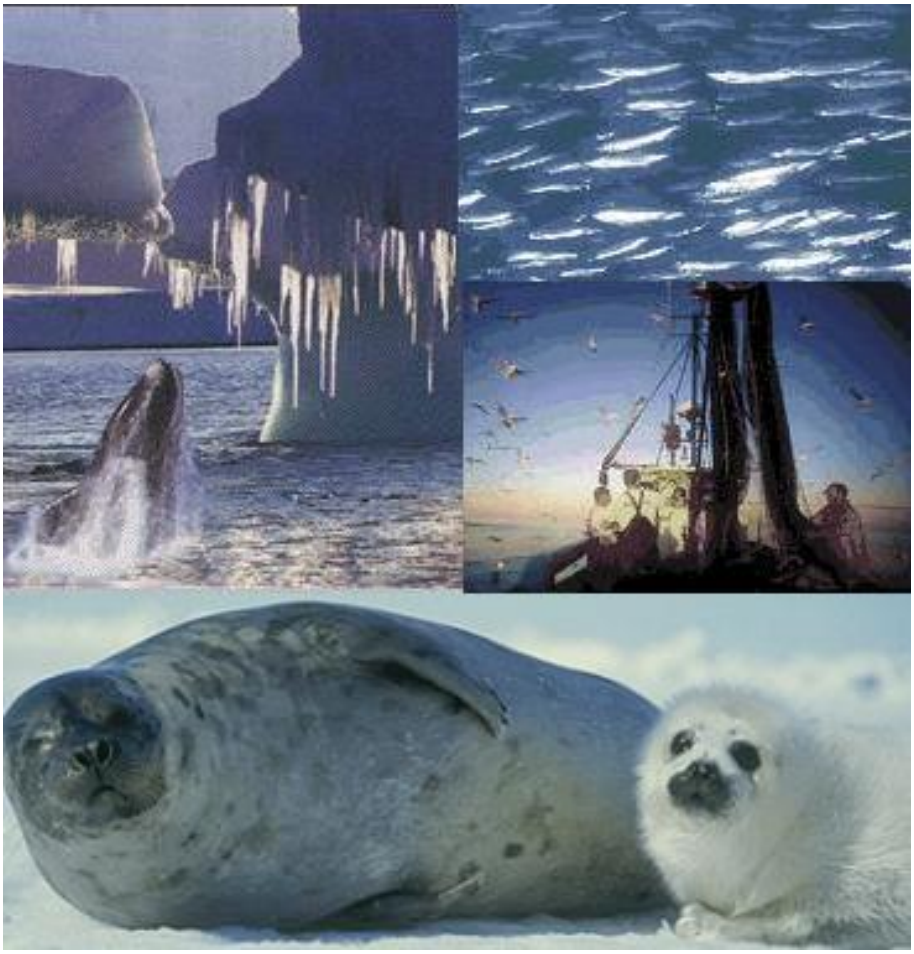
Inputs for the Scenario C simulation program.

Norwegian Computing Center
APPLIED RESEARCH AND DEVELOPMENT

NOTE



SAMBA

Sonia Mazzi

26th January 2005

Norwegian Computing Center
APPLIED RESEARCH AND DEVELOPMENT

NR Note

Title: Inputs for the Scenario C simulation program.

Date: 26th January 2005
Year: 2005
Note no.: SAMBA

Author: Sonia Mazzi <mazzi@nr.no>

Abstract: Scenario C is a model to study the effects of different management regimes of minke whaling and harp sealing on the populations of cod, herring and capelin in the Barents and Norwegian seas. This, in turn, is a useful tool to be used when implementing management practices on cod, capelin and herring. A description of the sources and processing methodologies of data to be used as part of the inputs for Scenario C is given.

Keywords: LaTeX, NR

Target group: All employees

Availability: Open

Project: SIP-Statistical Analysis of Risk / Scenario

Project no.: 830105 / 63002

Research field: Applied statistics

No. of pages: 22

Norwegian Computing Center
Gaustadalléen 23, P.O. Box 114 Blindern, NO-0314 Oslo, Norway
Telephone: +47 2285 2500, telefax: +47 2269 7660, http://www.nr.no

Contents

1 Introduction

The Barents and Norwegian Seas constitute a rich ecosystem where several fish stocks and mammals cohabitate and interact. The interaction happens mainly through a food chain where, for example, minke whales and harp seals predate on cod, capelin and herring, while cod predates on capelin, herring and young cod. Humans interact with the species by catching parts of the stocks.

A forecast of the status of the different stocks in the long run, given a scenario for the evolution of the species abundances, is of extreme importance since some of the named species are commercially exploited. The economies of Norway and Russia depend to an important extent on these fishing and whaling activities. Also, the management of present stocks will clearly influence the status of stocks in the future. It is necessary to find out certain optimal parameters presently affecting the stocks in order to prevent a situation of lack of sustainability of the stocks in the future.

Since it is not possible to carry out a real-life experiment in this situation, a computer or simulation model, called Scenario C, see Hagen et.al (1998), was created to simulate the ecosystem in the Barents and Norwegian Seas. The species considered are the ones named above namely, minke whales, harp seals, cod, capelin and herring. These species, although not the only ones found in the area, are the most abundant ones and certainly the most interesting ones from a commercial point of view. The model simulates predation between species and human intervention in the form of number of fishing fleets and set catch quotas.

The models for predation are key in the study. They have 2 components: the total food intake of an individual, by species and size, estimated from energetic considerations, and the relative diet composition, given the abundance of the various prey items in the actual area at the time. In addition to the modelled prey species, cod, capelin and herring, a category of "other food" is included. It is assumed that the abundance of "other food" is sufficient so that the modelled predators can satisfy their energy needs regardless of the abundance of the modelled prey species.

The inputs of Scenario C are of two types namely, input variables and parameters. Input variables are directly observable (e.g. historic catch data) whereas parameters are obtained using statistical inference (e.g. mortality rates).

One of the objectives at the moment is the estimation of parameters of natural mortality in excess of mortality caused by modelled predation.

In this work, however, only the observable inputs and the inputs based on observed data are described. The existing databases used as inputs to run Scenario C spanned until year 1993. We have updated these, using the surveys from 1994 until 2003. In some cases the existing inputs, data up to year 1993, had to be produced anew. In particular, new age at length distributions were produced for 1984-1993. For this purpose, information from 1995 and 2004 was used for cod and herring, respectively. The reasons for the update are that no information on how these databases before 1993 were produced and the stock estimates by age seem to differ substantially with the ones currently available.

In what follows we describe the data sources and the methodologies adopted to obtain the inputs required by Scenario C. Tables of data and summaries of estimation results are presented in the Annexes.

IMR stands for Institute of Marine Research.

2 Data sources and procedures

In this section we describe the general approach to produce the necessary inputs for Scenario C based on observed data. We differentiate the inputs based on the five species considered. The source of the observed data is IMR.

2.1 Minke Whales

For this species, data on yearly abundance and catch is needed.

Table 7 in Skaug et.al (2004) contains abundance estimates by survey region, not yearly, though. Using just the aggregated estimates for areas EB and ES, yearly abundance estimates were obtained by fitting an exponential curve by least squares. Note that we minimize the criterion $\sum y_i(\log y_i - \log A - Bx_i)^2$, where $y = Ae^{Bx}$; y denotes abundance estimate, and x is year, varying from 1983 until 2003. The least squares estimates of A and B are $\hat{\log A} = -23.75409$ and $\hat{B} = 0.01746319$. From 1952 until 1983, due to heavier exploitation, the abundance level stayed more or less at a lower constant value. Table 7 in Annex VII shows the abundance estimates from 1970 until 2003.

Table 8 in Annex VIII contains minke whale catches (units caught) in the Barents Sea. The source is the IMR "Ressursoversikt" from 1984 on. For previous years, the data was obtained from 37th report of International Whaling Commission, p.101.

2.2 Seals

The program Scenario C generates the data for seals according to the model in Skaug and Øien (2003).

2.3 Capelin

The age-length data, and weight at length class, for 1972-2003 can be obtained from

`www.assessment.imr.no/Bifrost/CapelinSeptemberData/index.html`

2.4 Cod

The Institute of Marine Research in Bergen collects age-length data in two surveys: the winter and Lofoten surveys, carried out in February and March/April, respectively, each year. In the winter survey, samples of reproductively immature cod are obtained. In the Lofoten survey mature cod are sampled.

For each year and for each of the three data sets, Lofoten, Winter, and the combination of Lofoten and Winter survey data, the modified Von Bertalanffy growth model (1) is fitted,

$$L(a) = \lambda(a) + \nu(a)\eta(a), \qquad d\lambda(a) = [J - K\lambda(a)]\, da + d\, b(a), \tag{1}$$

where η is a white noise process with variance σ^2 and ν is non–random. The process λ is a latent process and hence is not directly observable. It represents the true length at age. The constants $\nu(a)$ represent the age-specific noise-to-signal ratios. In the deterministic version of the Von Bertalanffy model, the ratio J/K is the limit of L as a tends to infinity and is interpreted as the maximum potential length that a fish can reach. The parameter K governs the rate of growth.

We obtain $\hat{\lambda}(a) = \hat{E}(\lambda(a)|\text{observed data})$, and the maximum likelihood estimates of $\nu(a)$ and σ, $\hat{\nu}(a)$ and $\hat{\sigma}$, respectively, using the data of one of the two surveys, or the combined data from the two surveys, depending on the age group. We use the data on proportion of mature cod at age in Annex III to determine which survey data to use for the estimation of the parameters. For example, in 1994 almost all fish aged 1-4 are immature and hence for these age classes we used the winter survey data. Fish aged 5-8 are a mixture of mature and immature fish and hence the combined data from both the winter and Lofoten surveys was used.

We assume that the length at age a is a random variable with the normal distribution

$$N(\hat{\lambda}(a), \hat{\nu}(a)^2\hat{\sigma}^2). \tag{2}$$

The estimates of the mean and standard deviation at age, by year, are given in Table 1. Using the yearly cod stocks by age given in Annex I, and the proportions of fish of age a and length in an interval (l_m, l_M) according to (2), we obtain the distribution of age at a certain length, as required by the Scenario C program.

Note that the cod stocks for ages 13 and above are aggregated into a single number. Since we need to differentiate between each age group, from 1-year-old to 15-year-old cod, we disaggregated the 13+-year-old category by saying that 52%, 31%, and 17% of fish in this age category are in the 13-, 14-, and 15-year-old groups, respectively. These percentages are arrived at by observing the composition of the 13+-year-old class in existing data from 1985 until 1993. The percentages are the approximate median values (so that they add up to one) of the proportions of 13-, 14-, 15-year-old fish in the 13+ category observed during 1985-1993.

Figure 1 in annex I indicates that the class born in 1983 is peculiarly abundant and remains so until death.

One of the advantages of using a model to determine the length at age distribution is that it gives a unified and consistent approach to the different challenges presented in estimating such distributions. For example, age-length data from the surveys exists only up to age 12 and hence the length distribution cannot be determined from data for ages 13, 14, 15. In this case the model is used to predict the lengths. Also, in some cases, the data is "patchy" in that no lengths or very few are recorded for a certain age but data is available for neighbouring age classes. In this case we use the model for interpolation.

Cod catch data is presented in Annex II. Observing Figure 2 we note how cod catch has decreased since around 1978.

To determine the weight at length we use the information in Annex IV.

2.5 Herring

Data on age/length for year 2004 as well as stock at age from 1994-2004 is available from IMR, Bergen. See Tables 2 and 3 in Annex VI.

The distribution at length by age was obtained for 2004 in the same way as for cod. These obtained mean and standard deviation were assumed to hold for 1984-2003 as well. Together with the data in Table 3 the distribution at length by age was obtained for 1984-2003. The reason why the distribution of age at length was re-estimated for 1984-1993 was that the estimates of stock of herring then used and the ones available now differ substantially.

Figure 2 in Annex II indicates that the class born in 1983, 1992 and 1993 are significantly highly abundant and seem to remain so during heir life span.

Catch of herring is in Annex VI, Table 4. An increase in catch is observed from 1985 on, when the former Soviet Union started fishing herring. Since 1995 on the increase in catch is quite marked since other European countries (Ireland, Netherlands, Germany, France, Poland, Sweden, Denmark), Greenland, the UK, Faroe Islands, and Iceland, started exploiting the resource as well.

3 Acknowledgements

I would like to thank Havforskningsinstituttet (Marine Research Institute), Bergen, and specially Bjarte Bogstad who kindly made possible that we received the data.

4 References

Hagen,G. and Hatlebakk,E. and Schweder,T. (1998). Scenario Barents Sea: a tool for evaluating fisheries management regimes. In *Models for Multispecies Management*. Ed. Tor Rødseth. Contributions to Economics series. Physica-Verlag.

Skaug,H.J., Øien,N. (2003). Historical population assessment when data are sparse; the case of Barents Sea harp seals (Pagophilus groenlandicus). Personal communication

Skaug,H.J., Øien,N., Schweder,T., Bøthun,G. (2004). Abundance of mink whales (Baleonoptera acutorostrata) in the Northeast Atlantic: variabiliy in time and space. *Can. J. Fish. Aquat. Sci.*. **61**. pp. 870-886.

Annex I. Cod stocks - number at age (start of year)

.

Numbers$\times 10^{-3}$. Source: IMR, Bergen.

Age	1946	1947	1948	1949	1950	1951	1952	1953
3	728139	425311	442592	468348	704908	1083753	1193111	1590377
4	577860	592530	347574	362238	382556	575973	865011	955076
5	402060	463732	473210	281072	290427	303320	401364	599477
6	197212	312115	340097	359415	198391	211595	190765	226975
7	93323	146496	208708	228044	204032	121764	131099	90099
8	96213	63939	79121	101579	112107	110900	66016	63110
9	244722	64933	40588	45487	56484	64808	60583	35603
10	101777	146581	35470	19586	25387	28785	32000	27799
11	38117	62991	77255	20227	11003	12568	14083	12237
12	39205	22142	23578	36361	8856	3651	6506	4133
13+	33324	42765	37377	21337	21133	13989	3938	1880
Age	1954	1955	1956	1957	1958	1959	1960	1961
3	641584	272778	439602	804781	496824	683690	789653	916842
4	1259285	514924	219807	350332	643259	378598	530599	612324
5	684912	891184	387619	158175	256234	406511	239862	346346
6	389987	429102	548181	200984	105033	145989	199996	138702
7	135956	228785	206850	225110	101196	49529	71623	103298
8	53333	74845	112048	91748	106395	48488	23986	37908
9	36525	34028	34036	46105	40060	55027	23813	12084
10	19673	19329	15591	14474	21860	20840	24380	13000
11	13311	8459	7368	6103	6291	8550	8592	9541
12	4985	4880	3232	2513	2118	2220	3650	3022
13+	2707	2738	3722	1687	857	1142	1351	2332
Age	1962	1963	1964	1965	1966	1967	1968	1969
3	728338	472064	338678	776941	1582560	1295416	164955	112039
4	709603	558039	374580	272501	621906	1245195	1029477	131705
5	382037	427678	360621	265306	199663	458995	875269	685697
6	172949	163321	166726	207288	146941	132256	313440	476187
7	67732	61876	48854	84015	108284	82121	88421	160667
8	49883	30149	19083	22424	45954	55340	43651	48433
9	15518	21185	10240	7448	10803	21072	22854	21054
10	4726	5614	6764	2883	2913	4313	7170	8373
11	4605	1444	1164	2373	1053	1052	1457	2610
12	2871	1455	281	261	907	522	253	606
13+	1351	1113	1278	670	351	461	498	278

Age	1970	1971	1972	1973	1974	1975	1976	1977
3	197105	404774	1015319	1818949	523916	621616	613942	348054
4	89647	154909	324399	799193	1224278	346265	468089	425778
5	85743	63671	114439	224670	535936	610486	229669	280485
6	347649	47037	41482	69576	129164	256342	296843	116349
7	227600	161288	29940	23112	38504	63643	104000	137232
8	60756	100131	78947	17401	12421	20199	25746	42398
9	15642	21306	35642	33463	6815	6253	8186	8650
10	5306	4863	6690	9391	10388	3320	2779	3089
11	2335	1461	1811	1435	3673	3513	1330	1436
12	451	815	517	408	571	1117	1160	590
13+	312	421	697	408	525	550	572	583

Age	1978	1979	1980	1981	1982	1983		
3	638490	198490	137735	150868	151830	166828		
4	249276	451722	154747	109237	120444	116234		
5	197708	163230	300088	111295	80899	79768		
6	108003	82807	94414	172067	72401	48848		
7	47987	37806	39202	41481	84063	34138		
8	57130	16658	15929	16316	14551	30937		
9	13943	18463	6259	6397	4542	4451		
10	2070	3093	5368	2004	1461	1167		
11	1172	605	946	1557	480	565		
12	631	158	118	176	490	152		
13+	1198	218	87	66	70	170		

(continued)

Age	1984	1985	1986	1987	1988	1989	1990	1991
1	2116310	1377120	1755210	492530	821750	818940	1518840	1732090
2	670310	1355100	787360	563120	238150	300980	539930	1129540
3	402810	528700	1047200	288860	206560	174630	245930	416570
4	135430	323300	410410	741520	211080	158800	138370	199620
5	78520	97990	223280	271770	483050	152210	114350	106460
6	47630	47270	55070	111620	133650	273020	95520	81860
7	24650	20820	21130	22270	35830	60220	149550	62070
8	13040	6480	6760	6700	5830	10320	24100	95290
9	9230	3180	1920	1860	1990	1790	3470	13570
10	1400	2140	1200	690	700	510	710	2090
11	390	440	1060	320	150	100	160	420
12	260	110	240	360	90	30	50	70
13+	120	210	130	160	80	60	40	20

Age	1992	1993	1994	1995	1996	1997	1998	1999
1	3054610	24295120	9362000	20094200	27794420	19342630	6815430	3105420
2	1279710	1569810	1530160	1377170	2542140	3116130	1327830	1177200
3	729670	906840	820970	666930	442130	725180	859140	604110
4	334870	573700	686060	545030	313370	225840	422540	485360
5	153550	241580	426590	459220	329000	180250	136670	243140
6	72260	100840	139840	248790	268050	178430	83400	66140
7	48610	38000	52130	60020	114350	127500	70760	31180
8	33200	23200	17660	13270	20150	44230	44880	26710
9	55220	14930	10440	5390	4230	6960	10520	12900
10	7590	28630	6270	2970	1690	1630	1490	2660
11	1330	3930	12050	1820	870	540	300	340
12	300	850	1630	3050	420	300	100	60
13+	50	190	230	410	1620	520	170	110

Age	2000	2001	2002	2003				
1	3522120	4079660	4361980	4333020				
2	858250	678490	1152170	898270				
3	692550	544450	448880	501570				
4	439480	529910	419550	324780				
5	323070	317440	392270	309670				
6	115080	176870	202160	249550				
7	25980	51460	87590	103950				
8	11250	9800	21510	33840				
9	7520	3170	3260	7460				
10	2570	1830	990	1110				
11	510	620	440	350				
12	110	130	200	180				
13+	40	50	60	120				

The following plots are based on the preceding data presented in tables.

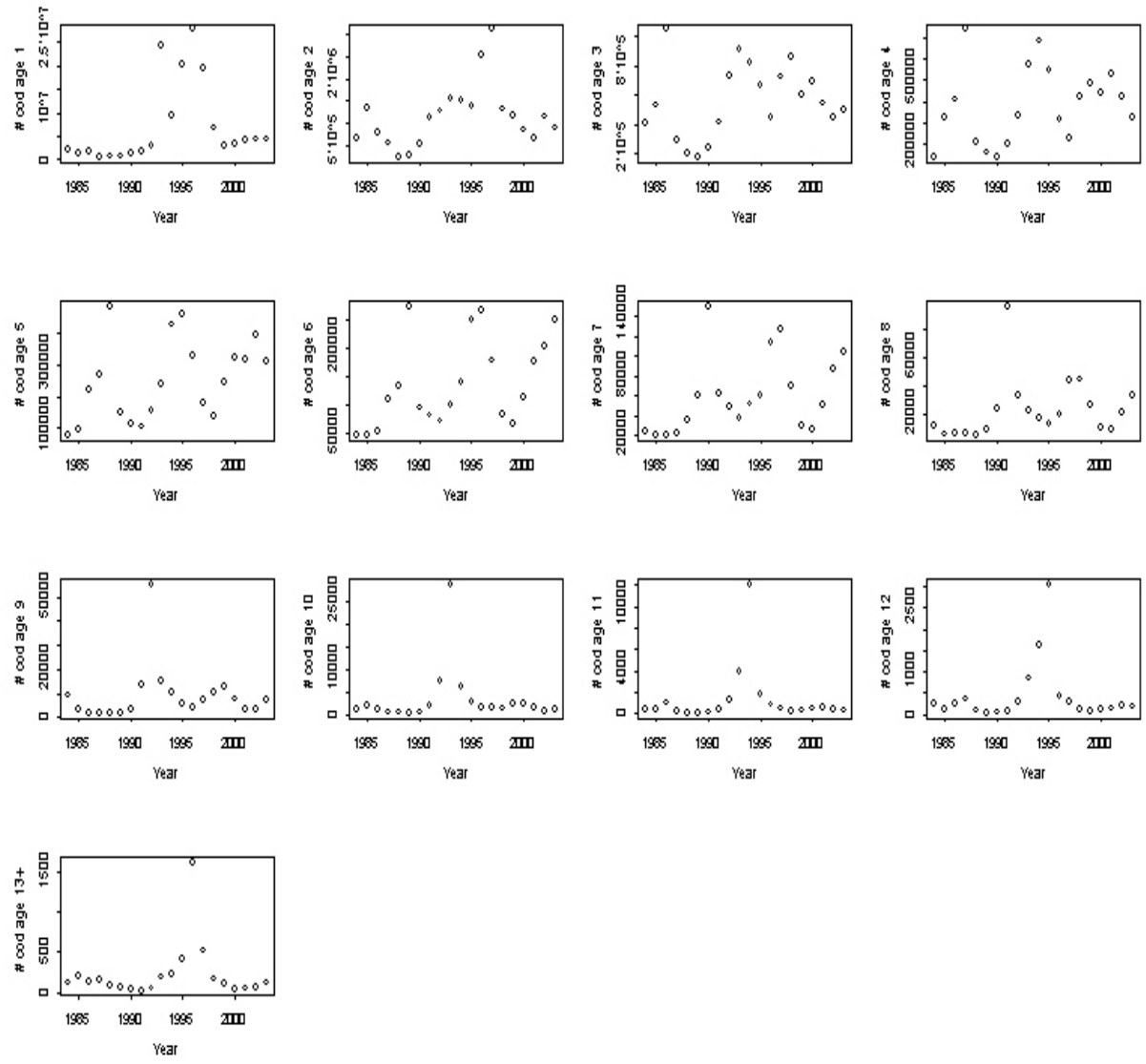


Figure 1: Cod stocks.

Annex II. Catch of arctic cod

Source: IMR, 2004.

Year	Number($\times 10^3$)	Tons landed	Year	Number($\times 10^3$)	Tons landed
1946	189376	706000	1975	496126	829377
1947	294576	882017	1976	465946	867463
1948	265539	774295	1977	490951	905301
1949	304823	800122	1978	339609	698715
1950	227796	731982	1979	200224	440538
1951	329242	827180	1980	175669	380434
1952	455852	876795	1981	135440	399038
1953	391515	695546	1982	132355	363730
1954	495894	826021	1983	99741	289992
1955	550296	1147841	1984	90732	277651
1956	582901	1343068	1985	135312	307920
1957	304619	792557	1986	222093	430113
1958	379354	769313	1987	329823	523071
1959	386107	744607	1988	248639	434939
1960	324884	622042	1989	170873	332481
1961	429983	783221	1990	78199	212000
1962	535685	909266	1991	101757	319158
1963	491574	776337	1992	161837	513234
1964	284025	437695	1993	199168	581611
1965	229081	444930	1994	289313	771086
1966	251976	483711	1995	308747	739999
1967	352179	572605	1996	287331	732228
1968	612679	1074084	1997	302899	762403
1969	574026	1197226	1998	279024	592624
1970	323792	933246	1999	251771	484910
1971	170067	689048	2000	204249	414868
1972	191622	565254	2001	196117	426471
1973	547596	792685	2002	236018	535045
1974	807885	1102433	2003	205507	521950

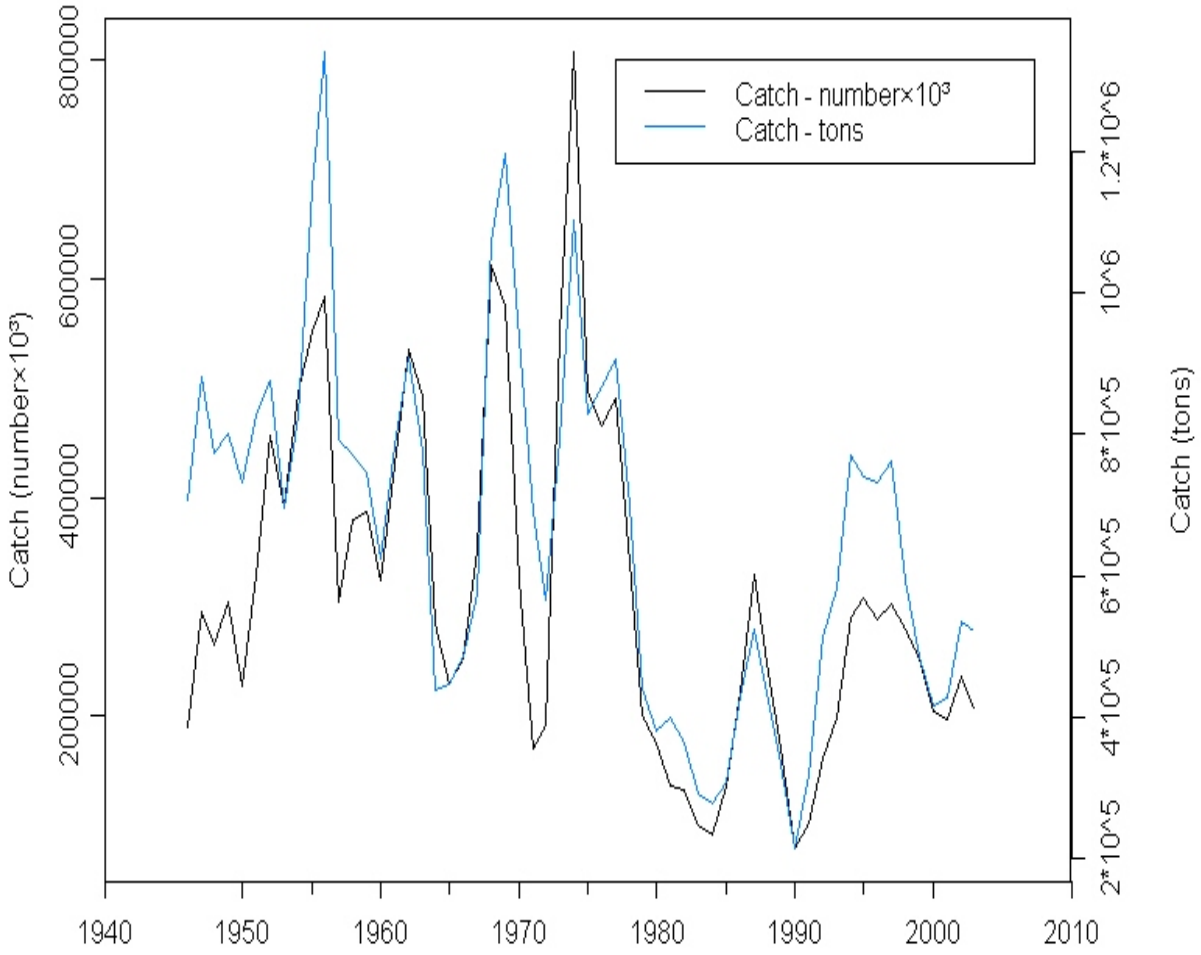


Figure 2: Cod catch.

Annex III. Proportion of mature cod at age

Age	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
6	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
7	0.06	0.06	0.07	0.09	0.09	0.10	0.08	0.07	0.08	0.07	0.06
8	0.11	0.13	0.13	0.17	0.23	0.24	0.22	0.19	0.16	0.13	0.12
9	0.18	0.16	0.25	0.29	0.35	0.40	0.41	0.40	0.37	0.26	0.14
10	0.44	0.42	0.47	0.54	0.52	0.58	0.63	0.64	0.68	0.53	0.41
11	0.65	0.75	0.73	0.79	0.79	0.72	0.82	0.84	0.87	0.83	0.67
12	0.86	0.91	0.91	0.88	0.95	0.85	0.92	0.94	0.93	0.92	0.91
13+	0.96	0.95	0.97	0.97	0.97	0.96	0.97	0.97	0.96	0.97	0.96

Age	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00
5	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.00	0.00	0.01	0.00
6	0.03	0.03	0.04	0.06	0.06	0.05	0.03	0.03	0.01	0.02	0.03
7	0.06	0.06	0.12	0.10	0.12	0.15	0.07	0.13	0.06	0.06	0.07
8	0.09	0.10	0.34	0.19	0.31	0.34	0.28	0.37	0.20	0.22	0.14
9	0.12	0.10	0.49	0.45	0.65	0.61	0.42	0.66	0.55	0.35	0.38
10	0.22	0.30	0.67	0.69	0.91	0.81	0.81	0.89	0.73	0.74	0.64
11	0.60	0.50	0.84	0.77	0.98	0.92	0.98	0.95	0.99	0.94	0.89
12	0.82	0.82	0.87	0.85	0.98	0.97	0.98	0.99	0.98	0.94	0.90
13+	0.97	0.97	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Age	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.01	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00
5	0.03	0.00	0.00	0.01	0.02	0.00	0.00	0.01	0.00	0.02	0.00
6	0.05	0.02	0.01	0.05	0.01	0.02	0.01	0.02	0.05	0.08	0.02
7	0.09	0.04	0.07	0.11	0.10	0.16	0.03	0.09	0.12	0.26	0.13
8	0.19	0.12	0.23	0.30	0.34	0.53	0.21	0.21	0.29	0.54	0.44
9	0.39	0.34	0.58	0.59	0.64	0.81	0.50	0.56	0.45	0.76	0.71
10	0.58	0.55	0.81	0.79	0.81	0.92	0.96	0.78	0.84	0.87	0.77
11	0.82	0.74	0.89	0.86	0.94	0.95	1.00	0.79	0.83	0.93	0.81
12	1.00	0.95	0.91	0.88	1.00	0.98	0.96	0.95	1.00	0.94	0.89
13+	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.90	0.80

Age	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.05	0.08	0.05	0.01	0.05	0.01	0.02	0.00
5	0.00	0.00	0.02	0.10	0.10	0.18	0.09	0.08	0.07	0.05	0.05
6	0.03	0.02	0.07	0.34	0.30	0.31	0.36	0.19	0.18	0.33	0.18
7	0.13	0.13	0.20	0.65	0.73	0.56	0.55	0.53	0.22	0.53	0.41
8	0.39	0.35	0.54	0.82	0.88	0.90	0.85	0.71	0.46	0.62	0.69
9	0.77	0.65	0.80	0.92	0.97	0.99	0.96	0.62	0.50	1.00	0.85
10	0.89	0.82	0.97	1.00	1.00	1.00	0.90	0.90	0.75	1.00	1.00
11	0.83	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	0.78	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13+	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Age	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	0.01	0.04	0.01	0.03	0.01	0.00	0.00	0.00	0.01	0.00	0.00
5	0.05	0.06	0.12	0.09	0.11	0.07	0.02	0.02	0.04	0.01	0.06
6	0.21	0.28	0.43	0.30	0.33	0.33	0.26	0.14	0.19	0.10	0.22
7	0.58	0.65	0.75	0.61	0.60	0.62	0.63	0.56	0.44	0.45	0.64
8	0.77	0.83	0.93	0.91	0.81	0.74	0.83	0.82	0.82	0.79	0.83
9	0.86	0.97	0.97	0.97	0.97	0.95	0.98	0.95	0.93	0.88	0.97
10	0.98	1.00	1.00	0.99	0.99	0.98	1.00	0.95	0.98	1.00	1.00
11	1.00	1.00	1.00	1.00	0.99	1.00	1.00	0.95	1.00	1.00	1.00
12	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13+	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Age	2001	2002	2003								
1	0.00	0.00	0.00								
2	0.00	0.00	0.00								
3	0.00	0.00	0.00								
4	0.01	0.01	0.00								
5	0.05	0.08	0.10								
6	0.34	0.40	0.37								
7	0.58	0.70	0.63								
8	0.77	0.86	0.88								
9	0.98	0.98	0.93								
10	1.00	1.00	1.00								
11	0.97	1.00	1.00								
12	1.00	1.00	1.00								
13+	1.00	1.00	1.00								

Annex IV. Weight-length relationship for cod

Source: IMR.

First column: Year, second column month, third column (always 70) shows 'cut-off point' for fitting length-weight relationship for small and large fish separately. Columns 4 and 5 are parameters a and b for fish < 70 cm, columns 6 and 7 are parameters a and b for fish > 70 cm.
W=0.00001(a*l**3 + b*l**4), W in kg, length in cm.

1981	1	70	0.8543	0.00210000	0.5839	0.00510000
1981	2	70	0.9493	-0.00080000	0.9493	-0.00080000
1981	3	70	1.1770	-0.00360000	0.6843	0.00340000
1981	4	70	0.8588	0.00060000	0.6518	0.00330000
1982	1	70	0.8543	0.00210000	0.5839	0.00510000
1982	2	70	0.9493	-0.00080000	0.9493	-0.00080000
1982	3	70	1.1770	-0.00360000	0.6843	0.00340000
1982	4	70	0.8588	0.00060000	0.6518	0.00330000
1983	1	70	0.8543	0.00210000	0.5839	0.00510000
1983	2	70	0.9493	-0.00080000	0.9493	-0.00080000
1983	3	70	1.1770	-0.00360000	0.6843	0.00340000
1983	4	70	0.8588	0.00060000	0.6518	0.00330000
1984	1	70	0.8481	0.00180000	0.8481	0.00180000
1984	2	70	0.7744	0.00230000	0.7744	0.00230000
1984	3	70	0.9685	-0.00002700	0.9685	-0.00002700
1984	4	70	0.8240	0.00110000	0.8240	0.00110000
1985	1	70	0.8240	0.00110000	0.8240	0.00110000
1985	2	70	0.7907	0.00071439	0.8105	0.00047600
1985	3	70	0.7966	0.00038101	0.8362	-0.00009530
1985	4	70	0.8025	0.00004763	0.8618	-0.00066700
1986	1	70	0.8486	-0.00030000	0.9317	-0.00130000
1986	2	70	0.8863	-0.00110000	0.9278	-0.00160000
1986	3	70	0.9239	-0.00190000	0.9239	-0.00190000
1986	4	70	0.6687	0.00175000	0.6687	0.00175000
1987	1	70	0.4135	0.00540000	0.4135	0.00540000
1987	2	70	0.8047	-0.00110000	0.6225	0.00160000
1987	3	70	0.9186	-0.00140000	0.8335	0.00002400
1987	4	70	0.8724	-0.00110000	0.6929	0.00166200

```
1988  1 70  0.8262  -0.00080000  0.5523   0.00330000
1988  2 70  1.0300  -0.00390000  0.4063   0.00490000
1988  3 70  0.8838   0.00080000  1.2390  -0.00440000
1988  4 70  0.9611  -0.00110000  0.7795   0.00160000

1989  1 70  0.9992  -0.00211600  0.8216   0.00064600
1989  2 70  1.1440  -0.00485400  0.7533   0.00121300
1989  3 70  0.9848  -0.00225900  0.6388   0.00253700
1989  4 70  1.0993  -0.00350600  0.6709   0.00264700

1990  1 70  1.0430  -0.00264500  0.7240   0.00177600
1990  2 70  1.2620  -0.00638700  0.7570   0.00105100
1990  3 70  1.2250  -0.00580800  0.5750   0.00340700
1990  4 70  1.1870  -0.00460900  0.7980   0.00078400

1991  1 70  1.2040  -0.00432500  0.8644   0.00032850
1991  2 70  1.1100  -0.00302900  0.7833   0.00076600
1991  3 70  0.9963  -0.00238300  0.7187   0.00168900
1991  4 70  0.8557   0.00082130  0.9206  -0.00033060

1992  1 70  0.9598  -0.00050000  0.9598  -0.00050000
1992  2 70  1.0320  -0.00200000  1.0320  -0.00200000
1992  3 70  0.8152   0.00110000  0.8152   0.00110000
1992  4 70  0.8714   0.00050000  0.8714   0.00050000

1993  1 70  0.7904   0.00140000  0.7904   0.00140000
1993  2 70  0.9329  -0.00080000  0.9329  -0.00080000
1993  3 70  0.8215   0.00050000  0.8215   0.00050000
1993  4 70  0.9556  -0.00110000  0.9556  -0.00110000

1994  1 70  0.7450   0.00190000  0.7696   0.00170000
1994  2 70  1.1103  -0.00460000  0.7321   0.00090000
1994  3 70  0.8049   0.00050000  0.7687   0.00060000
1994  4 70  1.0780  -0.00370000  0.6385   0.00240000

1995  1 70  0.7626   0.00190000  0.7844   0.00160000
1995  2 70  1.0308  -0.00380000  0.6953   0.00160000
1995  3 70  0.8372  -0.00020000  0.6982   0.00140000
1995  4 70  1.0811  -0.00410000  0.7792   0.00080000

1996  1 70  0.7524   0.00230000  0.7109   0.00250000
1996  2 70  0.9218  -0.00170000  0.5287   0.00400000
1996  3 70  0.8116   0.00020000  0.5862   0.00290000
1996  4 70  1.0835  -0.00400000  0.6170   0.00270000
```

```
1997  1 70  0.8198   0.00070000  0.6584   0.00260000
1997  2 70  0.8755  -0.00110000  0.5170   0.00360000
1997  3 70  0.8363   0.00007100  0.6386   0.00220000
1997  4 70  0.9704  -0.00220000  0.6272   0.00290000

1998  1 70  0.8132   0.00070000  0.6833   0.00250000  1998 min len 20 cm
1998  2 70  0.9538  -0.00240000  0.5291   0.00330000
1998  3 70  0.8194   0.00020000  0.5898   0.00310000
1998  4 70  0.9161  -0.00140000  0.7530   0.00060000

1999  1 70  0.8102   0.00080000  0.6260   0.00300000  1999 min len 20 cm
1999  2 70  0.9432  -0.00200000  0.3697   0.00600000
1999  3 70  0.8257   0.00030000  0.7169   0.00180000
1999  4 70  0.9280  -0.00150000  0.8241   0.00005200

2000  1 70  0.7882   0.00140000  0.7614   0.00160000  2000 min len 20 cm
2000  2 70  0.8853  -0.00120000  0.5412   0.00370000
2000  3 70  0.8500   0.00040000  0.6520   0.00240000
2000  4 70  0.9703  -0.00250000  0.7783   0.00050000

2001  1 70  0.8930  -0.00080000  0.7692   0.00120000  2001 min len 20 cm
2001  2 70  0.9603  -0.00230000  0.5536   0.00330000
2001  3 70  0.8871  -0.00130000  0.5567   0.00310000
2001  4 70  0.9274  -0.00110000  0.8535   0.00030000

2002  1 70  0.8126   0.00088900  0.7812   0.00146000  2002 min len 35 cm
2002  2 70  1.0005  -0.00194500  0.6905   0.00238800
2002  3 70  0.8822  -0.00005500  0.6769   0.00241000
2002  4 70  0.9317  -0.00053900  0.8106   0.00108000

2003  1 70  0.7842   0.00146600  0.8688   0.00046400  2003 min len 35 cm
2003  2 70  1.0992  -0.00381500  0.7961   0.00083200
2003  3 70  0.8282   0.00058700  0.7884   0.00006800
2003  4 70  0.8360   0.00072700  0.7694   0.00143800
```

Annex V. Age-Length relationship for cod

Age	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
1	12.31	12.55	12.53	11.69	11.61	12.65	15.80	12.41	12.15	12.38
	(1.25)	(0.87)	(0.55)	(1.85)	(2.00)	(1.65)	(2.02)	(1.58)	(1.25)	(1.02)
2	18.52	19.03	19.61	19.60	17.98	18.76	23.14	23.05	19.90	18.46
	(3.91)	(3.53)	(3.22)	(3.18)	(3.76)	(2.81)	(3.22)	(3.51)	(2.95)	(1.98)
3	30.62	30.39	28.55	30.61	31.23	29.43	27.34	33.24	30.85	28.85
	(5.11)	(5.93)	(5.31)	(3.93)	(4.81)	(4.22)	(4.39)	(4.30)	(3.67)	(3.35)
4	44.91	42.28	40.93	41.22	41.16	40.82	32.76	42.32	43.52	40.98
	(5.77)	(4.82)	(5.89)	(5.50)	(4.44)	(4.85)	(5.07)	(5.08)	(3.74)	(3.98)
5	56.09	54.14	49.98	50.94	51.43	50.85	52.01	52.69	52.26	53.14
	(7.52)	(4.27)	(5.65)	(4.95)	(4.38)	(4.24)	(5.15)	(4.93)	(4.38)	(4.29)
6	67.74	66.87	62.76	59.93	59.30	61.19	65.03	65.70	65.99	65.36
	(4.42)	(6.94)	(6.04)	(4.55)	(5.00)	(5.43)	(6.46)	(6.14)	(6.56)	(6.29)
7	76.21	75.61	73.76	72.20	70.41	74.79	66.82	71.34	69.57	69.73
	(7.22)	(4.49)	(7.56)	(5.43)	(5.75)	(6.71)	(7.91)	(4.25)	(5.18)	(4.65)
8	82.83	83.44	83.50	84.91	76.45	76.32	74.31	82.06	81.79	80.98
	(14.84)	(4.71)	(8.73)	(7.28)	(7.11)	(6.19)	(5.25)	(4.39)	(4.80)	(5.67)
9	91.02	92.24	90.42	100.71	92.01	87.44	83.37	87.29	89.11	90.88
	(5.28)	(7.23)	(8.36)	(4.85)	(7.39)	(8.08)	(6.16)	(9.33)	(7.22)	(8.98)
10	95.51	93.92	95.11	104.50	92.81	101.57	91.61	97.78	101.23	96.22
	(8.49)	(5.09)	(6.64)	(2.57)	(12.18)	(1.40)	(8.74)	(7.81)	(2.26)	(5.30)
11	94.02	99.86	98.23	104.68	96.25	102.55	94.72	101.04	94.03	102.61
	(7.09)	(5.92)	(6.65)	(5.11)	(13.35)	(1.37)	(4.66)	(7.40)	(10.43)	(6.43)
12	99.53	97.74	101.91	99.39	98.79	107.53	103.24	105.96	96.21	108.98
	(4.93)	(6.53)	(4.82)	(2.48)	(5.38)	(5.76)	(4.04)	(5.18)	(7.72)	(7.39)
13	100.81	107.53	104.03	101.20	100.65	112.01	108.99	110.51	97.92	115.33
	(4.38)	(5.76)	(7.15)	(7.94)	(5.75)	(6.77)	(5.48)	(6.03)	(8.61)	(8.23)
14	101.79	112.01	105.80	102.43	102.01	116.05	114.67	114.74	99.26	121.65
	(4.89)	(6.77)	(8.19)	(8.66)	(5.94)	(7.49)	(6.50)	(6.67)	(9.12)	(8.98)
15	102.54	116.05	107.26	103.27	103.02	119.69	120.29	118.66	100.32	127.95
	(5.17)	(7.49)	(8.83)	(8.97)	(6.04)	(8.03)	(7.36)	(7.18)	(9.42)	(9.68)

estimated using Winter Survey data.
estimated using pooled data from Winter and Lofoten survey.
estimated using Lofoten Survey data.
predicted values.
interpolated value.

Table 1: Estimated mean and standard deviation (in brackets) of length at age for cod.

Annex VI. Data sources for herring

Length	Age												Tot
	2	3	4	5	6	7	8	9	10	11	12	13	
15	66												66
16	187												187
17	2010												2010
18	3191												3191
19	4106	132											4238
20	2826	0											2826
21	1205	0											1205
22	1514	89											1603
23	1368	114	38										1520
24	449	199	0										648
25	161	484	0										645
26	121	243	0										364
27		148	223										371
28		54	430	161	54								699
29		0	800	753	141								1694
30		92	737	3226	922	138	46						5161
31			160	3559	2119	40	0						5878
32			38	1954	3082	113	38						5225
33				274	900	274	0						1448
34				81	244	190	163	27				27	732
35					0	29	29	29	88	59	235	117	586
36					32	32	63	0	32	32	190	126	507
37												116	116
38												13	13
Total	17204	1555	2426	10008	7494	816	339	56	120	91	425	399	40933

Table 2: Survey of herring in the Norwegian Sea- may 2004 - source: IMR, Bergen.

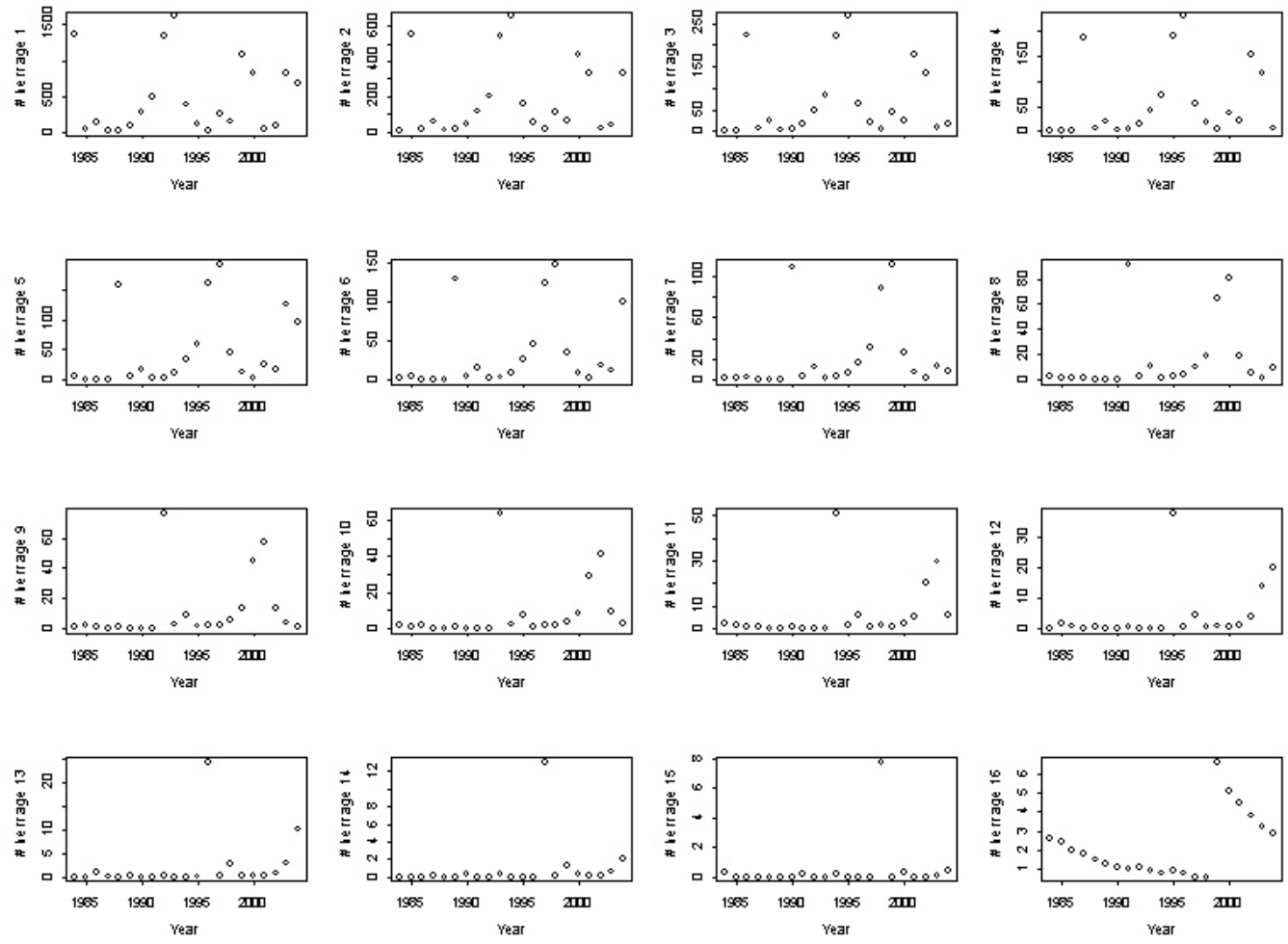


Figure 3: Herring stocks (numbers$\times 10^8$) 1984-2004.

Year	Age							
	1	2	3	4	5	6	7	8
1984	1358.6	3.8	0.7	0.8	5.8	2.5	1.7	2.9
1985	46.7	552.4	1.5	0.6	0.6	4.4	1.9	1.3
1986	145.1	18.9	223.3	1.1	0.4	0.4	2.6	1.1
1987	24.5	59.0	7.7	187.1	0.8	0.2	0.2	1.3
1988	36.5	9.9	23.7	6.4	156.4	0.5	0.1	0.1
1989	103.1	14.8	4.0	19.9	5.3	129.5	0.4	0.1
1990	284.6	41.9	5.9	3.4	17.1	4.5	108.5	0.3
1991	499.9	115.7	16.9	4.9	2.9	14.6	3.8	91.3
1992	1346.0	203.2	47.0	14.5	4.2	2.5	12.4	3.2
1993	1617.8	547.2	82.6	40.4	12.2	3.5	2.1	10.6
1994	392.40	657.80	222.40	70.80	33.70	9.70	3.00	1.80
1995	132.00	159.50	267.40	191.20	59.90	25.70	6.80	2.40
1996	36.90	53.70	64.90	229.60	161.30	45.80	16.20	3.70
1997	269.60	15.00	21.60	55.50	191.00	124.30	30.70	10.20
1998	158.40	109.60	6.00	17.40	45.30	147.70	88.50	19.40
1999	1077.40	64.40	44.00	4.50	12.70	35.50	110.80	64.40
2000	821.80	438.00	26.20	36.60	3.50	9.70	26.60	80.50
2001	51.70	334.10	178.00	21.70	26.30	2.70	7.30	19.10
2002	98.20	21.00	135.80	152.30	17.20	18.70	2.00	5.40
2003	824.70	39.90	8.10	115.10	125.10	12.40	13.10	1.40
2004	693.92	335.27	16.21	6.32	96.01	100.69	9.02	9.64

Year	Age							
	9	10	11	12	13	14	15	16
1984	0.7	1.7	2.0	0.0	0.0	0.0	0.3	2.6
1985	2.4	0.5	1.3	1.7	0.0	0.0	0.0	2.4
1986	0.6	1.5	0.4	0.8	1.0	0.0	0.0	2.0
1987	0.3	0.2	0.5	0.1	0.1	0.1	0.0	1.8
1988	0.8	0.1	0.0	0.4	0.0	0.0	0.0	1.5
1989	0.0	0.6	0.0	0.0	0.3	0.0	0.0	1.3
1990	0.0	0.0	0.5	0.0	0.0	0.3	0.0	1.1
1991	0.2	0.0	0.0	0.4	0.0	0.0	0.2	1.0
1992	76.5	0.2	0.0	0.0	0.3	0.0	0.0	1.1
1993	2.7	63.8	0.1	0.0	0.0	0.3	0.0	0.9
1994	8.80	2.10	51.10	0.10	0.00	0.00	0.20	0.80
1995	1.50	7.20	1.50	38.00	0.10	0.00	0.00	0.90
1996	1.90	1.10	5.60	0.50	24.20	0.00	0.00	0.80
1997	2.20	1.60	0.90	4.20	0.30	13.10	0.00	0.60
1998	5.70	1.40	1.20	0.50	2.80	0.10	7.80	0.60
1999	13.10	3.70	0.80	0.80	0.40	1.30	0.00	6.60
2000	44.60	8.60	2.20	0.50	0.30	0.30	0.30	5.10
2001	57.20	28.70	5.40	1.20	0.30	0.10	0.00	4.50
2002	13.70	41.50	20.00	4.00	0.80	0.20	0.00	3.80
2003	3.80	9.40	29.50	14.10	2.90	0.60	0.10	3.20
2004	1.00	2.55	6.00	20.06	10.06	2.10	0.44	2.84

Table 3: Numbers at age for herring by year (units $\times 10^8$).

Year	Catch(tons)	Year	Catch(tons)	Year	Catch(tons)
1972	13161	1983	23054	1994	479228
1973	7017	1984	53532	1995	905501
1974	7619	1985	169872	1996	1220283
1975	13713	1986	225256	1997	1426507
1976	10436	1987	127306	1998	1223131
1977	22706	1988	135301	1999	1235433
1978	19824	1989	103830	2000	1207201
1979	12864	1990	86411	2001	770066
1980	18577	1991	84683	2002	806086
1981	13736	1992	104448	2003	733494
1982	16655	1993	232457		

Table 4: Total catch of Norwegian spring-spawning herring by year (tons).

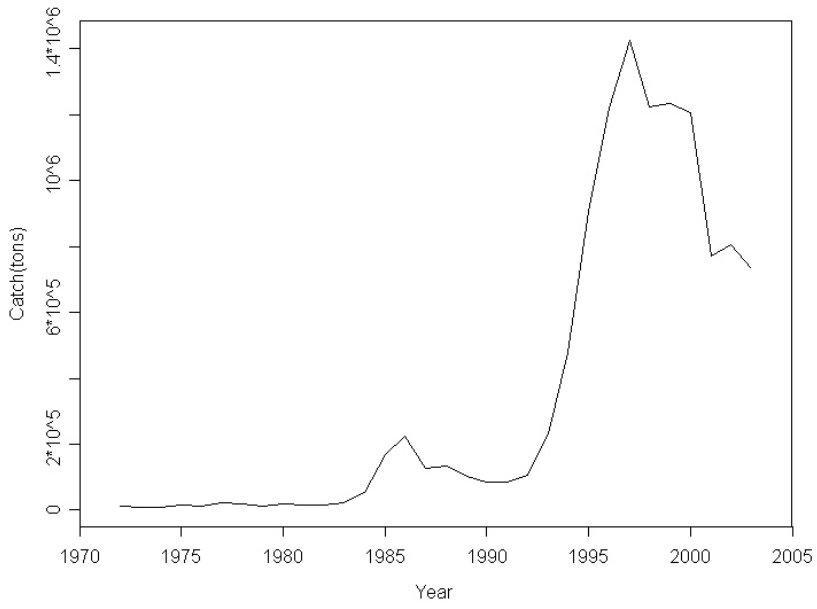


Figure 4: Norwegian spring-spawning herring catch.

Age	1	2	3	4	5	6	7	8
Weight	10	37	55	212	241	279	302	337
Fraction Mature	0.00	0.00	0.00	0.45	0.90	1.00	1.00	1.00
Age	9	10	11	12	13	14	15	16
Weight	354	355	360	371	400	412	445	445
Fraction Mature	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 5: Weight of herring and fraction mature by age (2004) according to Sea Star assessment method.

age	1	2	3	4	5	6	7	8
mean	14.80	19.65	24.84	29.01	30.75	31.59	32.70	33.69
sd	1.10	2.05	2.53	1.36	1.04	1.11	1.57	1.83
age	9	10	11	12	13	14	15	16
mean	34.27	34.65	34.89	35.05	35.98	35.75	35.60	35.51
sd	1.14	1.34	1.41	1.44	1.03	1.76	1.90	1.96

Table 6: Estimated mean and standard deviation of length at age for herring, in cm. (based on 2004 data).

Annex VII. Data sources for minke whales

Year	Abundance	Year	Abundance
1970	52861	1987	56685
1971	52861	1988	57684
1972	52861	1989	58700
1973	52861	1990	59734
1974	52861	1991	60786
1975	52861	1992	61857
1976	52861	1993	62947
1977	52861	1994	64056
1978	52861	1995	65184
1979	52861	1996	66333
1980	52861	1997	67501
1981	52861	1998	68690
1982	52861	1999	69900
1983	52861	2000	71132
1984	53792	2001	72385
1985	54740	2002	73660
1986	55704	2003	74958

Table 7: Minke Whale abundance estimates.

Year	Catch	Year	Catch	Year	Catch
1950	1990	1968	1986	1986	329
1951	2751	1969	2014	1987	325
1952	3324	1970	1890	1988	29
1953	2433	1971	1799	1989	17
1954	3499	1972	2172	1990	5
1955	4309	1973	1558	1991	0
1956	3654	1974	1410	1992	95
1957	3624	1975	1426	1993	213
1958	4338	1976	1884	1994	239
1959	3062	1977	1698	1995	176
1960	3233	1978	1383	1996	348
1961	3092	1979	1786	1997	483
1962	2975	1980	1807	1998	568
1963	3059	1981	170	1999	533
1964	2463	1982	1782	2000	430
1965	2114	1983	1688	2001	519
1966	1902	1984	630	2002	599
1967	1758	1985	634	2003	625

Table 8: Minke Whale catch.