Northwest Atlantic Fisheries Organization

Serial No. N1990 NAFO SCR Doc. 91/98

SCIENTIFIC COUNCIL MEETING - SEPTEMBER 1991

Testing Non-parametric Methods to Estimate Cod Recruitment in NAFO Div. 3NO

by

J. Paz and M. G. Larrañeta

Instituto de Investivaciones Marinas, Eduardo Cabello, 6
36208 Vigo, Spain

COD SYMPOSIUM, SEPTEMBER 1991

Abstract

The non-parametric methods to estimate fish stock recruitment are generally simple, and they do not need to be based on ecological hypotheses.

In this paper we test four non-parametric methods: the probability transition matrix (Rothschild and Mullen, 1985) and three algorithms to estimate recruitment probability density functions (Evans and Rice, 1988).

In the case of the transition matrix, our main conclusion is that the method is inadequate. We prove that the cod stock lacks the primary Markovian assumption: the transition probability must be constant and depend only on the previous state.

For the three algorithm tests, the fixed-interval algorithm, the the New England algorithm and the Cauchy algorithm, only the New England one was appropiate for calculating recruitment with these stock data. We obtain a regression coefficient of r=0.556 (f.d.=23, p=0.003) when we compare the observed with the estimated data.

The results obtained using the fixed-interval and Cauchy algorithms were unsuitable.

The validity of the New England algorithm to estimate future recruitment will depend on the biotic and abiotic enviromental conditions being similar in both the pre-recruit and the observation periods.

Material and Methods

Cod recruitment (N_3) and stock (B_{6+}) data have been taken from Bishop *et al* (1990). Recruitment estimates for the period 1986-1989 have not been taken into account because the VPA analysis tends to underestimate the last recruitment values. The year-classes considered are those of 1956-1982, and the stocks those of 1959-1982 (Table 1).

In a first analysis (Fig. 1) we see that recruitment was higher for the 1956-1969 year-classes than for the 1970-1982 ones. With logarithmic transformation it emerges that only recruitment of the 1963 year-class falls outside the normal distribution 95% level, though inside the 97% level. For this reason we consider that every recruitment value is within significantly probable limits of the normal variation.

For the transition matrix used we have followed Rothschild and Mullen (1985), and used the algorithms of Evans and Rice (1988).

To test the algorithms, a series of annual recruitments values as predicted by each algorithm was calculated. To obtain the recruitment value for each year, corresponding to the reported stock at that moment, the full stock-recruitment data available were used excluding the figure of that year.

Results and discussion

Transition Matrix

Each year-class 1959-1982 recruitment (N_3) and spwaning biomass (B_{6+}) has been classified into two similar series: 12 low and 12 high, to obtain the following "states":

S1= low stock/low recruitment,
S2= low stock/high recruitment,
S3= high stock/high recruitment,
S4= high stock/low recruitment.

Year-classes were placed in chronological order, and the number of transitions between states were observed, resulting in this matrix:

State	**1**	**2**	**3**	**4**
1	5	1	0	2
2	2	0	2	0
3	0	3	5	0
4	1	0	0	2

As the total number of transitions is 23, the mean frequency in each cell will be 23/16= 1.44. To test the observed frequency distribution for heterogeneity, a Chi-square test was used and the value, X^2=20.43, (f. d.=15, p>0.5) obtained. The heterogenity hypothesis has been rejected.

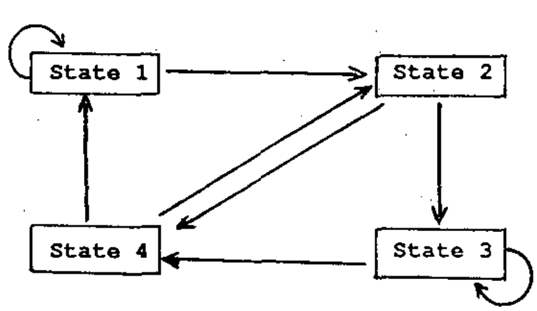
Dividing the number of transitions of ij^{-th} the element of the above matrix by the total number of transitions in the j-th row we obtain the p_{ij}-th element of the probability transition matrix among all four states:

State	1	2	3	4
1	0.625	0.125	0.00	0.25
2	0.50	0.00	0.50	0.00
3	0.00	0.375	0.625	0.00
4	0.333	0.00	0.00	0.667

The transitions 1-1, 3-3 and 4-4 have higher probabilities. This suggests a spawning biomass autocorrelation (which is reasonable because it is composed of several year-classes) with recruitment in successive years. In fact, Myers, Blanchard and Thompson (1990) obtain a high autocorrelation function (ACF=0.749) between cod recruitments in Div. 3NO. We have also obtained significant autocorrelations with lag of 1, 2 and 3 years: ACF_1= 0.80, ACF_2= 0.66 and ACF_3= 0.59. This signifies that the factors determining recruitment in consecutive years are similar. If VPA does not underestimate the last recruitment, these should provide a reliable estimate for the next recruitment.

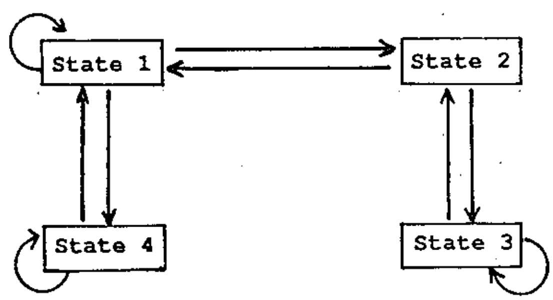
If we assume that these stock-recruitment transitions are Markovian, then further deductions regarding future observations of the stock-recruitment relationship can be made. The primary Markovian assumption is that transition probabilities are constant and only depend on the previous state. This Markovian condition will depend both on the prevailing physical environment, including fishing, and the ecological niche remaining constant during the projection time.

One method to test these probabilities is to draw a theoretical transition diagram according to the adopted classification. The result is as follows:



We have supposed that each state depends only on the previous state. Then, since with constant natural mortality, the change from low recruitment to high sotck is not possible, this transitions has been eliminated from the digram. The real problem is the transition between stock and the recruitment with variable natural mortality.

According to the probability transition matrix we obtain this pattern corresponding to the empirical transition diagram:



A comparison of the two diagrams reveals fundamental differences, not because of the missing transitions (transitions 3-4, 2-4 and 4-2 are abssent in the empirical matrix), which may be due to insufficient data, but because the theoretical diagram has extra transitions, such as the 4-4, 2-1, 3-2 and 1-4. These features indicate that the primary Markovian assumption is not valid for this cod stock. In fact, the cod matures at about six years old, so that spawning stock depends on recruitment six or more years earlier.

Non-parametric algorithms.

a) The fixed interval algorithm.

According to Evans and Rice (1988), the stock axis is divided into a chosen number of interevals, each containing as nearly as possible the same number of the past observations. The yerar`s stock lies in one of the intervals. It is assumed that only recruitments from past observations in that interval are possible, and they are of equal probability.

In our case the spawning stocks are divided into seven groups with four stocks in each, according to stocks increasing order. Given a stock its recruitment was estimated choosing the recruitment of the intermediate stock of the three remaining stocks.

The correlation coefficient between estimated and observed recruitment values is $r=0.260$ (f. d.=23, and $p= 0.224$), which is not significant.

b) The New England algorithm.

The stock and recruitment axes are divided subjectively into convenient intervals. The probability density function is constant within each recruitment interval, proportional to the number of past observations that are in both that recruitment interval and the stock interval containing the year's stock.

The spawning stock series was divided into six intervals of 30 thousands mt wide, the limits being 20 and 200 thousand mt. Recruitment values corresponding to the cod stock year-class in each interval were put in ascending order and the median selected. As an example, in figure 2 the ogive of the recruitment probability density function (pdf) for the 1959 and 1972 year-classes is shown.

The ordinate axis is divided into as many regular steps as there are stocks in the interval, and the abcissa represents increasing values of recruitment. The recruitment selected is that corresponding to the 50% level step.

The correlation coefficient between the estimated recruitment values and the observed values was r= 0.556 (f. d.= 23, and p= 0.03). This correlation can be considered significant.

c) The Cauchy algorithm.

The pdf is weighted according to algorithm $y=1/(1+(x/D)^2)$, where **D** is a chosen characteristic width (stock size), and **x** is the absolute difference between the past stock size and the stock size of this year. When x=0, then the recruitment probability corresponding to selected stock has a maximum. The pdf ogive should be also drawn in increasing order of the recruitment. As an exemple we show, in the figure 3, the pdf ojive of the 1959 and 1972 year-class recruitment.

If we take as a more probable recruitment value the one which has a higher **y** value, then, the correlation between the estimated and observed recruitment values is: r=0.279 (f.d=23, p=0.178); the correlation is not significant. In a new attemp following Figure 1, all periods studied were divided into two subperiods, one with high 1959-69 year-class recruitment and the other with lower 1970-82 year-class recruitment. The correlation in this case is r=0.496 (f. d.=23 and p=0.013).

Conclusion

The use of the New England algorithm was the only non-parametric method suitable to estimate cod stock Div. 3NO recruitment employing the remaining year-classes in the period

1959-1982. The validity of using this algorithm in the future will depend on the fact that the biotic and abiotic enviromental conditions be similar for the prerecruitment phase and the observation stock-recruitment period.

The results obtained using the transition matrix, the fixed interval algorithm and the Cauchy algorithm were unsuitable for this cod stock.

REFERENCES.-

Bishop, C. A., Baird J. W. and Murphy E.F..1990. The assesment of Cod Sotck in NAFO Div. 3NO. NAFO SCR Doc. 90/73 Serial nº 1795, 35p..

Evans, G. T. and Rice J. C. 1988. Preedicting recruitment from stock size without the mediation of a functinal relation. J. Cons. int. Explor. Mer 44: 111-122.

Rothschild,, B. J, and Mullen, A. J.. 1985. The information content of stock-and-recruitment data and its non-parametric classification. J. Cons. int. Explor. Mer, 42: 116-124.

Year-class	**Recruitment year**	**Population Number (000s)**	**Biomass (Tons) (B_{6+})**
1956	1959	53698	---
1957	1960	53179	---
1958	1961	82134	---
1959	1962	107755	89220
1960	1963	78284	72956
1961	1964	112516	90018
1962	1965	162762	80480
1963	1966	210243	88029
1964	1967	183387	112830
1965	1968	101714	120660
1966	1969	128599	104875
1967	1970	80905	93820
1968	1971	86121	83341
1969	1972	63163	81217
1970	1973	37594	82481
1971	1974	41586	90799
1972	1975	26552	81758
1973	1976	33510	61446
1974	1977	52753	60994
1975	1978	61688	27912
1976	1979	21747	23903
1977	1980	23345	35541
1978	1981	33823	42314
1979	1982	24673	52004
1980	1983	35426	103667
1981	1984	47223	157436
1982	1985	32581	172654

Table 1.- Population numbers (000s) and Biomass (Tons) for cod in Div. 3NO from Bishop *et al.* (1990).

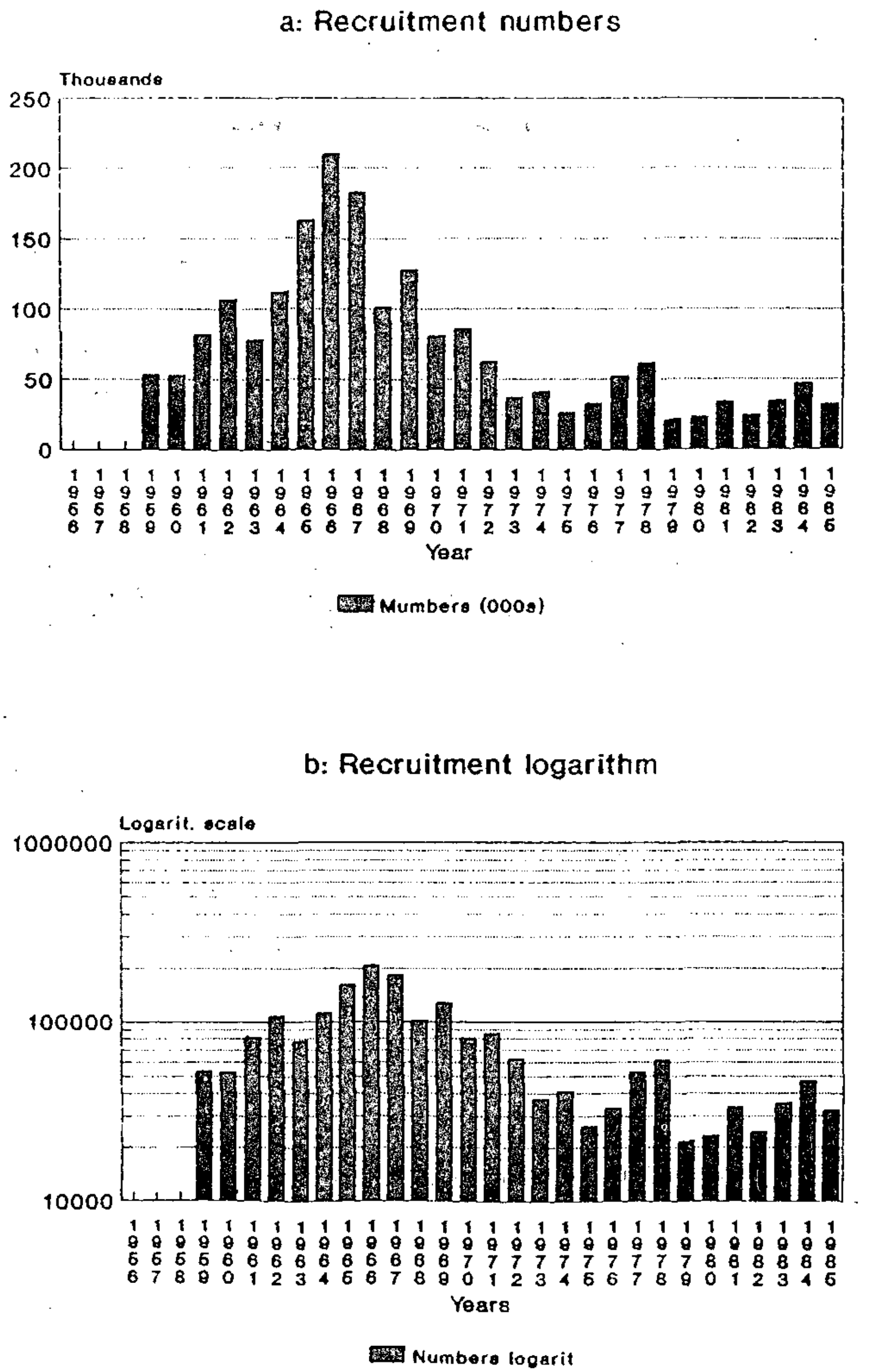


Figure 1.- Cod year-class recruitment in NAFO Divison 3NO.
a: recruitment number; b:recruitment logarithm.

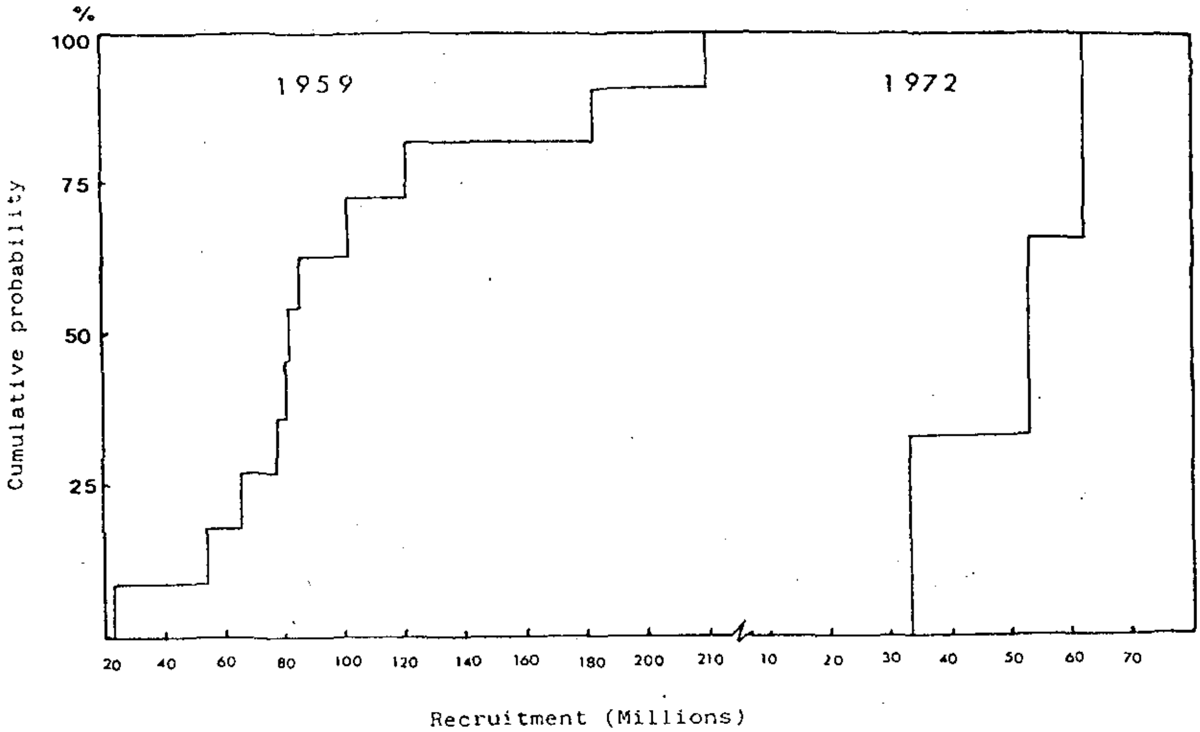


Figure 2.- The step function of cumulative probability of cod Div. 3NO recruitment. The New England algorithm used 3 stock intervals. 1959 and 1972 year-class recruitment.

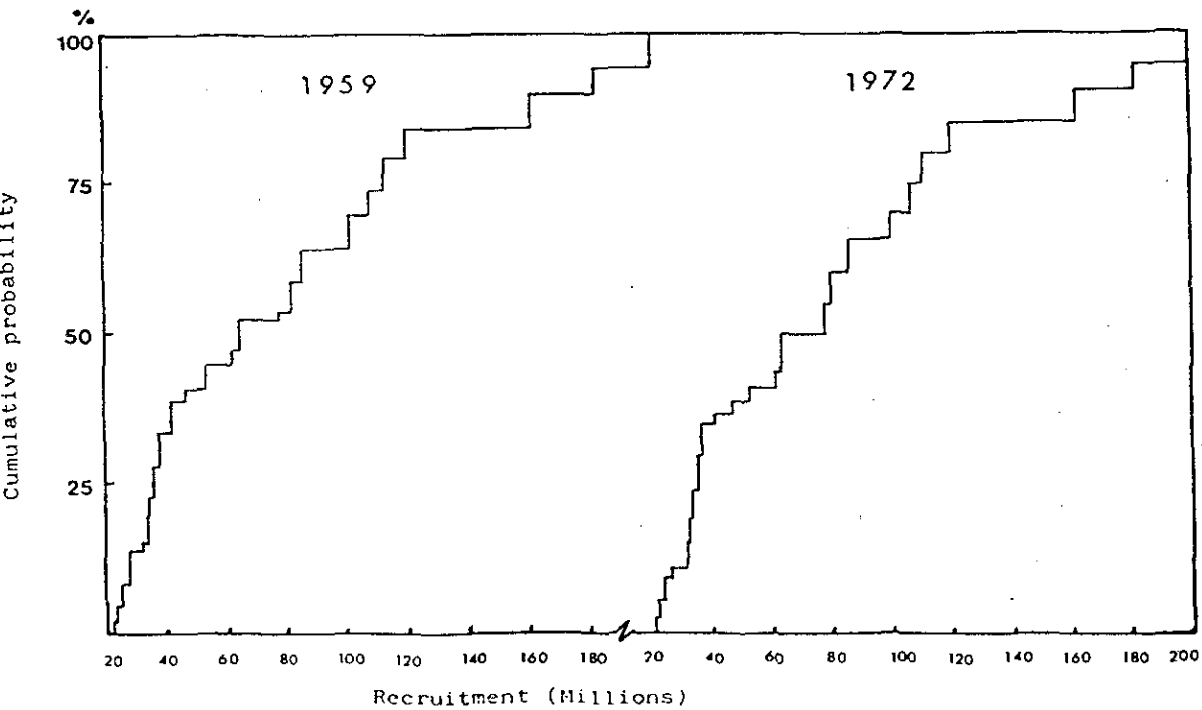


Figure 3.- The step function of cumulative probability of cod 3NO recruitment. The Cauchy algorithm used a characteristic width stocks units.