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Catch at age of 2J3KL cod in the diet of harp seals

by

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Abstract

The estimated annual consumption of cod by harp seals in NAFO Divisions 2J3KL has increased from 70,000 t in 1986 to 106,000 t in 1995. This Research Document provides estimates of removals of cod at age by harp seals in 2J3KL from 1986 to 1995. Cod otoliths found in seal stomach samples have been used to get semi-annual length frequencies of cod consumed. Age-length keys were derived from a subset of these otoliths. Because this key is sparse in places, an alternative key derived from research vessel survey samples was also considered. Accurate age composition of seal removals are a prerequisite to the incorporation of these data into a cod SPA.

Résumé

La consommation annuelle estimée de morue par le phoque du Groenland dans les divisions 2J3KL de l'OPANO a augmenté. Elle est passée de 70 000 t, en 1986, à 106 000 t, en 1995. Ce document de recherche présente des estimations de la récolte des morues, selon l'âge, par les phoques du Groenland en 2J3KL, de 1986 à 1995. Les fréquences de longueur semi-annuelles des morues consommées ont été déterminées à partir des otolithes trouvés dans les échantillons d'estomacs des phoques. Des clés âge-longueur ont été établies à partir d'un sous-ensemble de ces otolithes. Comme la clé n'est pas uniforme, une autre clé obtenue des échantillons prélevés au moment des relevés de recherche a aussi été utilisée. L'obtention d'une composition par âge exacte des prélèvements effectués par les phoques est essentielle à l'utilisation de ces données pour l'ASP de la morue.

Introduction

Estimates of the annual consumption of cod by harp seals in NAFO Divisions 2J3KL have risen from 70,000 t in 1986 to 106,000 t in 1995 (Hammill and Stenson, 1998). Consideration is being given to the inclusion of these removals in the cod SPA. For simplicity, the removals by seals could be treated as if seals were another fishery on 2J3KL cod. This requires the total "catch" by seals to be broken down into numbers at age through sample length frequencies and appropriate age-length keys.

Cod otoliths found in seal stomach samples have been used to get semi-annual length frequencies of cod consumed. Age-length keys were derived by age determination studies on a subset of these otoliths. Because this key is sparse in places, an alternative key derived from research vessel survey samples was also considered. Accurate age composition of seal removals are considered to be a prerequisite to the incorporation of these data in a cod SPA. Independent of the accounting of seal removals, the current cod SPA has been found to be unable to reconcile the differences between the research vessel index at age and the commercial catch at age over the late 1980s and early 1990s (Lilly et al. 1998).

Seal removals at age

Total cod consumption

The methods used to estimate the total consumption of cod, presented in Hammill and Stenson (1998) and Stenson et al. (1995), are briefly reviewed here. Opportunistic samples of seals were obtained from landsmen hunters predominately in the inshore area with the majority of samples prior to 1994 coming from nearshore areas (<30 km from the headlands of bays). Prior to 1985 most samples were obtained from the Northeast coast of Newfoundland whereas from 1985 onward sampling effort was reasonably consistent across eastern Newfoundland and southern Labrador. Samples were collected from all months with the majority taken between November and June. In recent years (1992-1995) samples were obtained from offshore areas, primarily along the northern edge of the Grand Banks during the winter and on the bank during spring. Composition of the diet was determined by identifying hard parts in the stomachs. The proportion of each prey species consumed was estimated by reconstructing the wet weights of the prey ingested using either undigested remains or species specific fish length-otolith length and fish length-fish weight regressions.

The annual amount of cod consumed by harp seals from 1981 - 1996 was estimated using the consumption model described in Hammill and Stenson (1997). The estimates for the 1990-1996 period are presented in Table D, Appendix 3 in Hammill and Stenson (1997). Annual estimates of consumption were obtained using assumptions of the energy obtained from various periods of the year based upon the seasonal distribution of age classes and daily energy requirements. Using these assumptions, described in Hammill

and Stenson (1997), the annual diet was split into quarters based upon the assumed energy obtained from each quarter of the year (Table 1).

Methods for calculating age composition

A total of 438 of the seal stomachs examined from 1986 to 1995 contained Atlantic cod (*Gadus morhua)* otoliths (Table 2). From these stomachs 1,547 otoliths were recovered (Table 3). Length frequencies of cod consumed were derived from the otolith length-fork length regression found in Lidster et al. (1994):

$$\text{Fork Length} = 25.751 + 10.109 * \text{otolith length} + 1.165 * \text{otolith length}^2$$

Data were originally separated into quarterly time periods (Fig. 1). Missing quarterly length frequencies were filled according to the following:

- 1989 quarter 4 filled from 1990 quarter 1;
- For all years quarter 3 used the frequency in 1990 quarter 3;
- 1995 quarter 4 is the sum of quarter 4 for years 1986-94;

This initial analysis was presented at the Zonal Canadian Stock Assessment meeting in St. John's in January/February 1998 and it was concluded that the data were too sparse for quarterly analysis and should be combined into two time periods, Jan-June and July-Dec. for all years (Fig. 2). The quarterly keys were combined to get half-yearly keys.

Two sources of data for constructing age-length keys were applied:

1. Otoliths from the seal stomachs that had not suffered much erosion were chosen for age determination. Semi-annual age-length keys were derived from all years combined (Tables 4 and 5);
2. Aged fish from the fall research surveys in 2J3KL using the Campelen 1800 shrimp trawl for years 1995 to 1997 were combined to give an age-length key for the second half of the year. For a first half of the year key the same age-length key was used with the age incremented by one year (Tables 6 and 7).

The age-length keys from the two sources differ considerably. For a specific fish length, the cod from seal stomachs are older than the cod caught in the trawl. The difference occurs at both times of the year but is more pronounced in the second half. The difference increases with increasing length. The reason for the difference has not been identified. It is possible that the seals are feeding on fish that are growing more slowly than fish taken in the trawl. However, the trawl samples cover the whole shelf except for a narrow band very close to the coast (Lilly et al. 1998). A second possibility is that the difference is caused by differences in the periods during which the samples were collected. The otoliths from seal stomachs were collected mainly during 1986-1995 and those from the trawl were obtained in 1995-1997. Length-at-age in cod older than about age 3 or 4 declined during the 1980s and early 1990s and increased again in the 1995-1997 period (Lilly et al. 1998), so age at length may have been greater at the time when

many of the otoliths from seal stomachs were obtained. A third possibility is that the length of the fish consumed by the seals may be underestimated by the body length to otolith length equation. This possibility will be explored briefly later in this paper. These and other potential causes of the difference must be examined before it can be determined which age length key is more appropriate.

The weight of individual cod was derived from the following relationship (Baird et al 1992).

$$\text{Log(weight)}=3.0879*\log(\text{length})-5.2106.$$

Semi-annual mean weights were used to calculate numbers consumed from estimated biomass consumed. Proportions at age were calculated by applying the semi-annual age-length keys to the semi-annual length frequencies in each year.

Trends in removals at age

For the January to June time period there has been a decline in the number of cod consumed since 1988 (with the exception of 1994 which had a lower mean weight than adjacent years) despite increasing consumption estimates. This is caused by a trend of increasing size (weight) of fish consumed (Fig. 3). Data for the July to December period are very variable, indicative of the small sample sizes. Numbers of cod consumed at age are given in Tables 8 -10 and Fig. 4 for the age-length keys from the seal stomachs and in Tables 11 –13 and Fig. 5 using the key from research surveys.

How well are cod lengths and weights being reconstructed from the otolith measurements?

The fork lengths (FL) of cod consumed by seals were estimated from otolith lengths (OL) with the following equation (Lidster et al. 1994):

$$FL = 25.751 + 10.109 * OL + 1.165 * OL^2.$$

This equation was intended for use with small otoliths in the range 1-12 mm in longest dimension, corresponding to fork lengths of approximately 3 - 30 cm.

Body round weights were estimated from fork lengths using the equation which has been routinely used in cod assessments in the Newfoundland Region:

$$\log(\text{weight}) = 3.0879*\log(\text{length}) - 5.2106.$$

To determine if these equations were providing satisfactory estimates, both length and weight were estimated from otolith lengths obtained from cod which had been measured and weighed during the autumn bottom-trawl survey in Divisions 3K and 3L in 1996. The estimated lengths appeared satisfactory for lengths up to about 30 cm, but then progressively underestimated length (Fig. 6, upper panel). As a consequence, weights estimated from the estimated lengths also departed from expected (Fig. 6, lower panel). The inadequacy of the FL - OL equation is more apparent in Fig. 7, which illustrates that

the underestimation of body length becomes relatively greater with increasing length. Most (perhaps 90%) of the otoliths found in harp seal stomachs in 2J3KL were less than 12 mm in length. For these the underestimation was less than 10%. A new relationship between otolith length and body length should be provided.

The weight to body length relationship also appears to be less than adequate. Weights calculated from lengths measured at sea are compared with weights determined at sea in Fig. 8. For the sample of fish included in the present test, weights calculated from the standard weight-length regression are overestimated for fish of about 0.5 – 1.0 kg, and underestimated for fish greater than 1 kg. It is recognized that the relationship between weight and length may vary with geographic area and time of year. However, the pattern in Fig. 8 is likely to be the result of the inability of a power function to adequately describe the relationship between weight and length. This also should be investigated further.

Incorporation of seal removals into the cod SPA

Once a reliable seal "catch at age" is deemed to have been constructed, consideration can be given to including the data into the cod SPA. Two problems are envisaged. Firstly, the current cod SPA is unable to reconcile the information content of past catch and survey data under the assumptions of constant natural mortality and accurate catch reporting and age determination (Lilly et al. 1998). Preliminary analyses have indicated that incorporation of seal consumption into the SPA does not rectify these problems. Secondly, the estimated consumption at age by seals gives recruitment and biomass trends in the cod SPA that are very different from those that are thought to have occurred.

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Table 1. Estimated quarterly nearshore and Offshore seal consumption of cod (tonnes) in NAFO divisions 2J3KL. From Hammill and Stenson 1997.

Seal consumption of cod											
	Nearshore					Offshore					Annual
YEAR/QRT	Jan-March	Apr-June	July-Sept	Oct-Dec	Total	Jan-March	Apr-June	July-Sept	Oct-Dec	Total	Total
1981	11,148	5,243	297	6,587	23,277	2,872	23,659	1,342	1,697	29,569	52,846
1982	11,454	5,387	306	6,768	23,915	2,951	24,308	1,379	1,743	30,381	54,296
1983	11,908	5,601	318	7,036	24,863	3,067	25,271	1,433	1,813	31,584	56,447
1984	12,785	6,013	341	7,555	26,694	3,293	27,132	1,539	1,946	33,910	60,604
1985	13,785	6,484	368	8,147	28,784	3,551	29,255	1,659	2,099	36,564	65,348
1986	14,867	6,993	397	8,786	31,043	3,830	31,551	1,789	2,263	39,434	70,476
1987	15,995	7,523	427	9,454	33,398	4,120	33,944	1,925	2,435	42,425	75,824
1988	16,996	7,994	453	10,046	35,489	4,378	36,069	2,046	2,588	45,080	80,569
1989	17,829	8,386	476	10,537	37,227	4,593	37,836	2,146	2,714	47,289	84,516
1990	18,387	8,648	490	10,866	38,391	4,736	39,020	2,213	2,799	48,769	87,160
1991	19,057	8,963	508	11,260	39,788	4,909	40,441	2,294	2,901	50,545	90,333
1992	19,844	9,333	529	11,725	41,432	5,112	42,113	2,388	3,020	52,634	94,065
1993	20,643	9,709	551	12,195	43,098	5,317	43,807	2,485	3,142	54,751	97,848
1994	21,632	10,174	577	12,780	45,164	5,572	45,907	2,604	3,292	57,376	102,539
1995	22,525	10,594	601	13,307	47,027	5,802	47,802	2,711	3,428	59,743	106,770
1996	23,398	11,005	624	13,823	48,851	6,027	48,553	2,754	3,561	60,895	109,745

Areas Combined					
YEAR/QRT	Jan-March	Apr-June	July-Sept	Oct-Dec	Total
1981	14,020	28,902	1,639	8,284	52,846
1982	14,405	29,695	1,684	8,512	54,296
1983	14,975	30,871	1,751	8,849	56,447
1984	16,078	33,145	1,880	9,501	60,604
1985	17,336	35,739	2,027	10,245	65,348
1986	18,697	38,544	2,186	11,050	70,476
1987	20,115	41,467	2,352	11,889	75,824
1988	21,374	44,063	2,499	12,634	80,569
1989	22,421	46,222	2,622	13,252	84,516
1990	23,123	47,668	2,704	13,665	87,160
1991	23,965	49,404	2,802	14,161	90,333
1992	24,956	51,446	2,918	14,745	94,065
1993	25,960	53,516	3,035	15,337	97,848
1994	27,205	56,082	3,181	16,072	102,539
1995	28,327	58,396	3,312	16,735	106,770
1996	29,426	59,558	3,378	17,384	109,745

Table 2: Number of seal stomachs sampled that contained cod otoliths by year, area and season in NAFO Divisions 2J3KL.

	AREA			
	INSHORE		OFFSHORE	
	Jan-June	July-Dec	Jan-June	ALL
	N	N	N	N
YEAR				
1982	6	.	.	6
1986	33	12	.	45
1987	25	8	.	33
1988	41	4	.	45
1989	31	.	.	31
1990	30	14	1	45
1991	21	5	.	26
1992	24	16	1	41
1993	30	14	.	44
1994	43	39	8	90
1995	28	.	4	32
ALL	312	112	14	438

Table 3: Number of otoliths found in seal stomachs sampled in NAFO Divisions 2J3KL.

	AREA			
	INSHORE		OFFSHORE	
	Jan-June	July-Dec	Jan-June	ALL
	N	N	N	N
YEAR				
1982	11	.	.	11
1986	60	46	.	106
1987	124	52	.	176
1988	109	12	.	121
1989	112	.	.	112
1990	131	60	1	192
1991	75	25	.	100
1992	94	23	7	124
1993	86	37	.	123
1994	125	227	12	364
1995	77	.	41	118
ALL	1004	482	61	1547

Table 4: Semi annual age length keys from otoliths collected in seal stomachs from 1986-95 in NAFO Divisions 2J3KL

Jan-June

LENGTH	0	1	2	3	4	5	6	7	ALL
4	.	1	.	.	.	.	.	.	1
7	1	61	.	.	.	.	.	.	62
10	.	26	4	.	.	.	.	.	30
13	.	1	35	.	.	.	.	.	36
16	.	1	37	10	.	.	.	.	48
19	.	.	11	11	.	.	.	.	22
22	.	.	.	11	.	.	.	.	11
25	.	.	.	4	4	.	.	.	8
28	.	.	.	3	2	.	.	.	5
31	.	.	.	1	3	1	.	.	5
34	.	.	.	.	3	4	1	.	8
37	.	.	.	.	.	6	3	.	9
40	.	.	.	.	.	.	3	.	3
43	.	.	.	.	.	.	.	1	1
46	.	.	.	.	.	1	.	1	2
52	.	.	.	.	.	.	.	1	1
ALL	1	90	87	40	12	12	7	3	252

Table 5: Semi annual age length keys from otoliths collected in seal stomachs from 1986-95 in NAFO Divisions 2J3KL

July-Dec.

LENGTH	0	1	2	3	4	5	6	7	ALL
4	1	.	.	.	.	.	.	.	1
7	44	.	.	.	.	.	.	.	44
10	7	7	.	.	.	.	.	.	14
13	.	5	3	.	.	.	.	.	8
16	.	4	3	.	.	.	.	.	7
19	.	1	5	.	.	.	.	.	6
22	.	.	3	2	.	.	.	.	5
25	.	.	2	4	.	.	.	.	6
28	.	.	.	5	5	.	.	.	10
31	.	.	.	1	1	.	.	.	2
34	.	.	.	.	3	4	1	.	8
37	.	.	.	1	2	6	3	1	13
40	.	.	.	.	.	2	1	.	3
43	.	.	.	.	.	.	.	1	1
46	.	.	.	.	.	.	.	1	1
52	.	.	.	.	.	.	.	1	1
ALL	52	17	16	13	11	12	5	4	130

Table 6: Semi annual cod age length keys from fall surveys in NAFO Divisions 2J3KL from 1995 to 1997 combined. First half of the year key is constructed by adding 1 to the age

Jan-June LENGTH	1	2	3	4	5	6	7	8	all
4	4	.	.	.	.	.	.	.	4
7	18	.	.	.	.	.	.	.	18
10	25	1	.	.	.	.	.	.	26
13	14	19	.	.	.	.	.	.	33
16	.	139	6	.	.	.	.	.	145
19	.	243	28	.	.	.	.	.	271
22	.	144	99	.	.	.	.	.	243
25	.	21	252	12	.	.	.	.	285
28	.	.	347	61	.	.	.	.	408
31	.	.	278	126	3	.	.	.	407
34	.	.	110	212	18	1	.	.	341
37	.	.	19	278	45	1	.	.	343
40	.	.	1	236	91	5	.	.	333
43	.	.	.	96	119	14	.	.	229
46	.	.	.	26	90	33	2	.	151
49	.	.	.	2	80	43	3	.	128
52	.	.	.	.	27	36	3	1	67
ALL	61	567	1140	1049	473	133	8	1	3432

Table 7: Semi annual cod age length keys from fall surveys in NAFO Divisions 2J3KL from 1995 to 1997 combined.

July - Dec LENGTH	0	1	2	3	4	5	6	7	all
4	4	.	.	.	.	.	.	.	4
7	18	.	.	.	.	.	.	.	18
10	25	1	.	.	.	.	.	.	26
13	14	19	.	.	.	.	.	.	33
16	.	139	6	.	.	.	.	.	145
19	.	243	28	.	.	.	.	.	271
22	.	144	99	.	.	.	.	.	243
25	.	21	252	12	.	.	.	.	285
28	.	.	347	61	.	.	.	.	408
31	.	.	278	126	3	.	.	.	407
34	.	.	110	212	18	1	.	.	341
37	.	.	19	278	45	1	.	.	343
40	.	.	1	236	91	5	.	.	333
43	.	.	.	96	119	14	.	.	229
46	.	.	.	26	90	33	2	.	151
49	.	.	.	2	80	43	3	.	128
52	.	.	.	.	27	36	3	1	67
ALL	61	567	1140	1049	473	133	8	1	3432

Table 8: Semi-annual estimates of cod removals (000's) at age by harp seals.
Age determination from cod otoliths found in seal stomachs.

Jan-June

	AGE								
	0	1	2	3	4	5	6	7	ALL
YEAR									
1986	366	234,320	719,810	361,007	31,186	11,341	2,835		1,360,865
1987	5,240	907,092	1,080,832	330,787	45,867				2,369,819
1988	21,484	2,120,989	995,297	374,150	29,239				3,541,158
1989	825	248,563	1,354,329	232,106	49,433	18,182	5,682		1,909,120
1990	3,316	656,035	705,120	362,679	62,712	17,820	1,713		1,809,395
1991	2,978	424,834	626,909	211,867	46,620	40,004	31,542		1,384,754
1992	1,234	176,899	434,419	230,115	44,477	35,071	24,709	19,130	966,054
1993	356	38,183	177,478	265,603	89,291	28,966	22,400	11,046	633,323
1994	8,842	689,216	225,347	119,077	104,922	60,212	14,604	8,987	1,231,207
1995	405	33,697	80,192	173,412	110,559	47,742	43,973	4,188	494,167

Table 9:Semi-annual estimates of cod removals (000's) at age by harp seals.
Age determination from cod otoliths found in seal stomachs.

July-Dec

	AGE								
	0	1	2	3	4	5	6	7	ALL
YEAR									
1986	283,535	289,488	113,647	4,124	3,866	5,155	1,289		701,106
1987	630,505	230,265	108,264	34,350					1,003,384
1988	61,826	61,058	27,649	6,203	7,030	8,547	4,273	6,203	182,789
1989	662,421	526,106	199,402						1,387,930
1990	20,037	25,024	22,748	17,038	12,019	10,055	4,789	2,789	114,500
1991	182,612	278,517	170,054	22,007	7,024				660,214
1992	53,759	42,719	28,448	19,958	8,972	7,237	3,138	8,566	172,797
1993	125,515	59,692	33,795	4,228	9,322	10,654	3,163	8,989	255,359
1994	548,639	93,818	55,865	17,523	12,758	5,849	1,806	6,193	742,452
1995	184,813	61,508	42,245	18,751	12,145	9,622	3,931	6,336	339,352

Table 10:Annual estimates of cod removals (000's) at age by harp seals.
Age determination from cod otoliths found in seal stomachs.

	AGE								
	0	1	2	3	4	5	6	7	ALL
YEAR									
1986	283,901	523,809	833,457	365,131	35,053	16,496	4,124		2,061,971
1987	635,745	1,137,357	1,189,096	365,137	45,867				3,373,203
1988	83,310	2,182,047	1,022,945	380,353	36,269	8,547	4,273	6,203	3,723,948
1989	663,246	774,670	1,553,732	232,106	49,433	18,182	5,682		3,297,050
1990	23,354	681,059	727,867	379,717	74,731	27,875	6,503	2,789	1,923,895
1991	185,590	703,351	796,962	233,874	53,644	40,004	31,542		2,044,968
1992	54,993	219,618	462,866	250,073	53,449	42,308	27,848	27,696	1,138,851
1993	125,872	97,875	211,273	269,831	98,613	39,620	25,562	20,035	888,682
1994	557,481	783,034	281,212	136,600	117,681	66,061	16,410	15,180	1,973,658
1995	185,218	95,205	122,437	192,163	122,704	57,364	47,903	10,524	833,519
ALL	2,798,710	7,198,026	7,201,848	2,804,987	687,444	316,456	169,847	82,428	21,259,744

Table 11:Semi-annual estimates of cod removals (000's) at age by harp seals.
Age determination from cod sampled in research vessel surveys 1995-97 combined.

Jan-June

	AGE								
	1	2	3	4	5	6	7	8	ALL
YEAR									
1986	294,854	650,191	383,688	20,791	5,670	5,670			1,360,865
1987	907,794	1,000,166	426,822	35,038					2,369,819
1988	2,014,237	1,082,923	416,925	27,073					3,541,158
1989	622,169	875,013	345,176	46,876	15,625	4,261			1,909,120
1990	555,155	749,345	435,214	44,549	21,704	3,427			1,809,395
1991	443,121	520,052	330,802	44,620	23,079	23,079			1,384,754
1992	248,687	385,784	235,137	50,216	23,115	23,115			966,054
1993	40,503	217,245	248,542	83,461	24,547	17,183	1,841		633,323
1994	674,018	214,188	188,725	76,389	53,173	20,221	2,247	2,247	1,231,207
1995	39,785	113,072	172,051	104,347	37,342	27,570			494,167

Table 12: Semi-annual estimates of cod removals (000's) at age by harp seals.
Age determination from cod sampled in research vessel surveys 1995-97 combined.

July-Dec

	AGE							
	0	1	2	3	4	5	6	ALL
YEAR								
1986	350,553	273,225	69,595	2,578	2,578	2,578		701,106
1987	691,521	239,547	63,276	9,039				1,003,384
1988	83,330	53,762	22,849	11,200	5,824	5,824		182,789
1989	820,140	473,158	94,632					1,387,930
1990	26,717	29,261	29,261	16,539	7,315	5,407		114,500
1991	287,966	257,530	100,671	9,365	4,682			660,214
1992	63,359	47,359	31,999	17,280	6,400	6,400		172,797
1993	144,992	56,265	27,051	9,738	7,574	7,574	2,164	255,359
1994	575,475	92,434	46,714	15,406	6,460	4,473	1,491	742,452
1995	202,062	64,538	40,776	17,073	7,803	6,395	704	339,352

Table 13:Annual estimates of cod removals (000's) at age by harp seals.
Age determination from cod sampled in research vessel surveys 1995-97 combined.

	AGE									
	0	1	2	3	4	5	6	7	8	ALL
YEAR										
1986	350,553	568,079	719,786	386,266	23,369	8,248	5,670			2,061,971
1987	691,521	1,147,340	1,063,442	435,862	35,038					3,373,203
1988	83,330	2,067,998	1,105,772	428,126	32,897	5,824				3,723,948
1989	820,140	1,095,326	969,645	345,176	46,876	15,625	4,261			3,297,050
1990	26,717	584,416	778,606	451,753	51,865	27,111	3,427			1,923,895
1991	287,966	700,652	620,723	340,167	49,302	23,079	23,079			2,044,968
1992	63,359	296,046	417,783	252,417	56,616	29,515	23,115			1,138,851
1993	144,992	96,769	244,295	258,281	91,035	32,122	19,347	1,841		888,682
1994	575,475	766,452	260,902	204,131	82,849	57,645	21,711	2,247	2,247	1,973,658
1995	202,062	104,323	153,848	189,124	112,151	43,737	28,274			833,519
ALL	3,246,115	7,427,402	6,334,803	3,291,302	581,997	242,906	128,886	4,088	2,247	21259744

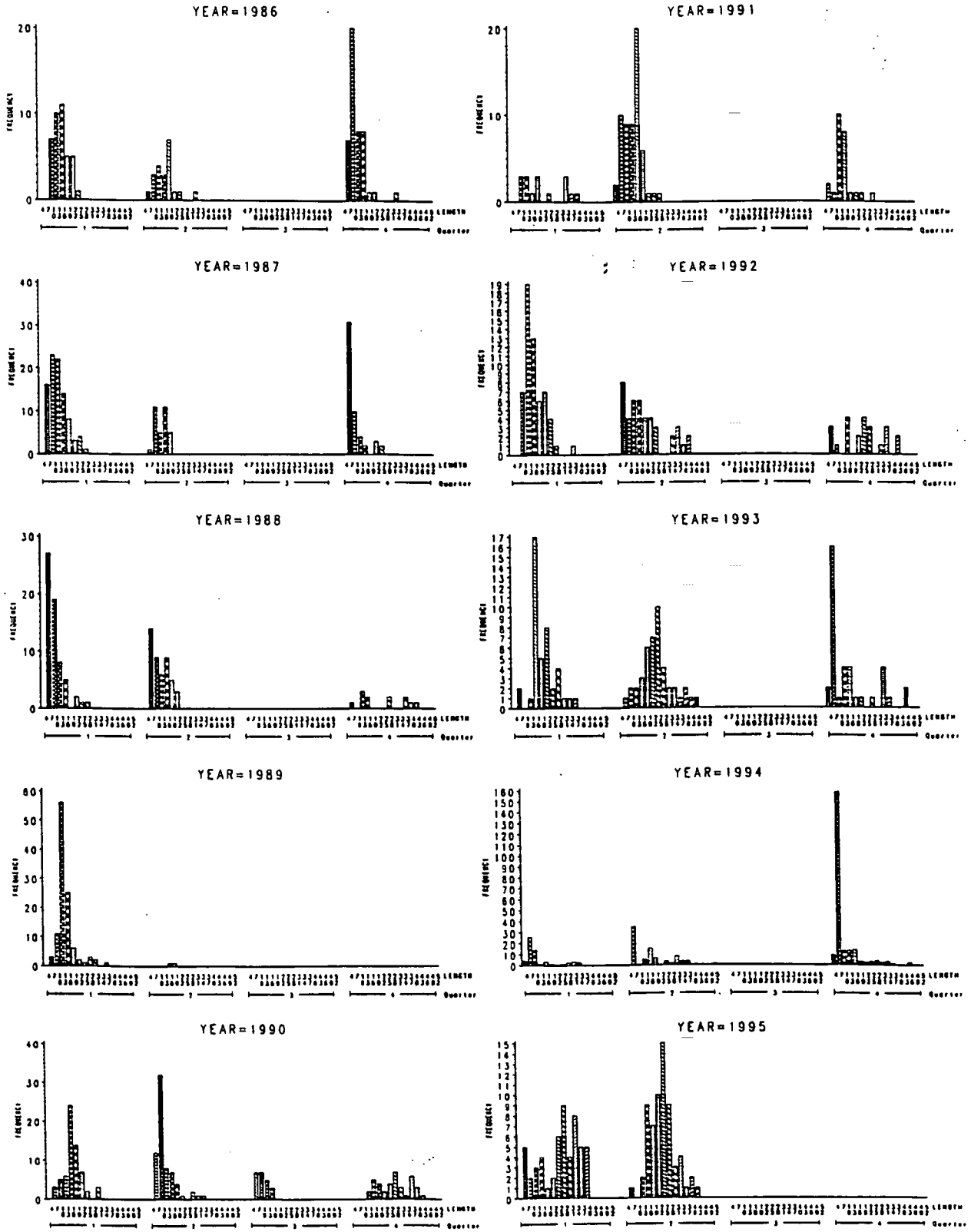

Fig. 1. Quarterly cod length frequency calculated from ololiths found in seal stomachs in NAFO divisions 2J3KL.

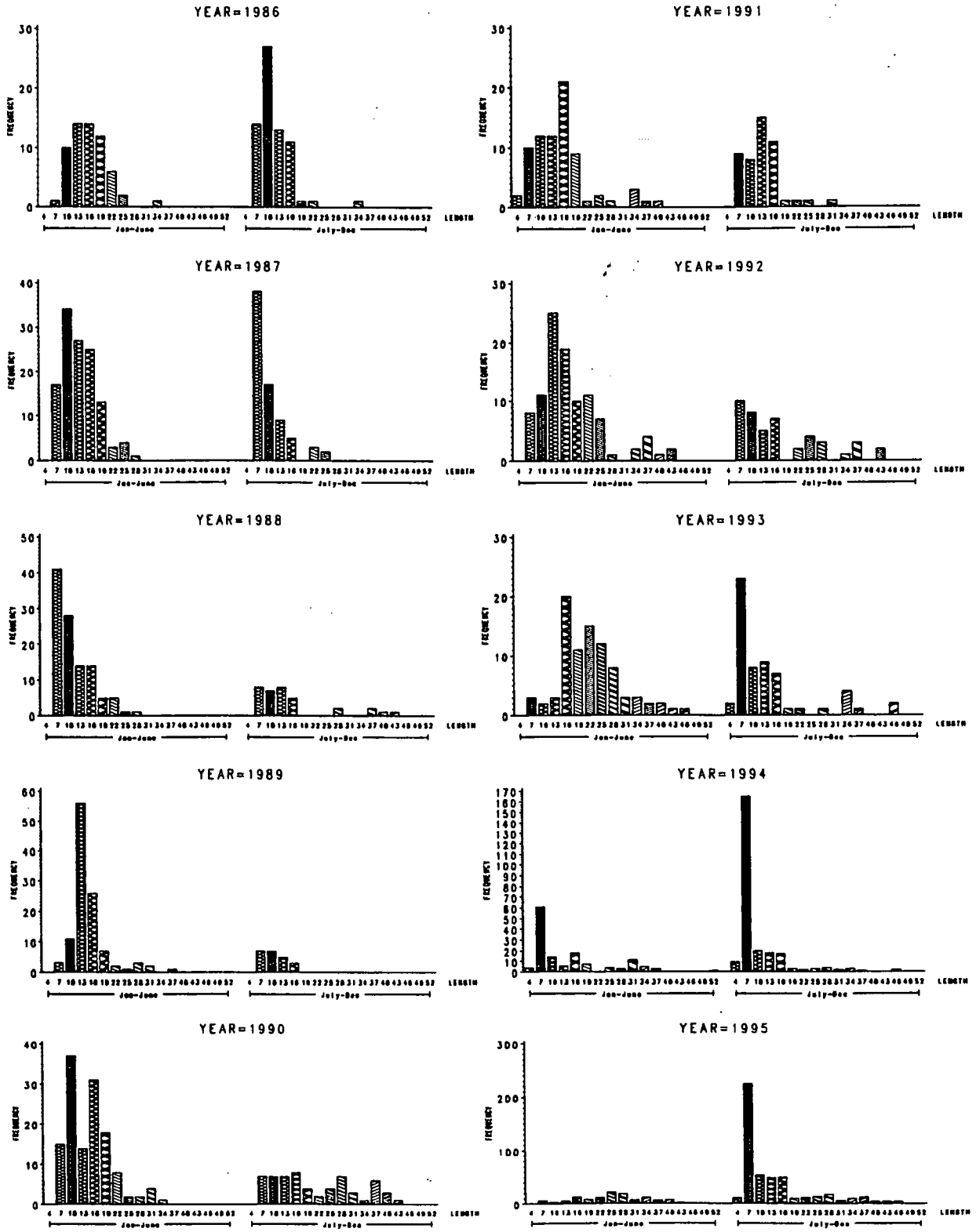

Fig. 2. Semi-annual cod length frequency calculated from otoliths found in seal stomachs in NAFO divisions 2J3KL after filling for missing quarterly samples.

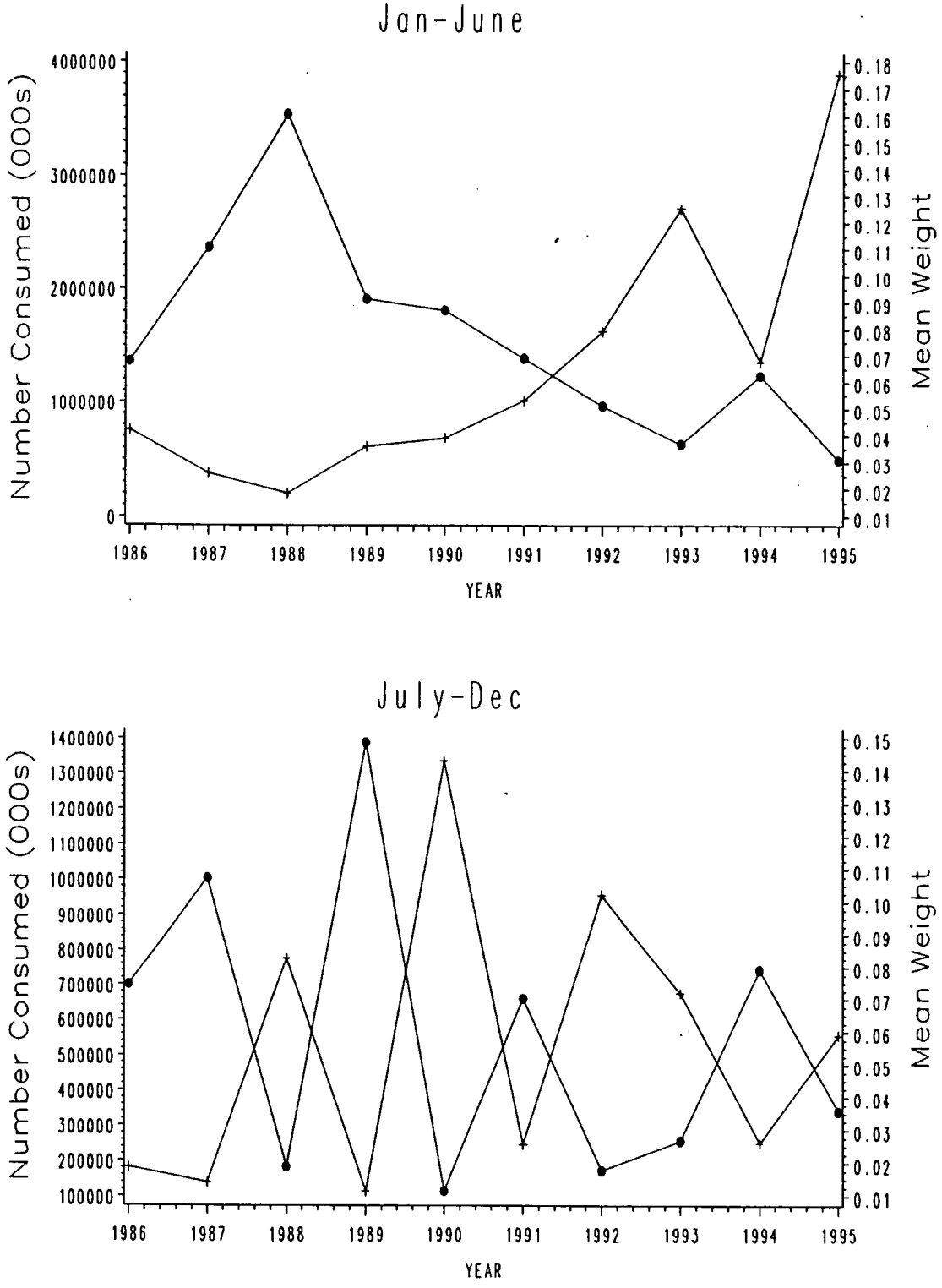

Fig. 3. Semi-annual estimates of cod removals (000s) and mean weight of cod.

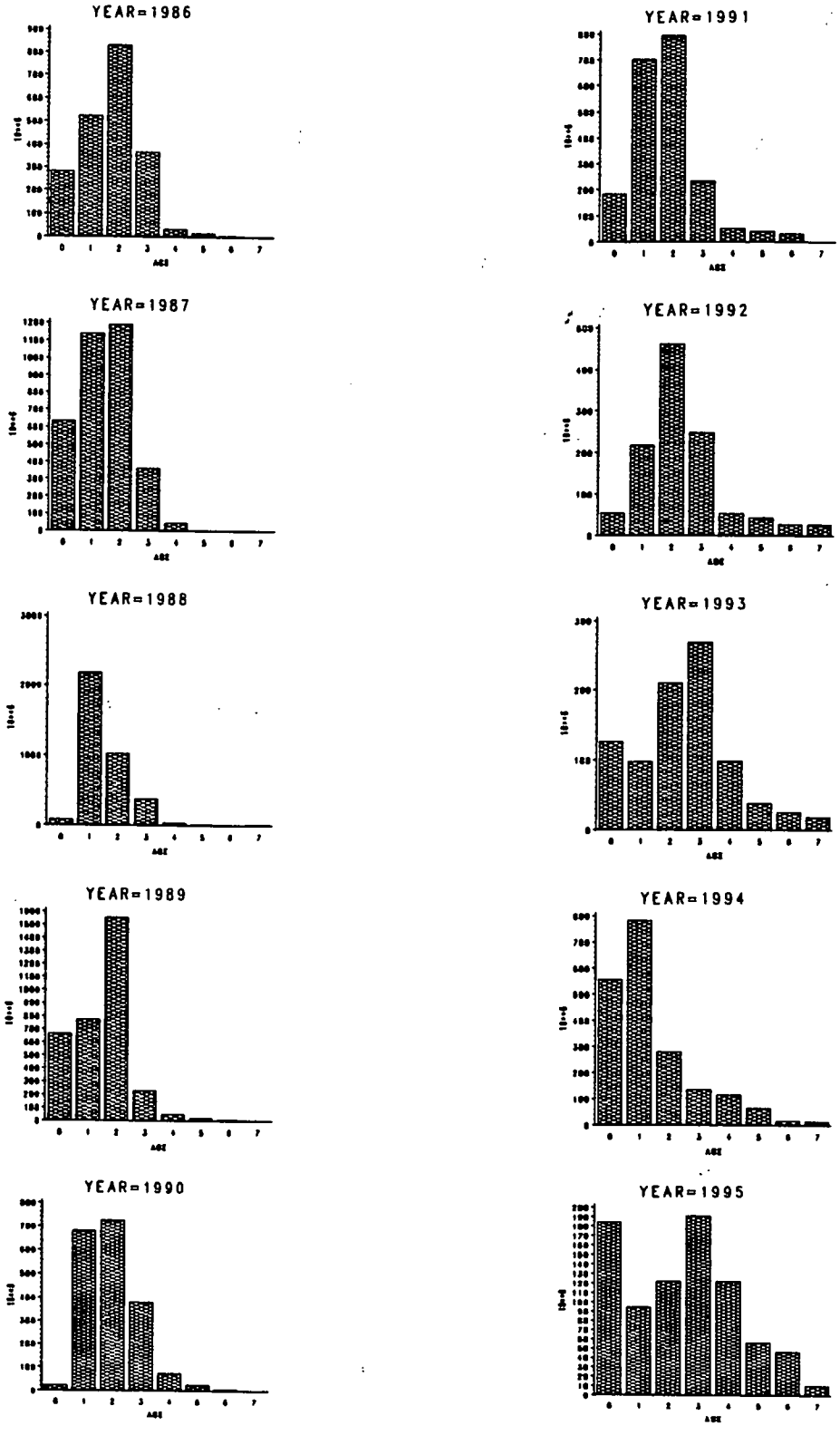

Fig. 4. Annual estimates of cod removals at age by harp seals. Age determination from cod ololiths found in seal stomachs.

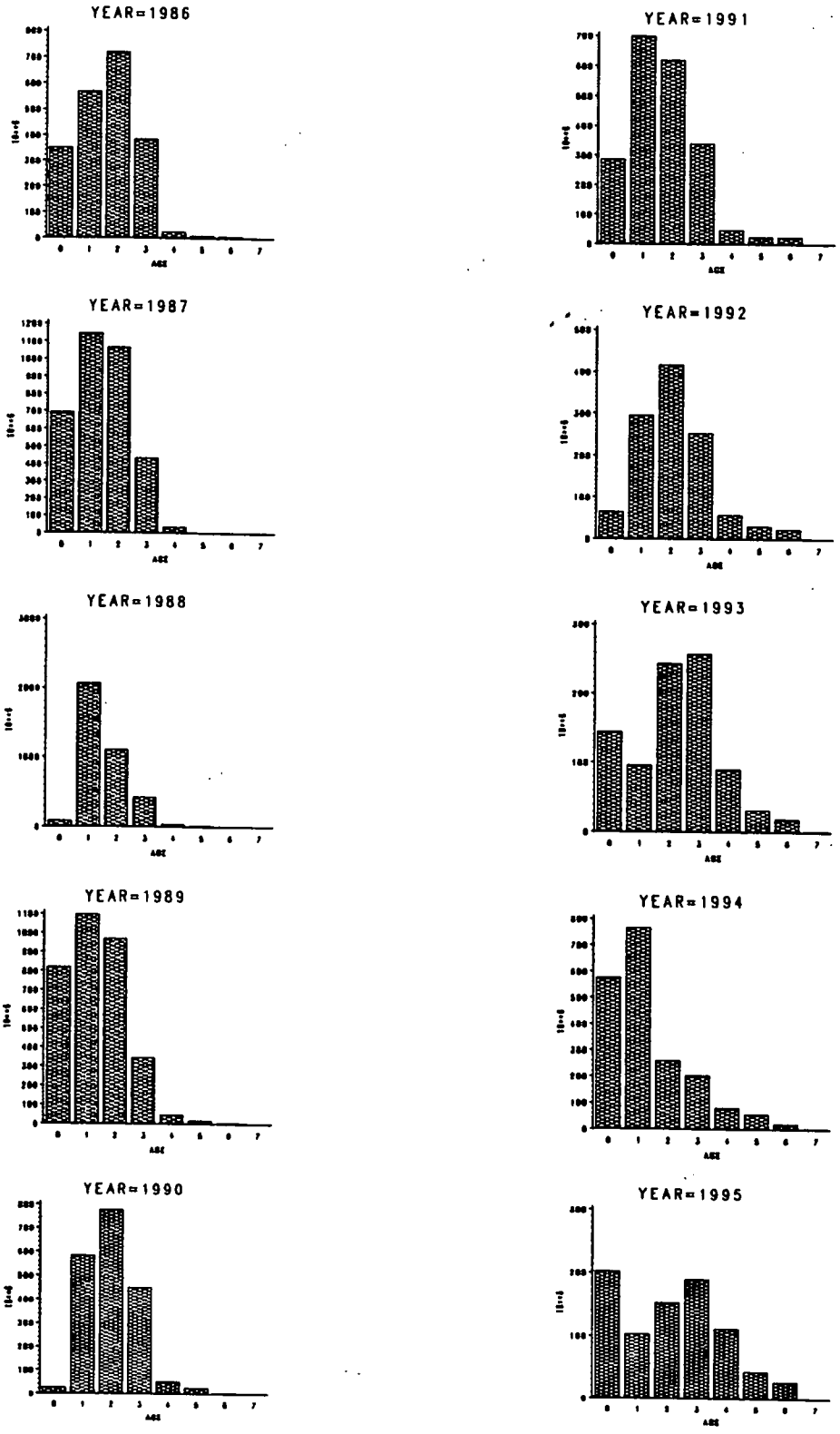

Fig. 5. Annual estimates of cod removals at age by harp seals. Age determination from cod sampled in research vessel surveys 1995-97

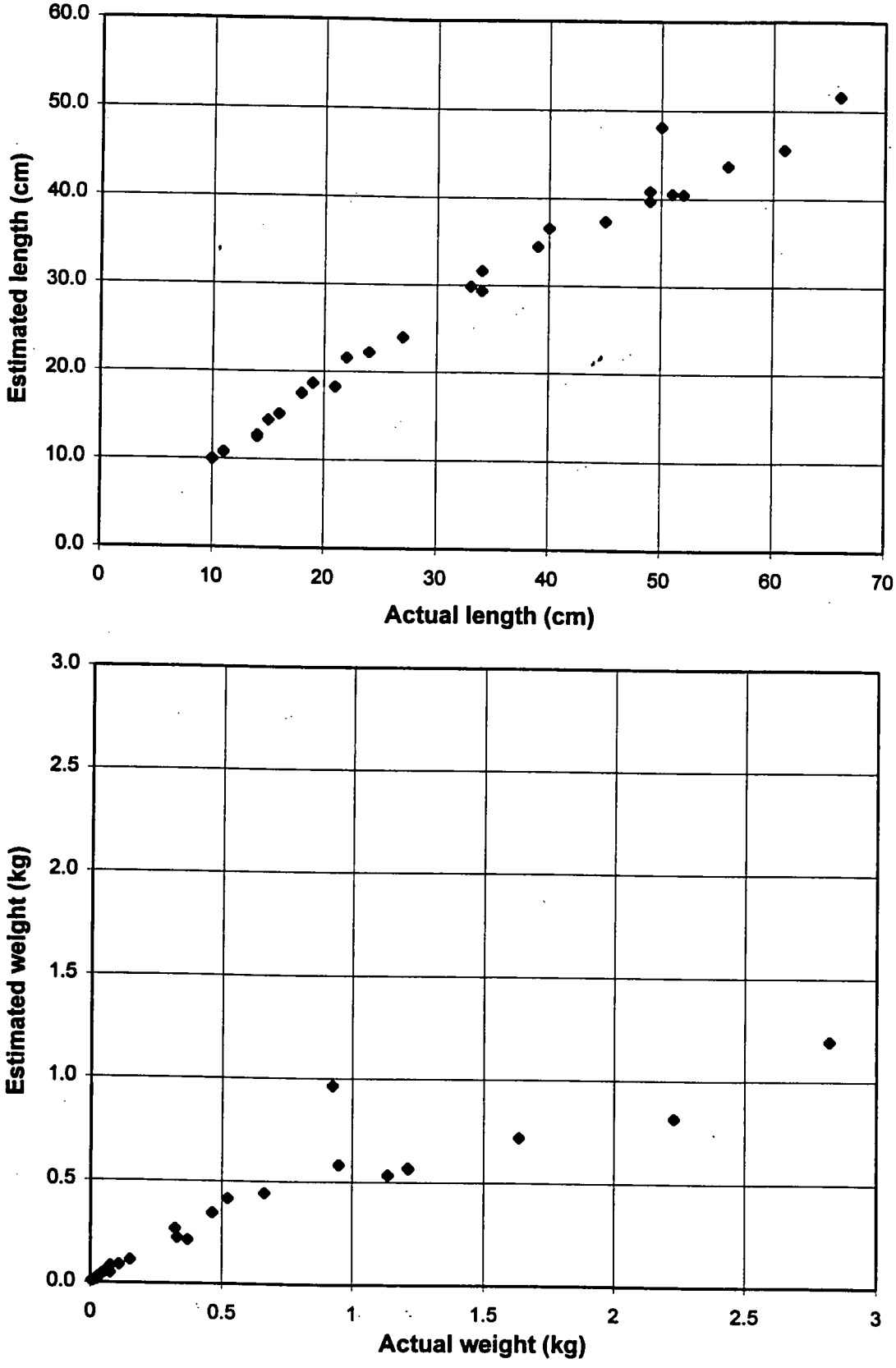

Fig. 6. Comparison between the actual length and weight of cod sampled at sea and the length and weight obtained by predicting body length from otolith length and body weight from body length.

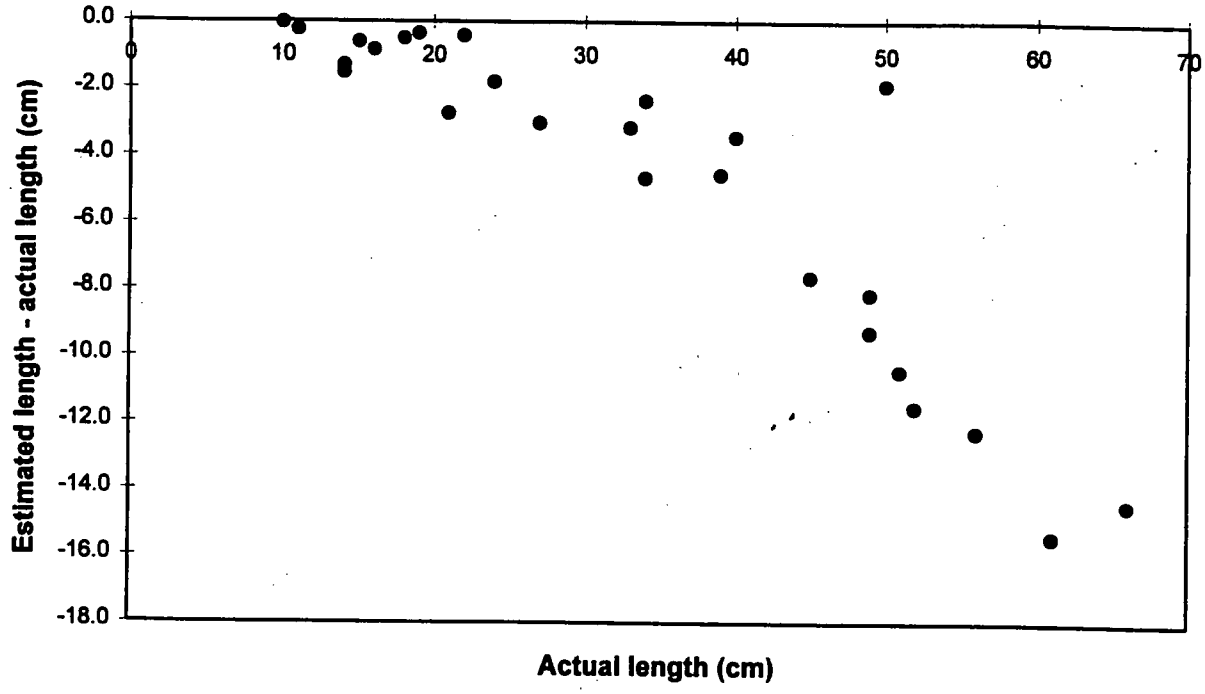

Fig. 7. The difference between the body length estimated from the otolith length and the body length measured at sea, plotted as a function of the length measured at sea.

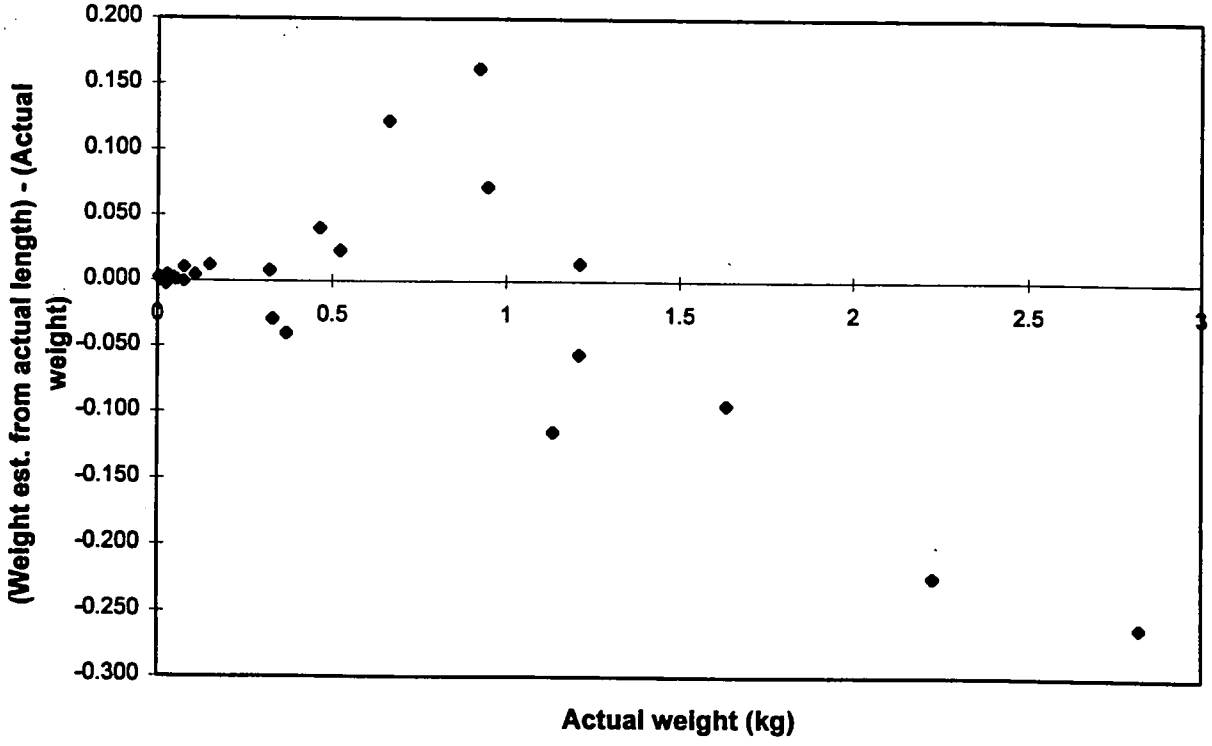

Fig. 8. The difference between the body weight of cod calculated from sea length using a standard weight-length relationship and the weight measured at sea, plotted as a function of the body weight recorded at sea.