International Council for the
Exploration of the Sea.

C.M.1980/G:34
Demersal Fish Committee

A simulation method for calculation a TAC of North Sea Sole.

by

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Abstract.

Using a stochastic recruitment model the distribution of the yield and spawningstock for different level of fishing mortality is found by simulation.

A stochastic recruitment model for the North Sea sole was used in the simulation of yield and spawningstock and examples of TAC are given, where the TAC is based upon the probabilities that the spawningstock in a given year exceeds a level decided upon and where the probabilities are given as a function of F.

Introduction.

Macer et al (1979) pointed out some uncertainties of catch prediction as performed by Working Groups. Recruitment is one of these.

Ursin 1978 discussed the consequenses of using average recruitment excluding the outstanding yearclasses as sometimes done by Working Groups and pointed out the subjectivity hereby introduced. He also points out that in cases when the yield over long series of years are based upon a few outstanding yearclasses, these should be included in long term prognoses.

In the case of North Sea sole the outstanding yearclass of 1963 had a strong influence on the catch even in 1970 when it constituted 30 % of the total catch. The yearclass are assumed fully recruited at age 3 for both males and females to the fishery.

Using meanrecruitment the effects of natural variation are ignored. This may be accepted in case of small variations but for some species I do consider them to big to be ignored because predictions of yield and spawningstock are highly dependent on the recruitment.

It therefore seems sensible to include the recruitment variation in the prediction procedure by substituting a simulation method for the traditionel average recruitment method. Important additional information on the possible and more or less likely development of a fish stock can be obtained this way. For such work a stochastic model of recruitment seems to be required and a procedure was in fact suggested by N.A. Nielsen (1979) in a study of herring. His method is here adapted to fit a description of the sole stock and the sole fisheries in the North Sea.

The model.

The important point of N.A. Nielsen (1979) model is that the numbers of recruits (R) to agegroup I is treated as a stochastic variabel and that the distribution of R is dependent of the spawningstock.

In the model described in this paper the numbers of recruits (R) to age group I is treated as a stochastic variabel and that the distribution of R is independent of spawning stock.

These assumption were made because figure 1 does not indicate any clear relationship between spawningstock and recruitment and actually there is no information on the first part of the stock/recruitmentplot except the point (0,0).

The distribution of yield and spawning stock can be derived from the distribution of the recruitnumbers.

An interesting part of the model is an expression for the probability that the spawning stock in a given year exceeds a size decided upon.

The distributrion of recruit numbers including outstanding yearclasses is shown on fig. 2 and table 1. A log normal distribution was assumed and seems in agreement with data (Fig. 2).

The model used is

$$\ln R \sim N(m, \delta^2)$$

R = numbers of recruits from the VPA agegroup I
m = mean of ln numbers of recruits
δ^2 = the variance.

Input Data.

Weight at Age.

The data used was the available 1979 data (W.G. 1980 table 2.13).
The weight of males and females were combined and a weighted mean weight was calculated and smoothed (fig. 3).

F at Age.

The F at age data was taken from the W.G. 1980 report (table 2.13).
The F values males and females were combined.

Catch by numbers.

The catch by numbers is as stated in the 1980 W.G. report (table 2.2)
m was .1 as in the W.G. report 1980.

The simulations.

In general the type of distribution of the biomass and the catch will depend on the stochastic recruitmentmodel, F and m and starting stock.

Therefore the distribution of the spawning stock and yield was examined before making the probabilities statement.

An examination of yield and spawning stock in 1982, 1985 and 1990 can be approximated with a log normaldistribution.

The distribution is shown on probabilitypaper on fig. 4.

The simulations runs were made for max F values .1, .2,...1.0 for F constant in the periode 1981-1989 and max F_{1979} = max F_{1980} = .7. It was assumed the exploitation pattern was unchanged in the periode and on the 1979 level (Table 2). Examples of the simulated expected yield in 1981, 1984 and 1989 are given in Fig. 6 and 8.

Assuming F = F_{79} throughout, the yields and the corresponding spawning stocks are shown in Table 3.

The results from the simulations method taking recruitment variation only into account (the stochastic model) were compared with a deterministic model using a geometric mean including the outstanding yearclasses 1958 and 1963. Note that the expected yields obtained with the simulations method taking recruitment variation only account exceed the prediction based on the deterministic model by 19 % in the short term prediction (yield 1981 and SSB 1982) and even by 45% in the long-term prediction (yield 1989 and SSB in 1990).

We shall also examine the probabilities of getting the corresponding spawning stock equal to or larger than a specified amount.

Three stock size 35.000 tonnes, 45.000 tonnes and 50.000 tonnes, were chosen.

The 45.000 tonnes agrees with the long-term objectives stated in the 1980 W.G. report.

The 50.000 tonnes are the mean level of the spawning stocks in the 70.th.

For all values below 35.000 tonnes no informations about the recruitment level are available.

The probabilities are

	Spawning stock		
	≥45.000	≥50.000	≥35.000
1982	29.8	21.8	50.4
1985	52.4	42.8	74.6
1990	55.5	47.4	75.8

The probabilities are functions of F as illustrated in Figs. 9 and 10.

The W.G. 1980 estimated the F max corresponding to M.S.Y. to $0.86 \cdot F_{79}$ (corresponding to a combined max F of .6).

An analysis of a reduction of F to the Fmax (M.S.Y.) value in 1981 gave the results shown in Table 4.

The simulation method (stochastic model) figures exceed the deterministic model by 23 % in the short term prediction and by 44 % in the long-term prediction.

The reduced F in 1981 led to the following probabilities

	Spawning stock		
	≥45.000	≥50.000	≥35.000
1982	32 %	24.2%	54.4 %
1985	66.3%	53.3%	84.4 %
1990	75.5%	65.9%	89.8 %

Discussion.

These examples shows that using the deterministic model results in lower estimates of spawning stock and yield.

The fishery is still considered "unregulated" and the sole stock did not collapse as predicted in the earlier W.G. reports. Instead the spawningstock more or less stabilised and remained at approximately the same level.

In 1980 the W.G. decided to use a geometric mean (including the outstanding yearclasses). But still the simulations method results for the short term TAC exceed

1) the W.G. results by 17-24 % and
2) the deterministic model used by 19-23;

and the simulations method results for the long-term TAC exceed

1) the W.G. results by 47-50 % and
2) the deterministic model used 44-45 %.

Because the traditional TAC calculation disregards the effect of yearclass variation.

A good yearclass affects the fishery more than a bad one does.

If an average ("normal") yearclass yields A tonnes then a "poor yearclass" causes a loss of no more than A tonnes. A good yearclass is often of more than twice normal strength and therefore yields more than A tonnes extra. The precise strength of a poor yearclass is immaterial: it is of little consequence whether it is one tenth or only one hundredth of normal strength.

Therefore the advice given using a meanrecruitment will be too pessimistic. It may even happen as it did happen to the Working Group, that the collapse of a stock is predicted when the stock is not immediately endangered.

Therefore a spawning stock and yield prediction would be better on a probability basis.

The example, Table 5, illustrates the consequences of using a 50 % probability level and 80 % probability level. In both cases the expected TAC will be higher than in the W.G. 1980 report. The same holds for the expected spawning stock.

The model also illustrate the probability of a collapse of the stock and Fig. 11 and Table 5 also show an increase in max F to f.ex. 1.0 would not be advisable because then the probabilitie to get spawningstock greater than the 35 000 tonnes would be 35 % in 1980.

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Table 1. Recruits in nos. I-group.

Year	♂♂	♀♀	total	in total
1957	50.218	74.258	124.476	11.73
1958	41.009	77.553	118.562	11.68
1959	157.226	221.800	379.026	12.84
1960	17.357	26.602	43.959	10.69
1961	26.925	37.118	64.043	11.07
1962	7.333	8.074	15.407	9.64
1963	34.554	11.000	45.554	10.73
1964	285.442	316.318	601.760	13.31
1965	61.701	65.886	127.587	11.76
1966	35.382	30.173	65.555	11.09
1967	34.697	32.114	66.811	11.11
1968	50.869	51.694	102.563	11.54
1969	23.358	26.368	49.726	10.81
1970	77.902	78.082	155.984	11.96
1971	23.968	16.870	40.838	10.62
1972	48.886	44.049	92.935	11.44
1973	55.579	57.216	112.795	11.63
1974	50.732	53.684	104.416	11.56
1975	17.347	21.181	38.528	10.56
1976	51.029	59.630	110.659	11.61

Table 2. Input data for the simulation runs.

Age	No. in catch 1979 (thousands)	Rel. F	Body weight in catch	Body weight on population
1	8	.0084	100	50
2	8179	.3966	203	130
3	41190	1.0000	279	230
4	16109	.8867	359	321
5	3035	.7082	427	400
6	3255	.5481	465	460
7	1787	.4207	550	550
8	862	.3618	578	600
9	245	.3088	639	640
10	400	.2762	702	696
11	153	.2521	757	750
12	121	.2295	788	784
13	107	.2266	790	830
14	73	.2125	810	870
15	77	.2125	820	890
16	405	.2125	830	910
17	6	.2125	840	930
18	40	.2125	850	930
19	39	.2125	850	930
20	93	.2125	850	930

Table 3. The mean yield (expected) assuming $F_{79}=F_{80}=F_{81}=F_{82}=F_{83}=F_{84}=F_{85}=F_{86}=F_{87}=F_{88}=F_{89}=.7$ and the corresponding spawningstock.

Yield

	1% fractile	Expected yield	99 % fractile	Prognosis using the inputdata (table 2) and meanrecruitment x)	Results from the W.G. 1980 xx)
1981	5321	22916	71725	19181	18040(19483)
1984	8538	26915	69325	19240	
1989	5189	27761	80743	19100	17161(18533)

Spawning stock.

	1% fractile	Expected yield	99% fractile	Prognosis using the inputdata and meanrecruitment	Results from the W.G. 1980
1982	12728	38636	97581	40292	40801
1985	17022	50970	125204	38067	
1990	16630	53204	138800	37097	37000

x) A prognosed based on the inputdata table 2 and mean recruitment (86 000 000) (The deterministic model).

xx) The value in the bracket is raised by 1.08 because the discrepancy in the S.O.P. was 8%.

Table 4. The expected yield and spawning stock with $F_{79}=F_{80}=.7$ and $F_{81}=F_{82}=F_{83}=F_{84}=F_{85}=F_{86}=F_{87}=F_{88}=F_{89}= .6$

Yield

	1% fractile	Expected yield	99% fractile	Prognosis x) using the inputdata (Table 2) and meanrecruit	Results from the W.G. 1980 xx)
1981	4889	20899	65809	16975	15600(16848)
1984	8493	26450	67029	18716	
1989	7777	27450	77264	19052	17252(18632)

Spawning stock.

	1% fractile	Expected yield	99 % fractile	Prognosis using the inputdata (Table 2) and meanrecruit	Results from the W.G. 1980
1982	13312	40415	101068	42625	39800
1985	20083	58676	143247	44141	
1890	22572	64611	157086	45518	46178

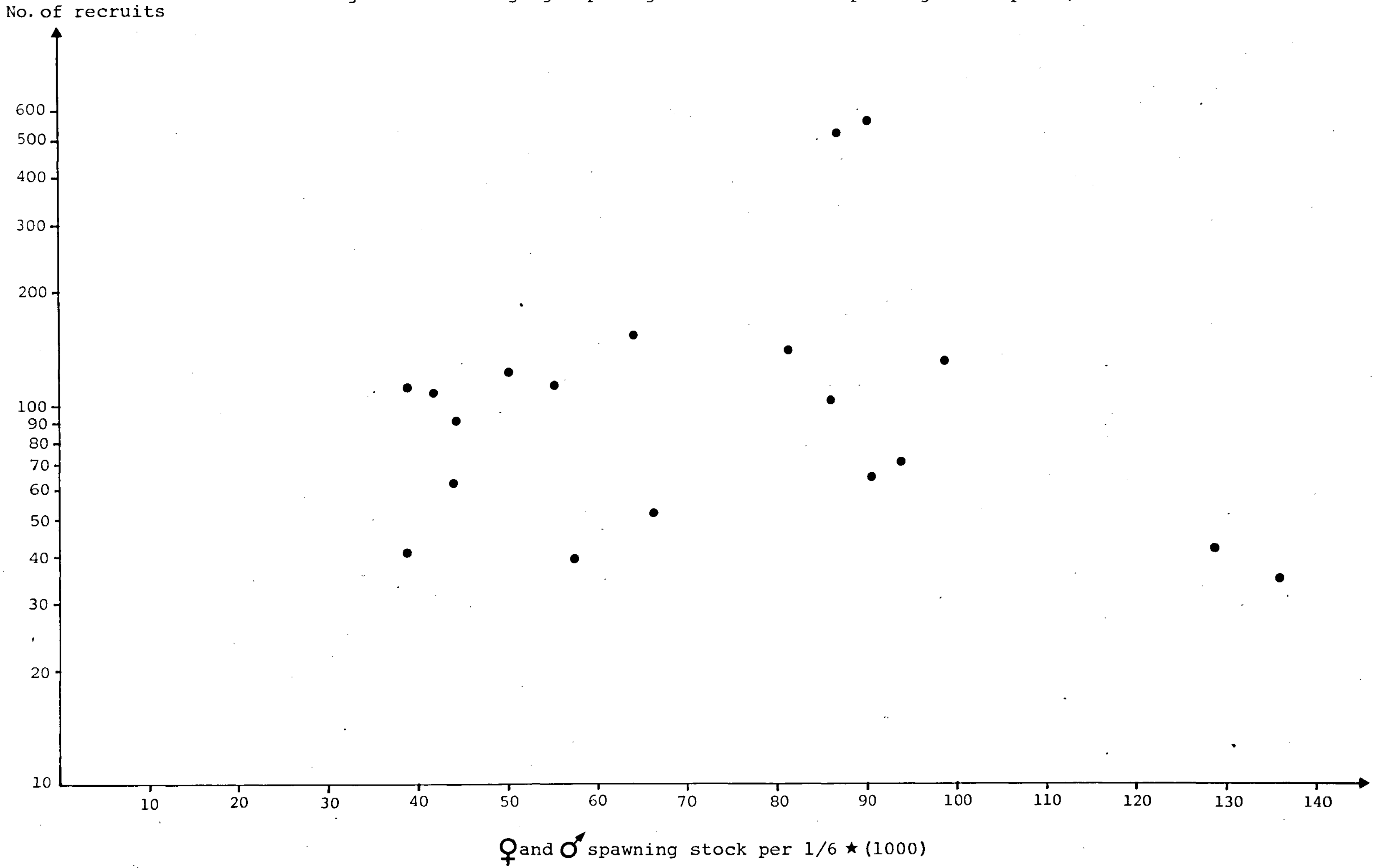
x) A prognosis based on the inputdata table 2 and mean recruitment (86 000 000) (The deterministic model).

xx) The value in the bracket is raised by 1.08 because the discrepancy in the S.O.P. was 8 %.

Table 5. The expected yield and spawning stock based on probabilitylevel.

Spawning stock	50 000 tonnes		45 000 tonnes		35 000 tonnes	
Probability level in 1990	80 %	50 %	80 %	50 %	35 %	50 %
$F_{81} = F_{89}$	.52	.69	.58	.71	1.0	.85
Expected yield 1989	26000	26000	26000	26000	26000	26000
Expected spawning stock 1990	76000	52000	68000	50000	32000	40000
Expected yield 1981	18200	23000	20200	23000	27000	25000
Expected spawning stock 1982	42000	39000	40000	38000	33000	36000

Fig.1: The UPA age-group I against the total spawning stock per 1/6



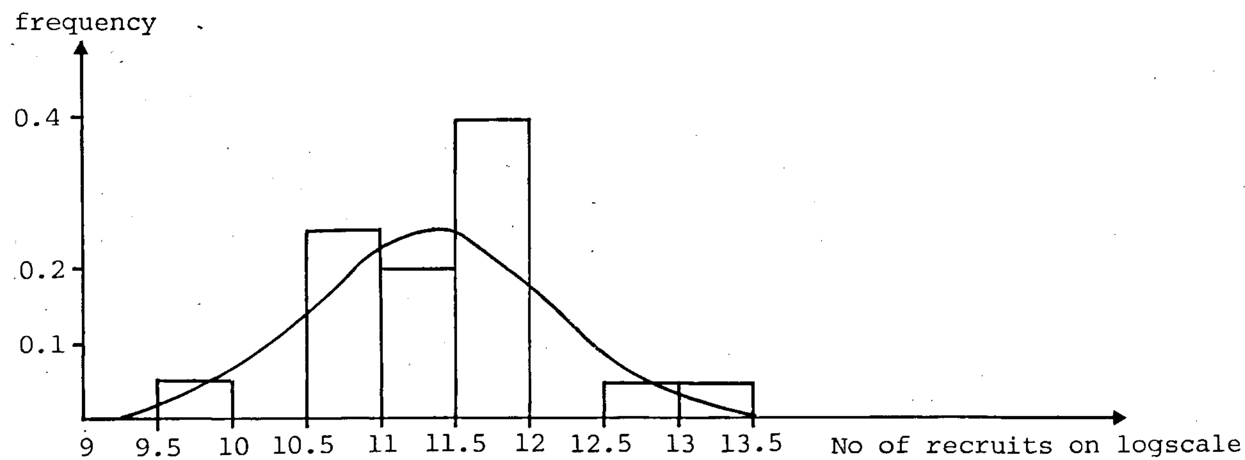


Fig.2: The distribution of the number of recruits

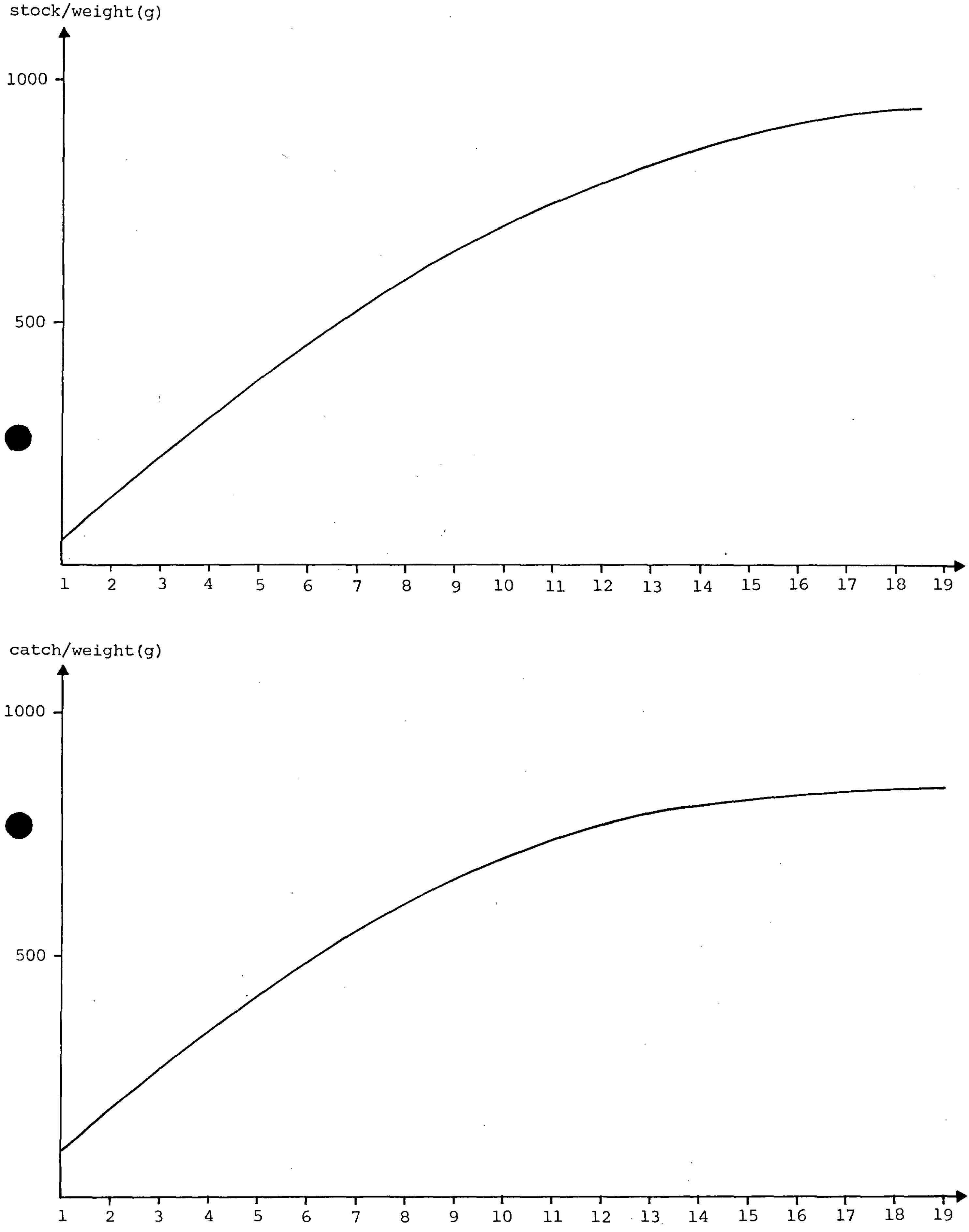


Fig.3: Combined male and female catch/weight, smoothed curve.

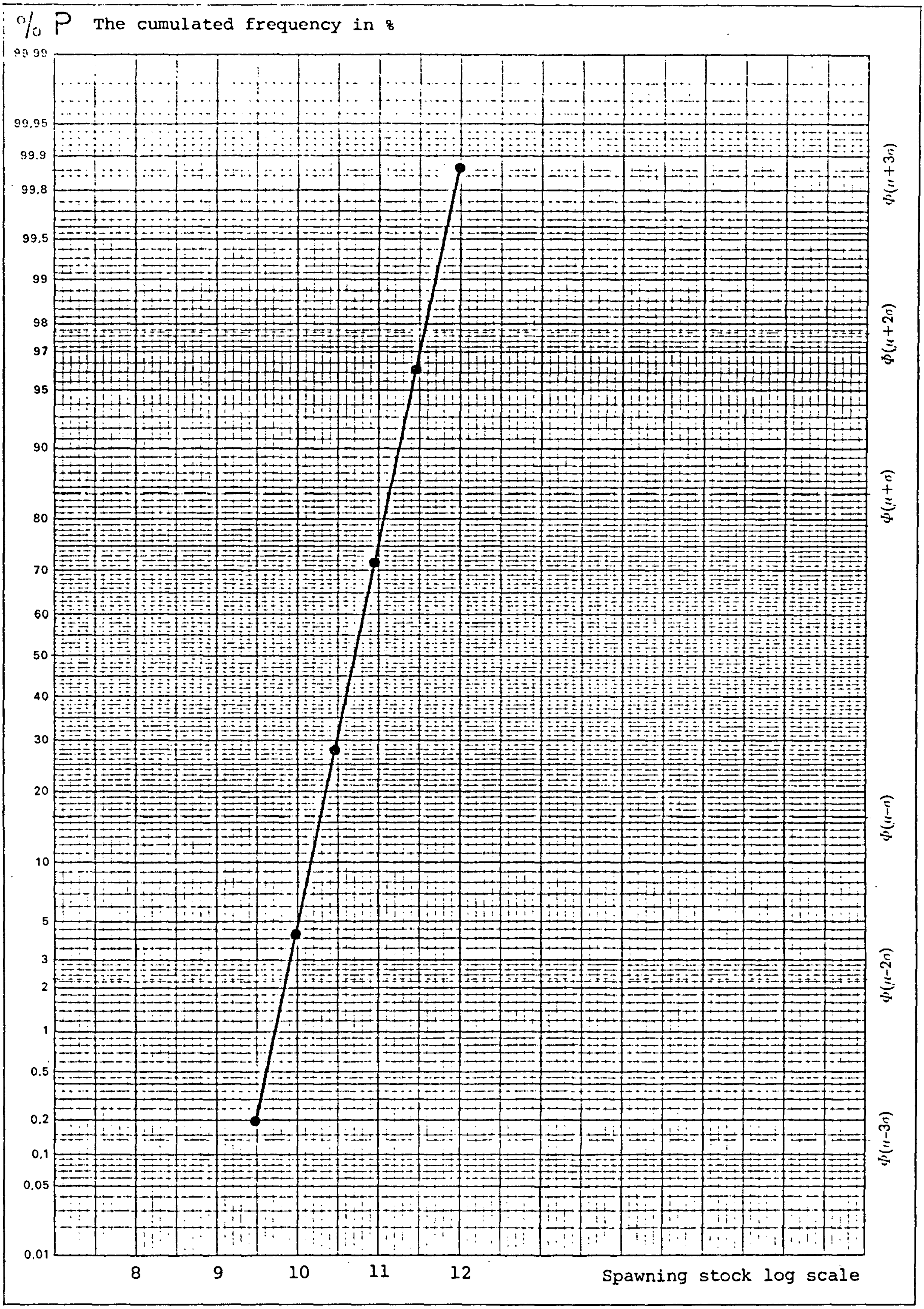


Fig.4: An example of the distribution of the spawning stock in 1985 (logarithmic transformed).

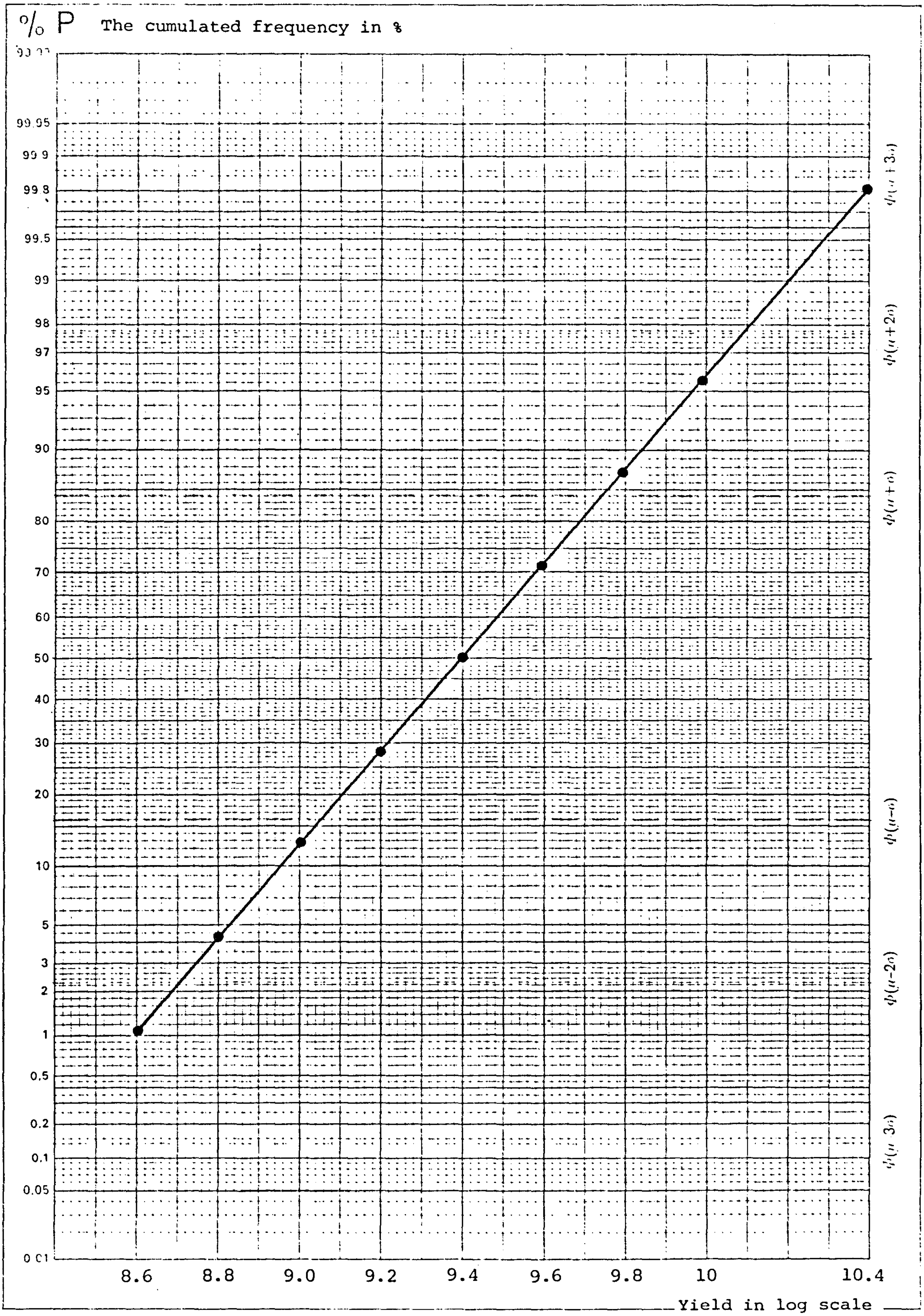
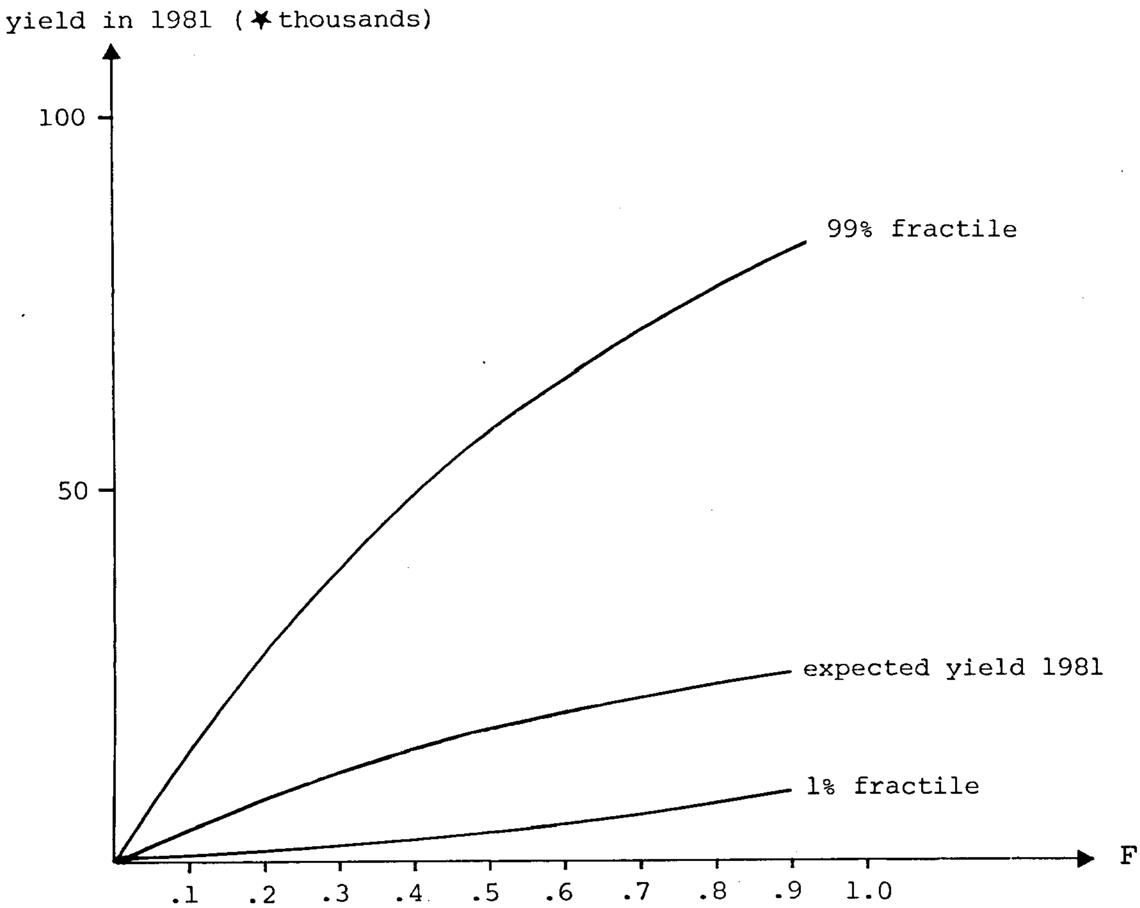


Fig.5: An example of the distribution of the yield in 1989 (logarithmic transformed).



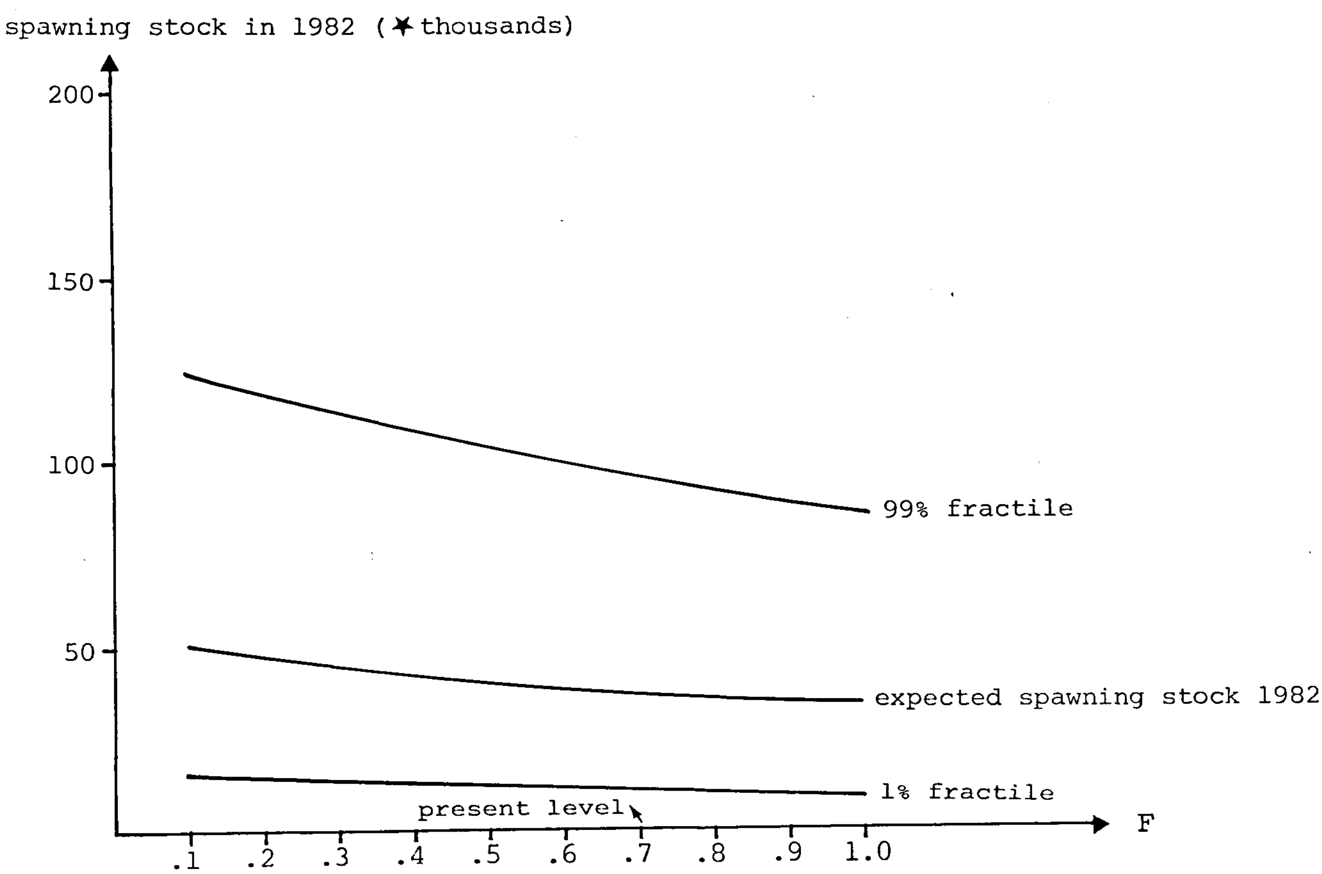
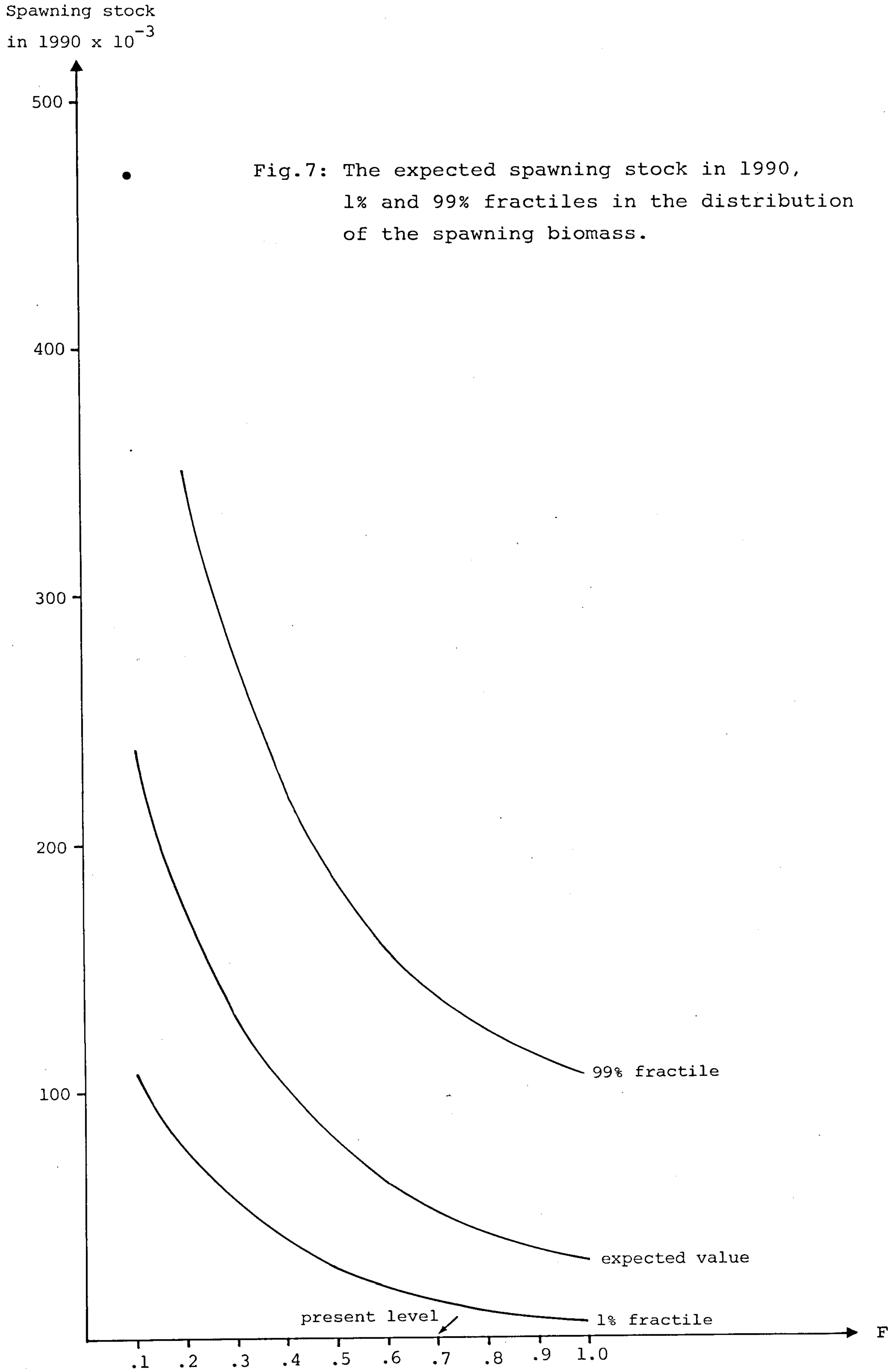


Fig.6: The expected yield and spawning stock in 1981 and 1982 respectively.

Fig.7: The expected spawning stock in 1990, 1% and 99% fractiles in the distribution of the spawning biomass.



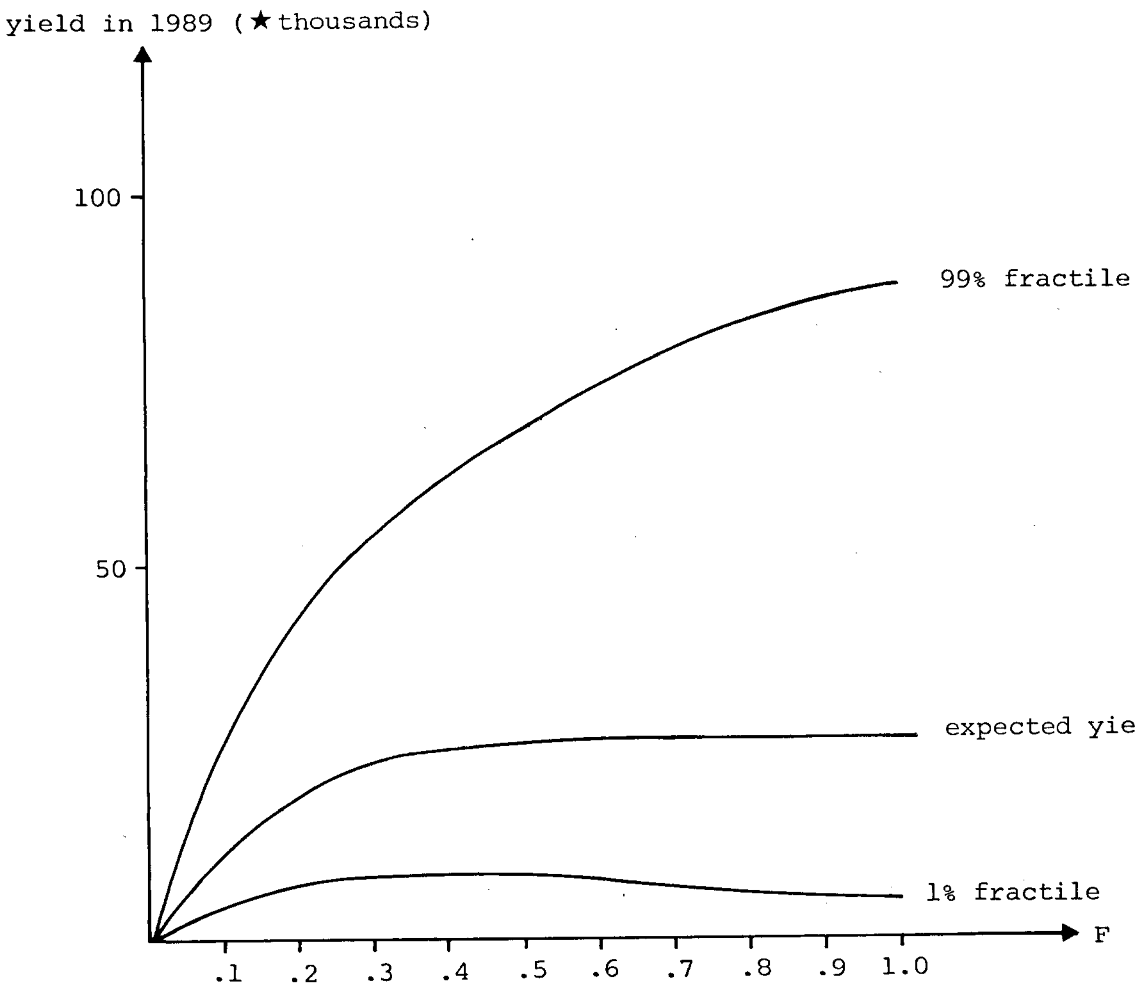


Fig.8: The expected yield in 1989, 1% and 99% fractile in the distribution af the yield.

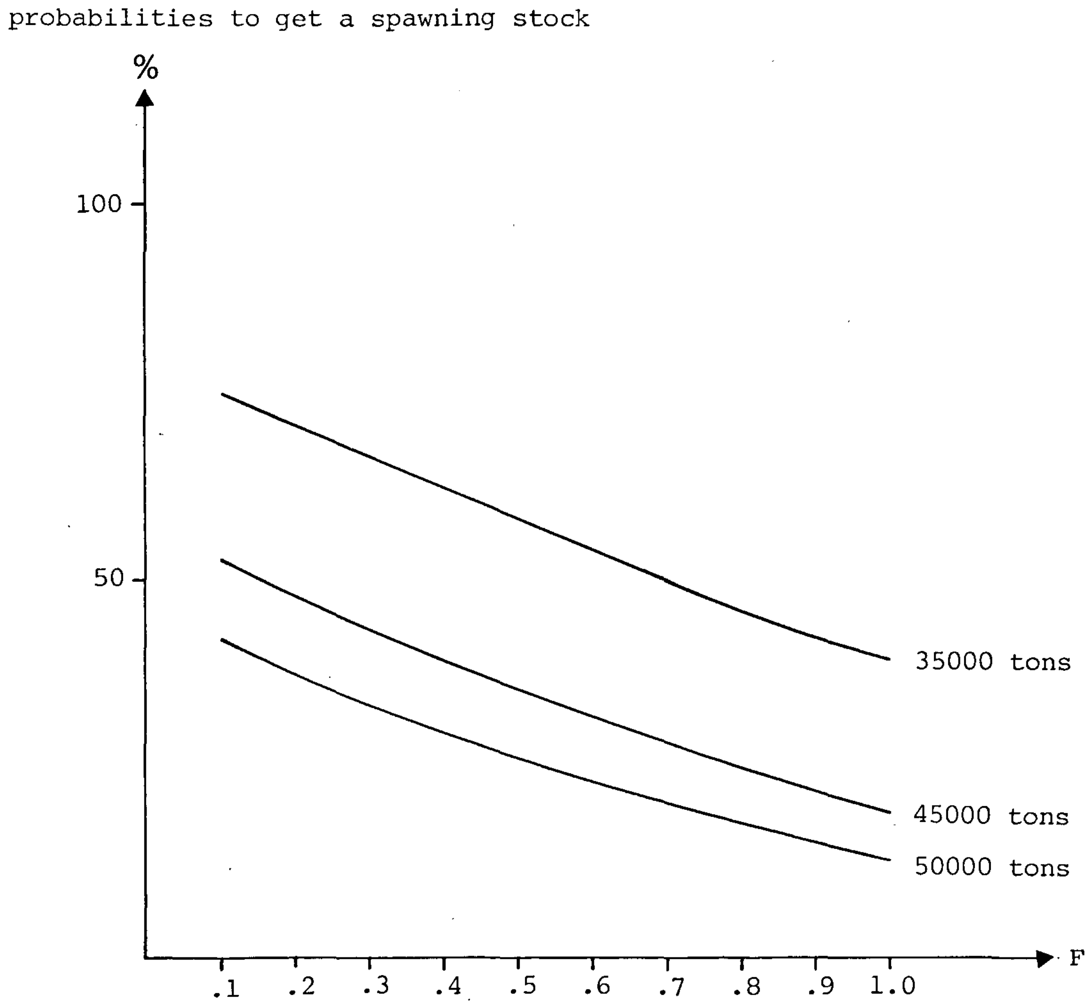


Fig.9: The probability as a function of F for a spawning stock level greater than 50000 tons, 45000 tons and 35000 tons in 1982.

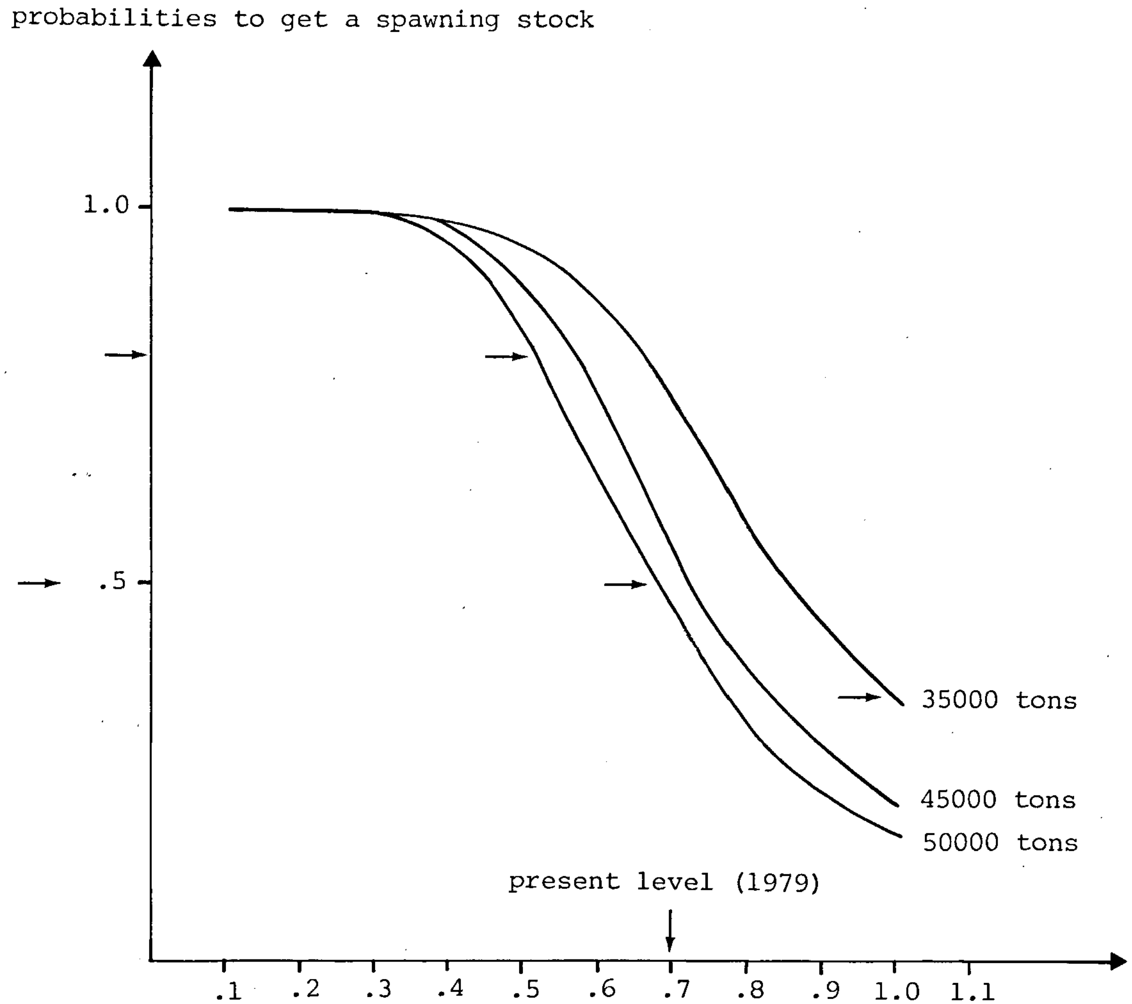


Fig.10: The probability as a function of F for a spawning stock level greater than 50000 tons, 45000 tons and 35000 tons in 1990.