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A New Interpretation of the Age-at-length Key for Shrimp (*Pandalus borealis*) in the Disko Area (Disko Bay and Vaigat) in West Greenland (NAFO Subarea 1).

by

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INTRODUCTION

Interpretation of age at length for the shrimp stock in the Disko Bay and Vaigat areas has since the introduction of annual stratified-random trawl surveys in 1991 been based on the age-length structure established by Savard et al. (1994) for shrimp in the Davis Strait, derived by modal analysis of shrimp samples from 1982 to 1987. Survey samples from the Disko area have showed similar modes as found in the offshore surveys from 1988 to 1997 (Carlsson and Kanneworff, 1997a), and shrimp in the two areas have been considered to belong to the same stock and have been assessed as such. (NAFO, 1994).

The progression from 1996 to 1997 of a distinct and significant mode of males in survey samples from the Disko area indicated, that the old interpretation is not applicable in this area, even though reasonable results have been obtained by the use of it in recent years. Therefore, survey samples from the Disko area from 1995 to 1997 were reanalysed by modal analysis, and a new age-at-length structure has been derived, indicating that shrimp change sex from males to females at age 6 rather than at age 7. The new interpretation also shows distinct van Bertalanffy growth.

MATERIAL AND METHODS

Overall length frequency distribution by stratum and by total area were calculated by combining length distributions of survey samples weighted by catch and stratum area (Carlsson et al, 1995; Folmer et al, 1996; Carlsson and Kannworff, 1997b). The combined distributions were examined for male modes by visual inspection, and the results were applied in modal analysis of the male components using the MIX program (Macdonald and Pitcher, 1979). In total 30 length frequency distributions were examined (nine combined strata distributions and one total distribution per year from 1995 to 1997).

The MIX runs were performed with a fixed coefficient of correlation, using values that seemed most applicable, but otherwise no constraints were used in most final runs. The best fit was judged from inspection of mean errors of

proportions and means, and from the plot of cohorts in relation to the original dsitribution, while little emphasis was put on Chi-square values, which were only used as guidelines.

In several cases the final fit was examined by a run with introduced van Bertalanffy growth, and results were in good agreement with the first obtained results.

RESULTS AND DISCUSSION

Visual inspection of combined strata distributions and total distributions strongly indicated 5 group of males (Table 1). Modes were identified in the intervals 8-9, 11.5-13.5, 16.5-17.5, 19-21.5, and 22-24.5 mm CL, however some of the groups of smaller males were absent or only indicated in a number of distributions, and they were removed before MIX analysis of those samples to reduce noise. In some samples a sixth mode was indicated at 24 mm CL, but inclusion of a group 6 was only reasonable in two runs for 1996 (strata D7 and D8), where they may be explained as some 6 years old shrimp, which did not change sex at the usual age. For practical purposes group 6 proportions were included in group 5 values for those samples.

In general a C.V. value of .06 was applicable, but in a few runs smaller C.V. values gave better estimates. Mean errors of proportions and means were generally far below .2 and .02, respectively - ranges are shown together with analysis results in Table 2, 3, and 4. Figures 1, 2, and 3 show plots of the results of analysis of total area distributions from 1995, 1996, and 1997.

Runs with introduced van Bertalanffy growth in some cases changed proportions and means slightly, but results were still in good agreement with the general trends.

Combination of a number of samples in overall length distributions may introduce some noise due to small differences in growth between depths and areas. Table 2, 3, and 4 show that in all three years there is generally good agreement between the means and proportions found in strata distributions and those found in the corresponding distributions for the total area. Figures 4, 5, and 6 illustrates a comparison of means of proportions found in strata and those found in total samples. The largest differencies between strata and total proportions is seen for age group 4 and 5 in Figure 5 (1996 data). Figure 2 shows that age group 4 is obviously overestimated and age group 5 understimated in the analysis of the total distribution for 1996, and that a reanalysis migth result in better agreement between proportions.

The similarity between dominant modes found in offshore survey distributions from the Davis Strait and distributions from the Disko area has been the argument to consider shrimp in the two areas to belong to the same stock, and in recent years they have been managed as such. This may stille be correct, e.g. does the overall length frequency distribution from the offshore survey in 1997 (Carlsson and Kanneworff, 1997a) show a dominant male mode at 18 mm CL in offshore areas, comparable to the one found in the Disko area at 17.5 mm CL in 1997. A reanalysis of samples from the Davis Strait may therefore be appropiate. The age at length interpretation by Savard et al. (1994) was based on data from 1982 to 1987, and it is possible that there has been a change in growth pattern since then. It is also possible that the interpretation has been misled due to the noise that can be expected in samples from a large area, where differencies in growth between areas and depths may occur.

Modal analysis can only lead to results reflecting the real situation in nature, when the input used is biologically relevant. Biological information on the growth of shrimp in nature is therefore very important for evaluation of the theoretical interpretations of length at age, which again are important for the evaluation of the strength of recruiting year classes.

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Table 1. Modes found by visual inspection of mean length-frequencies for strata and total area 1995-1997.

Area	Year	Estimated modes, CL					
		1	2	3	4	5	6
D1	1995	8.5	13	16.5	21	23	-
	1996	-	13	17	19.5	22	-
	1997	8.5	12.5	17	20	23	-
D2	1995	-	13	17	20	23	-
	1996	-	13.5	17	19.5	22	-
	1997	-	13	17	20	22.5	-
D3	1995	-	12.5	16.5	20	22.5	-
	1996	(8.5)	13.5	17	19	22	-
	1997	-	13	17.5	20	22.5	-
D4	1995	-	(13)	16.5	20.5	22.5	-
	1996	-	13	17	20.5	23	-
	1997	9	13.5	17	20	22.5	-
D5	1995	-	12.5	16.5	20.5	23	-
	1996	-	13	16.5	20	22	-
	1997	(9)	12.5	17	20.5	22	-
D6	1995	-	12.5	16.5	20	23	-
	1996	(8)	11.5	16.5	19	22.5	-
	1997	-	12.5	17	20.5	23.5	-
D7	1995	-	-	-	20.5	23	-
	1996	-	12.5	17	21	24	-
	1997	-	13.5	17.5	21.5	23.5	-
D8	1995	-	-	(17.5)	21	23	-
	1996	-	-	17	21.5	24	-
	1997	-	13.5	17.5	21	24.5	-
D9	1995	-	(12.5)	-	20.5	23	-
	1996	(8)	11.5	16.5	19	22.5	-
	1997	8	13.5	17	20.5	23.5	-
Total	1995	-	12.5	17	20.5	23	-
	1996	-	13	17	20.5	23	-
	1997	8.5	13	17	20.5	23	-

Table 2. Carapace length, percents-at-age, and abundance-at-age of male shrimp the Disko Bay in 1995, based on modal analysis of length-frequency distributions from strata and total area.

CL, mm STRATUM	AGE 1	2	3	4	5	6	C.V.	Standard error
D1	8.3	12.6	16.3	19.8	22.1		0.06	.06-.09
D2		13.1	16.7	19.5	21.6		0.05	.04-.07
D3		12.2	16.1	19.3	22.4		0.06	.03-.04
D4				19.5	22.4		0.06	.03-.04
D5		12.9	16.6	20.0	22.2		0.06	.07-.09
D6		12.5	15.8	19.1	22.2		0.06	.07-.13
D7				20.1	23.1		0.06	.04-.05
D8				20.7	23.4		0.05	.09-.13
D9		12.7	16.6	20.7	23.4		0.06	.05-.27
mean	8.3	12.7	16.4	19.9	22.5			
TOTAL		12.8	16.4	19.8	22.6		0.06	.06-.26

Proportions STRATUM	AGE 1	2	3	4	5	6	Standard error	TOTAL MALES
D1	0.01	0.04	0.13	0.34	0.47		.002-.020	428.8
D2		0.04	0.25	0.46	0.25		.003-.016	370.0
D3		0.06	0.13	0.36	0.45		.003-.008	854.7
D4				0.33	0.67		.010-.010	795.3
D5		0.03	0.08	0.50	0.40		.003-.024	441.3
D6		0.03	0.17	0.44	0.36		.004-.017	194.1
D7				0.40	0.60		.013-.013	414.2
D8				0.34	0.66		.036-.036	49.5
D9		0.01	0.01	0.39	0.59		.002-.017	437.5
mean	0.01	0.04	0.13	0.40	0.49			3985.4
TOTAL		0.03	0.10	0.39	0.48		.009-.048	3985.5

Abundance STRATUM	AGE 1	2	3	4	5	6	SUM	TOTAL MALES
D1	4.3	17.2	55.7	145.8	201.5		424.5	428.8
D2	0.0	14.8	92.5	170.2	92.5		370.0	370.0
D3	0.0	51.3	111.1	307.7	384.6		854.7	854.7
D4	0.0	0.0	0.0	262.4	532.9		795.3	795.3
D5	0.0	13.2	35.3	220.7	176.5		445.7	441.3
D6	0.0	5.8	33.0	85.4	69.9		194.1	194.1
D7	0.0	0.0	0.0	165.7	248.5		414.2	414.2
D8	0.0	0.0	0.0	16.8	32.7		49.5	49.5
D9	0.0	4.4	4.4	170.6	258.1		437.5	437.5
SUM	4.3	106.7	332.0	1545.3	1997.2		3985.5	3985.4
TOTAL	0.0	119.6	398.6	1554.3	1913.0		3985.5	

Table 3. Carapace length, percents-at-age, and abundance-at-age of male shrimp the Disko Bay in 1996, based on modal analysis of length-frequency distributions from strata and total area.

CL, mm STRATUM	AGE 1	2	3	4	5	6	C.V.	Standard error
D1		12.6	16.2	18.8	21.4		0.06	.03-.19
D2		13.4	17.0	19.2	21.8		0.05	.12-.50
D3		13.2	16.4	18.9	22.0		0.06	.08-.31
D4		13.1	16.0	19.1	22.4		0.06	.06-.21
D5		13.0	17.1	19.1	21.4		0.07	.08-3.93
D6		13.4	16.8	19.0	22.0		0.06	.08-.37
D7		12.8	16.8	18.9	21.7	24.2	0.05	
D8			17.0	18.7	21.6	24.2	0.05	
D9		11.6	16.5	20.0	22.7		0.06	.08-.72
mean		12.9	16.6	19.1	21.9	24.2		
TOTAL		12.8	16.6	19.6	22.5		0.06	.06-.30

Proportions STRATUM	AGE 1	2	3	4	5	6	Standard error	TOTAL MALES
D1		0.48	0.13	0.23	0.16		.014-.020	1244.5
D2		0.19	0.27	0.19	0.36		.029-.052	188.4
D3		0.26	0.34	0.19	0.21		.019-.031	603.6
D4		0.16	0.07	0.14	0.63		.009-.019	1263.5
D5		0.30	0.24	0.06	0.40		.020-.103	617.7
D6		0.23	0.27	0.20	0.29		.017-.038	686.6
D7		0.08	0.18	0.10	0.64		.008-.022	1032.7
D8			0.05	0.06	0.89		.012-.026	62.7
D9		0.29	0.10	0.10	0.51		.021-.054	270.8
mean		0.25	0.18	0.14	0.45			5970.5
TOTAL		0.25	0.19	0.20	0.36		.018-.032	5970.5

Abundance STRATUM	AGE 1	2	3	4	5	6	SUM	TOTAL MALES
D1		597.4	161.8	286.2	199.1		1244.5	1244.5
D2		35.8	50.9	35.8	67.8		190.3	188.4
D3		156.9	205.2	114.7	126.8		603.6	640.6
D4		202.2	88.4	176.9	796.0		1263.5	1263.5
D5		185.3	148.2	37.1	247.1		617.7	617.7
D6		157.9	185.4	137.3	199.1		679.7	686.6
D7		82.6	185.9	103.3	660.9		1032.7	1032.7
D8		0.0	3.1	3.8	55.8		62.7	62.7
D9		78.5	27.1	27.1	138.1		270.8	270.8
SUM		1496.6	1056.1	922.1	2490.7		5965.5	6007.5
TOTAL		1492.6	1134.4	1194.1	2149.4		5970.5	

Table 4. Carapace length, percents-at-age, and abundance-at-age of male shrimp the Disko Bay in 1997, based on modal analysis of length-frequency distributions from strata and total area.

CL, mm STRATUM	AGE 1	2	3	4	5	6	C.V.	Standard error
D1	8.8	12.5	16.9	19.6	22.2		0.06	.05-.30
D2		12.6	17.0	19.7	21.4		0.06	.07-1.08
D3		13.7	17.5	20.0	22.6		0.04	.03-.03
D4	8.6	13.1	16.9	19.3	22.4		0.06	.07-.35
D5		12.4	16.9	19.5	22.2		0.06	.04-.40
D6		12.7	16.9	19.8	22.2		0.06	.03-.51
D7		13.3	17.1	19.8	23.4		0.06	.09-.32
D8		13.8	17.6	20.1	23.6		0.06	.06-.17
D9	8.3	13.4	16.6	19.8	23.5		0.06	.02-.10
mean	8.6	13.1	17.0	19.7	22.6			
TOTAL	8.5	12.8	16.9	19.9	22.8		0.06	.06-.37

Proportions STRATUM	AGE 1	2	3	4	5	6	Standard error	TOTAL MALES
D1	0.02	0.15	0.46	0.13	0.24		.003-.020	1896.5
D2		0.15	0.69	0.09	0.08		.012-.068	829.2
D3		0.05	0.26	0.20	0.49		.004-.012	256.6
D4	0.02	0.13	0.41	0.14	0.29		.004-.026	1149.7
D5		0.32	0.38	0.13	0.18		.015-.025	950.9
D6		0.34	0.53	0.06	0.07		.011-.016	1757.3
D7		0.13	0.34	0.16	0.37		.012-.025	777.4
D8		0.04	0.10	0.19	0.67		.005-.018	131.7
D9	0.12	0.37	0.08	0.11	0.32		.004-.008	485.4
mean	0.05	0.19	0.36	0.13	0.30			8234.7
TOTAL	0.02	0.21	0.44	0.13	0.20		.004-.023	8234.7

Abundance STRATUM	AGE 1	2	3	4	5	6	SUM	TOTAL MALES
D1	37.9	284.5	872.4	246.5	455.2		1896.5	1896.5
D2		124.4	572.1	74.6	66.3		837.5	829.2
D3		12.8	66.7	51.3	125.7		256.6	256.6
D4	23.0	149.5	471.4	161.0	333.4		1138.2	1149.7
D5		304.3	361.3	123.6	171.2		960.4	950.9
D6		597.5	931.4	105.4	123.0		1757.3	1757.3
D7		101.1	264.3	124.4	287.6		777.4	777.4
D8		5.3	13.2	25.0	88.2		131.7	131.7
D9	58.2	179.6	38.8	53.4	155.3		485.4	485.4
SUM	119.2	1758.8	3591.7	965.3	1806.0		8241.0	8234.7
TOTAL	164.7	1729.3	3623.3	1070.5	1646.9		8234.7	

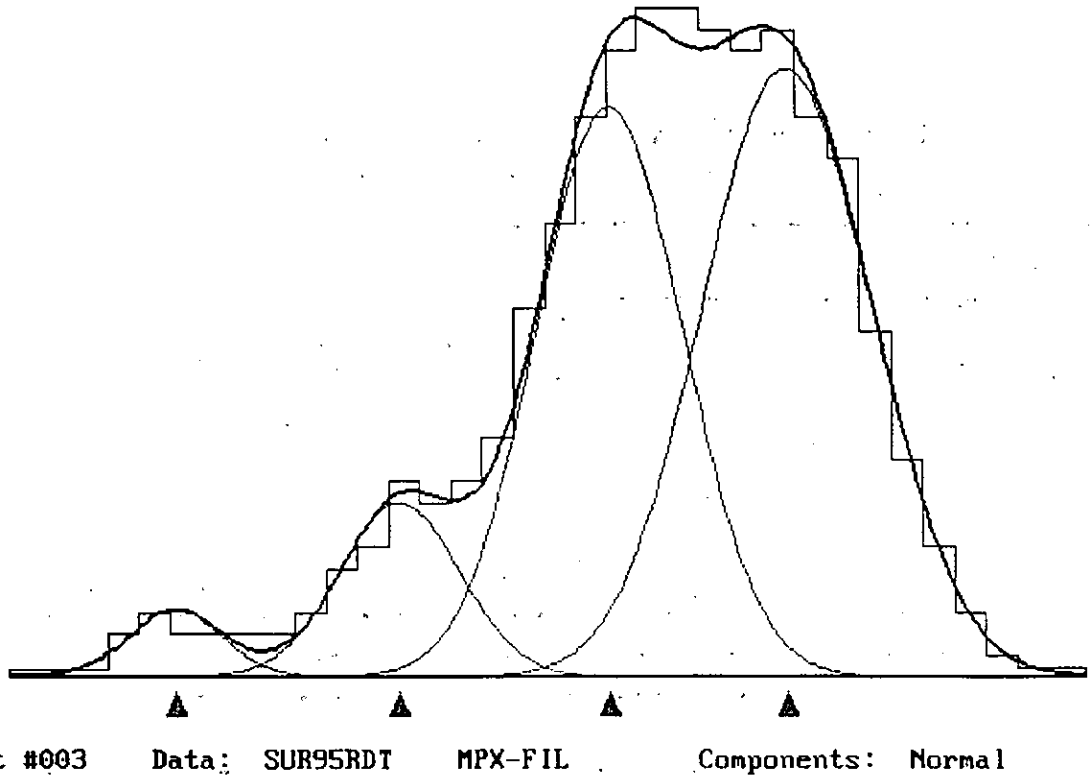

Figure 1. Result of MIX-analysis of total length distribution 1995.

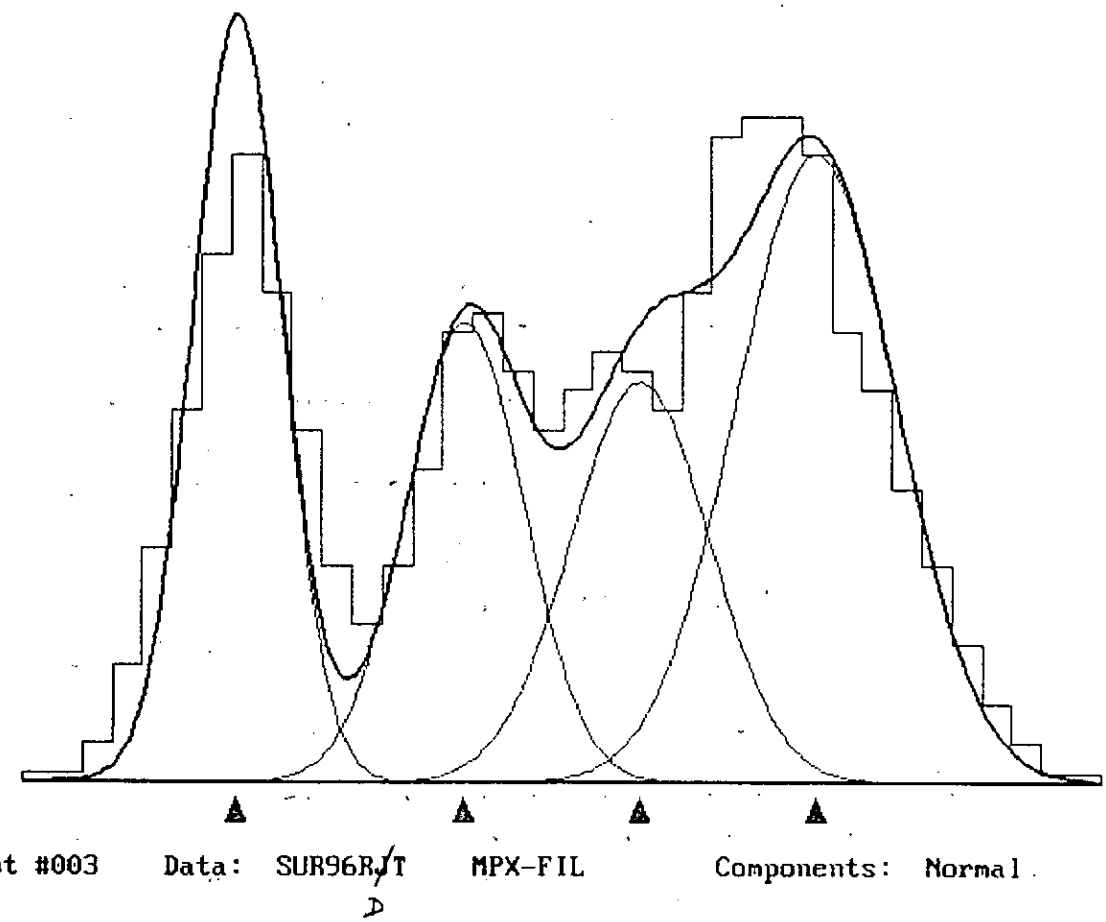

Figure 2. Result of MIX-analysis of total length distribution 1996.

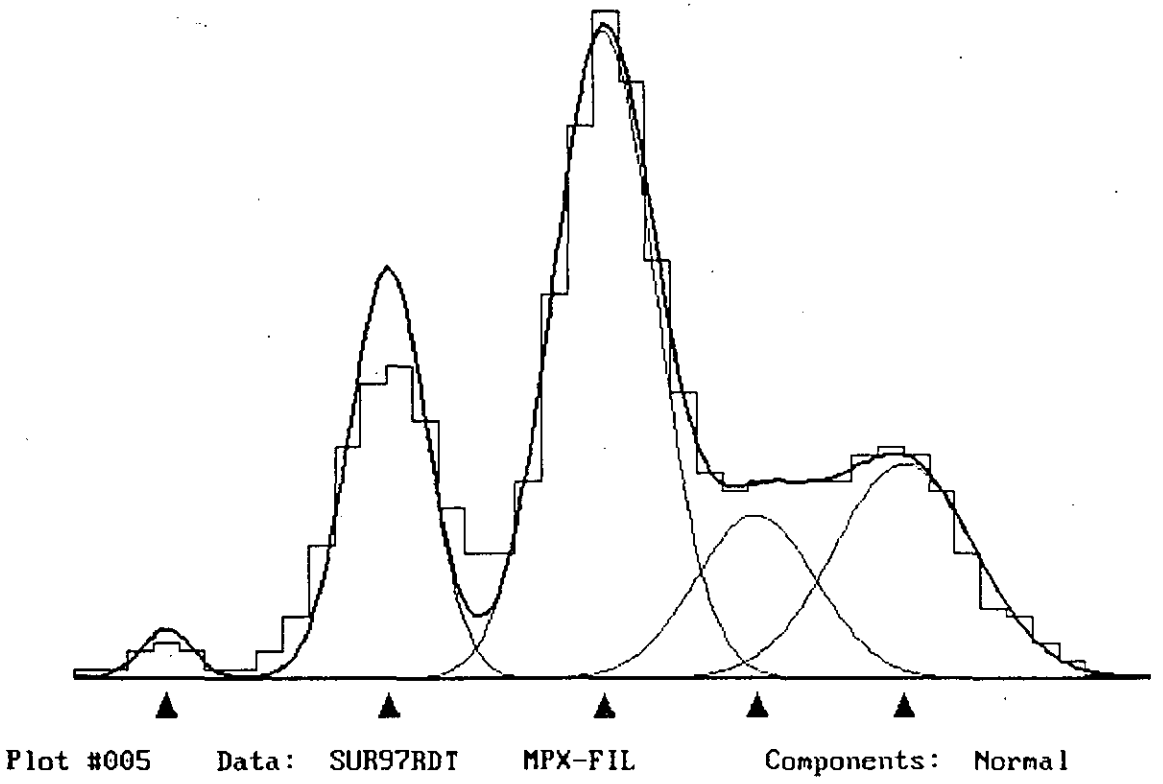

Figure 3. Result of MIX-analysis of total length distribution 1997.

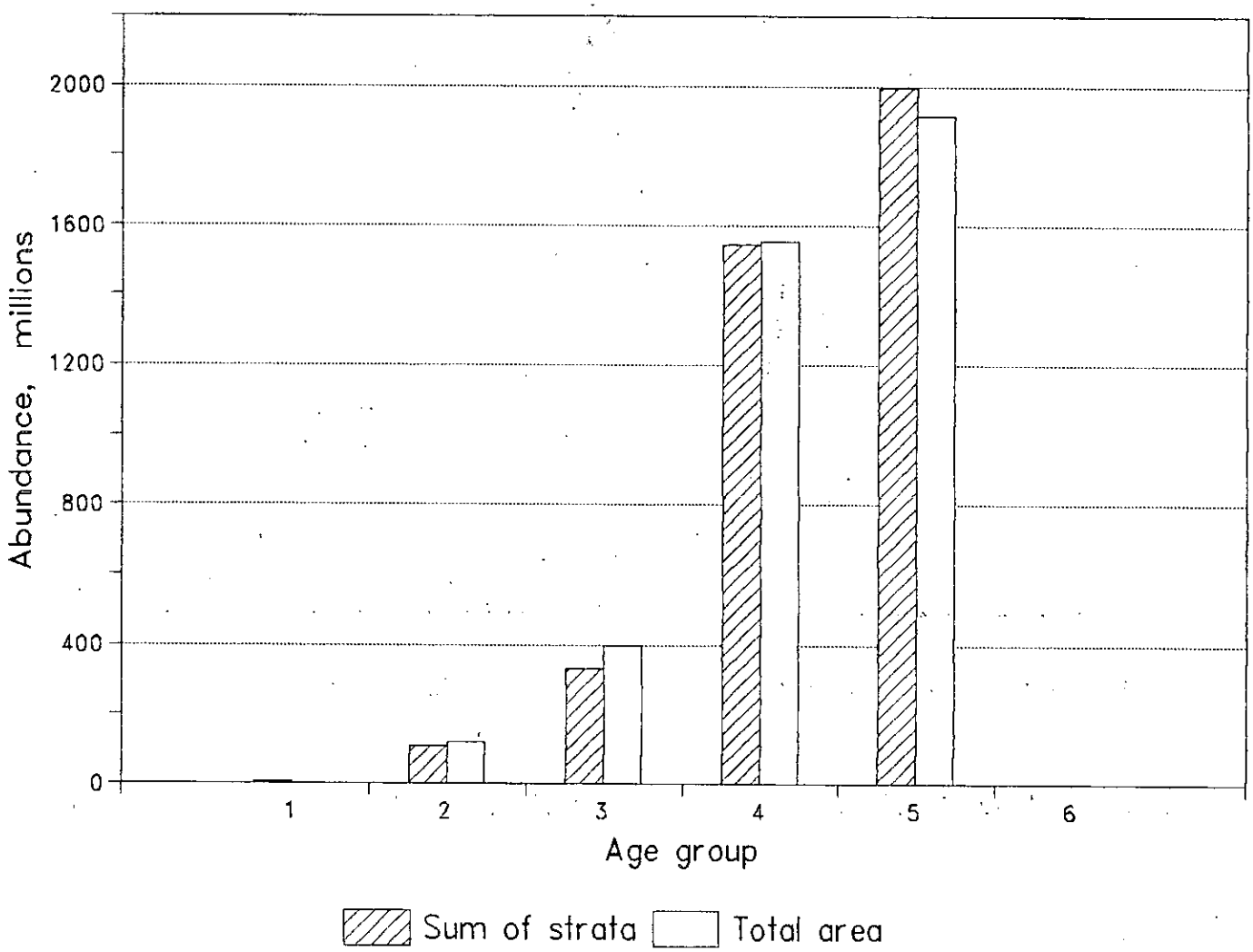

Figure 4. Comparison of total abundance of age groups calculated from strata length distributions and from total area length distribution, 1995.

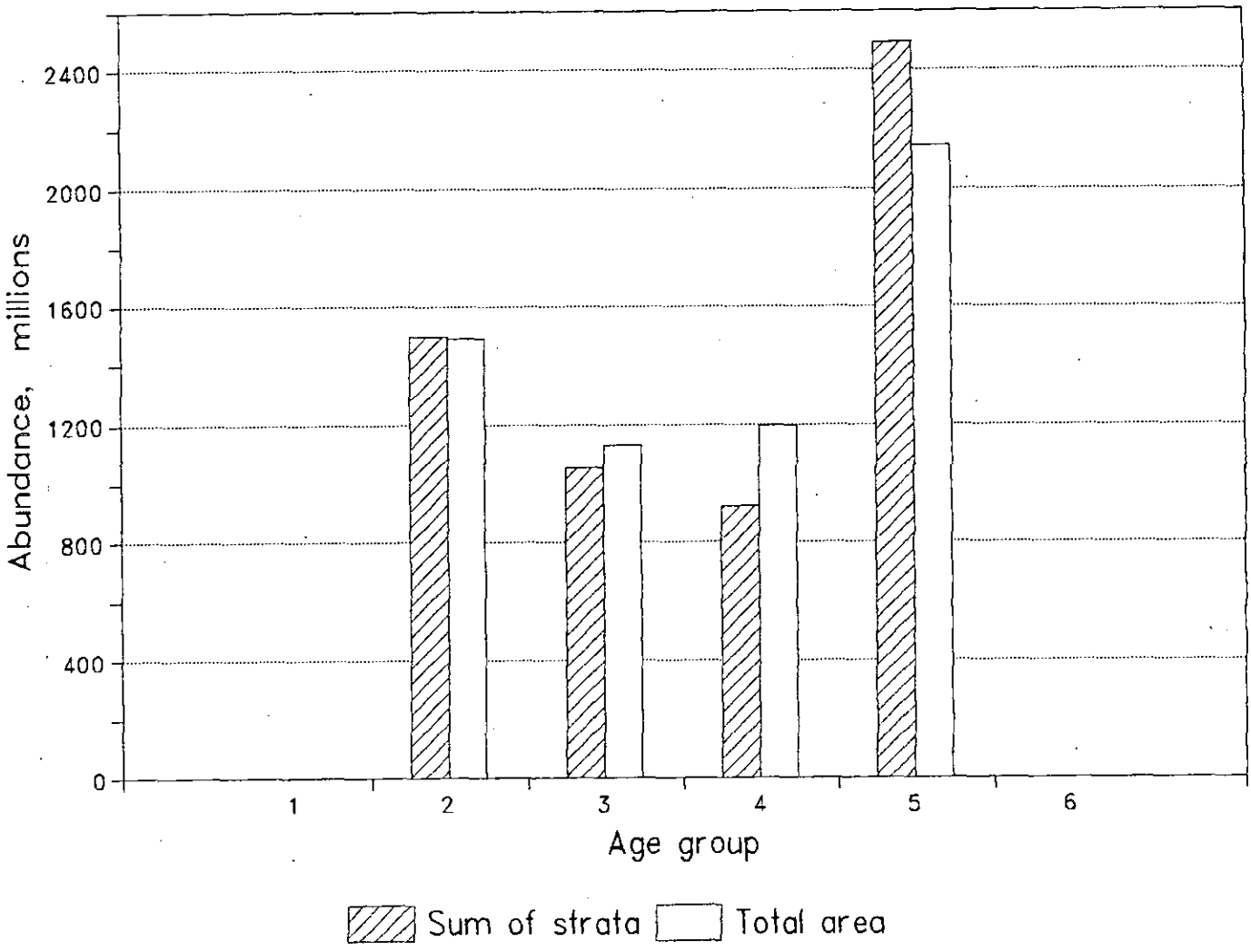

Figure 5. Comparison of total abundance of age groups calculated from strata length distributions and from total area length distribution, 1996.

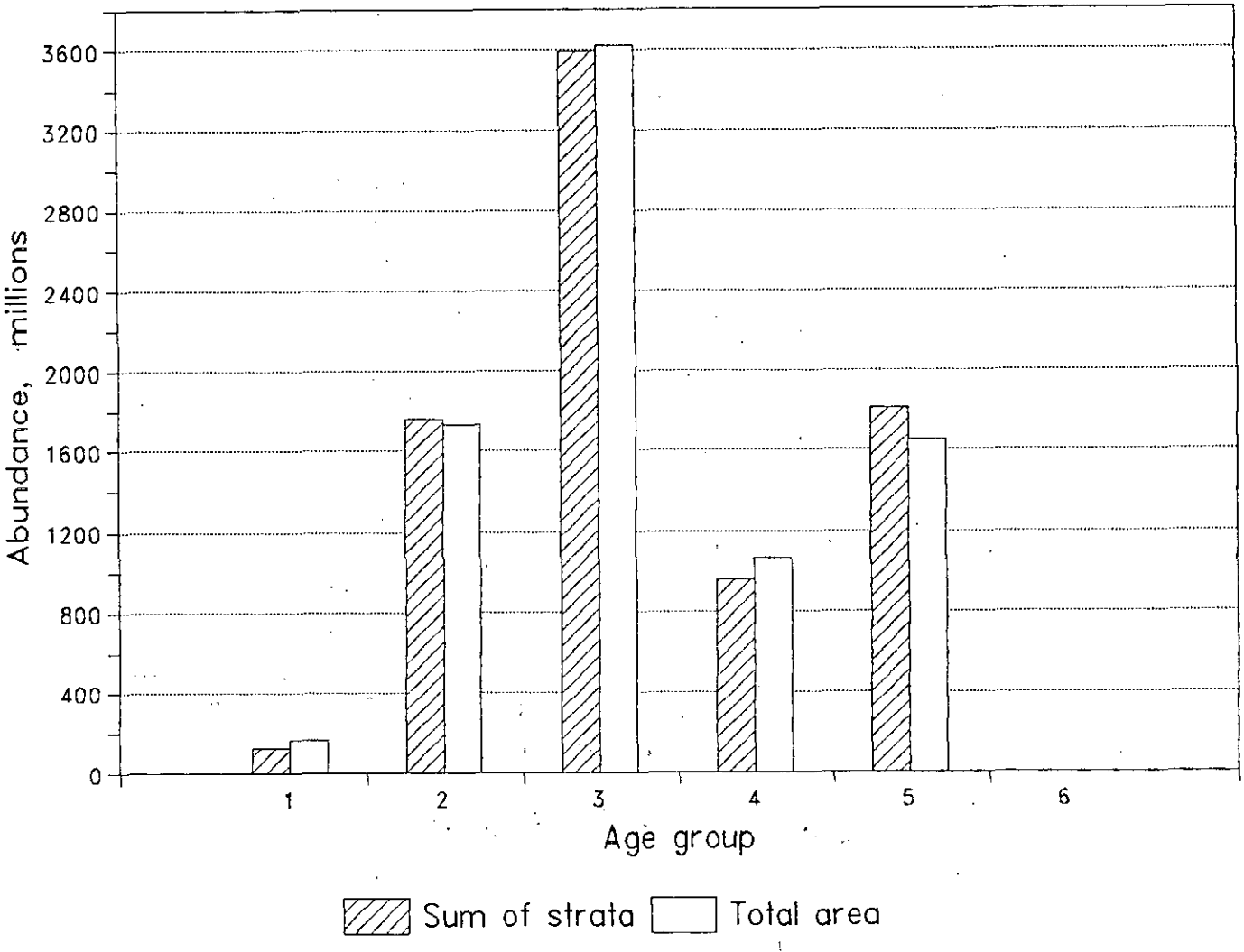

Figure 6. Comparison of total abundance of age groups calculated from strata length distributions and from total area length distribution, 1997.