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Evaluation of Year-class Strength in Samples From a Commercial Shrimp Fishery, a Theoretical Approach

by

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Introduction

Total weighted length distributions, e.g. from the commercial fishery, are often difficult to interpret, because seasonal growth tends to mask the annual length increment of the age groups. When using the various methods for determining age groups from length distributions it is essential that a clear growth from year to year is identifiable.

In order to investigate the effect of using the MIX program - created for modal analysis of length frequency distributions (Macdonald and Pitcher, 1979) - to calculate year-class proportions in combined weighted annual length distributions of commercial catches of shrimp a number of modelled scenarios with varying year-class sizes in the catch were created, and the MIX program was used to calculate proportions in the resulting distributions. Theoretical and calculated proportions were thereafter compared.

Materials and methods

In order to explore how variations in year-class strength and various weighting factors influence total weighted length distributions of shrimp some calculated examples are given based on theoretical distributions. The basic figures for length at age, year-class strength, and catch distribution over quarters are copied from information from analysis of the commercial fishery in Davis Strait in 1996 (Hvingel *et al.*, 1996).

In these examples commercial fishery catches are thought to be sampled the year round, and length samples combined quarterly and weighted with the total catch for the relevant periods.

Four year-classes are followed through the year, and the growth pattern is supposed to be stable, i.e. the length of a year-class after five quarters' growth equals the length of the next year-class in the first quarter. The growth of a year-class is supposed to be linear within a given year.

Length distributions are supposed to be normally distributed around means, roughly corresponding to peaks interpreted as age groups 2-5 in the offshore shrimp (*Pandalus borealis*) population. Standard deviations differ from year-class to year-class.

The mean length and the standard deviations (in brackets) chosen for the distributions are given below:

Year-class	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec
A	11.0 (0.8)	11.7 (0.8)	12.5 (0.8)	13.3 (0.8)
B	14.0 (0.9)	14.7 (0.9)	15.5 (0.9)	16.3 (0.9)
C	17.2 (1.0)	17.8 (1.0)	18.5 (1.0)	19.2 (1.0)
D	20.0 (1.1)	20.6 (1.1)	21.2 (1.1)	21.8 (1.1)

Five models with theoretical catches in a year of the four year-classes were investigated. In each quarter the same catch was taken of a year-class:

Model M1111: Four year-classes of equal strength were fished over a year.
Model M2111: Four year-classes, of which the first one was twice as abundant as the other three year classes, were fished over a year.
Model M1422: Four year-classes, of which the second was four times as abundant as the first, and the third and the fourth were twice as abundant as the first, were fished over a year.
Model M2142: Four year-classes, of which the first was twice as abundant as the second, and the third was four

Model M2214: Four year-classes, of which the first and the second was twice as abundant as the third, and the fourth was four times as abundant as the third, were fished over a year.

To facilitate the production of simulated catch composition a spreadsheet was created with a quarterly normal distribution of each year-class. By applying a weighting factor the different modelled catch compositions could easily be produced (Table 1).

The MIX program was used to calculate proportions of the four year-classes in the modelled catch compositions. As input was used the theoretical mean length in the third quarter (kept fixed), and a fixed C.V. of .065 similar to the value used by Hvingel *et al.* (1997) in calculation of year-class proportions in commercial catches based on commercial shrimp samples weighted and pooled by quarter. Theoretical and calculated proportions were then compared to evaluate the reasonability of the method.

Results and Discussion

Figure 1 shows as an example the theoretical distributions of the four year-classes in the second quarter. The distributions are clearly distinguishable. If all year-classes, however, are combined in one common distribution for the whole year, supposing that the year-classes are of equal strength and that the fishery has been evenly distributed over the year, all groupings are masked (Fig. 2).

If the year-classes are not of equal strength, it is possible to trace them in the combined length distributions. Figures 3-6 show examples of the combined distributions in case of a large (double strength) year-class followed by a weak (half strength) passes through the system.

The starting point in the interpretation of commercial length samples is normally a combined distribution based on a fishery with large seasonal variations. The sizes of the various age-classes are normally not known neither are their individual growth patterns. If in the present material variations of year-classes and of quarterly catches of observed magnitude is applied a more complex combined distribution is seen. If the four distributions are weighted with quarterly catch figures, e.g. from the large fleet fishery in NAFO SA1 in 1996, the age-group peaks are still visible (Fig. 7). A further weighting with the supposed year-class strength (roughly according to Hvingel *et al.*, 1996), however, has a pronounced masking effect (Fig. 8). Determining age-groups from length distributions of this kind is obviously very hazardous and subject to personal interpretations.

Figure 9 shows the cohorts produced by the MIX program for the five models, using the fixed mean values and the fixed coefficient of variation. Table 2 shows a comparison of the modelled year-class proportions and the proportions calculated by use of the MIX program.

The results show that in general the first year-class is overestimated and the fourth year-class underestimated. This is especially in the case when the adjacent year-class is bigger (models M1422 and M2142). Also small year-classes in group 2 or 3 with two larger adjacent year-classes tend to be overestimated (model M2142 and M2214).

In general, proportions in the model and the calculated proportions do not differ significantly under the given input of mean lengths of carapace and coefficient of variation. However, parameters used in the production of the pooled sample and as input to MIX are controlled, which is different from the situation when a pooled length distribution from commercial catches is analysed. Given that relative errors of up to 44% are found in the calculated proportions in a controlled scenario, larger errors may be found in an uncontrolled situation.

The number of scenarios that could be investigated by this method is unlimited. In particular it should be analysed, how calculated proportions by use of the MIX program would react to e.g. a change in the mean carapace length of year-classes or to changes in ratio of quarterly catches within a year. In all circumstances a more safe approach by the calculation of year-class proportions in samples from commercial catches would be used e.g. quarterly pooled samples rather than total year samples.

References

Hvingel, C., H. Siegstad and O. Folmer, 1996. The Greenland fishery for northern shrimp (*Pandalus borealis*) in Davis Strait in 1995 and January-October 1996. *NAFO SCR Doc.*, No. 109. Serial No. N2806.

Hvingel, C., H. Siegstad and O. Folmer. 1997. The Greenland fishery for northern shrimp (*Pandalus borealis*) off West Greenland, 1970-1997. *NAFO SCR Doc*, No. 98, Serial No. N2955.

Macdonald, P. D. M., and T. J. Pitcher. 1979. Age-groups from size-frequency data: a versatile and efficient method of analysing distribution mixtures. *J. Fish. Res. Board Can.*, **36**: 987-1001.

Table 1. Normal distributions of four age-groups (A-D) in four quarters of a given year. Means and standard deviations are given. Year-class strengths and quarterly catches are weighted evenly.

Distrib.	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4
Mean	11.0	11.7	12.5	13.3	14.0	14.7	15.5	16.3	17.2	17.8	18.5	19.2	20.0	20.6	21.2	21.8
STD	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1
YCfact.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
CAfact.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

LGR	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4
7.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
8.5	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9.0	0.022	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9.5	0.086	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10.0	0.228	0.052	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
10.5	0.410	0.162	0.022	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11.0	0.499	0.340	0.086	0.008	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
11.5	0.410	0.483	0.228	0.040	0.009	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12.0	0.228	0.465	0.410	0.133	0.038	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
12.5	0.086	0.302	0.499	0.302	0.111	0.022	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13.0	0.022	0.133	0.410	0.465	0.239	0.074	0.009	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
13.5	0.004	0.040	0.228	0.483	0.380	0.182	0.038	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14.0	0.000	0.008	0.086	0.340	0.443	0.328	0.111	0.017	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
14.5	0.000	0.001	0.022	0.162	0.380	0.432	0.239	0.060	0.010	0.002	0.000	0.000	0.000	0.000	0.000	0.000
15.0	0.000	0.000	0.004	0.052	0.239	0.419	0.380	0.156	0.035	0.008	0.001	0.000	0.000	0.000	0.000	0.000
15.5	0.000	0.000	0.000	0.011	0.111	0.299	0.443	0.299	0.094	0.028	0.004	0.000	0.000	0.000	0.000	0.000
16.0	0.000	0.000	0.000	0.002	0.038	0.156	0.380	0.419	0.194	0.079	0.018	0.002	0.000	0.000	0.000	0.000
16.5	0.000	0.000	0.000	0.000	0.009	0.060	0.239	0.432	0.312	0.171	0.054	0.010	0.002	0.000	0.000	0.000
17.0	0.000	0.000	0.000	0.000	0.002	0.017	0.111	0.328	0.391	0.290	0.130	0.035	0.009	0.002	0.000	0.000
17.5	0.000	0.000	0.000	0.000	0.000	0.004	0.038	0.182	0.381	0.381	0.242	0.094	0.027	0.007	0.001	0.000
18.0	0.000	0.000	0.000	0.000	0.000	0.001	0.009	0.074	0.290	0.391	0.352	0.194	0.069	0.022	0.005	0.001
18.5	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.022	0.171	0.312	0.399	0.312	0.143	0.059	0.018	0.004
19.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.005	0.079	0.194	0.352	0.391	0.240	0.126	0.049	0.014
19.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.028	0.094	0.242	0.381	0.327	0.220	0.110	0.041
20.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.035	0.130	0.290	0.363	0.313	0.200	0.095
20.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.010	0.054	0.171	0.327	0.361	0.296	0.180
21.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.018	0.079	0.240	0.339	0.357	0.278
21.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.028	0.143	0.260	0.349	0.349
22.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.008	0.069	0.161	0.278	0.357
22.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.027	0.082	0.180	0.296
23.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.009	0.034	0.095	0.200
23.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.011	0.041	0.110
24.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.014	0.049
24.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.018
25.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.005
25.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
26.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
26.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27.0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27.5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 2. Comparison of model proportions and calculated proportions.

Model	Model proportions				Calculated proportions				Difference, percent			
no.	1	2	3	4	1	2	3	4	1	2	3	4
M1111	0.25	0.25	0.25	0.25	0.28	0.24	0.27	0.22	12.0	-4.0	8.0	-12.0
M2111	0.40	0.20	0.20	0.20	0.42	0.19	0.21	0.17	5.0	-5.0	5.0	-15.0
M1422	0.11	0.44	0.22	0.22	0.16	0.42	0.23	0.19	44.0	-5.5	3.5	-14.5
M2142	0.22	0.11	0.44	0.22	0.23	0.13	0.46	0.18	3.5	17.0	3.5	-19.0
M2214	0.22	0.22	0.11	0.44	0.25	0.20	0.14	0.41	12.5	-10.0	26.0	-7.8

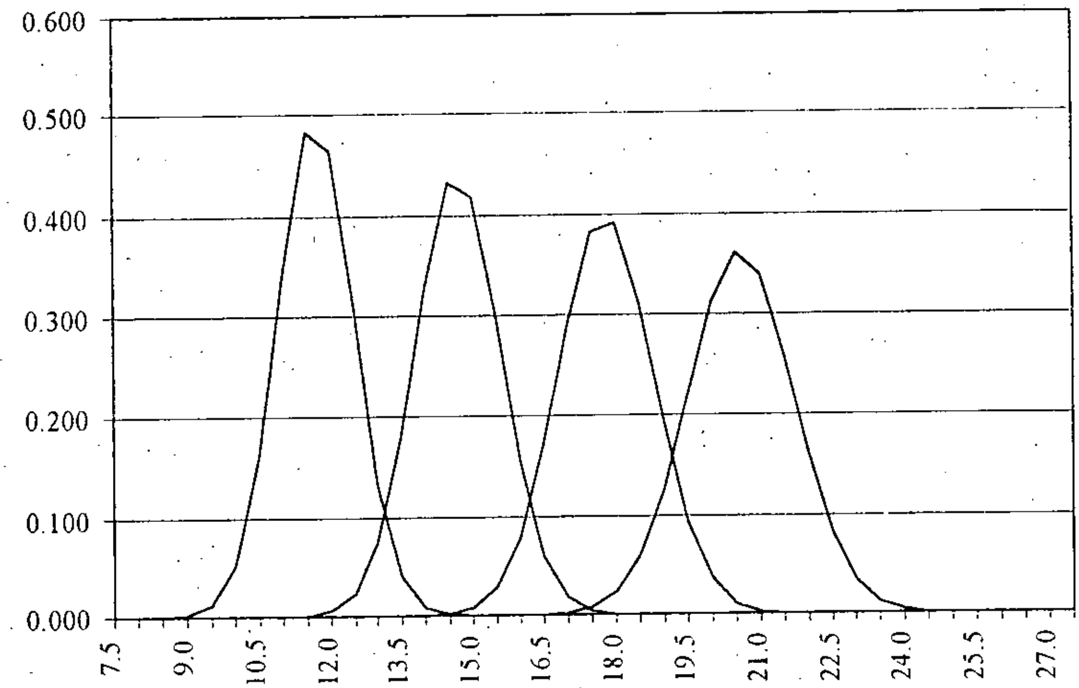

Figure 1. Distributions of the four year-classes in the second quarter.

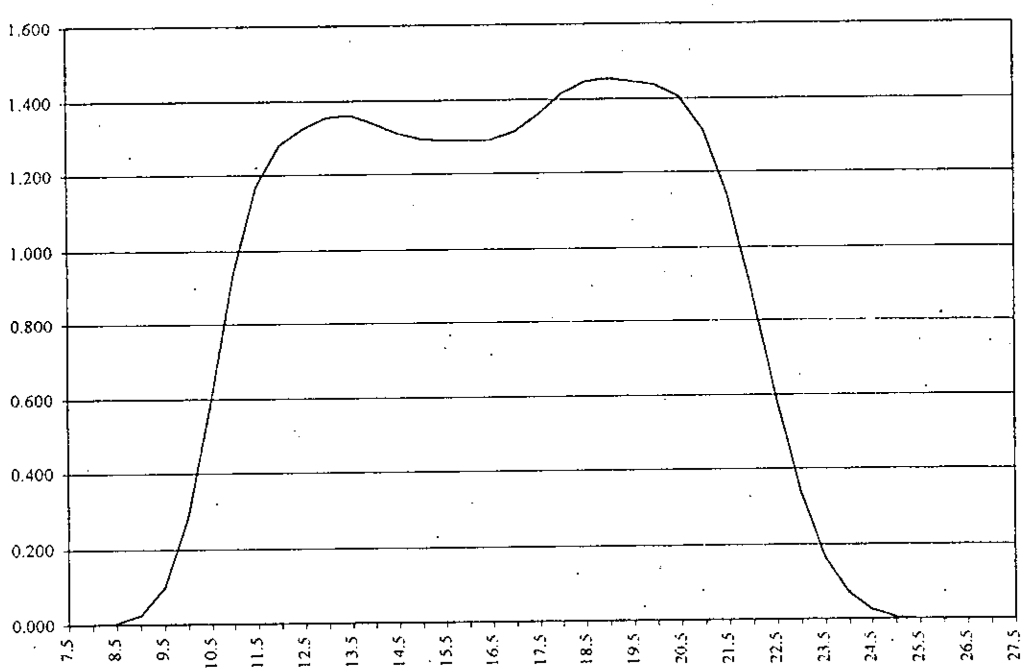

Figure 2. Combined size distribution of the four year-classes with equal weighting.

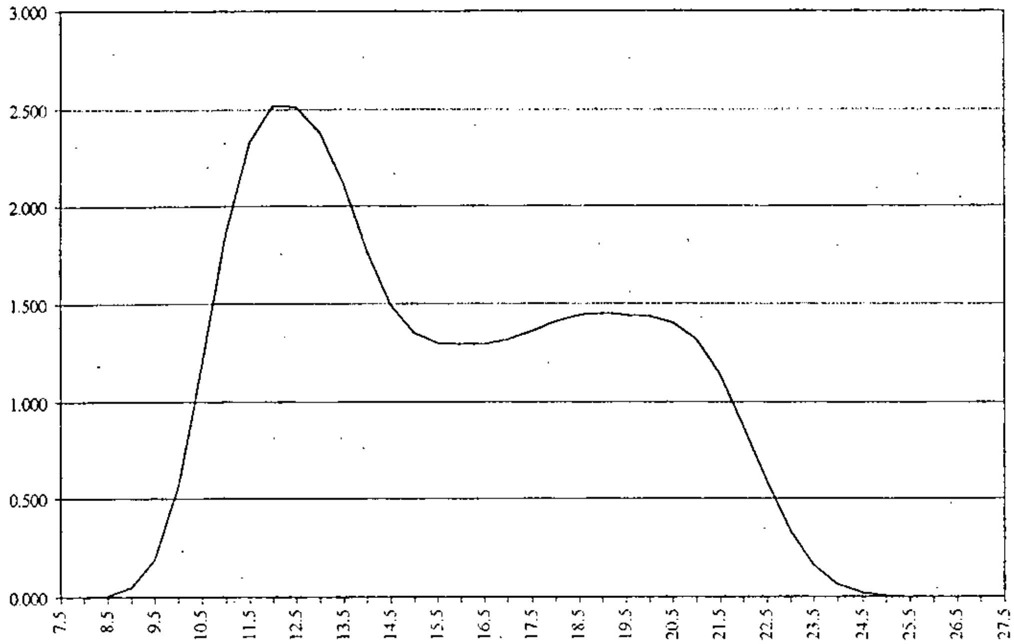

Figure 3. Combined size distribution of the four year-classes with different strength applied. Proportions between the age-groups are 2:1:1:1.

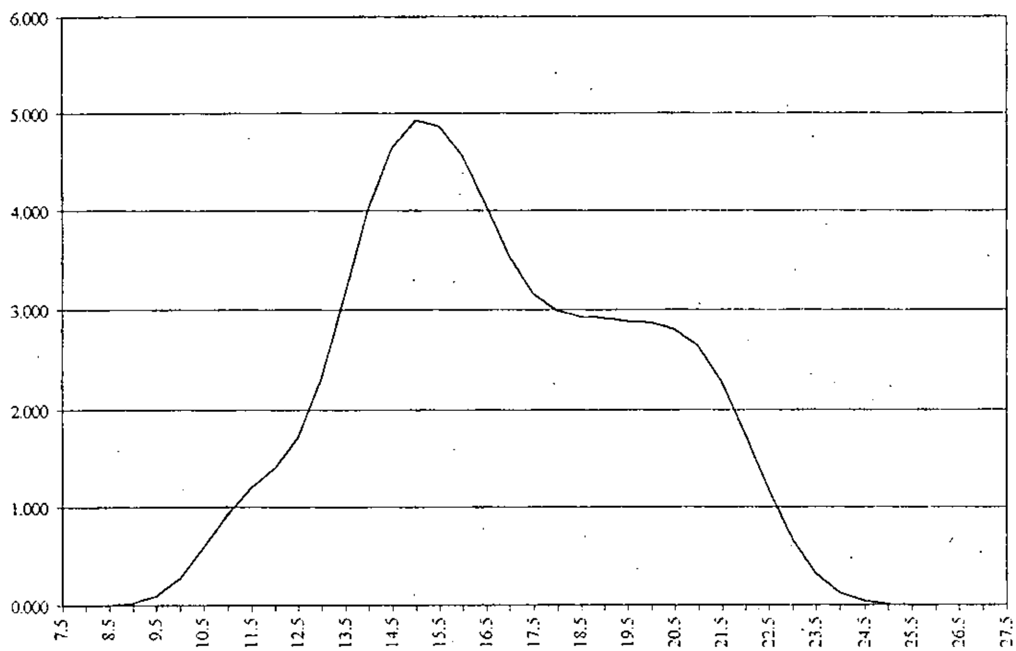

Figure 4. Combined size distribution of the four year-classes with different strength applied. Proportions between the age-groups are 1:4:2:2.

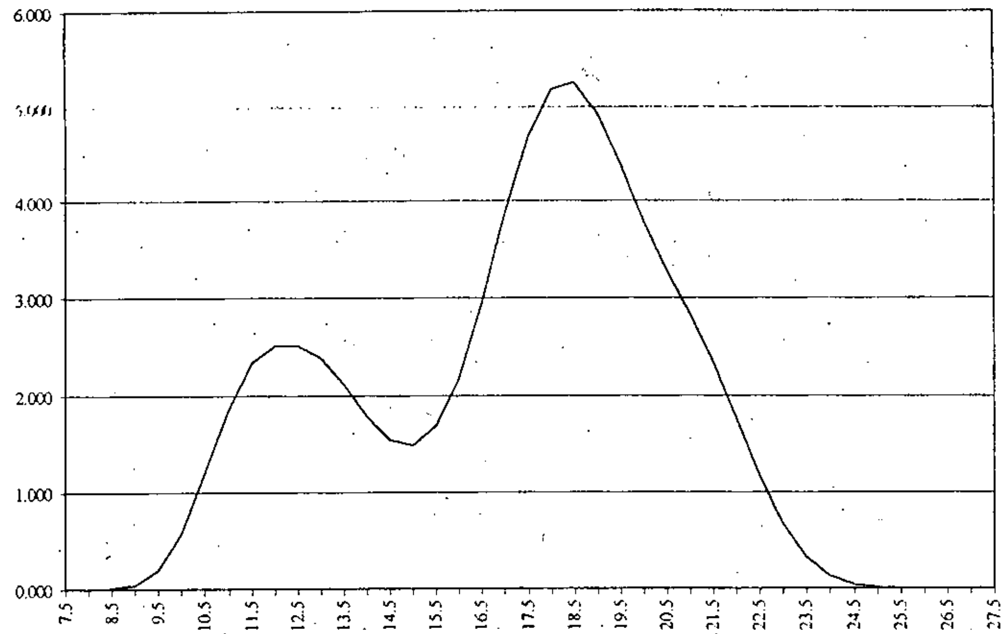

Figure 5. Combined size distribution of the four year-classes with different strength applied. Proportions between the age-groups are 2:1:4:2.

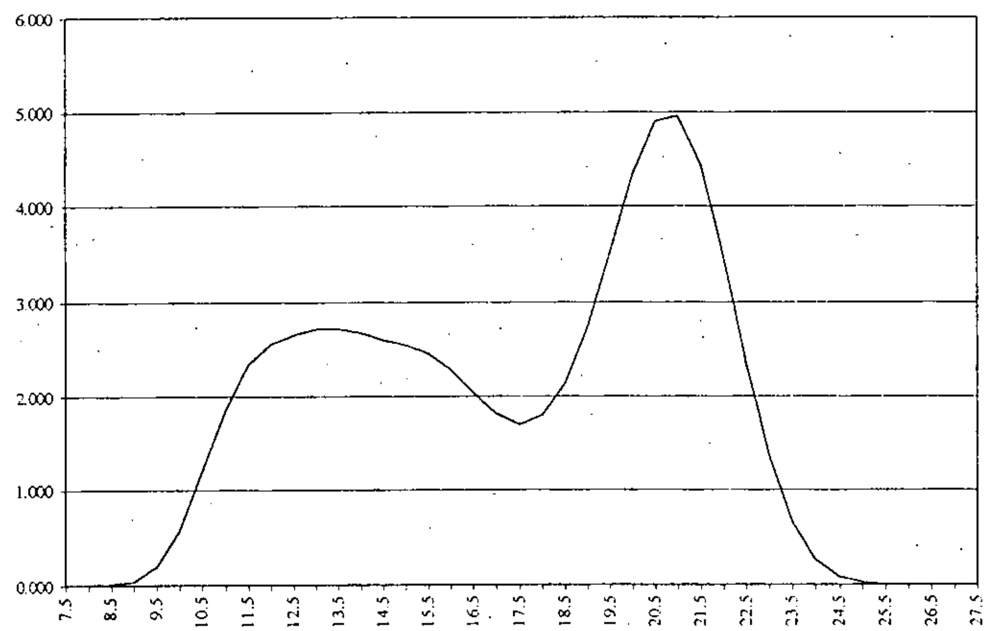

Figure 6. Combined size distribution of the four year-classes with different strength applied. Proportions between the age-groups are 2:2:1:4.

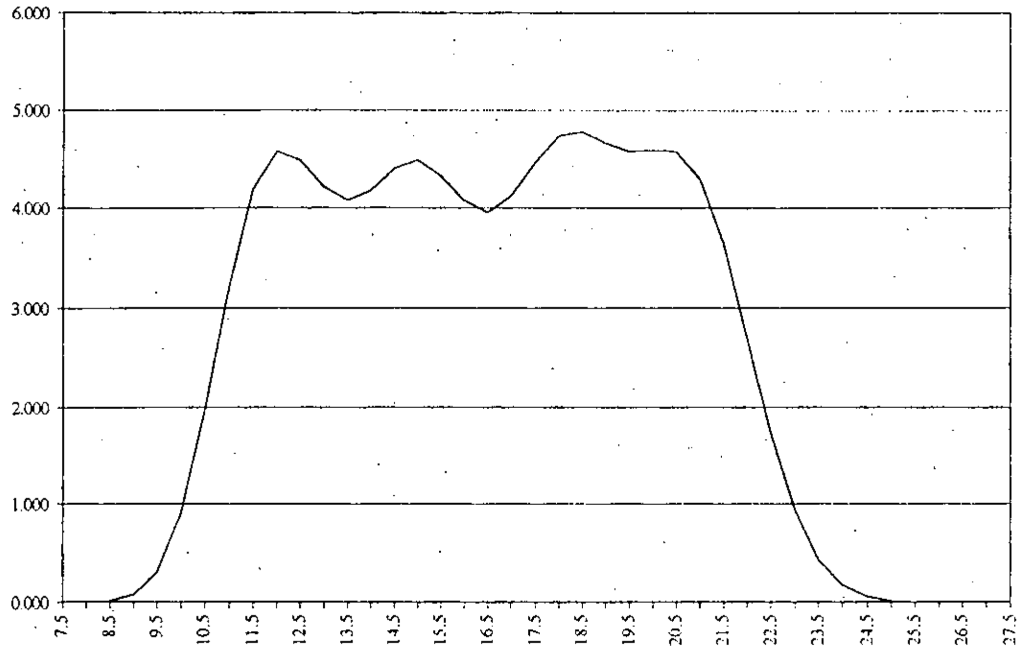

Figure 7. Combined size distributions of the four year-classes, weighted by quarterly commercial catches in the proportion 3:4:4:2 for the four quarters, respectively.

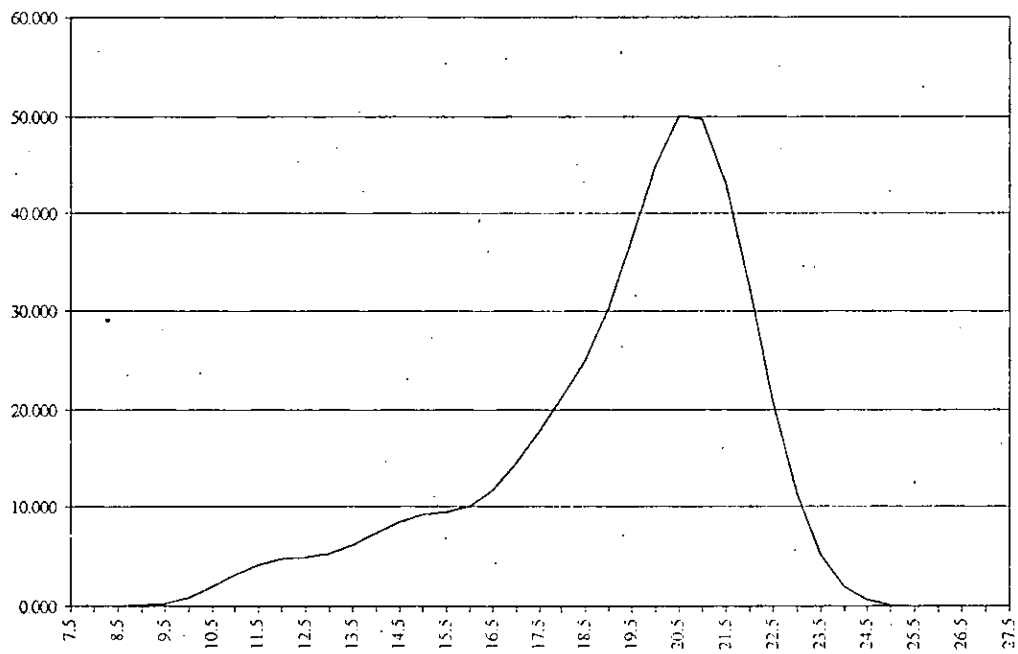

Figure 8. Combined size distributions of the four year-classes, weighted by quarterly commercial catches in the proportion 3:4:4:2 for the four quarters, respectively, and year-class strengths of 1:2:4:12 for the four year-classes, respectively.

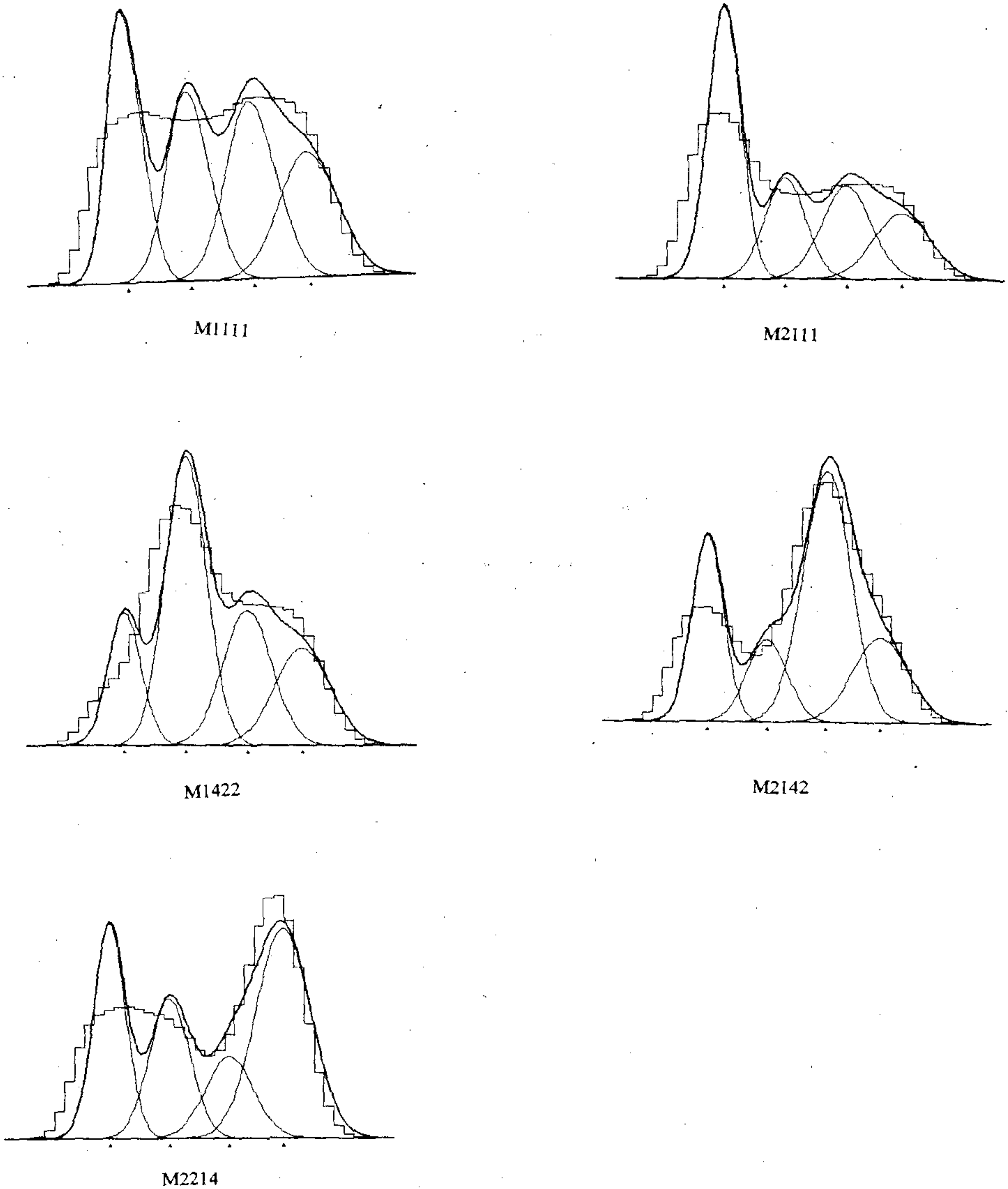

Figure 9. Cohortes produced by the MIX-program for five different models.