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HERMOD, A SINGLE SPECIES MODEL FOR THE NORWEGIAN SPRING SPAWNING HERRING STOCK

By

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ABSTRACT

HERMOD is a model for the population dynamics and migration of the Norwegian Spring spawning herring that is being developed with the double purpose of being an independent single species model and of being integrated into the Multispecies Model for the Barents Sea (MULTSPEC). This paper describes and discusses the presently used algorithms for maturation, recruitment, growth and migration, as well as the model's input and output options. A brief outline is given of the plans for further development.

INTRODUCTION

The herring model HERMOD has part of its origin in a program written in 1972 for Johannes Hamre of the Institute of Marine Research, Bergen, in order to simulate population dynamics in an exploited stock (Hauge, 1972). The program was later modified in order to describe the Norwegian Spring Spawning Herring Stock. That program introduced algorithms for density dependent growth and recruitment which are still included in HERMOD.

The purpose of writing HERMOD was to get a well documented basis for the further development of a single species model for the Norwegian spring spawning herring stock that both could function well on its own and could be easily integrated into the Multispecies Model for the Barents Sea, MULTSPEC.

Recently migration has been implemented in Hermod. Because the Norwegian spring spawning herring has changed its migration pattern several times since the 1950s and may be in the process of doing so again, the model is able to simulate two different sets of migration patterns. With this the model is almost ready to be integrated into the MULTSPEC model.

The development of HERMOD has received grants from the Norwegian research council during the years 1991-1994.

ALGORITHMS

HERMOD is basically a Beverton and Holt model (Beverton and Holt, 1957) which starts in January, with numbers for each year class supplied by the user, and adjusts the numbers one month at a time, using information about mortality which is also supplied by the user.

Growth

The presently used algorithm for growth in length has been taken over from earlier versions of the model. The basic idea is that growth should be density dependent. In order to facilitate this, the model compares two extreme stock situations: 1950 with a total stock biomass of 14 million tonnes, and 1970 with a total stock biomass of 83 thousand tonnes (based on VPA back calculations). In addition to the stock biomass, the mean length for each age group in each of those two years is known. Individual weight is determined by condition factors for each length group and each month. In January of each year the model runs, it calculates a new set of mean lengths by interpolating between the years 1950 and 1970, assuming a linear relationship between total stock biomass and mean lengths for the different age groups. The growth during the year for each age group will be the difference between the present mean length for that age group and the mean length for the next age group.

Maturation and spawning stock

Sexual maturation is dependent on length alone. A sigmoid function determines the proportion of each length group that matures. The function presently used is:

$$NumberMaturing = \frac{Number}{1 + Base^{(LM50 - ML)}}$$

where *Number* is the total number of herring in the length group, *ML* is the mean length of the length group, *Base* - is the base in the logarithmic expression and *LM50* is the length where 50% of the herring is maturing.

In the present model Base=9.0 and LM50=31.2. This gives a maturation curve as shown in Figure 1.

Recruitment to the 0-group

Spawning takes place in March. The resulting number of larvae is calculated in January from the biomass of the spawning stock at that time, and the 0-group herring are introduced into the model in June of each year the model runs. Between March and June no mortality is applied to the larvae, meaning that mortality of eggs and larvae before June must be taken care of by the recruitment function.

For the Norwegian spring spawning herring, the correlation between spawning stock and the number of larvae in June is weak. (Dragesund et al. 1980). In most years it seems that the mortality of the larvae is very high, giving poor or moderate recruitment even from large spawning stocks. But in some years, and much less frequently, the survival of the larvae seems to be very good, giving large year classes even from relatively small spawning stocks.

In order to simulate the relationship between spawning stock and recruits, two basic recruitment functions are available in the model.

Function 1:

$$Recruits = 31.0\,(1 - e^{(e^{-1.75} - e^{0.5\,(ParStock - 3.5)})})$$

where *Recruits* is the number of recruits in individuals x 10^{-9} and *ParStock* is the spawning stock biomass in million tonnes. This function represents a curve that increases asymptotically towards 31.2×10^9 recruits (Figure 2).

Function 2 is more complicated, and internally in the program it consists of two functions:

Function 2A:

$$Recruits = \frac{ParStock}{0.05 \cdot ParStock + 0.09}$$

This function represents a curve increasing asymptotically towards 20×10^9 recruits.

Function 2B:

$$Recruits = 10 \cdot ParStock$$

Function 2B represents a linear combination of parent stock biomass and number of recruits.

A combination of functions 2A and 2B is used to describe a periodicity in the success of the spawning in order to simulate the recruitment pattern that is observed in the stock. The asymptotic function (2A) is used for seven years in a row, and for the 8th year the linear function 2B is used.

In addition to the choice of recruitment functions, the user can select "stochastic recruitment", which means that the number of larvae calculated is multiplied by a "success factor", which is randomly selected from a table of 28 possible numbers as given in Table 1, and represents the ratio between the observed and the predicted number of larvae in the periods 1950 - 69 and 1973 - 80. The data are partly based on Dragesund, Hamre and Ulltang (1980), but also unpublished information has been used.

When stochastic recruitment has been selected, function 2B is not used.

The recruitment functions presently used have been taken over from earlier versions of the model. The basis for selecting the specific relationships used is not documented, and it will be necessary to re-evaluate those functions. Also there is now available a longer time series of data which must be utilized.

Migration

In the last version of HERMOD migration is implemented. The Norwegian Sea and the Barents Sea, which is the home range of this stock, have been divided into eighteen subareas (Figure 3). In the Barents Sea the areas are identical to those used by MULTSPEC, but in the Norwegian Sea new areas had to be defined. This has been done in such a way that the areas coincide roughly with the economic zones of the countries bordering the Norwegian Sea.

Matrices are constructed to describe the migration of the stock. The element a_{ij} on row i and column j of a matrix tells how many migrates from area i to area j. Since the elements in the last version of HERMOD represents parts they have values between zero and one. And because one time step is one month we need 12 matrices if we follow one specific herring throughout a year. But the route of a year depends on how old a herring is and whether it is mature or not, and seven migration routes have been described. This means we need one matrix pr. month pr. route. In addition two sets of matrices have been used in order to describe both the eventuality that the mature herring winters in the Ofotfjord/Tysfjord area in northern Norway, and the eventuality that it matures in the in the area east of Iceland like it did in the 1950s and early 1960s. The user may choose between these two sets of patterns which have been described as *clockwise* and *anticlockwise*. The migration is simulated by matrix multiplications between stock arrays and migration matrices.

An animation program has been made to visualize the migration patterns. This program uses the map in Figure 3.

INPUT

The following parameters are stored on a file and can be changed by the user (Figure 4).

- input data file
- natural mortality
- fishing mortality/catch per year
- distribution of catch on months through the year - recruitment to fishery (length dependent)
- recruitment function (choice of two) - stochastic recruitment (yes or no)
- steepness of maturation curve
- length at which 50% are mature
- migration pattern (clockwise or anti clockwise)
- choice of four output reports (see *output*)
- number of years to run the model
- number of times to run the model (if stochastic recruitment has been selected)

OUTPUT

Four types of output reports are possible: one rather comprehensive report, one condensed version, one containing length tables and one containing biomass tables

- The comprehensive report gives the following information: mean lengths and numbers of each age group for each month, biomass for the total stock and the spawning stock for each month, catch in numbers of each age group for each month, weight of total catch in each month, mean weight of the herring caught each month, and fishing mortality each month for the herring that is fully recruited.
- The condensed report is intended for use when the program is repeated many times to see the possible effect of stochastic recruitment, and gives the following information: success-factor, spawning stock, and catch for each run - mean and standard deviation of the same parameters for all the runs.
- The length tables are needed for input to the animation program which visualizes the migration of the total stock on a map of the Barents Sea and the Norwegian Sea (Figure 3).
- The biomass tables show the biomass predicted in the different areas during the year.

Example of the tables given in the comprehensive report and the condensed report is given in Tables 2 and 3, respectively.

DISCUSSION

The algorithm used for density dependent growth is rather primitive, and it only takes into account the biomass of the stock in the total area of distribution. Factors like geographical distribution, temperature, and availability of food in the present year and previous years are not taken into account. These factors may be as important as the total stock biomass, or even more important. In particular, local variations in density, temperature and availability of food may lead to quite different growth patterns for different components of the stock. In order to make the model more realistic, a new growth algorithm must be developed that takes into account the effects of temperature and food availability as well as density - or allows the user to compensate for these effects in the parameter file. As described earlier in this paper, the user can choose from two separate sets of migration patterns. A combination of these two patterns is impossible at present but would have been advantageous as the whole stock may not change migration patterns simultaneously.

In the present version of the model maturation, weight, and recruitment to the fishery are all length dependent. Thus, too high mean lengths will give too early maturation, too high spawning stock and too high total biomass, and the year classes will enter the fishery at a too early age. Too low mean lengths will have the opposite effect. A good algorithm for growth is therefore essential for good simulation.

The algorithm for maturation is of the same kind as the one used by MULTSPEC for capelin (Tjelmeland and Bogstad, 1989). The constants in the algorithm may need adjustment, but this can best be done when a better growth algorithm has been worked out.

The algorithms used for recruitment are not well documented at present. In addition, the optional "stochastic" recruitment is highly speculative. It is necessary to go carefully through the historical material that is available in order to substantiate the relationships that are expressed in the model - or adjust the recruitment algorithms.

Experience with the model shows that it is necessary to be able to adjust the model to known start situations, and it may be necessary to add options that allow the user to control growth, maturation, and recruitment.

A new version of this model is under development. Natural mortality will be made length dependent, it will be possible to use a different fishing mortality for each year, and it will be possible to combine the two sets of migration patterns. An effort will be made to improve algorithms for growth, maturity, and recruitment - possibly by using more traditional and straight forward solutions than those in the present model. First of all though HERMOD must be readied for interfacing with MULTSPEC.

LITERATURE

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Table 1. Spawning stock, observed number of recruits, predicted number of recruits, and ratio between observed and predicted number of recruits, using the recruitment functions 1 and 2 in HERMOD (Predicted 1 and Success 1, Predicted 2 and Success 2, respectively) for 28 years in the period 1950 - 1980. Note that the model has been in mode 'stochastic' during the calculation, so that only recruitment function 2A has been used.

Spawning stock in thousand tonnes
Number of larvae actually observed * 10^{-9}
Number of larvae predicted by recruitment function * 10^{-9}
Success of spawning (observed number/predicted number)

Year:	1950	1951	1952	1953	1954	1955	1956
Spawning stock:	9400	9100	8800	7100	7600	8800	8900
Observed no. of recruits:	97.4	26.1	27.9	21.0	16.9	9.2	11.1
Predicted from r.func. 1:	31.0	31.0	31.0	30.9	31.0	31.0	31.0
Predicted from r.func. 2:	16.8	16.7	16.6	16.0	16.2	16.6	16.6
Success 1:	3.1	0.8	0.9	0.7	0.5	0.3	0.4
Success 2:	5.8	1.6	1.7	1.3	1.0	0.6	0.7

Year:	1957	1958	1959	1960	1961	1962	1963
Spawning stock:	10000	8500	7500	5500	4100	3300	2500
Observed no. of recruits:	9.7	13.7	75.0	47.5	18.3	7.2	26.3
Predicted from r.func. 1:	31.0	31.0	31.0	28.6	21.4	16.1	10.9
Predicted from r.func. 2:	16.9	16.5	16.1	15.1	13.9	12.9	11.6
Success 1:	0.3	0.4	2.4	1.7	0.9	0.4	2.4
Success 2:	0.6	0.8	4.6	3.2	1.3	0.6	2.3

Year:	1964	1965	1966	1967	1968	1969	1973
Spawning stock:	3400	3700	2800	1400	280	90	110
Observed no. of recruits:	17.3	3.6	17.3	1.2	2.6	2.0	1.2
Predicted from r.func. 1:	16.8	18.8	12.8	5.0	0.8	0.2	0.3
Predicted from r.func. 2:	13.1	13.5	12.2	8.7	2.7	1.0	1.2
Success 1:	1.0	0.2	1.4	0.3	3.3	8.1	4.0
Success 2:	1.3	0.3	1.4	0.1	1.0	2.1	1.0

Year:	1974	1975	1976	1977	1978	1979	1980
Spawning stock:	90	80	120	240	290	330	380
Observed no. of recruits:	0.7	0.2	0.7	0.5	0.5	0.7	0.2
Predicted from r.func. 1:	0.2	0.2	0.3	0.7	0.8	1.0	1.1
Predicted from r.func. 2:	1.0	0.9	1.2	2.4	2.8	3.1	3.5
Success 1:	2.8	0.9	2.1	0.7	0.6	0.7	0.2
Success 2:	0.7	0.2	0.6	0.2	0.2	0.2	0.1

RESULTS

Year 1988

Mean lengths for age groups

Age	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	-	-	-	-	-	5.0	6.8	8.5	10.3	12.0	12.0	12.0
1	12.0	12.0	12.0	12.0	12.0	14.1	16.2	18.4	20.5	22.6	22.6	22.6
2	22.6	22.6	22.5	22.5	22.5	23.7	24.9	26.2	27.4	28.6	28.5	28.5
3	28.7	28.7	28.6	28.5	28.5	29.0	29.6	30.1	30.6	31.1	31.0	31.0
4	31.3	31.3	31.2	31.2	31.2	31.5	31.8	32.2	32.5	32.8	32.8	32.8
5	33.0	33.0	32.9	32.9	32.9	33.2	33.4	33.7	33.9	34.2	34.1	34.1
6	34.2	34.2	34.2	34.2	34.2	34.4	34.6	34.8	35.0	35.2	35.2	35.2
7	35.2	35.2	35.2	35.2	35.2	35.4	35.5	35.7	35.8	36.0	36.0	36.0
8	36.0	36.0	36.0	36.0	36.0	36.1	36.3	36.5	36.6	36.8	36.8	36.8
9	36.8	36.8	36.8	36.8	36.8	36.9	37.0	37.2	37.3	37.4	37.4	37.4
10	37.4	37.4	37.4	37.4	37.4	37.5	37.6	37.7	37.8	37.9	37.9	37.9
11	37.9	37.9	37.9	37.9	37.9	38.0	38.0	38.1	38.2	38.2	38.2	38.2
12	38.2	38.2	38.2	38.2	38.2	38.3	38.3	38.3	38.4	38.4	38.4	38.4
13	38.4	38.4	38.4	38.4	38.4	38.5	38.5	38.5	38.5	38.6	38.6	38.6
14	38.6	38.6	38.6	38.6	38.6	38.6	38.6	38.6	38.7	38.7	38.7	38.7
15	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7	38.7

Stock
Numbers in millions of individuals
Weight and spawning stock in thousand tonnes

Age	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0	0	0	262	259	256	254	251	248	6
1	262	259	256	254	251	248	246	243	240	237	232	9
2	143	141	137	132	131	130	128	127	125	120	114	113
3	267	264	242	222	219	217	214	212	210	198	186	184
4	150	148	133	118	117	116	115	113	112	105	98	97
5	6997	6922	6128	5426	5368	5310	5253	5196	5140	4798	4477	4429
6	18	18	16	14	14	14	13	13	13	12	11	11
7	10	10	9	8	8	8	7	7	7	7	6	6
8	15	15	13	12	11	11	11	11	11	10	9	9
9	28	28	24	22	21	21	21	21	20	19	16	18
10	23	23	20	18	17	17	17	17	17	16	15	14
11	44	44	38	34	33	33	33	32	32	30	[illegible]	28
12	41	41	36	32	31	31	30	30	30	28	[illegible]	26
13	1	1	1	1	1	1	1	1	1	1	[illegible]	1
14	21	21	18	16	16	16	16	15	15	14	[illegible]	13
15	31	31	27	24	24	23	23	23	23	21	[illegible]	19
Sum:	8051	7964	7098	6331	6262	6457	6387	6318	6250	5865	5502	5443
Weight:	2931.5	2930.4	2394.0	1932.3	1925.1	2247.9	2396.5	2530.8	2617.8	2457.8	2233.7	2130.8
Spawn:	2875.7	2875.7	2875.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Catch
Numbers in millions of individuals
Weight in thousand tonnes
Mean weight in grammes
Instantaneous fishing mortality per month for the fully recruited yearclasses

Age	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	1	2	0	0
2	0	3	3	0	0	0	0	0	4	5	0	0
3	0	20	18	0	0	0	0	0	10	10	0	0
4	0	14	13	0	0	0	0	0	6	6	0	0
5	0	723	639	0	0	0	0	0	289	270	0	0
6	0	2	2	0	0	0	0	0	1	1	0	0
7	0	1	1	0	0	0	0	0	[illegible]	0	0	0
8	0	2	1	0	0	0	0	0	[illegible]	1	0	0
9	0	3	3	0	0	0	0	0	1	1	0	0
10	0	2	2	0	0	0	0	0	1	1	0	0
11	0	5	4	0	0	0	0	0	2	2	0	0
12	0	4	4	0	0	0	0	0	[illegible]	2	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	[illegible]	2	0	0	0	0	0	[illegible]	1	0	0
15	0	[illegible]	3	0	0	0	0	0	[illegible]	1	0	0
Sum:	0	[illegible]	695	0	0	0	0	0	[illegible]	[illegible]	0	0
Weight:	0.0	[illegible]	250.8	0.0	0.0	0.0	0.0	0.0	[illegible]	[illegible]	0.0	0.0
M.wgnt:	-	[illegible]	361.1	-	-	-	-	-	[illegible]	[illegible]	-	-
F.mort:	0.00	[illegible]	0.12	0.00	0.00	0.00	0.00	0.00	[illegible]	0.06	0.00	0.00

Table 2. Part of a comprehensive report from HERMOD.

```
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
Printout from program hermod    date 29-07-1994    time 09:41:03
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
areas: 1 - 18    sexes:  1          ages: 0 - 15     lengths: 4 - 45
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

results
=======

success = observed/predicted number of larvae
catch = catch during the year in thousand tonnes
sstock = spawning stock in march in thousand tonnes
tstock = total stock in december in thousand tonnes
sumct = catch during the year + total stock in december

run no.	1992 success	1992 catch	1992 sstock	1993 success	1993 catch	1993 sstock	1994 success	1994 catch	1994 sstock	catch 1992-94	tstock 1994	sumct 1994
1	2.1	1125	5661	1.3	2508	10127	2.3	4820	17301	4820	66487	71307
2	0.2	1125	5661	0.6	2508	10127	1.0	4774	17301	4774	129145	138739
3	0.1	1125	5661	5.8	2508	10127	3.2	4772	17301	4772	191240	205606
4	0.6	1125	5661	0.1	2508	10127	0.2	4796	17301	4796	253201	272363
5	1.0	1125	5661	1.4	2508	10127	1.3	4825	17301	4825	319923	343909
6	3.2	1125	5661	1.0	2508	10127	0.6	4950	17301	4950	394248	423184
7	3.2	1125	5661	0.2	2508	10127	0.6	4950	17301	4950	467225	501112
8	1.0	1125	5661	1.3	2508	10127	0.2	4825	17301	4825	533113	571824
9	0.6	1125	5661	0.1	2508	10127	1.6	4797	17301	4797	595791	639300
10	4.6	1125	5661	0.7	2508	10127	1.3	5039	17301	5039	676127	724674
11	1.6	1125	5661	1.3	2508	10127	0.2	4856	17301	4856	745390	798794
12	0.8	1125	5661	0.2	2508	10127	0.6	4812	17301	4812	808815	867031
13	0.6	1125	5661	2.1	2508	10127	1.6	4803	17301	4803	875007	938025
4	1.0	1125	5661	1.4	2508	10127	0.2	4841	17301	4841	942180	1010039
15	0.1	1125	5661	1.3	2508	10127	0.7	4766	17301	4766	1004347	1076972
16	0.7	1125	5661	0.6	2508	10127	0.1	4807	17301	4807	1067728	1145161
17	1.0	1125	5661	1.0	2508	10127	1.3	4820	17301	4820	1133354	1215606
18	0.6	1125	5661	4.6	2508	10127	2.1	4796	17301	4796	1196909	1283958
19	1.7	1125	5661	2.3	2508	10127	0.7	4863	17301	4863	1267165	1359076
20	0.7	1125	5661	0.6	2508	10127	1.3	4825	17301	4825	1332317	1429053
mean:	1.3	1125	5661	1.4	1383	4466	1.1	2329	7175			
st.dev.:	1.2	0	0	1.4	0	0	0.8	0	0			

run no.	1995 success	1995 catch	1995 sstock	1996 success	1996 catch	1996 sstock	1997 success	1997 catch	1997 sstock	catch 1995-97	tstock 1997	sumct 1997
1	4.6	3496	9549	1.7	8034	32842	1.4	13163	53245	13163	1475438	1585337
2	1.3	3320	9526	0.1	7410	31493	0.7	11239	49645	11239	1563074	1684212
3	0.2	3261	9525	0.2	7390	31407	1.7	11615	48137	11615	1658082	1790834
4	1.3	3336	9537	5.8	7229	32101	1.4	10540	49336	10540	1763502	1906795
5	1.4	3520	9551	0.8	8047	32980	1.6	12604	53747	12604	1870614	2026511
6	1.6	3971	9613	0.3	9112	36592	1.7	14114	62542	14114	1977754	2147766
7	0.7	3924	9613	0.8	8880	36568	0.7	13488	61165	13488	2072726	2256225
8	0.3	3514	9551	0.6	7855	32977	1.6	11606	53499	11606	2146703	2341809
9	1.4	3341	9537	1.7	7396	32136	0.7	11198	49504	11198	2241106	2447410
10	1.4	4290	9657	1.3	10022	39157	1.0	15912	68812	15912	2365457	2587673
11	0.2	3674	9566	3.2	8384	33890	0.2	12741	57103	12741	2467628	2702584
12	0.2	3404	9545	4.6	7465	32582	0.2	10874	50758	10874	2539744	2785575
13	0.1	3474	9540	0.7	7988	32352	1.0	12535	53164	12535	2642550	2900916
14	0.3	3580	9559	1.7	8049	33446	0.1	11975	54886	11975	2725885	2996226
15	3.2	3292	9522	0.2	7339	31281	2.3	11307	49094	11307	2827338	3108987
16	1.0	3402	9542	1.0	7453	32425	4.6	10845	50863	10845	2905642	3198136
17	4.6	3480	9549	0.2	7855	32835	2.3	12486	52744	12486	3028849	3333829
18	0.3	3362	9537	1.0	7565	32125	1.0	11603	50184	11603	3121704	3438287
19	3.2	3711	9570	0.2	8559	34099	3.2	13553	57947	13553	3239942	3570078
20	0.6	3469	9551	1.0	7766	32952	1.0	11795	52275	11795	3331697	3673628
mean:	1.4	3541	9557	1.4	4449	23755	1.4	4270	20621			
st.dev.:	1.4	0	0	1.5	0	0	1.1	0	0			

concentrate of data, for all years and all runs
success = observed/predicted number of larvae
catch = catch during the year in thousand tonnes
sstock = spawning stock in march in thousand tonnes
tstock = total stock in december in thousand tonnes
sumct = catch during the year + total stock in december
means = means over years and runs
st.dev. = standard deviations over years and runs

	success	catch	sstock	tstock	sumct
mean:	1.3	2849	11872	27764	1654180
st.dev.:	1.2	0	0	0	1078612

Table 3. Example of a condensed report from HERMOD.

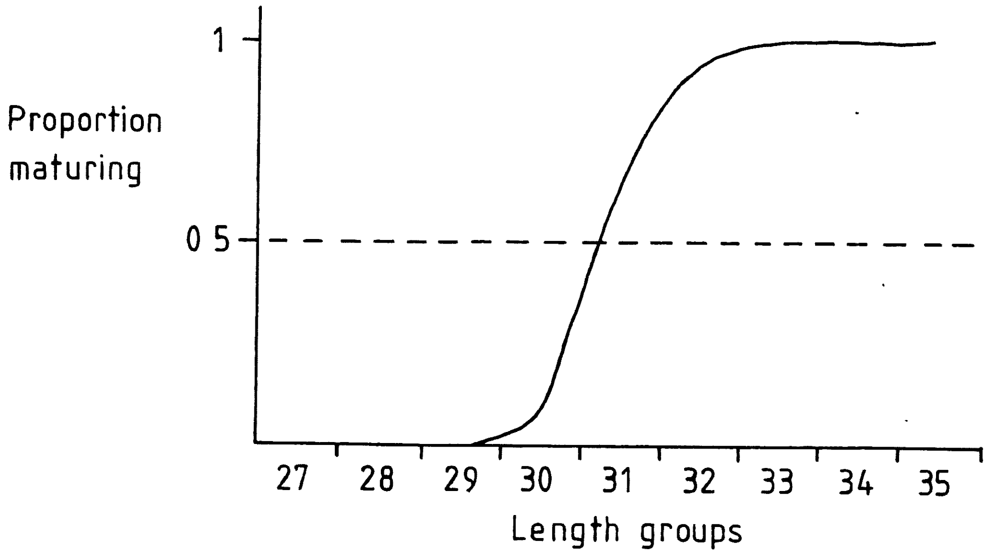

Figure 1. Maturation curve based on the algorithm used in HERMOD (*Base* = 9.0, *LM50* = 31.2).

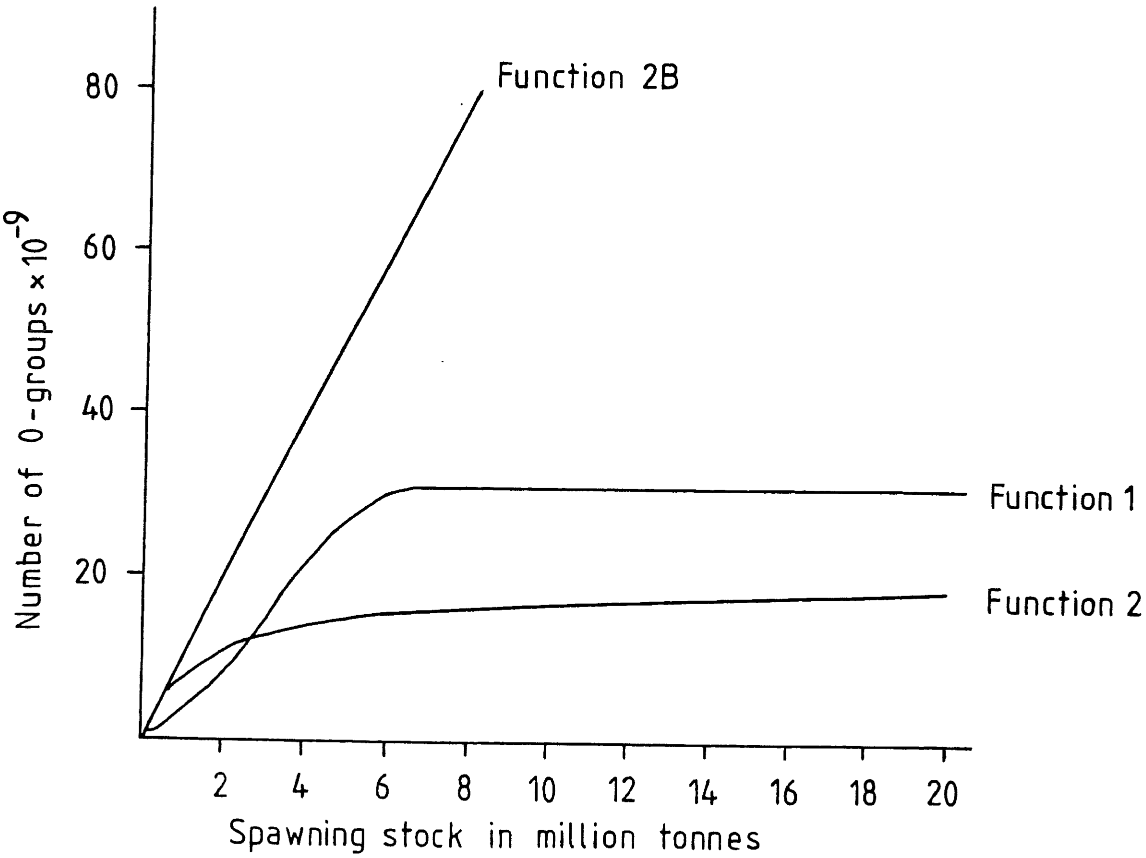

Figure 2. The recruitment functions used in HERMOD.

Figure 3. The areas used for implementing migration in HERMOD.

```
======================================================================
9.00   { start.bio.base       Determines steepness of maturation curve }
======================================================================

======================================================================
31.2   { start.bio.lm50       Length where 50% are mature. }
======================================================================

======================================================================
2      { start.bio.ralternative Recruitment alternative (1 or 2)  }
======================================================================

======================================================================
true   { start.bio.stochastic   True if stochastic recruitment is wanted }
======================================================================

======================================================================
cw     { start.bio.migpattern   Migration pattern. cw : clockwise, acw: anticlockwise
======================================================================
```

Figure 4. Part of the parameter file for HERMOD.