Zbigniew *NEJA*

Fish biology

THE STOCK SIZE AND CHANGES IN THE GROWTH RATE OF THE NORTHWEST ATLANTIC MACKEREL (*SCOMBER SCOMBRUS* L.) IN 1971-1983

WIELKOŚĆ STADA A ZMIANY SZYBKOŚCI WZROSTU MAKRELI (*SCOMBER SCOMBRUS* L.) W PÓŁNOCNO-ZACHODNIM ATLANTYKU W LATACH 1971-1983

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The influence of the year class size (in numbers) and a stock biomass on the growth rate of 13 cohorts (1971-1983) of the Northwest Atlantic mackerel were investigated. It has been stated that the year class size actually influenced the growth of the examined fish only in the first year of life. The stock biomass was strongly correlated with the growth rate during the first and the second years of life. The density-dependent growth in 3-7 years old mackerel was not observed.

INTRODUCTION

The phenomenon of the growth compensation occurs when the high increase in the population size causes such food limitation that its deficiency as well as the necessity of spending extra energy on searching for food longer leads to slowing down the fish growth. With the decrease of fish population the abundance of food supply is then the reason of faster fish growth. The changes in the growth rate dependent on the population size, known as the density-dependent changes, were observed in many fishes, mainly in the Georges Bank herring [Anthony 1971], in the Atlanto-Scandian herring [Dragesund et al. 1980; Bakken 1983] and in the Georges Bank haddock, which at the end of the 1960s, when its stock biomass was reduced by 95%, radically increased its growth rate, even though the average bottom temperature declined at the time [Clark et al. 1982].

In the case of the mackerel belonging to the Northwest Atlantic stock, during the last 300 years considerable fluctuations of the stock abundance were often observed and they were reflected by the changes in a commercial catch size [Anderson and Paciorkowski 1980]. It may be assumed that stock density changes were reflected also in the differentiation of the growth rate of this species.

The observations proving this thesis were taken, among others, by MacKay [1973], Paciorkowski [1985] and Overholtz [1989]. Other authors [Moores et al. 1975; Isakov 1976; Anderson and Paciorkowski 1980] were not able to prove on the basis of their research the occurrence of the mackerel growth rate changes dependent on the population density. Therefore, the aim of the present work was to evaluate the influence of the stock density on the mackerel growth rate in 1971-1983 when the stock was subject to significant changes in size and biomass.

MATERIALS AND METHODS

The materials used to estimate the mackerel growth rate were obtained from commercial-research cruises of the two Polish trawlers in NAFO Divisions 5Zw, 6A, 6B and 6C in 1983 and 1984. The mackerel growth rate was estimated by back calculations from otholits. A total of 1633 individuals belonging to consecutive thirteen 1971-1983 year classes were back calculated. To define the differences in the growth rate occurring between the year classes, the mean annual fork length (*longitudo caudalis*) increments for each of the analyzed cohorts during the first seven years of life were calculated. More detailed information about the methods of age readings and back calculations applied in this work has been included in Neja [1990].

The data concerning the 1971-1983 year classes abundance (in numbers) in their first seven years of life as well as the Northwest Atlantic mackerel stock biomass (ages 1 and older) come from Anderson [1985]. The term "stock" is understood here all the population of the Northwest Atlantic mackerel because there are no proofs found to support the idea of the genetic dissimilarity of this species' representatives living in this particular part of the Atlantic Ocean [Anderson and Paciorkowski 1980].

RESULTS

As the data in Table 1 shows, the mackerel length increments in the consecutive years of life significantly differed during 1971-1983. The most considerable divergencies were observed in the first and the second years of life, respectively 4.3 cm and 4.9 cm, but they were distinct also in the older fish. It is worth mentioning here that in the given calendar year both large and small length increments were observed in fish of different year classes. It is apparent in the case of the increments for the examined mackerel in 1983 (Tab. 1). The fish of the 1983 year class attained the mean length of 21 cm in the first year of life (the highest increment in this year of life among the studied fish). On the other hand, the 1980 year class mean length increment of 1.9 cm in the fourth year of life was the lowest increment in this year of life among the studied fish. The similar phenomenon can be observed in the course of analysis of the mackerel length increments in 1979. Fish born this particular year grew in the first year of life up to 20.4 cm (the second highest increment among the studied fish) whereas the individuals of the 1977 year class grew in the third year of life by 4.2 cm which is the second lowest increment among the examined fish. It seems necessary to answer the question whether the observed differences in the mackerel length increments in the period 1971 to 1983 were connected with the stock density changes.

The relationship between the mean length of a year class (L_1) and year class size (N_1) at age 1, including the 1971-1983 year classes, is presented in Figure 1. The course of the studied

correlation is similar to a hyperbola and a high determination coefficient ($r^2=0.643$) suggests the dominating influence of the year class size on the mackerel growth rate in the first year of life in the analyzed period.

Table 1

The mean annual length increments of the mackerel of the 1971-1983 year classes in the consecutive years of life. L.caud. (cm)

The calendar year in which the fish attained the given increment has been presented in brackets

Year class	No. of fish examined	L_1	L_2-L_1	L_3-L_2	L_4-L_3	L_5-L_4	L_6-L_5	L_7-L_6
1983	30	21.0 ('83)	-	-	-	-	-	-
1982	130	17.8 ('82)	9.0 ('83)	-	-	-	-	-
1981	385	18.3 ('81)	10.1 ('82)	4.3 ('83)	-	-	-	-
1980	106	19.0 ('80)	12.6 ('81)	3.3 ('82)	1.9 ('83)	-	-	-
1979	91	20.4 ('79)	10.9 ('80)	4.4 ('81)	2.2 ('82)	1.6 ('83)	-	-
1978	208	19.7 ('78)	10.8 ('79)	4.4 ('80)	2.1 ('81)	1.6 ('82)	0.9 ('83)	-
1977	39	19.9 ('77)	9.1 ('78)	4.2 ('79)	2.9 ('80)	1.8 ('81)	1.5 ('82)	1.0 ('83)
1976	37	18.3 ('76)	8.7 ('77)	5.3 ('78)	2.7 ('79)	1.7 ('80)	1.6 ('81)	1.3 ('82)
1975	120	17.5 ('75)	8.9 ('76)	5.3 ('77)	2.4 ('78)	1.7 ('79)	1.5 ('80)	1.3 ('81)
1974	269	17.1 ('74)	9.0 ('75)	5.1 ('76)	2.3 ('77)	1.7 ('78)	1.4 ('79)	1.2 ('80)
1973	143	16.7 ('73)	8.8 ('74)	4.6 ('75)	2.6 ('76)	1.6 ('77)	1.5 ('78)	1.3 ('79)
1972	47	17.3 ('72)	8.2 ('73)	4.4 ('74)	2.8 ('75)	1.6 ('76)	1.4 ('77)	1.3 ('78)
1971	28	17.7 ('71)	7.7 ('72)	4.3 ('73)	2.2 ('74)	1.7 ('75)	1.5 ('76)	1.2 ('77)

On the other hand, the comparison of the mackerel length increments (1971-1982 year classes) in the second year of life (L_2-L_1) with the year class size at age 2 (Fig. 2, Tab. 2) shows that there is no significant relationship between the variables. Also the annual length increments of older mackerel are not correlated with the year class size (Tab. 2).

The stock density measure different than its year classes size in numbers is its biomass. Therefore, it has been checked if there is any dependency between the mackerel length increments and the stock biomass (Fig. 3 and 4). It has been found that in the case of fish at ages 1-2 years the correlation coefficients are high and statistically significant at the 0.01 level (Tab. 3). When fish of 3-4 years of age are taken into consideration, the calculated coefficients (r) are within the range of -0.12 to -0.75 in the case of the linear regression and within the range of -0.09 to -0.74 when the curvilinear regression model is applied. In both cases the absolute value of the correlation coefficient grows together with the fish growing older, but only the correlation coefficient of the relationship between the length increments in the seventh year of life and the stock biomass is nearly statistically significant at the 0.05 level (Tab. 3).
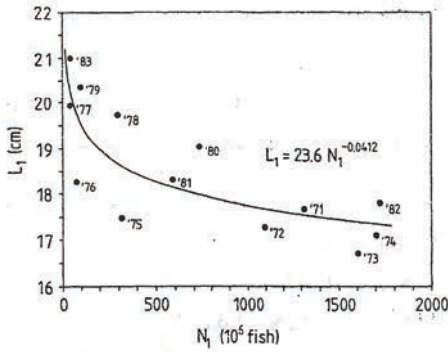
Fig. 1. Relationship between the mean length increments in the first year of life (L_1) and the mackerel year class size (N_1) at age 1 for 1971-1983 year classes
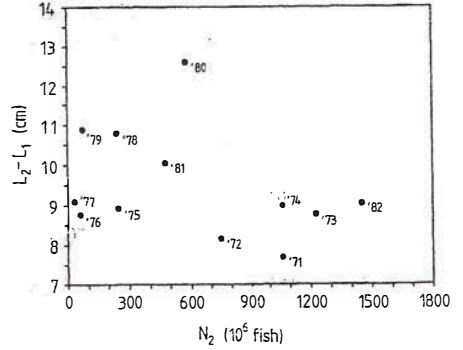

Fig. 2. Relationship between the mean length increments in the second year of life (L_2-L_1) and the mackerel year class size (N_2) at age 2 for 1971-1982 year classes
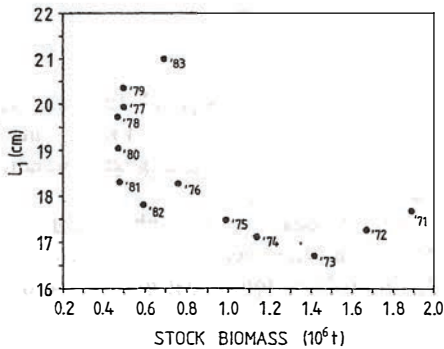

Fig. 3 Relationship between the mean length increments in the first year of life (L_1) and the mackerel stock biomass in 1971-1983
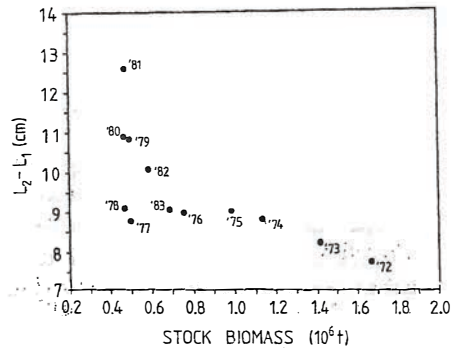

Fig 4 Relationship between the mean length increments in the second year of life (L_2-L_1) and the mackerel stock biomass in 1971-1983

Table 2

Coefficients of correlation (r) and determination (r^2), and the level of statistical significance (α) of correlation coefficients for regressions of mean annual length increments in the consecutive years of life (t) versus year class size of the Northwest Atlantic mackerel

Year of life t	Linear relationship				Curvilinear relationship (power)			
	n	r	r^2	α	n	r	r^2	α
1	13	-0.761	0.579	<0.01	13	- 0.802	0.643	<0.01
2	12	-0.346	0.120	>0.10	12	- 0.207	0.043	>0.10
3	11	-0.196	0.038	>0.10	11	- 0.172	0.030	>0.10
4	10	-0.469	0.220	>0.10	10	- 0.484	0.234	>0.10
5	9	-0.186	0.034	>0.10	9	- 0.387	0.150	>0.10
6	8	-0.160	0.026	>0.10	8	- 0.251	0.063	>0.10
7	7	0.402	0.161	>0.10	7	0.642	0.412	>0.10

Table 3

Coefficients of correlation (r) and determination (r^2), and the level of statistical significance (α) of correlation coefficients for regressions of mean annual length increments in the consecutive years of life (t) versus the biomass of the Northwest Atlantic mackerel stock

Year of life t	Linear relationship				Curvilinear relationship (power)			
	n	r	r^2	α	n	r	r^2	α
1	13	-0.663	0.439	<0.02	13	-0.710	0.503	<0.01
2	12	-0.690	0.477	<0.02	12	-0.742	0.551	<0.01
3	11	-0.116	0.014	>0.10	11	-0.093	0.009	>0.10
4	10	-0.016	0.000	>0.10	10	-0.030	0.001	>0.10
5	9	-0.236	0.056	>0.10	9	-0.308	0.095	>0.10
6	8	-0.502	0.252	>0.10	8	-0.517	0.267	>0.10
7	7	-0.747	0.558	≈ 0.05	7	-0.744	0.554	≈ 0.05

DISCUSSION

The significant differences in the growth between the respective Atlantic mackerel cohorts were observed already in the first half of the XX century [Bigelow and Shroeder 1953]. According to the authors mentioned here those differences could result from the changes of water temperature, food supply or population density. The data presented in the previous chapter demonstrate (Tab. 1) that it probably was not the changes of the physicochemical environmental factors including temperature that influenced significantly the differences in the growth rate of various mackerel cohorts in the consecutive years of life. It is difficult to believe that in the given year the water temperature (as well as oxygen concentration, salinity etc.) would influence in a different way the growth of fish belonging to the same species but varying in age a little. It is even less probable when we realize that in the shelf waters of the research area thermic anomalies both positive and negative were observed in subsequent months [Trites and Drinkwater 1986]. It means that the possible impacts of cool and warm water masses on the fish growth are not long-termed and should neutralize each other. According to Agnalt [1989] in the North Sea the rate of mackerel length and weight growth was increasing in the 1960s and 1970s both in the period of warming and cooling. At the beginning of the 1980s the reduction of the mean length and weight of young mackerel was observed, despite the increase in sea temperature. These observations prove the limited role of the water temperature changes as the factor determining the mackerel growth rate.

The first observations concerning the relationship between the year class size and the Northwest Atlantic mackerel growth rate were carried out by MacKay [1973]. He found that the most abundant cohorts of 1959 and 1967 grew slower in comparison with the medium size cohorts of 1965-1972. MacKay [1973] also added that the slower growth was observed especially in the first two years. Lett [1978, after Paciorkowski 1985] showed, by means of the size of the 0-age group as a density index, the strong correlation between the growth and the mackerel density in the first year of life. Overholtz [1989] compared the mean weight of one and two years old mackerel with the cohorts size and obtained high correlation coefficients (r=-0.77 and r=-0.75 respectively). Unfortunately, they were not significant because of the small number of the examined samples. Overholtz (op. cit.) suggested that the cohort size affects its growth not only in the first but also in the second year of life. It is in opposition to both Lett's conclusions as well as to the ones included in the present paper, namely that the mackerel cohort size affects its growth actually only in its first year of life. It must be emphasized, however, that Overholtz did not estimate the weight increments between the first and the second year of life completion of the examined fish but he dealt with the mean body weight of age 1-2 fish. Using this particular method of the growth rate estimation, one may wrongly attribute big sizes reached after the second year of life to the increments in the second year of life whereas they may actually be merely the derivative of an increment attained in the first year. Thus, the growth rate (increment) in the second year may be low. In such situation the comparison of fish weight (or length) reached at a certain age which has been conducted in order to appraise the impact of the cohorts size on the species' growth rate in the consecutive years of life (instead of comparing the increments of both weight and length) does not seem to be correct and can be misleading*.

The problem can be viewed differently if we treat a stock biomass as its density measure. Primarily, still in the 1970s, the differences in the mackerel growth rate were not connected with the stock biomass [Lett 1978; after Paciorkowski 1985; Grosslein et al. 1980]. Anderson and Paciorkowski (1980) maintained even that there was no proof of any changes in the mackerel growth rate related to the increase or reduction of a stock biomass. It was just Overholtz [1989] who found out that it was not a year class size alone but also a stock size that

* The remark also refers to way of determining the influence of the stock biomass on the growth rate

influenced the Northwest Atlantic mackerel growth rate. According to Overholtz [1989] the size of the mature stock probably plays an important role in the growth regulation process after recruitment. The results of the present work make this idea hard to reject, especially that the gradually rising impact of the stock biomass on the older fish growth rate can be observed (Tab. 3). Nevertheless, the highest correlation coefficients were calculated (Tab. 3) for the relationships between a length increment and a stock biomass with regard to the youngest mackerel of 1-2 years of age. It demonstrates the bigger impact of the stock biomass on the growth rate of young rather than older mackerel. Besides Overholtz [1989] himself pointed out that in the case of the regression of the mean weight-at-age versus stock size (estimated on the basis of a survey catch) there was a significant negative correlation in 1-3 years old mackerel. As for 4-5 years old fish, however, such correlation was not statistically significant. Also in the case of the analysis of the data on a commercial catch, the mean absolute value of the correlation coefficient for younger fish (1-4 years old) was higher (r= -0.517) than that of older ones (r= -0.401). Agnalt [1989], too, found that there was a negative correlation between the mean length of 1-2 years old mackerel belonging to the North Sea stock and the stock biomass. The mentioned phenomenon did not occur, however, in the 1980s when both the stock size as well as the growth rate of the first two age groups were reduced. Concluding the above considerations, it can be stated that the influence of a stock biomass on the mackerel growth rate has not been equally well documented as it has happened in the case of the year class size impact on its growth in the first year of live. Moreover, we cannot preclude the phenomenon observed by Toresen [1990] in the Norwegian spring-spawning herring. According to Toresen (op. cit.) the herring growth reduction can depend on density in certain areas, and when a big stock biomass occurs. Nevertheless, in most of the cases it is more likely that young herring of strong year classes disperse to areas with lower temperatures. Toresen [1990] concluded that this deterioration in average living conditions for abundant year classes being the effect of their migrations determines the reduction of the growth rate of these cohorts. Separate studies are required to establish the fact whether a similar phenomenon exists also in the Northwest Atlantic mackerel.

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WIELKOŚĆ STADA A ZMIANY SZYBKOŚCI WZROSTU MAKRELI (*SCOMBER SCOMBRUS* L.) W PÓŁNOCNO-ZACHODNIM ATLANTYKU W LATACH 1971-1983

STRESZCZENIE

W celu dokonania oceny wpływu wielkości stada na szybkość wzrostu makreli w północno-zachodnim Atlantyku porównano roczne przyrosty długości ogonowej (*longitudo caudalis*) w pierwszych siedmiu latach życia trzynastu analizowanych pokoleń (1971-1983) z liczebnością tych pokoleń w kolejnych latach życia oraz z wielkością biomasy stada w latach 1971-1983. Wyliczone przyrosty długości różniły się znacznie między sobą, zwłaszcza w dwóch pierwszych latach życia ryb (maksymalnie o 4.3 cm w pierwszym roku i o 4.9 cm w drugim), przy czym w danym roku kalendarzowym notowano zarówno małe, jak i duże przyrosty długości makreli, należących do różnych pokoleń (tab. 1).

Stwierdzono występowanie statystycznie istotnej korelacji pomiędzy przyrostem długości makreli w pierwszym roku życia a liczebnością pokolenia w wieku 1 roku (rys. 1). W przypadku ryb starszych (2-7 lat) statystycznie istotna korelacja pomiędzy analogicznymi zmiennymi nie występowała (rys.2, tab. 2).

Porównanie rocznych przyrostów długości z biomasą stada wykazało istnienie wyraźnej współzależności pomiędzy tymi zmiennymi u ryb w wieku 1-2 lat oraz jej brak u starszych makreli - pomimo stopniowego wzrostu bezwzględnej wartości współczynnika korelacji w miarę starzenia się ryb (rys. 3 i 4, tab. 3).

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