Northwest Atlantic Fisheries Organization

Serial No. N1280 NAFO SCR Doc. 87/11

SCIENTIFIC COUNCIL MEETING - JUNE 1987

Fishery Ecology of Silver Hake in the Division 4VWX

by

M. Báez

Centro de Investigaciones Marinas
Universidad de la Habana, Cuba

and

M. G. Larrañeta

Instituto de Investigaciones Pesqueras
Muelle de Bouzas, Vigo, Spain

S U M M A R Y

Data published on silver hake in the NAFO Divisions 4VWX area, were used: catch, effort and catch per unit effort (cpue); composition by age/years, breeding and feeding. An analysis was made also of the abundance of other species and the abiotic factors in the area. No clear-out lineal relations were - found to exist between the cpue and effort, with ecological implications. The recruitment of the silver hake has undergone variations since 1958: around 1967 and 1976. Cannibalism is not the fundamental regulation factor for the recruitment of this species. The fundamental factors regulating recruitment and, consequently, influence greatly abundance, are: the abundance of mackerel and the loading of the Saint Lawrence river.

INTRODUCTION

The silver hake is a voracious predator with a high fishery value in the New Scotia region. This region (NAFO Divisions 4VWX), presents a very complex hydrography, influenced by the Labrador river current and the Saint Lawrence river inshore, and the Gulf current in its offshore limit, in the opposite sense (Fig. 1).

Numerous research in the area have been conducted; nevertheless, not all the species have been systematically studied throughout the years, but a fairly complete survey can be made of the factors regulating the silver hake population in the area and, therefore, the fishery thereof.

METHODS

Data published on silver hake in the NAFO Divisions 4VWX were used: catch, effort and catch per unit effort (cpue), (NAFO, 1969-83; Clay, 1980); composition by age/years (Clay and Beanlands, 1980; Waldron and Harris, 1984); early maturation size (Mari and Ramos, 1979); spawning and larvae (Noskov et al., 1982); cannibalism (Bowman and Michaels, 1984; Clay et al., 1984) and feeding (Langton, 1982; Bowman and Michaels, 1984; Vinogradov, 1984a).

Also, the abundance of other species in the area was analyzed: Halliday (1975, 1976 a and b); Anderson and Paciorkowski (1980); Sinclair (1980); Bishop et al. (1984); Larrañeta (1984); Rowell and Young (1984); and the abiotic factors which have been examined therein: according to Sarnits and Sauskan (1967); Sutcliffe et al., (1976); Waldron (1983); Trites and Drinkwater (1984).

According to the methodology outlined by Larrañeta (1981), the cpue was analyzed by using the calculation of the indices of abundance made by Vázquez (1981), which derives from a multiplicative model and develops a method of analysis in the assumption that the variance of the catch is proportional to a power of the average catch. Vázquez and Larrañeta (1981) describe and use this method and provide a solution to the problem of working with different fishing rates; a characteristic value for each type of vessel is calculated.

This survey extends up to the year 1976, and is intended to analyze the first changes occured in this fishery.

<u>Changes in recruitment</u>

Nicholson (1984) has proposed a method of study of temporary variables which consists in calculating the average value for all the data series, and then proceed to an annual calculation of the cumulative sum of deviations with regard to the average value.

The application of this method to the value of Recruitment in Fig. 2 will result in the appearance of two periods: one extending from 1968 until 1976, the line depicting an upward trend; in the recruitment of this species two periods are thus characterized.

According to Larrañeta (1981), the variation of one of the parameters of the Stock-Recruitment ratio becomes manifest as two lines of regression in the effort-cpue ratio appear.

Regression concerning the silver hake have been calculated by relating annually the data from cpue and the effort made that year to the two previous years.

Figure 3a shows the relation between the cpue and the fishing effort so weighted by using data provided by Clay and Beanlands (1980); in Figure 3b, instead, the catch-and-effort data is used, the latter being measured by Vázquez method (1981), and Vázquez and Larrañeta - (1981). Both figures show no logical relation with each other, whether simple or double, as any one of the theoretical regressions would have to be necessarily decreasing, and in the figures the regressions would be horizontal and slightly increasing. This may be due to a simultaneous variation of both densely-independent and densely-dependent factors.

<u>Stock-Recruitment relations</u>

For the study of the Stock-Recruitment relation, Ricker's model (1958) has been used, as per the following expression:

$$R = A\,S\,e^{-BS}$$

where:

R = number of recruits aged 1 year in year t

S = number of spawning biomass in year t-1

A = parameter in relation to the densely-independent mortality.

B = parameter in relation to the densely-dependent mortality.

The breeders' population has been claimed to be composed of all fish aged 3 and more years, according to the early maturation size given by Mari and Ramos (1979).

The parameters have been calculated by means of the regression corresponding to the expression derived from Ricker's model:

$$\log R - \log S = \log A - BS$$

The data have been dealt with in two annual series according to the analysis of variability of the recruitment by Nicholson's method (1984), and have also been calculated for the totality pf the annual period. Results are given in Table 1 and Fig. 4. The absolute value of these correlation coefficients is not valid, as it is known, but it is used in this particular case to establish the comparisons between relations, for which it is indeed useful.

<u>Cannibalism</u>

Several authors (Clay <u>et al</u>., 1984; Bowman and Michaels, 1984), have shown that this species, as of age 6 years becomes highly predatory, and the possibility exists - that cannibalism becomes a very important or the most important factor in compensatory mortality (densely-dependent).

In order to study the cannibalism factor, Fig. 5 shows the relation between the biomass of the silver hake at age 6 or more and the recruitment of the following year.

No relation at all was found. Other authors (Lleonart et al., 1985) although in another species of hake and another zone, found that cannibalism affects, throughout the years, the composition by age, but not the total number of the population . Concerning cannibalism, one may claim that, yet being an important factor, is not primary in the natural regulation of the device.

Relations to other species

In tackling the problem of recruitment, it is necessary to examine the feeding rate of the first year in an indirect manner, relating the spawning biomass of - other species to the outcomes of recruitment. It is apparent that if a significant negative correlation is found between the spawning biomass of ther species and the recruitment of silver hake the following year, it means that a nutritional competition must have taken place between the larvae and postlarvae of both species or a depredation with negative effects for the survival of the silver hake during its first year - of life. If, otherwise, the correlation is positive, it will indicate that the ova and larvae of the other species may have been caught, during the first year of life, by the silver hake.

Table 2 shows the dominant species composing the diet of the silver hake (including the hake itself), the mackerel being foremost among them. Table 3 shows the correlation coefficients between the biomass or the abundance index of various species and the recruitment, the following year, of the silver hake in the Division 4VWX, based on data provided by Clay and - Beanlands (1980). None of these correlation coefficients is significant, except for the mackerel ($P < 0.01$) (Fig. 6).

In studying the feeding of adult silver hake, the mackerel is found to be the most important prey. Therefore, the growth rates and fecundity of silver hake are heavily dependent upon the population density of the mackerel. Besides, it follows from this that the existence of a positive correlation between the abundance of mackerel and the recruitment of silver hake, suggest that the ova and larvae of mackerel will become easy prey for the silver hake during its first year of life. On the whole, the ecological success of the silver hake is closely related to the ecological success of the mackerel.

<u>Relations with abiotic factors</u>

Data on abiotic factors which have been provided (Sarnits and Sauskan, 1967; Trites and Drinkwater, 1984; Sutcliffe <u>et al</u>., 1976) do not seem to show, each separately, a relation with the abundance of silver hake, nor there seems to be no evidence that with these factors predictions on recruitment can be made. Waldron (1983), also, failed to provide significant correlations between various abiotic factors and the abundance of silver hake. Nevertheless, an illustrative comparison of the loading of the Saint Lawrence river and the recruitment of this species the following year, shows a great coincidence between both variables (Fig. 7).

Sutcliffe (1972, 1973) has also found positive correlations between the loading of the Saint Lawrence river and the regional catch of <u>clam</u>, <u>American lobster</u> and <u>Atlantic halibut</u>, as a result of the rise in the amount of nutrients brought about by the mixing effects of - runoff. In this particular case, the influence of the Saint Lawrence river would extend over an area off Nova Scotia coast.

This would explain the change in parameter B of the Stock-Recruitment curves.

According to Koslow (1984), the large-scale oceanographic processes may exert influence upon the recruitment to fishery, and this would be confirmed, in this case, by the mathematical relation between both factors.

DISCUSSION

According to the analysis of the ecological significance of the parameters of Ricker's model made by Larrañeta (1981), parameter A is related to the physical variations of the abiotic environment, the variations of the recess and the genetic changes of the population; whereas parameter B would be related to the changes in productivity in the ecosystem.

In this case, the variation of the two parameters leads us to think of a variation of both the densely-independent (parameter A) and the densely-dependent factors - (parameter B). The effects of the loading of the Saint Lawrence river would be related to the densely-dependent factor, as primary productivity increases. The role of the mackerel is more difficult to discern. If the increase in the mackerel spawning biomass means that the initial states of the mackerel encroach upon those of the hake, it would amount to a change in the recess and, therefore, in parameter A. If there is always an overlapping of the areas of the initial states and the young of both species, then it would be a mere increase in the availability of preys (parameter B).

CONCLUSIONS

The analysis of the cpue/efforts will not result in clearly defined lineal relations with ecological implications.

The recruitment of the silver hake has undergone substantial changes since 1958: around 1967 and 1976.

Cannibalism is not the fundamental regulating factor in the recruitment of this species.

The fundamental factors which regulate the recruitment and, consequently, influence greatly abundance, are:

abundance of mackerel and the loading of the Saint Lawrence river.

The loading of the Saint Lawrence river would act as densely-dependent factors (parameter B) as the productivity of the area rises; thus, it would be unclear whether the breeding products of the mackerel would be a densely-independent factor (parameter A) in modifying the ecological recess or as a densely-dependent factor as well.

References

Anderson, E. D. and A. J. Paciorkowski. 1980. A review of the Northwest Atlantic Mackerel Fishery. Rapp. P.-v. Réun. Cons. int. Explor. Mer, 177:175-211.

Bishop, C. A., S. Gavaris and J. W. Baird. 1984. An assessment of the cod stock in Subdivision 3Ps. NAFO SCR Doc. 84/VI/53.

Bowman, R. E. and W. L. Michaels. 1984. Food of seventeen species of Northwest Atlantic fish. NOAA, Technical Memorandum, NMFS-F/NEC-28.

Clay, D. and Beanlands. 1980. Silver hake (Merluccius bilinearis) in Division 4VWX: A stock assessment and estimate of the total allowable catch (TAC) for 1981. NAFO SCR Doc. 80/VI/87.

Clay, D. L. , L. Currié and B. Swan. 1984. Food and feeding of silver hake (Merluccius bilinearis Mitchill), on the Scotian Shelf with special reference to cannibalism. NAFO SCR Doc. 84/VI/86.

Halliday, R. G. 1975. Eastern Scotian Shelf Cod (ICNAF Div. 4VsW)- A reconstruction of possible events in the fishery in 1958 to 1974 and a re-estimation of potential yield. ICNAF Res. Doc. 75/IX/136.

Halliday, R. G. 1976a.Scotian Shelf flatfish stocks-implications of 1975 data. ICNAF Res. Doc. 76/VI/24.

Halliday, R. G. 1976b. The Scotian Shelf redfish fihery in 1975. ICNAF Res. Doc. 76/VI/25.

Koslow, J. A. 1984. Recruitment patterns in Northwest Atlantic Fish Stocks. Can. J. Fish. Aquat. Sci., 41(12):1722-1729.

Langton, R. W. 1982. Diet overlap between atlantic cod, Gadus morhua, silver hake, Merluccius bilinearis, and fifteen other Northwest atlantic finfish. Fish. Bull., Vol. 80(4):745-759.

Larrañeta, M. G. 1981. A use of the catch-per-unit effort in ecology. An. Inst. Cienc. del Mar y Limnol., Univ. Nac. Autón. México, 8(1):183-190.

--. 1982. Relaciones entre los parámetros de las curvas de generaciones. Inv. Pesq., 46(2):231-238.

--. 1984. Dynamics of yellowtail flounder and American plaice in NAFO Divisions 3L, 3N and 30. NAFO SCR Doc. 84/VI/30.

Lleonart, J.,J. Salat and Macpherson. 1985. CVPA, an expanded VPA with cannibalism. Application to a hake population. Fish. Res., 3:61-79.

Marí, A. and I. Ramos. 1979. Fecundity of silver hake on the Scotian Shelf. ICNAF, Res. Doc. 79/VI/66.

NAFO. Fishery Statistics. Stat. Bull.

Nicholson, M. D. 1984. Some applications of CUSUM techniques in fisheries research. ICES, CM/1984/D:5.

Noskov, A.S., V. I. Vinogradov and A. I. Shertyukov. 1982. Results of ecological surveys on the Nova Scotia Shelf in 1974 and 1977-80 to study the spawning of silver hake. NAFO SCR Doc. 82/VI/33.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Bull. Fish. Res. Board Can., 119.

Rowell, T. W. and J. H. Young. 1984. Update of the distribution, biomass, and length frequencies of Illex illecebrosus in Division 4VWX from Canadian Research Vessel Surveys, 1970-1983. NAFO SCR Doc. 84/VI/69.

Sarnits, A. A. and V. V. Sauskan. 1967. Hydrological conditions and distribution of silver hake Merluccius bilinoaris Mitchill, on Georges Bank and Nova Scotia in 1962-64. ICNAF, Res. Bull. (4):76-86.

Sinclair, A. 1980. NAFO SCR Doc. 80/IX/139.

Sutcliffe, W. H., Jr. 1972. Some relations of land draimage, nutrients, particulate material, and fish catch in two Eastern Canadian Bays. J. Fish. Res. Board Can., 29: 357-362.

--. 1973. Correlations between seasonal river discharge and local landings of american lobster (Homarus americanus) and atlantic halibut (Hippoglossus hippoglossus) in the Gulf of St. Lawrence. J. Fish. Res. Board Can.,30:856-9.

Sutcliffe, W. H. Jr., R. H. Loucks and K. F. Drinkwater. 1976. Coastal circulation and physidal oceanography of the Scotian Shelf and the Gulf of Maine. J. Fish. Res. Board Can., 33:98-115.

Trites, R. W. 1981. NAFO SCR Doc. 81/IX/111/

Trites, R. W. and K. F. Drinkwater. 1984. Overview of environmental conditions in the Northwest Atlantic in 1982. NAFO Sci. Coun. Studies, (7):7-25.

Vázquez, A. 1981. Nuevo método para el cálculo de poderes de pesca e índices de abundancia en pesquerías. Inv. Pesq., 45(2):241-255.

Vázquez, A. and M. G. Larrañeta. 1981. Evaluación de la población de bacalao (Gadus morhua) en la Division 3 NO de la NAFO. Inv. Pesq., 45(1):123-134.

Vinogradov, V. I. 1984 a. Food of silver hake, red hake and other fishes of Georges Bank and adjacent waters, 1968-74. NAFO Sci. Coun. Studies, (7):87-94.

--. 1984 b. The distribution of food energy for major commercial fisheries in the trophic chain of the Georges Bank ecosystem. NAFO SCR Doc. 84/VI/42.

Waldron, D. E. 1983. Factors influencing Scotian Shelf finfish and squid interactions with special reference to silver hake. NAFO SCR Doc. 83/IX/92.

Waldron, D. E. and C. Harris. 1984. Assessment of the Scotian Shelf silver hake population size in 1983. NAFO SCR Doc. 84/VI/85.

Table 1. Stock-Recruitment Relations in the silver hake with the data given by Clay and Beanlands (1981)

Years	r	A	B
1958 - 78	- 0.65	62.78	- 0.0172
1958 - 67	- 0.90	112.08	- 0.0479
1968 - 78	- 0.80	147.14	- 0.0250

. . . .

Table 2. Dominant species composing the diet of silver hake

Species	% in weight	author, year
mackerel	24	Vinogradov, 1984 a
redhake	9	Vinogradov, 1984 a
mackerel	7.5/80	Bowman and Michaels, 1984
Clupeidae	2.7/80	Bowman and Michaels, 1984

. . . .

Table 3. Relations of the biomass or abundance rates of various species with the recruitment, the following year, of the silver hake in the NAFO Divisions 4VWX

Species	Units	Author, year	Correlation
cod	t (spawning biomass)	Halliday, 1975	0.56^{ns}
cod	t (spawning biomass)	Bishop et al., 1984	-0.43^{ns}
plaice	kg/h	Halliday, 1976 a	-0.01^{ns}
witbh flounder	kg/h	Halliday, 1976 a	-0.22^{ns}
yellowtail	kg/h	Halliday, 1976 a	-0.39^{ns}
yellowtail		Larrañeta, 1984	-0.64^{ns}
redfish	t/h	Halliday, 1976 b	0.42^{ns}
herring	t (spawning biomass)	Sinclair, 1980	0.42^{ns}
mackerel	t (spawning biomass)	Anderson and Paciorkowski, 1980	0.73**
squid	t (biomass)	Rowell and Young, 1984	-0.40^{ns}

. . . .

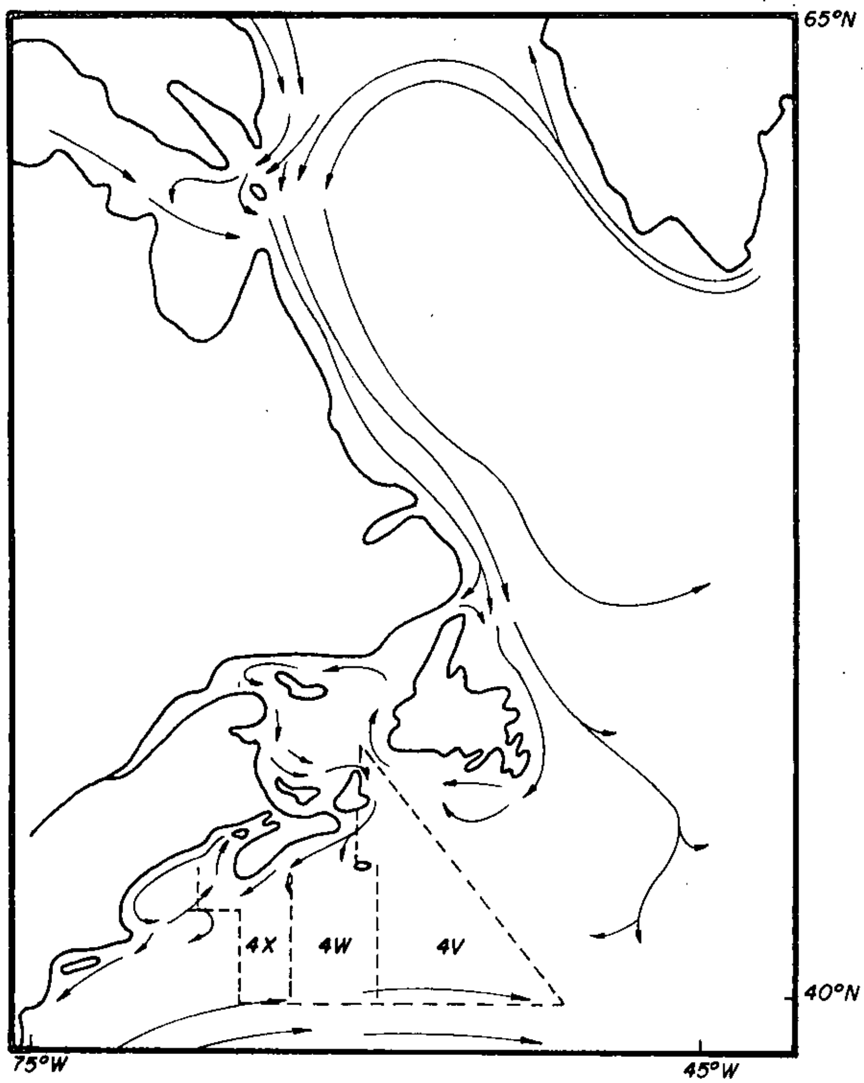

Fig. 1. Overall circulation pattern of NAFO Division 4VWX (as per Sutcliffe et al., 1976

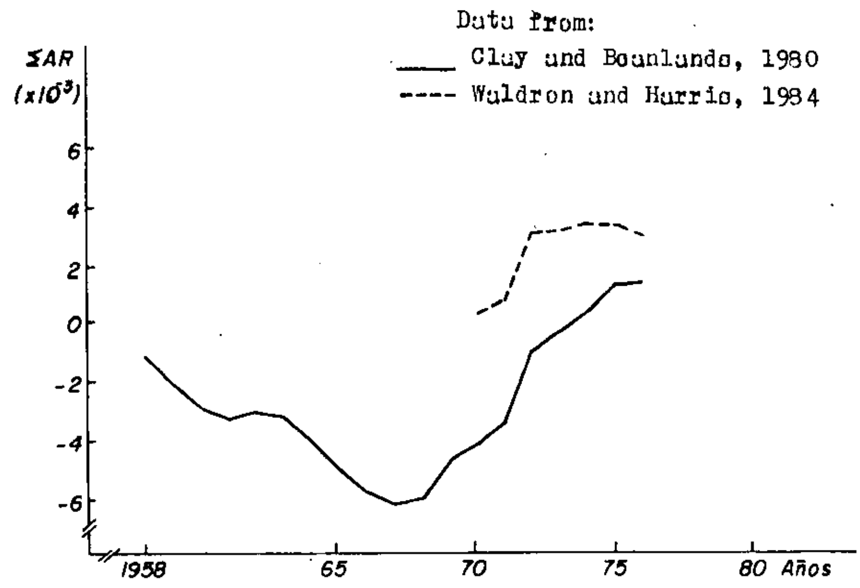

Fig. 2. Changes in the summations of the Recruitment of silver hake in NAFO Division 4VWX.

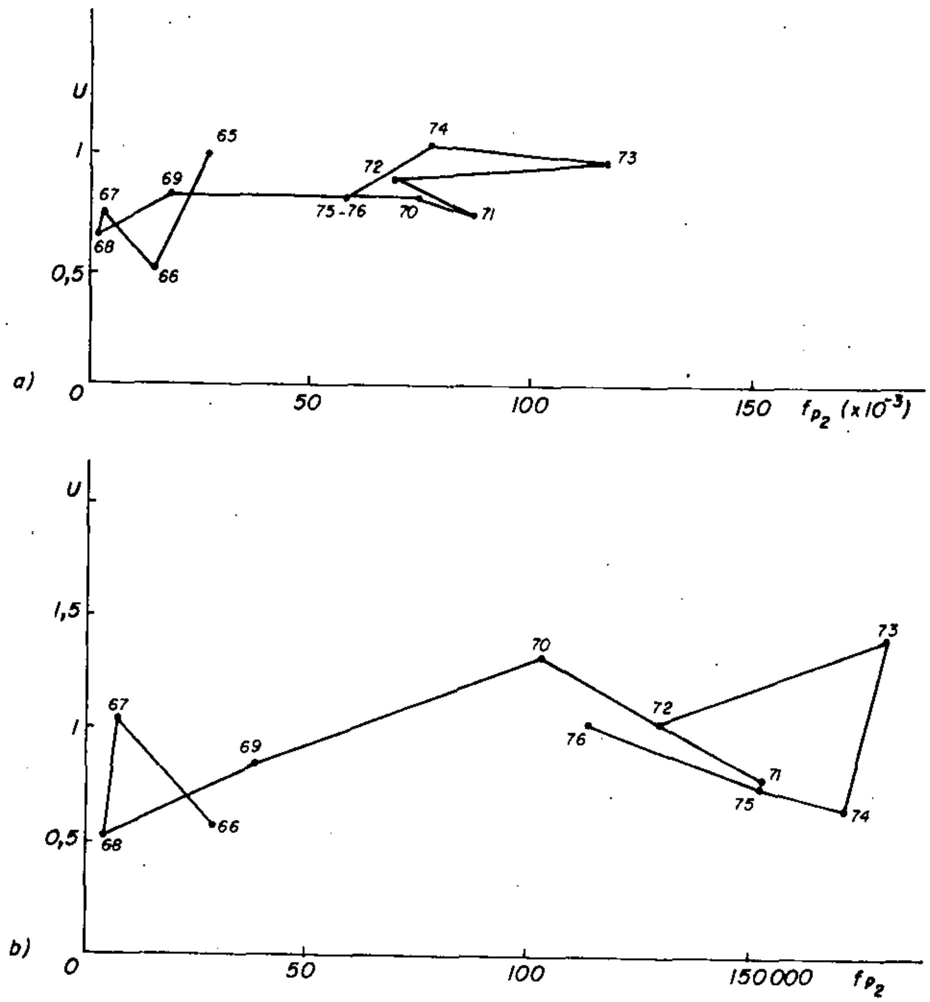

Fig. 3. opuo/offort ratio

a - Data from Clay and Boanlands, 1980

b - Data from Vázquoz, pors. oom.

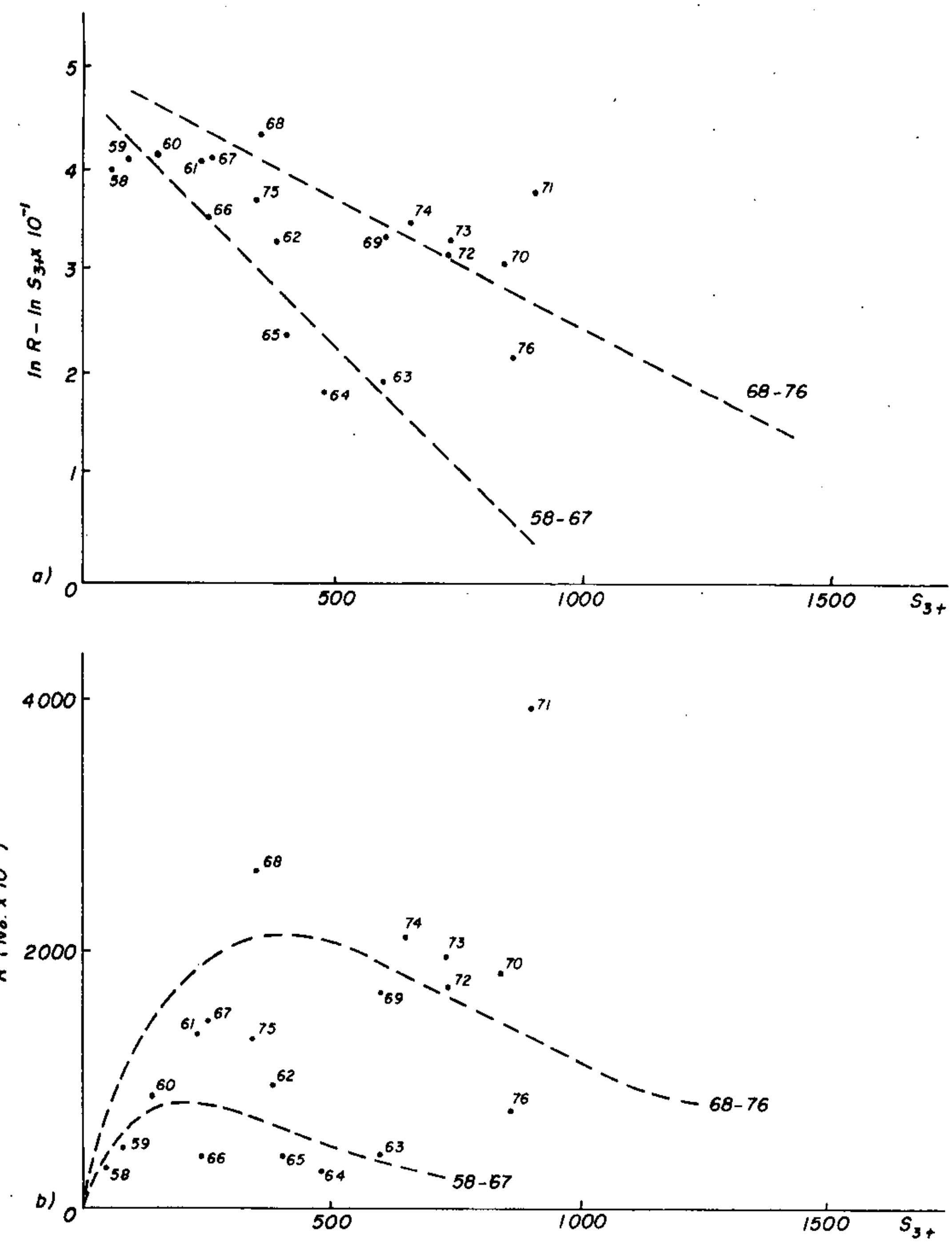

Fig. 4. Spawning biomass (S_3+)/Recruitment (R) ratio, the following year, of the silver hake. (Data from Clay and Beanlands, 1980).

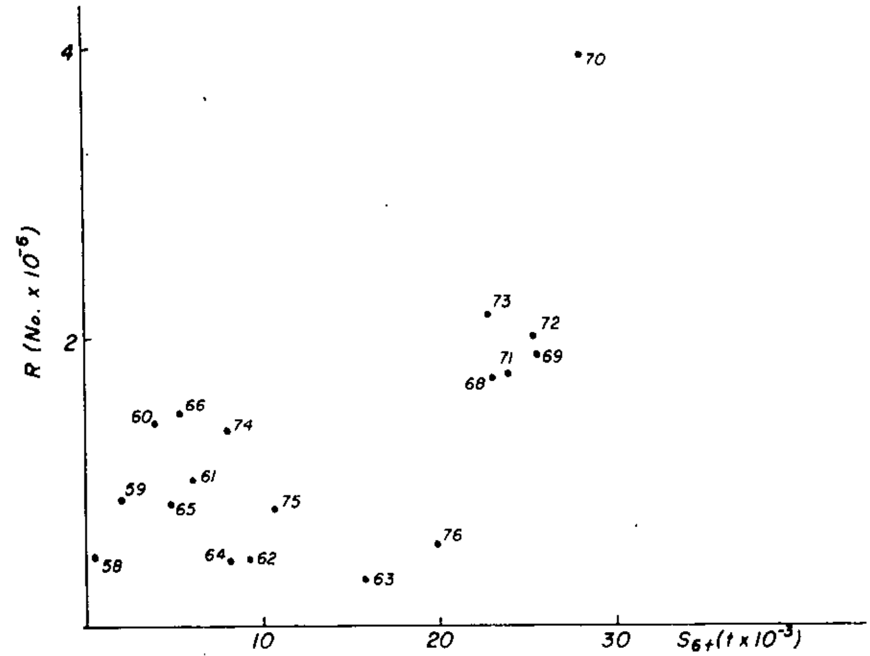

Fig. 5. Predators/Recruitment ratio, the following year of the silver hake (Data from Clay and Beanlands, 1980).

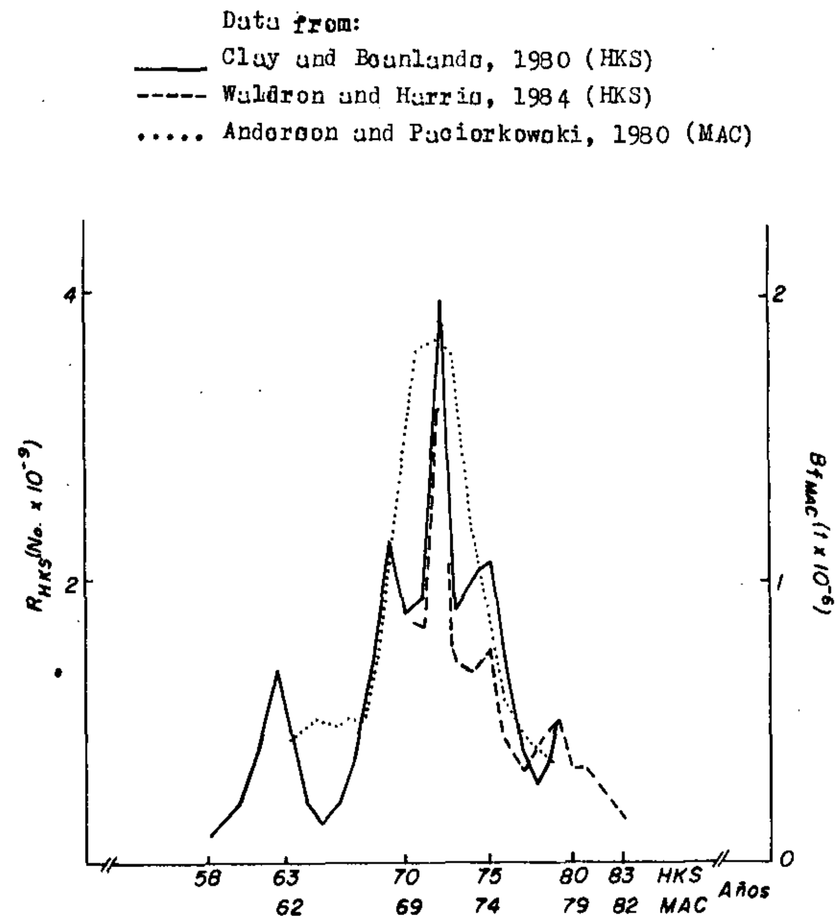

Fig. 6. Graphic relation of the spawning biomass of the mackerel (Bf mac) to recruitment the following year of the hake (Rhks).

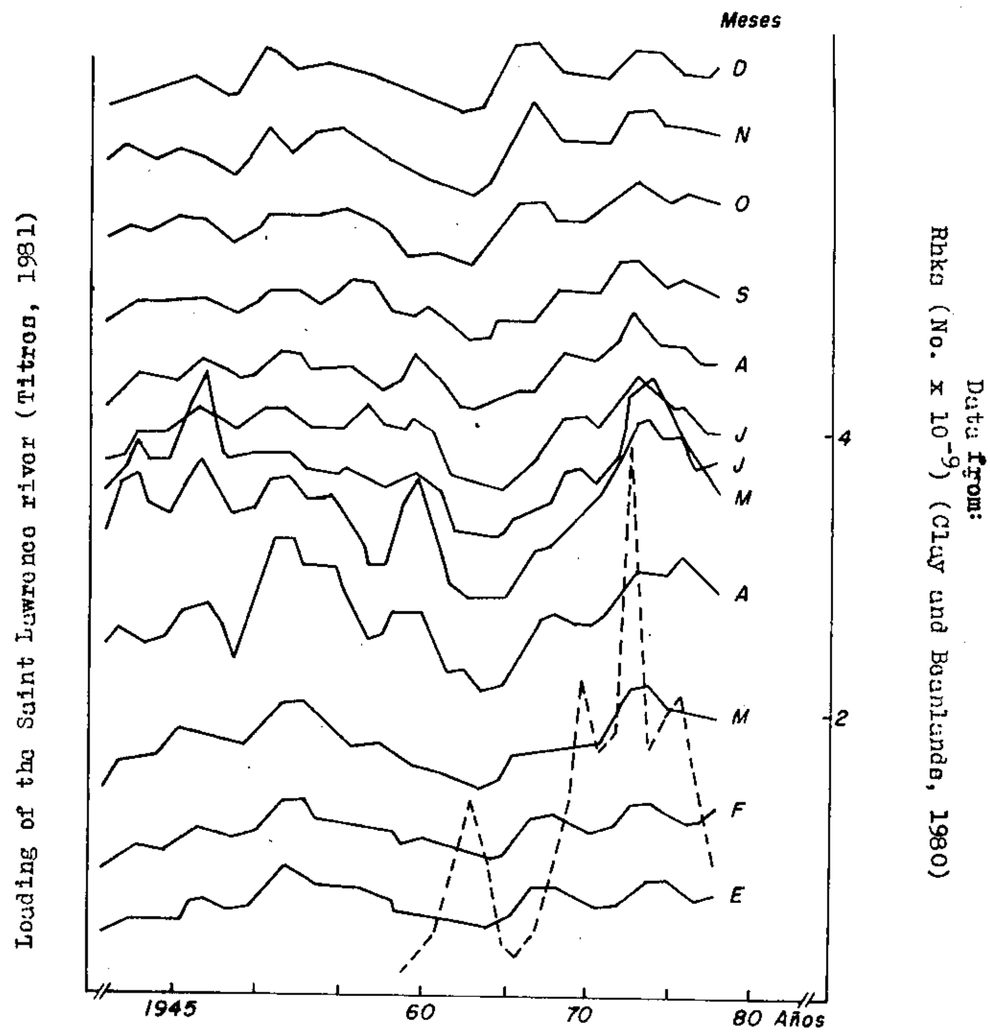

Fig. 7. Graphic relation of the loading of the Saint Lawrence river to Recruitment, the following year of the silver hake (Rhks).