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Comparison of catch at age matrices employed by Canada and the United States in assessments of stock status of Atlantic cod in 5Z

by

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Abstract

Differences in the catch-at-age matrices used by Canada and the United States are explored, and possible reasons for observed discrepancies suggested. While it appears that age determination biases are not the main cause of the discrepancies in the catch at age matrices, the evidence is not conclusive. It is suggested that differences in catch at age due to lack of agreement in ageing are less significant than those due to differing length compositions of catches for the two countries. We therefore recommend use of the sum of the catch at age derived from each country's sampling data.

Résumé

On étudie les différences dans les matrices des prises selon l'âge utilisées respectivement par le Canada et les États-Unis et on considère leurs causes possibles. Il semble que les distorsions dans la détermination de l'âge ne soient pas la cause principale de ces différences, quoique les preuves fournies à cet égard ne sont pas concluantes. On estime que les écarts dans les matrices des prises selon l'âge imputables à un manque d'homogénéité dans la détermination de l'âge sont moins importantes que ceux qui sont dus à une composition différente des prises selon la longueur dans les deux pays. On recommande donc d'utiliser la somme des prises selon l'âge établies d'après les données d'échantillonnage de chaque pays.

Introduction

Both Canada and the United States perform analytical assessments of Atlantic cod (*Gadus morhua*) on Georges Bank. The most recent assessments are provided by Hunt (1990) and Serchuk and Wigley (1990), for Canada and the United States, respectively. Both countries maintain independent RV surveys and commercial fishery sampling programs, although the data are exchanged on a regular basis. The geographic basis of the USA assessment includes NAFO Division 5Z and Statistical Area 6, whereas the Canadian assessment includes 5Zj and 5Zm, (Hunt 1990).

Apparent discrepancies have been noted between the Canadian catch-at-age data relative to USA data over the 1979-1985 period. Such differences were first noted by Hunt and Waiwood (1984, 1985). In the former document, Hunt and Waiwood suggest that the difference in age compositions is related to catch rather than interpretation of ageing structures, while in the latter document, the differences are attributed to possible differences in interpretation of otoliths. Hunt and Waiwood noted that there appeared to be a tendency for Canada to age fish older relative to USA ages at the same length. As a result of bilateral meetings between the United States and Canada, an otolith exchange occurred in 1985 and a cod ageing workshop was held in Woods Hole in 1986. United States investigators noted that "discussions at the workshop indicated that Canadian age readers were consistently over-aging Georges Bank cod by one year relative to USA age readers (a large settling check inside the first annulus was being counted as an annulus)" (Serchuk and Wigley 1986). Canadian workers interpreted the workshop results in a different light, noting that "Joint ageing of over 100 otoliths indicated a good level of agreement (>85%) between readers with no apparent bias" (Hunt and Gavaris 1986). Unfortunately, no consensus report was prepared summarizing the results of the workshop.

After examining various techniques to derive Canadian catch-at-age values which accounted for gear type/seasonality differences and the generally low sampling intensity for the Canadian fishery during the 1978-1985 period, Serchuk and Wigley elected not to use either Canadian age determinations or sampling information, pending resolution of the perceived age determination problem. Rather, they employed USA age/length keys and age composition data to calculate Canadian and total catch-at-age values for 1978-1985. Such a procedure assumes no differences exist in the age or size composition between the two fisheries.

In this paper, we examine the validity of the assumption that age and size composition of the catch does not vary between the two fisheries. We also attempt to address whether there are substantial discrepancies in the catch-at-age matrices employed by both countries after adjustment for known differences in the fisheries, and if they exist, what the sources of such discrepancies are.

Differences in the Fisheries

Gear Type

Fig. 1 shows the proportion of total landings by gear type over time. The United States fishery is dominated by otter trawlers, with fixed gear contributing a relatively minor fraction of total landings. In contrast, the dominance of mobile gear in the Canadian fishery has been variable since 1978, with fixed gear taking an increased proportion in certain years. In particular, 1984 and 1989 were exceptional when otter trawlers were not active in the area, with longliners taking the greatest proportion of Canadian landings.

Seasonality

Fig. 2 indicates the proportion of total landings by month and country, from 1978 to 1985. The main part of the USA fleet activity occurred relatively early in the year, whereas the Canadian fleet tends to operate somewhat later, with peak activity typically in the June to August period. The implication of such differences in timing of the fishery is that, all other things being equal, a greater average size at age in the Canadian landings would be expected. For example, the expected progression in mean length at age is exemplified below by sampling data from 1978, a year when ages were available for all quaters of the year for Canada (5Zjm):

Age	Quarter One	Quarter Two	Quarter Three	Quarter Four
2	43.2	46.3	47.7	50.7
3	52.0	58.1	56.1	63.0
4	57.9	65.7	59.4	66.7
#aged	387	340	282	299

Biological Sampling of the Catch

Sampling data from Canadian and US sampling programs used to determine length and age composition for 1978 to 1989 are summarized below (5Zjm only):

	CANADA		USA	
YEAR	#LENGTH	#AGED	#LENGTH	#AGED
1978	7684	1308	2047	385
1979	3991	656	1833	402
1980	2784	536	1258	286
1981	4147	842	1615	456
1982	4756	858	4111	778
1983	3822	604	3775	903

1984	1889	385	3891	1130
1985	7644	1062	2076	597
1986	5745	888	2145	644
1987	9477	1288	1865	525
1988	11709	1984	3229	797
1989	8716	1561	1522	1561

The sampling designs for both countries are similar, but in the case of USA-collected samples, only a subset of the total which related to catches reported as 5Zjm was used. Samples from both countries were analyzed separately using an identical procedure which required combining samples over time and gear intervals. Catch by gear corresponding to these intervals was used to estimate total removals.

Length Frequency Composition of Landings

Differences in the length-frequency distribution of landings by both countries are summarized in Fig. 3 for the 1978-1985 period. Subjective examination of the plots suggests that Canada took a greater proportion of larger fish in 1978, 1981, 1982 and 1984. In contrast, USA removed a greater proportion of large fish in 1980, 1983 and 1985. The mode at about 50 cm in 1979, apparent in both fisheries, probably represents the 1977 year-class. Modes in other years also reflect the relative strength of recruiting year-classes.

Comparison of Catch at Age Matrices

Allowing for the differences in the fisheries described previously, we limited our comparison to the catch-at-age matrices for third quarter, otter trawl proportional removals only (Table 1). By so restricting the comparison, we also reduced the number of age determinations used to compute the proportion at age to the point that comparisons between Canada and USA are valid for ages 2, 3 and possibly 4 only. The number of age determinations used for the calculation of proportion at age is also shown in Table 1. Data were available for the comparison for 1979 to 1988, excluding 1984 and 1987. As may be seen, the United States proportions at age 2 were considerably higher for all years except 1988. The proportions at age 3 were mixed, the Canadian proportion at age exceeding the American value in 4 of 6 instances, whereas for age 4, the Canadian proportions at age always exceeded the American values.

When such data were compared by Hunt (1990), he concluded the ratio of proportional catch at age for the USA and Canadian cod catches in 5Zjm is close to 1 for most dominant age groups but there was an indication of higher proportions in older age groups for USA catches. The apparent contrast to the findings presented here is due to the fact that Hunt (1990) examined total removals, whereas the data presented in Table 1 include third quarter otter trawl landings only, which removes the effect of seasonality and gear component on the comparison.

Possible Reasons for the Data Discrepancy in Catch at Age

Age Determination Inconsistencies

The difference in proportions at age demonstrated in Table 1 is consistent with a systematic difference in age determination, as suggested by Serchuk and Wigley (1990). Interpretation of a settling check as the first annulus would shift the overall distribution of Canadian ages to the right relative to the USA ages. To better assess whether such a possibility exists, we compared the mean length at age for Canada and the United States from Tables 8 and 6 of Hunt (1990) and Serchuk and Wigley (1990), respectively (Fig. 4) As may be seen, Canada has reported a smaller average length at age (ages 2 through 5), particularly through the 1978 to 1985 period. However, as mentioned before, the United States age-structured data reflect commercial sampling activity throughout NAFO Division 5Z and Statistical Area 6, whereas the Canadian data includes 5Zj and 5Zm only. To improve the comparability of the two data sets, we again limited the US data to third quarter otter trawls, 5Zj and 5Zm only (Fig. 5). The difficulty with this approach is that since the USA do not specifically target 5Zj and m for their commercial sampling program, the coefficients of variation associated with the age-stratified data are sometimes high. We arbitrarily selected only those data from the United States and Canada where the CV was ≤ 50%. As shown in Fig. 5, differences in the mean length at age persist, including a uniform trend for the length at age 2 of Canadian fish to be lower than those in the US catch at age matrix. Fig. 6 shows the actual mean lengths at age for Canada and the United States (5Zjm, otter trawl, quarter three only). Lengths at age 2 for Canada have remained more or less constant, whereas US values appear to have been following an increasing trend of late. In contrast, lengths at age 3 have been increasing for Canada, and somewhat irregular for the United States. In general, the greater fluctuations in length at age data from the United States likely reflect the low sampling effort directed towards 5Zjm.

Otolith exchanges between the two laboratories were completed 1986, 1990 and 1991. On the whole, precision appeared acceptable, with a percent agreement of 73 to 89% (Tables 2 -4). Recognizing that the differences in age ranges among the three exchanges made direct comparison of percent agreement impossible (Chang 1982), we calculated the Average Percent Error (Beamish and Fournier 1981):

$$\frac{1}{R}\sum_{i=1}^{R}\frac{|X_{ij}-X^{j}|}{X^{j}}$$

Where X_{ij} is the ith age determination of the jth fish, X_i is the average calculated for the jth fish, and R is the number of times each is aged. The resultant Average Percent Errors were as follows:

Year of Exchange	Average Percent Error
1986	2.4
1990	2.4
1991	1.2

Such values compare well with other groundfish stocks with a similar age range (R.J. Beamish, pers. comm., Withell and Wankowski 1989). We therefore conclude that USA and Canada show acceptable precision with respect to each other, and the extent of such precision has improved.

We also examined a selection of otoliths to ascertain whether a settling check was present. Indeed, a distinct check was often found within the first annulus. When the fish lengths were backcalculated using the nonlinear regression of Hunt (submitted), they corresponded reasonably well with the length at settling of Atlantic cod on Georges Bank of 60 - 100 mm (Lough et al. 1989). However, when age readers were shown such marks, they indicated they would not consider them the first annulus.

Differing Length Composition of the Catch

As was noted above and in Fig. 3, the annual length frequency distributions of Canadian and USA landings show substantial differences in some years. The assumption of similar length and age compositions between USA and Canadian landings is required before prorating the catch at age for one country to the total weight landed by both countries. To assess the validity of this assumption, we selected 1980 as a test since this year appeared to have the most difference in length frequencies and would represent the worst-case situation. Four sources of estimates - the sum of independent USA and Canadian estimates, USA prorated to total, Canadian prorated to total and Canadian length frequency samples partitioned with USA age length keys and then added to the USA catch at age. Results are given in Table 5 and summarized in Fig. 7. Substantial differences are apparent and consistent with the observed differences in length compositions. Both examples based on prorating appear not to provide a valid estimate of relative age composition. The USA prorated values underestimate catch at ages 2-3 while the Canadian values appear to be an overestimate. The two other estimates are remarkably similar and suggest little difference in catch at age based on independent age keys or based on only USA age keys. The similarity in estimated catch at age is further demonstrated in Fig. 8 which shows results using Canadian length frequencies partitioned with Canadian and with USA age keys. Given our results shown in Fig. 8, it is apparent that either US or Canadian age-length key used to partition length-frequencies would give similar estimates of catch at age.

Truncation of Ages included In US Commercial Samples

A further possible reason for the divergence in proportions at age shown in Table 1 is the often limited range of ages over which the United States has sampled in some years. For example, during the four years from 1979 to 1982, no US ages older than 5 years were available, whereas Canadian samples over those years typically included several other age groups (Table 1). When proportions at age are calculated, the US proportions at age for sampled ages would be somewhat inflated compared with Canadian proportions due to the absence of the older age groups.

Conclusions

While it is our view that age determination biases are not the main cause of the discrepancies in the catch at age matrices, the evidence is not conclusive. However, we would have expected that with the ongoing exchange of otoliths and the apparently high level of precision attained recently, the differences in the length at age data apparent in Figs. 5 and 6 would not persist, yet they do. Also, the suggestion of Serchuk and Wigley that a settling check had been misinterpreted as the first annulus seems dubious, since the uniform inclusion of an extra annulus would make Canada length at age 3 comparable to United States length at age 2, for example. Such comparability did not exist in our data. For example, over the years available for the construction of Fig. 6, the average length at age 3 for the Canadian data was 58.29 cm and for the United States age 2 was 53.65 cm and were significantly different (Mann-Whitney *U*, p=0.0071).

We suggest that differences in catch at age due to lack of agreement in ageing are less significant than those due to differing length compositions of catches for the two countries. It is unlikely that calculation of Canadian catch at age for all years using USA age keys would result in substantial changes from the catch at age derived using independent age keys. We therefore recommend use of the sum of the catch at age derived from each country's sampling data for the Canadian assessment of 5Zj,m cod. However, we also note that the analyses presented here do not rule out some bias in ageing. To specifically address this problem, it will be necessary to re-examine samples to verify ages and include a subset of the 1978-90 otoliths in a future exchange.

Acknowledgments

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Table 1. Comparison of Proportions at Age for 5Zjm cod,Canada and USA. Third quarter OTB included only.

Numbers aged by both countries are also shown

	Age 1 - C	Age 1 - US	(C-US)/C	Age 2 - C	Age 2 - US	(C-US)/C	Age 3 -C	Age 3 - US	(C-US)/C	Age 4 - C	Age 4 - US	(C-US)/C	Age 5 - C	Age 5 - US	(C-US)/C
1979	0	0.0143		0.3599	0.8494	-1.3601	0.2791	0.1039	0.627732	0.2594	0.0324	0.875096	0.0732	0	1
1980	0	0		0.3149	0.6501	-1.06446	0.4487	0.3499	0.220192	0.0752	0	1	0.1179	0	1
1981	0	0.017		0.1137	0.3567	-2.1372	0.4523	0.4791	-0.05925	0.265	0.1472	0.444528	0.0513	0	1
1982	0.0012	0	1	0.4001	0.718	-0.79455	0.2505	0.1049	0.581238	0.1333	0.1183	0.112528	0.1166	0.0544	0.533448
1983	0.0079	0	1	0.0971	0.2043	-1.10402	0.441	0.5751	-0.30408	0.3166	0.1087	0.656665	0.0695	0.0683	0.017266
1985	0.0013	0.0195	-14	0.6381	0.8537	-0.33788	0.2213	0.0423	0.808857	0.0557	0.0416	0.253142	0.0659	0.0314	0.52352
1986	0.0163	0	1	0.1223	0.1951	-0.59526	0.5778	0.7652	-0.32433	0.1303	0.0398	0.694551	0.0511	0	1
1988	0.009	0	1	0.085	0.0775	0.088235	0.6969	0.7484	-0.0739	0.0948	0.1224	-0.29114	0.834	0.0834	0.9

	#aged-C	#aged-US		#aged-C	#aged-US		#aged-C	#aged-US		#aged-C	#aged-US		#aged-C	#aged-US	
1979		1		84	56		52	7		144	3		65	1	
1980				54	12		79	7		17			50		
1981	3	4		51	49		80	63		68	26		28		
1982	6			105	152		90	39		69	51		68	30	
1983	13			58	46		121	145		90	47		47	50	
1985	4	1		154	34		80	5		59	5		101	5	
1986	23			65	19		113	34		31	3		26		
1988	18			51	8		73	100		42	19		62	13	

	Age 6 - C	Age 6 - US	(C-US)/C	Age 7 - C	Age 7 - US	(C-US)/C	Age 8 - C	Age 8 - US	(C-US)/C	Age 9 - C	Age 9 - US	(C-US)/C	Age 10+ -	Age 10+ -	(C-US)/C
1979	0.017	0	1	0.0063	0	1	0.0033	0	1	0.001	0	1	0.0008	0	1
1980	0.0309	0	1	0.0056	0	1	0.0011	0	1	0.0038	0	1	0.0019	0	1
1981	0.0713	0	1	0.0266	0	1	0.0112	0	1	0.0049	0	1	0.0036	0	1
1982	0.0315	0	1	0.0376	0.0002	0.994681	0.0197	0.0041	0.791878	0.0049	0	1	0.0047	0.0002	0.957447
1983	0.0359	0.028	0.220056	0.0121	0.0023	0.809917	0.0159	0.0114	0.283019	0.0032	0.0013	0.59375	0.001	0.0006	0.4
1985	0.0115	0.005	0.565217	0.0017	0.0065	-2.82353	0.0029	0	1	0.001	0	1	0.0006	0	1
1986	0.0855	0	1	0.0083	0	1	0.0059	0	1	0	0	#DIV/0!	0.0024	0	1
1988	0.0065	0.0074	-0.13846	0.0049	0.0039	0.204082	0.0142	0	1	0.0031	0.0005	0.83871	0.0022	0	1

	#aged-C	#aged-US		#aged-C	#aged-US		#aged-C	#aged-US		#aged-C	#aged-US		#aged-C	#aged-US	
1979	24			19			13			3			2		
1980	17			3			1			3			1		
1981	47			20			9			5			4		
1982	24			37	2		21	6		7			8	4	
1983	30	46		15	5		18	33		6	7		1	10	
1985	29	1		8	1		14			4			3		
1986	48			5			4						1		
1988	6	3		4	2		15			4	1		3		

Table 2. Results of Canada/US cod otolith exchange, 1986.

AGE COMPARISONS 1986

US \ Canada	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0																
1																
2			3													
3				14	2											
4					9	6	1									
5						21	9	1								
6							5	1								
7							1	14	2							
8									14	2						
9										1	1					
10										1	7	2	1			
11												1	1		1	
12													1			1
13																
14																
15																

CANADIAN COMMERCIAL SAMPLE #103,207

AGREE	73%
OVER	25%
UNDER	2%
N	123

Table 3. Results of Canada/US cod otolith exchange, 1990.

AGE COMPARISONS 1990

		Canada															
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
US	0	3															
	1	1	33														
	2		2	43	1												
	3				4	1											
	4				1	17											
	5					3											
	6																
	7																
	8																
	9																
	10																
	11																
	12																
	13																
	14																
	15																

DELAWARE II	
AGREE	92%
OVER	2%
UNDER	6%
N	109

Table 4. Results of Canada/US cod otolith exchange, 1991.

AGE COMPARISONS 1991

Canada

		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	0																
	1		1														
	2			14													
	3				19												
	4					13											
	5					2	28	2									
	6						3	1	2								
	7							2	11								
US	8																
	9										1						
	10											3					
	11																
	12																
	13																
	14																
	15																

N133	
AGREE	89%
OVER	4%
UNDER	7%
N	102

Table 5. Comparison of catch at age using combinations of prorating, age length keys and length frequencies for 1980 5Zj,m.

Source of C/A		Age 1	2	3	4	5	6	7	8
A. Canada	Number	1	775	1121	214	420	125	32	11
	Percent	-	28.7	41.5	7.9	15.6	4.6	1.2	0.4
B. USA	Number	0	212	374	51	496	220	77	9
	Percent		14.7	26.0	3.5	34.5	15.3	5.4	0.6
C. Total	Number	1	987	1495	265	916	345	109	20
	Percent	-	23.9	36.1	6.4	22.1	8.3	2.6	0.5
D. USA prorated to total catch		0	480	845	115	1122	498	173	19
E. CDN prorated to total catch		2	1395	2017	385	756	225	58	26
F. CDN LF's with USA keys		0	670	1072	84	545	171	49	11
G. B+F		0	882	1446	135	1041	391	126	20

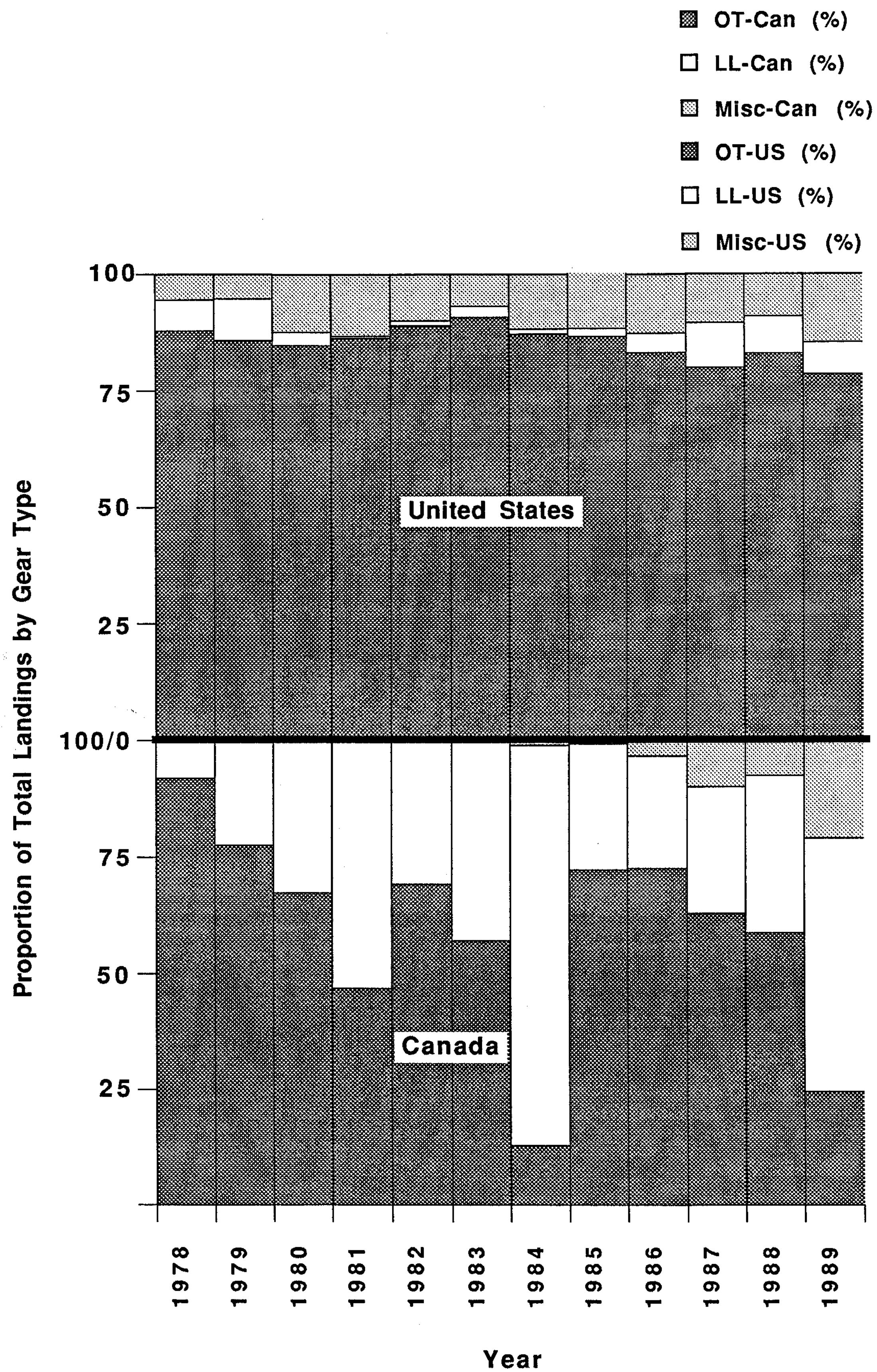

Fig. 1. Proportion of landings by gear type, Canada and USA, 1978-1990. 5Zjm (Canada) and 5Z + 6 (USA) cod.

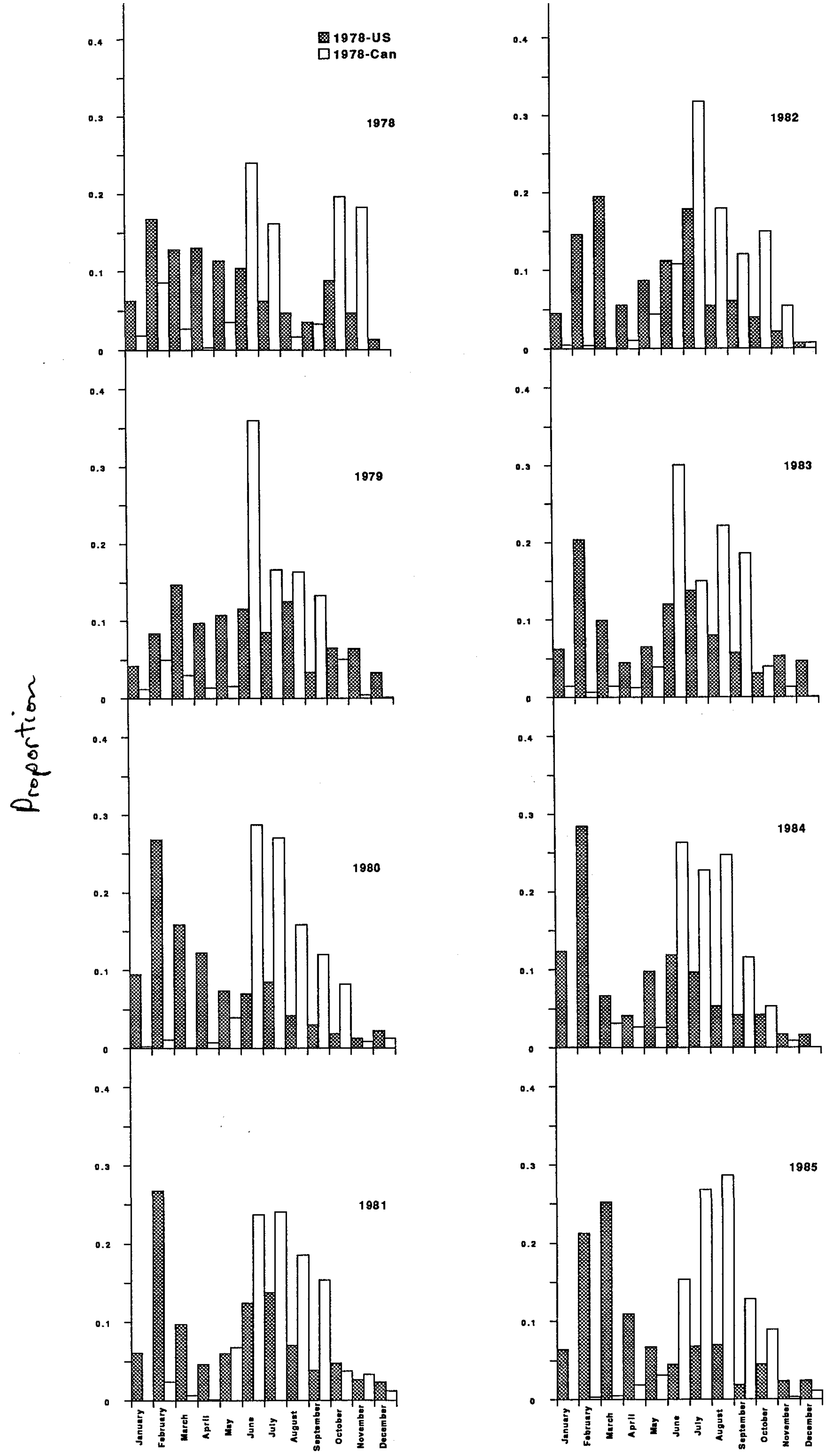

Fig. 2. Proportion of landings by month by Canada and U.S., 1978-1985. 5Zjm (Canada) and 5Z + 6 (USA) cod.

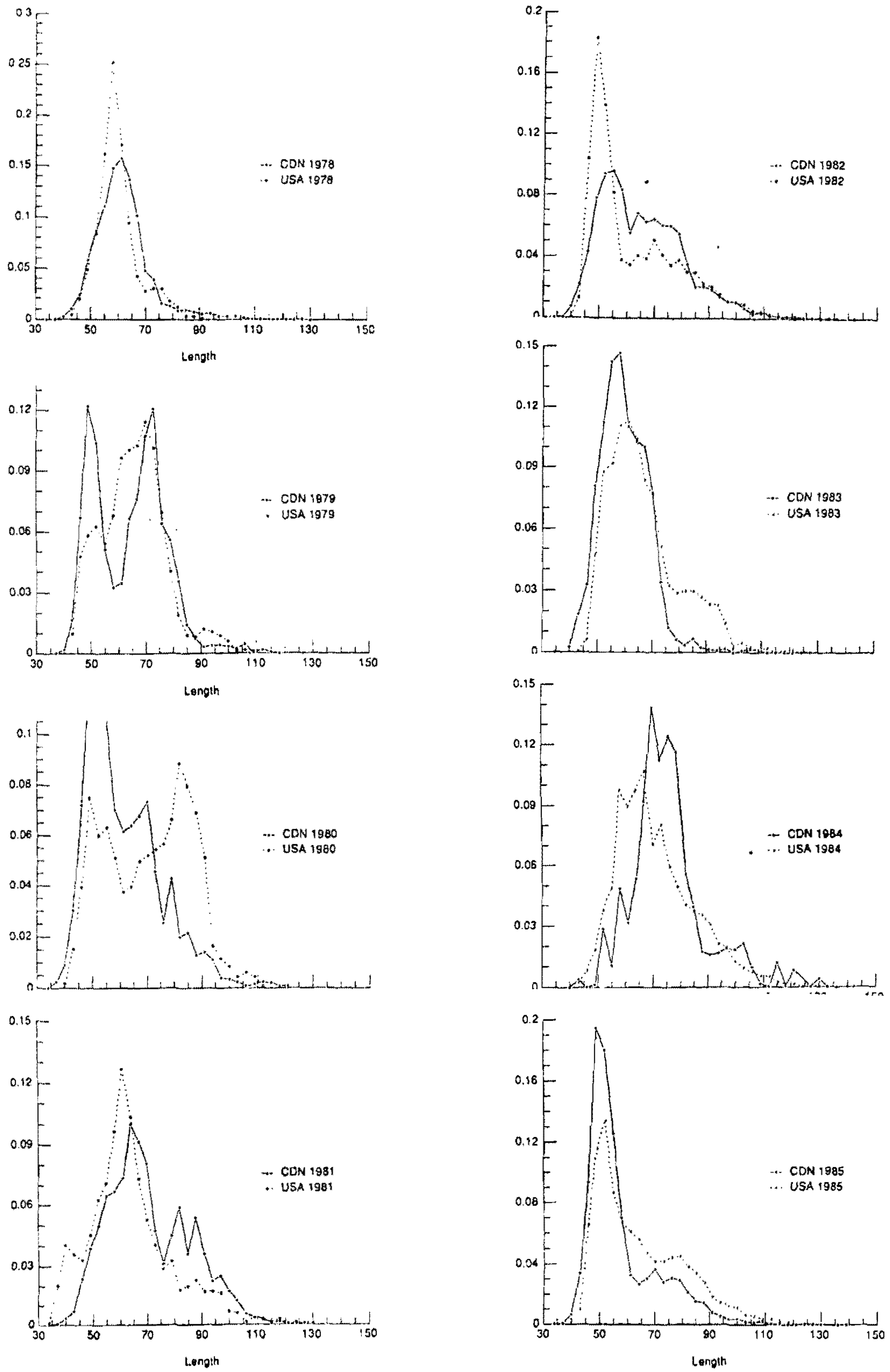

Fig. 3. Length-frequency distributions of Atlantic cod landed in fisheries by USA and Canada, 1978-1985. 5Zjm, all gear types.

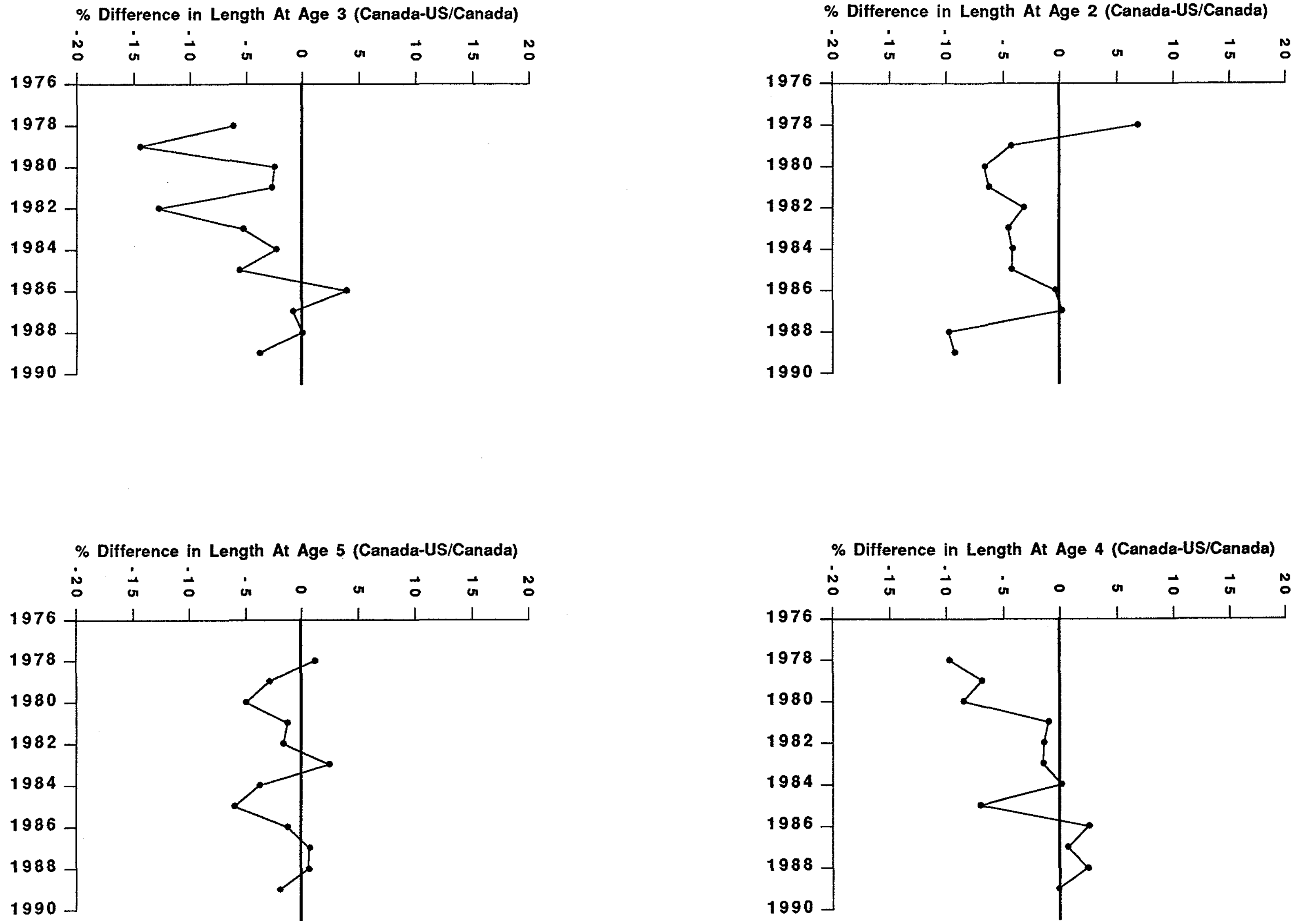

Fig. 4. Percent difference in length at age, Canada and US, 1978-1989. 5Zjm (Canada) and 5Z + 6 (USA) cod.

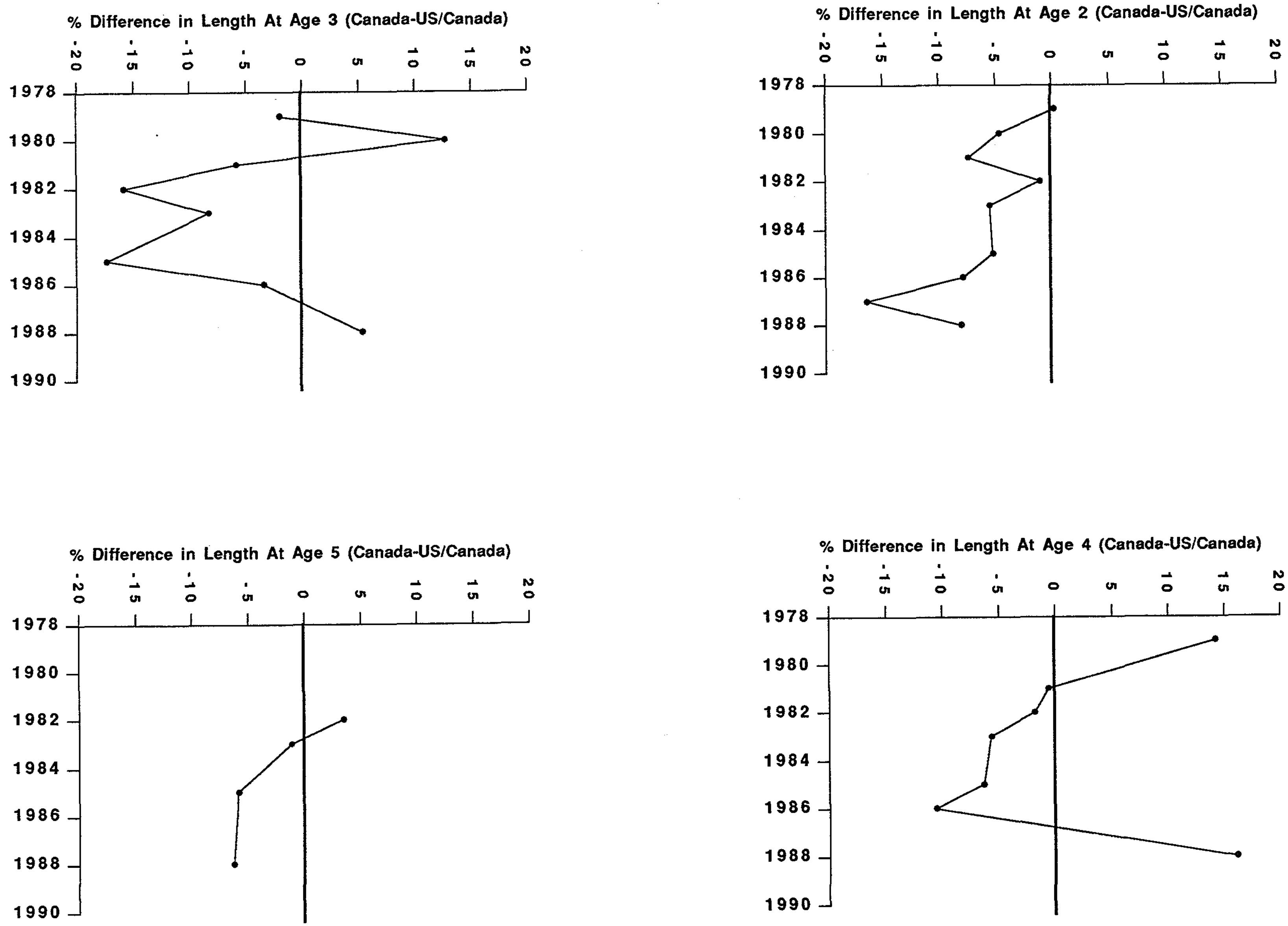

Fig. 5. Percent difference in length at age of Atlantic cod, Canada and US, 1979-1988. 5Zjm only, OTB, third quarter.

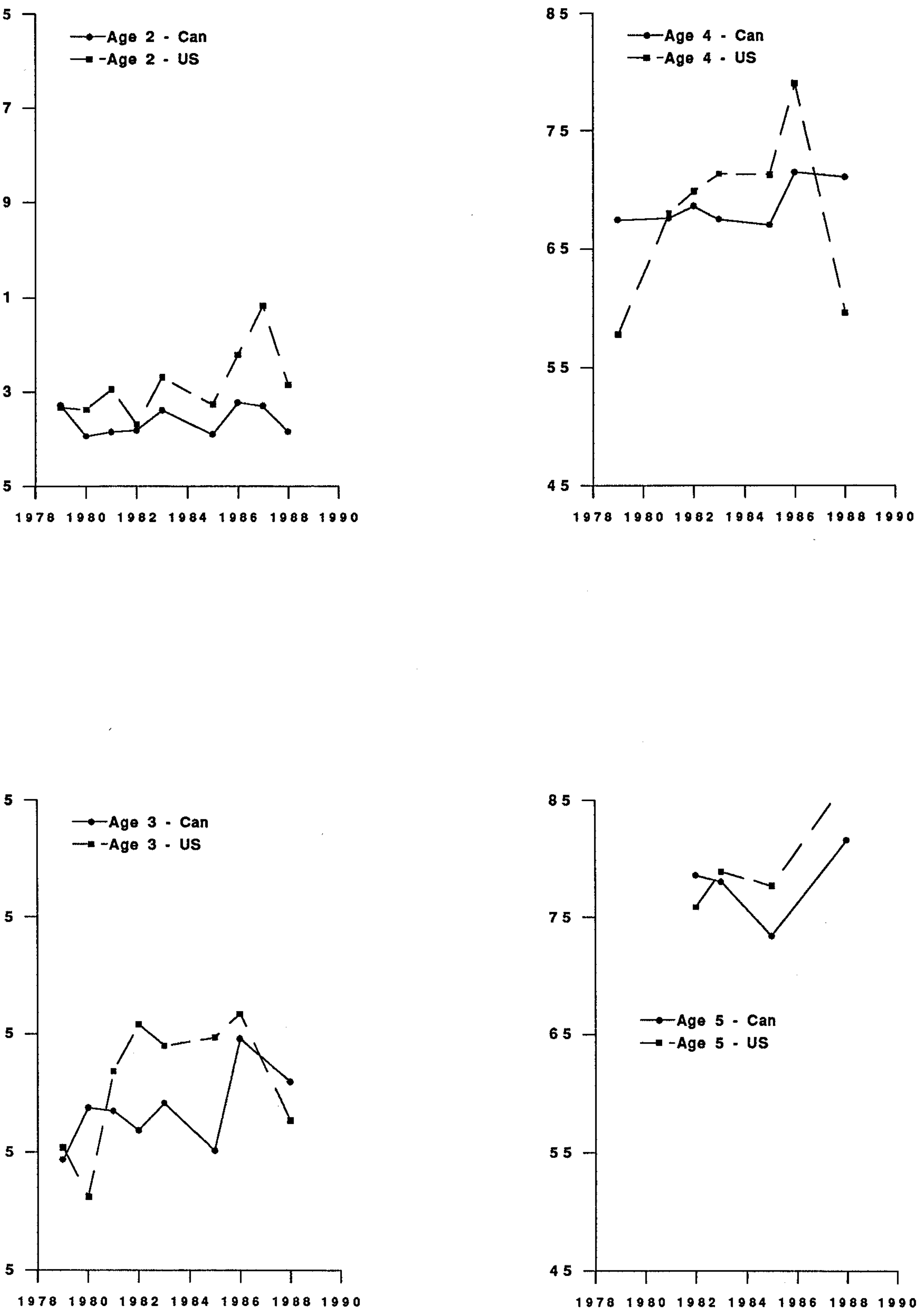

Fig. 6. Mean lengthjs at age of Atlantic cod, US and Canada, 1979-1988. 5Zjm only, OTB, third quarter.

Fig. 7 Comparison of catch at age for 1980

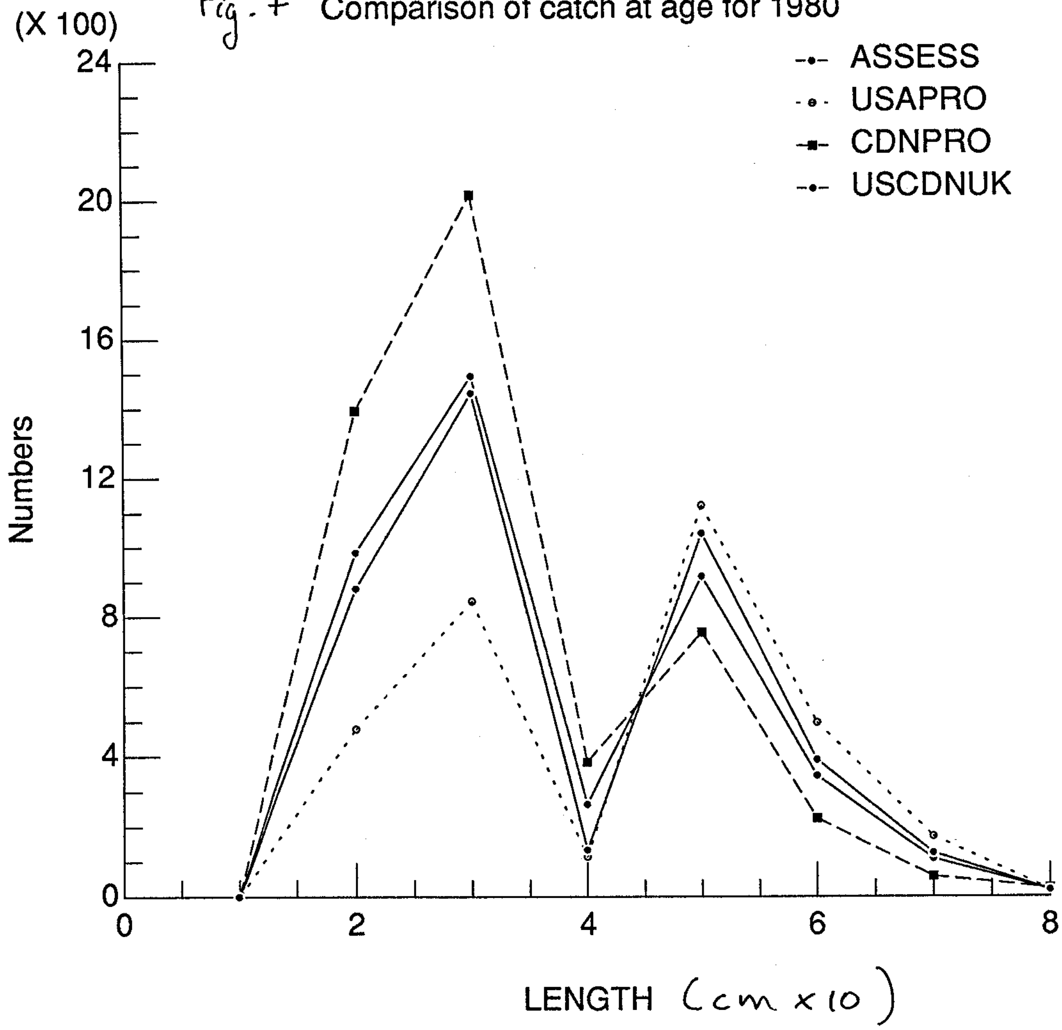

Fig. 8 Comparison of 1980 Canadian catch at age derived with Canadian and USA ALK