NOT TO BE CITED WITHOUT PRIOR
REFERENCE TO THE AUTHOR(S)

Northwest Atlantic Fisheries Organization

Serial No. N1730

NAFO SCR Doc. 90/15
Corrigendum

SCIENTIFIC COUNCIL MEETING - JUNE 1990

The Stock-Recruitment Dependence Nature in Some Fish Species From the Northwest Atlantic

by

V. A. Rikhter

Atlantic Scientific Research Institute of Marine Fisheries and Oceanography
(AtlantNIRO), 5 Dm. Donskoy Street, Kaliningrad, 236000, USSR

Please replaced the original Figure 9 in this document (page 32) with the following Figure 9.

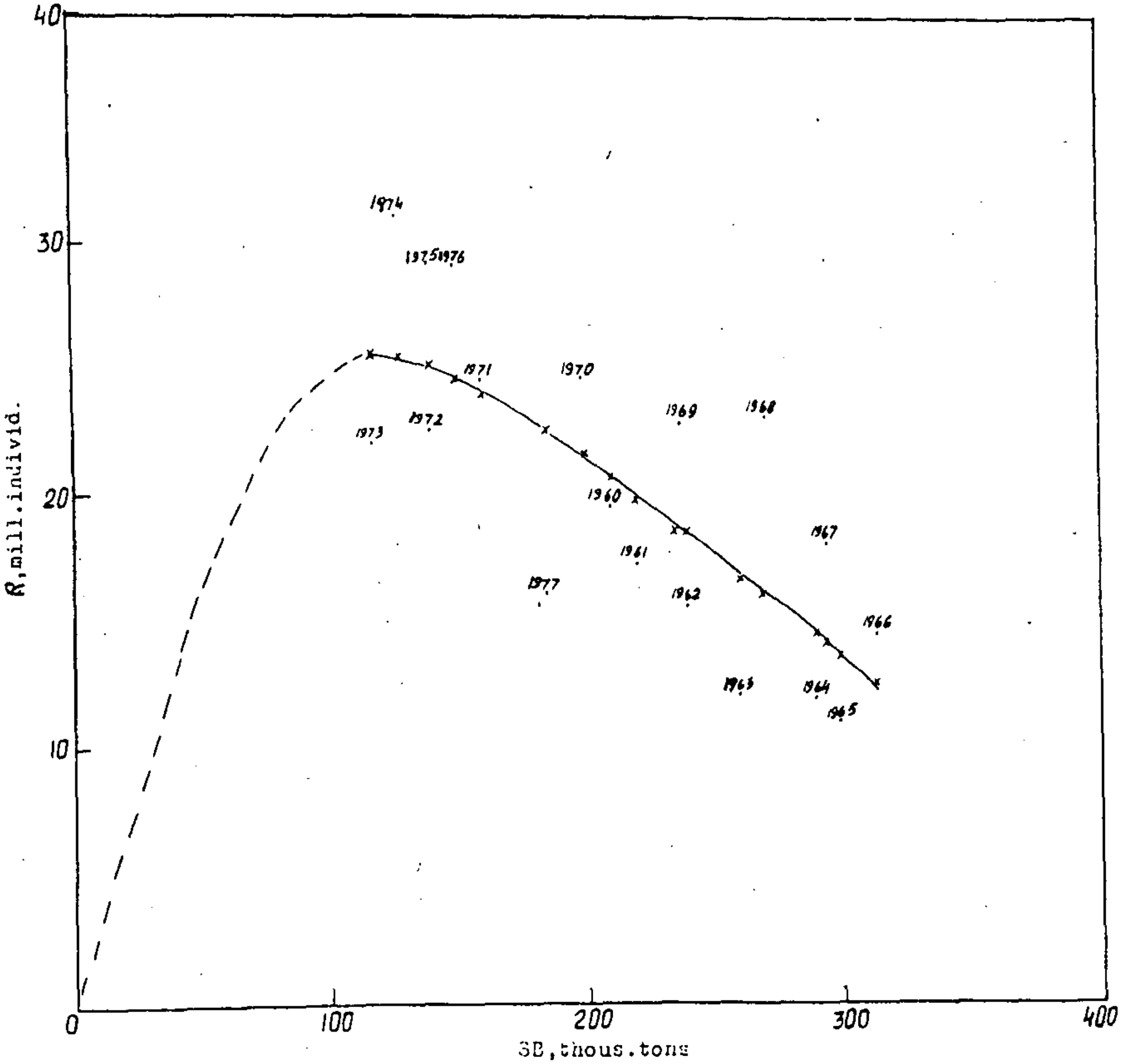

Fig. 9. Relation between the 3LNO american plaice spawning stock and recruitment.

Northwest Atlantic Fisheries Organization

Serial No. N1730 NAFO SCR Doc. 90/15

SCIENTIFIC COUNCIL MEETING - JUNE 1990

The Stock-Recruitment Dependence Nature in Some Fish Species From the Northwest Atlantic

by

V. A. Rikhter

Atlantic Scientific Research Institute of Marine Fisheries and Oceanography (AtlantNIRO)
5 Dm. Donskoy Street, Kaliningrad, 236000, USSR

ABSTRACT

The stock recruitment dependence (SRD) nature has been studied by different methods in six commercial fish species (11 units of resource) from the North-West Atlantic. The method which provides the best correspondence to the data observed has been selected for each stock unit. The nature of SRD curves plotted by the data calculated with the use of equation selected has been analysed. There has been made an approximate estimation of recruitment rate which showed that the latter parameter was most of all decreasing with biomass increase. At the same time, recruitment abundance in its absolute expression continues increasing with the spawning biomass increase in most cases. It has been suggested that the combined analysis of density dependence, environmental factors and fishery is the most perspective way of study of recruitment variability, since the above-mentioned factors never apparently act as net factors in practice.

INTRODUCTION

Problem of study of recruitment dependence nature on spawning stock amount for various fish species has attracted investigators' attention for many years. However, we don't succeed in getting a definite answer relevant the subject even at present. The reason seems to be that the problem itself is of complicated character which required an examination of a number of factors influencing the amounts of fish stock recruitment. In turn, the analysis of these factors influence on the recruitment variability is not a simple matter, as long-term studies frequently neccessary. It is also necessary to have large temporal series of data available concerning stocks and recruitments of species under investigations. In spite of the complexity of tasks planted, the work in this scope is continued which is attributed to the problem of fishery management. In the paper it has been made an attempt to clear up as far as possible the dependence of the stock-recruitment nature for some commercial species from the North-West Atlantic, being at least observed the latter condition (long--term observations).

MATERIAL AND METHODS

Six commercial species from the North-West Atlantic which form 11 stock units have been examined:

Species	NAFO Area and Division	Information Source
1	2	3
Silver hake	4 VWX	Waldron et al., 1988
- " -	5 ZE	Almeida, Anderson, 1979 (a)
Silver hake	5 ZW+6	Almeida, Anderson, 1979(b)
- " -	5 Y	Almeida, Anderson, 1979(c)
Cod	2 J+3 KL	Baird, Bishop, 1985
-"-	3 NO	Bishop, Baird, 1985(a)
-"-	3 Ps	Bishop, Baird, 1985(b)
Yellowtail flounder	3 LNO	Brodie, 1985(a)
American plaice	3 LNO	Brodie, 1985(b)
Mackerel	3-6	Anderson, Overholtz, 1979
Deepwater redfish	3 M	Chekhova et al., 1980

The stock recruitment dependence (SRD) has been calculated by the least square method for all the above-mentioned units using four different equations (Beverton and Holt, 1957; Ricker, 1954; Cushing, 1971; Chapman, 1973). The recruitment (abundance of year-classes entering fishery for the first time) has been evaluated in millions of specimens, being expressed the spawning stock in thousand tons. The latter has been determined as a total biomass for age-classes starting with a definite age:

Silver hake	5 Ze, 5 Zw + 6, 5Y	- 2+
-"-	4 VWX	- 3+
Cod	2 J + 3 KL	- 7+
-"-	3 NO, 3 Ps	- 6+
Yellowtail flounder	3 LNO	- 7+
American plaice	3 LNO	- 8+
Mackerel	3-6	- 3+
Deepwater redfish	3 M	- 10+

The equations obtained have been analysed from the standpoint of their correspondence to the observed data. Such criteria as correlation coefficients between the calculated data and those observed, value of mean squared deviation (σ) and the difference between calculated and observed values of recruitment have been used. The data calculated by the equations and selected with the aid of the above-mentioned criteria have been used for subsequent analysis.

RESULTS OF INVESTIGATIONS

Estimates of recruitment obtained with the aid of four above--mentioned equations are represented in Tables I - II. The next task consisted of selection of methods that could provide the best correspondence to the observed data. In Tables 12 and 13 correlation coefficients and values of total deviations (D) between the calculated and observed data, as well as mean squared deviations (σ) in the recruitment calculated values are indicated. The calculations for silver hake from the 4 VWX were made using the data for all the observations including two recent years for which the information appears to be questionable.

The data mentioned indicate that a strong correlation of 99% of probability exists between the calculated and those observed recruitment values for silver hake from the 4 VWX (all the dependence forms) and 5 Y (Ricker's dependence), and for american plaice from the 3 LNO (Ricker's and Cushing's dependence). A moderate correlation of 99% of probability was found for the 5 Ze silver hake (Ricker's, Chapman's dependence) and for the 3 Ps cod (Ricker's dependence). The correlation varied between weak and moderate one with coefficients less than critical ones for the rest of stock units.

The last value of mean squared deviation and the least difference between the observed and calculated recruitment values were also used as the criteria for selection of the most proper form of the stock-recruitment dependence. Two latter criteria were prefered in such cases when correlation coefficients were slightly different. Methods selected for a subsequent analysis of SRD in the stock units under consideration are represented in Table 14.

The data cited indicate that the most frequent form of dependence was that of Ricker's type. It was followed by the SRD forms suggested by Chapman and Cushing. Curves plotted by the equations selected are represented in Figures 1-11. The analysis of curve natures allowes for distinguishing between two types of them, i.e. curves of somewhat different maximum (Figs. 2, 3,7, 8, 9 and 10) and curves without maximum which are similar by their form to a linear dependence (Figs. 4, 5, 6 and 11) The spawning biomass which maximum recruitment is attained with as for the first type of curves was more than 50% of maximum biomass observed in the 5 Ze and 5 Zw+6 silver hake, the 3 LNO yellowtail flounder, the 3 Ps cod and the 3-6 mackerel. As to the 3 LNO american plaice, one may suggest that the biomass which corresponds to the maximum recruitment is of 35-40% of the maximum one in this species. The figures show that there may appear year-classes which strongly differ by their abundance with equal or similar to spawning biomass value. This is evidently attributed to the environmental factors influence. An attempt was made to evaluate if only roughly the recruitment type distinguishing between three levels of spawning biomass (low, average and high) for each species under consideration to reduce the environmental factors influence, and calculating mean values of biomass and recruitment for each group. As the initial data there were used the values of spawning biomass borrowed from the above-mentioned sources and recruitment estimates calculated with the equations selected (Tables 15, 16). The following levels of spawning biomass were selected:

Stock Units	Biomass Levels, thou. t		
	low	Average	High
Silver hake 4 VWX	120	120-140	140
-"- 5 Ze	150	150-300	300
-"- 5 Zw+6	100	100-200	200
-"- 5 Y	100	100-150	150
Cod 2J+3KL	300	300-600	600
-"- 3 NO	50	50-100	100
-"- 3 Ps	50	50-100	100
Yellowtail flounder 3LNO	10	10- 15	15
American plaice 3 LNO	15	15- 25	25
Mackerel 3-6	500	500-1000	1000

Calculation results are represented in Tables 15 and 16. The data cited evidence of the fact that in most cases the absolute recruitment abundance increases with the spawning biomass increase (Table 15). As to the recruitment rate, it decreses with biomass growth in most stock units (Table 16). As it had to be expected, in species with large life-span (flounder, cod) recruitment rate was in the whole rather low as compared to the species of lesser life-span.

DISCUSSION

The stock-recruitment dependence obtained for some commercial species of fish from the North-West Atlantic is in fact the result of a combined influence of spawning stock density (amount) and the environmental factors on the recruitment. At the same time, it is very difficult, if possible, in most cases to distiguish between the influence of density factors and those of the environment on the recruitment, although to the opinion by Welch (1987) this distinction is to be done. When we mean anomalously abundant year--classes, one may guess that unusually favourable (or unfavourable) for the survival of yearlings oceanographic factors are obviously of a leading role. However, such anomalies take place rather seldom. The most illustrative example amongst the species under investigation may serve the 1967 mackerel year-class and that of the 1985 4 VWX silver hake (Figs. 1, 10). The filtering technique suggested by

Welch (1986) leads on the one hand to a considerable omission in observations and on the other hand gives no chance to eliminate a substantial variability in the data on the recruitment. Welch (1987) suggests that further use of filtering theory concerns the analysis of environmental factors influence on the recruitment. However, since the SRD never is evidently observed in nature in its net form, but it is noticeable in the recruitment variability as the result of a combine influence of density factors and those of the environment, the question arises if it is real the task of complete elimination of variability caused by the environmental factors with filtering technique. It is possible that in such a case a complex analysis of reasons for fluctuations in the year-class abundance is more effective method. In fact, we mean using the raw data on stock and recruitment (Evans and Rice, 1988).

The necessity of better interpretation of situations, where the environmental factors, stock amount and fishery determine in common the recruitment size, is cited in the paper by Walters and Collie (1988). We may add that such situations are observed so frequently that opposed cases are to be rather considered as the exception. The SRD nature for the 4 VWX silver hake may serve as an illustration. Figure 1 and Table 16 show that the silver hake recruitment rate was accelerated as the spawning biomass increased for the period under consideration which could be mainly attributed to the anomalous (i.e. extremely favourable for the yearlings survival) environmental conditions in corresponding years. In the paper by Waldron (1989) which concerns cannibalism study in the Nova Scotian Shelf silver hake some data on cannibalism effect on the SRD nature are given. Having excluded a considerable number of data pairs as being doubtful and having used his equation, Ricker got a strongly pronounced domelike curve. However, if calculations are made using all the data without any exception, one may get a curve almost similar to that of figure 1 of this paper. Differences are only observed in the recruitment abundance. The environmental factors (and evidently oceanographic factors first of all) seem to suppress the effect of density dependent factors, including cannibalism, in definite periods with respect to the population under investigation. It is clear that this dependence cannot be used to make a forecast without taking into consideration the variational trends in the environment. It is worth paying attention to the period of 1975 through 1980, when both spawning biomass and recruitment were kept at a considerably stable and low level. Analogous situation was observed for the 5 Ze and 5 Zw+6 silver hake in 1955 through 1958 (Figs.2, 3) and for the mackerel in 1962 through 1965 (Fig. 10). The data for earlier period are lacked. The spawning stock amount by itself was evidently unsufficient for those years to produce under the average survival conditions suggested the year-classes strong enough for guaranteeing a pronounced biomass growth. In such a case it is most likely necessary that the survival conditions exceed an a erage level. One may suppose that the appearance of even a single strong year-class of some species is enough to engage the SRD mechanism.

On the whole, the recruitment variability to all appearance depends on the way of effect of density dependent factors and those of the environment. In some cases the synchronous variations in the spawning biomass and recruitment amount will be observed, being almost unpredictable fluctuations in year-classes strength in other cases. An ideal explitation rate for one or another stock unit must be determined by joint effect character of the above-mentioned factors to derive major benefit from the favourable situations and to prevent as far as possible the stock overexploitation under the unfavourable conditions.

Returning to the subject of the prognostic character of the stock-recruitment dependences, it is worth to note that they may be hardly used directly to forecast the recruitment. At the same time, it is evidently impossible to ignore the recommendations by Cushing and Harris (1973) as to the reaction of different species groups to the fishery in accordance with the SRD character when developing fishing strategy. The data of Tables 15 and 16 mainly evidence the reality of the SRD effect, in spite of many obstacles caused by the environmental factors enfluence. The above-mentioned information suggests that in most stock units studied the spawning biomass amount must be more than average one to provide the recruitment high level. The spawning biomass average level seems to be optimum only for mackerel and two species of flounder.

The above-mentioned discussion is certainly of somewhat abstract character, since it does not cover the whole variety of conditions. As it was already mentioned, the real situation including the forecast for the nearest years may be evidently estimated only with the analysis of a number of factors (spawning stock amount, environment, fishery) which determine the recruitment variability.

REFERENCES

1. Almeida F.P. and E.D.Anderson (a). 1979. Status of the Georges Bank silver hake stock - 1978. ICNAF res. Doc 79/84.

2. Almeida F.P. and E.D.Anderson (b). 1979. Status of the southern New England - Middle Atlantic silver hake stock - 1978. ICNAF Res. Doc. 79/84.

3. Almeida F.P. and E.D.Anderson (c). 1979. Status of the Gulf of Maine silver hake stock - 1978. ICNAF Res. Doc. 79/88.

4. Anderson E.D. and W.J.Overholtz. 1979. Status of the Northwest Atlantic mackerel stock - 1978. ICNAF Res. Doc. 79/90.

5. Baird J.W. and C.A.Bishop. 1985. Assessment of the cod stock in NAFO Divisions 2 J + 3KL. NAFO SCR Doc. 85/37, 38 p.

6. Beverton R.J.H. and S.J.Holt. 1957. On the dynamics of exploited fish populations. U.K.Min. Agric. Fish. Invest. (Svr.2) 19, 533 p.

7. Bishop C.A. and J.W.Baird (a). 1985. Assessment of the cod stock in NAFO Divisions 3 NO. NAFO SCR Doc. 85/39, 19 p.

8. Bishop C.A. and J.W.Baird (b). 1985. An assessmen of the cod stock in Subdivision 3PS. NAFO SCR Doc. 85/38, 25 p.

9. Brodie W. (a). 1985. An assessment of the yellowtail flounder stock in NAFO Div. 3L, 3N and 30. NAFO SCR Doc. 85/50, 20 p.

10. Brodie W. (b). 1985. An assessment update of the American plaice stock in NAFO Divisions 3 LNO. NAFO SCR Doc. 85/51, 28 p.

11. Chapman D.G. 1973. Spawner-recruit models and estimation of the level of maximum sustainable catch. Rapp. P. - V. Reun. Perm.Int. Explor. Mer 164, p. 375-389.

12. Chekhova V.A., A.K.Chumakov, I.S.Shafran and V.G.Korytin. 1980. Assessment of the stock of beaked redfish in the Flemish Cap area (Division 3M), NAFO SCR Doc. 80/119, 13 p.

13. Cushing D.H.. The dependence of recruitment on parent stock in different groups of fishes. J. Cons. Int. Explor. Mer, Vol. 33, No.3, p. 340-362.

14. Cushing D.H. and J.G.Harris. 1973. Stock and recruitment and the problem of density-dependence. Rapp. P.-V. Reun. Cons. Explor. Perm. Int. Mer 164, p. 142-155.

15. Evans G.T. and Rice J.C. 1988. Predicting recruitment from stock size without the mediation of a functional relation. J.Cons. Int. Explor. Mer Vol. 44, No.2, p.111-122.

16. Waldron D.E. 1989. Cannibalism in the Scotian Shelf silver hake population. NAFO SCR Doc. 89/81, 59 p.

17. Walters C.J. and Collie J.S. 1988. Is research on environmental factors useful to fisheries management? Can. J. Fish.and Aquat. Sci. Vol. 45, No.10, p. 1848-1854.

18. Welch D.W. 1986. Identifying the stock-recruitment relationship for age-structured populations using time-invariant matched linear filters. Can. J. Fish. and Aguat. Sci. Vol.43, No.1, p. 108-123.

19. Welch D.W. 1987. Influence of three life history strategies on the information content of stock-recruitment data. Can. J. Fish. and Aquat. Sci. Vol.44, No.7, p. 1375-1379.

Table 1

Recruitment estimates (mln. ind.) for the 4VWX silver hake by the SRD equations

Year	Recruitment observed	Recruitment calculated			
		Beverton and Holt	Ricker	Chapman	Cushing
I970	I708.9	I7I2.2	I973.0	2435.I	I976.2
I97I	3786.6	2286.6	2669.9	3287.8	2580.3
I972	I438.3	I774.3	2049.7	2532.I	2046.I
I973	I369.2	I623.I	I862.5	2294.0	I874.0
I974	I488.6	I063.4	II66.6	I369.8	II82.7
I975	855.I	I028.9	II24.I	I3II.7	II37.7
I976	693.9	969.0	I050.6	I2II.2	I059.2
I977	762.I	I059.0	II6I.2	I362.4	II77.0
I978	902.0	795.2	840.4	922.6	829.6
I979	573.6	76I.3	799.9	867.2	784.6
I980	769.7	82I.2	87I.4	965.I	863.9
I98I	II83.9	938.3	I0I3.2	II59.7	I0I8.8
I982	843.8	976.8	I060.I	I224.2	I069.4
I983	I563.7	8I0.0	858.0	946.8	849.I
I984	II72.3	I697.3	I954.5	24II.7	I959.3
I985	6704.2	I370.7	I548.2	I883.8I	I572.3
I986	I60I.9	I70I.3	I959.5	24I7.9	I963.9

Table 2

Recruitment estimates (mln. ind.) for the 5Ze silver hake by the SRD equations

Year	Recruitment observed	Recruitment calculated			
		Beverton and Holt	Ricker	Cushing	Chapman
I955	4I2.3	668.4	707.4	772.9	729.I
I956	5II.3	664.I	700.8	769.0	7I8.7
I957	883.4	645.3	672.0	752.5	674.5
I958	I304.6	669.4	709.I	773.8	73I.6
I959	I993.3	778.2	890.3	877.4	I037.4
I960	2206.8	908.8	II33.3	I026.8	I5I6.4
I96I	2993.0	I034.9	I360.2	I2I8.3	2002.I
I962	3256.6	II25.4	I442.2	I4II.3	I9II.5
I963	I950.7	II72.5	I403.5	I545.5	II35.2
I964	III7.9	II88.4	I368.I	I598.8	583.4
I965	I624.7	II5I.4	I43I.5	I48I.2	I603.9
I966	600.5	I00I.9	I306.5	II6I.7	I893.5
I967	557.2	908.3	II52.4	I026.2	I5I4.5
I968	5I3.4	8I5.6	957.7	9I6.8	II62.4
I969	437.4	799.7	728.9	899.8	II08.2
I970	639.8	793.2	9I7.I	893.0	I086.4
I97I	II66.6	769.3	874.7	868.4	I009.4
I972	I065.I	808.5	944.7	909.I	II37.8
I973	I254.7	838.I	999.2	94I.6	I242.5

- -

Table 3

Recruitment estimates (mln. ind.) for the 5Zw+6 silver hake by the SRD equations

Year	Recruitment observed	Recruitment calculated			
		Beverton and Holt	Ricker	Cushing	Chapman
I955	400.2	483.5	46I.3	530.7	492.6
I956	303.8	485.2	470.6	533.8	508.6
I957	336.I	488.3	488.I	539.6	539.5
I958	5I2.5	483.5	46I.3	530.6	492.6
I959	652.8	489.0	49I.9	540.9	546.5
I960	948.3	490.I	498.5	543.I	558.4
I96I	I549.4	5I3.I	665.0	600.3	9I2.3
I962	2002.I	525.8	77I.2	649.9	I208.2
I963	I876.0	535.5	80I.8	708.3	I25I.I
I964	I344.I	54I.5	7II.2	764.2	336.9
I965	90I.3	543.4	640.8	788.0	622.8
I966	53I.I	54I.5	7II.2	764.2	336.9
I967	235.6	535.0	803.6	704.5	I269.2
I968	240.6	529.9	796.6	67I.5	I287.3
I969	34I.8	524.3	759.8	642.9	II72.9
I970	580.9	494.6	526.3	552.2	6I0.4
I97I	772.I	490.0	497.9	542.9	557.4
I972	696.I	5I7.6	703.7	6I5.7	I0I2.2
I973	378.4	526.4	775.2	652.7	I220.7

Table 4

Recruitment estimates (mln. ind.) for the 5Y silver hake by the SRD equations

Year	Recruitment observed	Recruitment calculated			
		Beverton and Holt	Ricker	Cushing	Chapman
I955	549,8	206,8	439.4	404.8	4I.4
I956	602.6	205.8	428.9	393.6	5I.5
I957	608.4	205.8	428.4	393.0	56.0
I958	569.0	204.I	4II.3	375.5	I79.8
I959	536.8	20I.8	389.2	354.0	299.I
I960	485.7	I99.8	37I.4	337.4	368.4
I96I	480.I	200.6	378.4	343.9	343.5
I962	5I0.I	I99.5	368.5	334.7	377.7
I963	456.I	I98.9	363.5	330.2	392.7
I964	332.6	I98.8	362.4	329.3	395.7
I965	I7I.0	I96.I	34I.2	3I0.5	443.3
I966	96.0	I93.3	320.6	292.8	469.9
I967	86.8	I84.I	263.3	245.9	469.8
I968	63.2	I75.0	220.5	2I2.I	420.6
I969	53.I	I49.7	I40.7	I49.2	268.6
I970	76.4	I25.2	94.2	II0.9	I65.6
I97I	I24.9	90.3	52.8	73.7	77.8
I972	I42.6	I0I.9	64.4	84.3	I0I.2
I973	I78.0	II0.7	74.5	93.6	I22.5
I974	I37.9	I25.2	94,2	III,0	I65.6

Table 5

Recruitment estimates (mln. ind.) for the 2J+3KL cod by the SRD equations

Year	Recritment observed	Recruitment calculated			
		Beverton and Holt	Ricker	Cushing	Chapman
I962	8I6.7	329.9	45I.0	475.2	2522.3
I963	925.2	329.6	465.6	468.5	I790.2
I964	670.2	329.7	458.3	47I.9	2I50.9
I965	578.0	328.4	496.6	447.4	I98.0
I966	535.8	327.6	503.4	436.9	290.5
I967	589.0	326.9	504.4	427.6	592.0
I968	475.2	326.4	502.4	42I.0	748.5
I969	207.7	324.9	489.3	405.7	962.2
I970	I23.7	323.6	472.9	394.4	I0I9.8
I97I	I25.2	324.0	477.9	397.6	I0I0.7
I972	237.6	324.0	478.2	397.8	I0I0.0
I973	350.5	323.0	464.7	389.8	I025.2
I974	3I9.4	32I.I	437.6	376.8	997.8
I975	337.2	3I3.0	332.9	337.3	7I9.2
I976	I86.I	292.5	I92.4	286.2	33I.4
I977	246.6	288.4	I76.0	279.5	29I.8
I978	69I.9	286.3	I68.4	276.2	273.9
I979	564.7	298.6	222.0	297.8	406.5
I980	499.0	3I8.3	397.8	360.6	905.4

- - - - - - - - - - - - - - - - - - - -

Table 6

Recruitment estimates (mln. ind.) for the 3NO cod by the RSD equations

Year	Recruitment observed	Recruitment calculated: Beverton and Holt	Ricker	Cushing	Chapman
I959	I07.7	50.6	68.9	67.4	89.6
I960	78.I	49.2	68.2	62.3	IOI.3
I96I	III.7	50.7	68.9	67.6	88.6
I962	I62.3	50.0	68.9	64.9	97.5
I963	2I0.0	50.4	69.0	66.7	92.5
I964	I83.2	52.0	66.8	73.3	48.4
I965	I00.6	52.4	65.3	75.4	23.6
I966	I27.9	52.0	66.8	73.2	48.9
I967	80.3	5I.2	68.5	69.7	77.6
I968	84.6	50.3	69.0	66.2	94.0
I969	62.3	50.I	69.0	65.4	96.3
I970	35.4	50.2	69.0	66.0	94.6
I97I	37.7	50.8	68.8	68.3	85.5
I972	24.2	50.4	69.0	66.8	92.2
I973	29.8	48.9	67.9	6I.5	IOI.7
I974	56.6	47.4	65.2	57.4	98.8
I975	44.3	36.0	38.2	38.7	43.3
I976	2I.8	28.5	25.3	3I.3	23.3
I977	38.2	33.4	33.2	35.9	35.0
I978	73.5	36.5	39.0	39.2	44.8
I979	32.0	40.8	48.6	44.7	63.I
I980	29.0	49.8	68.8	64.3	98.8
I98I	I3.4	52.2	65.9	74.6	33.9

Table 7

Recruitment estimates (mln. ind.) for the 3Ps cod by the RSD equations

Year	Recruitment observed	Recruitment calculated: Beverton and Holt	Ricker	Cushing	Chapman
I959	486.7	668.0	594.9	708.8	370.4
I960	429.6	653.I	603.4	89I.9	48I.5
I96I	708.0	658.9	600.4	698.4	44I.4
I962	809.8	6I3.I	6I5.3	649.I	668.8
I963	844.2	604.4	6I5.9	640.2	693.2
I964	984.7	582.9	6I4.9	6I9.0	734.5
I965	70I.7	566.7	6II.8	603.5	750.9
I966	543.0	5I0.6	587.6	552.7	740.9
I967	354.9	494.I	577.2	538.6	724.3
I968	60I.7	5I9.9	592.9	560.9	745.0
I969	393.4	548.8	606.2	586.8	757.4
I970	3II.6	586.2	6I5.3	622,2	729.7
I97I	4I8.6	550.I	606.7	588.0	757.3
I972	566.3	499.0	580.4	542.8	729.7
I973	594.2	423.3	5I9.I	480.6	6I6.4
I974	756.4	39I.5	487.4	455.6	557.5
I975	40I.3	285.6	366.5	374.6	355.7
I976	242.5	235.0	303.3	335.6	266.0
I977	425.5	284.9	365.6	374.0	354.3
I978	II5,7	325.4	4I4.I	404.8	430.4
I979	685.0	400.0	496.0	462.I	573.3
I980	I277.4	486.I	57I.6	53I.8	7I4.7
I98I	I2I4.8	458.6	550.4	508.9	675.8

Table 8

Recruitment estimates (mln. ind.) for the 3LNO yellowtail flounder by the RSD equations

Year	Recruitment observed	Recruitment calculated			
		Beverton and Holt	Ricker	Cushing	Chapman
I968	I2.2	3.3	4.8	4.7	5.9
I969	II.3	6.5	7.0	6.8	9.2
I970	7.6	II.6	8.3	8.8	7.6
I97I	7.2	I4.0	8.4	9.6	4.8
I972	7.9	7.6	7.4	7.3	9.5
I973	8.4	4.I	5.5	5.4	7.2
I974	8.7	2.9	4.4	4.5	5.4
I975	6.9	2.8	4.3	4.4	5.2
I976	6.9	3.4	5.0	4.9	6.2
I977	I.2	3.I	4.6	4.6	5.7
I978	2.I	4.0	5.4	5.2	7.0
I979	I.6	2.6	4.I	4.2	4.8
I980	7.2	4.4	5.8	5.6	7.5
I98I	5.8	5.4	6.4	6.I	8.5

Table 9

Recruitment estimates (mln. ind.) for the 3LNO american plaice by the RSD equations

Year	Recruitment observed	Recruitment calculated			
		Beverton and Holt	Ricker	Cushing	Chapman
I960	I9,4	I7,5	20,5	I8,9	25,6
I96I	I7,2	I7,I	I9.7	I8.3	24.7
I962	I5.5	I6.4	I8.4	I7.4	22.6
I963	I2.2	I5.8	I6.7	I6.3	I8.5
I964	II.9	I5.I	I4.4	I5.0	I0.6
I965	II.3	I4.9	I3.5	I4.6	6.4
I966	I4.4	I4.6	I2.6	I4.I	I.6
I967	I8.2	I5.0	I4.0	I4.8	8.7
I968	22.8	I5.5	I5.9	I5.8	I5.9
I969	22.7	I6.4	I8.4	I7.4	22.6
I970	24.5	I8.3	2I.6	I9.9	26.5
I97I	24.6	2I.2	23.9	22.8	26.6
I972	22.4	25.3	25.0	25.6	25.0
I973	2I.9	33.5	25.4	29.0	22.4
I974	3I.0	28.8	25.3	27.3	23.7
I975	28.8	24.6	24.9	25.2	25.2
I976	29.I	22.6	24.4	23.9	26.I
I977	I6.0	I9.I	22.4	20.8	26.9

Table 10

Recruitment estimated (mln. ind.) for the 3-6 mackerel by the RSD equations

Year	Recruitment observed	Recruitment calculated			
		Beverton and Holt	Ricker	Cushing	Chapman
I962	427.9	7I7.6	I225.4	I229.9	I976.0
I963	428.4	758.8	I276.2	I257.7	2I03.7
I964	540.6	795.6	I320.0	I28I.9	22I6.I
I965	I207.9	772.8	I293.2	I267.0	2I46.9
I966	3I78.8	794.0	I3I8.2	I280.9	22II.5
I967	7790.7	787.3	I3I0.2	I276.5	2I90.9
I968	3084.6	I3I0.2	I760.2	I579.4	34I5.6
I969	3208.6	I940.0	I896.3	I889.7	2849.4
I970	I6I5.7	22I2.4	I836.7	20I6.3	I3I4.I
I97I	I688.0	2232.8	I829.8	2025.8	II54.4
I972	I203.5	22I0.9	I837.2	20I5.6	I325.6
I973	I869.8	I7I7.8	I894.9	I783.9	343I.8

Table 11

Recruitment estimates (mln. ind.) for the 3M

deepwater redfish by the RSD equations

Year	Recruitment observed	Recruitment calculated			
		Beverton and Holt	Ricker	Cushing	Chapman
I958	54.2	99.4	I25.6	I3I.5	I68.6
I959	56.8	89.6	IOI.3	I00.5	II5.3
I960	6I.2	84.5	89.7	89.0	94.3
I96I	64.2	85.0	9I.0	90.2	96.5
I962	76.0	85.9	92.9	92.0	99.8
I963	97.0	88.2	98.2	97.4	I09.6
I964	I23.2	87.8	97.I	96.2	I07.5
I965	I20.7	8I.2	82.9	82.7	83.0
I966	96.8	77.7	76.0	76.6	72.2
I967	77.2	82.0	84.6	84.3	85.7
I968	60.2	86.5	94.2	93.3	I02.I
I969	73.7	90.2	I02.8	I02.I	II8.2
I970	I30.2	93.7	III.3	III.8	I35.7
I97I	232.5	96.0	II7.2	II9.2	I48.6
I972	268.5	93.I	I09.9	II0.I	I32.7
I973	202.2	9I.6	I06.I	I05.8	I24.9

Table 12

Correlation between the observed recruitment amount and those calculated by the SRD equations

Stock units	Beverton and Holt r	Beverton and Holt P	Ricker r	Ricker P	Cushing r	Cushing P	Chapman r	Chapman P
4VWX silver hake	0.71	0.99	0.75	0.99	0.73	0.95	0.74	0.99
5Ze -"-	0.42		0.47	0.95	0.39		0.48	0.95
5Zw+6 -"-	0.30		0.28		0.27		0.15	
5Y -"-	0.67	0.99	0.81	0.99	0.81	0.99	-0.26	
2J3KL cod	0.19		0.08		0.42		0.36	
3 NO	0.36		0.34		0.39		0.11	
3Ps	0.32		0.41	0.95	0.32		0.31	
3LNO yellowtail flounder	0.32		0.29		0.25		0.31	
3LNO american plaice	0.65	0.99	0.75	0.99	0.76	0.99	0.60	0.99
3-6 mackerel	-0.10		-0.01		-0.09		0.23	
3M deepwater redfish	0.38		0.38		0.36		0.37	

Table 13

Sums of absolute deviations (D) between the recruitment amounts observed and those of calculated by the SRD equations and mean squared diviations of the equations

Stock units	Beverton and Holt		Ricker		Cushing		Chapman	
	D		D		D		D	
4VWX silver hake	5576	1424	6397	1379	6524	1379	5519	1351
5Ze -"-	11791		11572		11766		11745	
5Zw+6 -"-	7558	2544	7880	2298	7308	2327	10112	2961
5Y -"-	3742	1036	2381	584	2531	632	4698	1332
2J3KL cod	3928	1128	3658	1096	3374	946	11546	
3NO -"-	938	280	907	250	859	247	1028	275
3Ps -"-	4054	4498	3882	1290	3972	1353	4248	1268
3LNO yellowtail flounder	50	16	37	12	39	12	35	11
3LNO american plaice	70	20	20	63	94	17	64	27
3-6 mackerel	16042		14509		15314		15614	
3M deepwater redfish	741	267	733	248	732	248	800	239

Table 14

Methods which provide the best correspondence to the observed data and coefficients values for the SRD proper equations

Stock level	Method selected	Grounds			SRD equation coefficients	
		Best correlation (r)	Least sum of diviations (D)	Least squared deviation ( )		
4VWX silver hake	Chapman's	x	x		0.1840	-0.0648
5Ze -"-	Ricker's		x		2.1928	0.0023
5Zw+6 -"-	Ricker's			x	2.3709	0.0049
5Y -"-	Ricker's	x	x	x	1.2420	0.0022
2J3KL cod	Cushing's	x		x	166.3010	0.2265
3NO -"-	Cushing's	x	x	x	10.7650	0.4070
3Ps -"-	Ricker's	x	x		2.8511	0.0103
3LNO yellowtail flounder	Chapman's	x	x	x	0.5798	0.1079
3LNO american plaice	Ricker's		x	x	1.7720	0.0853
3-6 mackerel	Chapman's	x			0.3860	0.0087
3M deepwater redfish	Chapman's			x	0.3760	0.0216

Table 15

Average values of recruitment (R) and spawning biomass (SB) calculated for three levels of the latter

Stock unit	Low SB	Low R	Average SB	Average R	High SB	High R
4VWX silver hake	108.1	972.3	124.9	1295.8	176.1	2466.0
5Ze -"-	118.5	783.9	196.3	1026.5	475.6	1988.6
5Zw+6 -"-	61.5	563.3	139.7	868.1	294.2	977.6
5Y -"-	41.1	107.9	138.8	341.9	175.1	557.8
2J3KL cod	132.2	401.3	430.0	266.2	821.6	655.7
3NO -"-	22.7	42.0	84.4	79.3	114.8	106.3
3Ps -"-	33.9	437.7	73.1	574.0	116.1	608.5
3LNO yellowtail flounder	7.6	6.0	11.9	8.1	19.3	8.5
3LNO american plaice	13.1	26.0	20.0	21.1	28.8	15.1
3-6 Mackerel	476.0	428.2	592,9	3160.5	1643.6	1917.1

Table 16

Recruitment rate (R/SB) for different stock units depending on spawning biomass levels, %

Stock unit	SB levels: Low	Average	High
4VWX silver hake	9.0	10.4	14.0
5Ze -"-	6.6	5.2	4.2
5Zw+6 -"-	9.2	6.2	3.3
5Y -"-	2.6	2.5	3.2
2J3KL cod	3.0	0.6	0.8
3NO -"-	1.8	0.9	0.9
3Ps -"-	12.9	7.8	5.2
3LNO yellowtail flounder	0.8	0.7	0.4
3LNO american plaice	2.0	1.1	0.5
3-6 mackerel	0.9	5.3	1.2

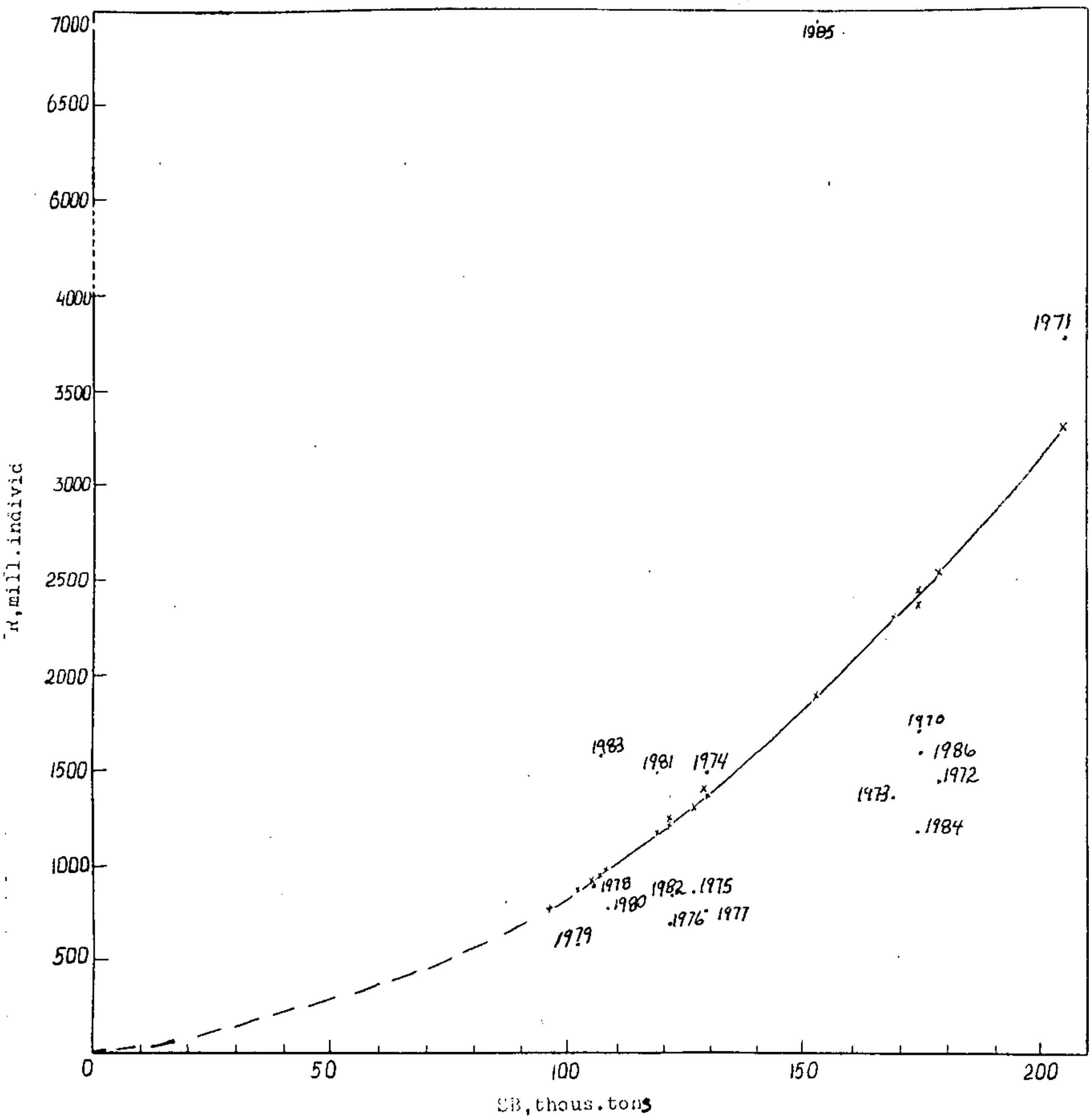

Fig. 1. Relation between the 4VWX silver hake spawning stock and recruitment.

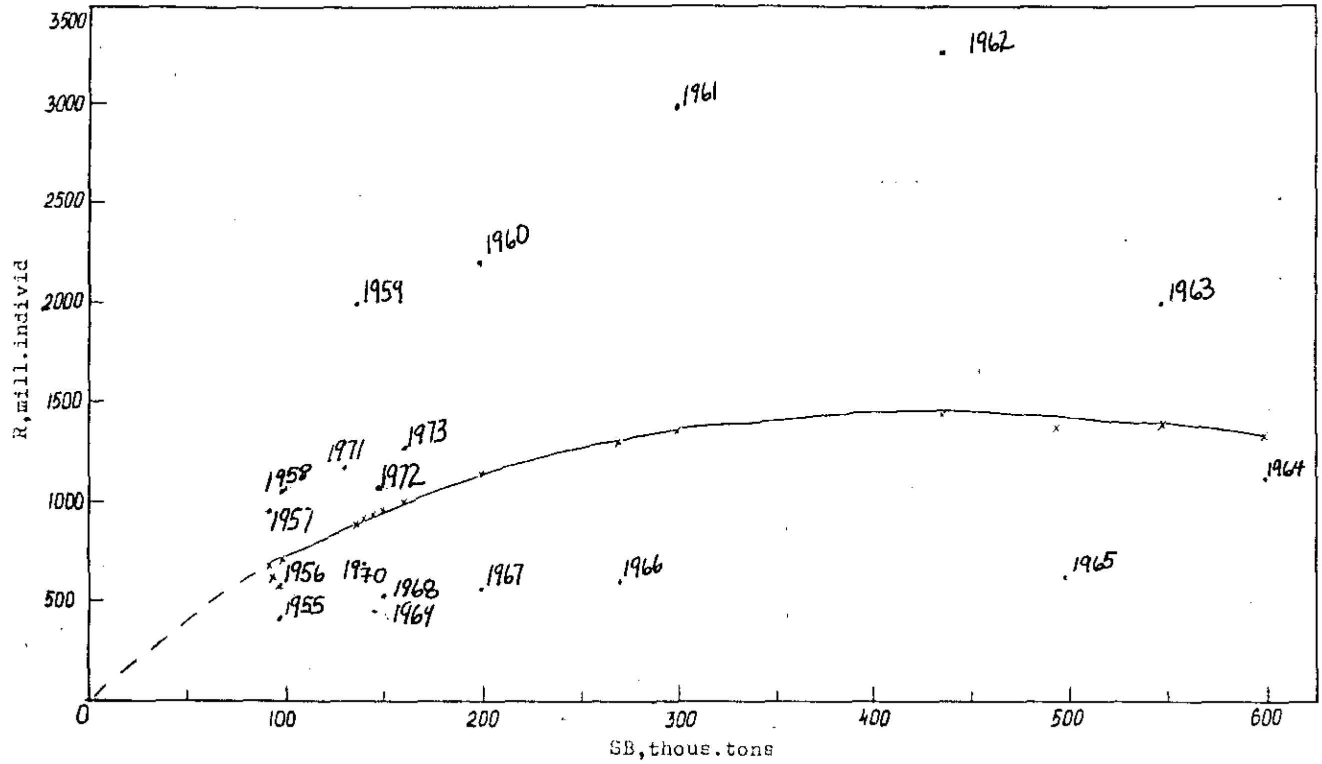

Fig. 2. Relation between the 5Ze silver hake spawning stock and recruitment.

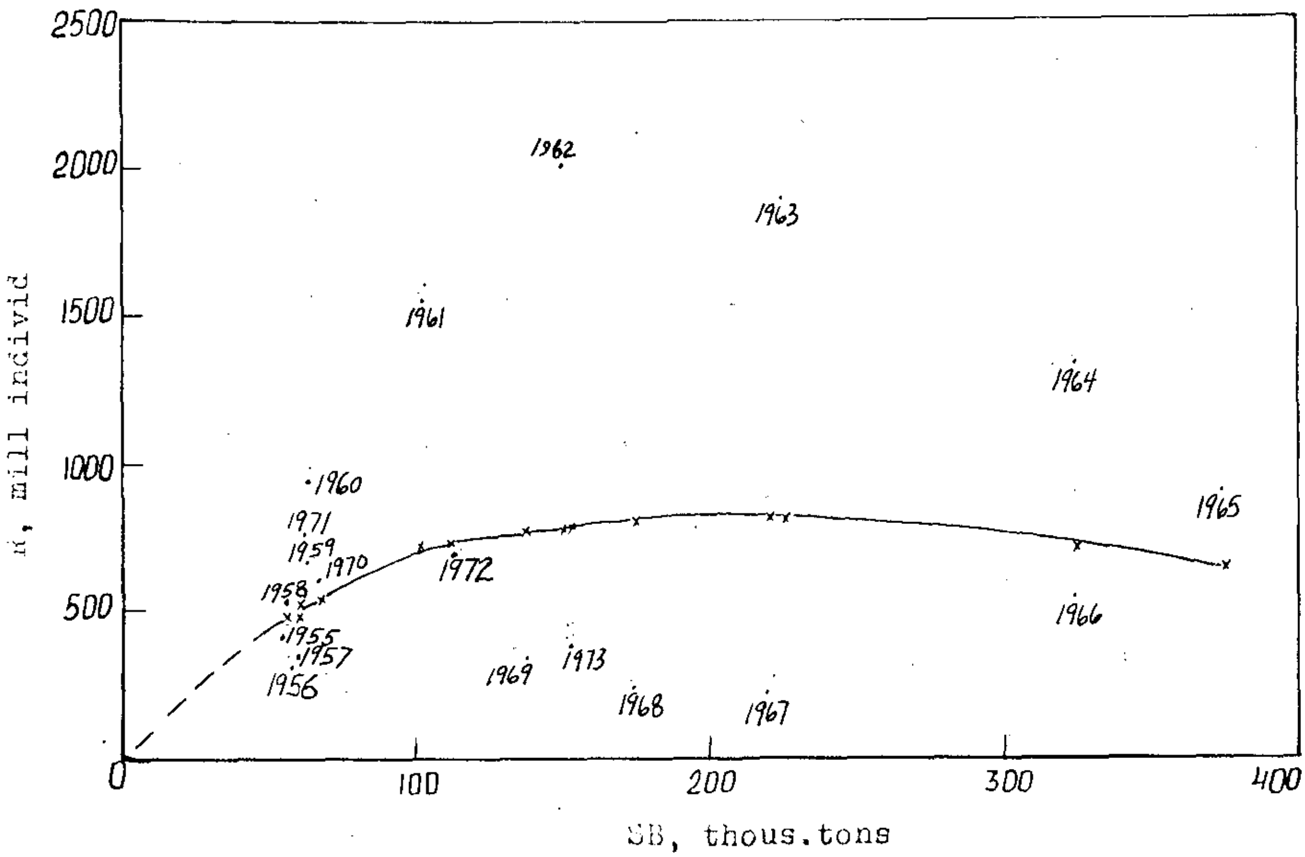

Fig. 3. Relation between the 5Zw+6 silver hake spawning stock and recruitment.

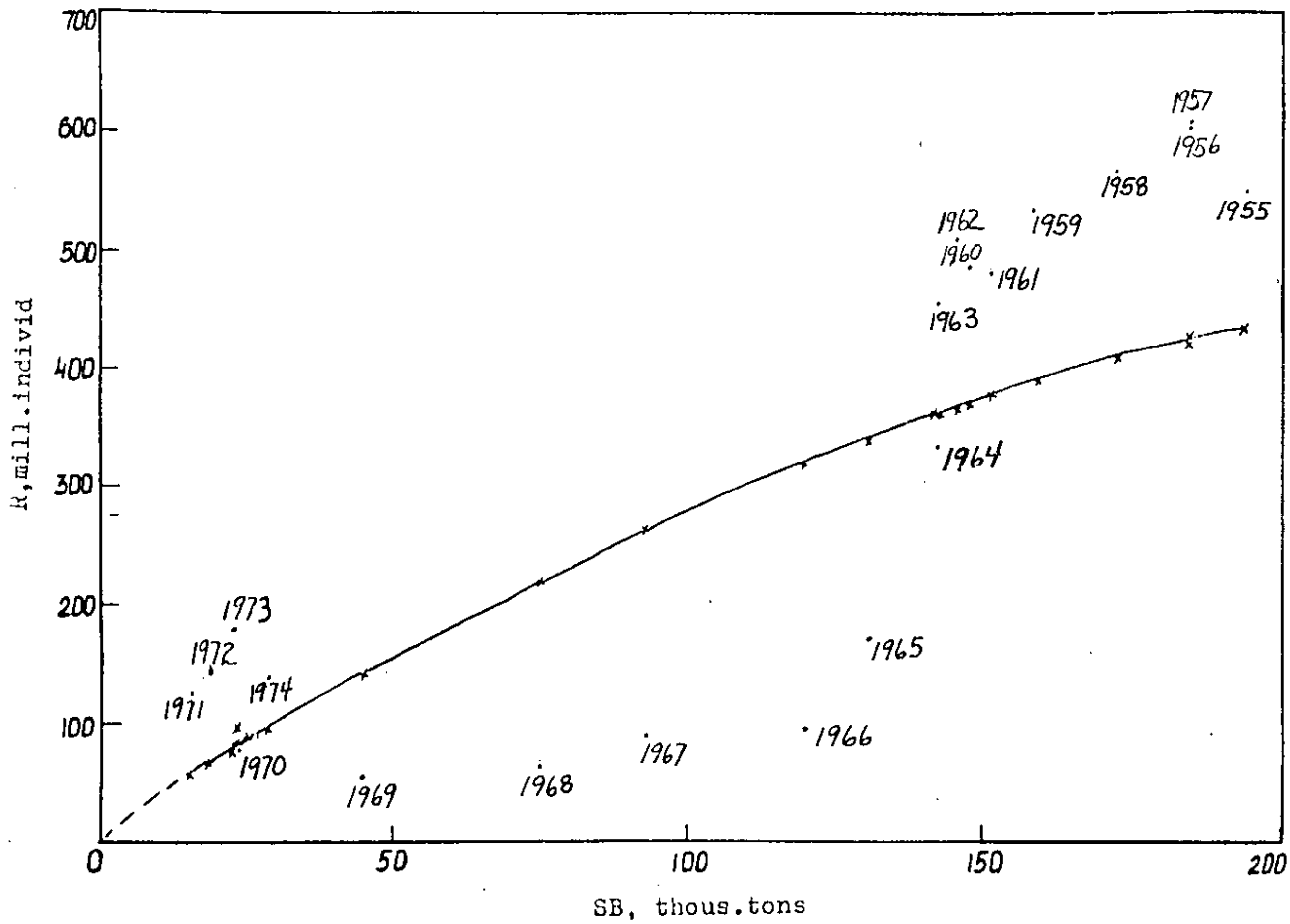

Fig. 4. Relation between the 5Y silver hake spawning stock and recruitment.

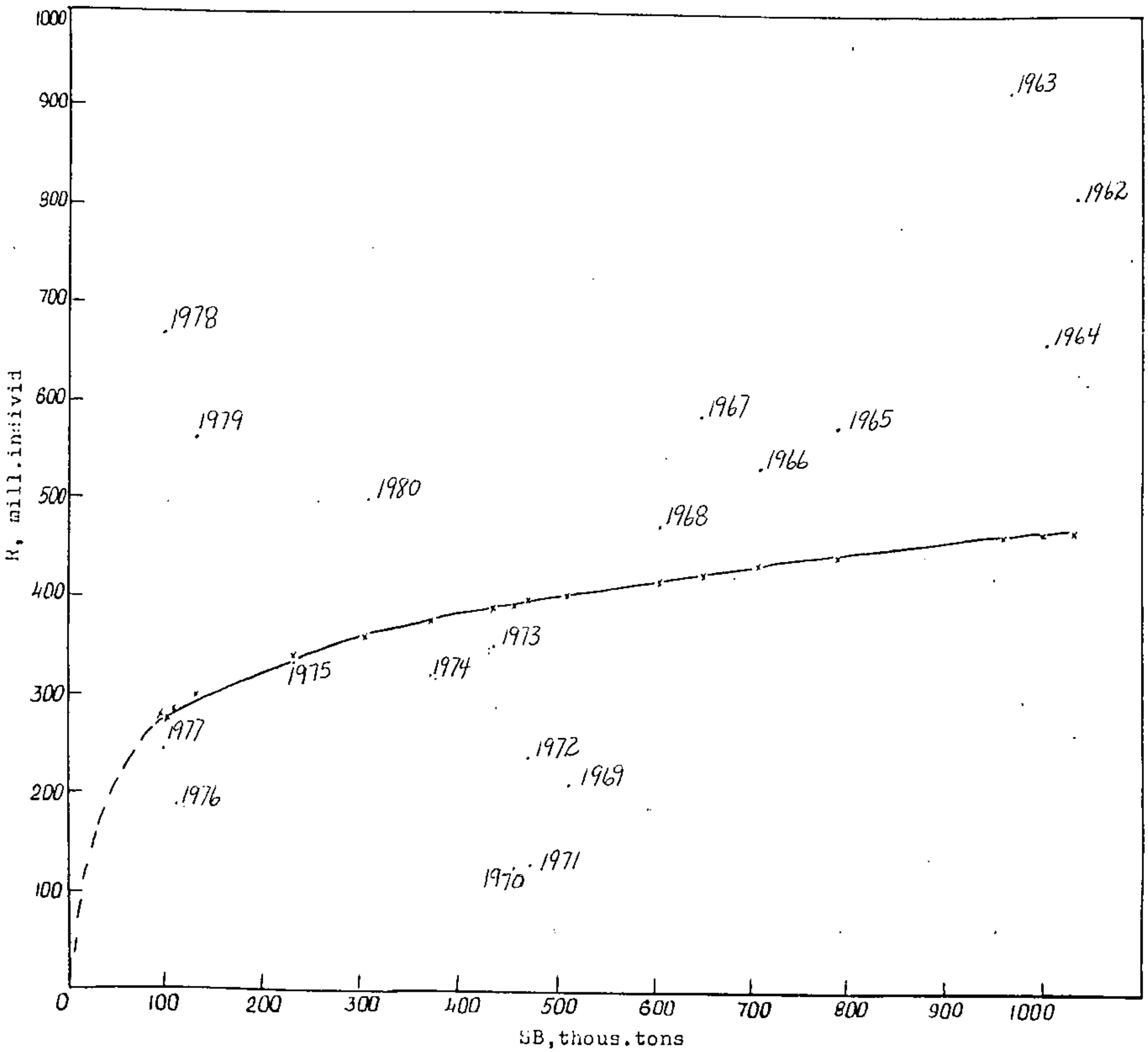

Fig. 5. Relation between the 2J+3KL cod spawning stock and recruitment.

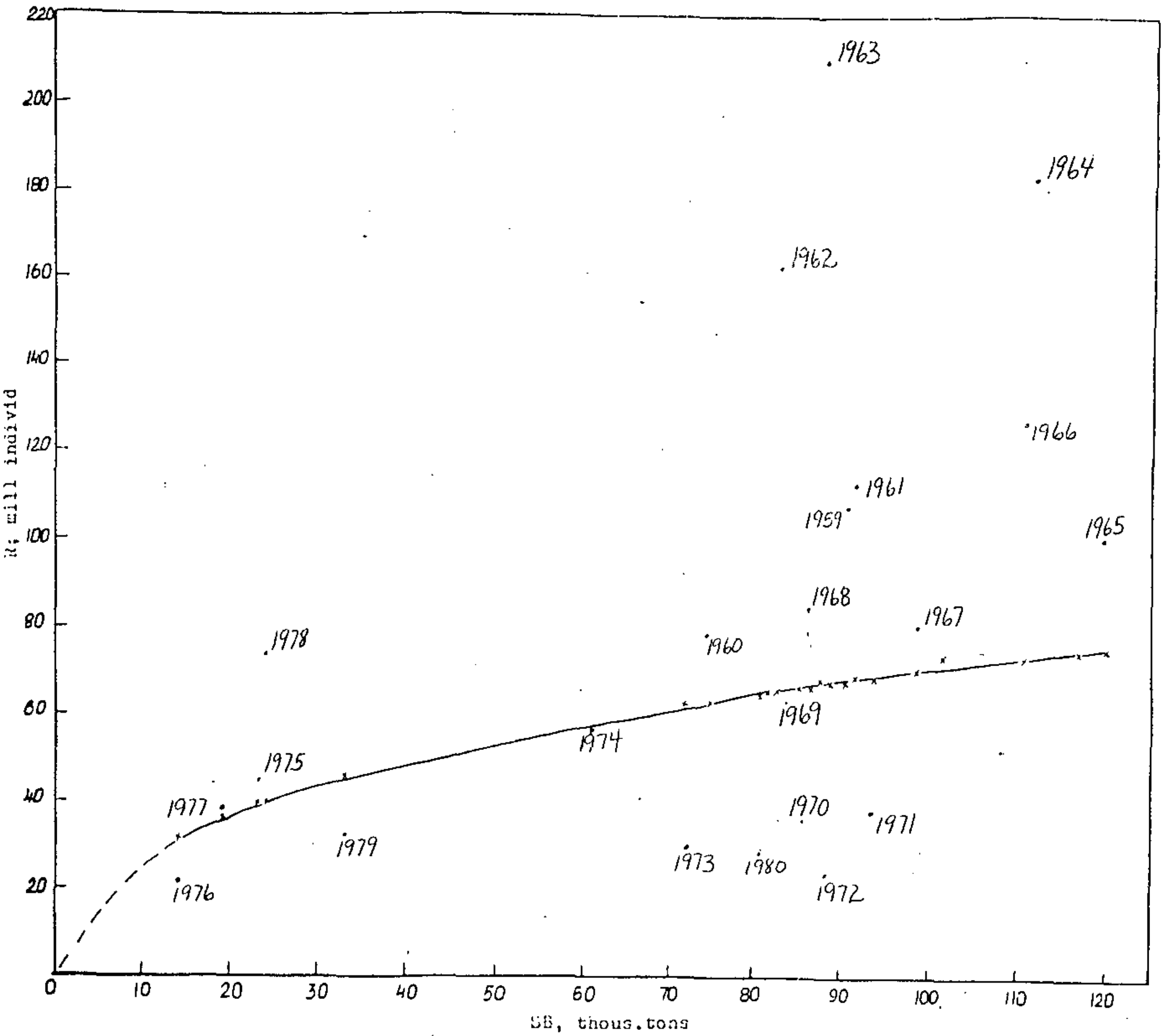

Fig. 6. Relation between the 3NO cod spawning stock and recruitment.

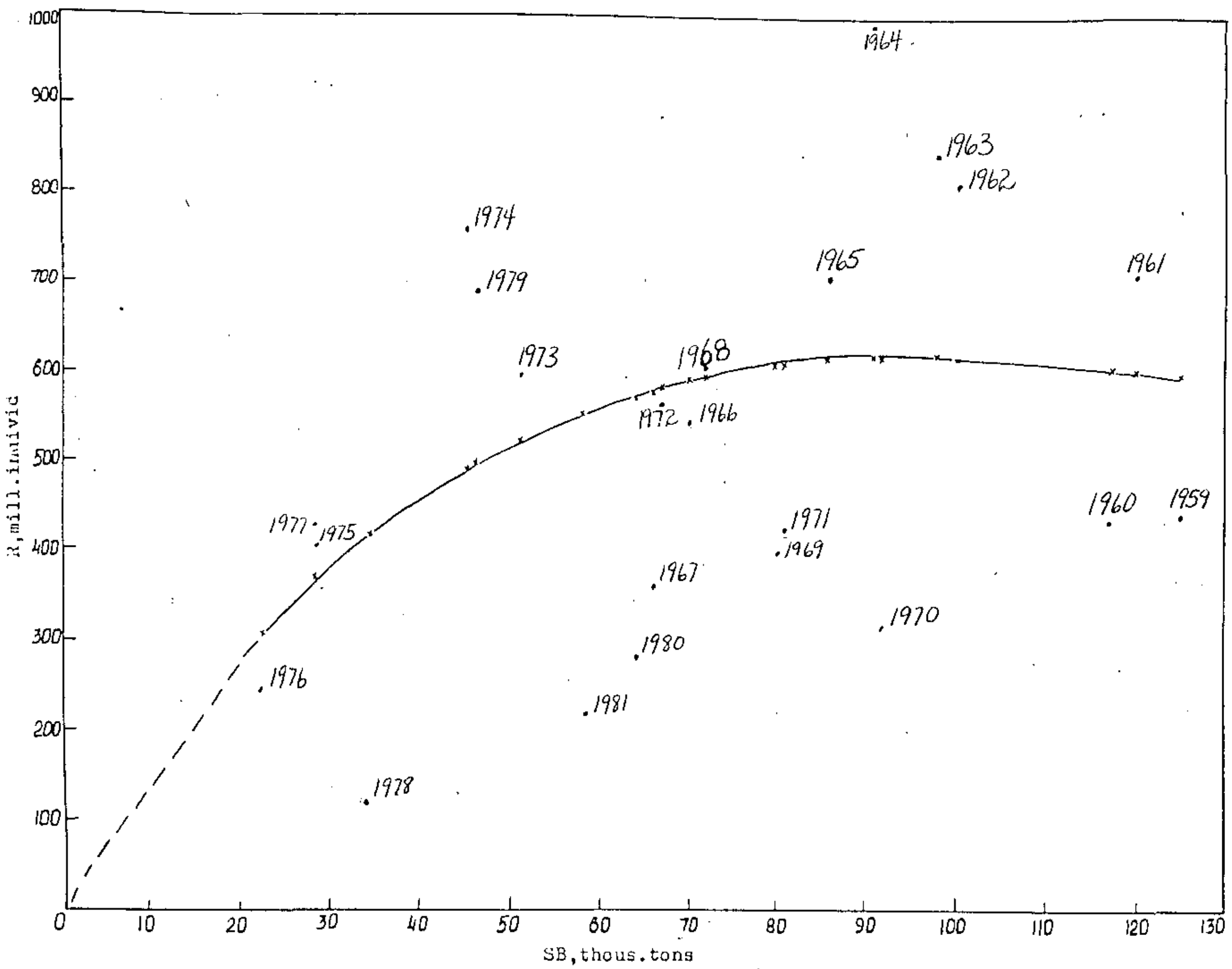

Fig. 7. Relation between the 3 Ps cod spawning stock and recruitment.

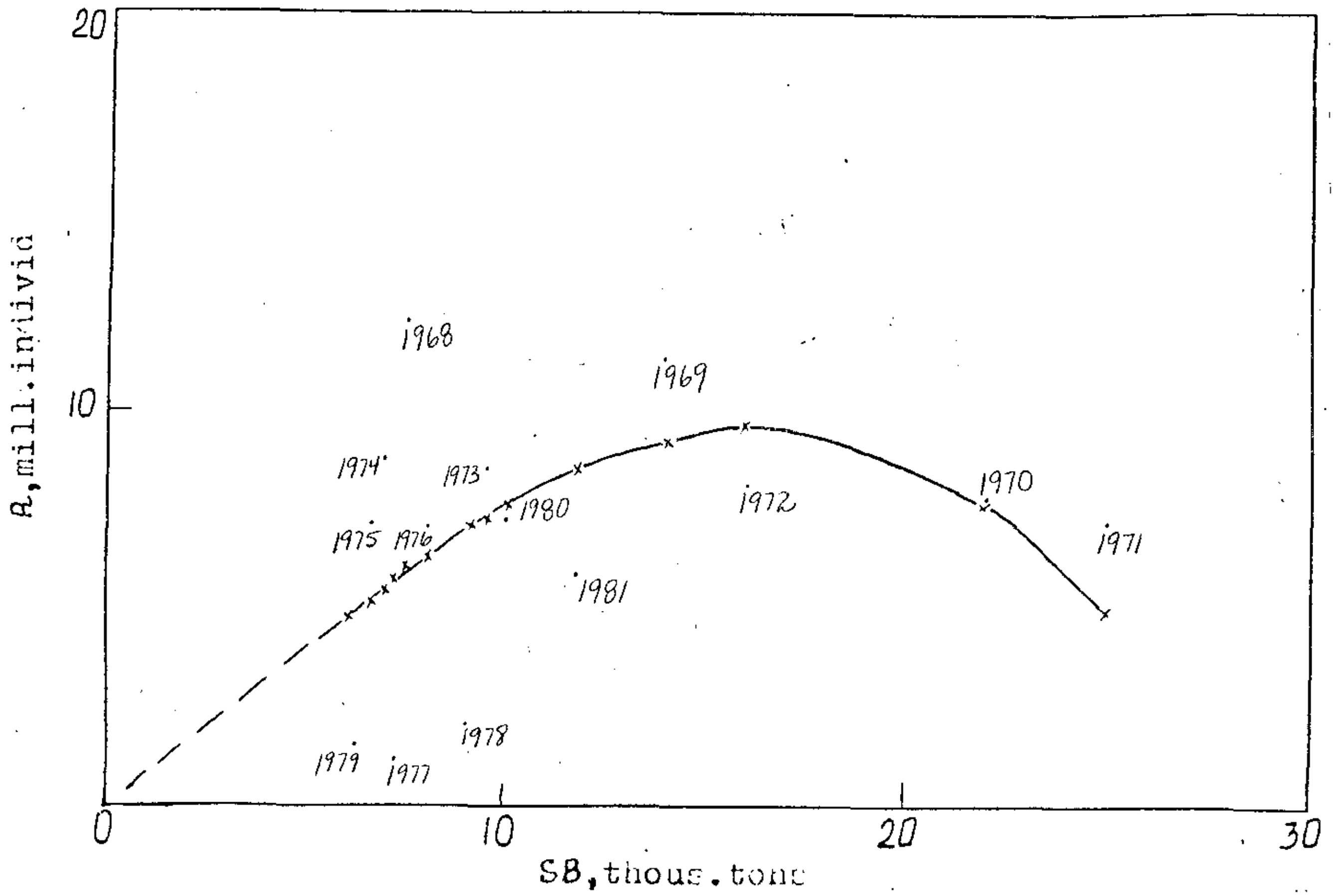

Fig. 8. Relation between the 3LNO yellowtail flounder spawning stock and recruitment.

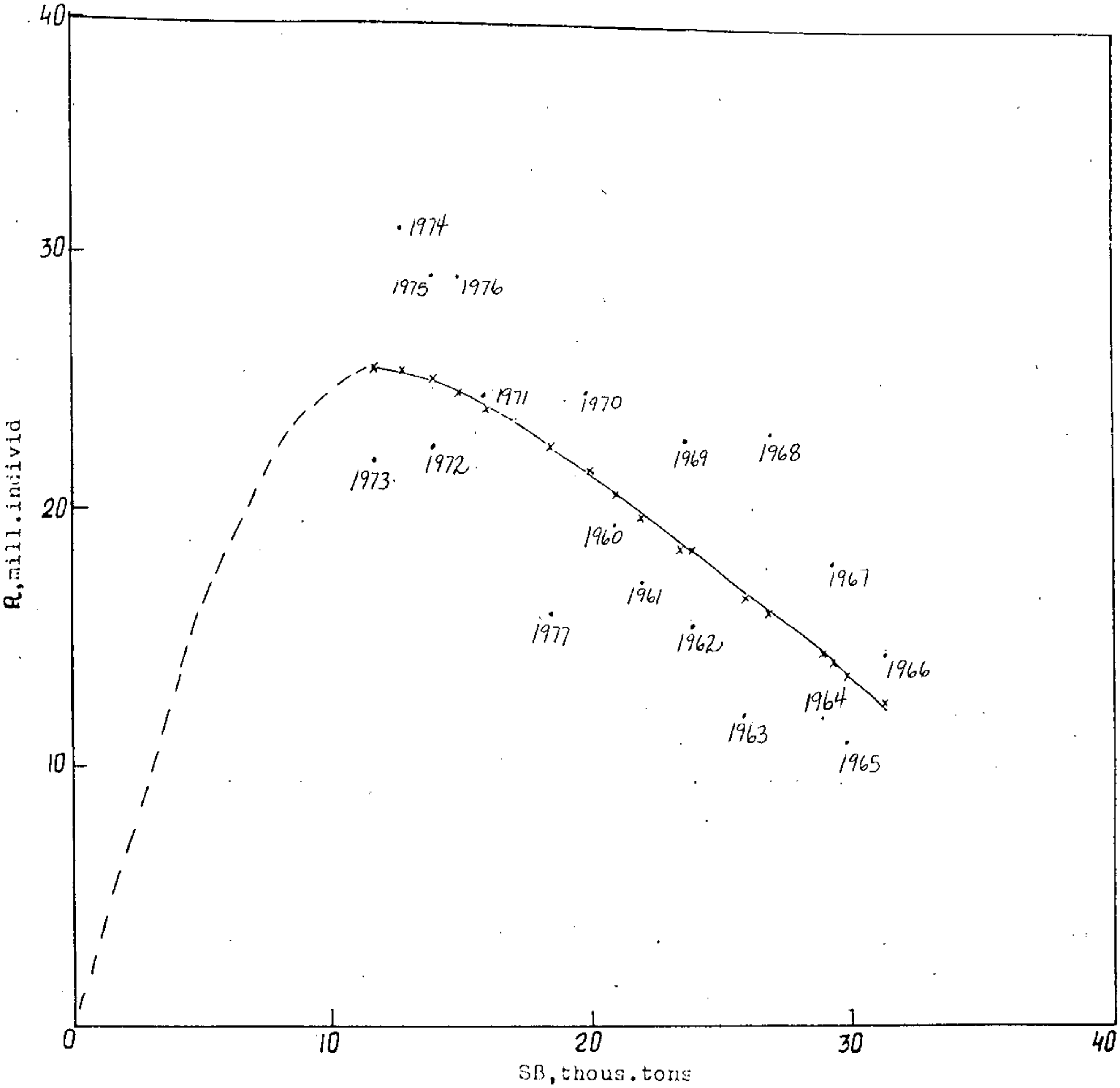

Fig. 9. Relation between the 3LNO american plaice spawning stock and recruitment.

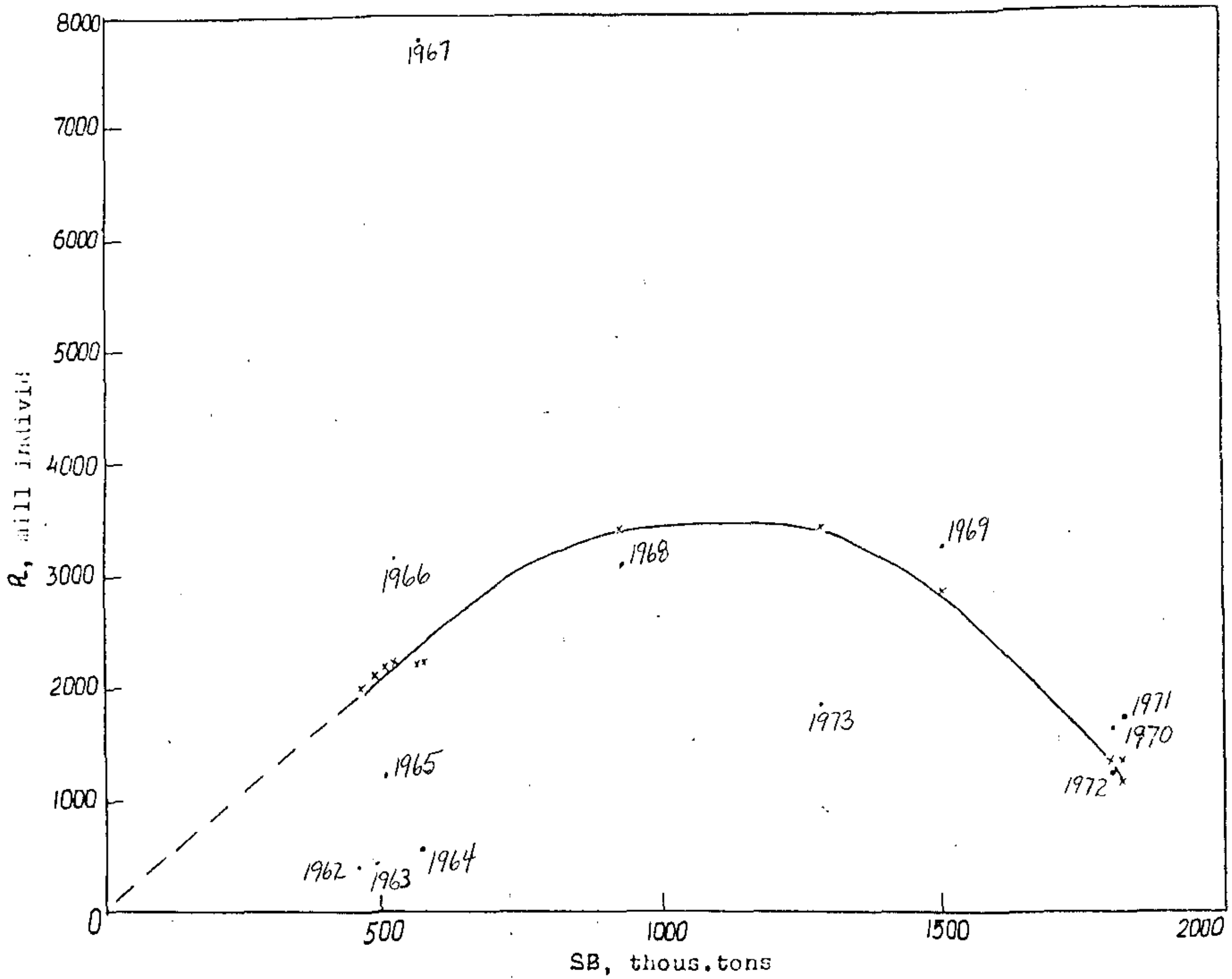

Fig.10. Relation between the 3-6 mackerel spawning stock and recruitment.

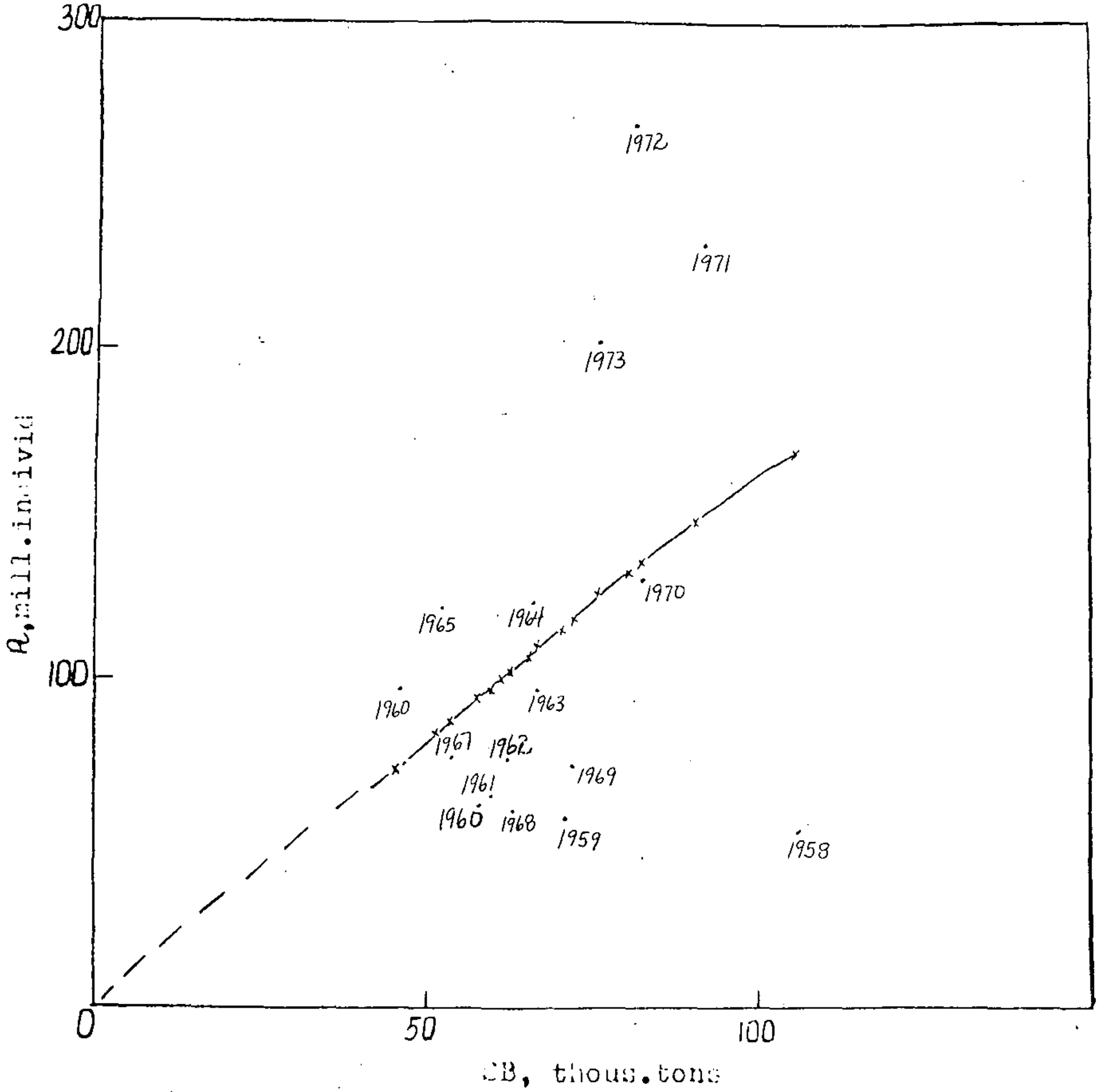

Fig.11. Relation between the 3M deepwater redfish spawning stock and recruitment.