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Further Work on Nonparametric Prediction of Recruitment of 2J3KL Cod from Stock and Environmental Influences

by

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ABSTRACT

Nonparametric methods for projecting expected recruitments from stock and environmental influences were used to estimate expected recruitments for the 2J+3JK cod stock. For the recruitments observed between 1962 and 1980, stock size accounted for 62% of the variance in recruitment. Spring and summer surface temperatures accounted for 6.5% of the residual variance in recruitment; winter temperatures and salinities accounted for 7.1% of the residual variance. Using these results, the 1981 year-class is predicted to be about 300 million recruits (numbers at age 4), the 1982 year-class is predicted to be slightly smaller (280 million recruits), the 1983 and 1984 year-classes between 350 and 400 million recruits, and the 1985 year-class substantially smaller; perhaps 200 million recruits. Ogives of the probability that recruitment will be of various sizes are presented for these predictions.

RESUME

Des méthodes non paramétriques pour la projection des recrutements prévus à partir du stock et des influences environnementales ont été utilisées pour estimer les recrutements prévus pour le stock de morue 2J+3JK. Pour les recrutements observés entre 1962 et 1980 la taille du stock expliquait 62 % de la variance du recrutement. Les températures de surface au printemps et en été en expliquaient 6,5 %; les températures et les salinités en hiver en expliquaient 7,1 %. A partir de ces résultats on prévoit que la classe d'âge de 1981 comptera environ 300 millions de recrues (nombre à l'âge de 4 ans), la classe d'âge de 1982 légèrement moins (280 millions de recrues), les classes d'âge de 1983 et 1984 entre 350 et 400 millions de recrues et la classe d'âge de 1985 un nombre substantiellement moins élevé soit peut-être environ 200 millions. Des ogives des probabilités des nombres de recrues en rapport avec ces prévisions sont présentées.

Introduction

Recruitment of cod in NAFO Divisions 2J+3KL has been shown to be influenced by both spawning stock biomass and environmental influences, including water temperatures (Rice and Evans 1986a, b). The true parametric functions relating these influences to recruitment are unknown, and are unlikely to be either simple or knowable. In such circumstances nonparametric probability density estimation methods are likely to be superior to alternative methods for estimating expected levels of recruitment.

Evans and Rice (in press) have developed a nonparametric method for estimating the probability density function (pdf) of recruitment expected, given a historical series of recruitment-independent variable pairs, and the current value of the independent variable. In this paper the pdf for strengths of recent year-classes of the northern cod stock are estimated given the estimated spawning stock biomass, as are the pdf of displacements of the expected recruitment, given environmental conditions in those years.

Methods

The data: Spawning stock biomasses were taken as the beginning of year 7+ biomass. Values up to 1980 were included in the historic series, and were taken from the 1986 assessment (Baird and Bishop 1986). Predictions were made for years from 1981 to 1985, where values for spawning stock biomass were also taken from Baird and Bishop 1986.

Environmental data were all from Station 27, and consisted of surface (0-20 m) and deep (100-150 m) temperatures, and surface salinities, for January, March, June, and October. Data from 1954 to 1986 were ordinated with both detrended correspondence analysis and principal components analysis (Gauch 1982). Ordination results will be described at the 1987 NAFO session on environment, as well as the analyses selecting the appropriate axes to serve as independent variables for this work (Rice, in prep.).

Analysis methods: Our nonparametric methods are described in detail, and contrasted with more commonly used parametric methods for predicting recruitment from stock in Evans and Rice (in press). Of the options described there, we used the Cauchy step function algorithm. In this algorithm the recruitment pdf can increase only at historically observed recruitments. The height of each step is determined by the Cauchy weighting function $1/(1+(X/D)^2)$, where X is the distance between the current value of the independent variable and the value associated with the historic recruitment, and D is the width of the influence window. We first determined the pdf for expected recruitment, from the historic stock-recruit data. We then estimated the pdf for deviations around the expected recruitment. We used the first two axes of the principal component analysis of temperatures and salinities as independent variables. The dependent variable was the deviation of the observed historic recruitment from the median recruitment of the pdf estimated using standard jacknife procedures for the stock-recruitment data from each historic year. Because principal component axes are uncorrelated, the pdf's of recruitment deviations can be constructed separately for each axis. Predictions for years after 1980 used the series from 1962 to 1980.

Results

For the historic series, we used the median recruitment, given the step function ogive, as the predicted recruitment for each year. The variance in recruitment over that period was $5.61X10^8$, and these median predictions from stock size accounted for 62% of that variation (Table 1). Predictions were fairly insensitive to the value of D, with a maximum reduction of variance at 1200, about 1/10 the range of the stock axis (Table 2). Largest residuals were for 1969 (-) and 1963 (+), with strings of large residuals for the 1969-71 and 1976-77 year-classes.

The two principal component axis accounted for similar, small portions of the residual variance. PC I accounted for 6.5% of the variance; PC II for 7.1%. Both fits were quite sensitive to the value of D, (Table 2) with an optimum value of 0.40 for PC I (1/8 the range of scores) and 0.41 for PC II (1/10 of the range) (Table 2).

PC I reflects influences of spring and summer surface temperatures and salinities. Values on both extremes of this axis were associated with predictions of large negative residuals, and large positive residuals expected from median to moderately high values on this axis. PC II reflects influences of winter temperatures and salinities. Large positive residuals are expected in years with positive PC II scores, i.e. with warm winter temperature (Fig. 3).

PC I does moderately well at correctly predicting poor recruitments; year-classes 1966, 1969, 1970, and 1971 were correctly predicted to be substantially smaller than expected, given the stock size. PC II is better at predicting good year-classes, correctly predicting the 1962, 1967, and 1968 year-classes as being strong. Neither axis predicts failures where exceptionally strong year-classes occurred, or vice versa. False alarms were also rare (1 of 19 for each axis), but both axes missed several exceptional year-classes; for example the strong 1963 and 1978, and weak 1964 and 1976 year-classes.

Predictions for 1981-85 year-classes

Based on spawning stock biomasses, the 1981, 1983, and 1984 year-classes should be about $3X10^8$ fish, with the 1982 and 1985 year-classes smaller; about $2X10^8$ fish. Except for 1982 all ogives are fairly steep around the median, implying recruitment sizes are unlikely to be very different from the median value, when only the stock influence is considered. For the 1982 prediction, the ogive is much flatter, and values as high as $3X10^8$ are nearly as good as $2X10^8$ for the prediction (Fig. 1).

When the environmental indicators are considered as well, some predictions change. PC I predictions suggest that the 1983 and 1984 year-classes may be stronger than expected, given stock size. Using PC II, all ogives suggest only small adjustments in stock-based predictions would be necessary (Fig. 2). However, because the median deviations for the historic series were biased low for the predictions using both axes, the suggestion from PC II that the 1982 year-class might be slightly stronger than expected may warrant extra consideration.

The ogives from 1982, 1984, and 1985 for PC II all have gradual slopes around the median. For the 1984 and 1985 year-classes, the slopes suggest weaker negative adjustment of the recruitments are possible. For the 1982 year-class, the slope suggests the year-class may be stronger.

In summary, spawning stock biomass suggest the 1981 year-class might be 3.00×10^8 fish with no environmentally based adjustments. The 1982 year-class might be up to one-third smaller, based on stock size alone, but environmental factors suggest increasing this value back to the neighborhood 2.7 to 3.0×10^8. The 1983 and 1984 year-classes should both be 3×10^8 from stock, with upward adjustments to 3.5 to 4.0×10^8 for the 1983 and possibly to 3.5×10^8 for 1984. The 1985 year-class may be substantially weaker, with a value of 2.0×10^8 suggested.

Note that throughout this work, spawning stock biomass has been assumed to be 7+ beginning of year biomass. Maturity is unlikely to be knife-edge at age 7, and there is evidence that maturation ogives of 3M cod have changed, as stock biomass changed (Wells 1986). The observation that recruitment appears to be on a higher trajectory as the 2J3KL stock rebuilds than it followed as the stock declined (Fig. 3) suggests that spawning stock biomass may be underestimated in recent years. Results of the analyses presented here can be viewed with more confidence when ongoing work on the environmental data base, and estimation of the actual spawning stock biomasses is completed.

References

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Table 1. Spawning stock biomass and numbers of recruits for 1962 to 1980 year-classes; PCA 1 and PCA II scores for those years, and median recruitment or deviations, and residuals of observed - median for Cauchy algorithm predictions. Units for biomass and numbers as in assessment document (Baird and Bishop 1986).

Year	Stock	Obs. Recr.	Median Recr.	Dev.	PC I Score	Median Dev.	New Dev.	PC II Score	Median Dev.	New Dev.
1962	12243	8160	6674	1486	-0.972	-111	1597	1.612	653	833
1963	11086	9250	5754	3496	-0.173	-111	3607	0.841	-133	3629
1964	12046	6674	8160	-1486	-0.955	-13	-1473	0.480	-111	-1375
1965	10087	5754	5865	-111	0.211	653	-764	0.120	-170	59
1966	8433	5343	4732	611	1.276	-943	332	0.911	170	-781
1967	7980	5865	4732	1133	-0.976	-111	1244	1.768	653	480
1968	7685	4732	4079	653	0.526	-13	666	1.598	1133	-480
1969	7222	2032	4732	-2700	1.699	-896	-1804	0.240	-111	-2589
1970	5660	1136	2032	-896	2.131	-943	47	-0.663	-170	-726
1971	5607	1089	2032	-943	1.238	-611	-332	-1.459	-13	-930
1972	5702	1919	2032	-113	-0.842	170	-283	-0.201	-170	37
1973	4613	3479	2901	578	-0.711	-111	689	-2.450	-170	748
1974	4075	3058	3071	-13	-1.006	-111	98	-1.598	-943	930
1975	2748	2901	3071	-170	-0.953	-13	-157	-0.019	-133	-37
1976	1497	1471	3071	-1600	-0.357	170	-1770	-0.028	-133	-1467
1977	862	1669	3071	-1402	-0.254	170	-1572	-0.884	-896	-506
1978	1020	4079	1919	2160	0.326	-13	2173	-0.106	-170	2330
1979	1401	3071	2901	170	-0.441	-111	281	0.635	-170	340
1980	2941	3755	2901	854	-0.016	-13	876	0.370	-170	1024

Table 2. Reduction in variance of recruitment (by stock) or residuals (by PC scores) for various values of the "D" parameter in the Cauchy algorithm. Variances are in same units as table 1.

Variance = 3.30×10^6		Variance = 2.11×10^6		Variance = 2.11×10^6	
Stock "D"	Variance Reduction	PC I "D"	Variance Reduction	PC II "D"	Variance Reduction
1000	3.143×10^6	0.200	1.008×10^5	0.275	-1.948×10^5
1100	3.413 "	0.225	1.048 "	0.300	0.319 "
1200	3.492 "	0.250	1.304 "	0.400	1.335 "
1300	3.463 "	0.300	1.304 "	0.410	1.491 "
1500	3.295 "	0.350	1.306 "	0.425	1.285 "
1600	3.203 "	0.390	1.389 "	0.500	0.803 "
1800	3.203 "	0.400	1.389	0.750	1.021 "
2000	3.013	0.500	1.069	0.900	1.070

Figure 1. Cumulative frequency distribution of probability of each historic recruitment, given the spawning stock biomass in years 1981 - 1985. Units for number of recruits are as in Baird and Bishop (1986).

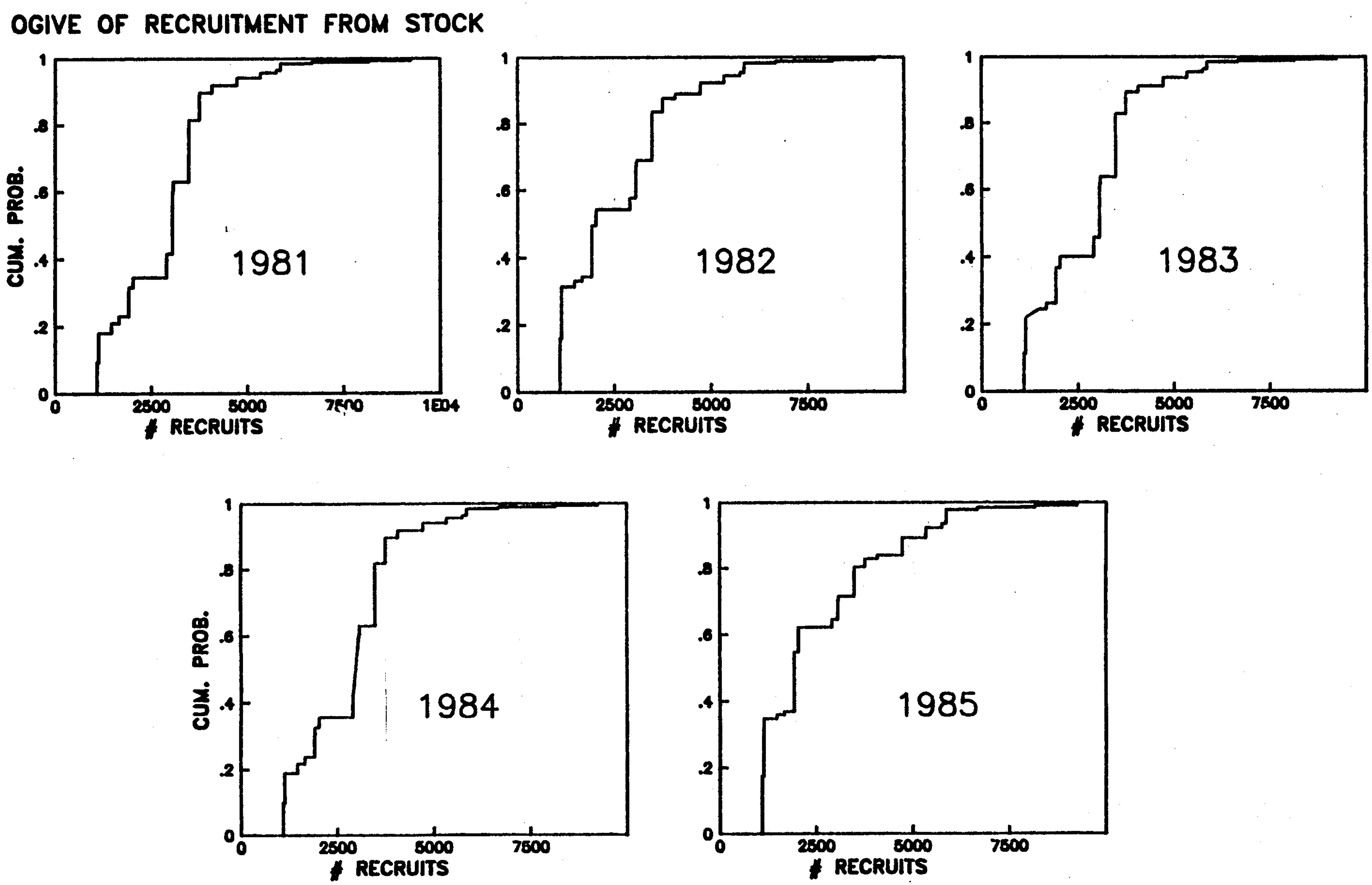
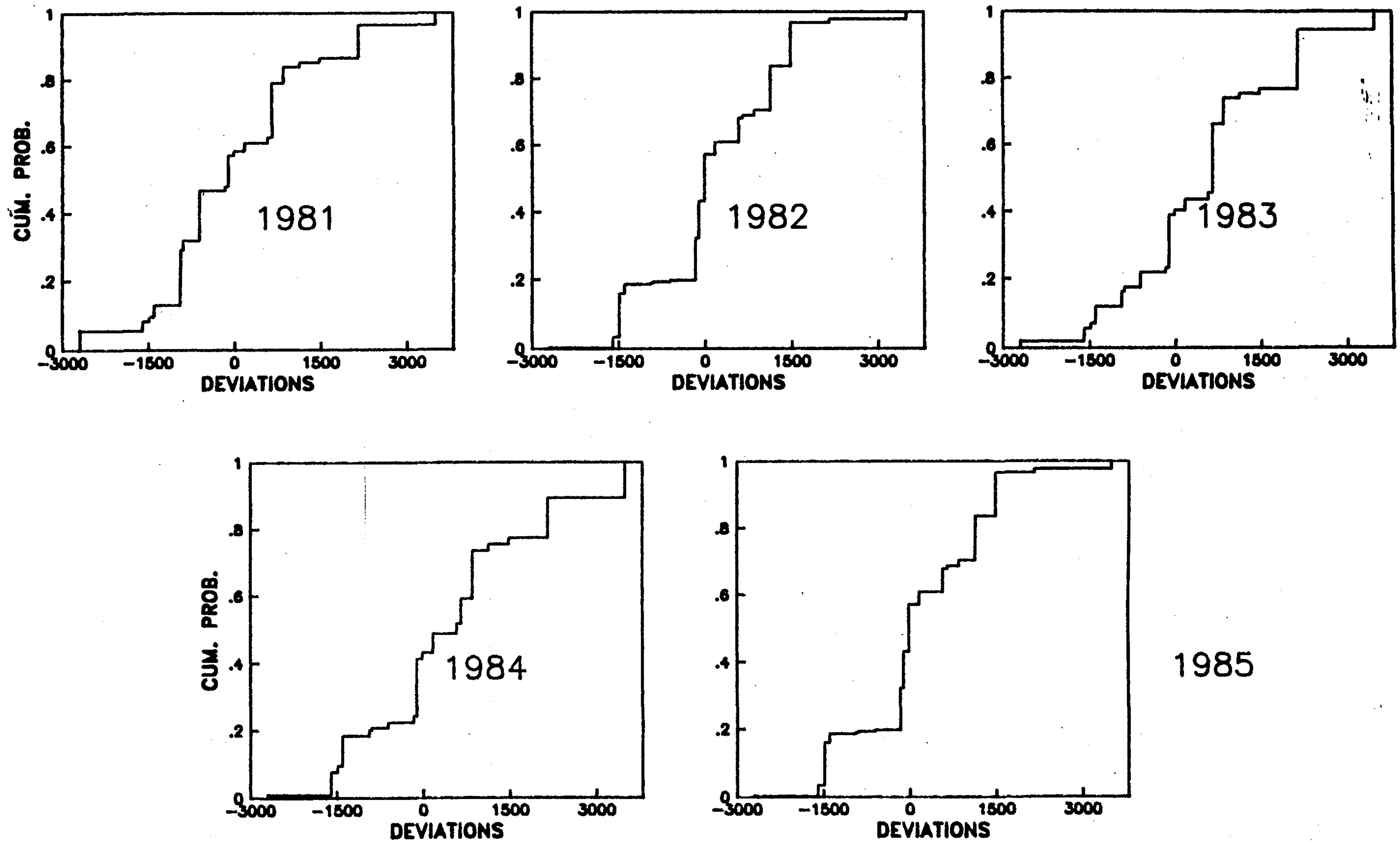


Figure 2. Cumulative frequency distribution of probability of each historic recruitment, given the score on PC I (a) or PC II (b), for years 1981-1985. Units of deviations are as in Baird and Bishop, 1986.

(a) **OGIVE OF DEVIATIONS FROM PC I**



(b) OGIVE OF DEVIATIONS FROM PC II

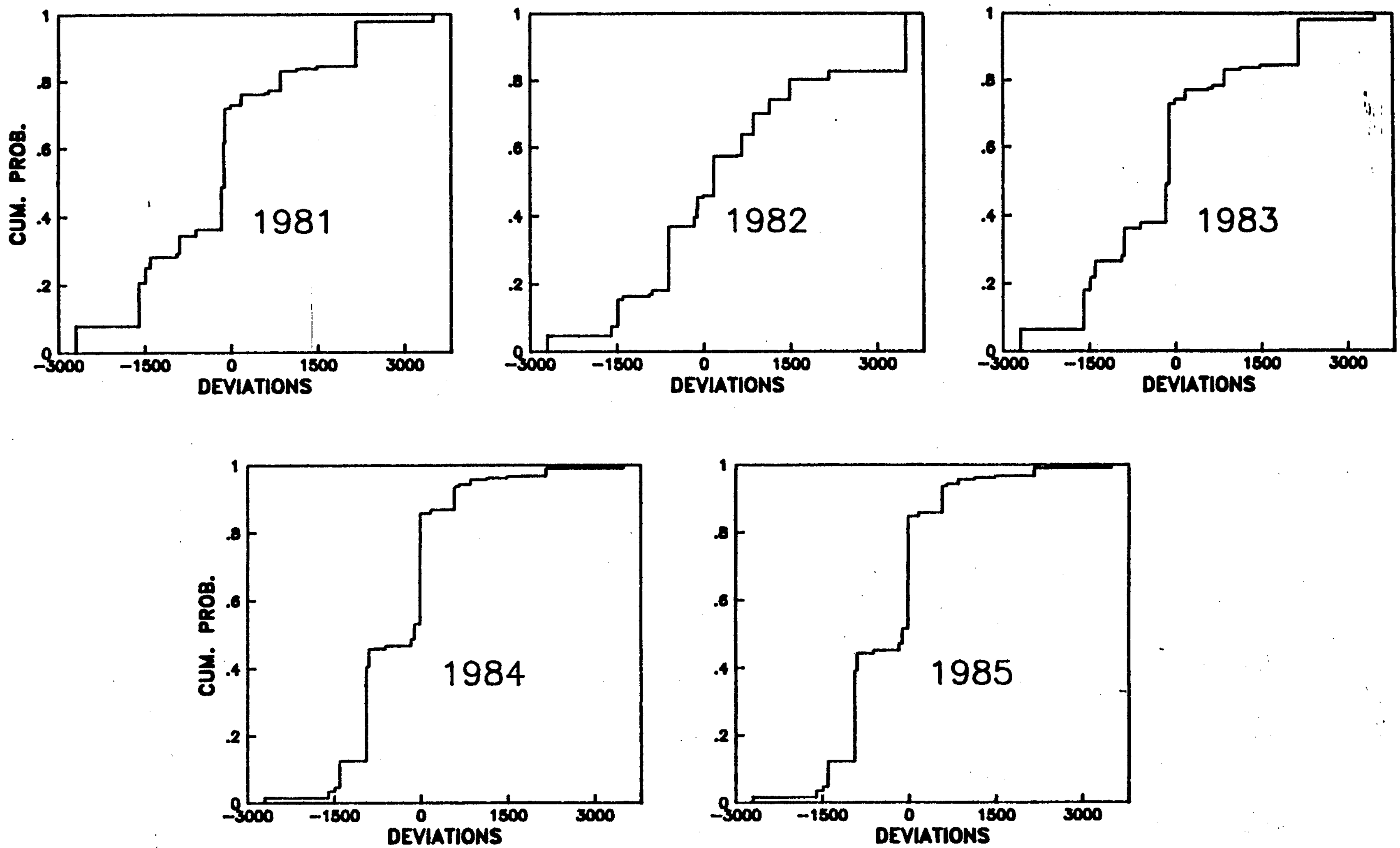


Figure 3. Plot of recruitment as a function of spawning stock biomass for the period 1962 - 1980, and scatterplots of deviations of observed from predicted recruitments as functions of scores on PC I and PC II axes.