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An Approach to the Stock-Recruitment Relationship of Cod (*Gadus morhua*) in Divisions 2J and 3KL.

by

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Introduction

According to previous papers (Larrañeta, 1981a; and Vázquez and Larrañeta, 1980) it has been considered that in Div. 3M and 3NO cod stocks, regressions of the c.p.u.e. against effort show two levels of productivity. The same conclusion could be drawn from Vázquez's paper (1981) for cod in Div. 2J3KL. Theoretically, these two levels of productivity can be explained by changes in parameters of the Ricker stock-recruitment curve (Larrañeta, 1981b).

With these previous statements it has been analyzed the stock-recruitment relationship in the Div. 2J3KL cod stock, using the most recent vital statistics (Bishop and Gavaris, 1982).

Stock and recruitment data

The data used were (Table 1) numbers ($x10^{-5}$) at age 4, as recruitment, and numbers ($x10^{-5}$) and biomass (kg x 10^{-5}) for ages 5+, as parental stock. These data were obtained from Table 12 of Bishop and Gavaris' paper.

Parental stock (P) and recruitment (R) are plotted in Figure 1. It could be observed that points from 1962 to 1968 are grouped into the top-right quadrant, and those from 1969 to 1977 appear spread suggesting a dome-shaped curve.

Fitting of the Ricker curve

The distribution of points in Figure 1 agrees with our theory about periods of low and high productivity. In Figure 2a a historical sequence of points of the relationship between c.p.u.e. and effort is reproduced from Figure 1 of Vázquez's

paper (1981). In Figure 2b the same relationship is shown but using data on "mean of the relative power" (c.p.u.e.) and effort from Table 9 of Bishop and Gavaris' paper. Both Vázquez and Bishopand Gavaris apply a multiplicative model, but Vázquez weights efforts during the last five years. From 1959 to 1970 a high level of c.p.u.e. appears and from 1972 to 1979 a low one does. Bishop and Gavaris' data confirm that during the last years a new high level has been again reached. Therefore, it seems reasonable to deal separately in Figure 1 1962-1968 points from 1969-1977 ones.

Parameters of the Ricker equation $R=APe^{-BP}$ have been estimated from regression $\log R-\log P=\log A-BP$, where R is the recruitment and P the parental stock.

The results for the 1969-1977 period are the following:

i) If parental stock in numbers, A=3.0201 and B=.000267. The curve is drawn in Figure 1a. The relative (R_{obs}/R_{cal}) deviation is $\bar{x}$=1.0946 and s=.3684.

ii) If parental stock in biomass, A=2.8625 and B=.000255. The curve is drawn in Figure 1b. The relative deviation is $\bar{x}$=.9795 and s=.2806.

In Table 2 average recruitment and 95% confidence interval for parental stock in numbers are given, and in Table 3 average recruitment and 95% confidence interval for parental stock in biomass are done.

Points of the 1962-1968 period are not directly suitable to estimate the stock-recruitment curve. Nevertheless, it is possible to estimate a conjectural curve starting from the curve belonging to the low productivity period. The new curve will be shaped by changing Parameter A or Parameter B (or both) of the former curve and it would cross a middle point among the high productivity period points. In Figure 1 the middle point has been marked with a cross.

To change simultaneously both parameters seems a too subjetive approach. It will be better to fix one and to change the other. In the election of the parameter to be changed the following considerations have been taken into account.

a) Variation of Parameter A means acological or/and genetical changes, and variation of Parameter B means primary productivity changes (Larrañeta, 1979).

b) The election of Parameter B to be changed is a more pesimistic decision than the Parameter A one, because with a change in Parameter B the recruitment will be lower on the average than with a change in Parameter A, during the high productivity period.

c) If Parameter A is changed it will be expected the maximum recruitment at a lower parental stock than with a variation of Parameter B.

d) Double regression lines in a c.p.u.e.-effort diagram joining themselves on the right side mean (Larrañeta, 1981b) a change in Parameter B.

Adopting a prudent strategy and because in Figure 2 the regression lines (dashed lines) seem to joint themselves on the roght, Parameter B has been elected to be changed.

Parameters for the high productivity period are the following:

Parental stock in numbers, A=3.0201, B=.000134, $\bar{x}$=1.0166, s=.3031.
Parental stock in biomass, A=2.8625, B=.000123, $\bar{x}$=1.0404, s=.3913.

In Figure 1 the dashed lines show the stock-recruitment curves for the high productivity period. In Table 4 average recruitment and 95% confidence interval for parental stock in numbers are given, and in Table 5 average recruitment and 95% confidence interval for parental stock in biomass are done, during the high productivity period.

Discussion and conclusions

This approach is based on the asumption that there are periods of low and high productivity in the fishery. At least, it seems to have happened during the 1962-1977 interval. If this is true, points of the 1969-1977 period are fairly spread to estimate a Ricker curve.

An estimation of parameters for the high productivity period, starting from the 1969-1977 curve, was made on the conservative strategy that the parameter to be changed was the B one. This was a necessary simplification, but actually some change of Parameter A will also be produced. These estimations mean, therefore, a first approach to the stock--recruitment relationship of the stock. On the other hand, more refined calculus would be made by taking into account the fecundity at each age to deal with an egg-recruitment or basic curve (Larrañeta, 1981c).

Tables 2-5 may be used in catch projections, but I realise that at present it is difficult to say with low parental stocks if we are in a low or high productivity period. Nevertheless, looking at Figure 1 it seems that perhaps the stock is actually entering in a new high productivity period.

A suggestive feature is that points of the 1962-1968 period have a decreasing sequence before the 'leap' to the low productivity curve (Figure 1). Taking into account that Parameter

A only determines the height of the curve, and that Parameter B determines both the height and the shape of the curve, the last one varing the optimum parental stock size, the following pattern of an annual class sequence may be imagined.

Starting from a low productivity period, a leap to a high productivity one (because of an oceanographical change) means a change (decrease) of Parameter B, moving the optimum parental stock to a greater size. With the new environmental state, in few (2-3) steps a maximum recruitment is reached. But during the high productivity period some ecological succession will take place and because Parameter A is the expression of the ecological relationships of the stock a gradual decrease of Parameter A can be expected, flattening the curve. The whole pattern will be a sudden increase of the annual classes followed by a smoother decrease of them until falling into a new low productivity period. This pattern has been found by Larrañeta and Vázquez (1982) in the NE Arctic cod stock.

Finally, an interesting conclusion can be drawn from Figure 1, this is that with a 5+ aged parental stock greater than 1000 millions of spawners or 1200 thousands tons of them the maximum recruitment is not to be expected. On the contrary, according to Figure 1, optimum parental stock during a low productivity period would consist of about 300 millions of spawners or 400 thousands tons, and during a high productivity period around 750 millions of spawners or 800 thousands tons. At presente the stock for ages 5+ has been estimated, by Bishop and Gavaris (1982), in 1981 on 890.6 millions of individuals and a biomass of 1480.03 thounsands tons.

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Table 1. Parental stock for ages 5+ in numbers ($x10^{-5}$) and biomass (kg $x10^{-5}$), and recruitment in numbers ($x10^{-5}$) at age 4. Data from Bishop and Gavaris (1982).

	Parental stock		
Annual class	Num.	Biomass	Recruitment
1962	15720	19172	8167
1963	14462	17577	9254
1964	13483	16187	6710
1965	12017	13931	5786
1966	12406	13669	5369
1967	13596	14201	5915
1968	14922	14215	4775
1969	12305	11681	2137
1970	10443	10386	1298
1971	9760	10004	1387
1972	9601	9676	2806
1973	8290	8707	4238
1974	5934	6155	5132
1975	3562	3640	4959
1976	2461	2290	2969
1977	2720	3251	3355

Table 2. Parental stock in numbers ($x10^{-5}$), average recruitment ($x10^{-5}$) and 95% confidence interval, for a low productivity period.

P	$\bar{R}$	95% interval	
1000	2312	827	4235
2000	3541	1267	6485
3000	4067	1455	7448
4000	4152	1486	7604
5000	3974	1422	7268
6000	3651	1306	6687
7000	3262	1167	5973
8000	2854	1021	5227
9000	2458	880	4502
10000	2091	748	3830
11000	1762	630	3226
12000	1471	526	2695
13000	1220	437	2235
14000	1006	360	1843
15000	826	295	1512
16000	674	241	1235
17000	549	196	1005
18000	445	159	814
19000	359	129	658
20000	290	104	531

Table 3. Parental stock as biomass (kg $x10^{-5}$), average recruitment ($x10^{-5}$) and 95% confidence interval, for a low productivity period.

P	$\bar{R}$	95% interval	
1000	2218	928	3418
2000	3438	1438	5297
3000	3996	1671	6157
4000	4129	1727	6362
5000	3999	1673	6162
6000	3719	1555	5730
7000	3362	1406	5181
8000	2978	1245	4588
9000	2596	1086	4000
10000	2235	935	3444
11000	1905	797	2936
12000	1611	673	2482
13000	1352	565	2083
14000	1128	472	1739
15000	937	392	1443
16000	774	324	1193
17000	638	267	982
18000	523	219	806
19000	428	179	659
20000	349	146	538

Table 4. Parental stock in numbers ($x10^{-5}$), average recruitment ($x10^{-5}$) and 95% confidence interval, for a high productivity period.

P	$\bar{R}$	95% interval	
1000	2641	1084	4286
2000	4620	1896	7498
3000	6061	2488	9836
4000	7068	2901	11470
5000	7727	3171	12539
6000	8110	3328	13160
7000	8275	3396	13428
8000	8271	3394	13422
9000	8138	3340	13206
10000	7908	3245	12833
11000	7608	3122	12346
12000	7259	2979	11779
13000	6877	2822	11161
14000	6478	2658	10512
15000	6070	2491	9850
16000	5663	2324	9189
17000	5262	2160	8539
18000	4873	2000	7908
19000	4498	1846	7300
20000	4141	1700	6721

Table 5. Parental stock as biomass (kg $x10^{-5}$), average recruitment ($x10^{-5}$) and 95% confidence interval, for a high productivity period.

P	$\bar{R}$	95% interval	
1000	2531	653	4614
2000	4477	1154	8161
3000	5938	1531	10824
4000	7001	1805	12762
5000	7738	1995	14106
6000	8211	2117	14960
7000	8471	2184	15442
8000	8560	2207	15605
9000	8516	2195	15524
10000	8367	2157	15253
11000	8138	2098	14836
12000	7851	2024	14312
13000	7521	1939	13710
14000	7162	1846	13056
15000	6785	1749	12369
16000	6400	1650	11667
17000	6013	1550	10962
18000	5630	1451	10263
19000	5256	1355	9579
20000	4891	1261	8917
21000	4541	1171	8279
22000	4207	1085	7669
23000	3889	1003	7090
24000	3589	925	6542
25000	3305	852	6026

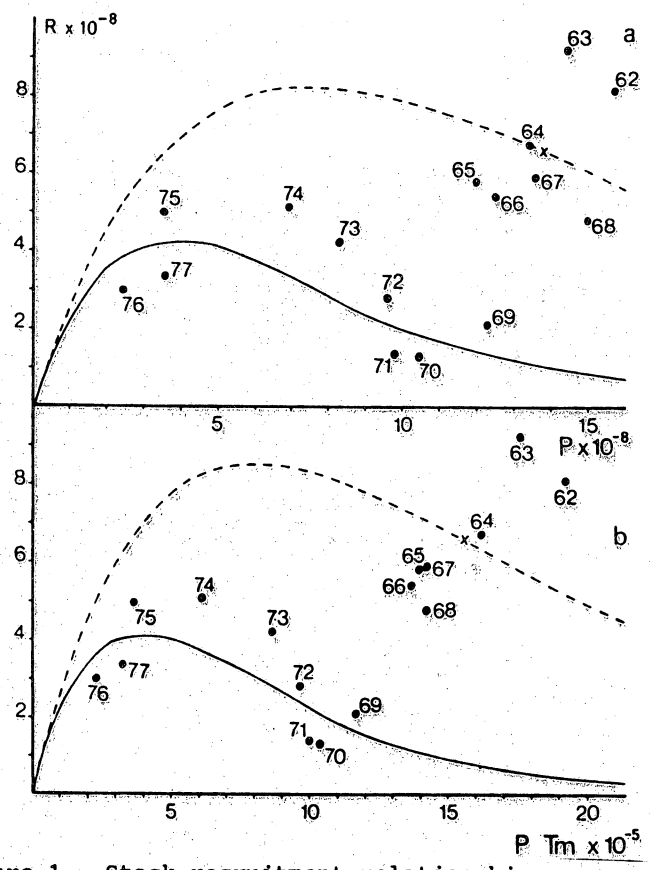

Figure 1.- Stock-recruitment relationship;
(a) parental stock in numbers;
(b) parental stock in biomass.

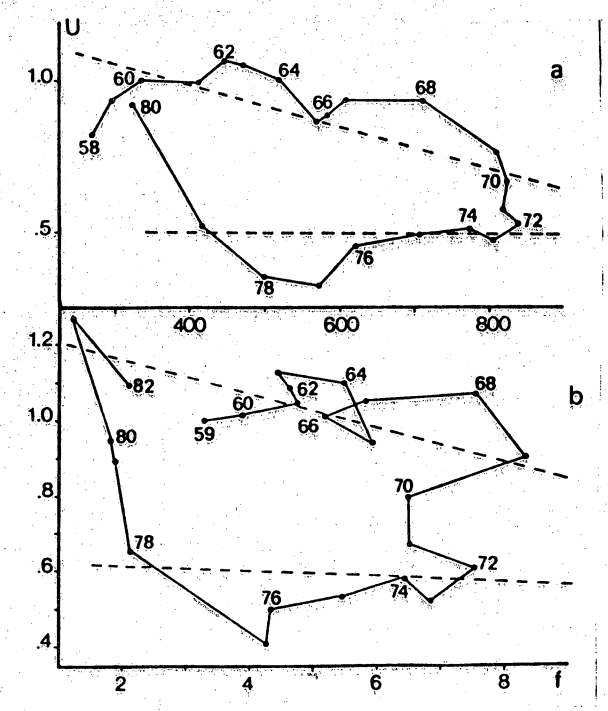

Figure 2.- C.p.u.e.-effort relationship; (a) from Vázquez (1981); (b) from Bishop and Gavaris (1982).