SCOS 98/5
Annex I
(SCOS 97/2)

Advice on the Status of British Grey Seal Populations: 1997

Summary

1. This document contains advice from the Natural Environment Research Council on the current size and status of British grey seal populations, and other related matters, based on information provided by the Sea Mammal Research Unit (SMRU).
2. The size of the British grey seal population at the start of the 1996 pupping season is estimated to be 111,200. This estimate was derived using the method introduced in 1996, which takes account of year to year variation in juvenile survival and age at first pregnancy.
3. The estimate of total population size for 1996 is 6% higher than for 1995. The mean annual increase in population size since 1984 is also 6%.
4. A total of 102,400 seals are associated with breeding sites in Scotland and 8,800 with breeding sites in England and Wales.
5. The method used to estimate total pup production from aerial photographs of grey seal breeding sites is described in SCOS 96/2, Annex I, Appendix 1. Tables 1-4 give estimated pup productions by year and breeding site. Paper SCOS 96/2, Annex I, Appendix 2 describes how the estimated pup productions are used to estimate all-age population size, given in Table 5.
6. The changes in total pup production and female population size for all major breeding colonies since 1984 are shown in Figures 1 and 2, respectively. Figure 3 shows the trends in pup production in different parts of Britain over the same period.
7. There is evidence that the rate of increase at the Monach Isles is slowing down. If this continues, pup production is predicted to stabilize at approximately 40% higher than the current level. However, there is also a close inverse relationship between changes in pup production at the major colonies in the Outer Hebrides and Orkney. Periods when the rate of increase in the Hebrides was higher than average have coincided with periods of lower than average increase in Orkney, and *vice versa*. Pup production at sites in Scotland which are not surveyed regularly cannot account for the decrease in the rate of increase in pup production at the Monach Isles.
8. Concerning habitat degradation at grey seal breeding sites, a cursory inspection of aerial photographs provides no evidence that the expansion of the breeding colony at the Monach Isles has adversely affected the machair community.
9. Estimates of grey seal diet composition in the North Sea still rely on data collected mostly in 1985. A proposal has been submitted to MAFF CSG to update this information.
10. To stabilize the Scottish grey seal population at its current level using immuno-contraception would initially require the sterilization of most adult females outside candidate SACs.

Scope of this document

This document seeks to provide advice on key fundamental questions related to the British grey seal population and other matters raised by the Scottish Office and Home Office. A list of these is given in Appendix 1, which also provides a glossary of technical terms.

Surveys conducted in 1996

Every year SMRU conducts surveys of the major breeding sites for grey seals (*Halichoerus grypus*) in Britain in order to determine the number of pups born there. In addition, new sites where grey seal pups have been reported or which appear to be suitable for colonisation are visited regularly. During 1996, aerial surveys were flown over all the major sites in the Hebrides and Orkney, and the Isle of May. Ground counts of the numbers of pups born at the Farne Islands were carried out by staff from the National Trust; similar counts were carried out by members of the Lincolnshire Trust for Nature Conservation at Donna Nook on the Humber estuary, by staff of Scottish Natural Heritage at South Ronaldsay, and by members of the Dyfed Wildlife Trust in Wales.

Estimation of Pup Production

Pup production at regularly surveyed sites is estimated each year from the aerial survey results using a model of the birth process and the development of pups. The method used to obtain the estimates for this year's advice is the same as that used since 1994, and is described in SCOS 96/2, Annex I, Appendix 1. Estimates of pup production at each site in the Inner Hebrides, the Outer Hebrides and Orkney calculated using this method are given in Tables 1-3, respectively. The Isle of May and Loch Eriboll are now also surveyed by air; estimates of pup production for these sites using this method are included in Table 4.

For sites not surveyed by air, pup numbers are counted directly on the ground either annually (Farne Islands, Donna Nook) or less frequently (SW England, Wales, Helmsdale, Shetland, South Ronaldsay). These counts are given in Table 4.

Estimates of pup production at all major breeding sites in England and Scotland (except Loch Eriboll, Helmsdale and Shetland) for the period 1984 to 1996 are shown in Figure 1.

Estimation of Population Size Associated with Regularly Surveyed Sites

The total number of seals associated with the sites surveyed regularly since 1984 (when the current survey methodology was established) is estimated by fitting a population model to the series of pup production estimates from these sites, to data on population pregnancy rates collected between 1978 and 1981, and to data on population age structure from management culls at the Farne Islands. This method, described in SCOS 96/2, Annex I, Appendix 2, was substantially modified prior to the SCOS meeting in 1996 according to comments made by external referees. It now takes account of year to year variation in juvenile survival and age at first pregnancy, and makes use of more of the available data on these population parameters.

The estimated size of the total female population at all major breeding sites in England and Scotland (together with pup production estimates generated by the population model) are shown in Figure 2. Table 5 gives estimates of the size of the total population over the period 1984-1996.

For illustrative purposes the components of this population which are associated with major breeding areas have been calculated. Trends in the estimated numbers of pups born in each of these breeding areas since 1984 are shown in Figure 3. Major breeding sites are shown in Figure 4. The distribution of seals outside the breeding season may not be the same as the distribution of the breeding sites. Sites where grey seals have been observed during the summer common seal surveys are shown in Figure 5(a) for the period 1998-1993 and Figure 5(b) for 1996.

The number of pups born each year in Orkney has continued to increase over the last 20 years, but there has been a slower increase in the Hebrides since 1992. Estimates of pup production and total population size for the main colonies surveyed in 1996, which account for more than 85% of all pups born each year, are:

Location	1996 pup production	Change from 1995	Total 1996 population (to nearest 100)
Inner Hebrides	3,191	+4%	9,600
Outer Hebrides	13,009	+3.5%	39,000
Orkney	14,025	+12%	42,100
Isle of May	1,582	+17.5%	4,700
Farne Islands	1,061	-1%	3,200
Donna Nook	310	-7%	900

Confidence Limits

Ninety-five percent confidence limits on the pup production estimates at each site are within 14% of the point estimate. The exact limits depend on a number of factors including the number of surveys which are flown in a particular year. It is also possible to calculate 95% confidence limits for the estimate of the female component of the population; for 1996, these are ±17.5% of the estimate (i.e. 47,000 - 67,000 for the estimate of the female population in 1996 - see Table 5). This is equivalent to a coefficient of variation of 9% of the estimate. The size of the male component has been estimated by assuming that the number of sexually mature males is 60% of the number of mature females, and that males become sexually mature at four years of age. The procedure used to generate confidence limits on the estimate of female population size could, in principle, be repeated for the combined female and male population. However, there are no current data on the relative numbers of males and females in the population which could be used for this purpose.

Population Size at Sites Surveyed Less Frequently

The total population associated with breeding sites which are not surveyed regularly has been calculated using the ratio of total population to pup production for the main areas. Confidence limits cannot be calculated for these estimates. The resulting figures are:

Location	Date of last survey	Pup production (to nearest 100)	Total population (to nearest 100)
Mainland Scotland & South Ronaldsay	Helmsdale 1996 Loch Eriboll 1996 South Ronaldsay 1994	1,300	4,100
Shetland	1977	1,000	3,300
Southwest Britain	Southwest England 1973 Wales 1994	1,500	4,700

Total Size of the British Grey Seal Population

Taken together, these figures provide an estimate of 111,200 for the size of the British grey seal population at the start of the 1996 pupping season: 102,400 seals are associated with breeding sites in Scotland and 8,800 with breeding sites in England and Wales. These estimates for 1995 are 95,900 for Scottish sites and 8,900 for those in England and Wales. Britain holds approximately one third of the world population of grey seals (Figure 6).

Recent and Predicted Changes in the British Grey Seal Population

The increase from 1995 to 1996 in the estimate of total population size associated with breeding sites which are monitored annually was 6.8%, with 95% confidence limits of 4.3-9.3%. The total population at these sites is estimated to have increased by 40% (95% confidence limits 30-50%) from 1991 to 1996.

If there are no changes in survival or fecundity rates (and no change in the number of seals associated with the sites which are not surveyed regularly), predicted increases for the next three years, their 95% confidence limits, and associated population sizes (to the nearest 500 animals) are as follows:

Year	Predicted increase in female population associated with sites surveyed regularly	95% confidence limits on increase	Female population	Male plus female population	Predicted total population (including sites not surveyed regularly)
1997	3.0 6.8% 3.0	3.8 - 9.8%	60,500	105,500	117,500
1998	4.2 13.5% 4.5	9.3 - 18.0%	64,500	112,500	124,500
1999	6.3 21.3% 7.5	15.0 - 28.8%	69,000	120,000	132,000

A simple power calculation shows that for annual population estimates with coefficient of variation equal to 0.09, an increase of 6.8% per year will be detected with 95% probability in 7 years. The probability of a series of 13 (1984-1996) such annual estimates detecting an increase of 6.8% is greater than 99.9%.

Trends in pup production and mortality, and body condition

The Scottish Office (SO) has requested further information on trends in pup production at the Monach Isles in the Outer Hebrides, and on trends in pup mortality. Nearly 70% of all pups born in the Outer Hebrides are produced at the Monach Isles, and this group of islands has dominated the dynamics of the Hebrides grey seal population. There is now evidence that the rate of increase in the Monach Isles is slowing down (Appendix 2). If this trend continues, pup production at the Monach Isles will stabilize at a level approximately 40% higher than the current level.

However, there is a close relationship between changes in pup production at the major colonies in the Outer Hebrides and in Orkney. Periods when the rate of increase in the Hebrides was higher than average have coincided with periods of lower than average increase in Orkney, and *vice versa* (see Appendix 2). One explanation for this is that there have been large scale movements of breeding animals between these two regions at different times in the last 30 years. It should be possible to test this hypothesis by examining the frequency of different microsatellite alleles in appropriate colonies. A joint proposal from SMRU and the University of Cambridge to carry out this analysis was short-listed as part of NERC's thematic programme on Ecological Dynamics and Genes (EDGE) but did not receive funding.

In response to a request from the SO earlier this year, a proposal for additional research to investigate the role of pup mortality and female condition in determining the limits to growth of the Scottish grey seal was prepared. This is attached as Appendix 3a. The SO passed this proposal to MAFF Chief Scientist's Group (CSG) which recognized the importance and relevance of the proposed research but was not able to fund it.

Pup Production at Unsurveyed Sites

Sites in Scotland which are not surveyed regularly but which are potential grey seal breeding sites or where small numbers of pups have been recorded in recent years are checked periodically. A list of these sites, the frequency at which they have been checked and the estimated number of pups at each one is given in Table 6. It is clear from these data that the decrease in the rate of increase in pup production at the Monach Isles cannot be accounted for by colonization of new sites.

Habitat Degradation Caused by Grey Seals

The SO has requested further information on habitat degradation at grey seal breeding sites. SMRU has offered Scottish Natural Heritage the use of aerial photographs of the distribution of breeding grey seals on the Monach Isles to investigate the risks of damage to the machair community. A cursory inspection of the photographs at SMRU did not provide any evidence that the expansion of the breeding colony at the Monach Isles has affected the machair.

Seals and Salmon

The SO has requested further information on the predation of at-sea wild salmon by seals. SMRU has not investigated the correlation between grey seal numbers and estimates of at-sea mortality of salmon. Earlier this year, SMRU was invited to submit a proposal to the SO on research to address the question of seal predation on salmon in rivers. A copy of this proposal is attached as Appendix 3b. The proposal was not funded nor passed to MAFF CSG.

Recently, SMRU staff have entered into discussion with representatives of the Atlantic Salmon Trust, the Tay District Salmon Fisheries Board and the Tay Foundation with a view to identifying profitable areas of research relating to seal predation on salmon and sea trout and developing a research programme in this area. Discussions have also begun with staff at the Scottish Office Freshwater Fisheries Laboratory, Pitlochry to determine if similar work can be incorporated into the Shieldaig Sea Trout Project on the west coast of Scotland

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Grey Seal Diet in the North Sea

The SO has requested advice on the current impact of grey seals on cod stocks in the North Sea.

The most recent comprehensive information on the impact of grey seals on fish stocks in the North Sea is given in SMRU's 1994 report to MAFF - *Grey seals in the North Sea and their interactions with fisheries*. In that report, information on diet collected mostly in 1985 (but also in later years in the central North Sea) was combined with estimates of population size for 1992 to provide estimates of annual consumption of fish prey by grey seals. Total annual consumption was estimated as 76,000 tonnes of which the dominant species were sandeels (36,000 tonnes) and cod (10,500 tonnes). At that time these consumptions were <3% of estimated total stock biomass of either species, and <5% and 10.7% of the commercial catch of sandeels and cod, respectively.

The relative abundance of fish species in the North Sea has changed since 1985 and it is likely that grey seal diet composition has also changed. SMRU has been invited by MAFF CSG to submit a proposal to update estimates of grey seal diet composition and consumption in the North Sea and off the west coast of Scotland.

Potential for Control of the Scottish Grey Seal Population Using Immuno-contraception

The SO has requested advice on whether it would be feasible to stabilize the Scottish grey seal population at the 1996 level or reduce it to 75,000 animals by using a one-shot persistent contraceptive immunovaccine on seals at sites which have not been identified as candidate Special Areas of Conservation (SACs). A rough indication of the numbers of seals which would be involved can be obtained from calculations carried out by A.R. Hiby for a report entitled *Population Management of Seals: An Evaluation of Non-lethal Methods of Population Control*, prepared for MAFF by the University of Aberdeen under contract CSA 2721.

In order to maintain the population at its current level it would be necessary to sterilize around 14,000 females in the first year and smaller numbers in subsequent years down to around 3,000 per year after seven years. In effect, this would require the sterilization of most of the adult female grey seals outside of the SACs. This is probably not feasible. Much higher numbers of seals would need to be sterilized for the size of the population to be reduced. The population could be stabilized at 180,000 animals (a level substantially higher than its current size) if 5,000 females could be treated each year. In response to a request from the SO, SMRU and the University of Aberdeen submitted a proposal to carry out the research required to determine if this was feasible (see Appendix 3c). This proposal was not funded nor passed to MAFF CSG.

TABLE 1 : Pup production estimates for islands in the Inner Hebrides group

YEAR	Gunna	Northern Treshnish	Fladda	Sgeir a Chaisteil & Eirionnach	Lunga	Soa	Eilean nan Ron	Eilean nan Eoin	Nave Island	TOTAL
1984	206	87	169	136	226	63	180	190	75	1332
1985	192	84	109	113	136	63	158	269	66	1190
1986	263	114	149	119	204	111	302	305	144	1711
1987	360	125	173	147	235	95	414	292	128	1969
1988	330	134	226	170	236	96	400	226	132	1950
1989	343	137	223	182	283	107	301	156	213	1945
1990	358	140	182	178	248	125	390	256	215	2092
1991	490	140	312	178	285	90	410	383	210	2498
1992	533	196	354	162	345	116	437	432	276	2851
1993	515	217	323	195	383	91	460	453	301	2938
1994	596	176	291	157	374	94	342	453	305	2788
1995	541	186	372	189	426	116	453	442	344	3073
1996	590	189	359	192	418	93	569	443	338	3191

TABLE 2: Pup Production estimates for islands in the Outer Hebrides group

YEAR	Gasker	Coppay	Shillay (Sound of Harris)	Haskier	Causamul	Deasker	Shivinish (Monachs)	Ceann Iar (Monachs)	Ceann Ear (Monachs)	Shillay (Monachs)	Stockay (Monachs)	Monachs total	Others	Rona	TOTAL
1960															
1961	847	62	120	81	67	13						0	0	1949	3142
1962															
1963															
1964															
1965															
1966	1084	230	120	96	242	0	0					38	0	1499	3311
1967	1084	153	80	96	161	0	0					114	0	1574	3265
1968	1084	115	161	96	161	0	0					152	0	1650	3421
1969															
1970	1129	324	714	130	103	41	0	0	84	60	460	605	0	2023	5070
1971															
1972	1141	316	605	167	271	67	0	0	274	49	730	1054	0	1309	4933
1973															
1974	1756	286	692	176	224	83	0	49	459	44	754	1307	0	1647	6173
1975	1538	367	631	212	202	51	0	141	690	217	932	1982	0	1961	6946
1976	1813	394	553	278	217	57	0	111	628	152	1053	1946	0	1886	7147
1977															
1978	1101	321	508	320	172	51	0	560	371	205	626	1764	0	2002	6243
1979	992	377	546	269	159	80	0	672	810	164	826	2474	0	1770	6670
1980	1345	462	794	351	163	31	0	1077	880	242	647	2848	162	1867	8026

TABLE 2 continued

YEAR	Gasker	Coppay	Shillay (Sound of Harris)	Haskier	Causamul	Deasker	Shivinish (Monachs)	Ceann Iar (Monachs)	Ceann Ear (Monachs)	Shillay (Monachs)	Stockay (Monachs)	Monachs total	Others	Rona	TOTAL
1981	1255	423	1016	278	178	68	0	1279	486	331	847	2944	136	1785	8086
1982	1443	634	219	322	260	110	0	1329	557	199	712	2798	85	1888	7763
1983															
1984	1120	389	386	277	143	0	83	2175	616	209	555	3638	0	1641	7594
1985	1303	408	335	254	168	0	261	2365	748	193	641	4208	0	1489	8165
1986	1258	378	356	225	108	0	283	2931	822	222	572	4830	0	1300	8455
1987	1319	416	379	233	126	0	349	3242	689	223	659	5162	0	1194	8829
1988	1194	368	390	203	135	0	426	3760	448	188	577	5399	0	1164	8853
1989	1255	399	365	176	82	0	520	3997	542	210	530	5799	0	1159	9235
1990	1395	422	349	154	127	0	571	4598	526	175	475	6345	0	1184	9976
1991	1363	465	337	160	98	0	580	5122	551	173	495	6921	0	1290	10634
1992	1531	441	548	188	83	0	581	5471	737	211	594	7594	0	1499	11884
1993	1538	377	456	166	117	0	648	5502	1047	204	518	7919	0	1442	12015
1994	1436	416	529	131	101	0	635	5991	944	206	526	8302	0	1311	12226
1995	1365	410	583	122	63	0	854	6151	976	209	488	8678	0	1344	12564
1996	1482	405	597	139	70	0	712	6450	1255	163	442	9022	0	1294	13009

TABLE 3: Pup production estimates for islands in the Orkney group

YEAR	Muckle Green-holm	Little Green-holm	Little Linga	Holm of Spurness	Point of Spurness	Linga Holm	Holm of Huip	Fara-holm	Faray	Rusk-holm	Wart-holm	Sweyn-holm & Gairsay	Grass-holm	Swona	Pentland Skerry	Auskerry	Switha	Stroma	Calf of Eday	Copin-say	TOTAL
1960	734	190	239	90	0	0	0	441	0	208	41	0	0	2	98	0	0	0	0	0	2048
1961	537	290	251	124	0	0	0	300	0	256	33	0	0	2	48	0	0	0	0	0	1846
1962	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1963	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
1964	934	469	154	25	0	0	0	22	117	208	16	55	3	14	24	0	0	0	0	0	2048
1965	671	366	279	138	0	0	0	113	151	247	29	21	66	19	85	0	0	0	0	0	2191
1966	688	454	344	138	0	0	0	270	154	87	8	59	18	14	48	0	0	0	0	0	2287
1967	600	445	395	98	0	0	0	270	165	252	8	111	0	6	36	0	0	0	0	0	2390
1968	650	310	399	278	0	13	0	257	258	195	8	81	36	27	52	0	0	0	0	0	2570
1969	567	298	576	189	8	28	0	214	28	208	4	77	59	35	20	0	0	0	0	0	2316
1970	747	318	519	135	45	42	22	171	95	223	4	13	66	43	85	0	0	0	0	0	2535
1971	588	351	708	158	49	137	30	320	88	103	16	70	40	67	36	0	0	0	0	0	2766
1972	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

TABLE 3 continued

YEAR	Muckle Green-holm	Little Green-holm	Little Linga	Holm of Spurness	Point of Spurness	Linga Holm	Holm of Huip	Fara-holm	Faray	Rusk-holm	Wart-holm	Sweyn-holm & Gairsay	Grass-holm	Swona	Pentland Skerry	Auskerry	Switha	Stroma	Calf of Eday	Copin-say	TOTAL
1973	503	207	519	233	66	177	88	351	35	15	12	86	92	51	52	87	0	0	0	0	2581
1974	525	190	479	146	21	61	137	500	72	132	0	134	69	71	73	84	0	0	0	0	2700
1975	483	230	483	271	49	39	117	477	65	63	4	111	21	59	48	152	0	0	0	0	2679
1976	605	175	648	328	53	68	68	398	85	60	4	198	21	92	65	375	0	0	0	0	3247
1977	679	210	684	305	78	50	130	477	58	111	4	194	21	92	65	199	0	0	0	0	3364
1978	333	210	800	471	136	79	192	700	58	219	4	149	36	104	57	134	0	90	0	0	3778
1979	546	294	344	430	127	144	368	672	92	280	4	142	69	92	65	145	0	152	0	0	3971
1980	496	166	676	415	107	315	275	817	165	336	0	167	74	108	81	97	0	174	0	0	4476
1981	442	199	860	449	45	293	510	712	202	319	4	108	92	225	125	249	0	223	0	0	5064
1982	454	87	716	665	29	326	521	817	146	295	4	104	103	148	147	294	153	227	0	0	5241
1983	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

TABLE 3 continued

YEAR	Muckle Green-holm	Little Green-holm	Little Linga	Holm of Spurness	Point of Spurness	Linga Holm	Holm of Huip	Fara-holm	Faray	Rusk-holm	Wart-holm	Sweyn-holm & Gairsay	Grass-holm	Swona	Pentland Skerry	Auskerry	Switha	Stroma	Calf of Eday	Copin-say	TOTAL
1984	517	127	601	518	0	303	368	834	376	335	0	111	79	85	70	219	119	79	0	0	4741
1985	483	191	568	643	0	342	245	796	526	315	0	115	60	260	82	261	151	161	0	0	5199
1986	637	227	602	533	0	390	358	752	811	345	0	145	81	191	70	278	157	219	0	0	5796
1987	593	245	661	575	0	501	559	817	908	258	0	105	84	313	89	216	159	257	0	0	6340
1988	424	186	613	432	0	577	559	845	953	248	0	75	13	354	68	225	168	243	0	0	5983
1989	451	207	592	434	0	715	651	778	1465	228	0	154	40	305	69	281	226	315	0	0	6911
1990	359	223	636	345	0	808	729	957	1304	187	0	182	40	344	77	253	204	359	15	15	7037
1991	479	208	753	390	0	1141	886	1000	1594	194	0	212	70	515	93	274	271	436	83	124	8723
1992	544	235	868	467	0	1189	1062	1321	1874	212	0	225	53	614	72	176	308	567	141	234	10162
1993	639	247	854	382	0	1252	1227	1324	1794	224	0	286	83	604	83	163	321	605	269	507	10864
1994	676	273	799	363	0	1530	1317	1258	1911	228	0	266	69	669	68	174	338	515	323	829	11606
1995	737	314	803	421	0	2078	887	1387	2135	258	0	425	33	-	-	127	-	-	277	946	12545
1996	779	309	838	416	0	2250	1338	1465	1952	251	0	518	65	818	83	121	367	573	397	1485	14025

TABLE 4: Pup production estimates for sites other than those covered by aerial surveys.

YEAR	Farne Islands	Isle of May	SW England	Wales	Donna Nook	Helms-dale	Loch Eriboll	Shetland	South Ronaldsay (Orkney)
1956	751	.	.	.	.	.	.	.	.
1957	854	.	.	.	.	.	.	.	.
1958	869	.	.	.	.	.	.	.	.
1959	898	.	.	.	.	.	.	.	.
1960	1020	.	.	.	.	.	.	.	123
1961	1141	.	.	.	.	.	.	.	152
1962	1118	.	.	.	.	.	.	.	.
1963	1259	.	.	.	.	.	.	.	.
1964	1439	.	.	.	.	.	.	.	115
1965	1404	.	.	.	.	.	.	.	74
1966	1728	.	.	.	.	.	.	.	107
1967	1779	.	.	.	.	.	.	.	132
1968	1800	.	.	.	.	.	.	.	152
1969	1919	.	.	.	.	.	.	.	127
1970	1987	.	.	.	15	.	.	.	103
1971	2041	.	.	.	1	.	.	.	148
1972	1617	.	.	.	0	.	.	.	.
1973	1678	.	107	.	0	.	.	578	123
1974	1668	.	.	.	.	.	.	.	136
1975	1617	.	.	.	.	.	.	.	197
1976	1426	.	.	.	.	.	.	.	160
1977	1243	.	.	645	.	.	.	700	156
1978	1162	.	.	.	.	.	.	.	169
1979	1320	300	.	.	.	.	.	.	164
1980	1118	499	.	.	.	.	.	.	140
1981	992	505	.	.	34	.	.	.	82
1982	991	603	.	.	43	.	.	.	103

TABLE 4 continued

YEAR	Farne Islands	Isle of May	SW England	Wales	Donna Nook	Helms-dale	Loch Eriboll	Shetland	South Ronaldsay (Orkney)
1983	902	336	.	.	.	.	.	.	.
1984	778	517	.	.	30	94	406	.	.
1985	848	810	.	.	53	.	.	.	.
1986	908	891	.	.	35	.	.	.	.
1987	930	865	.	.	72	.	.	.	.
1988	812	608	.	.	54	.	.	.	.
1989	892	936	.	.	94	280	666	.	.
1990	1004	1122	.	.	152	.	.	.	.
1991	927	1225	.	.	223	321	.	.	241
1992	985	1252	.	1308	200	225	612	.	246
1993	1051	1468	.	1372	205	.	700	.	244
1994	1025	1408	.	1350	302	.	700	.	258
1995	1070	1346	.	.	334	300.	.	.	.
1996	1061	1582	.	.	310	300	715	.	.

TABLE 5: Estimated size of the population associated with all major grey seal breeding sites in Scotland and eastern England, except Loch Eriboll, Helmsdale and Shetland. Estimates refer to the number of seals of age 1 and over at the time of the breeding season.

YEAR	Pup Production	Female Population	Female + Male Population
1984	14970	25645	44732
1985	16246	27360	47713
1986	17770	29250	51012
1987	19005	31342	54681
1988	18260	33570	58589
1989	20043	35750	62366
1990	21351	38111	66464
1991	24230	40690	70949
1992	27334	43492	75830
1993	28541	46565	81213
1994	29355	49741	86754
1995	30932	53172	92750
1996	33178	56782	99041

TABLE 6: Smaller, less important Scottish grey seal breeding sites which are either not surveyed annually or have recently been included in the annual program. Other potential breeding sites are checked visually when time, conditions and circumstances permit.

Location	Survey method	Last surveyed, frequency	Number of pups
Inner Hebrides			
Colonsay/Oronsay mainland	SMRU visual	1994, every 2-3 years	None seen
Loch Tarbert, Jura	SMRU visual	1993, every 3-4 years	None seen
West coast Islay	SMRU visual	1991, every 3-4 years	None seen
South coast Ross of Mull	SMRU visual	1990, infrequently	None seen
Treshnish small islands, incl. Dutchman's Cap	SMRU photo & visual	1996, annually	~20 in total
Staffa	SMRU visual	1995, every other year	~20
Little Colonsay, by Ulva	SMRU visual	1994, every 3-4 years	~5
Meisgeir, Mull	SMRU visual	1994, every 3-4 years	~5
Craig Inish, Tiree	SMRU photo	1995, every 2-3 years	2
Cairns of Coll	SMRU photo	1995, every 2-3 years	9
Muck	SMRU photo	1996, every other year	8
Rum	SNH ground	1996, annually	10-15
Canna	SMRU photo	1996, every other year	27
Rona	SMRU visual	1989, infrequently	None seen
Ascrib Islands, Skye	SMRU photo	1996, every other year	48
Lighthouses: Heisgeir Dubh Artach Skerryvore	SMRU visual	1995, every other year 1989, infrequently 1989, infrequently	None None None
Outer Hebrides			
Islands around Barra	SMRU visual	1989, infrequently	None seen
Sound of Harris islands	SMRU photo	1994, every 2-3 years	150
St Kilda	Anecdotal reports	not systematically	Pups are born
Shiants	SMRU visual	1994, every other year	None
Flannans	SMRU visual	1994, every 2-3 years	None
Bernera, Lewis	SMRU visual	1991, infrequently	None seen
Summer Isles	SMRU visual	1989, infrequently	None seen
Faraid Head	SMRU visual	1989, infrequently	None seen
Eilean Hoan, Loch Eriboll	SMRU visual	1996, annually	None
Rabbit Island, Tongue	SMRU visual	1996, every other year	None seen
Eilean nan Ron, Loch Tongue	SMRU photo	1996, annually since 1994	200
Orkney			
Sanday, Point of Spurness,	SMRU photo	1996, annually	8
Sanday, east and north	SMRU visual	1994, every 2-3 years	None seen
Papa Stronsay	SMRU visual	1993, every 3-4 years	None seen
Holm of Papa, Westray	SMRU visual	1993, every 3-4 years	None seen
North Ronaldsay	SMRU visual	1994, every 2-3 years	None seen
Calf of Flotta	SMRU photo	1996, annually	78
Others			
Firth of Forth: Inchcolm, Eyebroughy, Bass Rock, Fast Castle	Anecdotal records from local wardens	Infrequently and irregularly	~20

Legends to Figures

Figure 1. Total estimated pup production for all major breeding colonies in Scotland and England (except Loch Eriboll, Helmsdale and the Shetlands) from 1984 to 1996.

Figure 2. Estimated size of the total female population at all major breeding sites in Scotland and England from 1984 to 1996, shown with pup productions estimated from the population model.

Figure 3. Trends in pup production at the major grey seal breeding areas since 1984. Production values are shown with their upper and lower 95% confidence limits, where these are available. These limits assume that the various pup development parameters which are involved in the estimation procedure remain constant from year to year. They therefore underestimate the total variability in the estimate, but they are useful for comparison of the precision of the estimates in different years.

3(a) Outer Hebrides, Orkney and Inner Hebrides; 3(b) Isle of May, Farne Islands and Donna Nook. Note that the scale of these two figures differs by an order of magnitude.

Figure 4. The location of the main grey seal breeding sites in Britain

Figure 5. Distribution of the number of grey seals hauled out in Scotland as revealed by surveys for common seals conducted in the summers of (a) 1988-1993 and (b) 1996.

Figure 6. The distribution and abundance of grey seals in the North Atlantic.

Figure 1

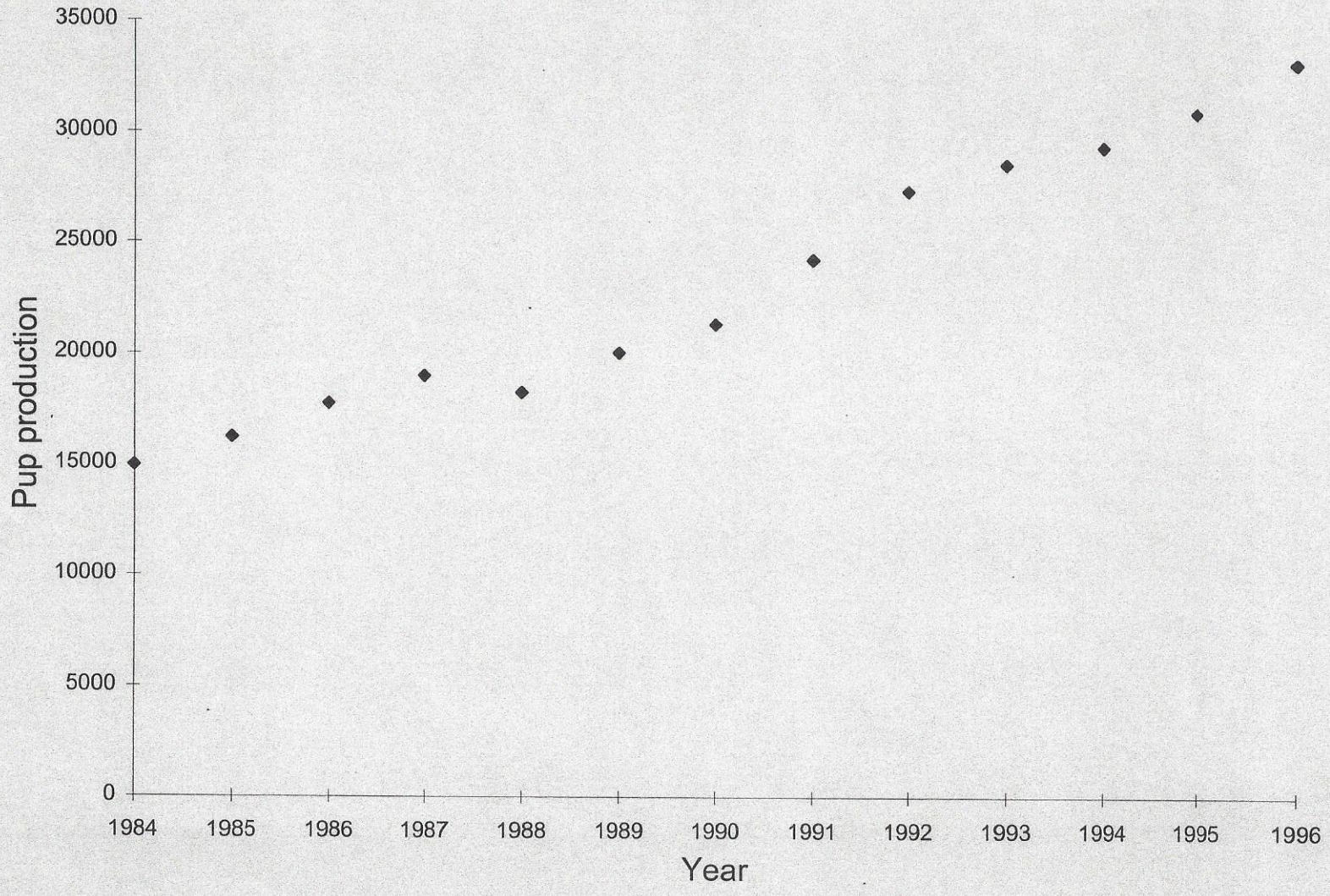

35000
30000
25000
20000
15000
10000
5000
0
Pup production
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
Year

Figure 2

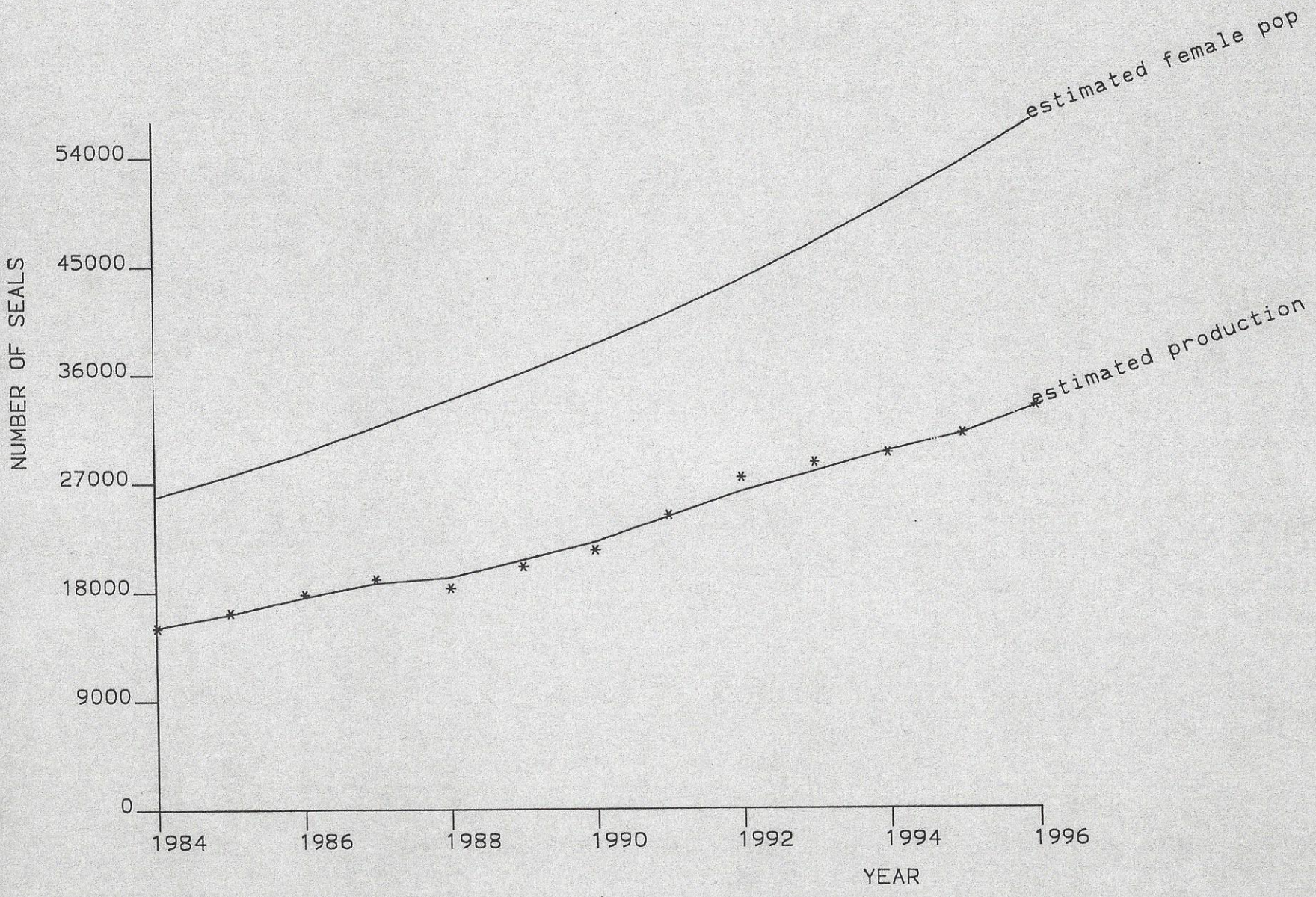
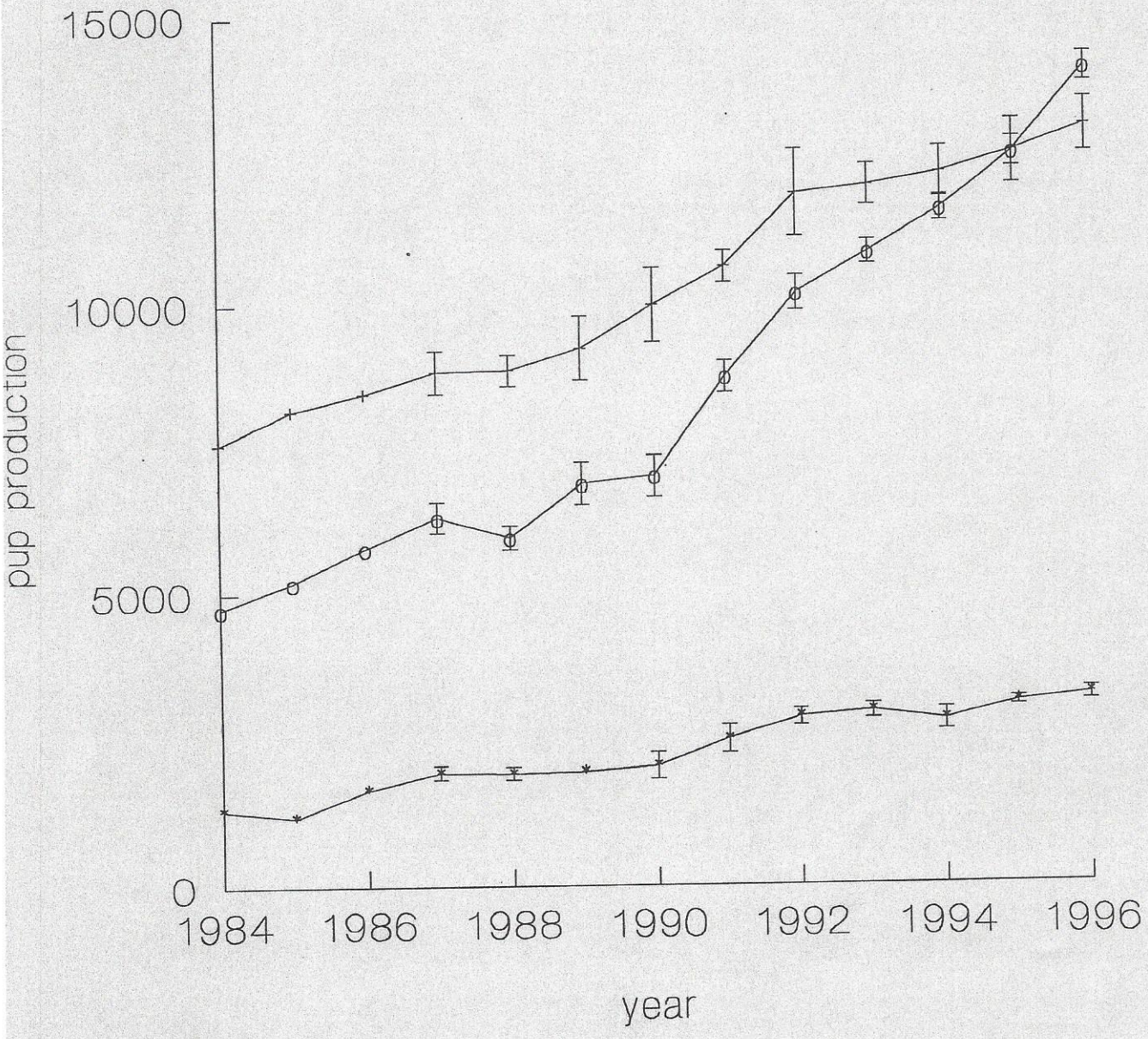
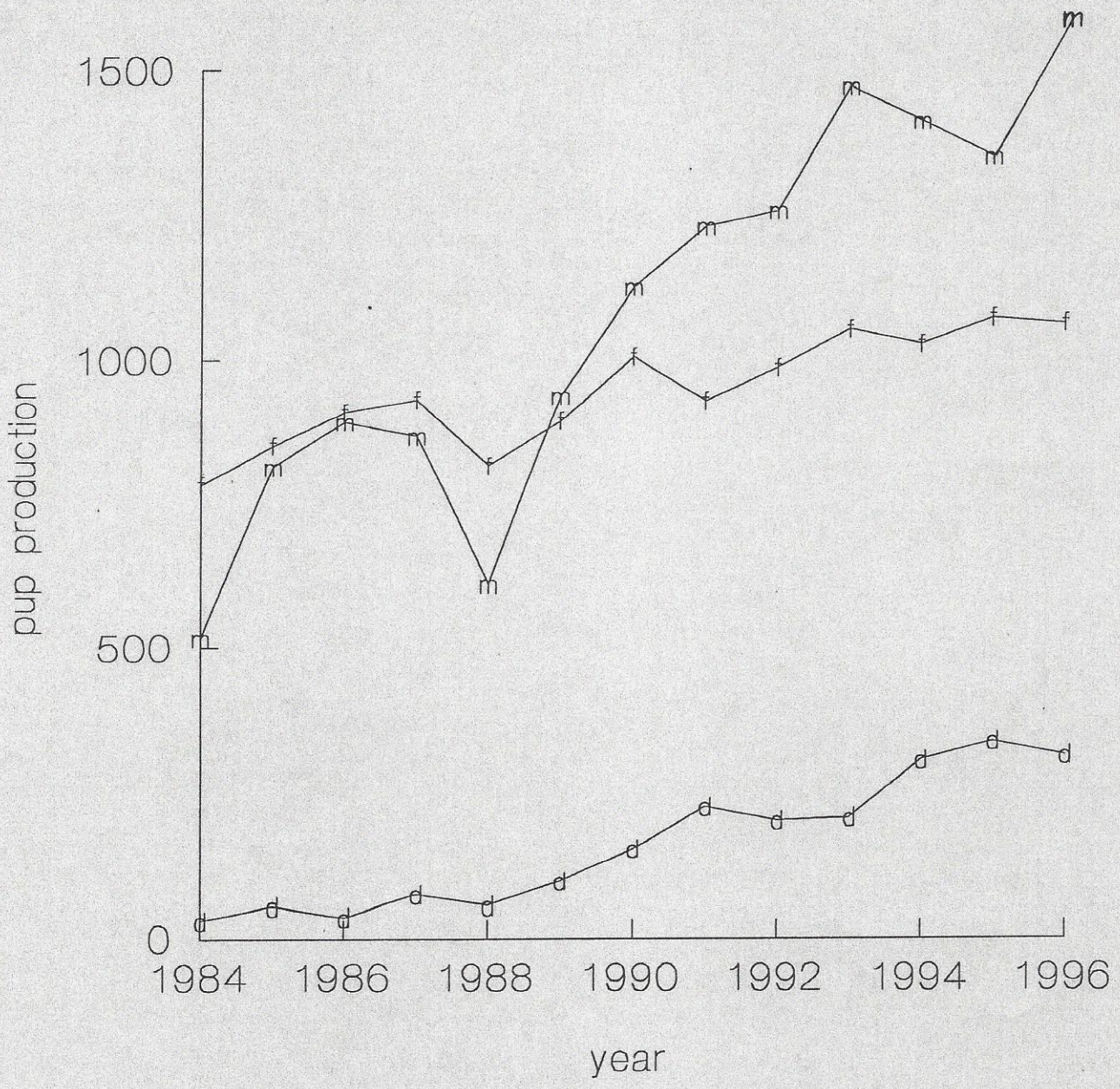

estimated female pop
estimated production
NUMBER OF SEALS
54000
45000
36000
27000
18000
9000
0
1984
1986
1988
1990
1992
1994
1996
YEAR

Figure 3a

o=orkney +=outer hebrides *=inner hebrides




f=farnes m=isle of may d=donna nook
1500
1000
500
0
pup production
1984
1986
1988
1990
1992
1994
1996
year

MAIN GREY SEAL BREEDING SITES

Figure 4

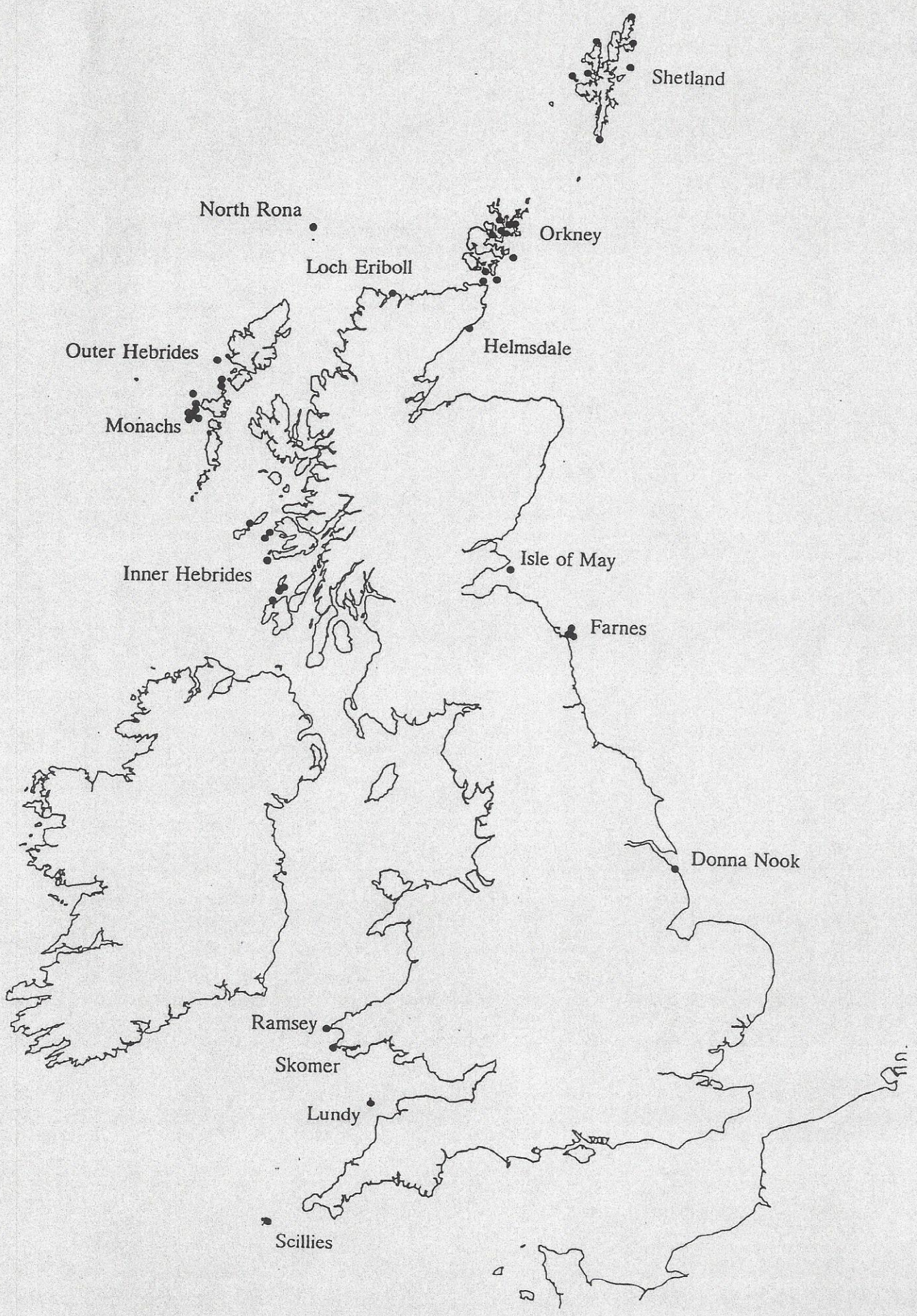
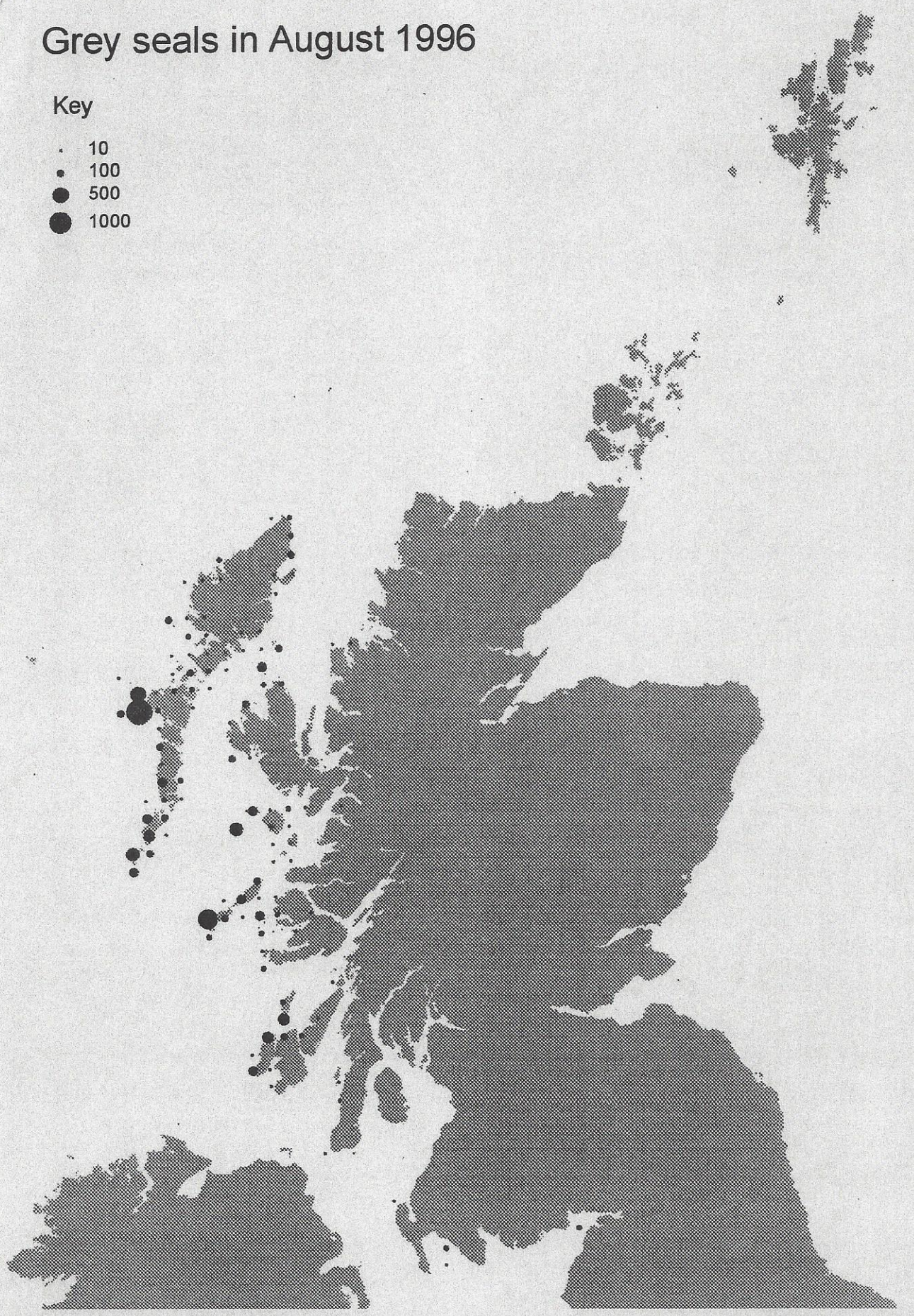
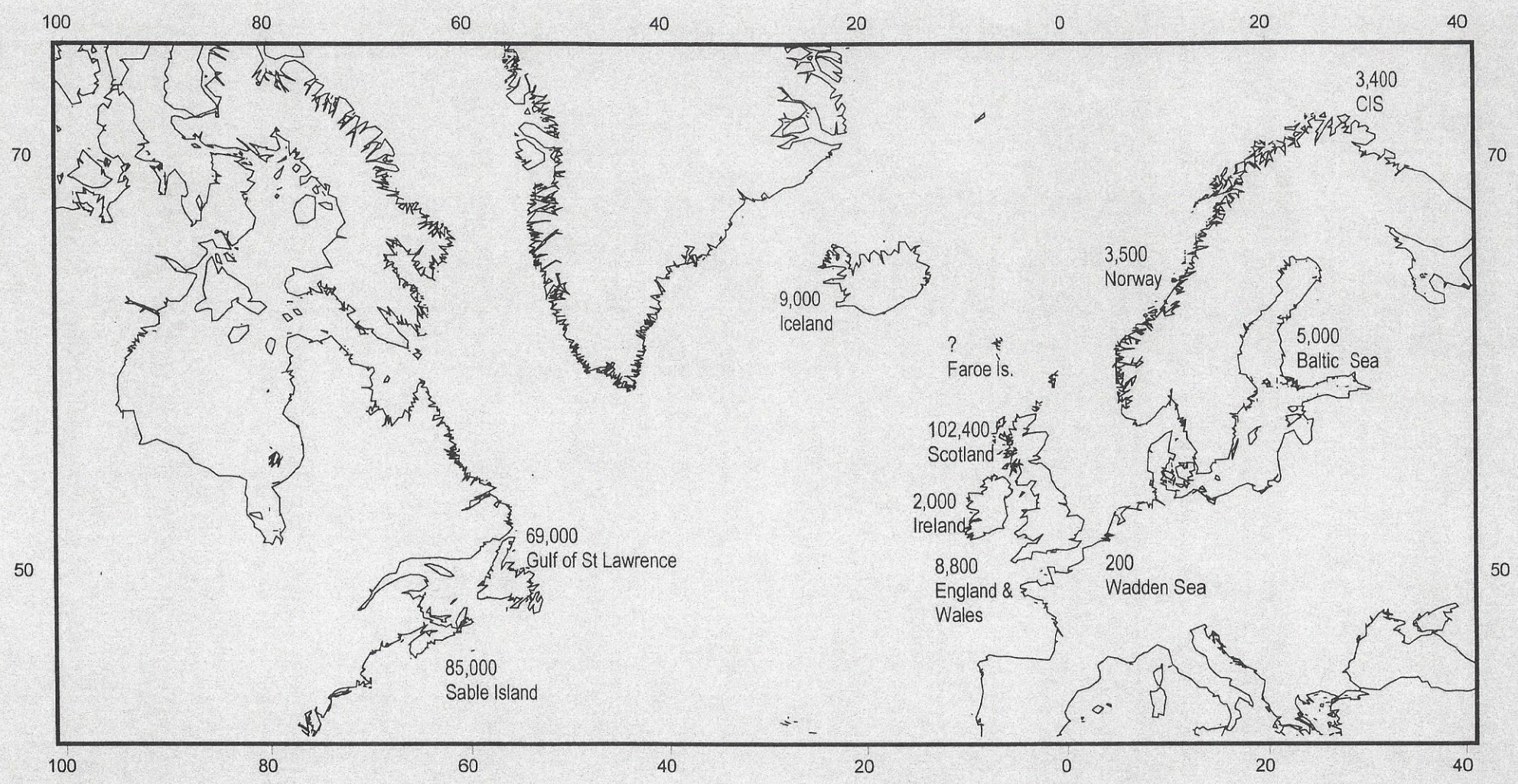


Figure 5a

Grey seals in August 1988 - 1993

Grey seals in August 1996





Distribution and abundance of Grey Seals in the North Atlantic

Figure 6

SCOS 97/2
ANNEX I
Appendix 1

Key elements of the advice and glossary of technical terms

This document seeks to provide advice on key fundamental questions related to the British grey seal population and other matters raised by the Scottish Office and Home Office.

Fundamental questions:

1. What is the current size of the British grey seal population?
2. How is this divided between Scotland and England /Wales?
3. What is the increase in population size over last year?
4. Is there evidence that the rate of increase is slowing down overall, or in a particular area?
5. What are future predicted population sizes?

Other questions addressed this year are:

1. What do the available data on trends in pup production in different areas tell us about the dynamics of the population?
2. Can pup production at newly colonized breeding sites account for any slowing of the rate of increase in pup production at the Monach Isles?
3. Is there evidence that breeding seals degrade habitat on the Monach Isles?
4. What is the role of seals in predation of salmon?
5. What is the current composition of the diet of seals in the North Sea?
6. Is immuno-contraception a viable means of population control?

Glossary

Pupping season: the period (October - November) when grey seal pups are born.

Ground count: direct count of pups born at a particular site made by observers on the ground.

Pup production: the total number of pups born at a particular site in a given year. This is estimated from counts of pups on aerial photographs and from ground count data.

All-age (total) population size: the population of males and females estimated from female population size, which is estimated from a population model using pup production estimates and other input data.

Power calculation: calculation to determine the power of a series of population estimates to show an increase (or decrease) at a given level of significance.

Immuno-contraception: the sterilization of females by the administration of an immunovaccine.

SAC: Special Area of Conservation under the European Habitats Directive.

SCOS 97/2
ANNEX I

Appendix 2

Non-equilibrium metapopulation dynamics of a large vertebrate: the British grey seal

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SUMMARY

1. Many colonially breeding pinnipeds have a population structure which conforms to that of a classical metapopulation, with individual breeding sites (equivalent to habitat "patches") subject to occasional extinction and recolonization. However, this structure is obscured because most of these populations are recovering from major perturbations. They therefore have a non-equilibrium metapopulation structure in which the rate of colonization exceeds the rate of extinction.

2. The advantages of considering pinniped populations in this context are considered using a 37 year time series for the British grey seal population as an example.

3. Forty-eight breeding sites have been monitored over this period. Twenty seven sites were occupied when monitoring began, and a further 20 have been colonized during the monitoring period. Four colonies have gone extinct and five are declining. Of the extant colonies, 33 (73%) are increasing in size at rates of between 0.008 and 0.683 per annum. However, five of these colonies show evidence of density dependent effects; at a further four colonies the relationship is approaching significance. Analysis of the detrended time series indicates that there has probably been substantial migration between certain colonies in the major island groups on a number of occasions.

4. Methods which can be used to estimate extinction and colonization rates for individual breeding sites are discussed. These estimated rates can then be used to examine the size and behaviour of the population at equilibrium.

INTRODUCTION

The metapopulation concept has been extremely influential in the study of populations whose spatial distribution appears to play a role in their dynamics. In the last ten years, the concept has replaced island biogeography as the central paradigm in conservation biology (Hanski and Simberloff 1997). In the process, there has been a tendency to consider any population which is spatially structured as a metapopulation. In an attempt to prevent this devaluation of the term, Hanski and Simberloff (1997) have suggested that it should be confined to populations which are "spatially structured into assemblages of local breeding populations and that migration among the local populations has some effect on long dynamics, including the possibility of population reestablishment following extinction". The latter phenomenon is usually referred to as population "turnover". A number of authors (Harrison 1994, Harrison and Taylor 1997, Thomas 1994) have suggested that very few populations actually comform to the "classical" metapopulation ideal. They suggest that many so-called metapopulations are in fact patchy populations (where migration is so high that there is little or no chance of extinction), mainland-island metapopulations (where one or more patch contains a population which never goes extinct and acts as the main source for recolonization of vacant patches), artificial metapopulations (which have been created by anthropogenic fragmentation of previously continuous habitat), or local populations which track ephemeral patches of habitat (where extinction coincides with the destruction of the habitat patch, so that there is no possibility of turnover).

Many mammals of the order Pinnipedia breed colonially on remote uninhabited islands or stretches of coastline. Populations made up of these colonies have all of the characteristics of a classical metapopulation. Suitable habitat patches are discrete and easily defined. They are surrounded by habitat which is unsuitable for breeding. Colonies do go extinct from time to time (usually because of excessive predation by man, but also because of rare catastrophic events), but sites can be and are recolonized. However, this metapopulation structure is obscured because most pinniped populations are recovering from overexploitation in the 19th century. As a result, the rate of formation of new colonies exceeds the rate at which they are going extinct (often by a wide margin) and population turnover, the characteristic feature of a classic metapopulation, is rarely observed. Hanski and Simberloff (1997) refer to such populations as "nonequilibrium metapopulations".

The British population of the grey seal (*Halichoerus grypus*) had been reduced to very low numbers by the end of the 19th century (Harwood and Greenwood 1985). Since that time, following the implementation of protective legislation, its numbers have increased to more than 100,000 and half the world population now breeds in this country (Reijnders et al. 1993). The number of seals breeding at all of the major colonies in Britain has been monitored almost annually since 1960 by the Sea Mammal Research Unit and its predecessors. In this paper, I analyse these time series in a metapopulation context and use this analysis to reach some conclusions about the future dynamics of the population.

METHODS

Most colonies have been monitored using a series of aerial photographs taken on 2-5 occasions during the pupping season, which runs from late September to November. Other islands or stretches of coastline which might also be used by breeding seals are surveyed at the same time. Counts of pups from these photographs are then used to estimate the total number of pups born at each colony using an estimation procedure described in Hiby et al. (submitted). At a few more accessibel sites pups are counted directly on the ground.

Rates of change at each colony were estimated by fitting the relationship

$$\ln(N_{i,t}) = r_i.t + c$$

where $N_{i,t}$ is the number of pups born at colony i in year t and r_i is the intrinsic rate of increase for that colony, to each time series using least-squares regression. Relationships between the dynamics of individual colonies were examined by testing for correlations between the residuals around this relationship.

Evidence for density dependence at individual colonies was sought by plotting year specific values for r (estimated as $\frac{1}{2}\ln(N_{i,t+1}/N_{i,t-1})$ - an algebraic sleight of hand proposed by Akçakaya et al. (1996) to avoid correlation between r_t and $N_{i,t}$) against $N_{i,t}$. A relationship with a negative slope significantly less than 0 was taken as evidence.

RESULTS

Figure 1 (not included) shows the locations of the 48 colonies which have been monitored over the last 37 years. Figures 2-5 show the time series of numbers and the fitted exponential relationships (where these were significant)for these colonies, which have been divided into four major geographical regions (Inner Hebrides, Outer Hebrides, Orkney, England and mainland Scotland). These colonies account for more than 85% of all the grey seal pups born in Britain each year.

During the study period 20 new colonies were established and three colonies (Deasker in the Outer Hebrides, Point of Spurness and Wartholm in Orkney) went extinct. Thirty-three of the 45 extant colonies are increasing at rates of between 0.009 and 0.683 per year. However, two of these rates (those for Calf of Eday and Copinsay in Orkney) are clear outliers (Figure 6) and are not possible without immigration. If these values are excluded, the mean observed rate of increase is 0.079 with a range of 0.009 to 0.193. Five colonies (Causamul, Stockay and Rona in the Outer Hebrides, Little Greenholm in Orkney, and the Farne Islands in England) are decreasing. The remaining six colonies show no evidence of a consistent increase or decrease.

Only five of the extant colonies (Shivinish and Ceann Iar in the Outer Hebrides, Calf of Eday and Colinsay in Orkney, and the Isle of May) show evidence of density dependence at the 5% level. These relationships are shown in Figure 7. A further four colonies (Nave Island in the Inner Hebrides, and Little Linga, Holms of Spurness and Stroma in Orkney) show evidence of

density dependence at the 10% level.

DISCUSSION

The analysis of trends in the time series for individual grey seal colonies indicate that there is turnover in this population and that 24-34% of the extant colonies appear to have reached or to be approaching equilibrium levels. Since the latter colonies include the largest colony in Britain (Ceann Iar) and the two most rapidly growing colonies (Calf of Eday and Colinsay), these results suggest that the entire British population may reach an equilibrium within one or two seal generations (15-30 years).

The existence of large numbers of positive correlations between the residuals of neighbouring colonies in the same geographical region (which is approximately equivalent to an analysis of variation at individual colonies with the underlying trends removed) suggests that variations in pup production at these colonies may be driven by environmental variation. This could occur, for example, if most breeding females from these colonies fed in the same area.

Approximately one quarter of the approximately 300 pairwise comparisons of residuals between colonies in the same geographical area show a significant correlation. Most (80%) of these are positive. If the numbers of pups born at colonies in each geographical area are aggregated to provide a single figure, there are no significant correlations between the residuals in different areas. Some support for this hypothesis comes from the fact that seals from the four major regions appear to have rather different foraging ranges and diets (SMRU unpublished). The lack of correlation between regions lends support to the somewhat arbitrary division of the British population into four major regions, and there is additional support for this from recent analysis of variation in the frequency of mitochondrial DNA haplotypes between colones (Walton et al., in prep.).

The small number of negative correlations between colonies suggest that seals remain relatively faithful to one colony (as suggested by the site fidelity shown by breeding females at Rona - Pomeroy et al. 1995) and do not alternate their breeding activities between sites. Where such relationships exist, they are normally between adjacent islands or island groups. However, there is one important negative correlation which has wider significance. If the five islands of the Monach Isles group are combined, the residuals around the regression of pups numbers on year show an inverse pattern of variation to that observed for the Orkney colonies (Figure 8a). When the residuals are converted to actual deviations in the numbers of pups born each year, there is a highly significant correlation ($r^2 = 0.80$) between the two set of deviations (Figure 8b). This implies that the early rapid growth at the Monach Isles may have been driven by immigration from Orkney (possibly induced by high levels of pup hunting there in the 1960s), and that the recent rapid growth of colonies in Orkney may be the result of density dependent emigration from the Monach Isles.

If individual British grey seal colonies are approaching equilibrium, as this analysis implies, it may be possible to investigate the ultimate equilibrium behaviour of the entire British metapopulation, which may involve complex dynamics (see Hastings 1993). To do this, we

require estimates of the probability of extinction for extant colonies and of recolonization for vacant sites.

Lande (1993) and Foley (1997) provide formula which can be used to calculate the probability of extinction for individual. We require an estimate of the intrinsic rate of increase (r) and its variance for each colony. This can be obtained from the individual time series in a manner analagous to that used in the tests for density dependence. Foley (1994) provides an equation which allows the variance of r to be corrected for the strong serial autocorrelations shown by these series. In addition, we require an estimate of the equilibrium size of each colony. This can be obtained readily for the colonies which are stable or show evidence of density dependence. It should be possible to derive relationships between seal density and colony area from these colonies which can be used to estimate equilibrium size for colonies which are still increasing.

The calculation of the colonization rate is usually more difficult (Ims et al. 1997). However, in this case, it can be derived from empirical observations of the 20 new colonizations which have been observed during the time series and from direct and indirect estimates of migration rates derived from genetic and capture-recapture analysis respectively.

Figure captions

Figure 1. Location of the grey seal colonies included in this study (not provided)

Figure 2. Changes in the number of pups (shown as ln(N)) born in the Inner Hebrides over the period 1984-1996. The straight lines are fitted relationships between ln(N) and time.
a. Gunna, b. Treshnish, c. Fladda, d. Sgeir a Chaisteill and Eirionnach, e. Lunga, f. Soa, g. Eilean nan ron, h. Eilean nan eion, i. Nave Island.

Figure 3. Changes in the number of pups (shown as ln(N)) born in the Outer Hebrides over the period 1984-1996. The straight lines are fitted relationships between ln(N) and time.
a. Gasker, b. Coppay, c. Shillay (Sound of Harris), d. Haskeir, e. Causamul, f. Deasker, g. Shivinish, h. Ceann Iar, i. Ceann Ear, j. Shillay (Monach Isles), k. Stockay, l. Rona. Shivish, Ceann Iar, Ceann Ear, Shillay and Stockay are collectively known as the Monach Isles.

Figure 4. Changes in the number of pups (shown as ln(N)) born in Orkney over the period 1984-1996. The straight lines are fitted relationships between ln(N) and time.
a. South Ronaldsay, b. Little Linga, c. Holm of Spurness, d. Huip, e. Lingaholm, f. Point of Spurness, g. Gairsay, h. Muckle Greenholm, i. Little Greenholm, j. Faraholm, k. Faray, l. Ruskholm, m. Wartholm, n. Sweynholm, o. Grassholm, p. Swona, q. Pentland Little Skerry, r. Auskerry, s. Switha, t. Stroma, u. Calf of Eday, v. Copinsay.

Figure 5. Changes in the number of pups (shown as ln(N)) born in England and on the Scottish mainland over the period 1984-1996. The straight lines are fitted relationships between ln(N) and time.
a. Helmsdale, b. Loch Eriboll, c. Farne Islands, d. Isle of May, e. Isle of May.

Figure 6. Frequency distribution of observed positive rates of increase at monitored colonies.

Figure 7. Relationship between intrinsic rate of increase and population size at the five colonies where this was significant at the 5% level.
a. Calf of Eday, Orkney, b. Copinsay, Orkney, c. Isle of May, d. Shivinish, Outer Hebrides, e. Ceann Iar, Outer Hebrides.

Figure 8. a. Variation with time in the residuals around the fitted exponential regression between ln(N) and year for all Orkney colonies and all colonies in the Monach Isles. b. Relationship between these residuals (expressed as numbers of pups) in Orkney and the Monach Isles.

FIGURE 2

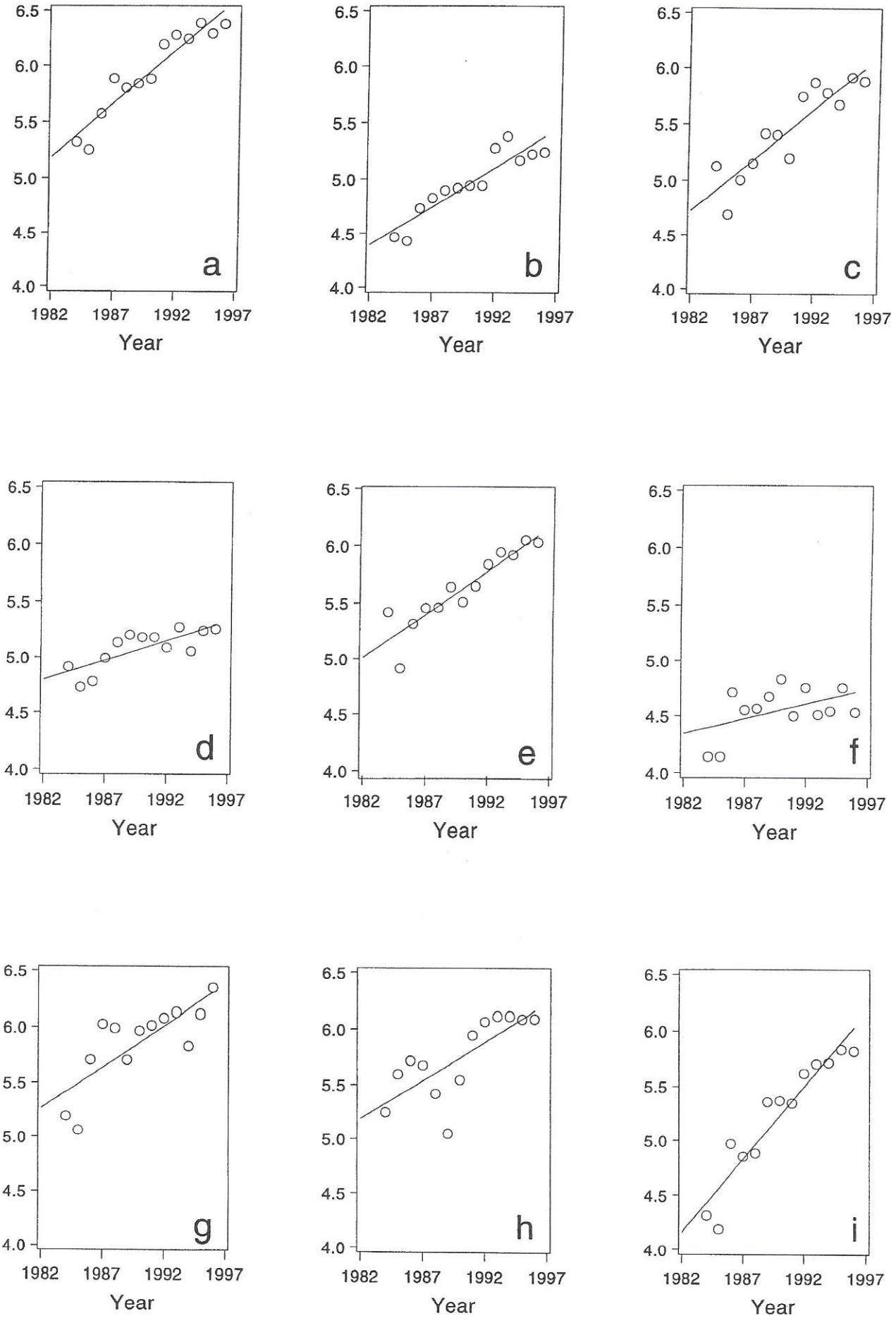
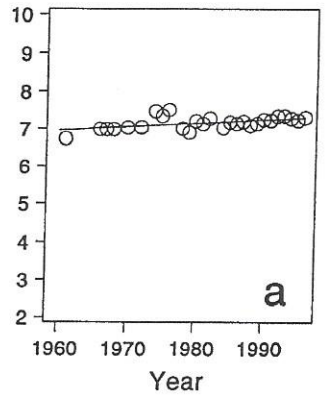


Figure 2


10
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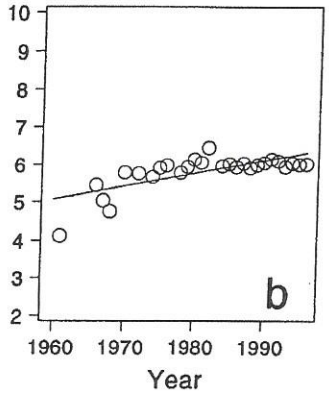
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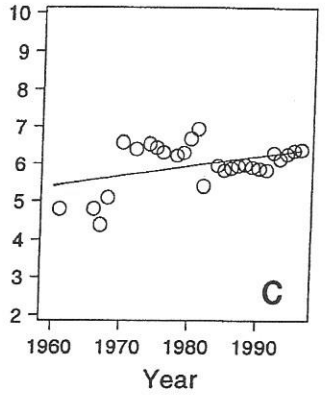
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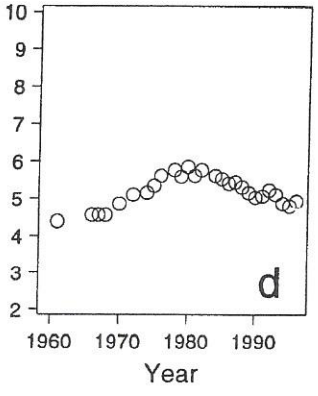
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1960 1970 1980 1990
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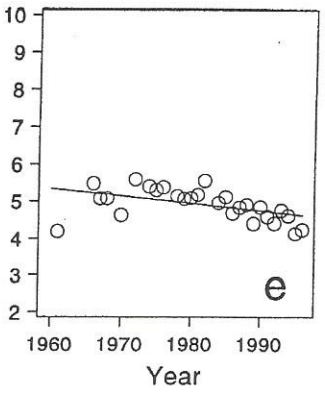
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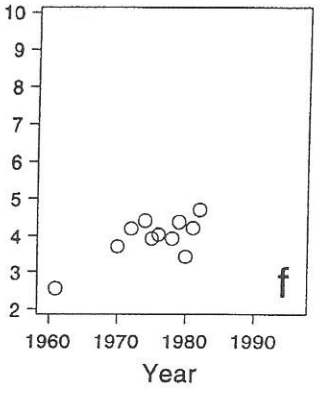
1960 1970 1980 1990
Year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f
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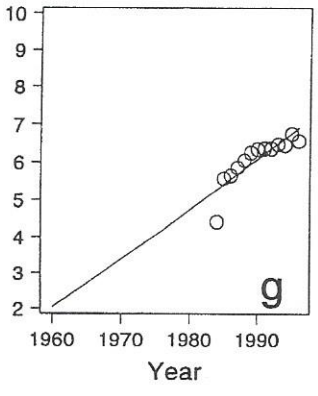
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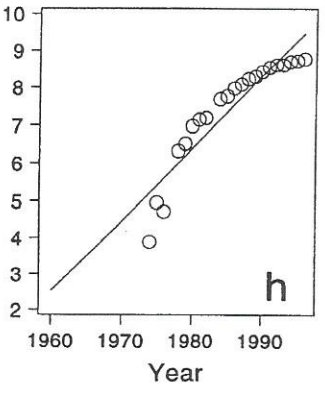
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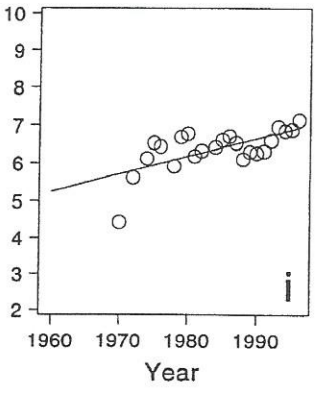
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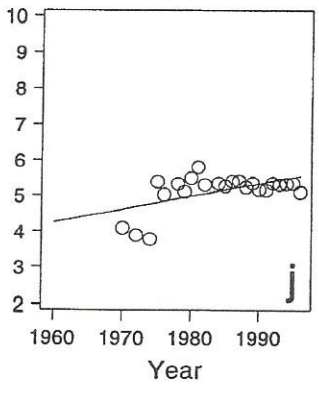
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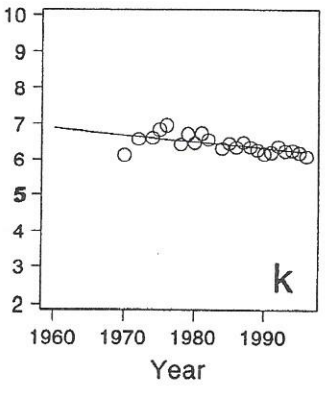
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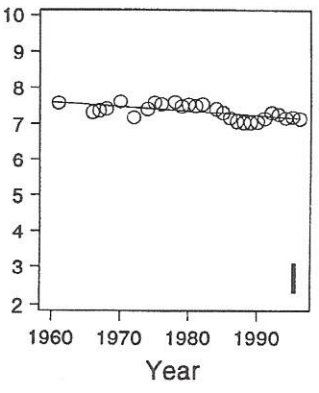
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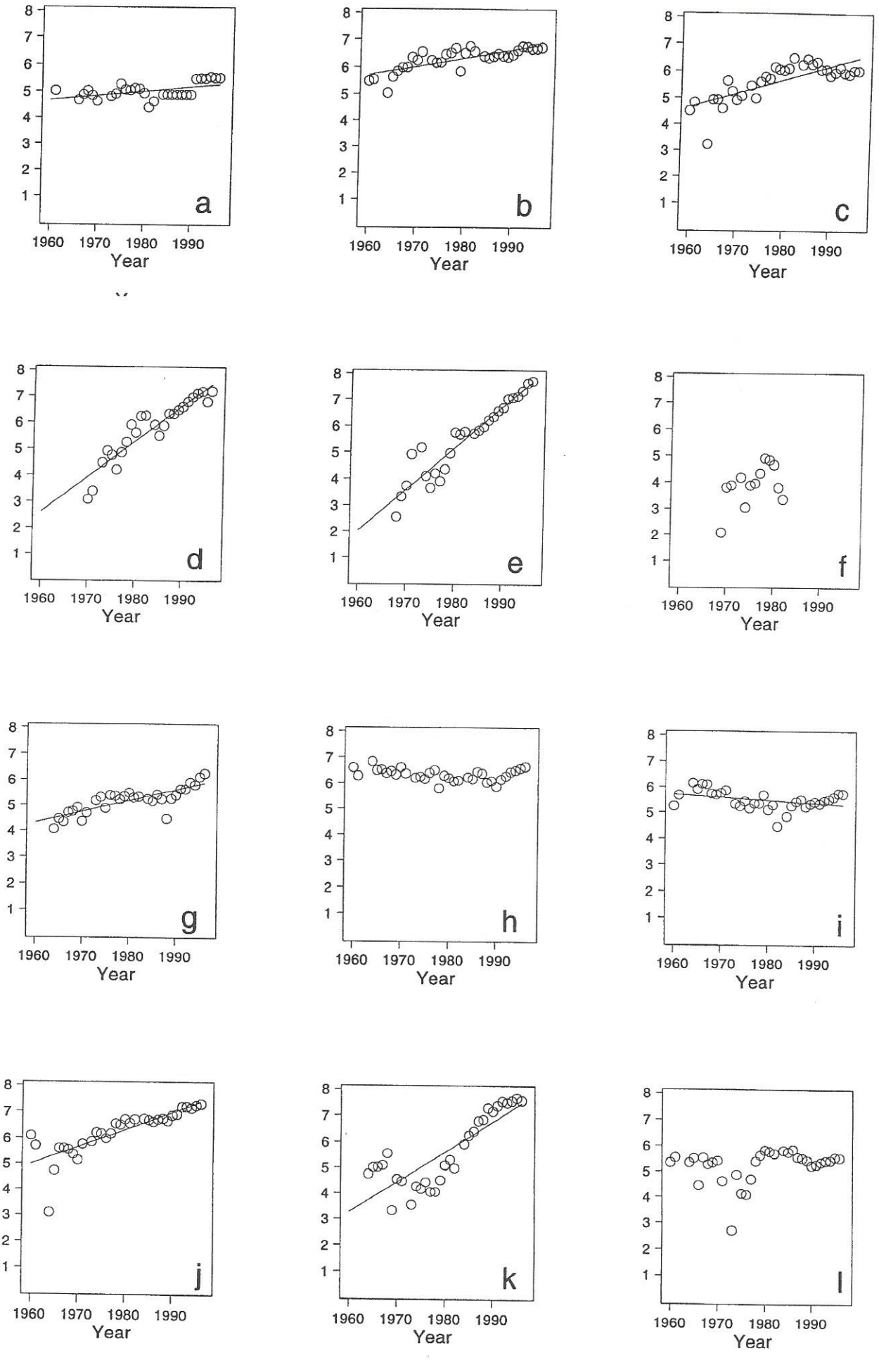
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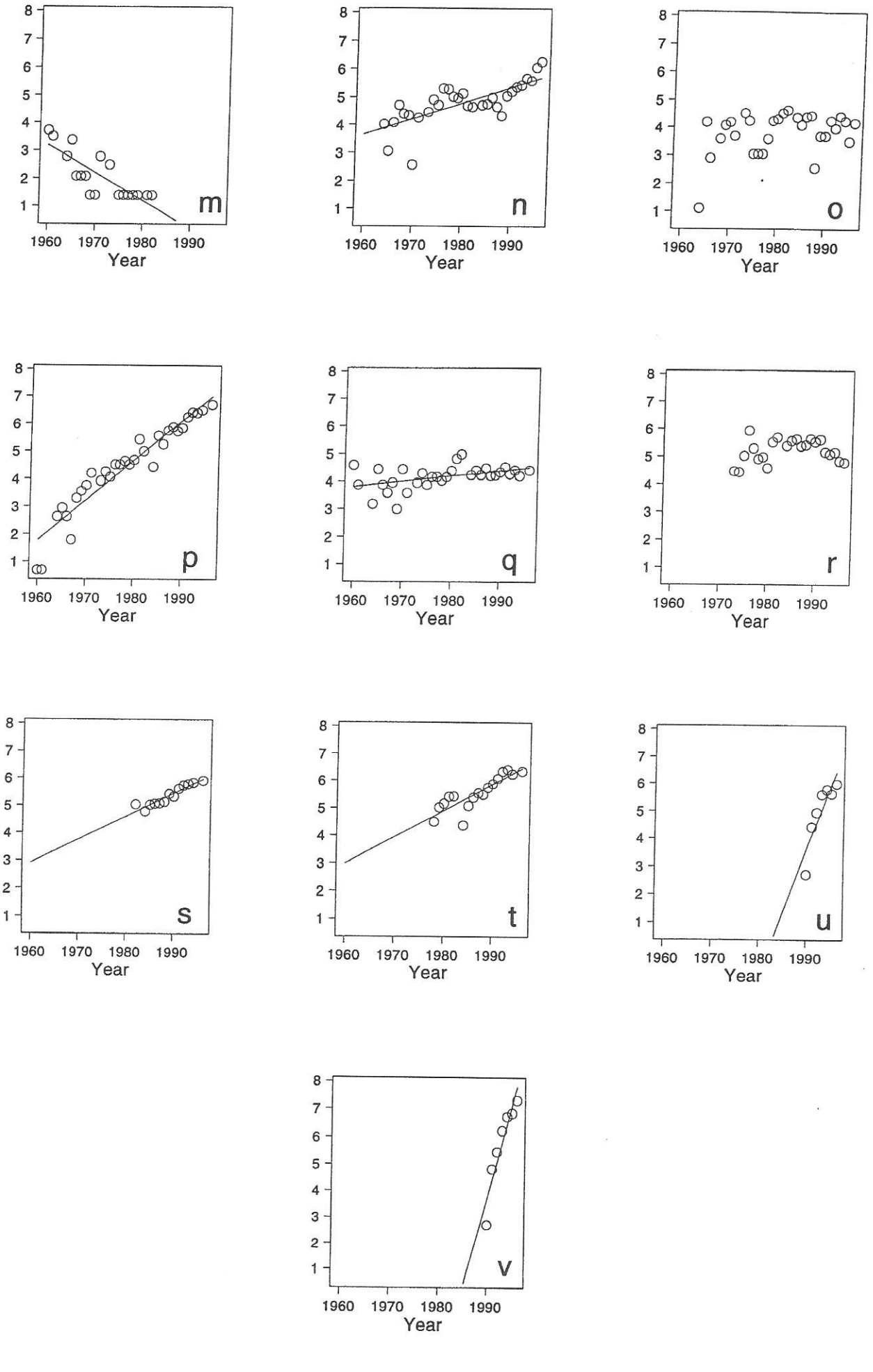
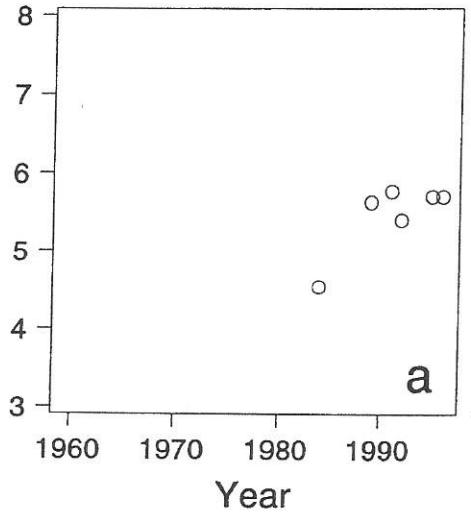


Figure 5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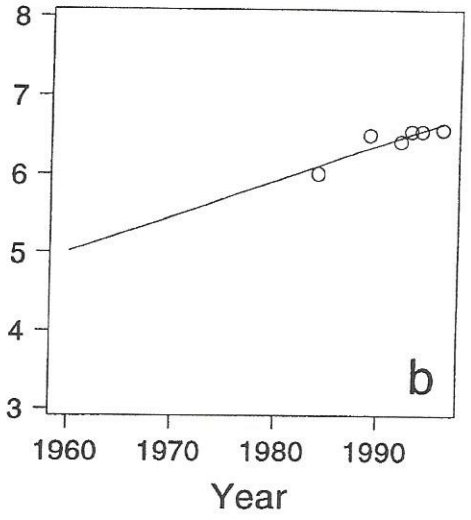
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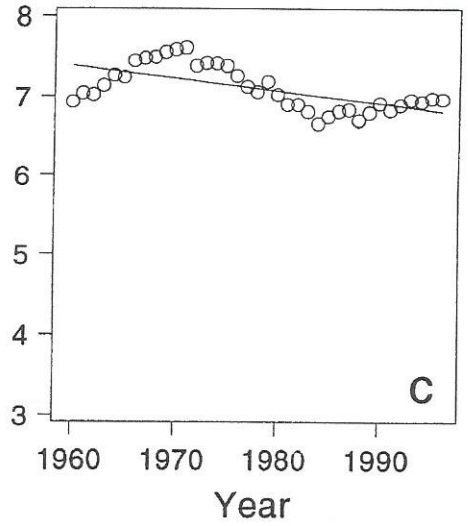
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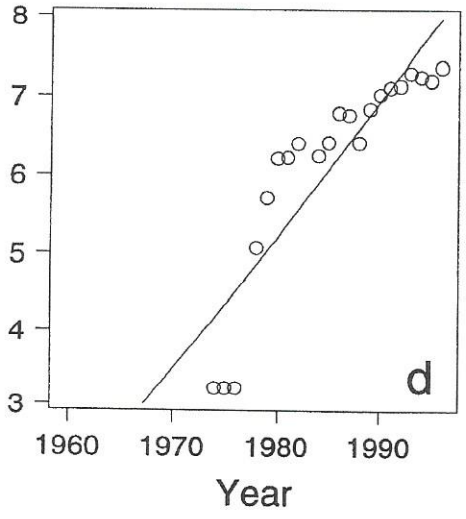
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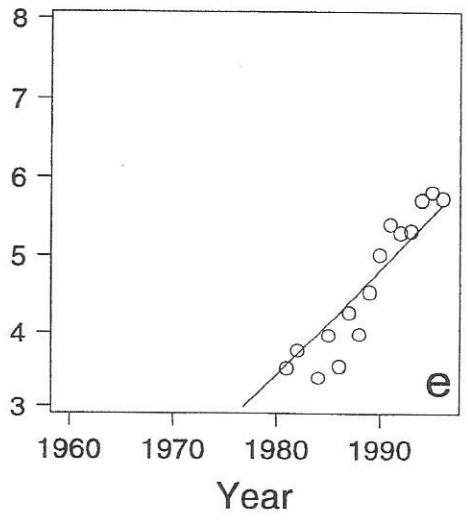
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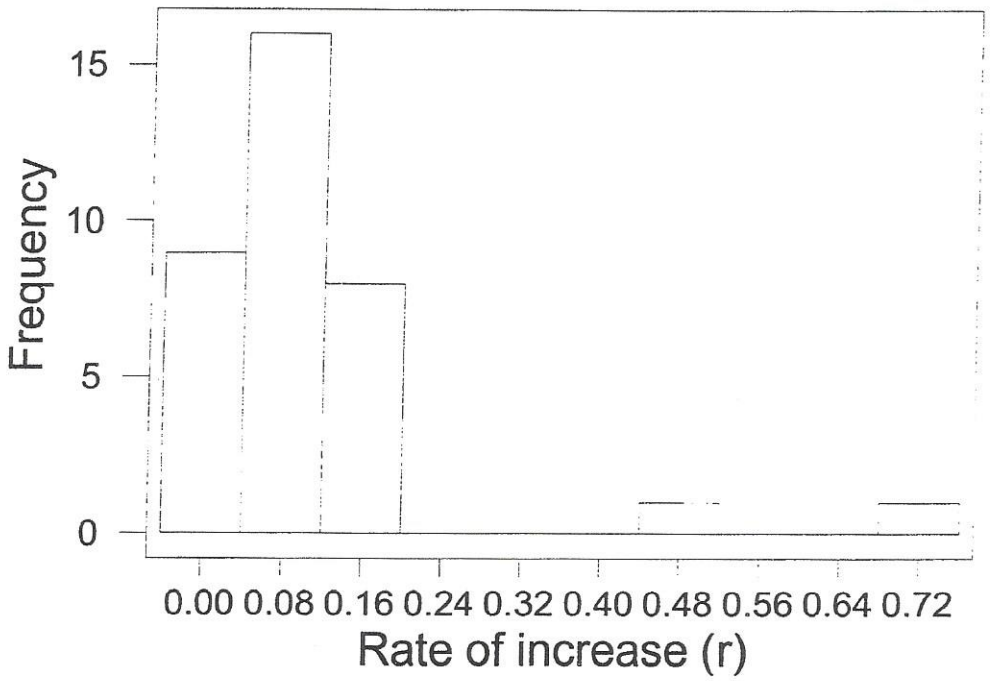
Figure 6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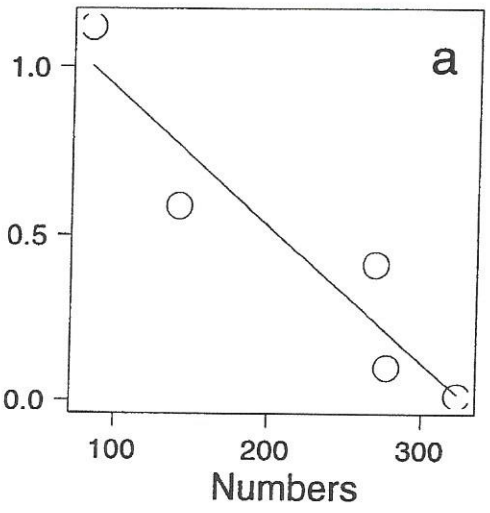
Rate of increase (r)

Figure 7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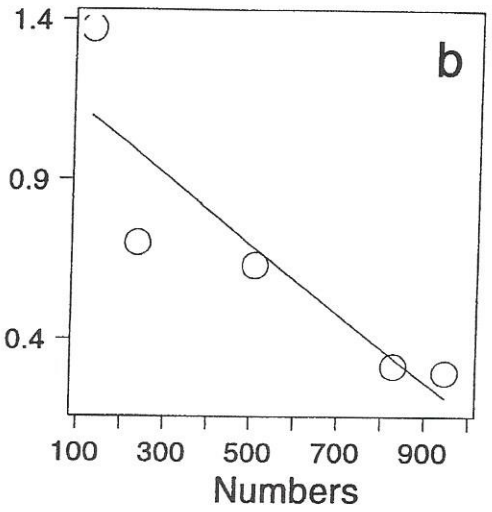
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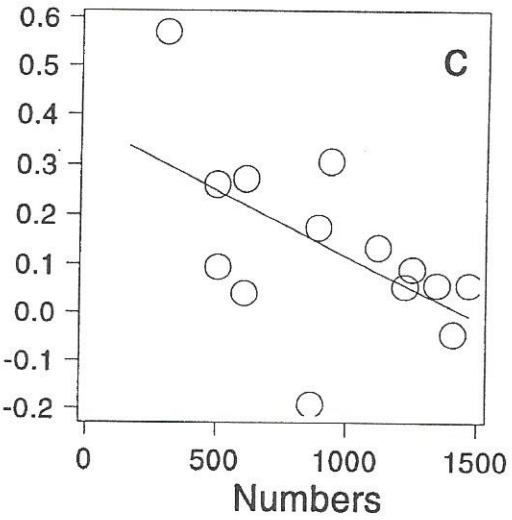
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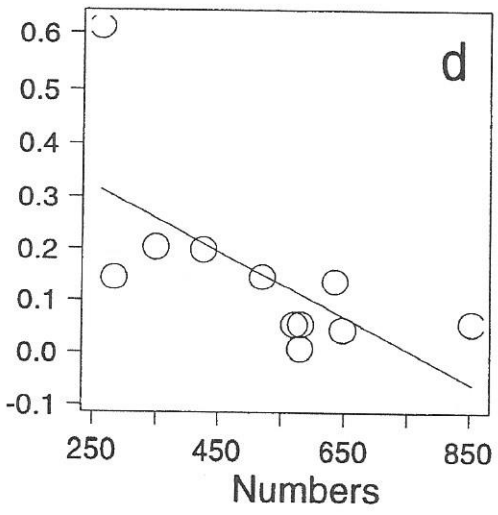
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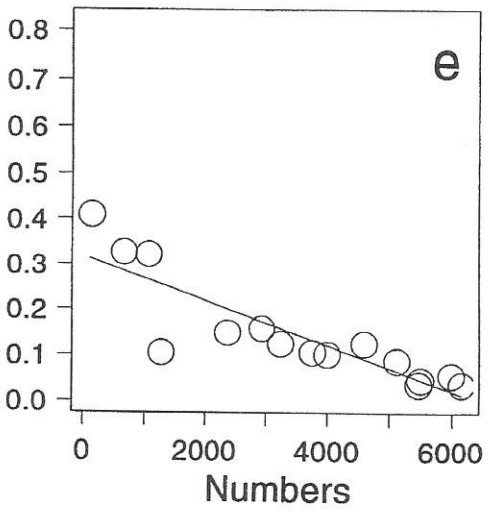
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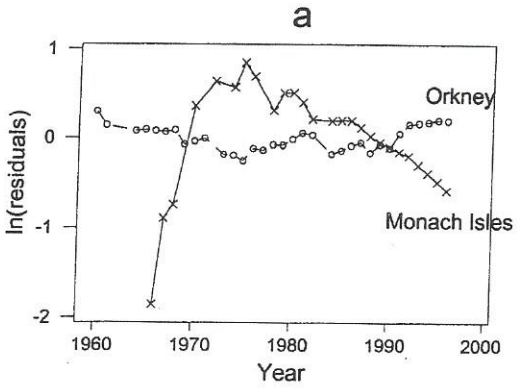
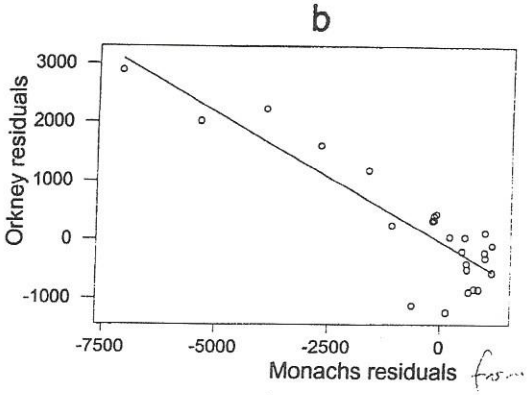
Figure 8





from our analysis

SCOS 97/2
ANNEX I
Appendix 3

Proposals submitted to the Scottish Office in 1997

Appendix 3a: Limits to the growth of the Scottish grey seal population

Appendix 3b: Seals and salmon in river systems

Appendix 3c: Breeding site fidelity and the feasibility of regulating grey seals numbers using fertility control

Appendix 3a: Limits to the growth of the Scottish grey seal population

BACKGROUND: The Scottish grey seal population has been increasing by 6% per annum for several decades. Although the number of pups born at certain colonies has stabilized during this period, there is no sign that the rate of increase for the whole population is slowing down. Ultimately, grey seal numbers are likely to be limited by the availability of space and food. Existing data collected by SMRU indicate that the effects of limitation will be to increase pup mortality at breeding colonies, and to decrease the amount of energy that females expend in reproduction. The latter effect may result in a decrease in the survival of pups in the first year of life. SMRU has a long time series of detailed aerial photographs of all major British grey seal colonies and has already begun research on the effects of density and the body condition of adult females on survival. This proposal will build on that on-going work to gain a better understanding of the eventual size of the British grey seal population, and the potential effects of various management options.

OBJECTIVES: To determine the relationship between topography, density and the equilibrium size of grey seal colonies where the numbers of pups have stabilized. To determine the relationships between density, pup survival and pup size at weaning. To determine the effect of pup size at weaning on subsequent survival. To investigate the effects of various forms of population regulation (including artificial manipulation of fertility) on the total amount of food consumed by Scottish grey seals.

METHODS: The location of grey seal pups on all aerial photographs from selected grey seal colonies where numbers have stabilized will be digitized and combined in a GIS system with data from high resolution OS maps on the topography of each island. Predictions from any observed relationship between density and trends in colony size will be tested against data from other colonies. The relationship between density, pup survival and the weight of weaned pups will be investigated by visiting colonies with different densities at the end of the pupping season to determine pup mortality and average pup weight. The relationship between female condition and pup size at weaning will be investigated by following individually-marked adult females at two study sites. The relative survival of pups in different weight classes will be investigated by attaching highly visible, colour-coded disks to their heads and determining the rate at which they are resighted. UHF tags will be attached to some animals so that resighting effort can be directed efficiently. The effect of different forms of population regulation on the amount of food consumed by the Scottish grey seal population will be estimated using fully age and sex-structured computer simulations.

DURATION: 3 years

DELIVERABLES: Estimates of the potential size of the Scottish grey seal population if no new colonies are established. Identification of sensitive indicators of population stabilization. Estimates of the effect of different forms of population stabilization on food consumption.

Appendix 3b: Seals and salmon in river systems

BACKGROUND: Removal of salmon from nets and damage to salmon by seals can result in substantial loss of income for salmon netsmen. Damage may also affect the value placed on rod caught fish. Predation by seals in estuaries and rivers will affect the size of the salmon run in a particular river, reducing the availability of salmon to netsmen and anglers. At present, the only method which has been used to reduce these perceived problems is to shoot seals in the vicinity of nets or in river systems. However, there have been frequent calls for reductions in the size of the seal population in the vicinity of particular river systems. In this project we will try to assess what effect such action might have on salmon within neighbouring river systems.

OBJECTIVES: To determine the proportion of time that grey and common seals from a large haul-out site (Abertay sands in the mouth of the River Tay) spend in neighbouring river systems (the Tay and the North Esk) throughout the year. To evaluate the relationship between this, the size of the salmon runs, and recorded levels of damage in the net and rod-and-line fisheries.

[Addition 1: To determine the wider movements of seals using Abertay Sands

Addition 2: To determine what proportion of seals using Abertay Sands actually consume salmon]

METHODS: UHF transmitters will be attached to 75 grey seals and 25 common seals captured at Abertay Sands over the course of the year. A network of automatic receiving stations will be located along the shore of the Tay and in the Montrose Basin to determine how often each individual enters these river systems and how high up each river they penetrate. Data on the movements of individual seals will be compared with independently collected information on the number of salmon running each week and levels of damage in fisheries. Regular surveys will be made of the numbers of grey and common seals on Abertay Sands and other haul out sites within the Firth of Tay. The numbers of grey seals associated with these sites will be estimated using capture-recapture analysis of photographs of individually-identifiable animals as part of a study funded by MAFF.

[If Addition 1 is selected, 8 Satellite Relay Data Loggers, which provide detailed information on movements and diving behaviour will be attached to grey seals. If Addition 2 is selected, blubber, blood, stomach and rectal samples will be taken from every animal which is caught. Stable isotope, fatty acid profiles, hard part and faecal DNA analysis will be used to determine whether these animals have consumed salmon.]

DURATION: 18 months (2 months preparation, 12 months data collection, 4 months analysis)

DELIVERABLES: Answers to the following questions: Do all seals spend some time in river systems or is it only certain individuals which do this? Is the proportion of time spent in river systems related to the number and type of salmon which are running? Are levels of damage related to the estimated number of seals in the river? What is the likely outcome of a reduction in the number of seals at Abertay?

Appendix 3c: Breeding site fidelity and the feasibility of regulating grey seals numbers using fertility control

(NB this project will be carried out in collaboration with the University of Aberdeen).

BACKGROUND: Experiments in Canada have shown that it is possible to render female grey seals infertile for at least for 5 years, and possibly indefinitely. News of these experiments has lead to suggestions that this approach could be used to limit the growth of the Scottish grey seal population. However, calculations made by Hiby in Racey et al. (1995) indicate that it would be necessary to treat 5,000 female seals each year in order to stabilize the population at around 180,000 animals. It is not clear whether this many untreated animals could be found each year, nor what effect operations on this scale will have on pup survival, female movement and the fecundity of untreated females. In this project, we propose a series of experiments to provide information needed to design and evaluate a programme aimed at stabilizing the Scottish grey seal population.

OBJECTIVES: To determine the maximum number of female grey seals which could be treated with anti-fertility drugs at Scottish colonies in a single year. To determine the likely effects of the disturbance associated with treatment on pup survival, female site fidelity and subsequent pup production. To estimate how many untreated females might be available for treatment at individual colonies in subsequent years.

METHODS: The availability of females for treatment will depend on their reaction to the presence of humans within the colony. In any colony, some females will leave as soon as they detect the presence of humans. However, the number of females which leave will depend on the topography of the colony, its history of disturbance, and probably on the length of time that a treatment team is in the colony. Females which leave may desert their pups completely, or stay away from the colony so long that the growth of their pups is compromised. Females which desert may not pup in the following season. We will visit a number of colonies with different topographies and histories of disturbance, and determine what proportion of the females using that colony are available for treating. Each of these females will be given a dummy "treatment" (probably marking with a paint gun) and photographed for subsequent identification. Each colony will be visited at the end of the pupping season and the number of dead and starving pups recorded. All weaned pups will be weighed. Similar data will be collected at neighbouring undisturbed colonies (or previously unvisited parts of larger colonies) with similar topographies and seal densities. During SMRU's annual aerial surveys of all Scottish grey seal colonies, high resolution photographs will be taken of the study colonies and surrounding colonies. It is possible to recognize individual female seals by their unique markings in these photographs. In the second year of the study, the colonies where the largest number of females were "treated" will be visited again and all females which can be treated will be photographed. A comparison of these photographs with those taken in the first year will allow us to estimate how many new, untreated animals are available in the second year. All study colonies will be visited again at the end of the pupping season to determine pup mortality and weaned weight in a season when there is no disturbance. High resolution photographs will be taken of the same colonies which were photographed in the first year to determine what proportion of animals from the study colonies have returned and what proportion have moved to neighbouring colonies. We will also compare pup production at study colonies in the two years to determine if disturbance affects fecundity..

DURATION: 2 years (3 months preparation, data collection in 2 breeding seasons, 9 months subsequent analysis).

DELIVERABLES: An evaluation of the feasibility and cost of a programme to limit the growth of the Scottish grey seal population using fertility control, and an assessment of its likely effect on the population.

SCOS 97/2
ANNEX II

Advice on the Status of British Common Seal Populations: 1997

Summary

1. This document contains advice from the Natural Environment Research Council on the current size and status of British common (or harbour) seal populations, based on information provided by the Sea Mammal Research Unit (SMRU).
2. Common seals in Scotland are surveyed by SMRU every five years; the second survey began in 1996 and was completed in 1997. Common seals in Lincolnshire and Norfolk, in England, are surveyed annually.
3. The minimum size of the British common seal population is estimated to be 31,512. The numbers of seals in various areas of Britain are given in Table 1. A more detailed area breakdown, and a comparison of counts from previous surveys, is given in Table 2.
4. Studies of the haul-out behaviour of common seals in Orkney and the Moray Firth in Scotland, and in the Wadden Sea in the Netherlands, suggest that the number of seals ashore represents between 60% and 70% of the population of animals aged one year and older. Applying this correction factor to SMRU's aerial survey data yields an estimate of the British common seal population (aged 1+) of between 45,000 and 52,500.
5. Counts of common seals on the Scottish west coast, including all Hebridean islands, in 1996 were between 19% and 21% higher than counts from the most recent previous surveys (1992 in the Outer Hebrides, 1988-1990 in Highland and Strathclyde).
6. Only one survey of east England was carried out in August 1996 due to adverse weather conditions. During this survey 2,151 common seals were counted in The Wash, an increase of 3% over the mean of the two August 1995 counts.
7. The average annual rate of increase in the number of seals counted in The Wash since 1989 is 6%. This is significantly greater than the average rate of increase between 1968 and 1988 of 3.5% per annum.

Survey Techniques

Until 1984, SMRU monitored the distribution and abundance of common seals in particular areas by counting the number of animals hauled out from inflatable boats. Counts were made during the pupping season, in late June and July. This method was time consuming and potentially inaccurate as seals could be disturbed from haul-out sites before being counted. Since 1988, surveys have been carried out in August, during the common seal annual moult. Studies of common seal haul-out behaviour in Orkney (Thompson & Harwood 1990) have shown that, at least on rocky shore sites, the numbers of seals ashore are greater and more consistent than during the pupping season. On certain sandbanks, however, where haul-out sites are not available to seals throughout the tidal cycle, there is less difference between numbers ashore during the breeding season and during the moult. Each site is typically surveyed only once in any year. Therefore, although the surveys are designed to provide counts that are as consistent as possible, they cannot take account of day-to-day variability in the number of seals hauled out.

Sites on the east coast of Great Britain, where common seals haul out on sandbanks and are clearly visible, are now surveyed using conventional aerial photography from a fixed-wing aircraft. Sites on the north and west coast of Scotland and on the northern and western islands, where seals haul out on rocks and can be well camouflaged, are surveyed using a thermal imager mounted in a helicopter.

Surveys Conducted during 1996

In 1996, SMRU began to repeat a survey of common seals around Scotland, using a thermal imager mounted in a helicopter, which had previously been carried out between 1988 and 1992. The west coast of Scotland, from Ullapool to Silloth in the Solway Firth, including all Inner and Outer Hebridean islands was surveyed. In addition, potential Special Areas of Conservation (pSACs) for common seals in the Inner and Outer Hebrides were surveyed, using the helicopter and thermal imager, for Scottish Natural Heritage during the 1996 breeding season (June/July). Common seals along the English east coast, from the Humber Estuary to Scroby Sands in Norfolk, were surveyed using conventional aerial photography from a fixed-wing aircraft.

Table 1 shows the numbers of common seals counted around the British coast in August between 1988 and 1996. Figure 1 shows the distribution of common seals in Scotland from the first series of surveys carried out between 1988 and 1993. Figure 2 shows their distribution on the Scottish west coast during the second survey in 1996. These data represent the minimum number of seals in each area, thus the minimum size of the British common seal population is 31,512. The British population is approximately 45% of the European sub-species *Phoca vitulina vitulina* and nearly 5% of the world total of the species (Figure 3).

Differences Between the 1996 Survey and Those Conducted Previously

A comparison of numbers of common seals counted in Scottish Regions is given in Table 1. The 1996 count in the Outer Hebrides was 21% higher than the count in 1992. In the part of the Highland Region that was surveyed, the 1996 count was 19% higher than comparable counts between 1988 and 1990. In Strathclyde, the count was also 19% higher than counts made between 1988 and 1990.

A detailed breakdown of all counts for individual subregions of Scotland is given in Table 2. In most cases the results from different counts were similar; larger differences have been highlighted. Caution must be exercised in drawing inferences from these apparent differences because of the day-to-day variability in such counts, as described above in the section on Survey Techniques.

Nevertheless, the results suggest that there is movement from year to year between sites within a Region. Higher counts in 1996 from Skye and Rona coincided with lower counts at Arisaig. Higher counts from Coll, Tiree and the Firth of Clyde coincided with lower counts from Islay and Jura (however, part of Islay was surveyed in marginal conditions). Higher counts from Lewis/Harris and North Uist coincided with lower counts from South Uist and Barra.

To be able to infer changes in population size from differences in the counts from year to year, longer term monitoring is required at selected sites. Annual counts have been carried out in the Moray Firth by the University of Aberdeen as part of work funded by the Scottish Office between 1988 and 1996. Results show that, during this period, numbers hauled out during the moult decreased to about 700 following the phocine distemper virus (PDV) epizootic in 1988, then increased to about 1100, with some suggestion of a recent decline (Thompson et al. 1997a). The coefficient of variation of multiple counts during the moult in a single year ranged from 0.03 to 0.08.

During the 1988 PDV epizootic, the Firth of Clyde was the only area on the west coast of Great Britain where significant numbers of common seal carcasses washed ashore. One explanation for the apparent increase in common seal numbers in this subregion is that it represents a recovery from the effects of PDV. Another possible explanation is that common seals may have moved from Strangford Lough in Northern Ireland (where, according to information from the National Trust and the Department of the Environment, Northern Ireland, numbers have decreased in recent years) into parts of Strathclyde. However, the observed decrease in Strangford Lough is not sufficiently large to account for all the increase in Strathclyde.

Common Seals in The Wash

In 1988, the population of common seals in The Wash declined by approximately 50% as a result of the Phocine Distemper Virus (PDV) epizootic. Prior to this, common seal numbers in The Wash had been increasing. Following the epizootic, from 1989, the area has been surveyed annually with one or two counts in the first half of August each year (Table 3).

Logarithmic regression analysis shows that the estimated average annual rate of increase was 3.5% (SE = 0.29%) per annum from 1968 to 1988 and 6% (SE = 1.4%) from 1989 to 1996 (Figure 4). The recent rate of increase is significantly higher than that prior to the epizootic ($t = 6.22$, 13 degrees of freedom, $p < 0.001$).

The present count in The Wash is still lower than the count in 1988, prior to the epizootic. This is in contrast to populations on the east and south sides of the North Sea which recovered rapidly from the effects of PDV and are now similar to or exceed their pre-epizootic levels (Reijnders, *pers comm*).

Estimating the Total Size of the British Common Seal Population

Even though counts made during August are generally greater than those made at other times of the year, it is unlikely that all members of the population are visible. Thus the data presented in this advice represent the minimum number of seals in each area surveyed. The relationship between this minimum number and total population size has not yet been fully established. However, studies of the haul-out behaviour of common seals in Orkney and the Moray Firth in Scotland, and in the Wadden Sea in the Netherlands (Thompson & Harwood 1990; Thompson *et al.* 1997; Ries *et al.* in press), suggest that the number of seals ashore represents between 60% and 70% of the population aged one year or older. Applying this correction factor to SMRU's aerial survey data yields an estimate of the British common seal population (aged 1+) of between 45,000 and 52,500.

References

Ries, E.H., Reijnders, P.J.H. & Hiby, A.R. in press. Maximum likelihood population size estimation of harbour seals in the Dutch Wadden Sea based on a mark-recapture experiment. *Journal of Applied Ecology*.

Thompson, P.M. & Harwood, J. 1990. Methods for estimating population size of common seals. *Journal of Applied Ecology* **27**(3): 924-938.

Thompson, P.M., Tollit, D.J., Mackay, A.D., Corpe, H.A. & Van Parijs, S. 1997a. The behaviour and ecology of common and grey seals in the Moray Firth. Final Report from the University of Aberdeen to the Scottish Office Agriculture, Environment and Fisheries Department.

Thompson, P.M., Tollit, D.J., Woods, D., Corpe, H.A., Hammond, P.S. & Mackay, A. 1997b. Estimating harbour seal abundance and status in an estuarine habitat in north-east Scotland. *Journal of Applied Ecology* **34**(1): 43-52.

Table 1. The number of common seals counted around Britain between 1988 and 1996 during their annual moult, in August. Some areas were surveyed twice in 1996; in these cases both counts are given. These data represent the minimum number of seals in each area surveyed.

Region	Date of survey	Number counted	Survey method	Status
Shetland	1993	**6,227**	Helicopter with thermal imager (TI)	Unknown
Orkney (including Stroma)	1993	**7,873**	Helicopter with TI	Unknown
Outer Hebrides	1992 1996	**2,329** **2,820**	Helicopter with TI	1996 count 21% higher than 1992
Highland: Dornoch to Ullapool	1991	**669**	Helicopter with TI	Unknown
Highland: Ullapool to Loch Linnhe	1988-1990 1996	**2,526** **3,016**	Helicopter with TI	1996 count 19% higher than 1988-1990
Strathclyde	1988-1990 1996	**5,341** **6,333**	Helicopter with TI	1996 count 19% higher than 1988-1990
Dumfries & Galloway	1992 1996	**8** **6**	Helicopter with TI	Unknown
East coast Scotland	1994	**1,694**	Fixed-wing aircraft	Unknown
East coast England	1994-1996	**2,874**	Fixed-wing aircraft	Wash increasing at 6% per annum since 1989
TOTAL	**1991-1996**	**31,512**		

Table 2. Numbers of common seals in subregions of Scotland counted during the first thermal image survey session, between 1988 and 1993, and in 1996. Subregions where numbers have changed markedly are highlighted.

Region	Location	1988	1989	1990	1991	1992	1993	1994	1996
Highland	Little Loch Broom	0	-	-	-	-	-	-	0
	Gruinard Bay	3	-	-	-	-	-	-	5
	Loch Ewe	7	-	-	-	-	-	-	1
	Gairloch	2	-	-	-	-	-	-	7
	Torridon	18	-	-	-	-	-	-	3
	Applecross	48	-	-	-	-	-	-	45
	Plockton	282	158	-	-	-	-	-	277
	Raasay	3	-	-	-	-	-	-	38
	Rona	**21**	**-**	**-**	**-**	**-**	**-**	**-**	**101**
	Skye	**1233**	**1269**	**-**	**-**	**1296**	**-**	**-**	**1728**
	Kyle of Lochalsh	43	15	-	-	-	-	-	9
	Sound of Sleat	43	53	-	-	-	-	-	76
	Loch Nevis	30	68	-	-	-	-	-	75
	Arisaig	**456**	**499**	**-**	**-**	**-**	**-**	**-**	**213**
	Ardnamurchan	118	-	-	-	-	-	-	152
	Sound of Mull	23	-	-	-	-	-	-	36
	Loch Linnhe	110	-	-	-	-	-	-	135
	Rum	-	-	10	-	-	-	-	2
	Eigg	-	-	29	-	-	-	-	36
	Muck	-	-	25	-	-	-	-	58
	Canna	-	-	41	-	-	-	-	19
Strathclyde	**Coll**	**-**	**-**	**367**	**-**	**-**	**-**	**-**	**947**
	Tiree	**-**	**-**	**124**	**-**	**-**	**-**	**-**	**338**
	Mull	607	940	1008	883	825	950	-	1059
	Treshnish Isles	29	-	-	-	-	-	-	41
	Lismore	535	398	491	405	340	597	-	611
	Loch Creran	36	-	-	-	12	-	-	66
	Firth of Lorn	-	-	461	-	-	-	-	432
	Colonsay	-	-	109	-	-	-	-	83
	Jura	**-**	**-**	**375**	**-**	**-**	**-**	**-**	**122**
	Islay	-	-	724	-	-	-	-	507
	West coast Kintyre	-	-	1153	-	-	-	-	1012
	Clyde Estuary	**-**	**381**	**-**	**-**	**-**	**-**	**-**	**991**
	Oronsay	-	-	24	-	-	-	-	0
	Loch Etive	-	-	35	-	-	-	-	26
Outer Hebrides	**Harris and Lewis**	**-**	**-**	**-**	**-**	**517**	**-**	**-**	**926**
	North Uist	**-**	**-**	**-**	**-**	**357**	**-**	**-**	**724**
	Benbecula	-	-	-	-	212	-	-	249
	Monach Isles	-	-	-	-	0	-	-	0
	South Uist	-	-	-	-	785	-	-	666
	Barra	**-**	**-**	**-**	**-**	**458**	**-**	**-**	**255**
Dumfries & Galloway	Dumfries & Galloway	-	-	-	-	8	-	-	6

Table 3. Numbers of commons seals counted on the east coast of England since 1988. Data are from aerial surveys carried out during the August moult.

Date of survey	13.8.88	8.8.89 12.8.89	11.8.90	2.8.91 11.8.91	1.8.92 16.8.92	8.8.93	6.8.94 12.8.94	5.8.95 15.8.95	2.8.96
Blakeney Point	701	- 307	73	- -	- 217	267	- 196	438 392	372
The Wash	3087	1531 1580	1532	1226 1551	1724 1618	1759	2277 1745	2266 1902	2151
Donna Nook	173	- 126	57	- -	18 -	88	60 146	115 36	162
Scroby Sands	-	- -	-	- -	- -	-	61 -	- 49	51
The Tees	-	- -	-	- -	- -	-	- 35	- -	-
Holy Island	-	- -	-	- -	- -	-	- 13	- -	-
Essex & Kent	-	- -	-	- -	- -	-	- -	90 -	-

Figure legends

Figure 1. The numbers and distribution of common seals in Scotland from surveys carried out in August between 1988 and 1993. Data are displayed at a 10 km resolution with the size of circles proportional to the numbers of seals in each 10 km square.

Figure 2. The numbers and distribution of common seals on the west coast of Scotland from surveys carried out in August 1996, also at a 10 km resolution. Orkney, Shetland and the Scottish east, north and far north-west coasts were surveyed in 1997 but the data have not yet been analyzed.

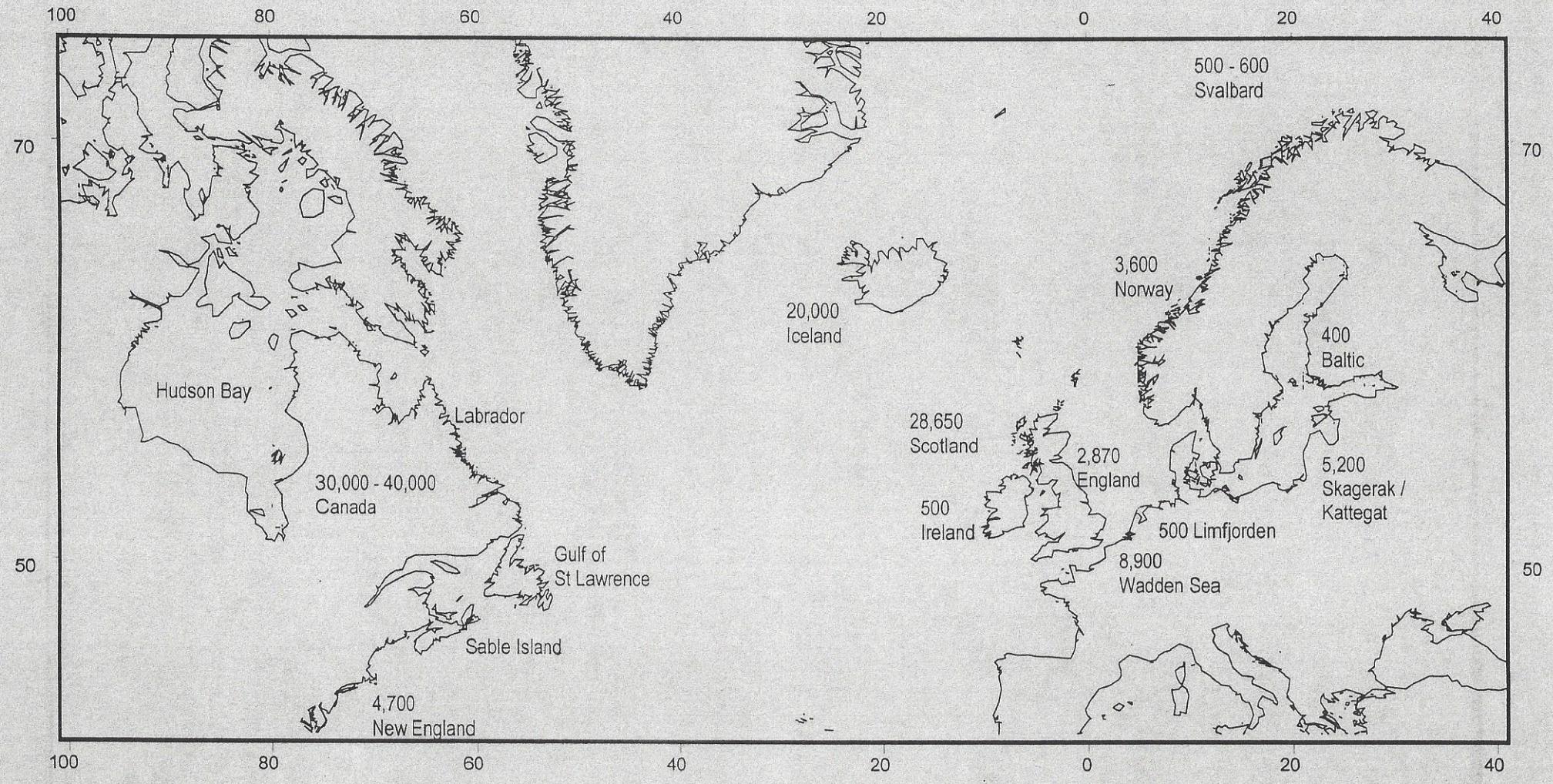
Figure 3. The distribution and numbers of common seal populations in the North Atlantic.

Figure 4. Counts of common seals in The Wash. Data are from SMRU's fixed-wing surveys which, since 1984, have been carried out during the August moult. In years when two counts were made, both are shown. The fitted curves show average rates of increase of 3.5% for 1968-88 and 6% for 1989-1996.

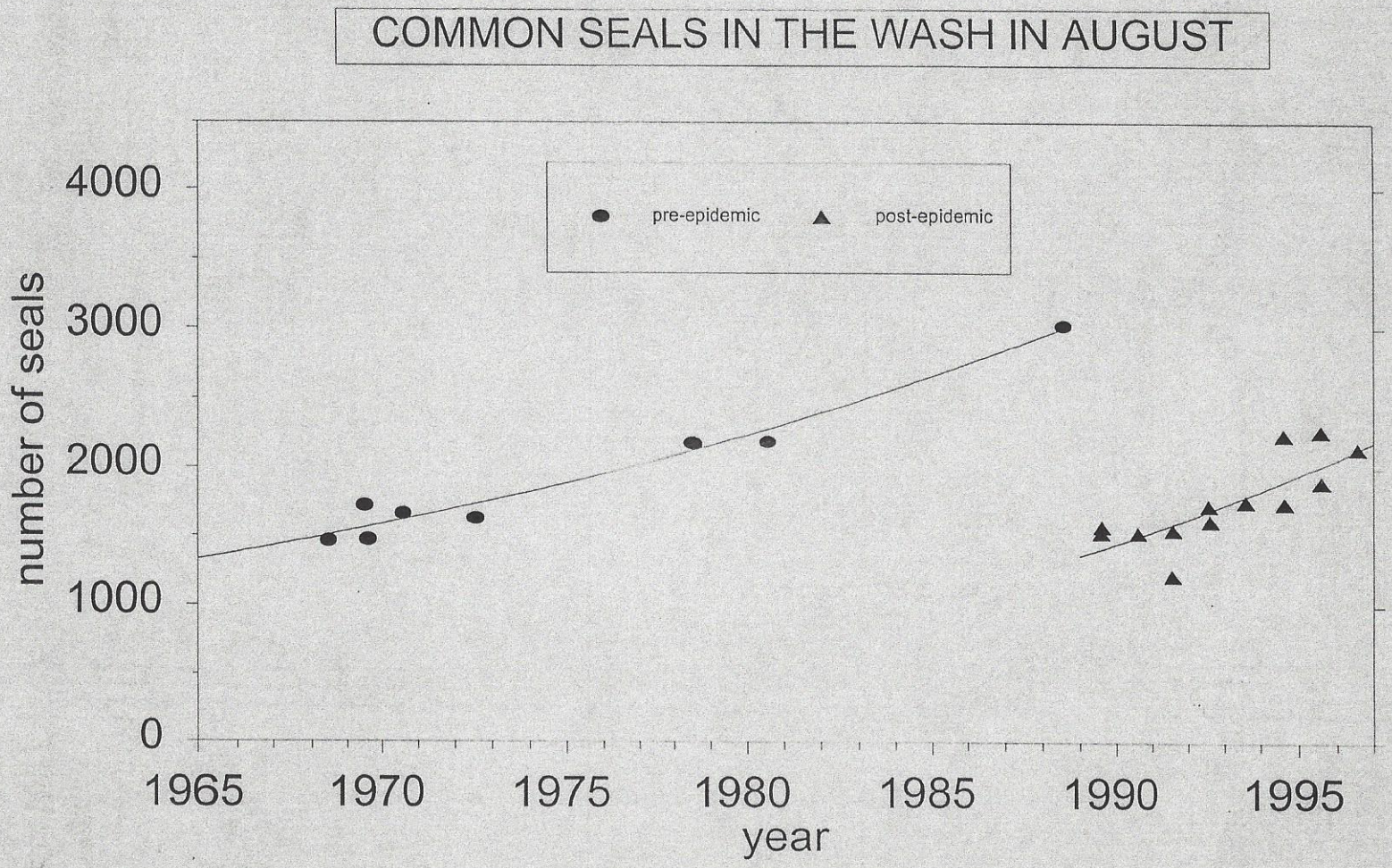
Common seals in August 1988 - 1993

Figure 2

Figure 3



Distribution and abundance of Common Seals in the North Atlantic


COMMON SEALS IN THE WASH IN AUGUST
pre-epidemic
post-epidemic
number of seals
4000
3000
2000
1000
0
1965
1970
1975
1980
1985
1990
1995
year