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Cod in Div. 3NO: Year-Class Variations and the Abundance of Other Commercial Fish

by

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INTRODUCTION

Physical-environmental factors govern the fluctuations of ecosystems, especially the long term changes, but how these fluctuations effect the species is not clear yet. It can be expected that the immediate factors in the dynamics of a species are essentially biological ones through the feeding process, and that physical factors are remote causes of these relationships. Perhaps multispecific models have the defect of limiting themselves to trophic relationships, ignoring the fact that these depend, at least in the long term, on physical environmental factors.

In this paper we explore the possible biological relationships of cod (*Gadus morhua*) with other fish of commercial importance, with no other reason for selection than to have a major amount of available data. To be exact, cod year class variations are compared with variations of yellowtail flounder (*Limanda ferruginea*) and American plaice (*Hippoglossoides platessoides*) spawning biomasses, mackerel (*Scomber scombrus*) age 1+ group abundances, and redfish (*Sebastes sp.*) densities. Adults of these species are not considered to be predators of eggs and larvae of cod, though they can be of their young. The biomasses of adult fishes of these species are considered as an index of their egg and larval abundances. There will be competition and predator-prey relationships between the 0-age groups and young individuals of cod and these species. The sign of correlations will indicate the nature of these relationships.

The possibility of trophic relationships between 0-age groups and juveniles belonging to cod and other species is explored relating every cod year-class size to the biomass of the other species, from one to three years before (negative lag) or after (positive lag) the year of the cod year class. Finally, the cod year class is also related to the cod spawning biomass which gave rise to it, and to the cod spawning biomass lagged from one to three years before or after. The cod year-class size is measured at time of recruitment according to VPA; in the usual practice at three years old (N_3).

MATERIAL AND METHODS

The cod recruitment (N_3) and spawning biomass (B_{6+}) data have taken from Baird and Bishop (1988). The yellowtail flounder spawning biomass data from Brodie and Walls (1987), getting higher correlation coefficients using table 23 than using table 24 of the authors. The American plaice spawning biomasses (B_{11+}) have been taken from Brodie (1988). The redfish abundances have been taken from Power and Atkinson (1987), using figure 3 of the authors on catch rates in NAFO Div. 3LN during 1959-1986, the values used being the mean abundances calculated from three consecutive years. Finally, the mackerel biomasses (B_{1+}) have been taken from Anon. (1986), referred to the Labrador-North Carolina area. All these data are shown in tables 1-5.

When a 0-lag is used, the year class of recruitment is related to the spawning biomass of the species in the same year as the cod year class, that is to say, three years before recruitment (N_3).

RESULTS

Correlations between cod recruitment and cod spawning biomasses are shown in table 6; no coefficient appears to be significant, the only exception a slight significance for 0-lag.

Correlation coefficients between cod year-class size and redfish abundance are shown in table 7, none of them being significant. Also, no correlation coefficients between cod recruitment and yellowtail flounder spawning biomass (table 8) appear significant, except with a +3 years lag. On the contrary, correlations between cod recruitment and mackerel abundance (table 9) are negative and slightly significant, and with American plaice biomass are positive and strongly significant (table 10) with 0. +1, +2 and +3 years lags.

DISCUSSION

The relationship between cod recruitment and its spawning biomass (table 6) corresponds to the complex problem of the stock-recruitment question, which is not the object of this study. Simply, these correlations are made to follow the same method as in the case of the other species abundances. Nevertheless, the absence of negative correlations with negative lags (cod spawning biomass before the year class) indicates that cannibalism does not determine year class size.

There is no significant relationship between redfish and yellowtail flounder abundances, on the one hand, and cod year class size on the other. On the contrary, a negative correlation appears with mackerel suggesting that this species is a cod predator. These correlations extend also to +1 and +2 year lags, but predation by mackerel on 1 and 2-age groups of cod seems anadmissible because of the excessive size of the prey. It is more reasonable to think that mackerel abundance will remain similar during the following two years to that of the 0-lag year, giving an unreal biological relationship. According to Koslov *et al.* (1978), several authors have noted the influence of mackerel abundance on Gadidae and herring recruitment in areas from Georges Bank to the Gulf of Saint Lawrence, which has been attributed to predation by mackerel. In contrast, one of us (Báez and Larrañeta, 1987) has found that silver hake year class sizes on the Scotian Shelf are positively correlated with mackerel biomasses, suggesting predation on mackerel 0-age group by silver hake 0-age group.

The most spectacular results (table 10) are obtained with the American plaice. The positive and high correlations suggest a great predation of 0-group cod on American plaice spawning products and resulting 0-group fish, which occurs throughout the cod pre-recruitment period. Significant correlations with -1 and -2 lags may be because of American plaice spawning biomasses will have a previous similar abundance to that corresponding the year with lag 0 year. In a previous paper (Larrañeta, 1986) it was shown that variations of cod Div. 3NO and American plaice year class sizes were inversely related; which is coherent with the present results. In fact, if 0-group cod prey actively on 0-group American plaice, or both are strenuous competitors, they would mutually exclude the simultaneous production of the highest year classes possible for each species.

In the literature we find data that permit us to accept that the American plaice can be an important prey of cod during the 0-age group and pre-recruitment stages. For example, Marak (1960) studied the feeding habits of haddock and cod postlarvae (19-23 mm) on Georges Bank and found that 33% of the stomach content were fish eggs. Palsson (1983), in Iceland waters - in October and November - cited the predation of cod on American plaice. The stomach content weigth in cod ranging from 15 to 19 cm was formed by 16% of American plaice, and 9% in those of 25-29 cm. Daan (1973) cites the Pleuronectidae (85% *Limanda*

limanda) as food of cod 10-19 cm long in the North Sea. Hawkins (1985) also quotes the Pleuronectidae, without being more specific, as food of young cod (13-43 cm). These studies support the idea of strong predation by cod on the 0-group American plaice and also an active predation on juveniles of this species.

The data available on cod and American plaice distribution in Div. 3NO favour this idea. The northern and southeastern slopes of the Grand Bank support the largest American plaice concentration in the Northwest Atlantic (Pitt,1966). According to Wells *et al.* (1988), cod and American plaice have similar distributions on the Grand Bank, though cod does not tolerate temperatures less than -1ºC as well. Yellowtail flounder is distributed in shallower zones and warmer waters, with temperatures always above 1ºC. On the south of the Grand Bank a separation between American plaice pre-recruits and adults is not observed (Walsh, 1982; Walsh and Brodie, 1988) as it is in Europe, because the oceanographic conditions tend to retain the spawning products near the spawning area (Nevisky, 1973). The metamorphosed juvenile individuals (>20 mm) occupy the same areas as the spawning adults. American plaice larvae concentrate almost exclusively on the Southeast Grand Bank, in waters colder than 1ºC. One other distinguishing characteristic of yellowtail flounder larvae is that they are distributed in waters warmer than 1ºC. According to Kenneth *et al.* (1988) American plaice appear not to migrate vertically during either the larval or pelagic juvenile phase, and were always collected below the pycnocline with an average depth of about 30 m. The poor dispersion of American plaice could make it more vulnerable.

These considerations suggest two conclusions:

a) It is not possible to obtain cod and American plaice year classes of the highest level simultaneously.

b) The presence of an abundant American plaice spawning biomass promates high cod recruitment.

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Table 1.- Cod Div.3NO: recruitment (N_3) and spawning biomass (B_{6+}).From Baird and Bishop (1988).

Year class	Recruits (10^3)	Biomass (tons)
1956	53690	-
1957	53183	-
1958	82103	-
1959	107740	89675
1960	78245	73485
1961	112308	90569
1962	162565	81108
1963	210010	88649
1964	183244	113136
1965	100519	120736
1966	127870	104829
1967	80340	93442
1968	84482	82672
1969	62130	80264
1970	35153	81224
1971	37006	88151
1972	23398	78144
1973	27996	76244
1974	46587	53972
1975	45802	19545
1976	24151	12711
1977	25669	17604
1978	36031	21234
1979	23395	28761
1980	36816	62439
1981	58518	98261
1982	40439	112095
1983	9585	126851
1984	23574	127189
1985	-	140613
1986	-	156649

Table 2.- Yellowtail flounder Div.3LNO: spawning stock biomass (B_{6+}). From tables 23 and 24 of Brodie and Walls (1987).

year	t. 23 (tons)	t. 24 (tons)
1968	25926	25926
1969	40372	40372
1970	50199	50199
1971	48747	48747
1972	33846	33846
1973	24049	24049
1974	21034	21034
1975	18159	18159
1976	19152	19152
1977	18809	18809
1978	21776	21776
1979	17413	17412
1980	26322	26322
1981	20350	20337
1982	16838	16642
1983	30565	28894
1984	53811	47448
1985	63087	50550
1986	39536	23722

Table 3.- Redfish Div. 3LN: average catch rate of three years. From figure 3 of Power and Atkinson (1987).

Midle year	Catch rate
1960	1.15
1961	1.21
1962	1.28
1963	1.25
1964	1.04
1965	1.11
1966	1.08
1967	1.06
1968	0.89
1969	0.90
1970	1.01
1971	1.04
1972	1.06
1973	1.15
1974	1.18
1975	1.13
1976	1.02
1977	0.92
1978	0.98
1979	1.11
1980	1.25
1981	1.33
1982	1.33
1983	1.25

Table 4.- Mackerel Labrador-North Carolina: population biomass (B_{1+}). From figure 19.1, Anon. (1986).

Year	Biomass (000 tons)
1963	275
1964	311
1965	323
1966	371
1967	623
1968	1198
1969	1533
1970	1856
1971	1868
1972	1653
1973	1389
1974	1126
1975	970
1976	719
1977	491
1978	467
1979	503
1980	467
1981	479
1982	599
1983	695
1984	1078

Table 5.- American plaice.Div. 3LNO: spawning stock biomass (B_{11+}). From Brodie (1988).

Year	Biomass (tons)
1965	138197
1966	158756
1967	157325
1968	138837
1969	120238
1970	94378
1971	81403
1972	62129
1973	52619
1974	50889
1975	45906
1976	39864
1977	45515
1978	48818
1979	60846
1980	67125
1981	53278
1982	46852
1983	42294
1984	46090
1985	56357
1986	43383

Table 6.- Correlation between cod years class size (N_3) and cod spawning stock biomass.

Lag	-3	-2	-1	0	1	2	3
n =	23	24	25	26	27	28	29
r =	0.300	0.320	0.324	0.342	0.331	0.277	0.168
p =	0.166	0.128	0.115	0.087	0.092	0.156	0.387

Table 7.- Correlations between cod year class sizes (N_3) and redfish catch rates.

Lag	-3	-2	-1	0	1	2	3
n =	22	23	24	24	24	24	24
r =	0.305	0.285	0.317	0.178	-0.001	-0.198	-0.303
p =	0.169	0.190	0.132	0.409	0.995	0.358	0.152

Table 8.- Correlations between cod year class sizes (N_3) and yellowtail flounder spawning stock biomass (B_{6+}).

Lag		-3	-2	-1	0	1	2	3
F_t=1.5	n=	14	15	16	17	18	19	19
	r=	0.019	-0.037	-0.011	-0.065	0.006	0.278	0.599
	p=	0.950	0.899	0.967	0.808	0.982	0.254	0.006

Table 9.- Correlations between cod year class sizes (N_3) and mackerel stock biomass.

Lag	-3	-2	-1	0	1	2	3
n =	19	20	21	22	22	22	22
r =	-0.435	-0.476	-0.458	-0.438	-0.393	-0.266	-0.087
p =	0.062	0.033	0.036	0.041	0.070	0.235	0.705

Table 10.- Correlations between cod year class size (N_3) and A. plaice spawning stock biomass.

Lag	-3	-2	-1	0	1	2	3
n =	17	18	19	20	21	22	22
r =	0.394	0.644	0.745	0.857	0.821	0.858	0.940
p =	0.119	0.003	<0.001	<0.001	<0.001	<0.001	<0.001