	0.75	1.19
2005	611	60	1.04	0.86
2006	754	36	1.14	0.56
2007	840	30	1.02	0.62
2008	801	26	1.04	0.55
2009	794	25	1.06	0.48
2010	841	20	0.99	0.46
2011	790	23	1.11	0.45

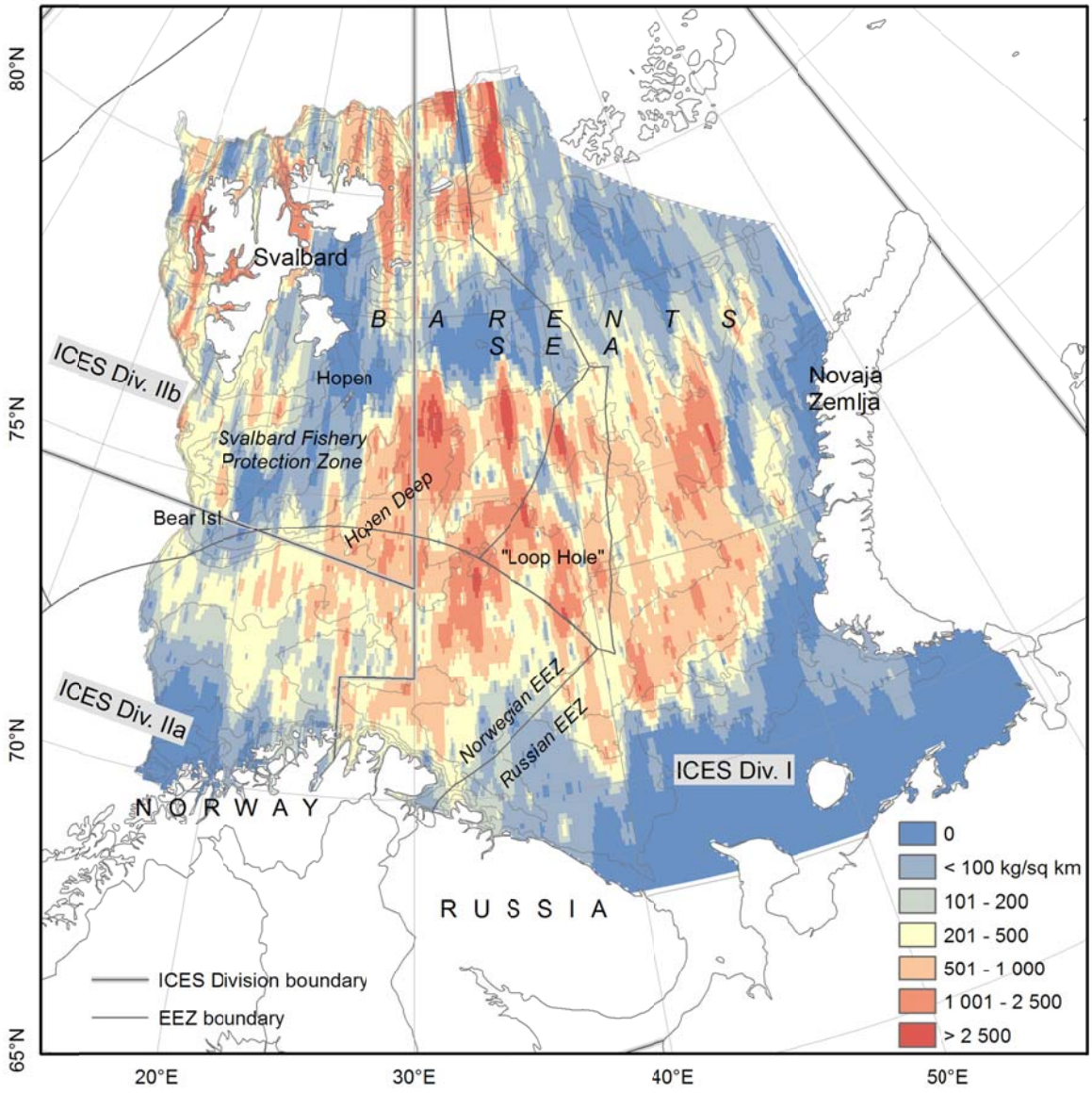

Fig. 1. Shrimp in the Barents Sea: stock distribution mean density (kg/km^2) based on survey data 2000-2010.

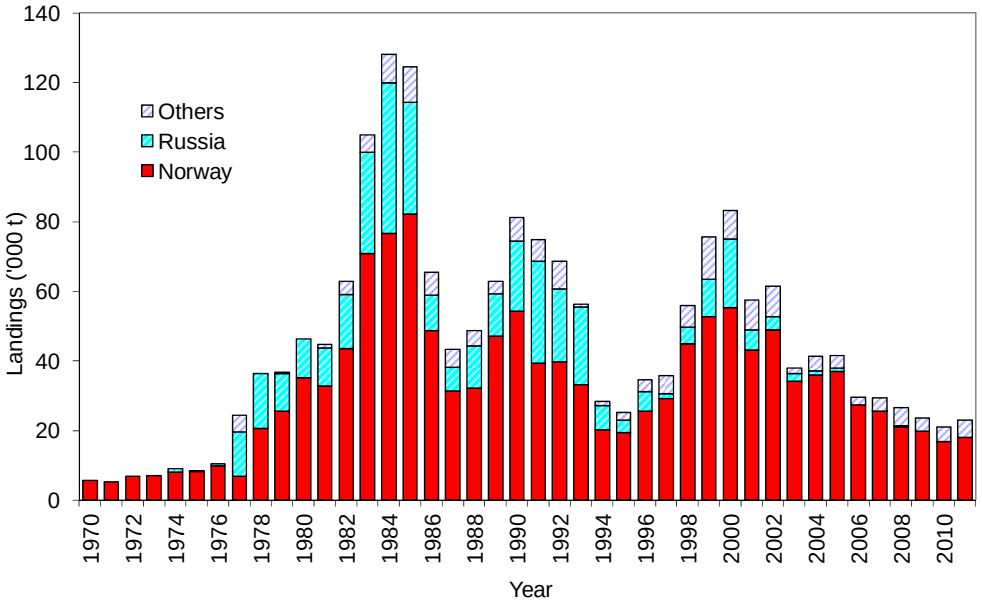

Fig. 2. Shrimp in the Barents Sea: Total annual landings. The 2010 projected value is estimated based on data until August and information from the industry.

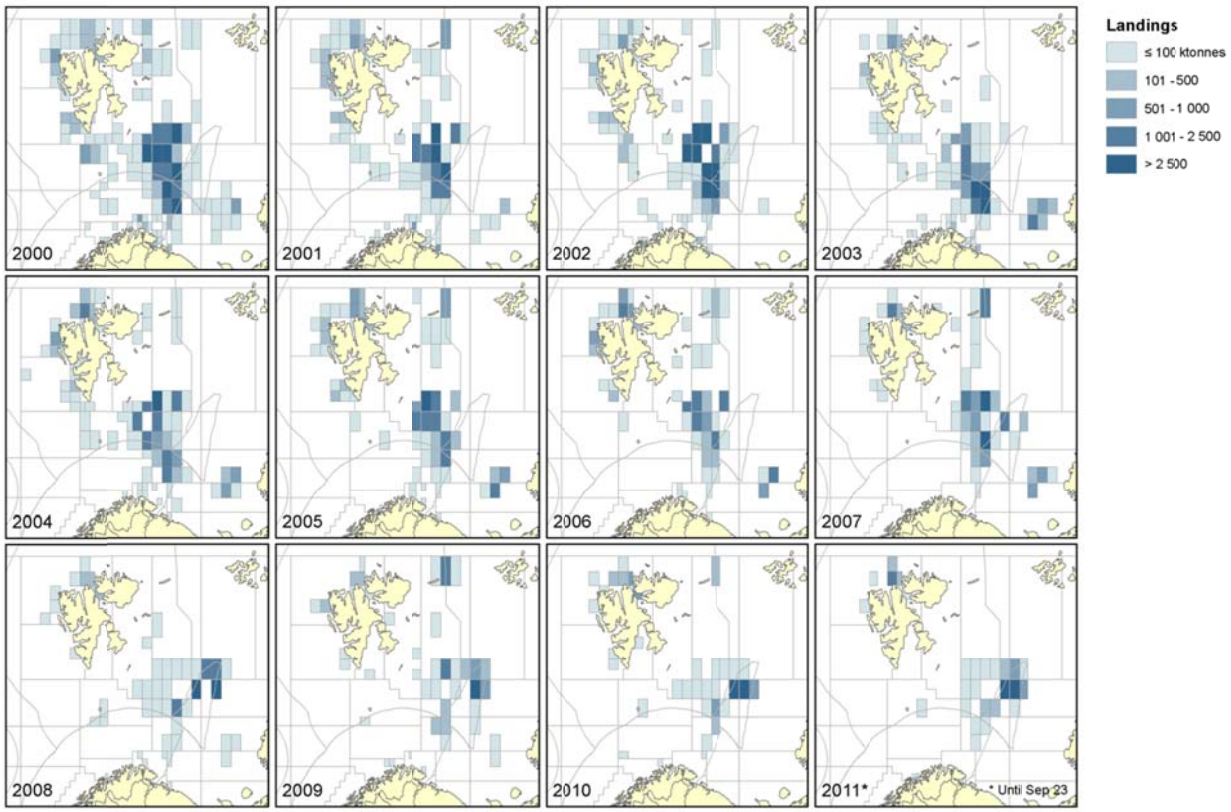

Fig. 3. Distribution of catches by Norwegian vessels 2000-2010 based on logbook information. (2011 only data until August)

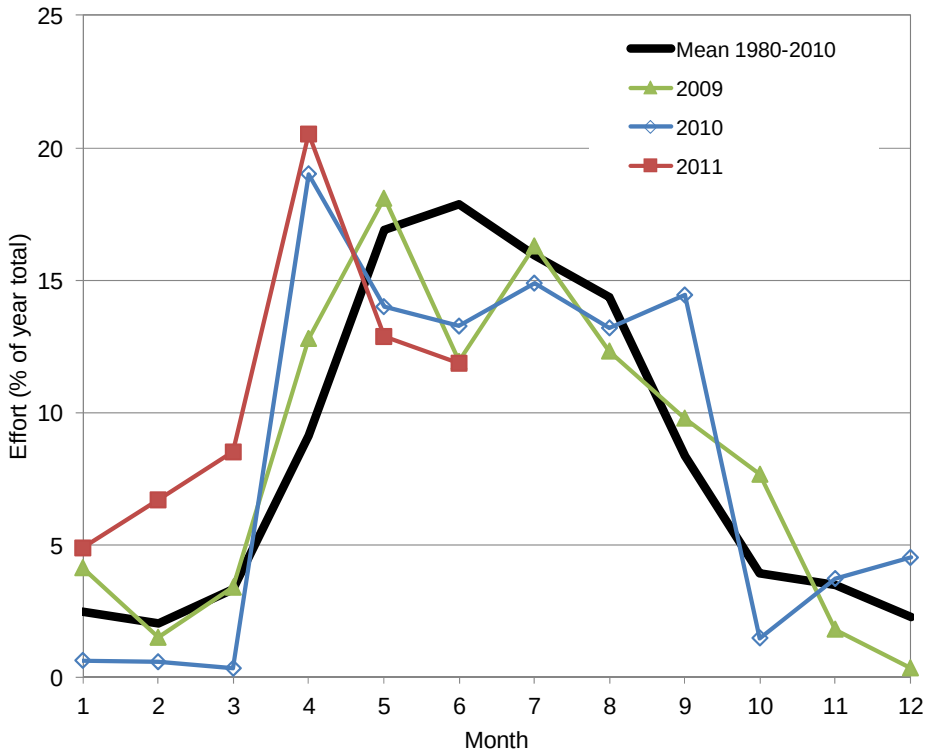

Fig. 4. Shrimp in the Barents Sea: Seasonal distribution of fishing effort 2006-may 2011 and mean 1980-2010. Hours trawled in a month as a percentage of total effort of the year. Norwegian data.

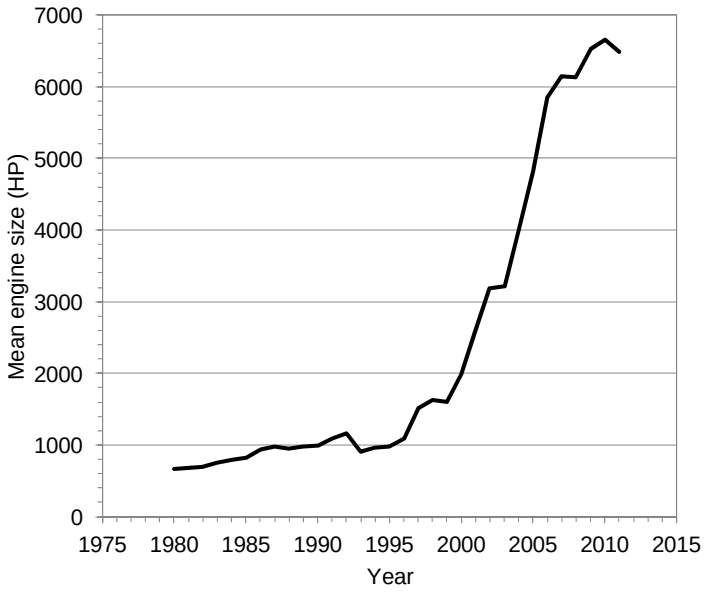

Fig. 5. Shrimp in the Barents Sea: Mean engine size (horse powers) behind an hour of trawled in the years 1980-2011.

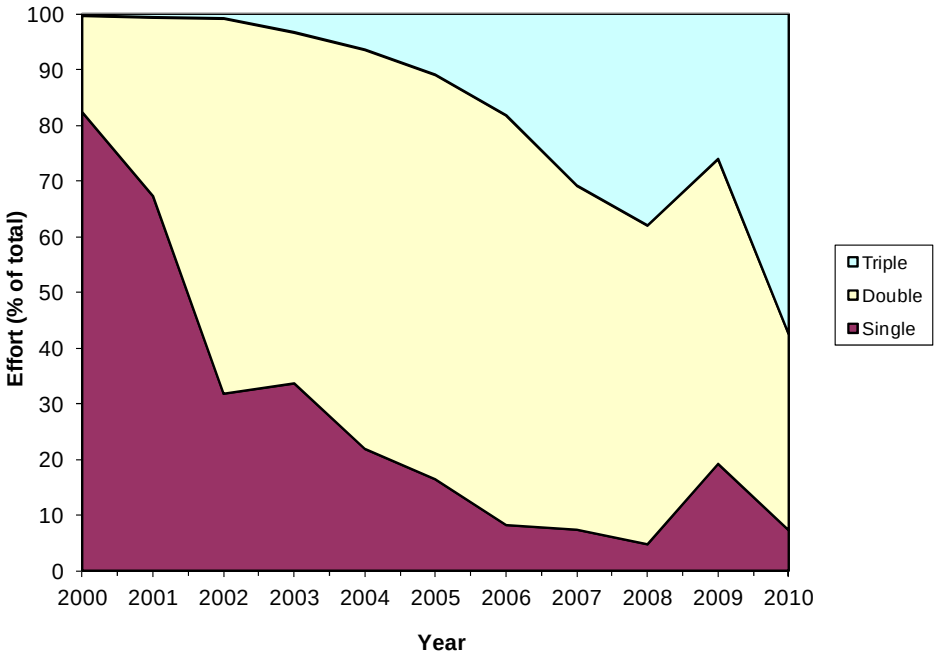

Fig. 6. Shrimp in the Barents Sea: Percentage of total fishing effort spent by using single, double or triple trawls 2000-2010. Norwegian data.

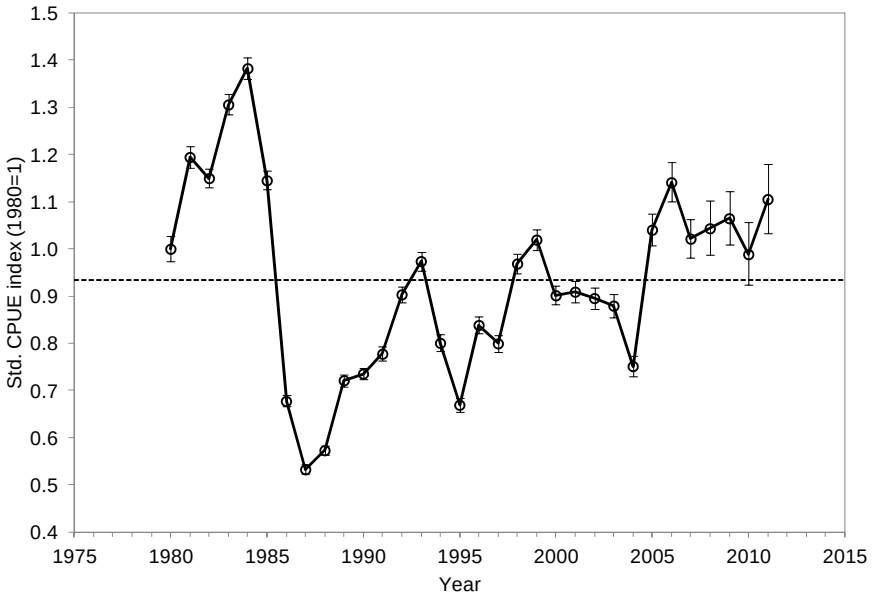

Fig 7. Shrimp in the Barents Sea: Standardised CPUE, Norwegian data.

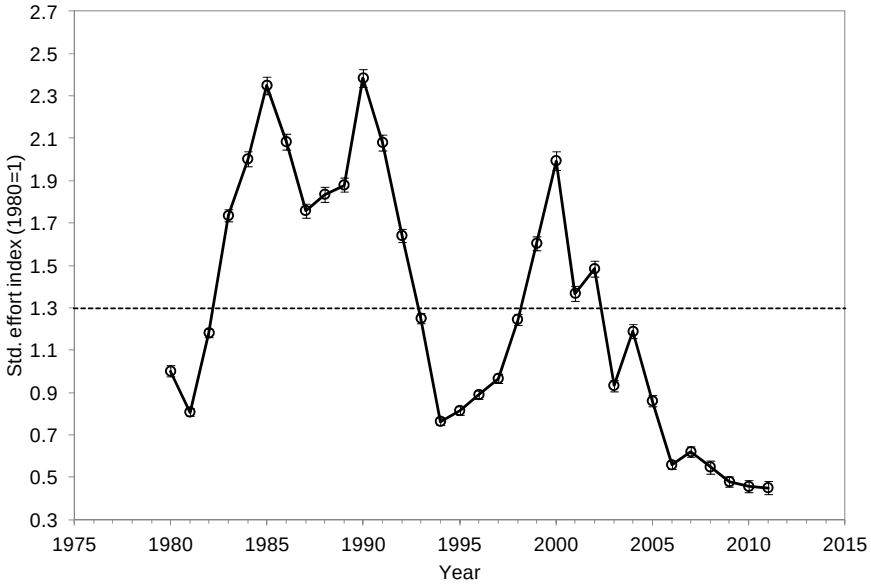

Fig 8. Shrimp in the Barents Sea: Standardised effort, Norwegian data.

Appendix 1. Output from GLM-run of the Barents Sea index. Gear 55=single trawl, grar 58=double trawl, gear 59= triple trawl. Strata definitions see Hvingel 2007. Vessels are individual vessel identification code.

Class Level Information

Class	Levels	Values
strata	8	A B C D E F G H
gear	3	55 58 59
vessel	426	Not listed
year	31	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 2008 2009 2010 2011
month	12	1 2 3 4 5 6 7 8 9 10 11 12

Number of Observations Read 207950
Number of Observations Used 207950

Dependent Variable: lncpue
Weight: effort

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	476	981018.547	2060.963	541.24	<.0001
Error	207473	790031.531	3.808		
Corrected Total	207949	1771050.078			

R-Square	Coeff Var	Root MSE	lncpue Mean
0.553919	37.53034	1.951378	5.199468

Source	DF	Type III SS	Mean Square	F Value	Pr > F
strata	7	16710.6173	2387.2310	626.92	<.0001
year	30	146005.6615	4866.8554	1278.10	<.0001
gear	2	189.5406	94.7703	24.89	<.0001
vessel	426	2339.8158	5.4925	1.44	<.0001
month	11	57398.9549	5218.0868	1370.34	<.0001

Parameter		Estimate	Standard Error	t Value	Pr > |t|
Intercept		3.788161370 B	2397.661417	0.00	0.9987
strata	A	-0.087839086 B	0.005465	-16.07	<.0001
strata	B	0.065604096 B	0.004842	13.55	<.0001
strata	C	0.069601686 B	0.004521	15.40	<.0001
strata	D	0.022566671 B	0.009464	2.38	0.0171
strata	E	0.192740707 B	0.003789	50.86	<.0001
strata	F	0.035413272 B	0.009823	3.61	0.0003
strata	G	0.015416540 B	0.005582	2.76	0.0058
strata	H	0.000000000 B	.	.	.
year	1981	0.177663212 B	0.009763	18.20	<.0001
year	1982	0.139420368 B	0.008554	16.30	<.0001
year	1983	0.266612228 B	0.008285	32.18	<.0001
year	1984	0.323812187 B	0.008506	38.07	<.0001
year	1985	0.135711399 B	0.008625	15.74	<.0001
year	1986	-0.388958636 B	0.008903	-43.69	<.0001
year	1987	-0.629097901 B	0.009445	-66.61	<.0001
year	1988	-0.556159779 B	0.009138	-60.86	<.0001
year	1989	-0.326199760 B	0.008795	-37.09	<.0001
year	1990	-0.307007996 B	0.008746	-35.10	<.0001
year	1991	-0.251321201 B	0.009235	-27.21	<.0001
year	1992	-0.101622343 B	0.009524	-10.67	<.0001
year	1993	-0.026170367 B	0.009982	-2.62	0.0087
year	1994	-0.221571621 B	0.011034	-20.08	<.0001
year	1995	-0.400533704 B	0.011068	-36.19	<.0001
year	1996	-0.175493630 B	0.010727	-16.36	<.0001
year	1997	-0.223408305 B	0.010933	-20.44	<.0001
year	1998	-0.031484969 B	0.010691	-2.95	0.0032
year	1999	0.019587644 B	0.010524	1.86	0.0627
year	2000	-0.103006482 B	0.011041	-9.33	<.0001
year	2001	-0.094205381 B	0.012381	-7.61	<.0001
year	2002	-0.108406744 B	0.012975	-8.35	<.0001
year	2003	-0.126253364 B	0.014066	-8.98	<.0001
year	2004	-0.282830319 B	0.014035	-20.15	<.0001
year	2005	0.043746098 B	0.015855	2.76	0.0058
year	2006	0.135970157 B	0.018389	7.39	<.0001
year	2007	0.029552180 B	0.019882	1.49	0.1372
year	2008	0.052976105 B	0.027639	1.92	0.0553
year	2009	0.068286548 B	0.026197	2.61	0.0091
year	2010	0.044148789 B	0.046993	0.94	0.3475
year	2011	0.000000000 B	.	.	.
gear	55	-0.128391395 B	0.027737	-4.63	<.0001
gear	58	-0.067951058 B	0.026327	-2.58	0.0099
gear	59	0.000000000 B	.	.	.

vessel	Not listed					
month	1	0.215545460	B	0.009192	23.45	<.0001
month	2	0.166173019	B	0.009586	17.33	<.0001
month	3	0.280863335	B	0.008971	31.31	<.0001
month	4	0.206229358	B	0.008112	25.42	<.0001
month	5	0.138116319	B	0.007707	17.92	<.0001
month	6	0.131639337	B	0.007672	17.16	<.0001
month	7	0.076368745	B	0.007719	9.89	<.0001
month	8	0.016241507	B	0.007751	2.10	0.0361
month	9	-0.156071510	B	0.007967	-19.59	<.0001
month	10	-0.385197883	B	0.008643	-44.57	<.0001
month	11	-0.185277822	B	0.008403	-22.05	<.0001
month	12	0.000000000	B	.	.	.

Plot of STUDENT*ESTIMATE. Legend: A = 1 obs, B = 2 obs, etc.