Northwest Atlantic Fisheries Organization

Serial No. N1019

NAFO SCR Doc. 85/67

SCIENTIFIC COUNCIL MEETING - JUNE 1985

Assessment of the Historical Consistency of Canadian Research Vessel Surveys as an Indicator of Silver Hake Abundance

by

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Introduction

Independent indices of stock abundance are required input parameters for 'fine tuning' sequential population analysis models. These indices allow estimates of terminal fishing mortality to be selected which provide the best relationship between observed and calculated population size and estimates of abundance derived from research vessel surveys have been used for many species with varying degrees of confidence. Waldron et al (1983) considered various indices of abundance for silver hake but found poor correlation with results of sequential population analysis. Survey design and catchability of silver hake were identified as potential reasons for poor correlation (Koeller, 1981).

The present analysis was untaken to assess the consistency of research survey population estimates in terms of recruitment to the survey gear and yearclass numbers in consecutive years. Identification of the most consistent age-specific index was also considered.

Methods

Research vessel surveys, using a stratified random design, have been conducted by Canada in NAFO Divisions 4VWX from 1970 to the present. The time period from 1973-84 was selected for this study since ageing of silver hake had not been completed for earlier years. The surveys are conducted in a four week time period in July and cover the entire Scotian Shelf and Bay of Fundy. Three vessels and two gear types have been used for the survey and conversion factors were applied to the data, based on results of comparative trawling experiments.

A second series of research cruises conducted in March from 1979-84 using the same stratification and sampling protocol as July surveys was available. These surveys were conducted using a stern trawler and the same conversion factors were applied to reduce abundance estimates to a common standard.

Estimates of population abundance are calculated by aerial expansion for each depth-defined stratum. A minimum of two 30 minute tows are completed in each stratum, the mean of the catch at age calculated and expanded to an estimate for the total bottom area of the stratum. Stratum totals are then summed by specified NAFO unit areas to provide an estimate of total population. Numbers at age in NAFO Divisions 4VWX and Division 4W were derived for each of the surveys.

Estimates of age for silver hake for all of the surveys were made by the author using accepted conventions (Hunt, 1980) and numbers at age were treated separately for males and females. Indices of abundance at age were limited to age groups one to five since fish older than five are taken in small numbers and ageing of older fish may be less precise.

Absolute population numbers derived from surveys are generally considered a minimum estimate and, to standardize results, a relative index of abundance was calculated. This index was defined as the estimated number at age from each survey divided by the mean number at age from the 1973-84 July surveys and the 1979-84 March surveys. Values greater than 1 indicate above average numbers and those less than 1 below average abundance. Indices for 4VWX and 4W were calculated separately.

Mean lengths at age in July were calculated for each survey over the entire 4VWX area and used to describe growth. The ratio of males to females by age was was also determined.

The calculated relative index was determined for age groups 1 to 5, for the average of age groups 1 and 2 and 2 and 3 and for the five year average of age groups 1 to 5. Comparison of indices at age 1 and 2 and at age 2 and 3 and for the average of agegroups 1+2 and 2+3 were made for each yearclass for Divisions 4VWX and Division 4W. The percent at age by yearclass for consecutive surveys was also determined. The relative proportion of the total population derived from strata in Division 4W was determined for each yearclass and for each survey. Comparisons between estimates for yearclasses present in both the July and March surveys was made to assess variation in abundance during two time periods.

Results of sequential population analysis given by Waldron et al (1984) were used to compare research survey population estimates.

Results

A total of seventeen research surveys were used for the analysis and each survey consisted of about 150 sets in Divisions 4VWX. July surveys were done by a side trawler using Yankee 36 gear from 1973-81 and by two different stern trawlers using Western IIA gear in 1982-84. Fanning (1984) analyized results of a comparative fishing experiment between the two stern trawlers and found no significant difference in catches while Koeller and Smith (1983) recommend a conversion factor of 2.399 for the stern to side trawler catches. Catches in 1982-84 were therefore adjusted downwards by a factor of 2.399 to standardize population estimates. Waldron et al (1984) noted one large catch in the 1982 July survey which appeared anomolous and therefore replaced this catch with the next largest in the stratum and the same procedure was used for this study. March surveys were conducted with a stern trawler using Western IIA gear from 1979-84 and catches have been adjusted downward by the same 2.399 factor.

The arithmetic average of catch at age (000's) for the 1973-84 surveys is given in Tables 1 and 2 for Divisions 4VWX and 4W. The estimated mean number at age ranged from 37 million at age one to 4 million at age 5 for males and females combined in July and from 54 million to 5 million in the March survey. The ratio of males to females in July decreased from 0.98 at age 1 to 0.33 at age five but this trend was not observed in March. The relationship between estimated numbers at age in 4VWX and 4W is shown in Figure 1 and was best described by the lines:

July: Number in 4W = 0.516 (Number in 4VWX) + 1710.8

March: Number in 4W = 0.634 (Number in 4VWX) - 388.4

with a correlation coefficient of 0.86, although considerable variance was associated with the means. Substantial differences between mean numbers at age for the July and March surveys were noted and the linear regressions (Figure 2):

March 4VWX number = 1.548 (July 4VWX number) + 2052.8

March 4W number = 1.896 (July 4W number) - 2185.5

with a correlation coefficient of 0.98 best described the relationship.

Estimates of numbers at age (000's) and the calculated relative index for the 1969-83 yearclasses at ages 1 to 5 are given in Tables 3 and 4 for 4VWX and 4W in July and in Tables 5 and 6 for March. At age 1, population estimates ranged from 49 million for the 1981 yearclass to 2 million for the 1976 yearclass and the relative index from 2.665 to 0.086 for the same yearclasses in July. Similar ranges were observed in Division 4W and for other age groups. In March, population estimates ranged from 78 million to 6 million for the 1983 and 1979 yearclasses, respectively. The relative index for a yearclass at a specific age was similar for males and females and this is shown for age two in Figure 3. The relationship for July surveys was best described by the line:

Number of males = 0.76 (Number of females) - 0.012

with a correlation coefficient of 0.93 and indicates a trend for the number of females to exceed the number of males. The ratio of males to females in July, by age and yearclass, is given in Table 7 and shows a decline from about 1 at age one to about 0.25 at age five.

Mean length at age in July for males and females, by yearclass, for ages 1-5 are given in Table 7. Mean length at age one ranged from 16.7 to 20.9cm for both sexes but showed a steady divergence between males and females after age one. Growth curves for males and females using mean length at age for the 1969-83 yearclasses and range bars for each age are given in Figure 4.

The July average of male and female relative abundance indices for ages 1-3 and for the mean of ages 1 and 2, 2 and 3 and for ages 1-5 for the 1972-83 yearclasses are given in Tables 8 and 9 for Divisions 4VWX and 4W. At age 1, the average index ranged from 2.467 for the 1983 yearclass to 0.085 for the 1976 yearclass. Similar trends were apparent for other age groups and these trends were consistent for both 4VWX and 4W. However, the relative index for a yearclass at different age groups did not appear to be consistent. For example, the index at age one was 1.855, at age two 1.157 and 0.093 at age 3 for the 1972 yearclass while it was 0.085, 0.266 and 1.385 for the same age groups in the 1976 yearclass. The variation in relative abundance for each age by yearclass is shown in Figures 5 and 6 for Divisions 4VWX and 4W. Scatter diagrams relating the age one index to the age two index and age two to age three are shown in Figure 7 and confirm the lack of correlation between ages. The relation between the average index for ages 1 and 2 and for ages 2 and 3 in Divisions 4VWX and 4W is given in Figure 8 and shows good correlation and a slope of about 1 for both ages. The trend in relative abundance for the same age groups, by area, is shown in Figure 9 and also indicates good correlation between areas. Similar results were obtained for the 1976-83 yearclasses in the March surveys and are shown in Tables 10 and 11. A comparison of indices of relative abundance at ages 1, 2 and 2+3 for the same yearclasses in the March and July surveys is given in Table 12. Scatter diagrams of the index at ages one and two for March and July in Divisions 4VWX and 4W are given in Figure 10 and indicate poor correlation between the two time periods.

The proportion at age for the 1972-83 yearclasses, in successive July surveys, is given in Tables 13 and 14 for Divisions 4VWX and 4W. The mean of the proportion at age ranged from 0.407 at age two to 0.040 at age five and is shown in Figure 11 for ages one to five. The proportion at age one appears to be consistently less than that at age two and older age groups are also less than age two. If the mean at age two is equated to 1.0, this implies that age group one is about 69% recruited to the survey gear and may suggest that the index at age two is more reliable.

The relative proportion of total numbers at age in July derived from Division 4W strata by age and yearclass is given in Table 15 and the average was determined to be about 0.6 of the total population estimate. A slight trend for the older (>2) age groups to be more concentrated in 4W was noted. Variation with yearclass and survey year is shown in Figure 12 and indicates a general trend for more of the population estimate to be derived from Division 4W in the period from 1975-81 with a downward shift since 1982. The 1982 yearclass was poorly represented in Division 4W. March surveys tended to derive more of the total population estimate from Division 4W, as shown in Table 16, but this may be a function of survey coverage. Poor weather conditions in March frequently result in reduced spatial coverage during surveys with a higher emphasis placed on completing strata in Division 4W.

A matrix of correlation coefficients for various indices of abundance for research survey results and for results of sequential population analysis (SPA) (Waldron et al, 1984) is given in Table 17. Several coefficients relating SPA and survey results are above 0.8 but these are strongly influenced by the 1981 yearclass survey result. The July index at age 2 in Division 4W shows good correlation with the SPA estimate of age two numbers (0.821) and the survey number at age one in Divisions 4VWX also shows good correlation (0.815) with SPA numbers at age 2 for the same yearclass. Removal of the 1981 yearclass from the relationship reduces the correlation for these two data sets to 0.2 and 0.5, respectively. The March survey indices for ages 2+3 in Division 4VWX and age one in Division 4W appear to be well correlated with the VPA numbers at age one and two, ranging from 0.822 to 0.958, but removal of the 1981 yearclass from the relationship produces non-significant correlation, ranging from -0.007 to -0.745, and limits application for determining VPA input parameters.

Discussion

Research surveys have been conducted with a standard protocol since 1973 and, for 1982-84, adjustments have been made to the data to ensure a consistent series of observations. Note must be made that these surveys were not designed on a species-specific basis but are rather a general survey to estimate the abundance of most groundfish species with emphasis on cod and haddock. Koeller (1981) suggests that the diel vertical migration of juvenile silver hake and the relatively low opening of the sampling gear may reduce catchability for silver hake. He also reports (1984) that surveys conducted for 0-group silver hake were confined to periods of darkness to optimize availability to a juvenile sampling trawl. However, a good correlation between the estimate of 0-group numbers in a juvenile survey and numbers at age one in the July survey was suggested (coefficient of 0.98, excluding the 1982 yearclass). Results of the juvenile survey were also strongly correlated with the 4W relative index of abundance from this study (0.91) including the 1982 yearclass in the analysis. These two independent estimates of yearclass abundance suggest consistency in the July survey as an indicator of stock size at age one.

Estimates of abundance for a yearclass at several ages do not appear to be consistent. Differences in the relative index at ages one, two and three are evident for all yearclasses included in the analysis which could related to mortality, catchability and temporal distribution. Natural mortality of silver hake is assumed to be 0.4 (Waldron, 1984) and there is no evidence to indicate a change in this value over the time series used in this study. However, the effect of fishing mortality has probably changed with implimentation of quotas and specified fishing areas. Introduction of a small mesh gear line (SMGL) in 1977 limited spatial distribution of catches and may have had some effect on the temporal distribution of catches as well. Prior to 1977 catches generally occured over most parts of the Scotian Shelf from spring through autumn but have since changed to the SMGL and most catches are taken in March and April. July research surveys have therefore changed from a mid- to a post-fishery estimate of abundance during the 1973-84 time period. Changes in minimum mesh size used for silver hake may have effected the catch of younger age groups and could have influenced survival at different age groups in a specific yearclass. Partial recruitement of silver hake to the commercial fishery is currently assumed to be 33% at age 2 and 100% at age 3+ and the influence of the fishery on juvenile abundance could be substantial. Reduction in fishing mortality, however, would tend to increase the survival rate and should produce higher estimates of abundance for a yearclass in successive survey years. It is unlikely that changes in catch would result in substantial inter-year difference in survey estimates of relative abundance such as this study found.

Variation in availabilty to survey gear would seem to offer a better explaination of inter-year differences in estimates of relative indices of yearclass abundance. Spawning of silver hake occurs from June through September and is thought to peak in July and aggregation of spawning fish is probably variable from year to year. This would be expected to have some impact on catch rates for surveys and influence the estimate of abundance of a yearclass at different ages. Recruitement of age one fish to the survey gear appears to be variable from year to year and it is likely the age two fish are not fully recruited to the spawning population. Both of these factors could have some year to year effect on catch rates. Temperature is another variable factor and Waldron (1984) noted the cold water front in 1982 which may have contained fish in a small area and resulted in anomalous commercial catch rates for that year. Similar impact on research survey catch rates could be expected. Variation in the spatial distribution of silver hake is also apparent from the proportion of total population estimate derived from Division 4W at successive ages in a yearclass.

The relationship between abundance estimates for the July and March surveys for the 1976-83 yearclasses apears to be well correlated and, for example, the index at age one in 4W has a correlation co-efficent of 0.977. However, in all cases the relationship between the two estimates is strongly influenced by the by the 1981 yearclass.

In summary, evidence presented in this study suggests that research survey estimates of silver hake abundance are inconsistent from year to year and may have limited application as an independent index for use in resolving input parameters for sequential population analysis.

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Table 1. Average estimates of abundance, by age group, derived from MARCH, 1979-84, and JULY research surveys, 1973-84, in NAFO Divisions 4VWX.

		JULY			MARCH		
Age Group		Mean	Ratio	Variance	Mean	Ratio	Variance
1	male	18411		16267	28178		23395
	female	18844		16035	25900		22816
	combined	37255	0.98	-	54078	1.088	-
2	male	25030		17827	40154		26640
	female	27088		20809	42916		32471
	combined	52118	0.92	-	83070	0.936	-
3	male	8206		10973	25090		21889
	female	17457		20448	24527		21941
	combined	25663	0.47	-	49617	1.023	-
4	male	2743		2810	7792		6047
	female	5687		5324	7137		5279
	combined	8430	0.48	-	14929	1.092	-
5	male	909		1060	1961		1406
	female	2764		1543	3272		1661
	combined	3673	0.33	-	5333	0.599	-

Table 2. Average estimates of abundance, by age group, derived from MARCH, 1979-84, and JULY research surveys, 1973-84, in NAFO Division 4W.

		JULY			MARCH		
Age Group		Mean	Ratio	Variance	Mean	Ratio	Variance
1	male	9284		11546	7550		6771
	female	9973		11573	6772		7726
	combined	19257	0.93	-	14322	1.115	14550
2	male	13568		10796	28837		22349
	female	15099		11763	30101		30368
	combined	28667	0.90	-	58938	0.958	53896
3	male	4499		5377	20472		16898
	female	12803		15349	20202		17584
	combined	17302	0.35	-	40674	1.013	-
4	male	1966		2821	6852		5390
	female	4181		4892	5124		4763
	combined	6147	0.47	-	11976	1.337	-
5	male	734		1009	1438		1568
	female	2016		1396	2268		2230
	combined	2750	0.36	-	3706	0.634	-

Table 3. Comparison of research survey estimates of abundance (thousands) of male and female silver hake by age group. Parameters observed are: a- number of males, b- relative abundance of males, c- number of females, d- relative abundance of females, for 1969-83 yearclasses. Relative abundance is the number at age divided by the mean number at age for 1973-84 JULY surveys, in NAFO Divisions 4VWX.

Year Class		Age 1	Age 2	Age 3	Age 4	Age 5	+Year +Class	Age 1	Age 2	Age 3	Age 4	Age 5
	a	-	-	-	2710	108		-	-	1794	31	-
	b	-	-	-	0.988	0.119		-	-	0.219	0.011	-
'69	c	-	-	-	4667	1624	'70	-	-	7086	1720	766
	d	-	-	-	0.477	0.588		-	-	0.406	0.302	0.277
	a	-	57014	2707	188	148		32567	41975	515	2509	-
	b	-	3.026	0.330	0.069	0.163		1.769	2.227	0.063	0.915	-
'71	c	-	73631	11316	1303	1913	'72	36548	56526	2138	3252	743
	d	-	2.718	0.648	0.229	0.692		1.940	2.087	0.122	0.572	0.269
	a	11297	6331	1739	401	570		8606	29347	3029	920	1713
	b	0.614	0.336	0.212	0.146	0.627		0.467	1.557	0.369	0.335	1.884
'73	c	19304	10358	5283	1754	2838	'74	8950	25669	7549	3563	4184
	d	1.024	0.382	0.303	0.308	1.027		0.475	0.948	0.432	0.627	1.514
	a	10601	7451	3244	2714	643		1592	5036	10600	1699	3245
	b	0.576	0.395	0.395	0.989	0.707		0.086	0.267	1.292	0.619	3.570
'75	c	11421	7036	4897	7287	1528	'76	1557	7180	25806	2490	5204
	d	0.606	0.260	0.281	1.281	0.553		0.083	0.265	1.478	0.438	1.883
	a	6180	41520	5788	9883	454		17274	4912	19667	2233	841
	b	0.336	2.203	0.705	3.603	0.499		0.938	0.261	2.397	0.814	0.925
'77	c	6391	33860	8914	19455	4338	'78	14987	6231	48863	4410	3972
	d	0.339	1.250	0.511	3.421	1.569		0.795	0.230	2.799	0.775	1.437
	a	3201	21282	2205	3544	2276		7984	43470	8615	6081	-
	b	0.174	1.129	0.269	1.292	2.504		0.434	2.307	1.050	2.217	-
'79	c	4026	22627	7981	5889	3296	'80	8373	35264	11583	12459	-
	d	0.214	0.835	0.452	1.036	1.192		0.444	1.302	0.664	2.191	-
	a	49071	25787	38563	-	-		27605	16231	-	-	-
	b	2.665	1.368	4.699	-	-		1.499	0.861	-	-	-
'81	c	46571	28554	68073	-	-	'82	21054	18120	-	-	-
	d	2.471	1.054	3.899	-	-		1.117	0.669	-	-	-
	a	44950	-	-	-	-						
	b	2.441	-	-	-	-						
'83	c	46951	-	-	-	-						
	d	2.492	-	-	-	-						

Table 4. Comparison of research survey estimates of abundance (thousands) of male and female silver hake by age group. Parameters observed are: a- number of males, b- relative abundance of males, c- number of females, d- relative abundance of females, for 1969-83 yearclasses. Relative abundance is the number at age divided by the mean number at age for 1973-84 JULY surveys, in NAFO Division 4W.

Year Class		Age 1	Age 2	Age 3	Age 4	Age 5	+Year +Class	Age 1	Age 2	Age 3	Age 4	Age 5
	a	-	-	-	80	108		-	-	220	-	-
	b	-	-	-	0.041	0.147		-	-	0.049	-	-
'69	c	-	-	-	929	1582	'70	-	-	2219	1679	283
	d	-	-	-	0.222	0.785		-	-	0.173	0.402	0.140
	a	-	7593	2595	162	-		13226	28089	345	530	-
	b	-	0.560	0.577	0.082	-		1.425	2.070	0.077	0.270	-
'71	c	-	23715	7990	400	547	'72	13876	39825	489	1297	287
	d	-	1.571	0.624	0.096	0.271		1.391	2.638	0.038	0.310	0.142
	a	7617	702	994	170	519		3308	22891	1736	708	478
	b	0.820	0.052	0.221	0.086	0.707		0.732	0.793	0.330	0.083	0.010
'73	c	15817	1969	2634	454	1952	'74	2023	14352	3029	2769	2422
	d	1.586	0.130	0.035	0.109	0.968		0.203	0.951	0.237	0.662	1.201
	a	4462	2898	2704	1618	596		457	2575	8660	1433	3102
	b	0.481	0.214	0.601	0.823	0.812		0.049	0.190	1.925	0.729	4.226
'75	c	4304	4064	4041	5652	1184	'76	408	2655	22192	2153	4372
	d	0.432	0.269	0.316	1.352	0.587		0.041	0.176	1.733	0.515	2.169
	a	1991	32724	5378	9509	391		3950	3562	19029	992	626
	b	0.214	2.412	1.195	4.837	0.533		0.425	0.263	4.230	0.505	0.853
'77	c	1882	25683	8126	17502	3791	'78	4390	4401	45345	3404	3100
	d	0.189	1.701	0.635	4.186	1.880		0.440	0.291	3.542	0.814	1.538
	a	2248	19450	1054	3236	2253		5975	15803	8089	5148	-
	b	0.242	1.434	0.234	1.646	3.069		0.644	1.165	1.798	2.619	-
'79	c	2883	20776	6370	4963	2652	'80	6808	22120	9936	8971	-
	d	0.289	1.376	0.498	1.187	1.315		0.683	1.465	0.776	2.146	-
	a	31824	17816	3188	-	-		2313	8710	-	-	-
	b	3.428	1.313	0.709	-	-		0.249	0.642	-	-	-
'81	c	31360	15405	41268	-	-	'82	2228	6227	-	-	-
	d	3.144	1.020	3.223	-	-		0.223	0.412	-	-	-
	a	34033	-	-	-	-						
	b	3.666	-	-	-	-						
'83	c	33694	-	-	-	-						
	d	3.379	-	-	-	-						

Table 5. Comparison of research survey estimates of abundance (thousands) of male and female silver hake by age group. Parameters observed are: a- number of males, b- relative abundance of males, c- number of females, d- relative abundance of females, for 1974-83 year-classes. Relative abundance is the number at age divided by the mean number at age for 1979-84 MARCH surveys, in NAFO Divisions 4VWX.

Year Class		Age 1	Age 2	Age 3	Age 4	Age 5	+Year +Class	Age 1	Age 2	Age 3	Age 4	Age 5
	a	-	-	-	-	769		-	-	-	1645	1863
	b	-	-	-	-	0.392		-	-	-	0.211	0.950
'74	c	-	-	-	-	1967	'75	-	-	-	2625	3332
	d	-	-	-	-	0.601		-	-	-	0.368	1.018
	a	-	-	3566	3441	926		-	20030	8549	6582	4438
	b	-	-	0.142	0.442	0.472		-	0.499	0.341	0.845	2.263
'76	c	-	-	6146	4831	1204	'77	-	22530	11594	2610	5993
	d	-	-	0.251	0.677	0.368		-	0.525	0.473	0.366	1.832
	a	57715	26830	36490	17079	1102		2379	28884	32332	4792	2670
	b	2.048	0.668	1.454	2.192	0.562		0.084	0.719	1.289	0.615	1.362
'78	c	57596	24338	32401	10389	3228	'79	1875	28193	21838	6194	3909
	d	2.224	0.567	1.321	1.456	0.987		0.072	0.657	0.890	0.868	1.195
	a	8479	81591	9428	13212	-		16996	65422	60177	-	-
	b	0.301	2.032	0.376	1.696	-		0.603	1.629	2.398	-	-
'80	c	5444	91197	10286	16175	-	'81	21572	76832	64899	-	-
	d	0.210	2.125	0.419	2.266	-		0.833	1.790	2.646	-	-
	a	54342	18167	-	-	-		29154	-	-	-	-
	b	1.929	0.452	-	-	-		1.035	-	-	-	-
'82	c	49245	14404	-	-	-	'83	19665	-	-	-	-
	d	1.901	0.336	-	-	-		0.759	-	-	-	-

Table 6. Comparison of research survey estimates of abundance (thousands) of male and female silver hake by age group. Parameters observed are: a- number of males, b- relative abundance of males, c- number of females, d- relative abundance of females, for 1974-83 year-classes. Relative abundance is the number at age divided by the mean number at age for 1979-84 MARCH surveys, in NAFO Division 4W.

Year Class		Age 1	Age 2	Age 3	Age 4	Age 5	+Year +Class	Age 1	Age 2	Age 3	Age 4	Age 5
	a	-	-	-	-	227		-	-	-	1186	1487
	b	-	-	-	-	0.158		-	-	-	0.173	1.034
'74	c	-	-	-	-	370	'75	-	-	-	916	2376
	d	-	-	-	-	0.163		-	-	-	0.179	1.048
	a	-	-	1978	2799	697		-	12334	6619	5732	3956
	b	-	-	0.097	0.408	0.485		-	0.428	0.323	0.837	2.751
'76	c	-	-	3344	3860	986	'77	-	13087	8580	2183	5654
	d	-	-	0.166	0.753	0.435		-	0.417	0.425	0.426	2.493
	a	1681	16450	28372	16786	482		864	18702	30642	3178	1781
	b	0.223	0.570	1.386	2.450	0.335		0.114	0.649	1.497	0.464	1.239
'78	c	1604	16245	27056	9747	1627	'79	658	20206	20118	4339	2591
	d	0.239	0.518	1.339	1.902	0.717		0.098	0.644	0.996	0.847	1.142
	a	3514	75428	6210	11429	-		14462	38323	49005	-	-
	b	0.465	2.616	0.303	1.668	-		1.915	1.329	2.394	-	-
'80	c	1792	85195	6959	12722	-	'81	19857	44863	55153	-	-
	d	0.267	2.716	0.344	2.483	-		2.954	1.430	2.730	-	-
	a	6143	11786	-	-	-		18636	-	-	-	-
	b	0.814	0.409	-	-	-		2.468	-	-	-	-
'82	c	4072	8640	-	-	-	'83	12348	-	-	-	-
	d	0.606	0.275	-	-	-		1.837	-	-	-	-

Table 7. Comparison of research survey estimates of mean length at age (cm) of male and female silver hake by age group. Parameters observed are: a- length of males, b- length of females, c- ratio number of males to females, for 1973-84 JULY surveys in NAFO Divisions 4VWX.

Year Class		Age 1	Age 2	Age 3	Age 4	Age 5	+Year +Class		Age 1	Age 2	Age 3	Age 4	Age 5
	a	-	-	-	-	-			-	-	30.5	-	-
'69	b	-	-	-	-	-	'70		-	-	32.8	-	39.4
	c	-	-	-	0.58	0.07			-	-	0.25	0.02	0.00
	a	-	27.4	-	30.0	-			19.9	27.9	31.3	-	-
'71	b	-	28.7	-	35.1	-	'72		19.8	29.3	33.8	-	-
	c	-	0.77	0.24	0.14	0.08			0.89	0.74	0.24	0.77	0.00
	a	20.0	29.0	-	32.7	32.6			20.9	-	31.9	-	-
'73	b	20.5	30.6	-	35.9	37.3	'74		20.9	-	33.0	35.4	39.2
	c	0.59	0.61	0.33	0.23	0.20			0.96	1.14	0.40	0.26	0.41
	a	-	27.3	30.3	32.5	32.7			17.4	26.3	29.0	30.9	-
'75	b	-	28.7	31.6	34.9	38.5	'76		16.7	27.3	31.6	33.6	36.6
	c	0.93	1.06	0.66	0.37	0.42			1.02	0.70	0.41	0.68	0.62
	a	16.7	27.8	30.0	31.1	33.8			19.6	26.2	29.3	31.6	33.0
'77	b	18.3	28.9	32.0	34.0	36.4	'78		18.5	26.6	31.6	34.6	37.4
	c	0.97	1.23	0.65	0.51	0.10			1.15	0.79	0.40	0.51	0.21
	a	17.2	27.9	30.6	31.9	32.3			18.3	26.9	30.3	31.0	-
'79	b	17.2	27.8	32.6	34.8	36.2	'80		17.6	28.4	32.0	33.4	-
	c	0.80	0.94	0.28	0.60	0.69			0.95	1.23	0.74	0.49	-
	a	17.2	25.9	28.9	-	-			18.6	27.2	-	-	-
'81	b	17.2	26.5	30.3	-	-	'82		19.3	28.4	-	-	-
	c	1.05	0.90	0.57	-	-			1.31	0.90	-	-	-
	a	19.4	-	-	-	-		a	18.7	27.3	30.2	31.4	32.9
'83	b	19.5	-	-	-	-	Mean	b	18.7	28.3	32.1	34.6	37.6
	c	0.96	-	-	-	-		c	0.97	0.93	0.43	0.43	0.26
		Range for males							Range for females				
Min		16.7	25.9	28.9	30.0	32.3	Min		16.7	26.5	30.3	33.4	36.2
Max		20.9	29.0	31.9	32.7	33.8	Max		20.9	30.6	33.8	35.9	39.4

Table 8. Indices of relative abundance, by yearclass, of silver hake derived from JULY research surveys, 1973-84. Relative abundance defined as the number at age divided by the mean number at age for 1973-84, in NAFO Divisions 4VWX.

Yearclass	Age Group 1	2	3	Mean 1 + 2	2 + 3	1 - 5
1972	1.855	1.157	0.093	1.506	0.625	0.797
1973	0.819	0.359	0.258	0.589	0.309	0.211
1974	0.471	1.253	0.401	0.862	0.827	0.861
1975	0.591	0.328	0.338	0.460	0.333	0.604
1976	0.085	0.266	1.385	0.176	0.826	0.998
1977	0.338	1.727	0.608	1.033	1.168	1.444
1978	0.867	0.246	2.598	0.557	1.422	1.137
1979	0.194	0.982	0.361	0.588	0.672	0.910
1980	0.439	1.805	0.857	1.122	1.331	-
1981	2.568	1.211	4.299	1.890	2.755	-
1982	1.308	0.765	-	1.037	-	-
1983	2.467	-	-	-	-	-

Table 9. Indices of relative abundance, by yearclass, of silver hake derived from JULY research surveys, 1973-84. Relative abundance defined as the number at age divided by the mean number at age for 1973-84, in NAFO Divisions 4W.

Yearclass	Age Group 1	2	3	Mean 1 + 2	2 + 3	1 - 5
1972	0.773	1.745	0.028	1.259	0.887	0.556
1973	0.665	0.068	0.110	0.367	0.089	0.287
1974	0.153	0.974	0.152	0.564	0.563	0.440
1975	0.251	0.179	0.220	0.215	0.200	0.362
1976	0.025	0.135	0.940	0.080	0.538	0.707
1977	0.111	1.520	0.439	0.816	0.980	1.370
1978	0.238	0.206	1.977	0.222	1.092	1.055
1979	0.146	1.040	0.500	0.593	0.770	1.450
1980	0.365	2.338	1.442	1.352	1.890	-
1981	4.326	2.070	5.813	3.198	3.942	-
1982	0.311	0.935	-	0.623	-	-
1983	4.637	-	-	-	-	-

Table 10. Indices of relative abundance, by yearclass, of silver hake derived from MARCH research surveys, 1979-84. Relative abundance defined as the number at age divided by the mean number at age for 1979-84, in NAFO Divisions 4VWX.

Yearclass	Age Group 1	2	3	Mean 1 + 2	2 + 3	1 - 5
1976	-	-	0.201	-	-	-
1977	-	0.523	0.418	-	0.471	-
1978	2.167	0.629	1.392	1.398	1.011	1.369
1979	0.080	0.684	1.095	0.382	0.890	0.768
1980	0.255	2.070	0.398	1.163	1.234	-
1981	0.707	1.704	2.528	1.206	2.116	-
1982	1.898	0.390	-	1.144	-	-
1983	0.894	-	-	-	-	-

Table 11. Indices of relative abundance, by yearclass, of silver hake derived from MARCH research surveys, 1979-84. Relative abundance defined as the number at age divided by the mean number at age for 1979-84, in NAFO Divisions 4W.

Yearclass	Age Group 1	2	3	Mean 1 + 2	2 + 3	1 - 5
1976	-	-	0.134	-	-	-
1977	-	0.431	0.382	-	0.407	-
1978	0.236	0.555	1.360	0.396	0.958	0.967
1979	0.109	0.644	1.245	0.377	0.945	0.755
1980	0.371	2.657	0.323	1.514	1.490	-
1981	2.401	1.376	2.555	1.889	1.966	-
1982	0.715	0.338	-	0.527	-	-
1983	2.168	-	-	-	-	-

Table 12. Comparison of indices of relative abundance for the 1977-83 year-classes at ages 1, 2 and 2+3 from the MARCH and JULY surveys.

(a) Divisions 4VWX

Yearclass	Age Group 1		2		2+3	
	MARCH	JULY	MARCH	JULY	MARCH	JULY
1977	-	-	0.523	1.727	0.471	1.168
1978	2.167	0.867	0.629	0.246	1.011	1.422
1979	0.080	0.194	0.684	0.982	0.890	0.672
1980	0.255	0.439	2.070	1.805	1.234	1.331
1981	0.707	2.568	1.704	1.211	2.116	2.755
1982	1.898	1.308	0.390	0.765	-	-
1983	0.894	2.467	-	-	-	-

(b) Division 4W

1977	-	-	0.431	1.520	0.407	0.980
1978	0.236	0.238	0.555	0.206	0.958	1.092
1979	0.109	0.146	0.644	1.040	0.945	0.770
1980	0.371	0.365	2.657	2.338	1.490	1.890
1981	2.401	4.326	1.376	2.070	1.966	3.942
1982	0.715	0.311	0.338	0.935	-	-
1983	2.168	4.637	-	-	-	-

Table 13. Relative strength of yearclasses of silver hake derived from JULY research surveys, 1973-84. Index defined as the number at age divided by the sum of the number at ages 1-5 in each survey, in NAFO Divisions 4VWX.

Yearclass	Age Group 1	2	3	4	5
1972	0.314	0.687	0.062	0.063	0.020
1973	0.207	0.423	0.075	0.063	0.075
1974	0.466	0.601	0.324	0.101	0.036
1975	0.240	0.487	0.201	0.061	0.053
1976	0.106	0.303	0.222	0.106	0.051
1977	0.322	0.478	0.370	0.173	0.025
1978	0.204	0.286	0.392	0.034	0.035
1979	0.186	0.280	0.052	0.068	0.022
1980	0.105	0.402	0.147	0.070	-
1981	0.488	0.395	0.407	-	-
1982	0.356	0.136	-	-	-
1983	0.367	-	-	-	-
Mean	0.279	0.407	0.225	0.082	0.040

Table 14. Relative strength of yearclasses of silver hake derived from JULY research surveys, 1973-84. Index defined as the number at age divided by the sum of the number at ages 1-5 in each survey, in NAFO Division 4W.

Yearclass	Age Group 1	2	3	4	5
1972	0.480	0.663	0.086	0.037	0.018
1973	0.217	0.268	0.074	0.044	0.104
1974	0.562	0.707	0.349	0.146	0.025
1975	0.171	0.522	0.311	0.064	0.054
1976	0.069	0.252	0.276	0.112	0.050
1977	0.188	0.558	0.420	0.176	0.033
1978	0.078	0.253	0.406	0.036	0.054
1979	0.169	0.280	0.058	0.120	0.028
1980	0.089	0.323	0.267	0.080	-
1981	0.552	0.494	0.417	-	-
1982	0.068	0.087	-	-	-
1983	0.389	-	-	-	-
Mean	0.253	0.401	0.266	0.091	0.046

Table 15. Relative proportion of silver hake population numbers esimated for NAFO Division 4W compared to the total for Divisions 4VWX by age group for 1973-84 JULY research surveys.

Yearclass	Age Group 1	2	3	4	5	Mean	Survey Year
1969	-	-	-	0.137	0.976	0.557	-
1970	-	-	0.275	0.959	0.369	0.534	-
1971	-	0.240	0.755	0.377	0.265	0.409	-
1972	0.392	0.689	0.314	0.317	0.386	0.420	-
1973	0.766	0.160	0.517	0.290	0.725	0.492	0.261
1974	0.304	0.677	0.450	0.776	0.492	0.540	0.829
1975	0.398	0.481	0.827	0.727	0.820	0.651	0.305
1976	0.275	0.428	0.847	0.856	0.885	0.658	0.435
1977	0.308	0.775	0.919	0.921	0.867	0.758	0.376
1978	0.259	0.715	0.939	0.662	0.774	0.670	0.613
1979	0.710	0.916	0.729	0.869	0.880	0.821	0.620
1980	0.782	0.482	0.892	0.762	-	0.730	0.804
1981	0.661	0.611	0.686	-	-	0.653	0.889
1982	0.093	0.435	-	-	-	0.264	0.680
1983	0.737	-	-	-	-	0.737	0.648
1984	-	-	-	-	-	-	0.700
Mean	0.474	0.551	0.679	0.638	0.676	0.604	0.597

Table 16. Relative proportion of silver hake population numbers esimated for NAFO Division 4W compared to the total for Divisions 4VWX by age group for 1979-84 MARCH research surveys.

	Age Group						
Yearclass	1	2	3	4	5	Mean	Survey Year
1975	-	-	-	0.492	0.744	0.618	-
1976	-	-	0.548	0.805	0.790	0.714	-
1977	-	0.597	0.755	0.861	0.921	0.784	-
1978	0.028	0.639	0.805	0.966	0.487	0.585	-
1979	0.358	0.667	0.937	0.684	0.665	0.662	0.210
1980	0.381	0.930	0.668	0.822	-	0.700	0.673
1981	0.890	0.585	0.833	-	-	0.769	0.722
1982	0.099	0.627	-	-	-	0.363	0.929
1983	0.635	-	-	-	-	0.635	0.414
1984	-	-	-	-	-	-	0.759
Mean	0.547	0.674	0.758	0.772	0.721	0.648	0.618

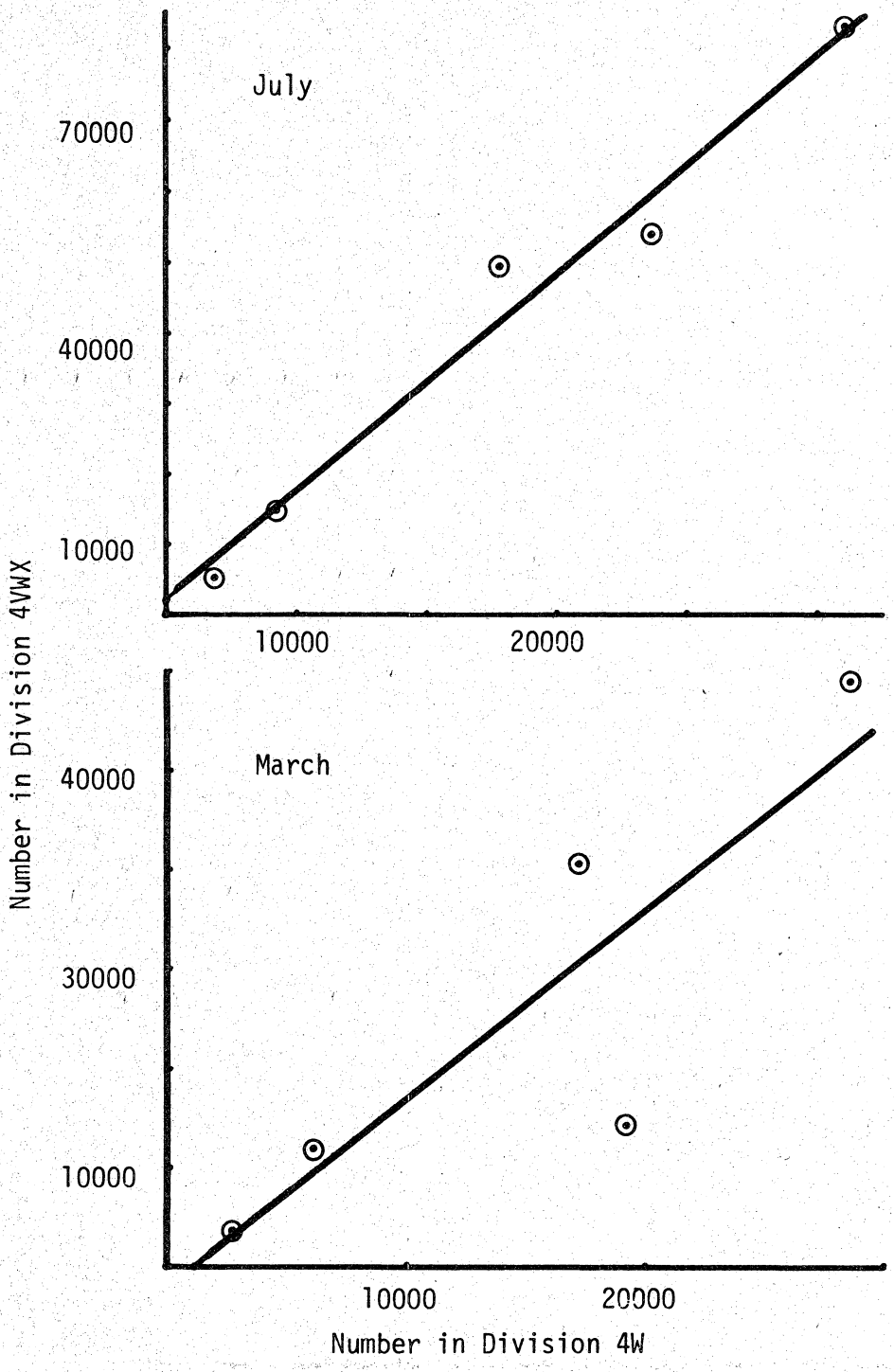

Figure 1. Regression of mean number at age in Divisions 4VWX and 4W for the March and July research surveys

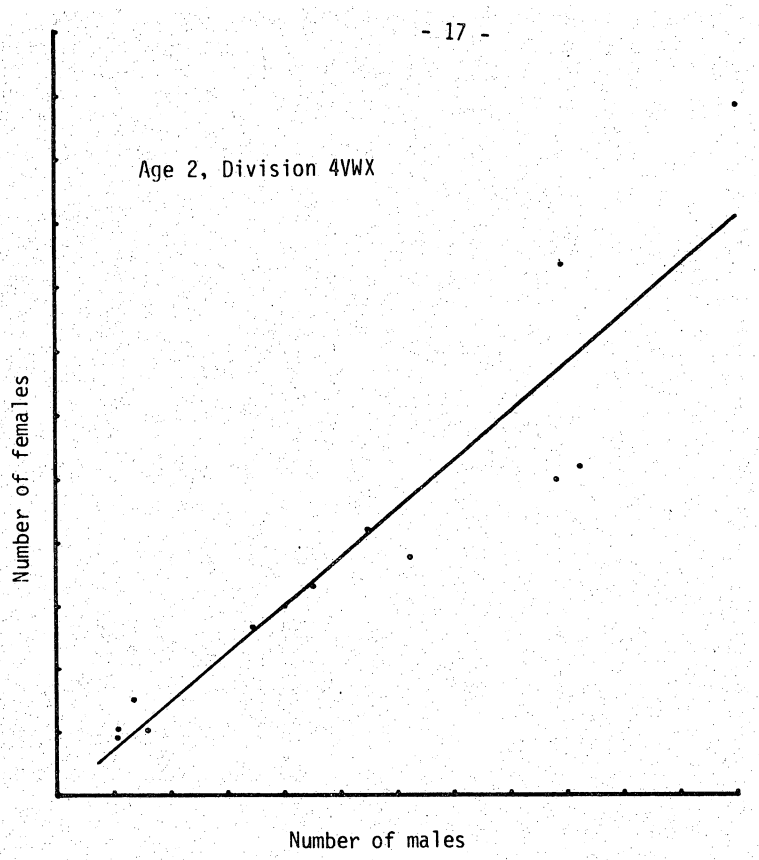

Figure 3. Regression of the number of males on the number of females at age 2 for the 1972-82 yearclasses in July, Divisions 4VWX.

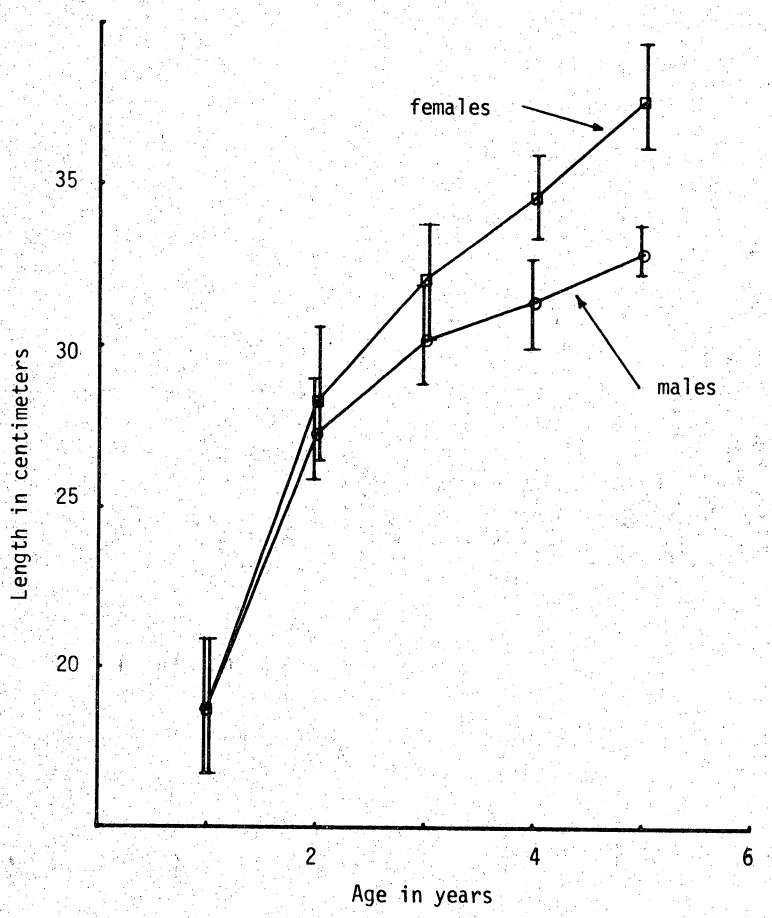

Figure 4. Mean length at ages 1-5 from July research surveys in Divisions 4VWX. Range in length shown by vertical bars.

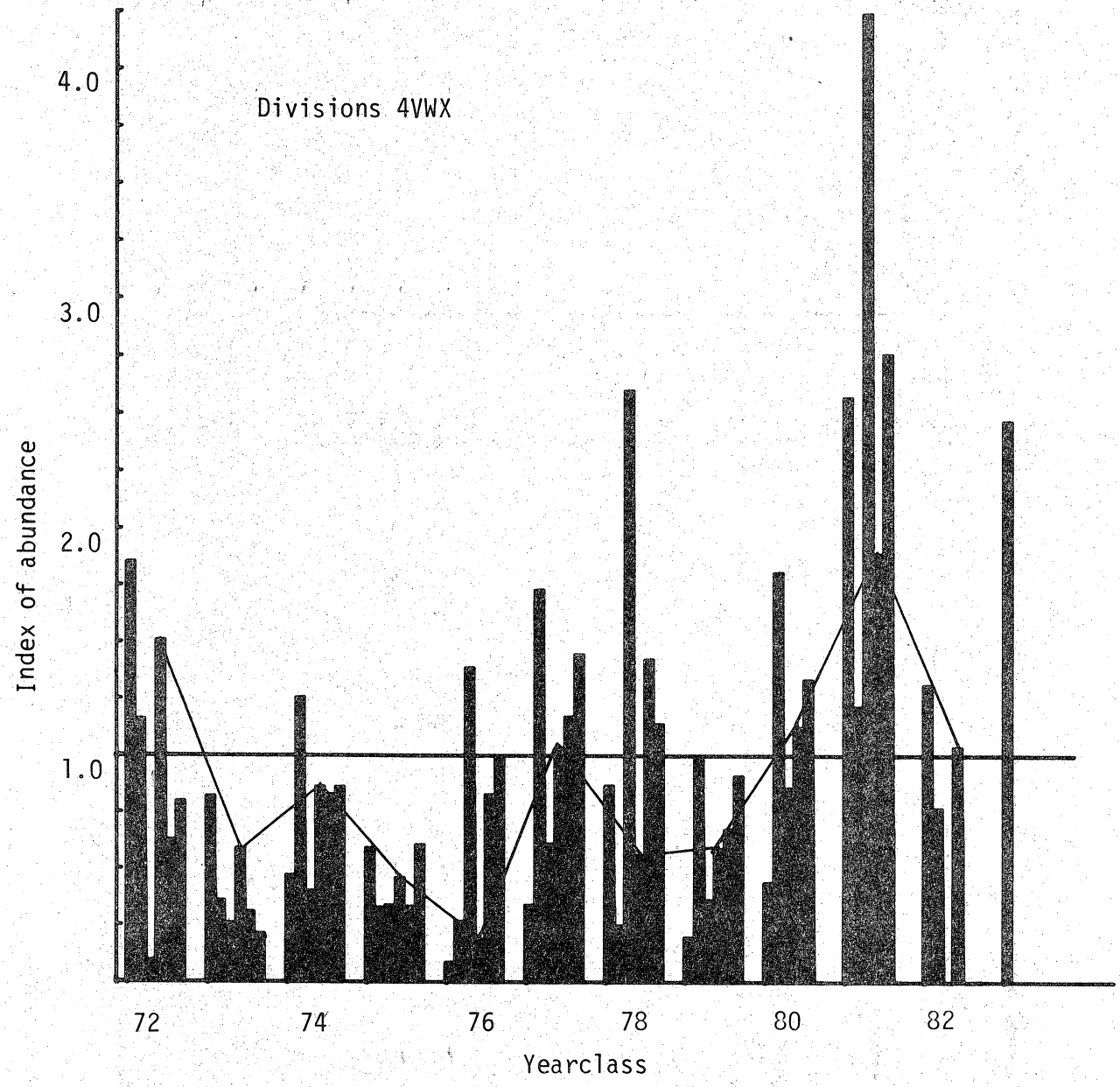

Figure 5. Indices of abundance for the 1972-83 yearclasses at ages 1, 2, 3, 1+2, 2+3 and 1-5 from the July research surveys, Divisions 4VWX.

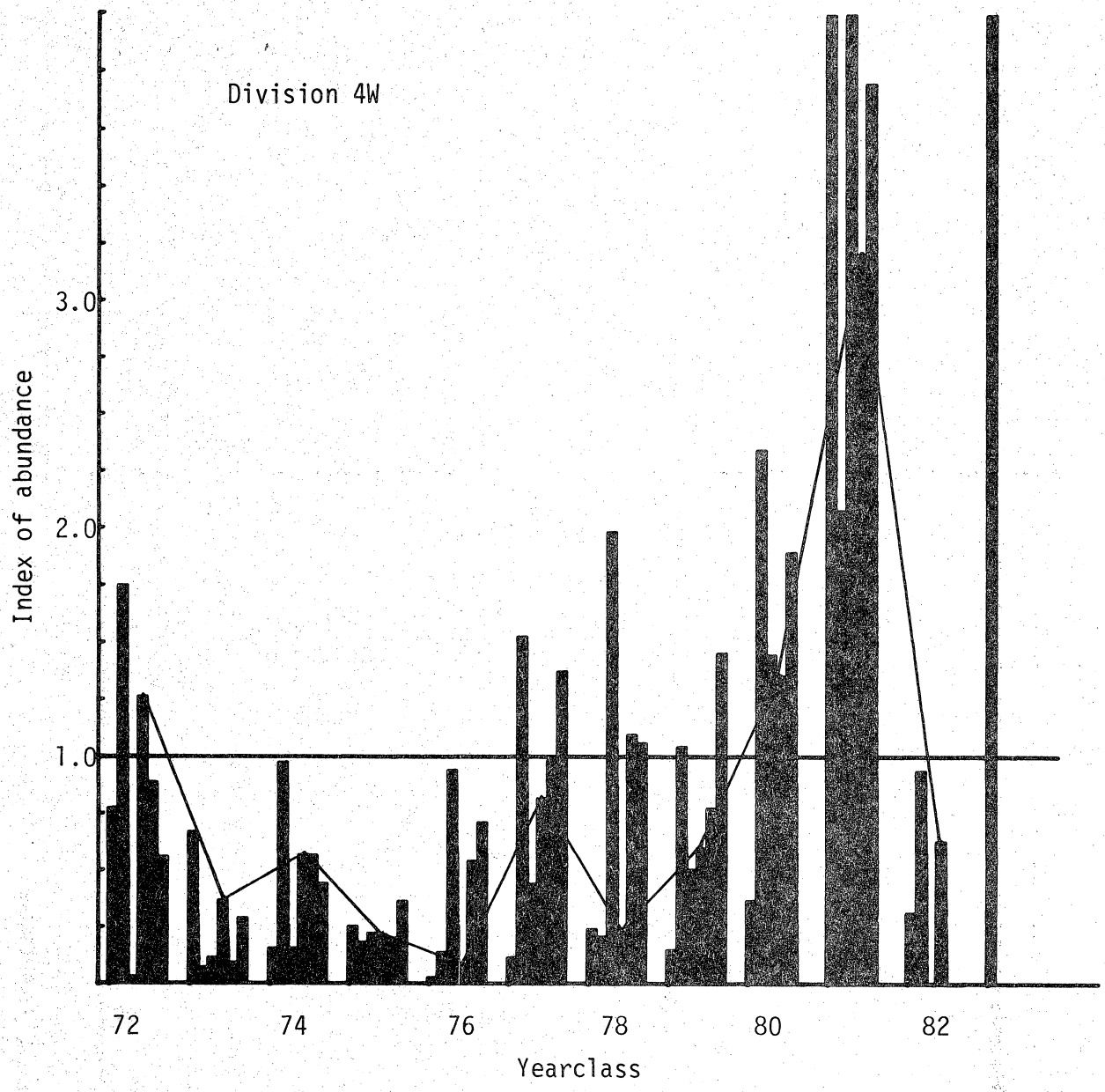

Figure 6. Indices of abundance for the 1972-83 yearclasses at ages 1, 2, 3, 1+2, 2+3 and 1-5 from the July research surveys, Division 4W.

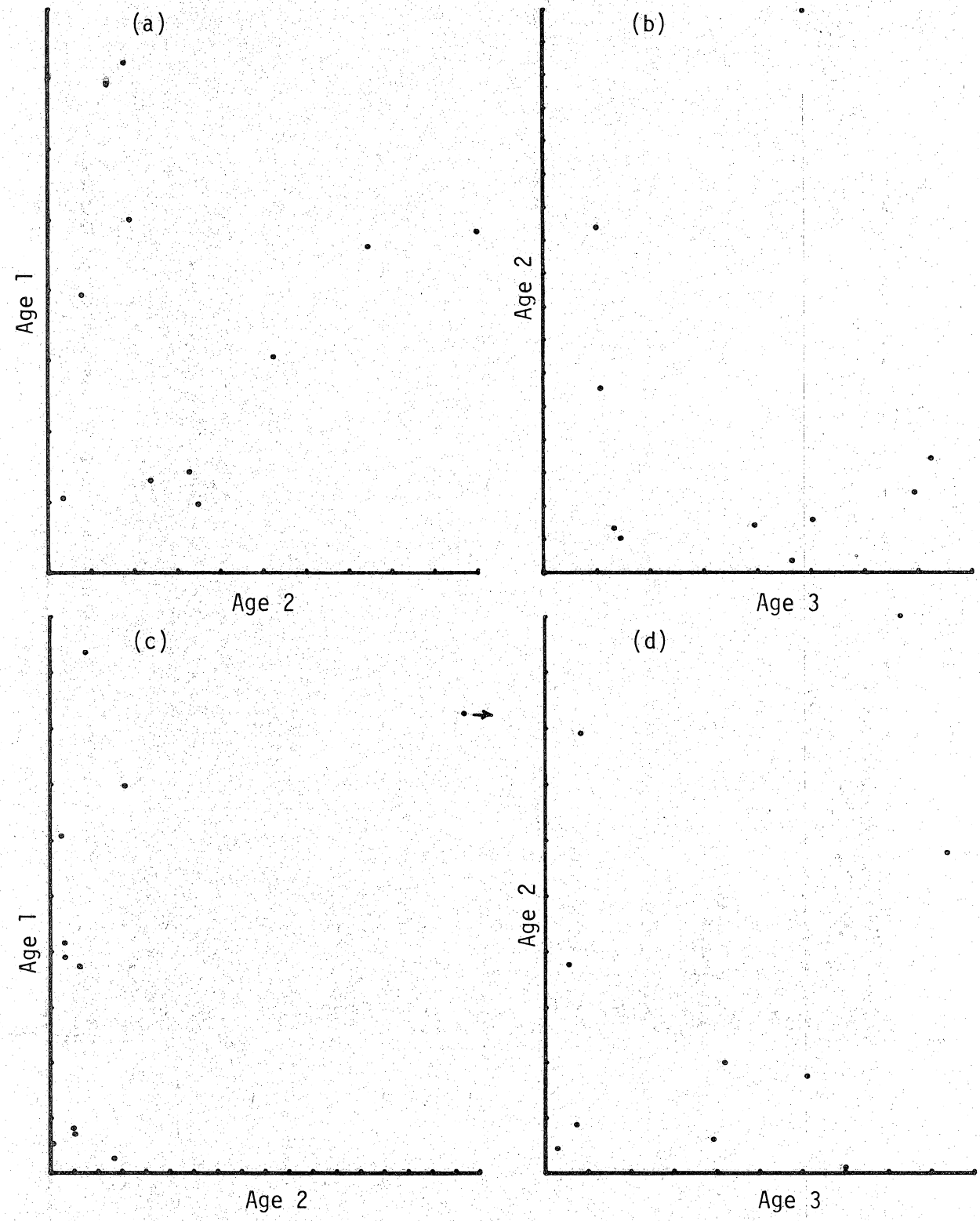

Figure. 7. Comparison of July indices of abundance for the 1972-83 yearclasses in (a) Divisions 4VWX age 1 vs. 2; (b) Divisions 4VWX age 2 vs. 3; (c) Division 4W age 1 vs. 2; (d) Division 4W age 2 vs. 3

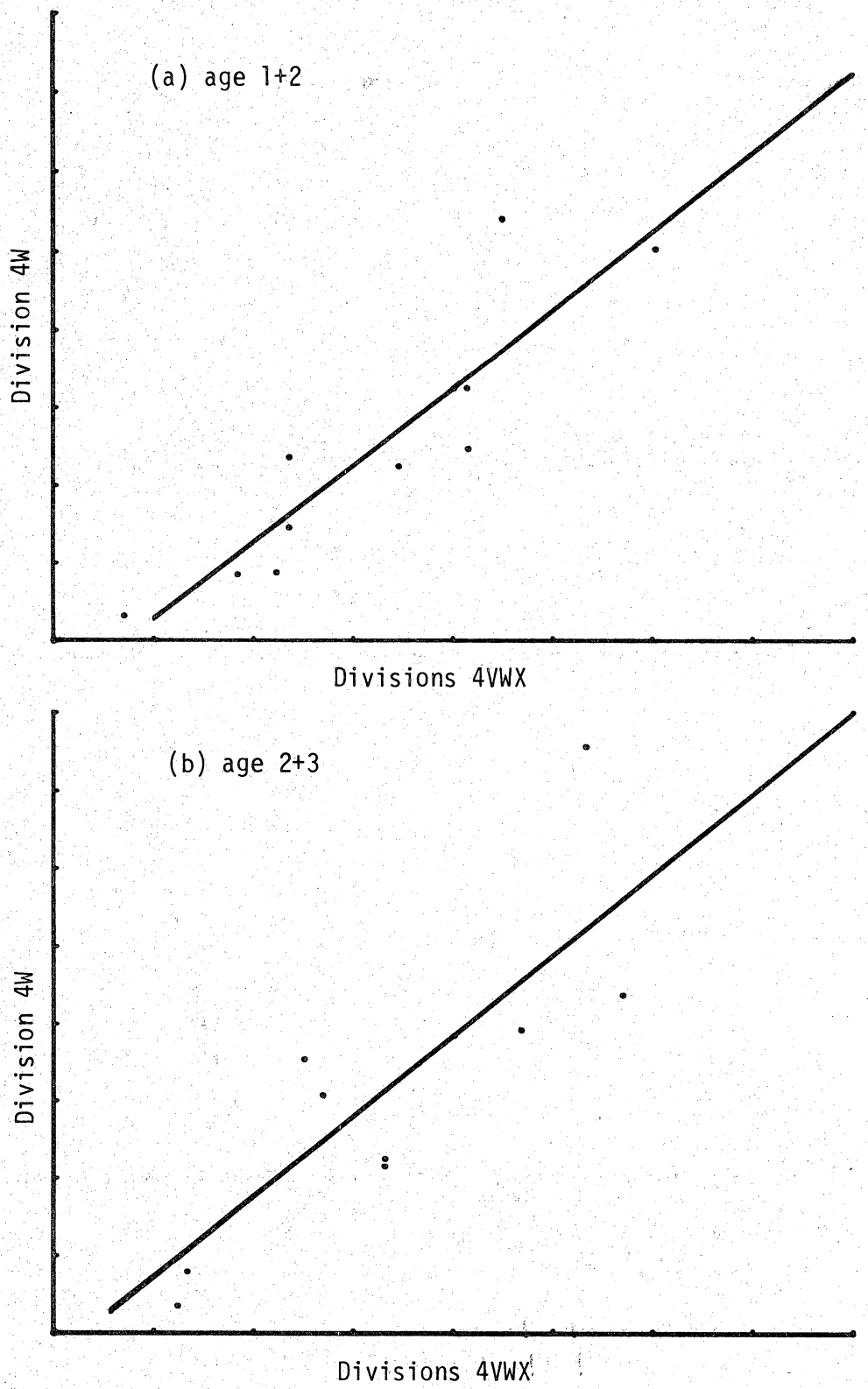

Figure 8. Regression of July index of abundance in Division 4VWX on Division 4W for ages (a) 1+2 and (b) 2+3

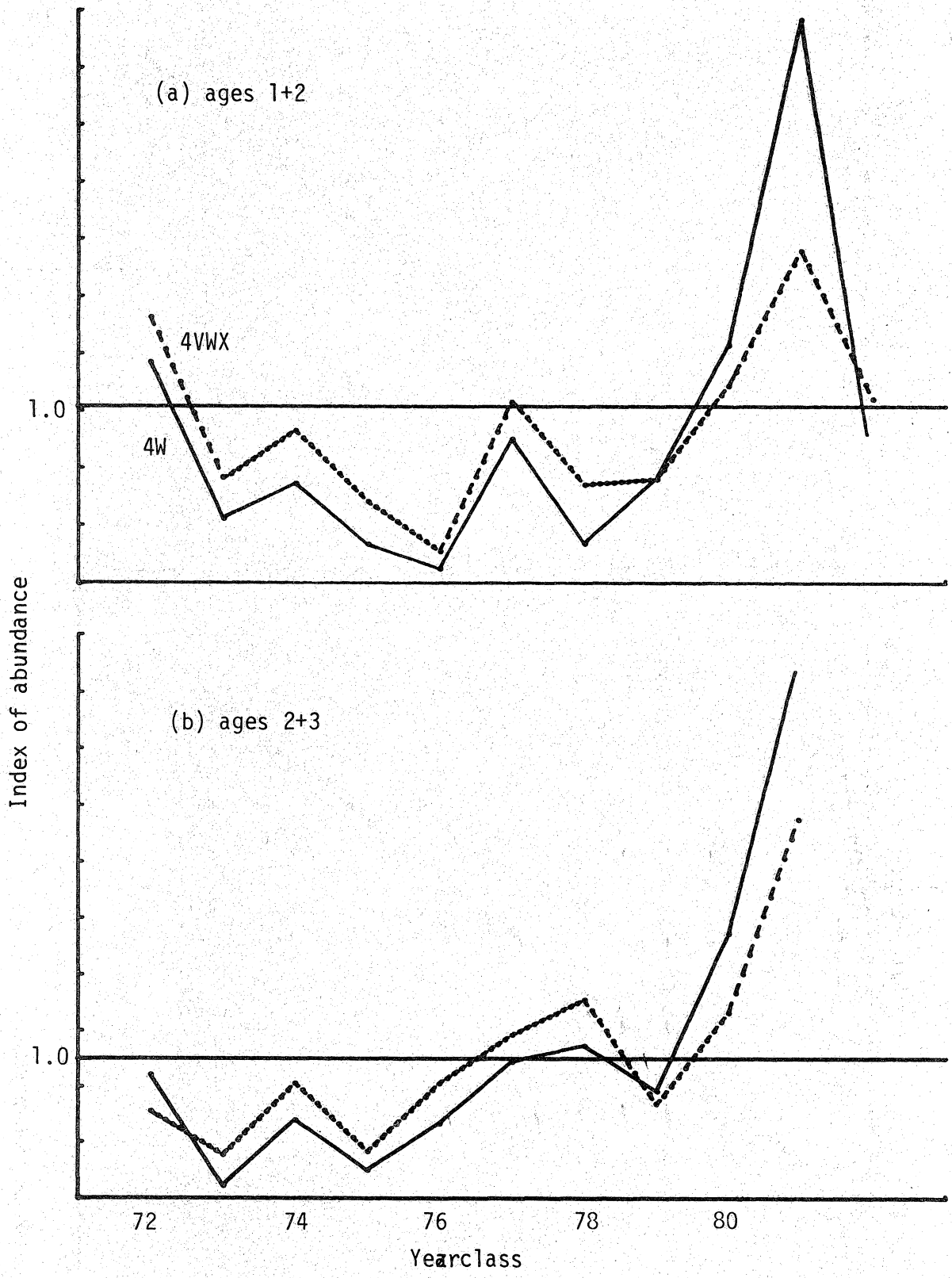

Figure 9. Comparison of July indices of abundance at ages (a) 1+2 and (b) 2+3 for the 1972-83 yearclasses in Divisions 4VWX and 4W.

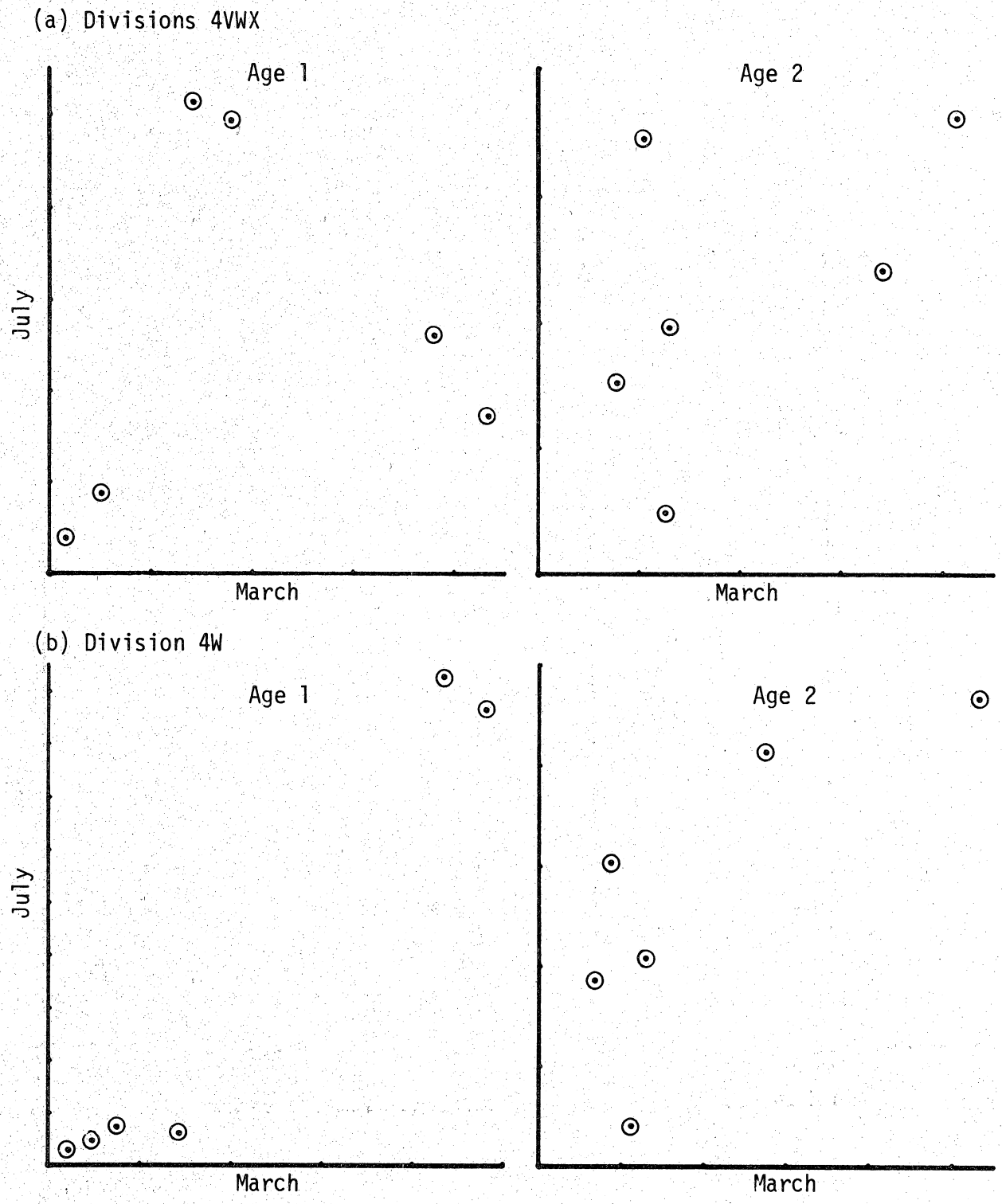

Figure 10. Comparison of March and July indices of abundance at ages 1 and 2 for the 1976-83 yearclasses in (a) Divisions 4VWX and (b) Division 4W

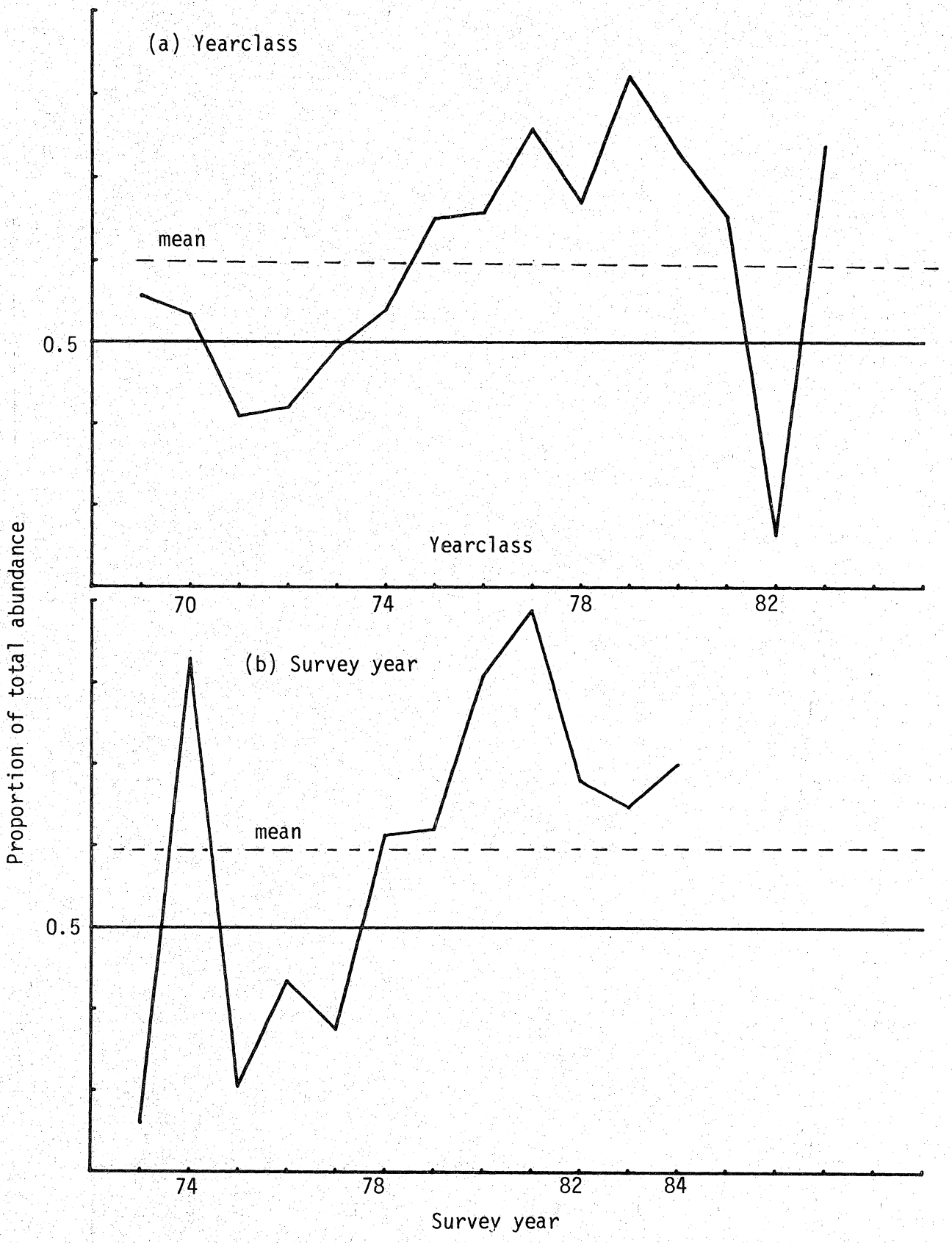

Figure 12. Comparison of the proportion of the total abundance derived from Division 4W for (a) 1972-83 yearclasses and (b) 1973-84 survey years, in July.