SESSION 3: Crustaceans

Shrimp

M. Aschan[1], S. Bakenev[2], B. Berenboim[2] and K. Sunnanå[1]: Management of the shrimp fishery (*Pandalus borealis*) in the Barents Sea and Spitsbergen area.

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Stock characteristics

The shrimp (*Pandalus borealis*) is a protandric hermaphrodite that changes sex from male to female at an age of four to seven years in the Northeast Atlantic (Nilssen and Hopkins 1991). The shrimp spawns in autumn and the females carry their eggs as out roe until spring, when the larvae hatch. Within a period of two to three months the shrimp larvae pass through seven developmental stages whereafter they settle on the bottom (Shumway et al. 1985, Bergstrøm 2000).

The shrimp is an opportunistic omnivorous feeder and its food may consist of polychaetes, mollusca, crustaceans as well as detritus. It is an important prey for cod, ray, long rough dab and Greenland halibut. In the Barents Sea it is distributed from the North Norwegian coast to North and East of Svalbard at depths of 100-600m. The highest historical densities have been observed in the Hopen deep.

Genetic investigations have demonstrated that there are no distinct sub-populations in the open sea, and that there is a high degree of genetic variance among individuals within each location (Drengstig *et al.* 2000, Martinez *et al*. 1997). Shrimp in the North Norwegian fjords are considered to be isolated populations. Genetic gradients related to geographic distance and sea currents have been identified in the open sea. Data on larval hatching, development, and behaviour of shrimp larvae have been obtained from field and laboratory experiments and have been used as input data for particle tracking and biological models. This reveals that the majority of shrimp larvae settle approximately 80 km from the spot where they have hatched (Pedersen *et al*. 2002). For this reason, the shrimp in the Barents Sea and Svalbard area is considered as one stock.

History of the Fishery

Norwegian vessels began to exploit the shrimp fisheries in the Barents Sea and Svalbard area in 1970. Russian vessels entered the shrimp fishery in 1974. The catches increased continuously (Figure 1.) until 1984 when the total catch reached a maximum of 128 000 t. By that time vessels from other countries had entered the fishery. Since then, biomass and catch levels have fluctuated due to variation in recruitment, predation by cod and fishing effort. The catch peaked at 81 000 tonnes in 1990 and at 82 000 tonnes in 2000, and the lowest catch was 25 000 tonnes in 1995.

Reported landings for 2002 for all countries are 60 000 tonnes, however, the preliminary estimate for 2003 is around 36 000 tonnes.

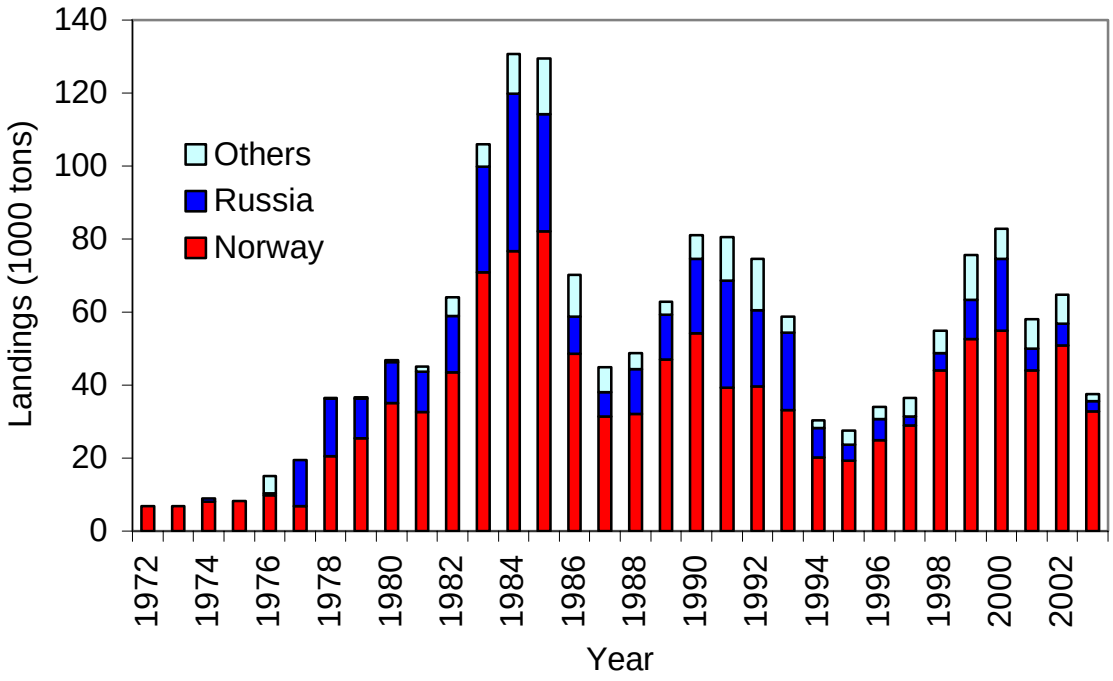

Figure 1. Shrimp landings from ICES areas I, IIa and IIb by Norway, Russia and other countries in the period 1970–2003.

Management strategy

Fisheries regulation

There is no direct regulation of the shrimp fishery with the aim of maintaining a stable standing stock and a good annual catch. In the Svalbard area the shrimp fisheries are regulated by number of effective fishing days and number of vessels by country. Fishing grounds are closed if by-catch limits defined as number of individuals of other species per 10 kg of shrimp are exceeded. In 2003 the values of permitted by-catch were set at eight for the sum of cod and haddock, ten for redfish and three for Greenland halibut. The Norwegian shrimp fishery is also regulated by smallest allowable shrimp size (maximum 10% of catch weight may be < 15 mm carapace length, CL) and by provisions of the fishing licences. In the Russian Economic Zone, a TAC is established each year by the Russian authorities. The assessment and prognosis are based on analysis of logbook statistics from the shrimp fishery and annual surveys.

Fishing effort and CPUE

Catch, effort, and annual CPUE series for Norway and Russia are presented in Figure 2. Since the late 90s, the Norwegian shrimp fleet has been upgraded by the introduction of new vessels and multi-trawl systems. In the logbooks, the use of these trawl types have been difficult to register and thus make them available for further use. This problem has now been overcome and revised series of catch per unit of effort (CPUE), effort and corresponding catch have been made. The Norwegian data show a peak in effort in 2000, at the same level as the earlier peaks in 1985 and 1990. The Norwegian effort decreased in 2001. The Russian series of effort data is unchanged and both series show an increase in effort in 2002. The CPUE of the Russian fleet (vessels<1300hp) has fluctuated in accordance with the shrimp biomass (Berenboim *et al.* 2001, Figure 2). The revised Norwegian series show the same trend. It

should be noted that the Russian fleet is also under development and the effort is thereby likely to increase.

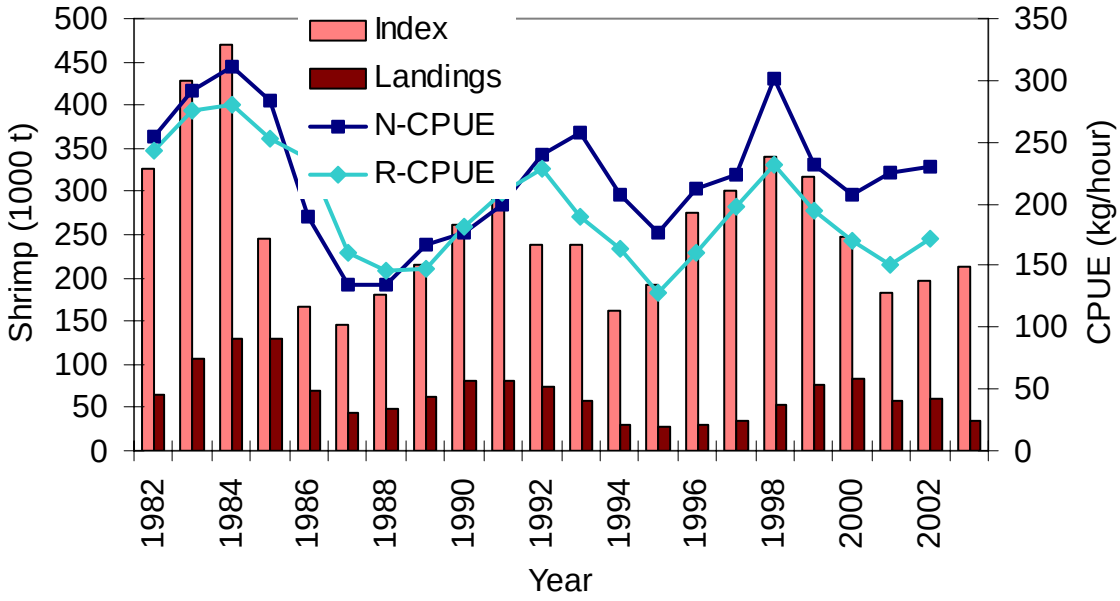

Figure 2. Biomass indices from the Norwegian surveys, total landings and Norwegian and Russian CPUE for ICES areas I, IIa and IIb.

Survey results

The shrimp surveys have been conducted since the early 80s and are believed to provide a good swept area index of the shrimp stock size (Aschan and Sunnanå 1997). There is a strong correlation between the Norwegian and the Russian survey results (Figure 3).

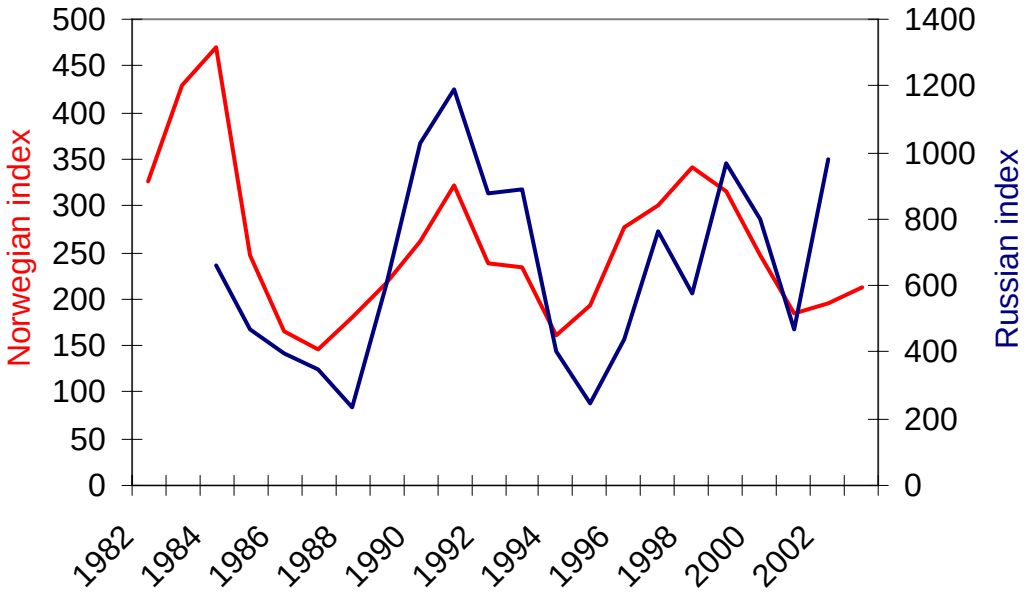

Figure 3. Shrimp biomass indices from Norwegian and Russian surveys in the Barents Sea and Spitsbergen area in 1982-2003. The Russian survey was not conducted in 2003

Unfortunately, no Russian shrimp survey was conducted in 2003. Biomass indices were highest in 1984, and have since fluctuated between 30% and 60% of this level, with peaks in

1991 and 1998-1990 and low values in 1987-1988, 1994-1995 and 2001. Norwegian and Russian bottom trawl surveys indicate an increase in shrimp biomass in the Barents Sea and Svalbard area of 6% and 109% respectively from 2001 to 2002 (Tables 1 and 2). The main survey areas are shown in Figure 4. The increase in biomass may be explained by the average strength of the 1998 and 1999 year-classes following the weak 1996 and 1997 year-classes (Table 3, Aschan *et al.* 2000) and a decline in predation by cod (Korzhev and Berenboim 2003; Berenboim *et al*. 2001) (Figure 5).

Table 1. Indices of shrimp biomass from Norwegian surveys in 1982-2002 by main areas.

Main area	A East Finnmark	B Tiddly Bank	C Thor Iversen Bank	D Bear Island Trench	E Hopen	F Bear Island	G Storfjord Trench	H Spits-bergen	Total	Sum. A,B,C, E
Strata	1 - 4	6 - 7	10 - 12	5, 8, 9, 13	14 - 18, 24	19 - 22 31 - 40	41 - 50	51 - 70		
1982	35	34	44	53	66	56	17	22	327	179
1983	40	57	61	53	112	52	21	33	429	270
1984	40	51	64	60	141	66	20	29	471	296
1985	23	17	27	18	96	31	17	17	246	163
1986	10	7	13	25	57	34	10	10	166	87
1987	29	13	18	23	31	10	9	13	146	91
1988	26	18	18	36	32	24	13	14	181	94
1989	41	17	13	17	33	53	22	20	216	104
1990	31	13	25	42	58	43	27	23	262	127
1991	22	28	22	54	120	44	21	10	321	192
1992	18	22	33	37	62	38	14	15	239	135
1993	17	19	32	29	85	20	12	19	233	153
1994	19	8	13	15	52	33	9	12	161	92
1995	10	10	11	17	83	33	16	13	193	114
1996	21	8	26	26	110	42	21	22	276	165
1997	24	34	20	34	116	44	12	16	300	194
1998	18	24	41	26	120	72	12	28	341	203
1999	17	19	23	21	169	31	21	16	316	227
2000	14	29	25	26	102	29	10	12	247	170
2001	*18*	10	30	15	61	25	*10*	*17*	**184**	118
2002	*11*	18	28	16	86	18	*9*	*10*	**196**	143
2003	15	17	36	12	94	15	8	15	**212**	162
% 03/02	*38*	-3	30	-22	9	-19	-12	49	**6**	14

Table 2. Indices of shrimp biomass (1000 t) from Russian survey in the 1984-2002 by main areas. Catchability of 0.182 is used in the estimate.

Main Area	A East Finmark	B Tiddly Bank	C Thor Iversen Bank	E Hopen	F Bear Island	G Storfiord Trench	H Spits-bergen	I Kola coast	K Goose Bank	Total	Sum. A,B,C,E
Strata	1-4	6,7,1s	10-12,25	14-18	38-40, 43-45	48-50	53-55,58-60,63-65, 58-70	2s-6s	7s-8s		
1984	38	137	99	254				133		661	528
1985	14	45	74	255		6	46	19	9	468	388
1986	9	19	44	140		42	127	9	9	399	212
1987	16	17	59	107	45	36	27	25	14	346	199
1988	14	31	39	49		22	29	36	13	233	133
1989	70	128	57	132	6	60	25	105	20	603	387
1990	90	195	119	259	14	110	30	196	15	1028	663
1991	90	153	104	541	9	70	27	155	43	1192	888
1992	80	153	92	409				65	77	876	734
1993	45	91	159	382	9		58	37	111	892	677
1994	4	35	48	255	21			14	27	404	342
1995	5	28	15	80	33	53		16	18	248	128
1996	20	98	127		21			67	108	441	245
1997	26	108	130	341				108	52	765	605
1998	14	106	136	172				108	41	576	427
1999	43	139	107	523				93	61	966	812
2000	29	73	109	328	9	39		72	141	800	539
2001	11	52	105	185	19	14	13	14	55	468	353
2002	30	129	198	353	15	39	51	70	105	980	710
% 01\00	-62	-29	-4	-44	111	-64		-81	-61	-42	-35
% 02/01	173	148	89	91	-21	179	292	400	91	109	101

Length distribution data and by-catch data have been gathered by the Norwegian monitoring programmes since 1995. In 2002 observers on board commercial Spanish vessels collected samples in the Svalbard zone. Length and sex distribution data and data on by-catch were obtained. However, such sampling is not continuous in time and space.

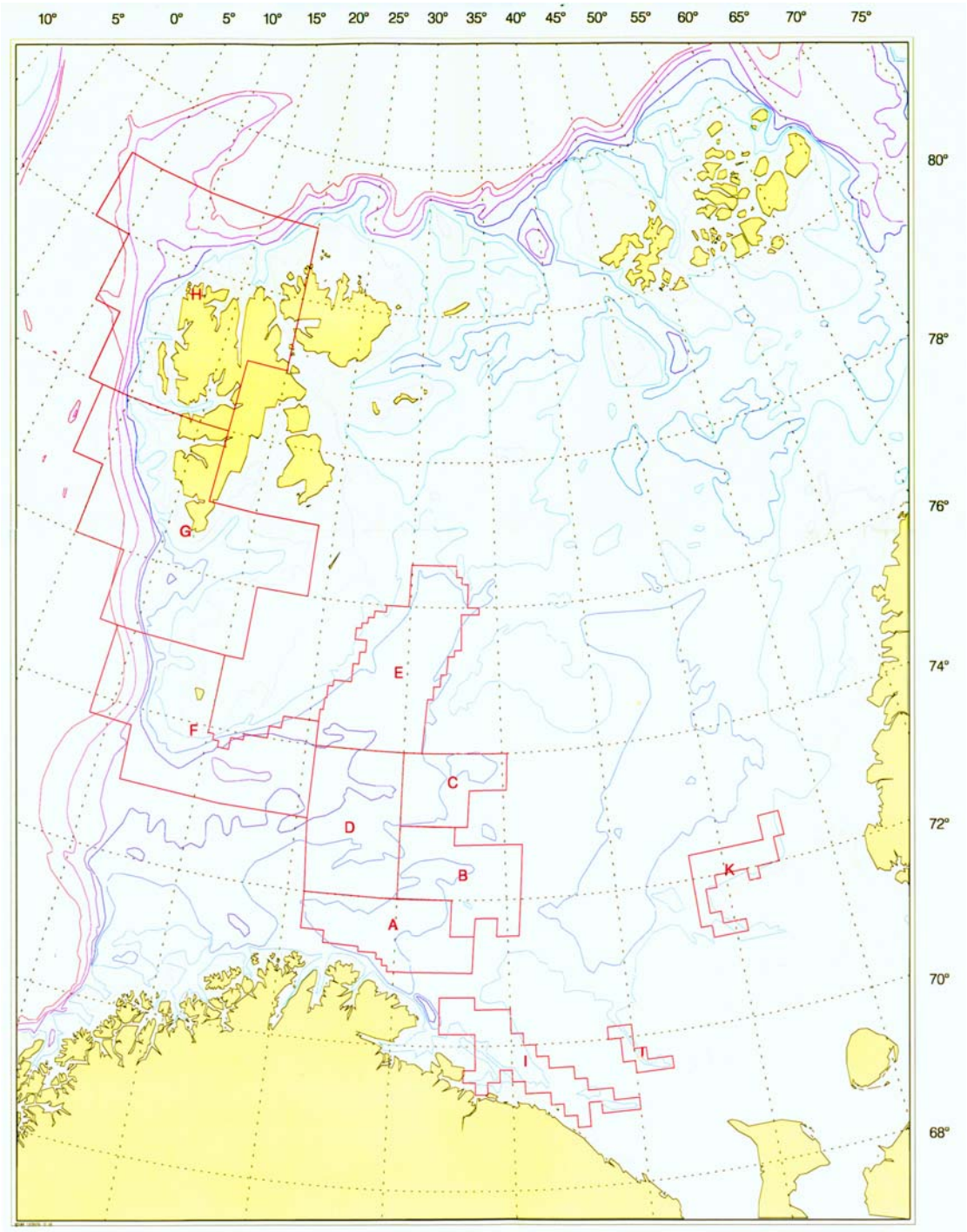

Figure 4. Survey strata are combined into 10 larger areas marked A to K. East Finnmark (A), Tiddly Bank (B), Thor Iversen Bank (C), Hopen (E), Bear Island (F), Storfjord Trench (G), Spitsbergen (H), Kola coast (I) and the Goose Bank (K).

Status of the Stock

Norwegian and Russian CPUE and survey biomass indices indicate an increase in CPUE and stock from 2001 to 2002 (Table 1 and 2, Figure 3). The Russian survey in 2002 and Norwegian surveys in 2002 and 2003 indicate a slight increase in the stock. Unfortunately, Russian scientists conducted no shrimp survey in the area in 2003. The CPUE series show that the Norwegian series is above the average and the Russian is below the average. The 1998 and 1999 year classes of average strength have probably resulted in the slight growth of

the survey index in year 2002 and 2003. The 2000-2001 year classes are of uncertain strength but may contribute to some increase in shrimp stocks in 22004 if they turn out to be of average size. The decrease in shrimp consumption by cod will probably result in an increase in the shrimp stock biomass.

Table 3. Recruitment index for shrimp in the Barents Sea defined as index of numbers in size groups according to carapace length at age in the Norwegian Barents sea survey (whole mm).

CL (mm)	age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
<9	1	0.2	4.2	2.8	3.8	4.2	0.1	0.2	0.2	0.1	0.9
9<cl<12	2	4.5	28.1	42.9	31.7	16.1	12.3	14.0	13.7	2.8	7.4
12<cl<15	3	32.6	92.1	127.9	112.8	60.6	66.9	77.9	84.4	85.7	26.4
15<cl<18	4	343.0	299.6	361.9	415.7	247.2	305.5	468.0	561.2	544.7	342.5

CL (mm)	age	2000	2001	2002
<9	1	0.5	0.0	0.2
9<cl<12	2	21.1	12.2	14.6
12<cl<15	3	70.6	44.6	54.7
15<cl<18	4	191.2	163.3	323.2

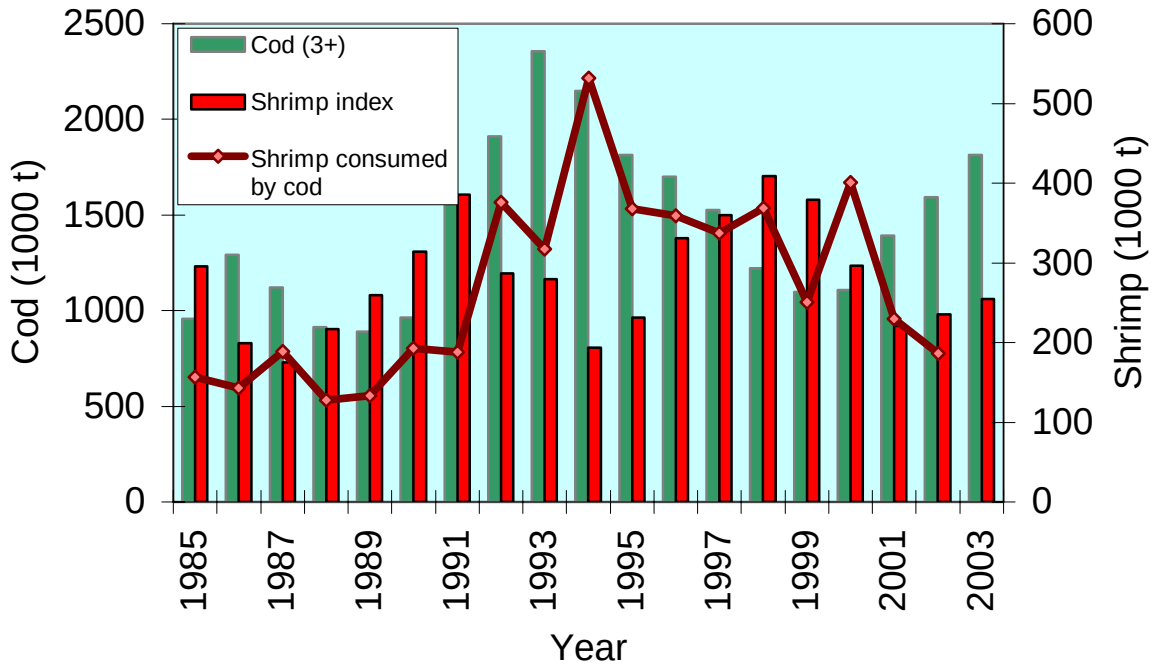

Figure 5. Shrimp biomass indices from the Norwegian surveys, biomass estimate for cod (age 3 years and older) and shrimp consumed by cod in the Barents Sea.

Assessment methods under progress

The great plasticity in shrimp growth rates and in age at sex change, as well as a lack of biological data and length distributions from the catches make it difficult to apply traditional analytical fishery assessment methods to the data. Therefore, a spreadsheet performance report (Caddy 1999, Koeller *et al.* 2001) has been used to assess the available information.

Other models have been used in assessing shrimp and some of these are listed below together with the experience gained by their use.

Production models

1) Shaefer and Fox stock models;
2) Stock production model, including predation (Stefánsson *et al.* 1994, Berenboim and Korzhev 1997);
3) Age-structured production model (Shepherd 1991);
4) Biomass dynamic models (Hilborn and Walters 1996).
5) Dynamic production model (Babayan and Kizner, 1998).

The dynamic production model introduced by Babayan and Kizner was used to assess the MSY of the Barents Sea shrimp, but since cod consumption is not included in this model the Stefánsson production model is to be preferred.

The production model elaborated by Stefánsson *et al*. (1994) for shrimp in north Icelandic waters was applied to Barents Sea shrimp data (Berenboim and Korzhev, 1997). This model considers cod and shrimp populations without dividing them into age or length groups.

Catch-at-age analysis (cohort models)

1) Single-species virtual population analysis;
2) Multi-species virtual population analysis.

For these models it is important to apply reasonable values for the natural mortality coefficient as a function of age and year, because these parameters are important in shrimp models due to high predation by cod.

Single-species VPA

Single-species VPA (Lowestoft ICES) may be used in two ways:

- To estimate total natural mortality in advance (for example with the help of a multispecies model), or
- To introduce the predator as an additional "fleet".

Multispecies model MSVPA

The MSVPA is developed in the MAWG ICES (Sparre 1984). Cod stomach data are obtained from the Joint Russian-Norwegian stomach database. Methods used in parameter estimation and preparation of input files are described in Bulgakova *et al.* (1995) and Anon. (1996).

Length at age analysis

1) Jones´ analysis (for sustainable stock);
2) Analysis including stochastic growth (Sullivan *et al*. 1991, Kunzlik 1991);
3) Fleksibest (Frøysa *et al.* 2002);
4) Bormicon – multispecies analysis (Stefánsson and Pálsson 1997).

Conclusions

Since there is no direct regulation of the shrimp fishery with the aim of maintaining a stable standing stock and a good annual catch, annual catches have fluctuated between 27 and 83 000 tonnes. The predicted great increase in the biomass of the stock due to good recruitment in 1998-2001 has not come to pass, due to greater fishing effort and higher fishing pressure on younger year classes (3-4-year-olds). Since 2000, management advice has been supplied by the ICES Arctic Fisheries Working Group, but in 2004 the advice will be prepared by the *Pandalus* Assessment Working Group, which will hold a joint meeting with the NAFO Scientific Council. The aim is to gather all scientists responsible for *Pandalus borealis* stocks in the North Atlantic in order to give the best advice.

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