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Possible Approach to the Analysis of Stock-recruitment Relationship by the Example of Some Fish Species in NAFO Area: Role of the Latter in These Species Abundance Dynamics and Fishery Management

By

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Abstract

The attempt was made to reveal the indications of the stock-recruitment relationship effect, differences in its manifestation pattern and to evaluate, at least at the qualitative level, the extent of its impact on recruitment abundance formation in 12 unit stocks of fish in NAFO area. Classification of the spawning biomass by favourable, high and low level and estimation of respective mean ratios became the methodical basis of this approach application. The indications of SRR effect were found in all stocks considered. The results obtained, allow to distinguish 2 fish groups distinctly different in this relationship extent and manifestation pattern. For each group the recommendations on fishery management and, accordingly, optimal range of spawning biomasses was proposed on the basis of qualitative assessment of the limiting reference points level.

INTRODUCTION

Since the classic publication by Ricker (1954) on the «stock-recruitment» problem, scientists of the world continue this problem investigation. It would seem that during the years passed everything was studied that could be ever studied. But what is the actual fact? Certainly, at present many evidences exist that the stock-recruitment relationship (SRR) is of universal nature exposing more or less in all freshwater, marine and ocean fishes (Nikolsky, 1974; Cushing, 1975; Parrish (editor), 1973). The precautionary approach (PA) to fishery management, officially recognized as the principle mechanism of fishery regulation in convention areas, is to a great extent based on this idea. On the basis of above considerations it might seem that SRR is always the major factor affecting fish population abundance dynamics. However, actually SRR is most pronounced in Pacific salmon only. In other fish species the extent of the relation impact on their stocks dynamics varies considerably and sometimes even is almost totally suppressed by environmental factors within a wide range of stock spawning biomasses (SSB). The form of SRR manifestation in different species and populations also could not be the same. Sometimes the erroneous impression of the total SRR absence in some species considered may appear based on chaotic scatter of points on respective plots. As you can see, there are still areas to be researched in this field.

In this work the attempt has been taken to find the ways of SRR effect detection, to reveal differences in the form of SRR manifestation in the stock units considered, and to evaluate, at least qualitatively, the extent of the density relationship impact on year-classes abundance.

MATERIAL AND METHODS

Twelve stock units of commercial fish species living in NAFO subdivisions 2-6 were studied. Retrospective data on recruitment (abundance of the first age group represented in analytical estimates) and spawning biomass for respective years (as indicated in the Legends) were obtained from the following sources:

Stock unit	Data Source
2J+3KL Cod	Baird and Bishop, 1986
3NO Cod	Healey *et al*., 2003
3Ps Cod	Bishop and Baird, 1985
4VWX Silver Hake	Showell, 1997
5Ze Silver Hake	Almeida and Anderson, 1979
5Zw+6 Silver Hake	Almeida and Anderson, 1979
5Ze Red Hake	Almeida *et al*., 1979
5Zw+6 Red Hake	Almeida *et al*., 1979
2+3 Greenland Halibut	Darby *et al*., 2004
3LNO Yellowtail Flounder	Brodie, 1985
3LNO American Plaice	Brodie, 1985
3+6 Atlantic Mackerel	Isakov *et al*., 1976

In all cases estimated were obtained using the virtual population analysis. Spawning stocks were estimated as a sum of age groups biomasses starting from specific age (Rikhter, 2004), except Atlantic mackerel and cod 3NO, when estimations were based on ogives of sex maturity (Isakov *et al*., Healey *et al*., 2003).

Note that the above mentioned study is of one-sided nature, since it considers SRR effect at the right side of biomass observations series only, while in the fishery management practice the left side is much more important. As is known, PA is based on assessment of the lower limiting reference point boundaries of SSB only.

Analysis was made applying non-parametric methods in view of the following considerations. During the latest 50 years scientists from various countries have made numerous attempts to fit the empiric data to the theoretic SRR curves. However, the progress achieved in this aspect could be hardly considered as significant in respect to efficient solution of problems of abundance dynamics and fish population management. The author's attempt to attain success in this way, using appropriate theoretical relationships, has not become an exception (Rikhter, 1990). It seems that this research direction was self-exhausted and something new should be proposed, at least tried, in order to promote the research in this field.

To solve this problem the *ad hoc* methodical approach has been applied, which was mentioned for the first time in 2004 (Rikhter, 2004). The essence of this method is the following. The years are selected when strong year-classes appeared. In this case year-class abundance deviation from the long-term mean, exceeding 20% at the age of first occurrence in analytical estimates, was use as the criterion.

Certainly, the question may arise concerning the correctness of applying this criterion. However, in this case a counter-question occurs - whether any strictly grounded mathematically criterion of year-classes strength is available at all. It is known that they are divided by categories at the qualitative level only. For example, a strong year-class is described as significantly exceeding the long-term mean during several years, covering the main period of its exploitation. In our case the criterion selected meets all above requirements and therefore may be considered acceptable to demonstrate the proposed methodical approach.

Further such parameters as the mean spawning biomass being most favourable to abundant year-classes production (MSSBfav) and mean high and low biomasses (MSSBhigh and MSSBlow respectively). MSSBfav is estimated as the mean biomass in the years when strong year-classes appeared. To estimate MSSBhigh and MSSBlow the deviations from the mean SSB both to the less and to the higher values exceeding 20% were also used. The years with high and low biomasses were selected and the mean values were obtained.

RESULTS

Figure 1 (part «f» of which deserves more detailed comments) gives the idea of SRR pattern, actually reflecting the combined effect of density relationship and environment factors (first of all oceanographic) on the abundance dynamics of respective stock units. The points scatter in (f) corresponds to Riker's type relationship visually better than in other plots. Solid vertical lines on the figure indicate the upper and the lower limits of 20%

deviations from the mean spawning biomass, and dotted horizontal line indicates the level above which the year-classes classified as strong, based on the criterion assumed are located. Besides, the figure outlines three zones the explanations to which are given in the next section. In order to provide a more detailed idea of SRR effect in compliance with the methods described above, MSSBhigh, MSSBlow and MSSBfav ratio to the first two were estimated (Table 1). Let us denote them briefly Cr and Cl (right and left coefficients, respectively), which seem to provide a definite idea of SSB effect extent and pattern at the left and right sides of biomass observation series.

The data presented show that MSSBfav/MSSBlow (Cl) ratio considerably varies by stock units from 1.11 in American plaice to 4.68 in cod 2J+3KL. Evidently, that difference between MSSBfav/MSSBhigh (Cr) ratios was considerably less, and this is not surprising, because these values are actually able to vary only within the range from zero to one.

DISCUSSION

The pattern of points scatter in the figure allows to assume, in some cases, a strong effect of environment factors on year-classes abundance masking, or more exactly, suppressing SRR effect within a wide range of biomasses. In such cases MSSBfav cannot be interpreted as a target level to be achieved and retained. In this situation the above parameter may be used only in revealing the indications of SRR effect in seemingly chaotic scatter of points in the figure. The ratios presented in the last two columns of the table seem to allow qualitative evaluation of the pattern and extent of the relationship considered.

Let us start with the ratio MSSBfav/MSSBhigh. As the respective values approach to one, the compensation factors effect seems to weaken and finally approaches zero, which actually means the direct dependence of year-classes abundance on SSB value. No restriction of the upper biomass limit is required to the populations with similar type of density relationship. However, if during several years the environment conditions unfavourable to young fish survival persist, the stock size may decrease rapidly to extremely low level, unable to provide the stock recovery even in comparatively favourable conditions, including total cessation of fishery. In our case the above said type of abundance dynamics is observed in cod 2J+3KL and 3NO, though, judging from the points scatter in fig.1(g), the compensatory pattern of the density relationship seems to become apparent. However, an appearance may be delusive. The impact of environment factors on year-classes formation may play a certain role here, resulting in some distortion on SRR pattern inherent in this population.

As Cr values decrease, the effect of compensatory factors becomes stronger. This is most apparent in American plaice, yellowtail flounder and Greenland halibut (0.47, 0.50 and 0.65, respectively). For these stock units the biomass exceeding a certain level may become an adverse factor increasing the probability of poor year-classes appearance. It seems that in such cases the definition of the upper SSB limit would be in accordance with PA strategy.

Now let us consider the situation at the left side of the biomass observation series. It is evident that with the higher Cl values, the higher shall be the level of SSB favourable to strong year-classes formation. This means, that the higher MSSBfav value requires the higher threshold of the limiting reference point B_{lim} and vice versa. Therefore, the limit of this reference point has to be at the highest level for cod in 2J+3KL and 3NO. The results obtained allows to assume that B_{lim} level, recommended by NAFO Scientific Council for the latter stock (60 thousand tons), is slightly underestimated (NAFO, 2000). It is more likely that the estimate within 70-80 thousand tons complies better to the above level. On the other hand, for two species of flounders, Atlantic mackerel, silver hake in 4VWX and red hake in 5Ze B_{lim} boundary is probably to be closer to the lowest biomass observed. At relatively low SSB strong year-classes are not rarely observed also in Greenland halibut. Therefore, the optimum biomass range, requiring two-sides limiting reference points are mostly pronounced in yellowtail flounder, American plaice and Greenland halibut. In such cases it seems reasonable to to determine both lower and upper boundaries of the above reference points, identifying them as B_{lim} (lower) и B_{lim} (upper). In the context of the other stock units, practical management it is possible to speak about SSB maintenance at a definite level, probably, at the left end of the range only.

The above considerations may be best of all demonstrated with Fig. 1(f), where points scattering allows to distinguish three SSB zones. The first zone is the region of low biomass associated with poor year-classes appearance. As can be seen, only one point there is located above the horizontal line. The overwhelming majority of strong year-classes are located in zone 2, which includes SSB in the range 23-36 thousand tons. Availability of two weak year-classes there can be probably explained with the environment conditions extremely unfavourable to young Greenland halibut survival, which suppressed the effect of the density relationship during respective years. And at last, zone 3 is the region of high biomass. However, only one point out of seven located there is located above the horizontal line. All other year-classes are non-abundant. It is likely that in the case considered the role of the Ricker's type relationship is very distinct. The extent of SRR effect seems to be evaluated best of all on the basis of Cr and Cl values in percent (Table. 1). At the same time it is possible to assume that a certain relationship exists between SSB value and the environment conditions impact on year-classes abundance formation. For example, with Cr values close to zero the effect of oceanographic factors will be suppressed by counteraction of compensatory factors. On the contrary, when Cr values approach to one (100%), the effect of oceanographic factors may be significant (sometimes determinative one) actually at any level of the spawning biomass, though the maximum biomass is likely to weaken their effect. On the left end of SSB observation series the minimum value of Cl actually evidences the determinative role of the environment factors in formation of recruitment. At the same time, within a favourable (optimal) biomass range, SRR role in the above process must be the determinative one, though in this case the environment conditions impact in some years may be considerable.

In short, the role of SRR and environment conditions in stock dynamics determination should be evaluated in every individual case with subsequent utilization of the obtained information in fishery management.

As can be seen, we are actually speaking about the necessity to consider the ecosystem components in fishery management. At the same time it would be useful to pay attention to another aspect of the problem considered. Extremely high abundance (biomass) of one or another species is sometimes a dangerous factor for associated fish species (predation, feeding competition, etc.). Therefore, the restriction of the upper biomass limit may sometimes be useful, irrespective of the type of density relationship for respective population.

CONCLUSIONS

The methodical approach used in this work allowed to distinguish two groups of fish distinctly different in the extent and pattern of the stock-recruitment relationship manifestation. The first group includes cod in 2J+3KL and 3NO, the second includes American plaice, yellowtail flounder in 3LNO and Greenland flounder in 3LNO. Naturally, these groups fishery management must be different also. In the first case, as is evident, no restriction of the spawning biomass upper limit is required, while the lower limit of the reference point should be fixed at a rather high level. In the second case the upper boundary of B_{lim} fixation seems reasonable in view of probable compensation effect of the density relationship. At the same time the lower threshold of the spawning biomass optimal range may be at the level close to the lowest observed value. Other stock units considered occupy the intermediate position between the above said groups.

In general, the results obtained evidence in favour of the assumption that the density relationship is inherent in all stock units considered, though the extent and pattern of its manifestation in some species and even in populations of the same species differ considerably.

As regards the considered stock units management, it should be of a complex nature, taking in account both specific character of the above relationship and the effect of the environment factors, which may prevail within a wide range of the spawning biomass values.

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TABLE 1. Estimates of mean spawning biomass (favourable, high, low) and respective ratios in 12 unit stocks in NAFO Area.

Stock Unit	MSSBfav, thous. t	MSSBhigh thous. t	MSSBlow thous. t	MSSBfav/MSSBhigh		MSSBfav/MSSBlow	
				Actual value	%	Actual value	%
2J+3KL cod	865	841	185.0	1.03	100.00	4.68	100.00
3NO cod	115	114	27.8	1.01	98.06	4.11	87.82
3Ps cod	77	107	36.3	0.72	69.90	2.12	45.30
4VWX silver hake	163	203	86.0	0.80	77.67	1.35	28.85
5Ze silver hake	325	476	128.6	0.68	66.02	2.52	53.85
5Zw+6 silver hake	201	294	71.0	0.68	66.02	2.83	60.47
5Ze red hake	52	78	34.5	0.67	65.05	1.50	32.05
5Zw+6 red hake	101	116	42.0	0.87	84.47	2.40	51.28
2+3 Greenland halibut	31	48	17.8	0.65	63.11	1.74	37.18
3LNO yellowtail flounder	10	20	7.7	0.50	48.54	1.35	28.85
3LNO American plaice	156	331	140.2	0.47	45.63	1.11	23.72
3-6 Atlantic mackerel	982	1375	665.0	0.71	68.93	1.27	27.14

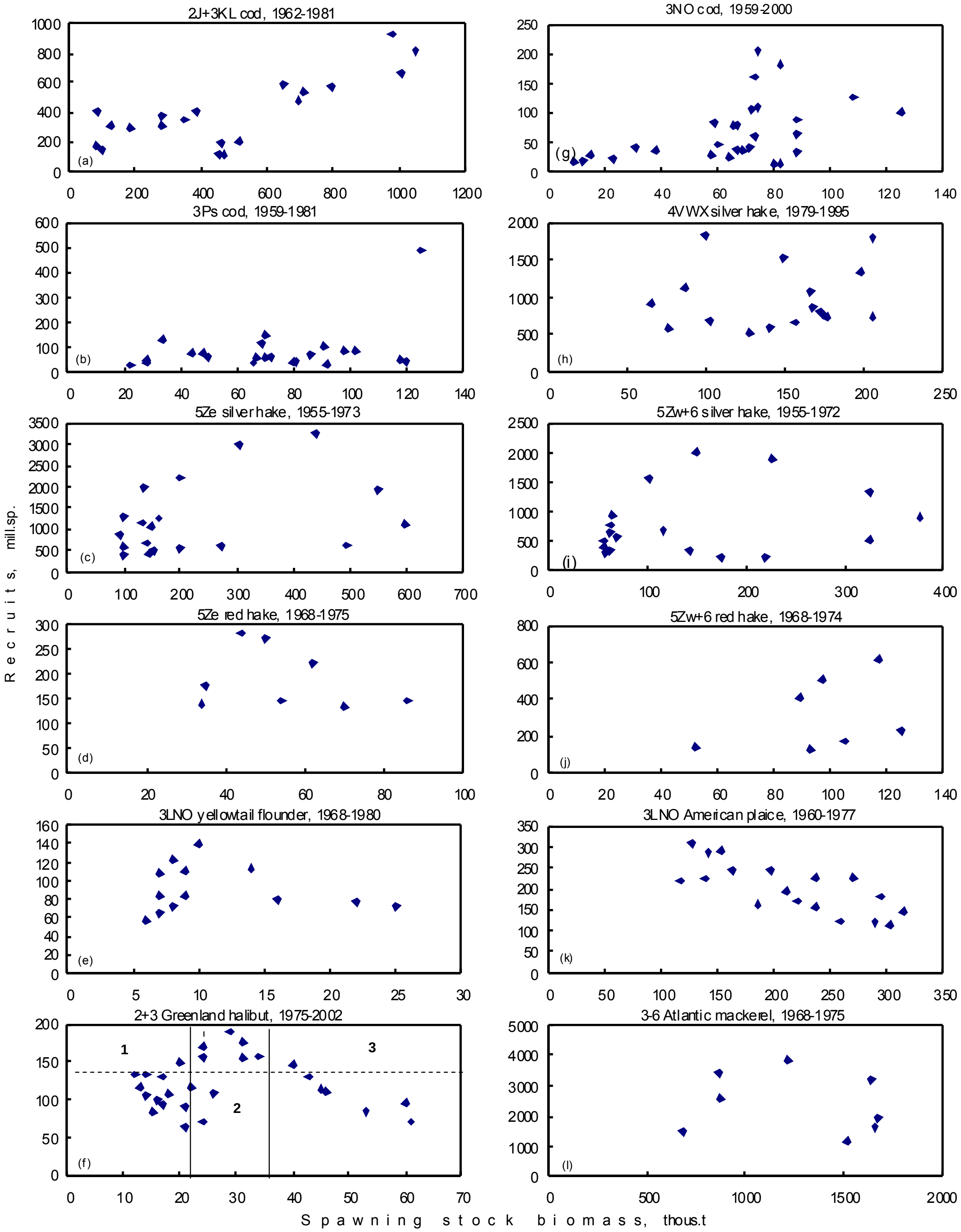

Fig. 1. Relationship between spawning stock biomass and recruitment in 12 unit stocks in NAFO Area.