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An Analysis of Inconsistencies in Estimates of Silver Hake Catch at Age *

by

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Introduction

Estimates of age composition of commercial catches are essential input parameters for sequential population analysis (SPA). The SPA model is based on the assumption that number of individuals in a cohort in successive years is a function of mortality due to natural causes and removals due to fishing. Losses due to natural mortality are usually assumed to be constant over all agegroups. Losses due to fishing are estimated by calculation of catch at age in numbers using sampling data obtained from commercial catches or landings. It is possible to incorporate estimates of variance in catch at age due to factors such as ageing and sampling but precise values for these data are difficult to obtain. The problem is compounded when bias due to ageing or sampling is introduced and when more than one source of data is used.

In recent years, differences between independent estimates of catch at age made by Canada and the USSR of silver hake from commercial fisheries have been have been noted (NAFO, 1983). Age determination was assessed to be a factor in these differences, although results of replicate age readings by Soviet, Cuban and Canadian readers did not indicate significant disagreement (Hunt, 1986; Dominquez and Varea, 1986; Hunt, this meeting).

This report examines the extent of differences in estimated age composition of silver hake as reported by the USSR and Canada and attempts to attribute the influence of ageing and sampling.

Methods

Comparison of Canadian (Waldron and Fanning, 1986) and Soviet (Noskov, 1986) estimates of catch at age for 1980-85 were made to assess the degree of difference. The ratio of Canadian to Soviet percent age composition was calculated by dividing the Canadian estimate by the Soviet for ages 1-9. Ratios greater than 1.0 indicate a higher percent composition in the Canadian estimate while those less than 1.0 indicate a higher percent composition in the Soviet estimate for each agegroup.

The relative strength of year-classes within the two estimates of percent age composition was determined by dividing the percent catch at age for each agegroup by the largest observed percent within the agegroup. This results in a value of 1.0 for the year-class with the greatest percent at age and values less than 1.0 for other year-classes at the same age. Agreement between the Canadian and Soviet estimates of relative strength of year-classes by agegroup was assessed by calculating the ratio of the two values. It was assumed that catchability (Q) was constant within agegroups for the 1980-85 time period.

Estimates of year-class abundance at age derived from Canadian surveys in July of the Scotian-Shelf (Waldron and Fanning, 1986) were examined to determine the relative strength by agegroup. Percent numbers at age were reduced to a relative index by dividing each value by the largest observed value within the agegroup.

* See APPENDIX (page 13) for an analysis of inconsistences in 1986 data.

Differences in age determination between Canadian and Soviet age readers was assessed by calculating percent age composition using age length keys provided by each country. The catch at length for 1985 was estimated by prorating the reported Soviet monthly length frequency samples to monthly catch (preliminary data from NAFO). The mean fish weight in samples was used to determine sample weight and numbers at length from samples were increased to reflect the reported monthly catch. Males and females were considered separately and the catch by sex was estimated from the ratio of males to females in sampling data. Monthly age length keys, derived from the Canadian and Soviet ageing, were used to determine catch at age by month and then summed to estimate the total catch at age for 1985.

Estimates of the length frequency composition of commercial catches of silver hake are made from samples collected by the International Observer Program (IOP) and from samples collected by national observers. The degree to which the two sources of information are combined in national summaries is not reported. However, length frequency summaries (and catch at age) reported by the USSR appear to represent only the proportion of the total catch taken by the USSR. Three sources of length frequency sampling data for 1985 were examined to assess possible differences. These included results of IOP sampling, summaries for Soviet sampling as reported to NAFO and summaries of Cuban sampling (Dominquez, 1986). Comparisons were made based on calculated percent composition by one centimeter length groups.

Results of age determinations of silver hake otoliths by Canadian, Soviet and Cuban readers during recent exchanges were reviewed to assess the level of agreement. The design of these exchange projects was examined to determine their usefulness and to recommend improvements.

Results

Percent age composition of commercial catches for 1980-85, as reported by Canada and the USSR, are given in Table 1 and summarized in Figure 1. It is apparent that over 90% of the catch is accounted for by agegroups 1-5 and that substantial differences in the contribution of year-classes exist in the two estimates. The ratio of Canadian to Soviet percent age composition (Table 1) ranged from a high of 4.6 for the 1983 year-class at age one to a low of 0.4 for the 1979 year-class at age five. Agegroups one and four appeared to have the most significant differences and the mean ratio for ages 1-5 was 2.089, 1.236, 1.045, 0.684 and 0.819, respectively. These mean values imply that the Canadian estimate of catch at age is generally higher at ages one and two, approximately equal at age three, and lower at ages 4 and older. Differences at age one are not accounted for by reciprocal differences at age two, suggesting that ageing determination was not the primary factor. For example, the 1983 year-class accounted for 23% at age one in Canadian results but only 5% in Soviet results. If some proportion of the fish aged as as agegroup one by Canada were aged as agegroup two by Soviet readers, a higher percent at age two in Soviet data would be expected. However, results indicate similar compositions (9.4 and 10.1, respectively) at age two. It is unlikely that fish aged as one would be aged as older than two by another reader.

The influence of age determination at ages two and older is more difficult to assess. In 1980 ages 2, 3 and 4 accounted for 29, 39 and 17% in Canadian results and 17, 36 and 32% in Soviet results. If age determination was the main factor in these differences, it would imply that some proportion of fish aged as two by Canada were aged as three by the USSR and some proportion of fish aged as three by Canada were aged as four by the USSR. A similar trend is apparent in 1981-84 data and is even more evident in 1985 data in which the 1982 year-class accounts for almost twice the Canadian percent composition in Soviet estimates.

The relative strength of year-classes by agegroup are given in Table 2 for 1980-85 Canadian and Soviet data. If catchability by agegroup (a function of temporal, geographic, partial recruitment and abundance factors) is similar over the 1980-85 time period, internal differences in relative strength of a year-class within the data sets might be attributed to inconsistency in ageing. For example, a year-class with a high relative strength at one agegroup but low or variable values in other agegroups may indicate inconsistency in assigning fish to the correct agegroup and year-class. Examples, based on differences of >50%, are shown in Table 2 by diagonal lines joining year-classes at successive agegroups. Canadian results indicate three inconsistencies between ages one and two, one between ages two and three and one between ages four and five. Soviet results indicate one difference between ages one and two, three between ages two and three and one between ages four and five. The number of differences between ages one and two in the Canadian data may be influenced by the high (23%) percent composition of the 1981 year-class which results in other year-classes at age one being given relatively low strength. In both data sets, except for age four to five, the tendency is for a year-class to appear to have a higher relative strength at the older age.

The ratio of relative year-class strength between Canadian and Soviet data is given in Table 2. At age one, only the 1983 year-class has a similar strength in both data sets but the influence of the high percent (23%) catch at age one in Canadian data has a strong influence on the strength of other year-classes. Correspondence at age two appears to be more consistent and only the 1978 year-class has a ratio (1.615) significantly different than 1.0. This ratio implies that the Soviet estimate is 62% of the relative strength of the 1978 year-class estimated from Canadian data. At ages three and older, the ratios are variable with no apparent trend.

The relative strength of year-classes by age group derived from percent age composition of silver hake in the Canadian July survey of the Scotian Shelf is given in Table 3. Differences >50% in the relative strength of a year-class in successive agegroups are noted by diagonal lines. Several inconsistencies are apparent, but as Hunt (1985) notes, this may be due to inter-annual changes in catchability for the surveys.

Soviet sampling data for 1985, as reported to NAFO, consisted of length frequency samples for May, June, July and August for males and females with corresponding age length keys. Total catch in numbers was determined with the following algorithm:

Catch (USSR) X percent males = catch of males (repeat for females)

Mean sample weight X number of fish = sample weight

Catch weight / sample weight = ratio sample to catch

Sample number at length X ratio = catch number at length

The resultant catch number at length was then proportionally allocated to age groups using the appropriate age length key and these values summed over months to estimate total catch by agegroup. A total of 546 length frequency samples and 1178 age determinations were reported by the USSR. Monthly age length keys for males and females derived from Canadian ageing of IOP samples for 1985 were compiled from a total of 1568 age determinations and used to estimate catch at age from the USSR catch number at length. Percent catch at age derived from the two sources of age determination for 1985 are shown below:

	Agegroup									
	1	2	3	4	5	6	7	8	9+	Total (millions)
USSR ageing	4.9	36.3	28.5	21.4	7.3	1.3	0.2	0.1	0.0	499
* Assessment	5.4	33.7	29.9	21.8	7.7	1.2	0.3	0.0	0.0	347
CDN ageing	2.7	36.9	21.0	28.8	6.9	2.8	0.8	0.1	0.0	496
* Assessment	9.4	42.9	16.4	22.4	5.6	2.2	0.8	0.2	0.1	409

* as used in the respective 1986 assessment document

Differences between the percent catch at age derived from Soviet age determinations are minor and may reflect the use of mean sample weight rather than a length-weight relationship to estimate catch numbers at length. The total catch in numbers estimated in this study (499 million) was substantially different than the 347 million reported by Noskov (1986), although the latter number excludes the catch at age one. Differences between the percent catch at age based on Canadian ageing are more substantial and may be the result of different estimates of catch numbers at length derived from Soviet and IOP data.

Comparison of the percent catch at age derived from the same catch number at length (Soviet) using the two sets of age length keys show good correspondence for ages 1-2 but substantial differences at ages three and four. The Soviet data indicate 29% age three and 21% age four while Canadian data estimate 21% age three and 29% age four. This implies that 36% ([28.5-21.0]/28.5) of fish aged as three by Canada were aged as four by the USSR. These agegroups account for 50% of the total catch in numbers and the differences due ageing would result in close to a 20% difference in estimate catch at age.

Length frequency data for 1985 were reported to NAFO by the USSR and by Cuba (Dominquez and Varea, 1986) and results of IOP sampling were available. Cuban samples were obtained from three commercial vessels operating in NAFO Division 4W from April to July as part of a special research study. A total of 102 samples and 66000 individual length measurments were obtained. Soviet data collected from commercial vessels resulted in 546 samples and 190000 individual length measurements for May - August. IOP sampling produced 1110 samples from Soviet, Cuban, Portuguese and Japanese vessels and 285028 individual length measurments for April - September (Table 4).

Numbers measured at length were separated for males and females, reduced to percent and then combined to estimate total numbers at one centimeter length intervals for each data set. Cuban samples were reported as measurement of total length, Soviet and IOP samples as fork length. No conversion from fork to total length was available but examination of a small number of silver hake specimens indicated an approximate relationship of:

$$\text{Total length} = 1.0175 \text{ Fork length}$$

which results in equivalent total lengths of 20.3, 30.5, 40.7 and 50.9 cm for fork lengths of 20, 30, 40 and 50 cm, respectively. The maximum adjustment required for Cuban data would be 1 cm and, since most lengths were between 25 and 35 cm, it was decided not to apply any conversion. This could result in an apparent shift towards smaller lengths when Cuban data are compared to data based on total length measurments.

Comparison of per mille length frequency composition of Cuban and USSR silver hake catches for 1985, derived from national and IOP samples, is given in Figures 2 and 3. The two independent estimates of Cuban catch length composition (Fig. 2) are in good agreement for April and May but have some differences in June and July. In the latter two months the IOP samples appear to indicate higher contributions by fish less than than 25cm as well as differences at larger length groups. The anticipated shift due to fork length and total length measurements is also evident.

Results for the USSR catches (Fig. 3) show good correspondence for May and July but estimates for June and August have substantial differences. Both the June and August estimates appear to be out of phase by one centimeter suggesting an error in data recording. However, a review of the data sets did not identify an error in either the reported data or in calculations. If these results do not have an error then substantial differnces in age composition derived from the two sets of length data would be expected.

The estimated length frequency distribution for total catch and for USSR catch only is shown in Figure 4. The total catch length frequency was estimated by weighting IOP data for Cuba and the USSR with the respective reported national catch and summing the two values and the reported USSR catch and length frequency was compared with this value. Canadian calculated catch at age is derived from the summed length frequencies for all countries reporting silver catch while the USSR catch at age appears to be an estimate for USSR catches only. Comparison of the distributions for May-July, when Cuban catches were substantial, indicates significant differences in length distribution. Estimates derived from IOP data suggest a shift towards smaller lengths in both May and June but good correspondence for July.

Exchanges of silver hake otoliths (100) between Canadian and Soviet age readers to estimate levels of inter-reader agreement have been carried out annually since 1982. Cuban age readers participated in the 1985 exchange. Previous to the exchanges, a number of workshops were held to ensure that readers used the same conventions and basis for subjective interpretation of otoliths and Hunt (1980) summarized results and presented guidelines for age determination. No discussion between age readers has occured since 1980 and it is assumed that the same criteria for estimating age are followed by all readers. The author has completed all ageing for Canada but the individual(s) completing Soviet and Cuban ageing is not reported. The 1986 and 1987 samples were aged by the Canadian reader without prior knowledge of either fish length or sex, but information available to Cuban and Soviet readers at the time samples are aged is not reported.

Results of 1984-87 otolith exchanges are summarized in Table 4 and indicate an inter-reader agreement of 68-93 percent. The 1984 exchange showed an initial 74% agreement which was increased to 82% after the Canadian reader re-examined otoliths which had ages different than the Soviet age. Eight ages were changed, based on alternate interpretation, to conform with the Soviet age. For example, a fish aged as a preferred age 3, possible age 4 was changed to agree with the Soviet interpretation as age four. Results indicated 100% agreement at ages 1 and 2 but a bias for Soviet ages to be higher than the Canadian age for fish 3 years and older.

The two 1985 exchanges (Dominguez and Varea, 1986; Hunt, 1986 Senina and Stulova, 1986) resulted in contrasting levels of agreement between Soviet and Canadian ages. The Cuban/Canadian/Soviet sample produced 68 and 83 percent concurrence between Canada and the USSR and Cuba, respectively. Differences in age were biased towards a lower age relative to the Canadian age for both Cuba (76%) and the USSR (84%). The Soviet/Canadian exchange indicated an 85% overall agreement but in this case differences resulted from a Soviet age higher than the Canadian age in 93% of the examples.

The 1986 Soviet/Canadian exchange resulted in 82% overall agreement and 61% of the differences were due to a higher Soviet age. The 1987 exchange produced 70% agreement and 24% of the differences were also due to a higher Soviet age relative to the Canadian estimate.

In summary, otolith exchanges between Canadian and Soviet readers appear to indicate a level of agreement of greater than 80% which should not result in substantial differences in age length keys. However, the tendency for differences to be biased towards a lower Canadian relative to Soviet age is cause for concern and could produce significantly different estimates of population age composition. The bias noted in exchange samples is also evident in estimates of catch at age reported by the two countries. It is unlikely that further exchanges of otoliths between readers will improve the level of agreement or reduce the bias in differences without discussion and resolution of the source of disagreement.

Discussion and Conclusions

Results confirm substantial differences between Canadian and USSR estimates of catch at age for the 1980-85 time period. Age determination appears to be a factor in these differences and the tendency is for the USSR estimate of catch at age to underestimate the contribution of agegroups one and two and overestimate the contribution of agegroups three and older, relative to the Canadian estimate. However, analysis of the data suggests that age determination is not the only factor involved. It should also be noted that the USSR estimate of catch at age appears to relate only to the USSR portion of the total catch.

Comparison of independent estimates of length frequency distribution for the 1985 catch also indicates significant differences between sources of data. In some months IOP data are at variance with the Cuban and USSR reported results of sampling and the tendency is for IOP data to have a higher relative contribution by fish at smaller lengths. This interpretation of results would suggest an additive effect for age determination and length frequency differences which would introduce a substantial bias in independent esitmates of catch at age derived from two data sources.

Otolith exchange results suggest a bias between age readers which is consistent with differences observed in reported catch at age. Current design of these exchanges does not allow assessment of the sources of different ages or the level of intra-reader agreement.

It is unlikely that improvement in independent estimates of catch at age can be achieved without further resolution of age determination and length frequency differences. Until this is accomplished, it is suggested that one source of catch at age be used for input to population analysis.

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Table 1. Percent age composition of silver hake catches as reported by Canada and the USSR for 1980-85 and the ratio of the Canadian to USSR percent age composition.

	Agegroup								
	1	2	3	4	5	6	7	8	9
Canada									
1980	3.0	29.1	39.4	17.2	7.3	3.0	0.8	0.2	0.0
1981	0.8	10.2	58.1	20.1	7.4	2.9	0.3	0.1	0.0
1982	7.8	20.5	26.6	26.3	13.8	3.5	1.1	0.4	0.0
1983	1.8	45.7	27.4	15.0	6.9	2.4	0.6	0.2	0.0
1984	23.2	9.4	44.6	16.8	4.5	1.3	0.2	0.0	0.0
1985	9.4	42.9	16.4	22.4	5.6	2.2	0.8	0.2	0.1
USSR									
1980	1.4	16.8	36.2	32.4	9.6	2.2	0.6	0.5	0.3
1981	0.7	9.9	42.6	33.0	10.3	2.6	0.7	0.1	0.1
1982	4.9	14.9	24.1	37.6	12.8	4.1	1.1	0.4	0.1
1983	1.4	42.6	27.0	20.6	5.8	1.9	0.5	0.1	0.1
1984	5.0	10.1	38.6	33.1	10.5	2.0	0.6	0.1	0.0
1985	5.4	33.7	29.9	21.8	7.7	1.2	0.3	0.0	0.0
Ratio Canada to USSR									
1980	2.150	1.731	1.088	0.532	0.765	1.350	1.350	0.340	0.133
1981	1.157	1.030	1.363	0.610	0.723	1.115	0.500	0.700	0.300
1982	1.594	1.375	1.102	0.698	1.074	0.863	1.009	1.050	0.500
1983	1.264	1.072	1.014	0.730	1.191	1.237	1.220	2.500	0.400
1984	4.636	0.932	1.156	0.506	0.428	0.630	0.400	0.400	1.000
1985	1.735	1.274	0.549	1.027	0.730	1.825	2.767	0.000	0.000

Table 2. Relative strength of yearclasses, by agegroup, derived from percent catch at age as reported by Canada and the USSR and the ratio of Canada to USSR yearclass strengths.

Year	Agegroup 1	2	3	4	5	6	7	8	9
Canada									
1980	0.129	0.637	0.678	0.654	0.529	0.857	0.727	0.500	0.000
1981	0.034	0.223	1.000	0.764	0.536	0.829	0.273	0.250	0.000
1982	0.336	0.449	0.458	1.000	1.000	1.000	1.000	1.002	0.000
1983	0.078	1.000	0.472	0.570	0.500	0.686	0.545	0.500	0.000
1984	1.000	0.206	0.768	0.639	0.326	0.371	0.182	0.000	0.000
1985	0.405	0.939	0.282	0.852	0.406	0.629	0.272	0.500	0.000
USSR									
1980	0.259	0.394	0.850	0.862	0.750	0.537	0.545	1.002	1.000
1981	0.130	0.232	1.000	0.878	0.805	0.634	0.636	0.200	0.333
1982	0.907	0.350	0.566	1.000	1.000	1.000	1.000	0.800	0.333
1983	0.259	1.000	0.634	0.548	0.453	0.463	0.455	0.200	0.333
1984	0.926	0.237	0.906	0.880	0.820	0.488	0.545	0.200	0.000
1985	1.000	0.791	0.702	0.580	0.602	0.293	0.273	0.000	0.000
Ratio of Canada to USSR									
1980	0.499	1.615	0.798	0.759	0.705	1.597	1.333		
1981	0.266	0.960	1.000	0.871	0.666	1.307	0.429		
1982	0.371	1.283	0.809	1.000	1.000	1.000	1.000		
1983	0.299	1.000	0.744	1.041	1.103	1.480	1.200		
1984	1.080	0.868	0.847	0.729	0.398	0.761	0.333		
1985	0.405	1.187	0.402	1.469	0.675	2.140	2.667		

Table 3. Relative strength of agegroups derived from July Canadian research survey percent catch at age, 1980-85.

Year	Agegroup 1	2	3	4	5	6	7	8	9
1980	0.385	0.627	0.857	0.564	0.962	1.000	1.000	1.000	1.000
1981	0.217	0.614	1.000	0.994	0.942	0.405	0.500	0.300	0.125
1982	0.631	0.993	0.307	0.558	0.423	0.405	0.444	1.000	0.125
1983	0.869	0.875	0.337	0.366	0.615	0.270	0.167	0.100	0.125
1984	1.000	0.260	0.869	0.331	0.308	0.297	0.278	0.200	0.250
1985	0.540	1.000	0.211	1.000	1.000	0.622	0.333	0.300	0.125

Table 4: Comparison of numbers of fish sampled for length frequency by Cuba, USSR and IOP in the 1985 silver hake fishery.

	Cuba	USSR	Cuba IOP	USSR IOP	IOP Total *
April					
Males	15594	-	23289	-	-
Females	11123	-	12820	-	-
Total	26717	-	40104	-	44693
May					
Males	15333	15722	22137	24178	-
Females	9104	10708	13528	14327	-
Total	24437	26430	35675	38505	95572
June					
Males	8053	15007	8825	26842	-
Females	3702	19200	7360	26431	-
Total	11755	34207	16185	53273	87346
July					
Males	2299	18888	1510	22650	-
Females	803	13913	1313	15033	-
Total	3102	32801	2823	37683	46293
August					
Males	-	8105	-	5840	-
Females	-	7794	-	4554	-
Total	-	15899	-	10394	10394

* IOP total includes samples from all countries.

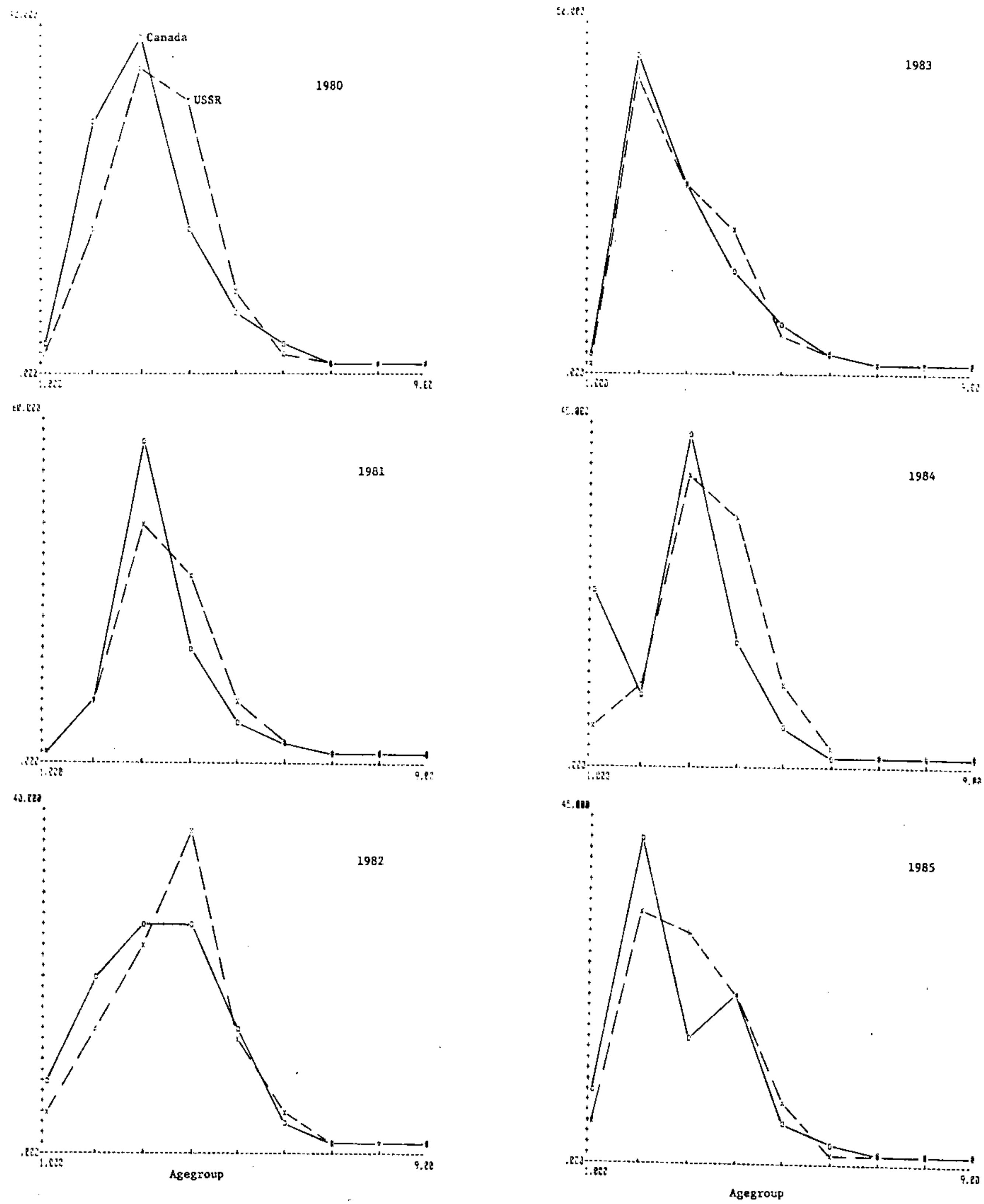

Figure 1. Percent age composition of silver hake as reported by Canada (o———) and the USSR (x---), 1980-85.

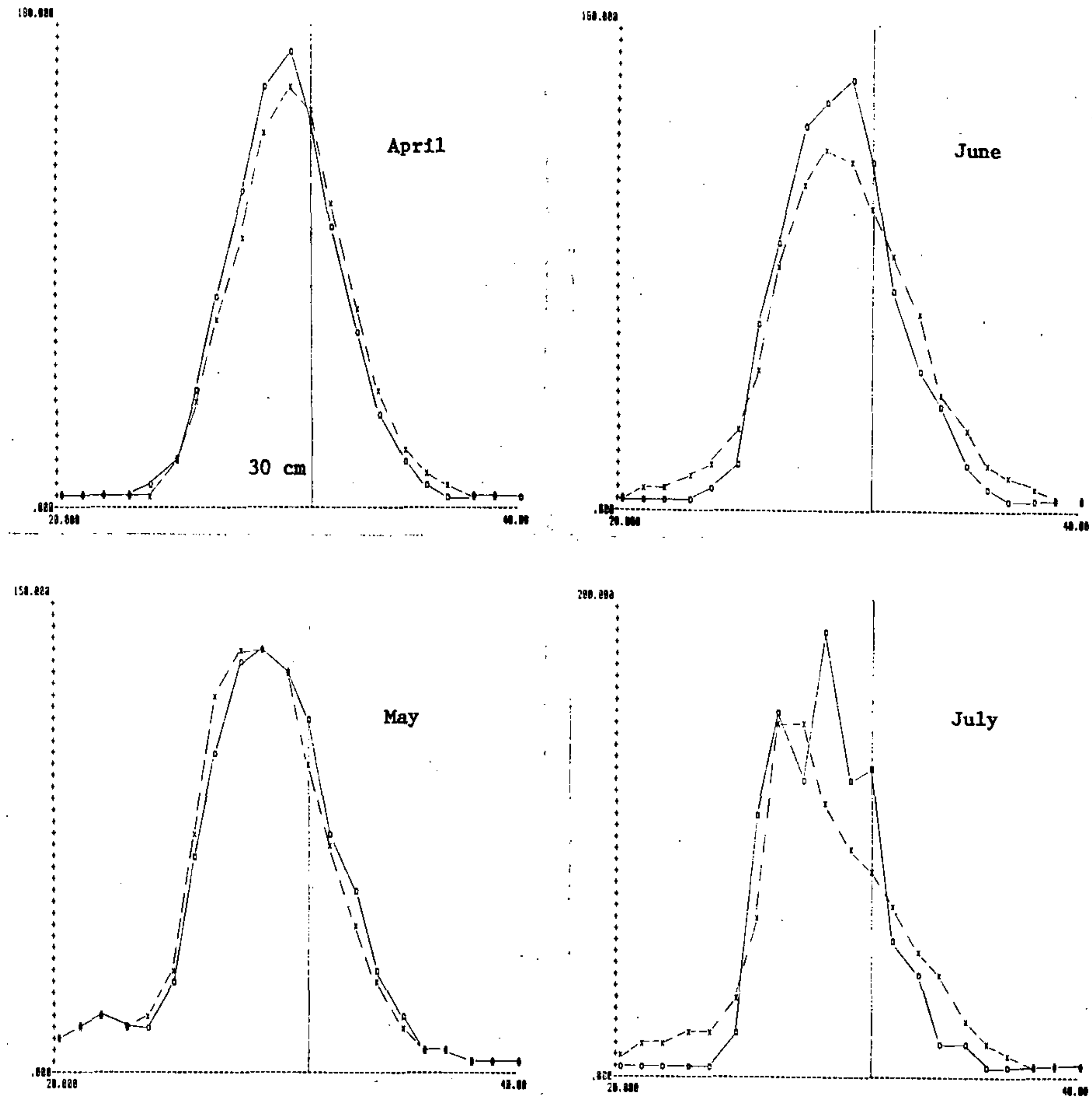

Figure 2. Length frequency (per mille) of silver hake in 1985 derived from Cuban (o——) and IOP (x----) sampling data.

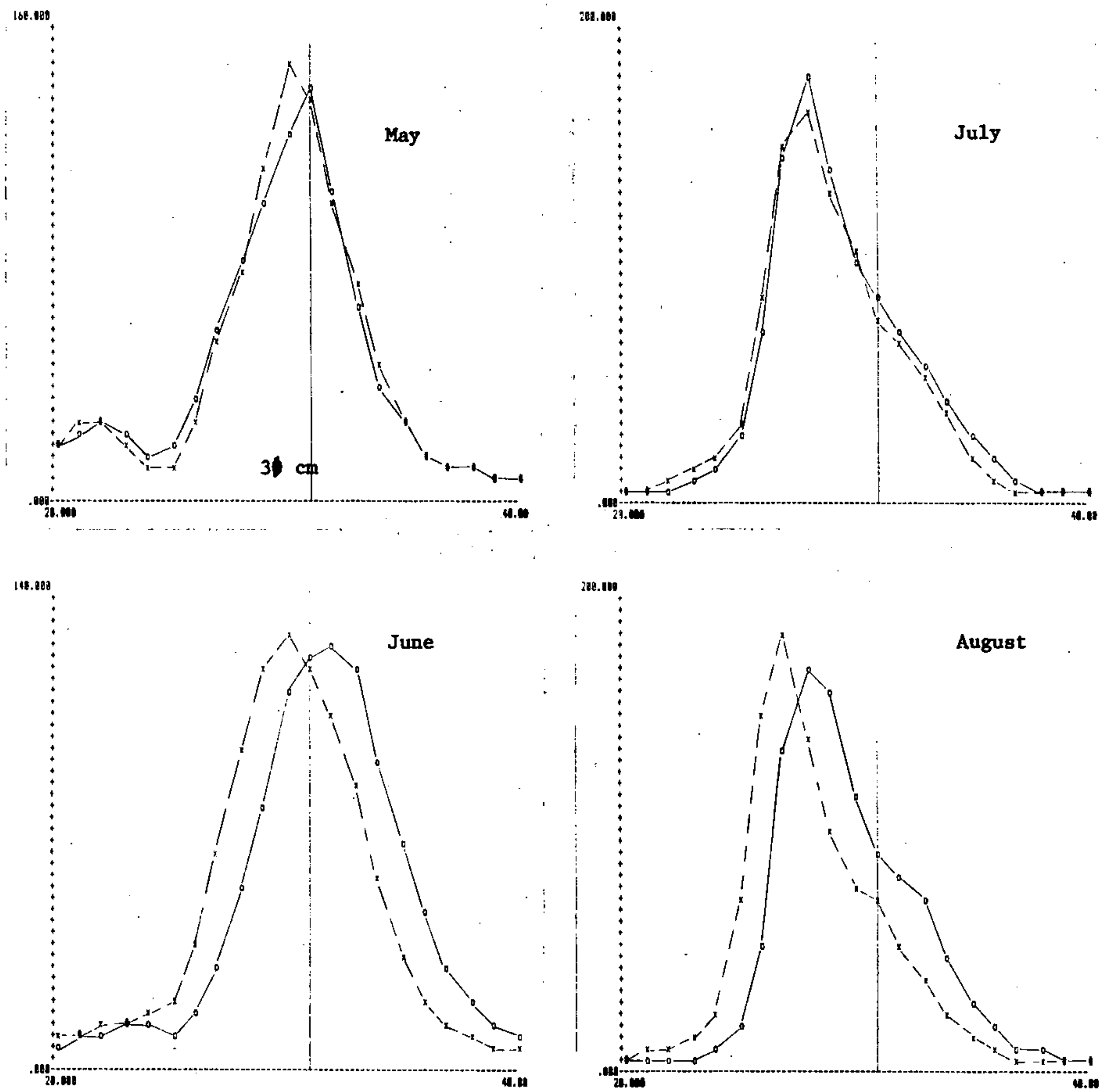

Figure 3. Length frequency (per mille) of silver hake in 1985 derived from USSR (o——) and IOP (x----) sampling data.

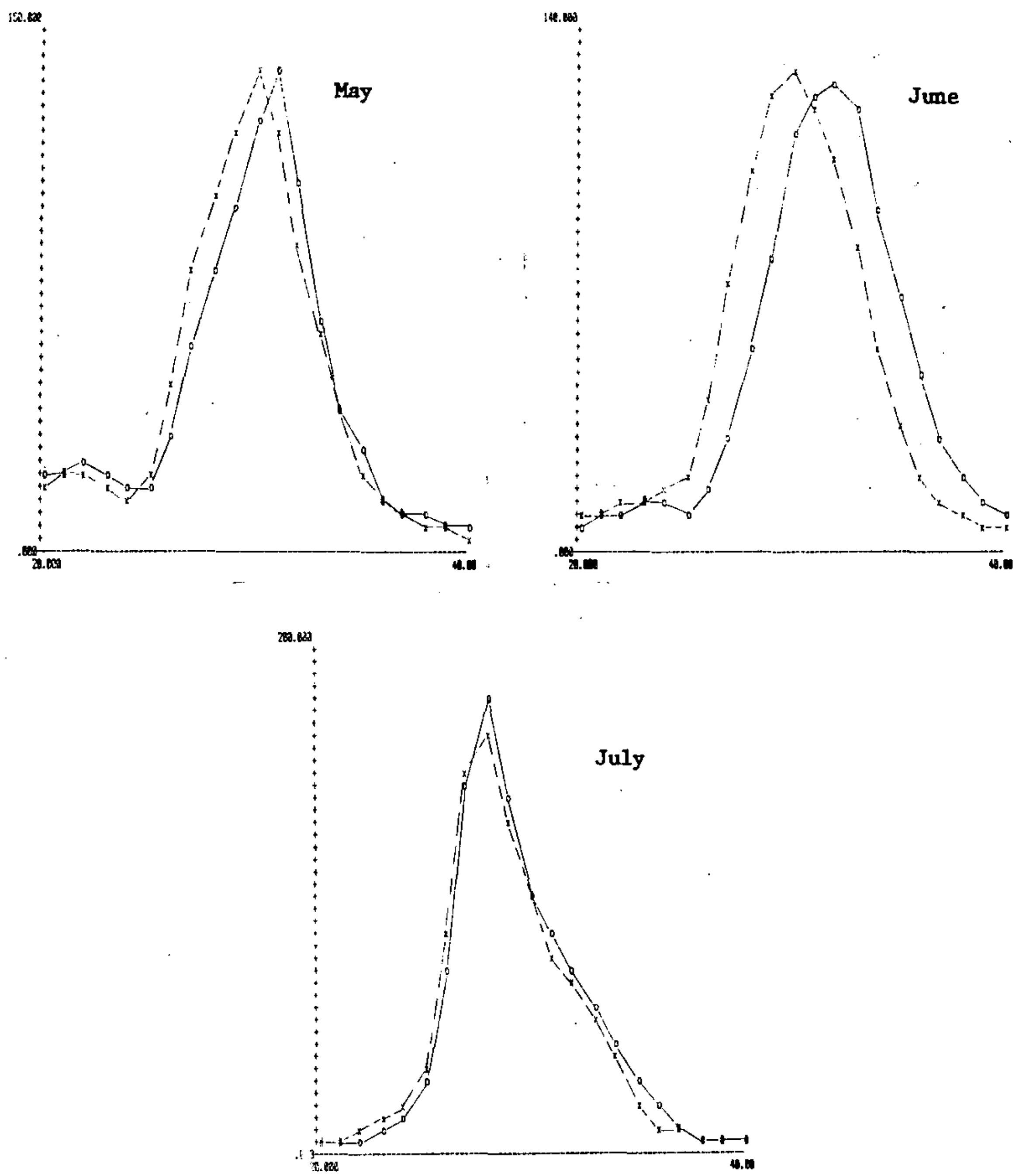

Figure 4. Comparison of per mille length frequency distribution for silver hake in 1985 derived from IOP (x---) sampling for total catch and USSR (o---) sampling for USSR catches.

APPENDIX

An Analysis of Inconsistencies in Estimates of Silver Hake Catch at Age*

by

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