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A Statistical Description of Recruitment in Eighteen Selected Fish Stocks

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Abstract

For understanding and predicting purposes, one is concerned with identifying suitable models and methods for describing empirical and theoretical relationships that may exist between fish stock, environment and recruitment. In this paper, recruitment in 18 fish stocks around the world is reviewed by examining the frequency distributions of observed year-class strength. These frequency distributions represent the probability density functions which incorporate the total effect of all factors. The actual frequency distributions of recruitment were plotted and each set of data tested for goodness-of-fit to normal and lognormal distributions. Conclusions from the tests were that most of the data sets could be described by a lognormal distribution function.

Comparison of recruitment estimates and associated catches over time (years) indicated that significant deviations in catch closely followed significant deviations in recruitment. Serial correlation analyses of the recruitment data indicate, in most cases, that recruitment in 1 year is correlated with that of the previous year.

Introduction

Worldwide fisheries developed in the early 1970's to the point of encompassing nearly all of the important fish stocks and productive ocean areas. Increases in fishing activity in the last decade have not resulted in increased catches. Many recently developed and traditional fisheries have suffered declines in yield, and the development of alternative fisheries has been limited. This state of affairs has led to concern about the future of fisheries and to increasing proposals for and actual limitations on fishing activity.

The traditional habit of collecting fishery statistics expanded as fisheries became more important, and studies of population dynamics based on these statistics also expanded. The studies led more and more to the conclusion that fishing mortality had become a pervasive and primary cause of changes in stock abundance. This in turn led to studies of the effect of changes in stock size on productivity and also to consideration of regulating fishing mortality as a means of controlling change in stock size. Because implementation of this type of management usually meant a cutback in catch, or, at the very least, no further increase, the validity of the concept became rather controversial.

The size of the exploited stock is, of course, primarily based on the process of recruitment, i.e. the annual quantity of young fish that are produced by the processes of spawning, hatching, growth and survival. Concern about the effect of spawning stock size on this process led to extensive investigation and formulation of stock-recruitment models. Unfortunately, fundamental studies of the process in the ecological setting were very few (in fact, they are just now getting started) and most research was empirical, being based on observations from the fishery.

For both understanding and predictive purposes, one is concerned with identifying suitable models and methods that are descriptive of the empirical and theoretical relationships that may exist between stock, environment and recruitment. Generally speaking, the models and the methods discussed in the literature have attempted to express recruitment in terms of stock, seldom incorporating parameters to represent variation due to the environment. Although some association between stock size and recruitment was demonstrated, it seems that most conclusions about cause-effect were foregone (Hennemuth, 1979).

It is only natural that a comprehensive model for the study of recruitment should incorporate different factors involving the stock and the enviroment, including any time dependent features. Such models are not yet developed. In this paper, recruitment in 18 fish stocks around the world are examined with respect to the frequency distribution of observed year-class strength. These frequency distributions represent the probability density functions which incorporate the total effect of all factors.

Recruitment, as here defined, involves a series of events and processes. These include spawning, survival and hatching of eggs, growth and survival of larvae, and growth and survival of juveniles through the pre-adult stage to the point of vulnerability to the fishery. The state of the spawning stock, both magnitude and physiological condition, affects spawning and subsequent survival of eggs and larvae because of preconditioning and the density and distribution of eggs. Environmental conditions affect every stage but probably exert the greatest effect by modifying the time and place of spawning, the distribution of eggs and larvae, and the production and distribution of larval food. In the total ecological setting, competition and predation within the plankton populations and predation by nekton are also important. The multiplicity of processes, the magnitude of the time-space continuum, and the inefficiences of sampling tools make it difficult to obtain adequate observations and construct appropriate models. The process seems much too variable to measure only one of the factors to determine its effect.

We can begin the statistical analysis by examining the joint probability density function (PDF) of recruitment and the total effect of all conditions that influence recruitment (e.g. spawning stock, environment, etc.). The latter are most likely conditional and not independent, so that statistical inversion may not be possible. However, this approach can provide some insight into the possible form of marginal density distributions.

More important perhaps is the utility of this approach in demonstrating the shape of the recruitment function, so that a realistic view of expectation can be generated without compounding this view by bringing in spawning stock size and the implied regulatory control of it. There is much information in the joint PDF of recruitment, and some rather clear and useful advice can be based upon it. More specifically, we hypothesize a function which is continuous except at the origin and which may be multimodal; that is, there is either no finite probability of zero recruitment, or the function is discontinuous with respect to recruitment greater than zero. There are many functions which could be used to express a PDF of this sort. As a first approach, the actual frequency functions of recruitment in a number of fish stocks were plotted and some empirical goodness-of-fits examined.

TABLE 1. Statistical description of recruitment in 18 selected fish stocks. (S.D. = standard deviation; C.V. = coefficient of variation; Ratio = ratio of largest to smallest estimates of recruitment.)

					Untransformed recruitment data					Transformed recruitment data			
Species	Area	Source[a]	Age	Period	Mean	S.D.	Ratio	C.V.	P-value	Mean	S.D.	C.V.	P-value
Cod	Georges B.	A	1	1960–73	24,766	6,302	2.5:1	0.25	>0.20	10.09	0.27	0.03	>0.20
	North Sea	B	1	1963–77	232,937	146,880	5.5:1	0.63	>0.20	19.08	0.62	0.03	>0.20
	NE Arctic	C	1	1962–77	1,011,370	774,546	16.2:1	0.77	<0.20	13.55	0.80	0.06	>0.20
Haddock	Georges B.	D	1	1931–73	72,231	73,039	2700:1	1.01	<0.01	10.59	1.55	0.15	<0.01
	Georges B.	D	1	1931–65	88,611	73,358	19:1	0.83	<0.01	11.22	0.54	0.05	<0.10
	Georges B.	D	1	1966–73	6,588	5,956	92:1	0.90	>0.20	7.94	1.78	0.22	>0.10
	North Sea	B	1	1961–78	1,082,995	1,542,532	100:1	1.42	<0.01	13.13	1.31	0.10	>0.20
	NE Arctic	C	1	1962–78	273,897	356,238	9:1	1.30	<0.05	11.94	1.12	0.09	>0.20
Herring	Georges B.	E	2	1963–74	1,743,079	1,040,054	5.2:1	0.60	>0.20	14.22	0.58	0.03	>0.20
	North Sea	F	0	1957–74	7,771,000	4,753,970	10:1	0.61	<0.05	15.71	0.59	0.04	>0.20
	Norwegian[b]	G	1	1950–69	13,734,900	19,059,000	130:1	1.39	<0.01	15.64	1.38	0.09	>0.20
Mackerel	NW Atlantic	H	1	1962–73	2,107,308	2,070,906	18:1	0.78	<0.05	14.19	0.90	0.06	>0.20
	North Sea	I	1	1969–78	683,364	976,403	41:1	1.43	<0.01	5.87	1.18	0.20	>0.20
Saithe	North Sea	J	1	1961–78	265,372	157,683	12:1	0.59	<0.05	12.33	0.60	0.05	>0.20
Whiting	North Sea	B	1	1963–78	1,333,274	651,530	6.5:1	0.49	>0.20	20.89	0.53	0.03	>0.20
Pilchard	S Africa	K	3[c]	1950–75	13,673,500	10,354,600	9.6:1	0.76	<0.05	16.18	0.73	0.05	<0.15
Anchovy	S Africa	K	0[c]	1964–76	56,030,770	15,411,700	2.7:1	0.28	<0.20	17.80	0.27	0.02	>0.20
Round herring	S Africa	K	?[c]	1964–76	2,830,770	2,233,600	10:1	0.79	<0.05	14.57	0.80	0.05	>0.20
Anchovy	Peru	L	?[c]	1961–76	307,563	145,626	11:1	0.47	>0.20	12.50	0.61	0.05	>0.20
Silver hake	Georges B.	M	1	1955–73	1,207,453	874,699	9.6:1	0.72	<0.05	13.80	0.69	0.05	>0.20

[a] Source: A, Serchuk *et al.* (MS 1978); B, ICES (MS 1979a); C, ICES (MS 1979b); D, Clark and Overholtz (MS 1979); E, Anthony and Waring (1980); F, Saville and Bailey (1980); G. Dragesund (1980); H, Anderson and Paciorkowski (1980); I, ICES (MS (1979c); J, ICES (MS 1979d); K, Newman and Crawford (1980); L, Csirke (1980); M, Anderson (MS 1977).

[b] Spring spawners.

[c] Age not given in tables presented in source reference but inferred from interpretation of text where possible.

Materials and Methods

Eighteen fish stocks, in which recruitment estimates in a quantitative sense were available for at least 10 years, usually from virtual population analysis (VPA) techniques (Ricker, 1975), were examined for this paper (Table 1). The stocks chosen were the Northeast Arctic, the North Sea and Georges Bank cod, *Gadus morhua*; haddock, *Melanogrammus aeglefinus*, in the same three areas; North Sea saithe, *Pollachius virens*, and whiting, *Gadus merlangus*; Georges Bank silver hake, *Merluccius bilinearis*; North Sea, Norwegian spring-spawning, and Georges Bank herring, *Clupea harengus*; North Sea and Northwest Atlantic mackerel, *Scomber scombrus*; South African pilchard, *Sardinops ocellata*, anchovy, *Engraulis capensis*, and round herring, *Eutremus teres*; and Peruvian anchovy, *Engraulis ringens.*

Source documents for information on these stocks were the laboratory reference document series of the Northeast Fisheries Center, USA National Marine Fisheries Service, Woods Hole, Massachusetts; the 1979 working group reports of the International Council for the Exploration of the Sea (ICES); and the papers presented to the ICES/ICNAF Symposium on the Biological Basis of Pelagic Fish Stock Management in July 1978. For the latter two sources, all data were used as presented in the documents. For the Northwest Atlantic stocks, the statistical analysis was limited to the 1972 and earlier year-classes which would not be sensitive to starting fishing mortality values used in the virtual population analyses. The estimates of year-class strength for the years since 1972, for these stocks, were examined after the statistical analysis had been performed on the earlier data to determine whether or not the most recent information contradicts or supports the pattern observed in the data tested.

The recruitment frequency data used for analysis and plotting were scaled on the abscissa to provide similarity of dimension. The interval width (X) for year-class strength was calculated by dividing the mean of each data set by five. The initial interval is labelled X, the second 2X, etc., in the plots of Fig. 19.

Results

The recruitment time series of data, with the associated catches are illustrated in Fig. 1-18. It should be noted in comparing the trends that the estimates of recruitment are not independent of the catches. However, analyses of independent observations on recruitment from bottom trawl surveys for species such as haddock, silver hake and mackerel on Georges Bank indicate a significant correlation between survey abundance indices and virtual population estimates (Clark, 1979). It should also be noted that the virtual population estimates of recruitment are in error to the extent that the catch statistics are in error. However, this more likely affects the absolute rather than the relative magnitude of the estimates, which is the critical concern of this study. The extent that there was greater under-reporting when populations were large would tend to result in the extreme values used here being in reality even more extreme, but again this would not have a great effect on the fitted distribution.

Two aspects of interest are evident in the plots of recruitment and catch (Fig. 1-18). First is the observation that significant deviations in catch closely follow significant deviations in recruitment; that is, the development of fisheries, either new ones or after periods of low catch, and the expansion of more steady fisheries were caused by the entrance of one or two very strong year-classes. Explicit calculations have not yet been made, but a significant share of the total catch over the time periods is due to a few good year-classes. Secondly, there appear to be time-related trends in some of these data. For example, the recruitment of South African round herring (Fig. 16) rose to a peak, declined sharply and rose again over a period of about 10 years, and the recruitment of Georges Bank haddock (Fig. 4) showed a general increase over about 30 years followed by a rapid decline. In fact, there are two distinct periods in the Georges Bank haddock time series, 1931-65 and 1966-73. Therefore, the recruitment data for this stock were examined not only for the total time series but also for the two separate time series.

The Kolmogorov-Smirnov (K-S) one-sample, goodness-of-fit test was used to test the null hypothesis that the recruitment data for an individual stock represent a sample of yearly data drawn from a normally-distributed population. The alternate hypothesis was that the sample was not drawn from a normally-distributed population. Thus, a low P-value ($\leqslant 0.05$) casts doubt on the null hypothesis; conversely, a high P-value supports the hypothesis. The K-S test was chosen because it is a powerful test of goodness-of-fit, especially for small sample sizes (Seigel, 1956; Lilliefors, 1967). A logarithmic transformation was applied to the data ($Y = lnX$), and each sample was tested to determine if the values were drawn from a population with a lognormal distribution.

For the untransformed recruitment data (Table 1), the null hypothesis was rejected at the $\alpha = 0.05$ level of significance for Georges Bank haddock in 1931–73 and 1931–65, for North Sea and Northeast Arctic haddock, for Norwegian spring-spawning and North Sea herring, for Northwest Atlantic and North Sea

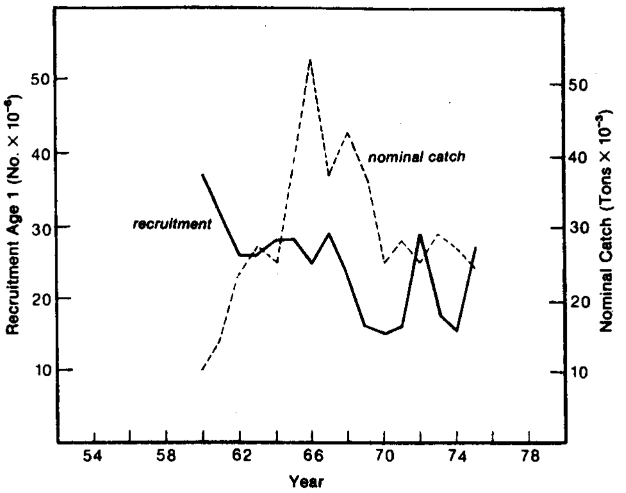

Fig. 1. Recruitment and nominal catch for Georges Bank cod, 1960–75.

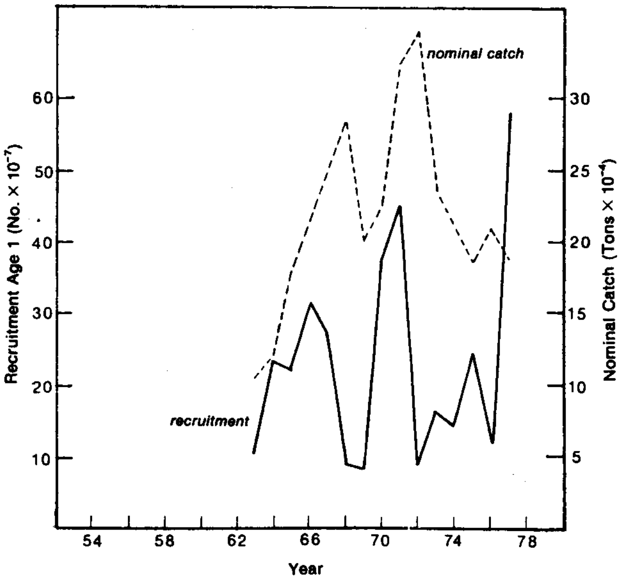

Fig. 2. Recruitment and nominal catch for North Sea cod, 1963–77.

mackerel, for North Sea saithe, for South African pilchard and round herring, and for Georges Bank silver hake. The null hypothesis was not rejected for the three cod stocks, for Georges Bank haddock in 1966–73, for Georges Bank herring, for North Sea whiting, and for South African and Peruvian anchovy. For the logarithmically-transformed recruitment data, the null hypothesis was rejected at $\alpha = 0.05$ only for Georges Bank haddock in 1931–73, and P-values of 0.20 or higher were obtained for Georges Bank, North Sea and Northeast Arctic cod, for Georges Bank (1966–73), North Sea and Northeast Arctic haddock, for herring and mackerel in all areas, for North Sea

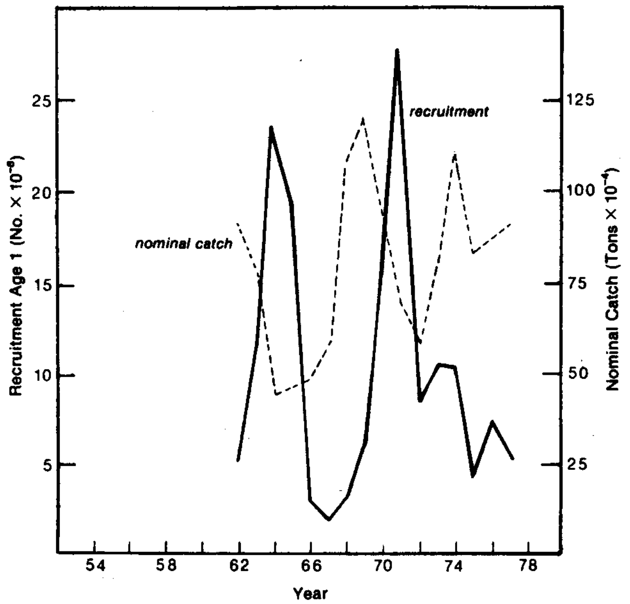

Fig. 3. Recruitment and nominal catch for Northeast Arctic cod, 1962–77.

saithe and whiting, for South African anchovy and round herring, and for Georges Bank silver hake. In only two cases (Georges Bank cod and Peruvian anchovy) was the test statistic for the untransformed data observably lower than those for the transformed data, indicating that the data for these two stocks fit a normal better than a lognormal distribution. In all other cases where the null hypothesis was not rejected, the transformed data gave considerably better fit than the untransformed data.

It is reasonable to suspect that, for an individual species, the number in the recruiting year-class in year $i + k$ is related to the number in the recruiting year-class in year i. Serial correlations are used to test for this dependency between observations of stock size in successive years. This serial correlation coefficient (r_k) is defined as

$$r_k = \frac{\mathrm{Cov}(X_i, X_{i+k})}{\sqrt{\mathrm{Var}(X_i)\mathrm{Var}(X_{i+k})}}$$

where $r_o = 1$, $r_{-k} = r_k$ (Yamane, 1967),

k = lag time in years,

and X_i = number of fish at age in year i for an individual species.

Because the time series presented here are short ($n \leqslant 20$ years) in all but two cases and may have trends present, a noncircular definition of r_k is used.

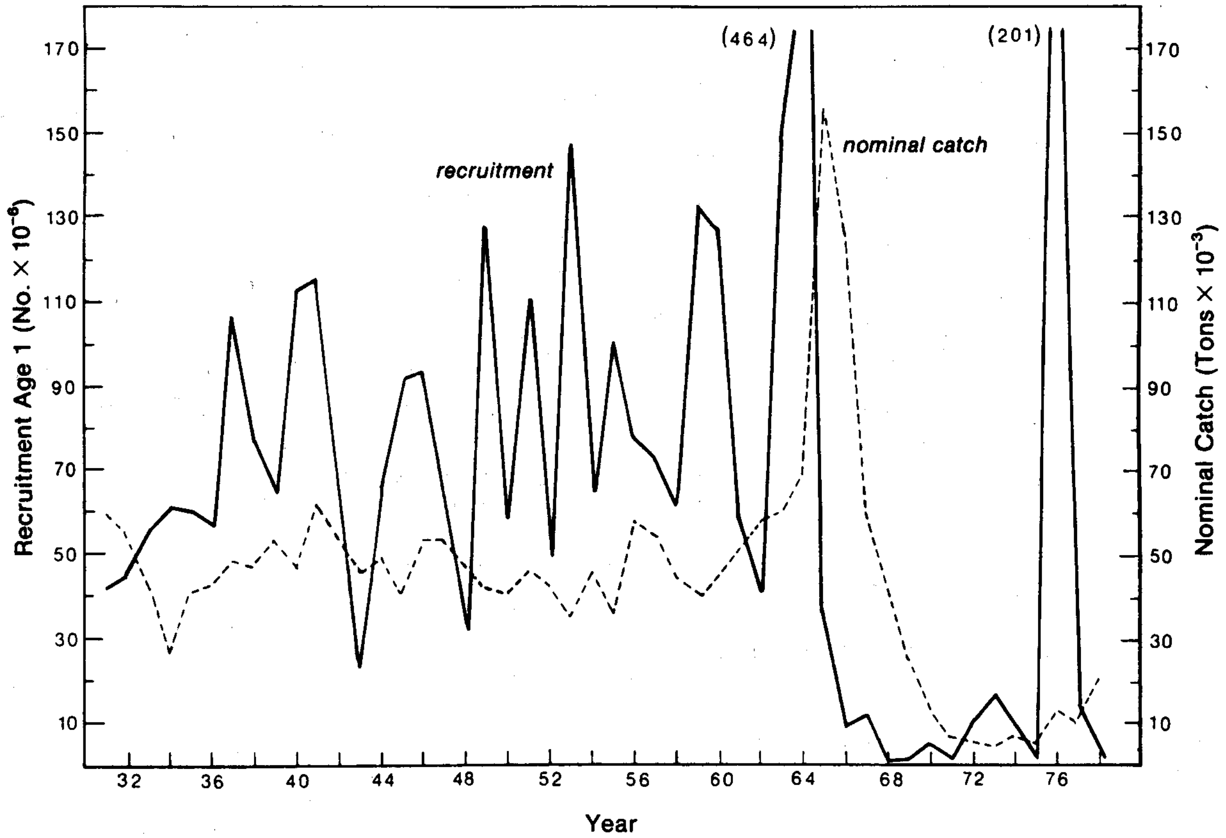

Fig. 4. Recruitment and nominal catch for Georges Bank haddock, 1931-78.

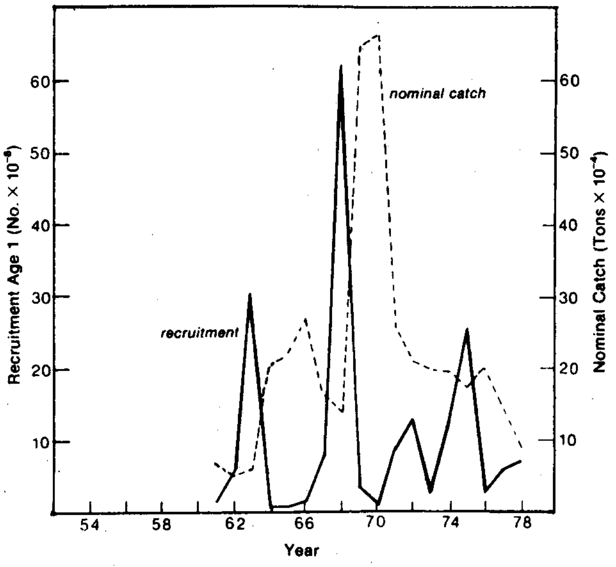

Fig. 5. Recruitment and nominal catch for North Sea haddock, 1961-78.

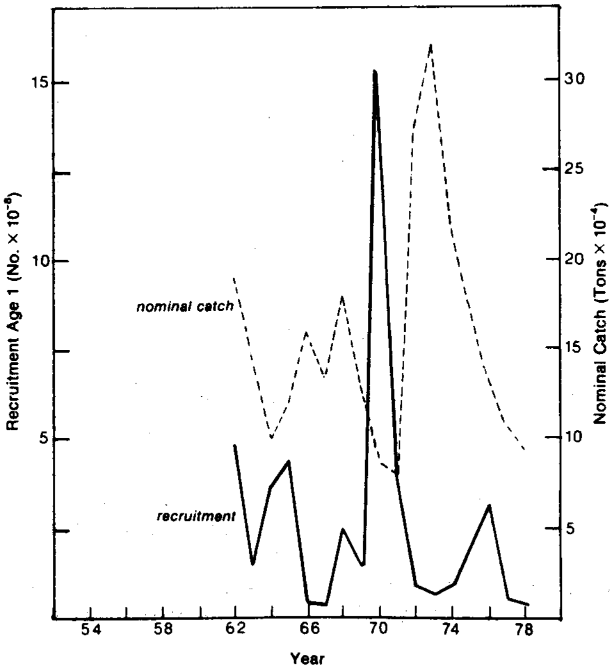

Fig. 6. Recruitment and nominal catch for Northeast Arctic haddock, 1962-78.

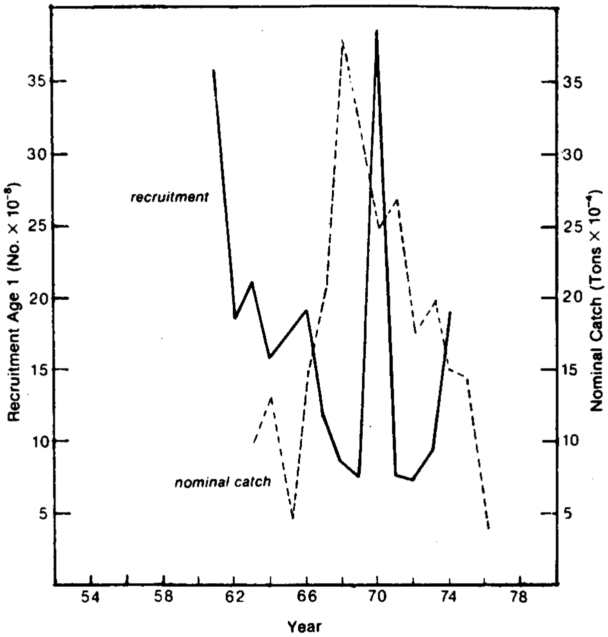

Fig. 7. Recruitment and nominal catch for Georges Bank herring, 1961-76.

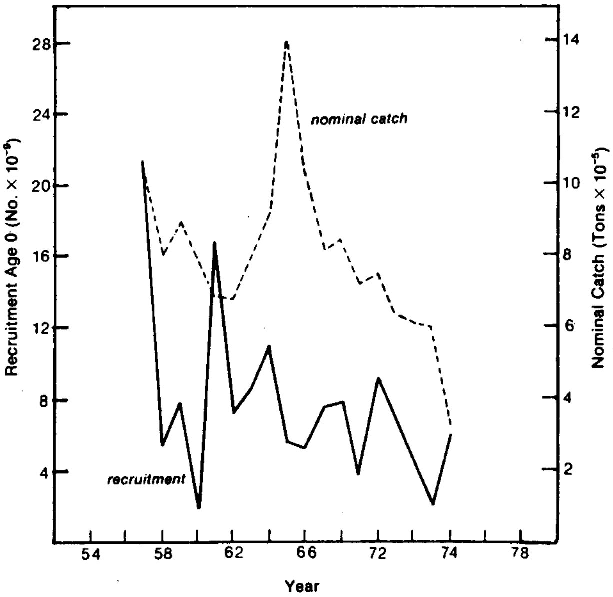

Fig. 8. Recruitment and nominal catch for North Sea herring, 1957-74.

Noncircular means that, for each series, it can be assumed that $X_i \neq X_{n+i}$. Correlations were calculated with time lags (k) of 1 and 2 years, and, in some cases where the 2-year correlation was significant at the $\alpha = 0.05$ level of significance, a time lag of 3 years was examined.

The test results (Table 2) indicate significant correlations for Georges Bank cod and silver hake, Norwegian spring-spawning herring, Northwest

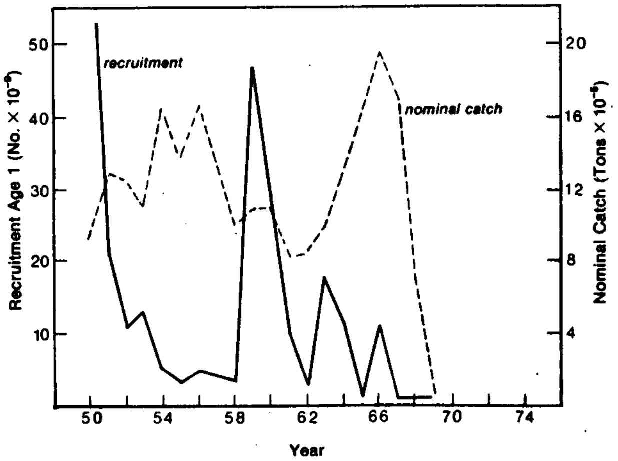

Fig. 9. Recruitment and nominal catch for Norwegian spring-spawning herring, 1950-69.

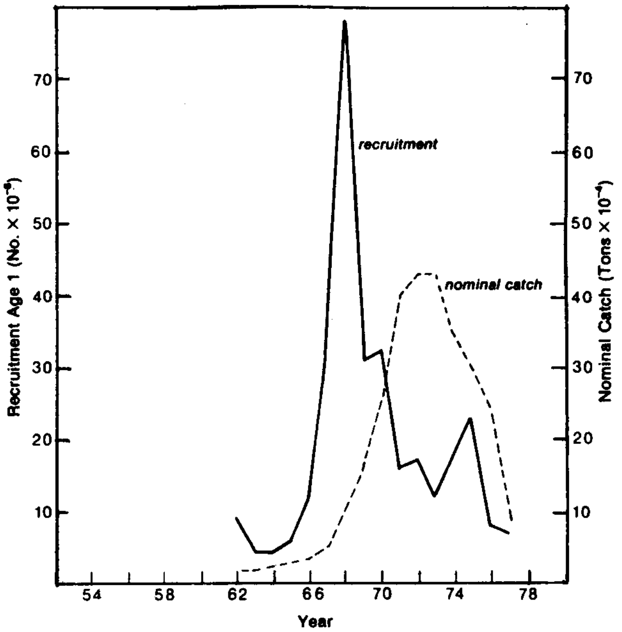

Fig. 10. Recruitment and nominal catch for Northwest Atlantic mackerel, 1962-77.

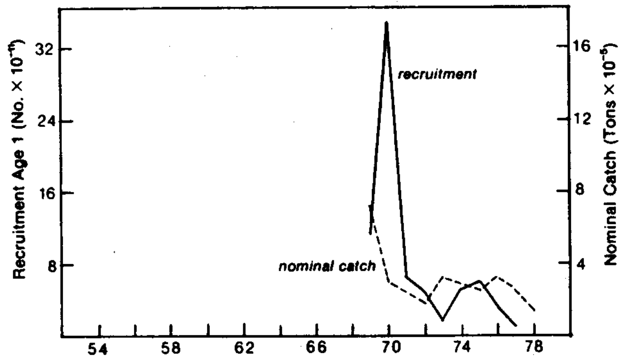

Fig. 11. Recruitment and nominal catch for North Sea mackerel, 1969-78.

TABLE 2. Serial correlations for recruitment estimates in 18 selected stocks. (•indicates significance at $\alpha = 0.05$.)

Species	Area	Period	No. of Years	Correlation coefficients 1-yr lag	2-yr lag	3-yr lag
Cod	Georges B.	1960-73	14	0.575*	0.359*	0.202
	North Sea	1963-77	15	-0.111	-0.354	—
	NE Arctic	1962-77	16	0.327	-0.274	—
Haddock	Georges B.	1931-73	43	0.201	-0.054	—
	Georges B.	1931-65	35	-0.008	-0.254	—
	Georges B.	1966-73	8	0.207	-0.122	—
	North Sea	1961-78	18	-0.131	-0.342	—
	NE Arctic	1962-78	17	0.058	-0.143	—
Herring	Georges B.	1963-74	12	-0.158	—	—
	North Sea	1957-74	18	-0.224	0.109	—
	Norwegian[a]	1950-69	20	0.335*	-0.052	—
Mackerel	NW Atlantic	1962-73	12	0.447*	0.134	—
	North Sea	1969-78	10	0.235	0.315	—
Saithe	North Sea	1961-78	18	0.312	-0.013	—
Whiting	North Sea	1963-78	16	0.200	-0.004	—
Pilchard	S Africa	1950-75	26	0.830*	0.510*	0.200
Anchovy	S Africa	1964-76	13	-0.056	0.032	—
Round herring	S Africa	1964-76	13	0.545*	0.124	—
Anchovy	Peru	1961-76	16	0.194	-0.041	—
Silver hake	Georges B.	1955-73	19	0.835*	0.491*	0.101

[a] Spring spawners.

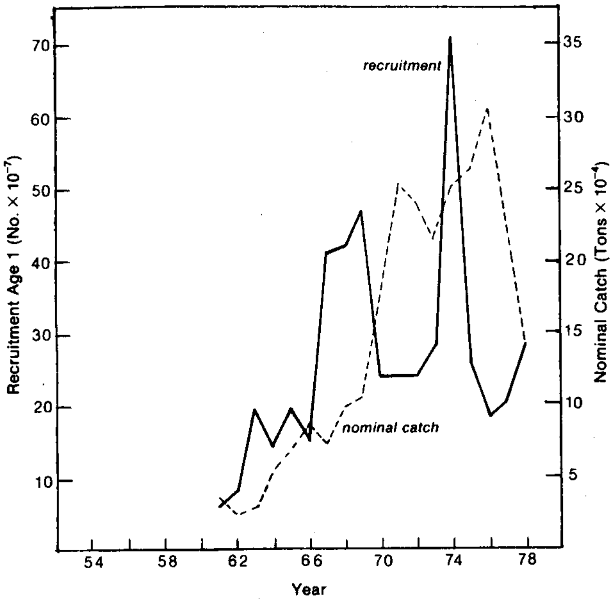

Fig. 12. Recruitment and nominal catch for North Sea saithe, 1961–78.

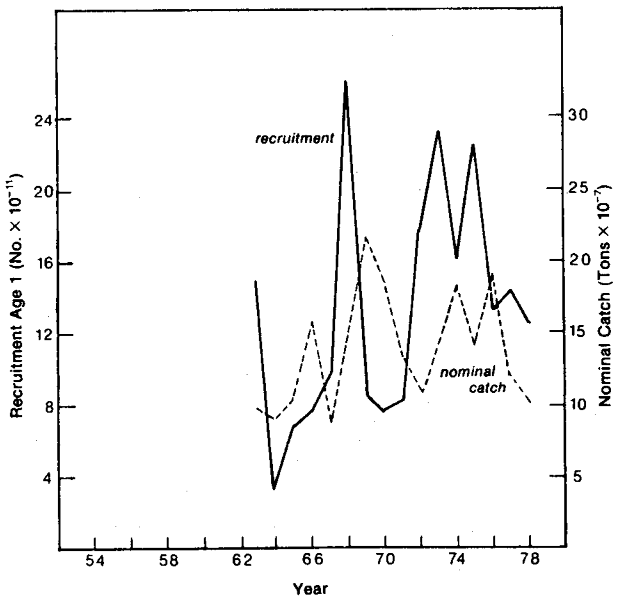

Fig. 13. Recruitment and nominal catch for North Sea whiting, 1963–78.

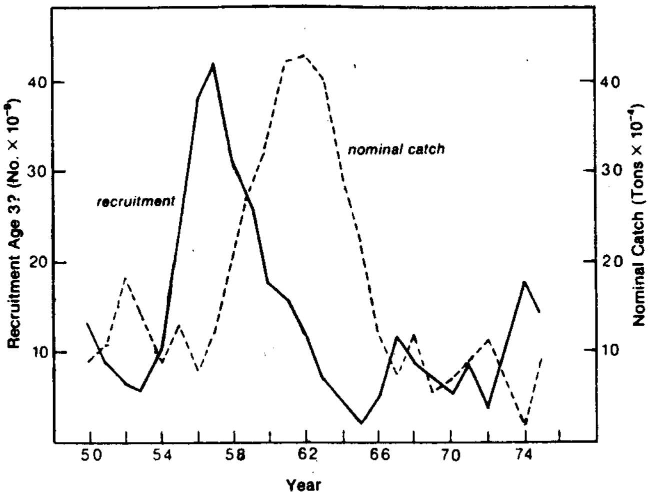

Fig. 14. Recruitment and nominal catch for South Africa pilchard, 1950-75.

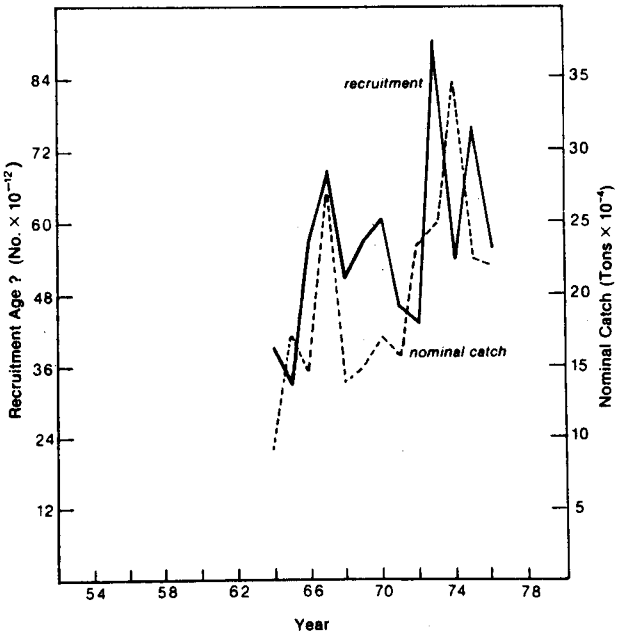

Fig. 15. Recruitment and nominal catch for South Africa anchovy, 1964-76.

Atlantic mackerel, and South African pilchard and round herring with a 1-year time lag. Thus, the time series for these stocks are non-random if the observations are only 1 year apart. With 2-year time lag, Georges Bank cod and silver hake and South African pilchard were the only stocks to show significant correlations. None of these three stocks had significant correlations with a 3-year time lag.

Discussion

The conclusion from the analyses of the recruitment data is that a lognormal distribution

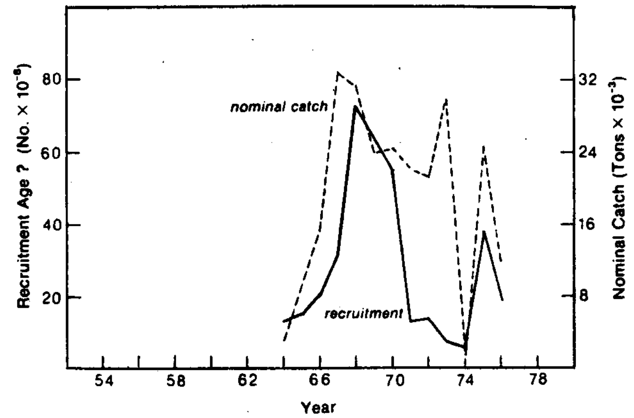

Fig. 16. Recruitment and nominal catch for South Africa round herring, 1964-76.

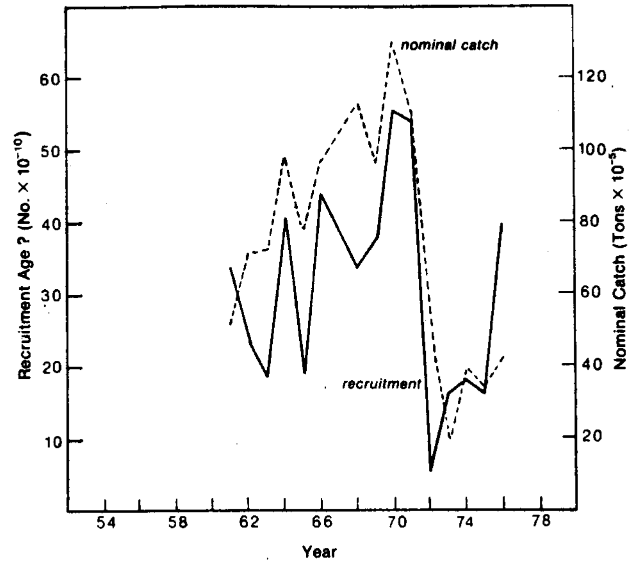

Fig. 17. Recruitment and nominal catch for Peruvian anchovy, 1961-76.

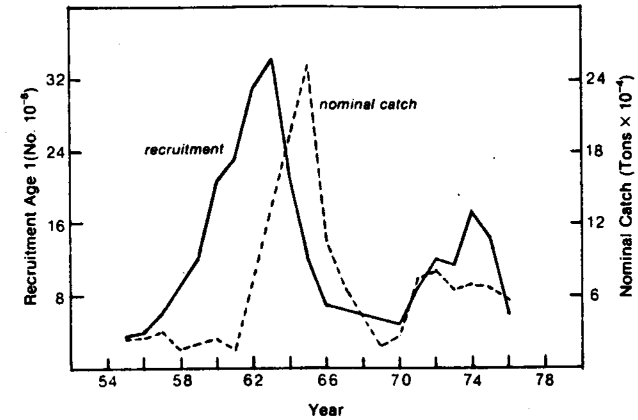

Fig. 18. Recruitment and nominal catch for Georges Bank silver hake, 1955-76.

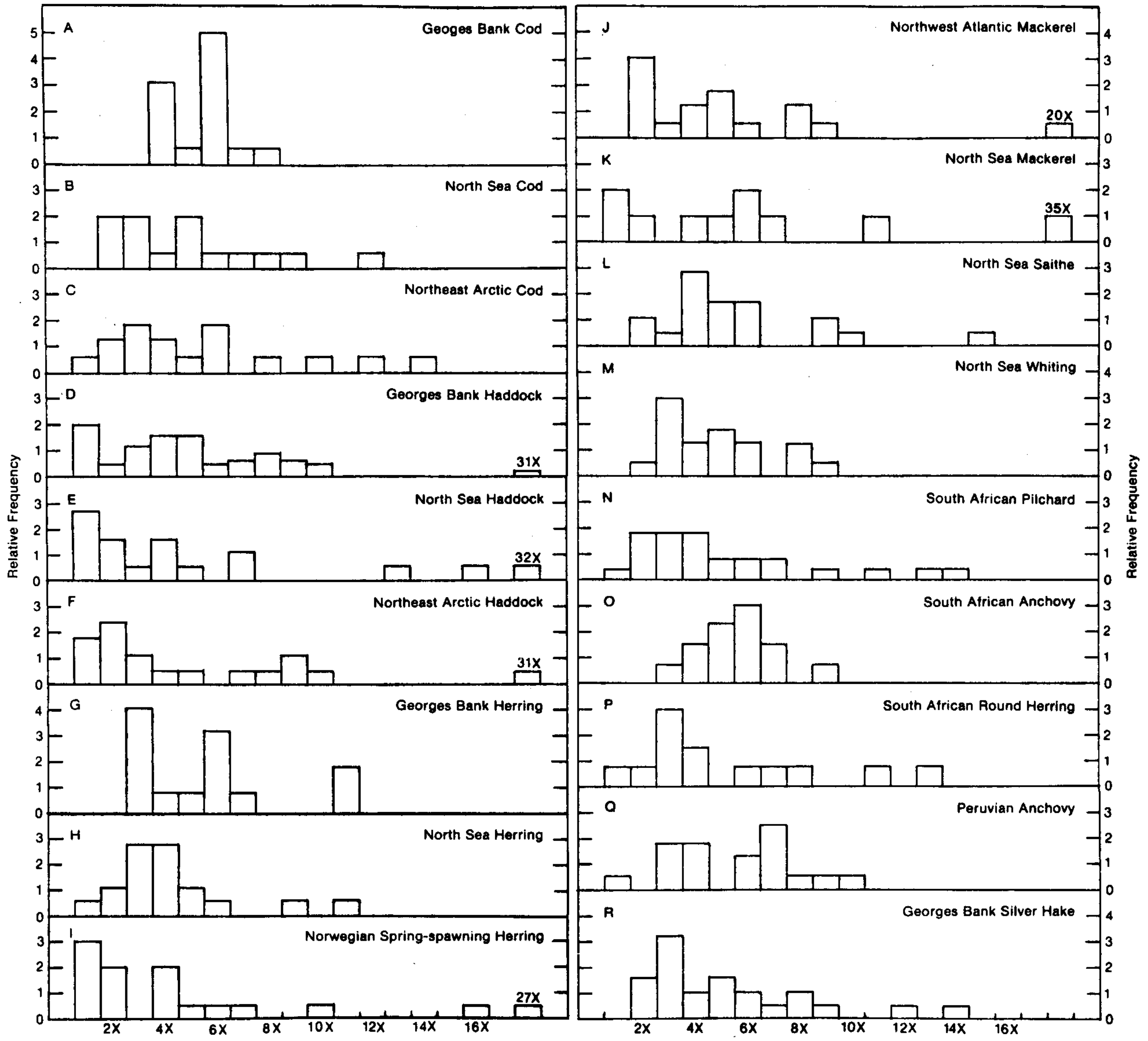

Fig. 19. Frequency distributions of recruitment in the 18 fish stocks illustrated in Figures 1-18. (The interval width (X) for year-class strength was calculated by dividing the mean of each data set by five.)

function describes all data sets except that for Georges Bank haddock in 1931-73 (Table 1). A visual examination of the histograms of the data (Fig. 19) supports this conclusion. However, Georges Bank cod and Peruvian anchovy (Fig. 19A, Q) appear more normally than lognormally distributed. Multimodal distributions are not considered here, but Georges Bank haddock and Northeast Arctic haddock (Fig. 19D, F) show indications of multimodality, and many other do also if the extreme points are considered as modes. The generally more normal distribution of recruitment for cod than for other species may be indicative of the fact that cod yields and stock sizes tend to be more stable and less subject to extreme fluctuations than many of the other species reviewed here.

Some caution must be noted with respect to the conclusions above. The significance of the normal or lognormal fits does not exclude the applicability of other probability distribution functions (e.g. binomial, Neyman types, etc.). In fact, most of the well-known standard, single or even joint probability distribution functions do not account for the frequency of occurrence in long right-hand tails observed in some cases. The very large year-classes, of dimension greater than 15X, have very significant effects on fisheries.

The Georges Bank haddock stock presents an interesting aspect because the entire series from 1931 to 1973 cannot be described by either a normal or a lognormal distribution (Table 1). Two different patterns are evident in the distribution of year-class size for the periods 1931-65 and 1966-73 (Fig. 4). One cannot reject a fit to a lognormal distribution for the 1931-65 data, and, as illustrated in Fig. 20, the fit is quite acceptable. Data for the 1966-73 period fit both a normal and a lognormal distribution. Since 1973, recruitment was poor for the 1973, 1974, 1976 and 1977 year-classes and strong for the 1975 year-class. Thus, the strong 1975 year-class would be more appropriate to a lognormal than to a normal distribution. Interestingly enough, the probability of a year-class as large as the preliminary estimate (200 × 10^6) for the 1975 year-class occurring under the lognormal distribution fit to the values estimated for the 1966–73 period would be only about 1 in 100, when in fact the observed frequency was 10 times greater. Comparison of the parameter estimates of the lognormal distributions for the two time periods indicates that data for the latter period has both a smaller mean and a larger variance. The ratio of largest to smallest recruitment was 2,700:1 for the entire period, 19:1 for the earlier period, and 92:1 for the latter period. The ratio for the latter period would be about 1,100:1 if the 1975 year-class was included.

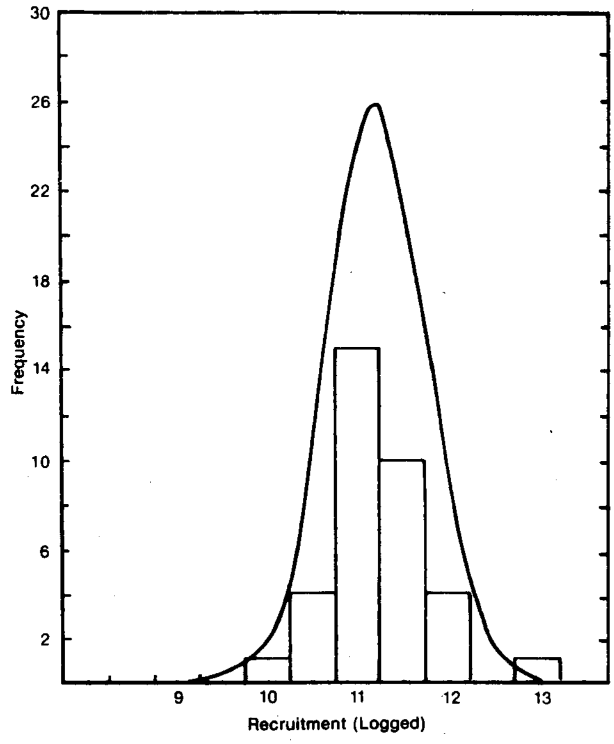

Fig. 20. Fit of the normal curve to the logarithms of the recruitment estimates for Georges Bank haddock, 1931-65.

Recruitment in the herring stocks of all areas can be described by a lognormal distribution, but a normal distribution could not be rejected for the Georges Bank stock (Table 1). The relatively shorter time series of observations for the Georges Bank stock and the smaller range in stock size, due to the earlier cessation of fishing when the stock was rapidly declining, may account for the observed fit to a normal distribution. With the exception of the large range for Norwegian spring-spawning herring (130:1), the variation in year-class size for the other herring stocks is much less than that for haddock but closely resembles that for cod in the same areas. The lower range for Georges Bank (5:1) than for North Sea herring (10:1) may be due in part to the effect of compensating mortality, in that the North Sea observations are based on age-0 fish and those of Georges Bank on age-2 fish.

Recruitment in the two mackerel stocks can be described very well by lognormal distributions (Table 1). The range in year-class size for the Northwest Atlantic stock (18:1) was considerably lower than that for the North Sea stock (41:1), but, if the North Sea observations for the last 2 years (1977 and 1978) are eliminated, the ratio becomes 20:1, essentially the same as that for the Northwest Atlantic stock. The smaller variation in recruitment for Georges Bank cod and herring and Northwest Atlantic mackerel, compared with those stocks in the North Sea, may indicate a more stable situation in the Northwest Atlantic area. It is also possible that the smaller ranges in recruitment for the Georges Bank stocks may be related to the more rapid implementation of management measures in the Northwest Atlantic, halting declines in stock sizes at proportionally larger sizes than in the North Sea.

Recruitment in the other two North Sea stocks examined, saithe and whiting, can also be described by lognormal distributions. The ratio of largest to smallest year-class size for whiting is 6.5:1 and that for saithe is 12:1. Interestingly, these ratios are only slightly higher than those for North Sea cod and herring respectively. Data for the only other Georges Bank stock examined, silver hake, with variation in year-class strength of approximately 10:1, fit slightly less well to a lognormal distribution than several of the other stocks.

The four southern hemispheric stocks examined present a rather interesting pattern. With the exception of Georges Bank cod, the lowest ratio of largest to smallest year-class size was found for the South African anchovy (2.7:1). Recruitment for this stock can be described by both normal and lognormal distributions. South African pilchard and round herring and Peruvian anchovy all had year-class size ratios of about 10:1. Recruitment in the Peruvian anchovy is better described by a normal than a lognormal distribution, but the reverse is true for the other two stocks.

The serial correlation results (Table 2) indicate that the most frequently occurring correlations were with a 1-year time lag, the correlation coefficients tending to decline as the time lag is increased. The implication of short time-lag correlations in examining recruitment is that, at least in some instances, one should not only examine the probability distribution functions, as if recruitment estimates were independent random variables, but also consider the relationships of adjacent year-classes. However, the relative infrequency of such significant correlations and the low values of the correlation coefficients in most cases (the values for pilchard and silver hake were the only ones above 0.8) imply that ignoring them would create only moderate problems in examining the probability distribution function of year-classes as independent variables. Short-term correlations would be expected when environmental conditions affecting egg and larval survival were similar in adjacent years. In addition, these correlations would be influenced by stock-recruitment relationships to the extent that the spawning potential in adjacent years might be similar.

This study of recruitment in a variety of fish stocks has some interesting implications. It is obvious that a clear distinction between pelagic and demersal stocks cannot be made on the basis of recruitment variability or the presence of dominant year-classes. Furthermore, there is great similarity in the form of the probability distribution functions of widely differing stocks. The approach of studying these functions, as more data are accumulated, may provide useful guidelines in understanding the influence of recruitment on fish populations and fisheries.

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