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SPECIAL SESSION ON ENVIRONMENTAL CONDITIONS

The Role of Environmental Temperature and Seasonal Migration on Estimates of Cod Abundance in the NAFO Div. 2J+3KL Research Surveys

by

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Abstract

The bottom temperature and timing of the research surveys in NAFO region 2J3KL are shown to have a large effect of the estimated abundance of cod. The uncorrected estimates of cod abundance using a stratified random analysis give misleading results if these factors are not considered. I have tried to test a series of hypotheses with these data to develop consistent series that can be used for assessing the stock status.

In the future, every effort should be made to carry out the research surveys on the same dates each year.

1 Introduction

I have analyzed the 2J3KL surveys using the methods that have been described in an ICES document (Myers and Pepin 1986; ICES 1986/D:9). The basic idea of this model is to transform the abundance such that it is approximately multiplicative. The transformation used was $log_e(number + \frac{1}{2})$. This transformation is justified if the variation in numbers caught per set follows a negative binomial distribution in which the parameter k is approximately equal to 1. An analysis of intensively fished strata on the Grand Banks showed the observed distribution of catch per strata was approximately negative binomial with a k parameter close to 1 (Myers and Pepin 1986). Simulation models showed that good results could be obtained if the multiplicative assumption was reasonable and there were not too many zero catches in the data set, i.e. less than 10%. In 2J3KL there are few trawls in the appropriate depth zones in which no cod are caught.

The models presented below initially consider a stratum effect, and a year effect in an approximately multiplicative interaction. This model should be regarded as a simple first approximation to the variation observed in the data. I have run the analyses several ways to test the robustness of my conclusions. In particular, I have used unweighted and weighted (by the area of the strata) least squares to estimate parameters. The results were similar in both cases because the number of tows per stratum was approximately proportional to the stratum area in depths less than 500m. In the results below I have weighted the results by stratum area.

In general the model residuals were reasonably homoscedastic (see Figures below). The frequency distribution of the residuals was approximately normal (Fig. 1), with some skewness to the left because of the presence of zero catches in regions of high mean abundance. These relatively large negative residuals can also be seen in residuals plots below, but they should have a small effect on my conclusions (Myers and Pepin 1986).

2 Stratified Random Analysis

The research surveys are carried out using a stratified random survey design. The estimates of abundance for each stratum are combined to obtain an overall estimate, with associated confidence limits (Fig. 2; the label STRAP stands for stratified random analysis). Details of the the analysis can be found in the latest CAFSAC assessment, they have been updated to include more recent information. The stratified random analysis has been included so that the results can be compared with my analysis. In both the STRAP analysis and my analysis, the estimate is for all fish caught (although I present the results in terms of estimated mean catch per tow).

Approximate 95% confidence intervals are given in both cases. The confidence limits for both sets of analysis are probably overestimated because the entire population is not surveyed each year. Furthermore, the confidence limits from my model are inflated because the multiplicative assumption does not hold exactly.

3 Preliminary Information

- Only a part of the 2J3KL region is surveyed each year (see figures in CAFSAC 87/42). In particular, the inshore regions are not surveyed. This problem is most severe in 3K.
- The timing of the surveys is not constant in each year (see Fig 3). For example, the mean date of the 2J surveys varies by a month.
- There are seasonal migrations between regions and into unsurveyed regions. In particular, there is an inshore and southward summer migration, and a return migration in the fall. The

return migration appears to be in the late fall in 2J, and early to the south (Henry Lear, pers. com.). The situation is more complex in the 3K region in which fish that winter in 3K appear to move inshore and into 3L in the summer. However, a migration into 3L occurs into 3K during this period.

- There is strong interannual variability in bottom temperature (see CAFSAC 87/42). In particular, 1985 was very cold (Fig. 3).
- Bottom temperature usually decreases with depth if depth is greater than 100m (Petrie et al. 1988).
- Bottom temperature within the depth range 100m to 400m usually increases from August to December (Petrie et al.1988). This increase is relative small, on the order of 0.5 to 1.0 degrees.
- The interannual variability in salinity at depths below 150 meters is greater than the seasonal variability (Myers et al. 1988).

4 Effects of survey timing and bottom temperature

I investigated the effects of survey timing and bottom temperature using simple linear models. The results for NAFO region 2J are reported in Table 1 and Fig. 4, 3K in Table 2 and Fig. 5, and 3L spring surveys in Table 3 and Fig. 6. For each model I have also plotted the estimated mean number per tow (Fig. 3, 4, and 5). The residuals versus depth or temperature (which is labeled "temp" in the plots) have been plotted for several of the analyses in Fig. 6.

The hypothesis that survey timing and temperature were important to the survey results was initially tested by examining residual plots of the results of a year and strata effect model. The hypothesis was further tested by including the Julian date and bottom temperature for each individual tow in the above model using an analysis of variance formulation. The Julian date and temperature are very significant, and improves somewhat the residuals.

5 Mitigation of the effects of survey timing and bottom temperature

It would be best to use some other index of abundance, but this is not an option. Therefore I investigate several methods of mitigating the effects of the variable timing of the surveys. It must be recognized that this is in some ways a hopeless task: we simply cannot project into the regions where we have not surveyed. Nevertheless, the following are approaches that were investigated.

5.1 Compare only years in which the timing and temperature were similar

For example, in NAFO region 2J, we can compare the results for 1982-1984, and 1987 because the mean dates of the surveys were similar. The results for both the STRAP analysis and the multiplicative model are similar: the 1987 abundance is slightly lower than the mean of the 1982-1984 surveys. This approach is a good one because it requires no model assumptions.

5.2 Eliminate early strata and repeat the multiplicative results

I have included two analyses 2J: one in which I have included only tows from Nov. and Dec. , and one in which I have included tows only from Nov. 10 to Dec. 31. (Note that 1985 is missing from this figure because all the surveys took place before Nov. 10 in that year.) Similar analyses were done for 3L (spring).

The residuals for the analysis leaving out October observations still show strong patterns with respect to depth. The residuals using only those observations after Nov. 10 appear to be between, and thus are probably more reliable. One obvious disadvantage of this approach is that data is eliminated, and that many strata are left empty.

5.3 Include the timing of the surveys and temperature in the analysis

The results for the inclusion of the Julian date and bottom temperature of each tow has already been described. This correction may be regarded only as a first order correction of the changing of the survey timing. In 2J, the residuals still show patterns with respect to depth, i.e. in 1985 when the survey was early there were relatively more fish in shallow water. Nevertheless, this approach does provide a first order correction.

The correction for Julian day, i.e timing of the survey, is probably reasonable because we know that the fish are inshore migrating out in 2J during the survey period. Thus, a linear correction may be a first step to appoximating the process. Similarly, in the 3L spring surveys, the later the survey date, the more fish from 3K will have migrated into the region.

The correction for temperature may not be justified. If the fish are responding to temperature by remaining in the same location but moving up in the water column, then a linear correction may be reasonable. Similarly, if they are remaining inshore longer above the cold intermediate layer, the correction may also be justified. However, if they are changing position within the region surveyed, then it would not be justified to use the correction for temperature in the estimates of abundance.

5.4 An analytic model of migration

I have begun modeling the migration using nonlinear models and projecting how many fish are in the unsurveyed regions. While, these may be useful in the future models are probably more unreliable than the above and will not be reported.

6 ESTIMATES OF ABUNDANCE

6.1 NAFO region 2J

The residuals of a year and strata effect model clearly show that during years in which the survey was done early, i.e. 1985, cod tend to be more inshore. Unfortunately, during years in which the bottom temperature was cold, the surveys were done early. Note, that during years in which the surveys were conducted early, in 1982-1985, 1987, the surveys are negatively biased. This shows up very clearly in the residual plots. During years in which the surveys are early the peak abundance is at shallow depths, but during years in which the surveys are later the peak abundance is deep. Note the shift in the depth of peak abundance. It appears that the depth distribution is deeper during warm years.

The interpretation of the residual plot with depth is made a bit more complicated because some of the shallow strata are in fact on Hamilton Bank which is not inshore. However, the abundance in the inshore zones is higher than usual for 1984 as well.

I next considered a model in which temperature and Julian date of the survey were entered as covariates. This reduced the trends in the residuals with depth. Both factors entered very significantly (Table 1). Using the exponential or the logarithm of temperature or Julian date did not significantly improve the fit.

We should not expect a simple linear model to be an adequate representation of the migration pattern; therefore, we must treat the new results as a slightly better approximation at most.

6.2 NAFO region 3K

The results for the 3K fall survey were similar to the results obtained for 2J (Table 2). However, it is questionable whether the resulting estimates of abundance should be used in an assessment.

The principal difficulties with the 3K data are:

- Much of the inshore region is not surveyed.
- There are substantial migrations into 3L from 3K, and into 3K from 2J.
- The confounding of the timing of the survey and bottom temperature as previously mentioned.
- The surveys in 3K were sometimes done before and after the 2J surveys, resulting in a large spread of the time required to carry out the surveys.

I could not obtain an internally consistent analysis for this region. I therefore recommend that it not be used in the assessment.

6.3 NAFO region 3L

The Fall surveys in this region seem to be more affected by migration and timing of the surveys than the spring surveys (this is based upon Henry Lear's tagging studies). Therefore, I have only analyzed the spring surveys.

There have been changes in the timing of the 3L spring surveys (Table 3). The bottom temperature has also varied greatly. Note that the effects of temperature appears to have an effect mainly below zero degrees.

To determine if timing of the surveys had on the I analyzed the data using only tows before July (Table 3a), using data before June (Table 3c), and using data before May 20 (Table 3d). The results are probably most reliable for the data before May 20 because this is before the migration from 3K probably occurs. The results for my analysis for the data collected before May 20 show an increasing abundance in 3L before 1983; that is reasonably consistent with the STRAP analysis. The very large estimate for abundance in 1981 is caused by one strata and should be interpreted with caution. The analysis of the 3L surveys using Julian date as a covariate should be considered as a reasonable estimates of abundance as well (Table 3e).

There was a change in the vessel and gear during this series. It is believed that the fishing efficiency is the same for the two vessels but I do not know how reliable this belief is. In any case there is no indication of a large change in abundance since the 1985 estimate.

If the fishing efficiency is the same for the two vessels, then there appears to be a general increase since 1982, consistent with the trend seen in 2J.

7 GENERAL CONCLUSION FROM THIS ANALYSIS OF RESEARCH SURVEYS

2J. There is convincing evidence that the abundance from 1982 to 1987 is greater than in previous years. There is no reason to believe that there are any large changes in the last three years.

3K. The data from 3K cannot be reliably interpreted at this time.

3L. There is no evidence for a decrease in the population during the last 5 years. If the data from the Cameron are comparable to the Templeman, then there is a similar increase in 3L as is observed in 2J. However, it is unlikely that the change in catchability is greater than a factor of 2; thus, there is good evidence that there has not been a decrease in 3L, and probably an increase.

GENERAL The timing and bottom temperature both have large influences on the estimates of abundance.

GENERAL Every effort should be made to carry out the research surveys on the same dates each year.

8 Acknowledgments

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9 References

Myers, R. A., S. A. Akenhead and K. F. Drinkwater. 1988. The North Atlantic Oscillation and the ocean climate of the Newfoundland Shelf. NAFO SCR. Doc. 88/65 Ser. No. N1508. 22 p.

Myers, R. A., and P.Pepin. 1986. The estimation of population size from research surveys using regression models. ICES 1986/D:9

Petrie, B., S. Akenhead, J. Lazier and J. Loder. 1988. The Cold Intermediate Layer on the Labrador and Northeast Newfoundland Shelves, 1978-86. NAFO Sci. Coun. Studies, 12: 57-69.

able 1a. Results for NAFO region for the simple year, strata effects model.

COD, 2J, DEPTH <500, Oct Nov Dec, Yr*Strata model
GENERAL LINEAR MODELS PROCEDURE

EPENDENT VARIABLE: LOGABUN
EIGHT: AREAS

OURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
ODEL	32	1165981.79440456	36436.93107514	14.87	0.0	0.325272	1452.2925
RROR	987	2418656.56056817	2450.51323259		ROOT MSE		LOGABUN MEAN
ORRECTED TOTAL	1019	3584638.35497273			49.50265884		3.40858736

OURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
EAR	10	158650.70424348	6.47	0.0001	10	178371.75387960	7.28	0.0001
STRATA	22	1007331.09016108	18.68	0.0	22	1007331.09016108	18.68	0.0

LEAST SQUARES MEANS

YEAR	LOGABUN LSMEAN	STD ERR LSMEAN	PROB > |T| H0:LSMEAN=0
77	2.49343145	0.16194136	0.0
78	2.20783261	0.20058667	0.0001
79	2.00935865	0.19683340	0.0001
80	2.03459332	0.19708327	0.0001
81	2.01481466	0.16168434	0.0001
82	2.62218933	0.13739884	0.0
83	2.65042599	0.14889933	0.0
84	3.03567087	0.16486964	0.0
85	2.80068576	0.14769707	0.0
86	3.18494514	0.16001923	0.0
87	2.50299660	0.14847463	0.0

Table 1b, Results for NAFO 2J, for year, strata model in which temperature and Julian date have been entered as covariates.

COD, 2J, DEPTH <500, Oct Nov Dec, Yr*Strata, Julian, temp model

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGABUN
WEIGHT: AREAS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	34	1236152.46607747	36357.42547287	15.39	0.0	0.350676	1421.4092
ERROR	969	2288900.43380920	2362.12635068		ROOT MSE		LOGABUN MEAN
CORRECTED TOTAL	1003	3525052.89988667			48.60171140		3.41926246

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
YEAR	10	157821.41708973	6.68	0.0001	10	216135.82297416	9.15	0.0001
STRATA	22	976257.68811715	18.79	0.0	22	976298.18171535	18.79	0.0
JULIAN	1	51486.80468955	21.80	0.0001	1	61090.57629554	25.86	0.0001
TEMP	1	50586.55618105	21.42	0.0001	1	50586.55618105	21.42	0.0001

GENERAL LINEAR MODELS PROCEDURE

LEAST SQUARES MEANS

YEAR	LOGABUN LSMEAN	STD ERR LSMEAN	PROB > |T| H0:LSMEAN=0
77	1.36786265	0.23467349	0.0001
78	1.37727459	0.23837714	0.0001
79	0.80612647	0.26975451	0.0029
80	0.74197319	0.29603292	0.0124
81	1.17913042	0.20867332	0.0001
82	2.92843677	0.15201279	0.0
83	3.07048051	0.16661204	0.0
84	3.56593881	0.18374316	0.0
85	3.75799980	0.22506074	0.0
86	2.88205774	0.17749155	0.0
87	2.95745262	0.16545366	0.0

Table 1c. Results for NAFO 2J, for year, strata model in which the tows before November 1 have been eliminated.

COD, 2J, DEPTH <500, Nov Dec, YR, STRATA

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: N01ABUN
WEIGHT: AREAS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	32	965362.24637593	30167.57019925	12.30	0.0	0.313498	1420.5309
ERROR	862	2113967.05118040	2452.39797121		ROOT MSE		N01ABUN MEAN
CORRECTED TOTAL	894	3079329.29755633			49.52169193		3.48613969

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
YEAR	10	215634.11805967	8.79	0.0001	10	234040.53011743	9.54	0.0001
STRATA	22	749728.12831626	13.90	0.0	22	749728.12831626	13.90	0.0

LEAST SQUARES MEANS

YEAR	N01ABUN LSMEAN	STD ERR LSMEAN	PROB > |T| H0:LSMEAN=0
77	2.51340570	0.16491455	0.0
78	2.31924764	0.20383003	0.0001
79	2.06833827	0.20005270	0.0001
80	2.10665063	0.20019027	0.0001
81	2.07799335	0.16512626	0.0001
82	2.70718426	0.14320006	0.0
83	2.78075499	0.16117212	0.0
84	3.33657309	0.18293585	0.0
85	3.35137596	0.19270649	0.0
86	3.24537065	0.16331528	0.0
87	2.76784685	0.16098451	0.0

Table 1d. Results for NAFO 2J, for year, strata model in which the tows before November 11 have been eliminated.

COD, 2J, DEPTH <500, DAY>Nov10, Yr, Strata Model

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: N11ABUN
WEIGHT: AREAS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	31	591504.86231675	19080.80201022	7.32	0.0001	0.308476	1546.8549
ERROR	509	1326003.40012578	2605.11473502		ROOT MSE		N11ABUN MEAN
CORRECTED TOTAL	540	1917508.26244254			51.04032460		3.29961948

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
YEAR	9	134639.19090182	5.74	0.0001	9	194045.94483017	8.28	0.0001
STRATA	22	456865.67141493	7.97	0.0001	22	456865.67141493	7.97	0.0001

LEAST SQUARES MEANS

YEAR	N11ABUN LSMEAN	STD ERR LSMEAN	PROB > |T| H0:LSMEAN=0
77	2.65596140	0.19493606	0.0001
78	2.54610509	0.23846076	0.0001
79	2.26275146	0.23225632	0.0001
80	2.31570822	0.23219750	0.0001
81	2.30407982	0.19728637	0.0001
82	3.08999653	0.25506315	0.0001
83	3.69482136	0.27424425	0.0001
84	4.10809818	0.31466468	0.0001
86	3.41953663	0.23657886	0.0
87	3.02564311	0.25776027	0.0001

Table 1e. Results for NAFO region 2J for a Year and strata effect model with Julian date as a covariate.

COD, 2J, DEPTH <500, Oct Nov Dec, Yr*Strata Julian model

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGABUN
WEIGHT: AREAS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	33	1217387.64337727	36890.53464780	15.37	0.0	0.339612	1437.5046
ERROR	986	2367250.71159545	2400.86279066		ROOT MSE		LOGABUN MEAN
CORRECTED TOTAL	1019	3584638.35497273			48.99859988		3.40858736

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
YEAR	10	158650.70424348	6.61	0.0001	10	189787.96196609	7.90	0.0001
STRATA	22	1007331.09016108	19.07	0.0	22	952890.32233220	18.04	0.0
JULIAN	1	51405.84897271	21.41	0.0001	1	51405.84897271	21.41	0.0001

LEAST SQUARES MEANS

YEAR	LOGABUN LSMEAN	STD ERR LSMEAN	PROB > |T| H0:LSMEAN=0
77	1.98332850	0.19454122	0.0001
78	1.66830882	0.23024921	0.0001
79	1.26886813	0.25212590	0.0001
80	1.03496659	0.29107396	0.0004
81	1.49845374	0.19510203	0.0001
82	2.93270395	0.15165460	0.0
83	3.00635734	0.16624862	0.0
84	3.35339009	0.17704752	0.0
85	3.57085288	0.22152947	0.0
86	3.22775839	0.15865985	0.0
87	2.82206661	0.16233546	0.0

Table 2a. Results for the analysis of NAFO region 3K, year, strata model.

COD, 3K, DEPTH <500, Oct Nov Dec, Yr*Strata model
GENERAL LINEAR MODELS PROCEDURE

EPENDENT VARIABLE: LOGABUN
EIGHT: AREAS

OURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
ODEL	33	1331179.80149381	40338.78186345	15.22	0.0	0.327511	1877.4388
RROR	1031	2733349.81021232	2651.16373444		ROOT MSE		LOGABUN MEAN
ORRECTED TOTAL	1064	4064529.61170613			51.48945265		2.74253698

OURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
EAR	10	242856.25692659	9.16	0.0001	10	172685.11963891	6.51	0.0001
TRATA	23	1088323.54456722	17.85	0.0	23	1088323.54456722	17.85	0.0

LEAST SQUARES MEANS

YEAR	LOGABUN LSMEAN	STD ERR LSMEAN	PROB > |T| H0:LSMEAN=0
77	3.17328822	0.44801352	0.0001
78	2.53165159	0.17438155	0.0
79	2.77311636	0.17216409	0.0
80	2.41397199	0.16376005	0.0
81	2.32375478	0.14496141	0.0
82	2.29169385	0.13704457	0.0
83	2.58167210	0.14110155	0.0
84	2.17758206	0.18504065	0.0001
85	1.79286720	0.12547024	0.0
86	2.77055709	0.14549681	0.0
87	2.06595452	0.13013236	0.0

Table 2b. Results for the analysis of NAFO region 3K, year, strata effect model with Julian date and temperature covariates included.

COD, 3K, DEPTH <500, Oct Nov Dec, Yr*Strata, Julian, temp model

GENERAL LINEAR MODELS PROCEDURE

EPENDENT VARIABLE: LOGABUN
EIGHT: AREAS

OURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
ODEL	35	1474448.46733544	42127.09906673	17.05	0.0	0.370291	1816.2634
RROR	1015	2507411.77792157	2470.35643145		ROOT MSE		LOGABUN MEAN
ORRECTED TOTAL	1050	3981860.24525700			49.70268032		2.73653487

OURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
EAR	10	254024.97120722	10.28	0.0001	10	71489.29753956	2.89	0.0014
TRATA	23	1046467.65992034	18.42	0.0	23	1073659.41480727	18.90	0.0
ULIAN	1	29404.21875904	11.90	0.0006	1	42289.45220694	17.12	0.0001
EMP	1	144551.61744884	58.51	0.0001	1	144551.61744884	58.51	0.0001

LEAST SQUARES MEANS

YEAR	LOGABUN LSMEAN	STD ERR LSMEAN	PROB > |T| H0:LSMEAN=0
77	2.47966646	0.44128131	0.0001
78	2.42388726	0.19744261	0.0001
79	2.52159238	0.17021844	0.0
80	2.07032071	0.16508337	0.0001
81	1.78164704	0.16094917	0.0001
82	2.19846308	0.13393525	0.0
83	2.52713283	0.13711132	0.0
84	2.47543413	0.19075152	0.0001
85	2.16064197	0.13432057	0.0
86	2.28263160	0.15557756	0.0
87	2.05604130	0.12744399	0.0

Table 3a. Results for NAFO region 3L (spring survey) for the year, strata effect model.

COD, 3L(spring), Depth <500, Yr*Strata model

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGABUN
WEIGHT: AREAS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	41	2103838.00069947	51313.12196828	19.86	0.0	0.375666	1952.2635
ERROR	1353	3496447.50686574	2584.21840862		ROOT MSE		LOGABUN MEAN
CORRECTED TOTAL	1394	5600285.50756521			50.83520836		2.60391126

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
YEAR	9	325283.88315941	13.99	0.0001	9	384344.90416448	16.53	0.0001
STRATA	32	1778554.11754007	21.51	0.0	32	1778554.11754007	21.51	0.0

LEAST SQUARES MEANS

YEAR	LOGABUN LSMEAN	STD ERR LSMEAN	PROB > |T| H0:LSMEAN=0
77	1.77798059	0.22261720	0.0001
78	1.74171939	0.22486345	0.0001
79	2.41165741	0.21267676	0.0001
80	2.38761789	0.21892764	0.0001
81	1.61609828	0.23415467	0.0001
82	1.92735573	0.22324599	0.0001
85	2.70089698	0.19830073	0.0
86	2.66231758	0.20177043	0.0001
87	2.80332652	0.20504103	0.0
88	2.89297831	0.20898726	0.0

Table 3b. Results for NAFO region 3L (spring survey) for the year, strata effect model.

COD, 3L (Spring), DEPTH <500, Yr*Strata, Julian, temp model
GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGABUN
WEIGHT: AREAS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	43	2322350.89355405	54008.16031521	22.53	0.0	0.420873	1884.6502
ERROR	1333	3195587.09099306	2397.28964065		ROOT MSE		LOGABUN MEAN
CORRECTED TOTAL	1376	5517937.98454711			48.96212455		2.59794224

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
YEAR	9	308689.47704124	14.31	0.0001	9	501560.71480610	23.25	0.0001
STRATA	32	1763649.91536424	22.99	0.0	32	1365521.08417958	17.80	0.0
JULIAN	1	30278.19241192	12.63	0.0004	1	14790.38345780	6.17	0.0131
TEMP	1	219733.30873664	91.66	0.0001	1	219733.30873664	91.66	0.0001

LEAST SQUARES MEANS

YEAR	LOGABUN LSMEAN	STD ERR LSMEAN	PROB > |T| H0:LSMEAN=0
77	1.48836282	0.21873886	0.0001
78	0.83409707	0.24035169	0.0005
79	1.52460095	0.22344400	0.0001
80	1.79515243	0.21898433	0.0001
81	1.34606072	0.26206962	0.0001
82	1.53803948	0.22094709	0.0001
85	2.75738411	0.19475919	0.0
86	2.59811741	0.19465283	0.0001
87	2.29800625	0.20450018	0.0001
88	2.62723093	0.20386923	0.0001

Table 3c. Results for NAFO region 3L spring survey using data only from before June 1.

COD, 3L (Spring), DEPTH <500, Yr*Strata model, before June

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: M31ABUN
WEIGHT: AREAS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	41	2114303.45381798	51568.37692239	20.06	0.0	0.387003	1950.5376
ERROR	1303	3348969.57077012	2570.19921011		ROOT MSE		M31ABUN MEAN
CORRECTED TOTAL	1344	5463273.02458811			50.69713217		2.59913636

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
YEAR	9	317785.74678265	13.74	0.0001	9	384456.81245803	16.62	0.0001
STRATA	32	1796517.70703533	21.84	0.0	32	1796517.70703533	21.84	0.0

LEAST SQUARES MEANS

YEAR	M31ABUN LSMEAN	STD ERR LSMEAN	PROB > |T| H0:LSMEAN=0
77	1.76841966	0.22214694	0.0001
78	1.73704918	0.22440970	0.0001
79	2.41034107	0.22024678	0.0001
80	2.27984078	0.22370204	0.0001
81	1.60953522	0.23362452	0.0001
82	1.92015046	0.22278199	0.0001
85	2.69832488	0.19793102	0.0
86	2.65731575	0.20139537	0.0001
87	2.78725744	0.20578021	0.0001
88	2.88738087	0.20857803	0.0

Table 3d. Results for NAFO region 3L spring survey using data only from before May 20.

COD, 3L (Spring), DEPTH <500, Yr*Strata model, before May 20

GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: M20ABUN
WEIGHT: AREAS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	41	1980179.08691045	48297.05090025	19.70	0.0	0.473539	2004.6579
ERROR	898	2201477.93728175	2451.53445132		ROOT MSE		M20ABUN MEAN
CORRECTED TOTAL	939	4181657.02419220			49.51297256		2.46989637

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
YEAR	9	242862.73218447	11.01	0.0001	9	407248.98312351	18.46	0.0001
STRATA	32	1737316.35472598	22.15	0.0	32	1737316.35472598	22.15	0.0

LEAST SQUARES MEANS

YEAR	M20ABUN LSMEAN	STD ERR LSMEAN	PROB > |T| H0:LSMEAN=0
77	1.86369186	0.21871649	0.0001
78	1.85315201	0.22125094	0.0001
79	1.64110579	0.31936319	0.0001
80	2.02248872	0.26589135	0.0001
81	1.62859113	0.22979146	0.0001
82	1.99389860	0.21933490	0.0001
85	2.76192607	0.20048968	0.0
86	2.69232278	0.20777258	0.0001
87	2.95892982	0.24675886	0.0001
88	3.23798364	0.21442054	0.0

Table 3e. Results for NAFO region 3L spring survey using all date before July, but including the Julian date of the survey.

COD, 3L (Spring), DEPTH <500, Yr*Strata, Julian model
GENERAL LINEAR MODELS PROCEDURE

DEPENDENT VARIABLE: LOGABUN
WEIGHT: AREAS

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	42	2126795.28047798	50637.98286852	19.71	0.0	0.379766	1946.5632
ERROR	1352	3473490.22708722	2569.14957625		ROOT MSE		LOGABUN MEAN
CORRECTED TOTAL	1394	5600285.50756521			50.68677911		2.60391126

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
YEAR	9	325283.88315941	14.07	0.0001	9	308840.10316202	13.36	0.0001
STRATA	32	1778554.11754007	21.63	0.0	32	1798524.38502433	21.88	0.0
JULIAN	1	22957.27977851	8.94	0.0028	1	22957.27977851	8.94	0.0028

YEAR	LOGABUN LSMEAN	STD ERR LSMEAN	PROB > |T| H0:LSMEAN=0
77	1.83975848	0.22292722	0.0001
78	1.79358088	0.22487713	0.0001
79	2.26732009	0.21748358	0.0001
80	2.29233979	0.22060313	0.0001
81	1.93873035	0.25721115	0.0001
82	1.97465523	0.22315583	0.0001
85	2.81454285	0.20134359	0.0
86	2.64450278	0.20126955	0.0001
87	2.70154303	0.20725841	0.0001
88	2.88411549	0.20839815	0.0

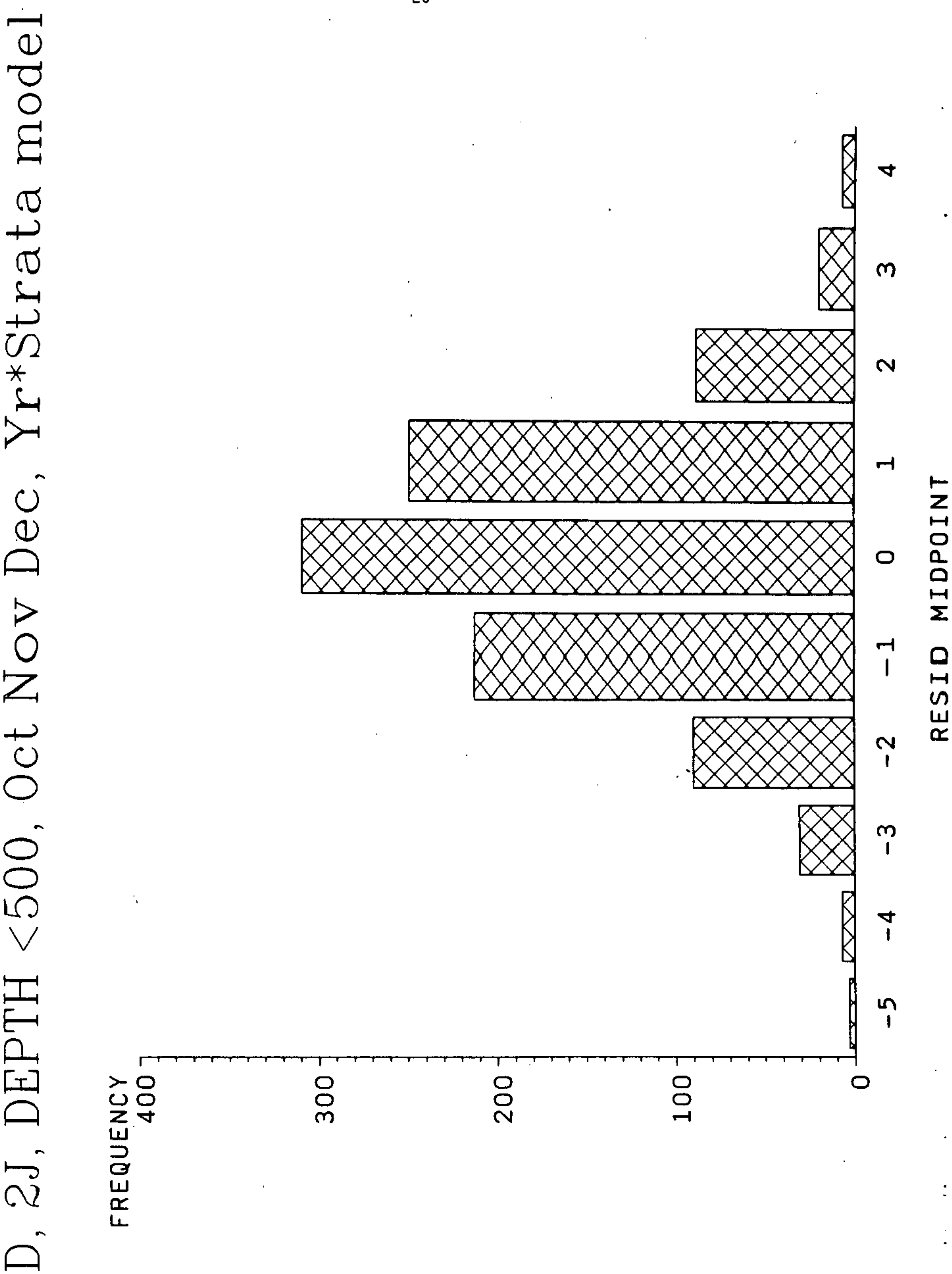


Fig. 1. Residuals for the strata and year effect model on 2J cod. All data were used from depths less than 500 meters.

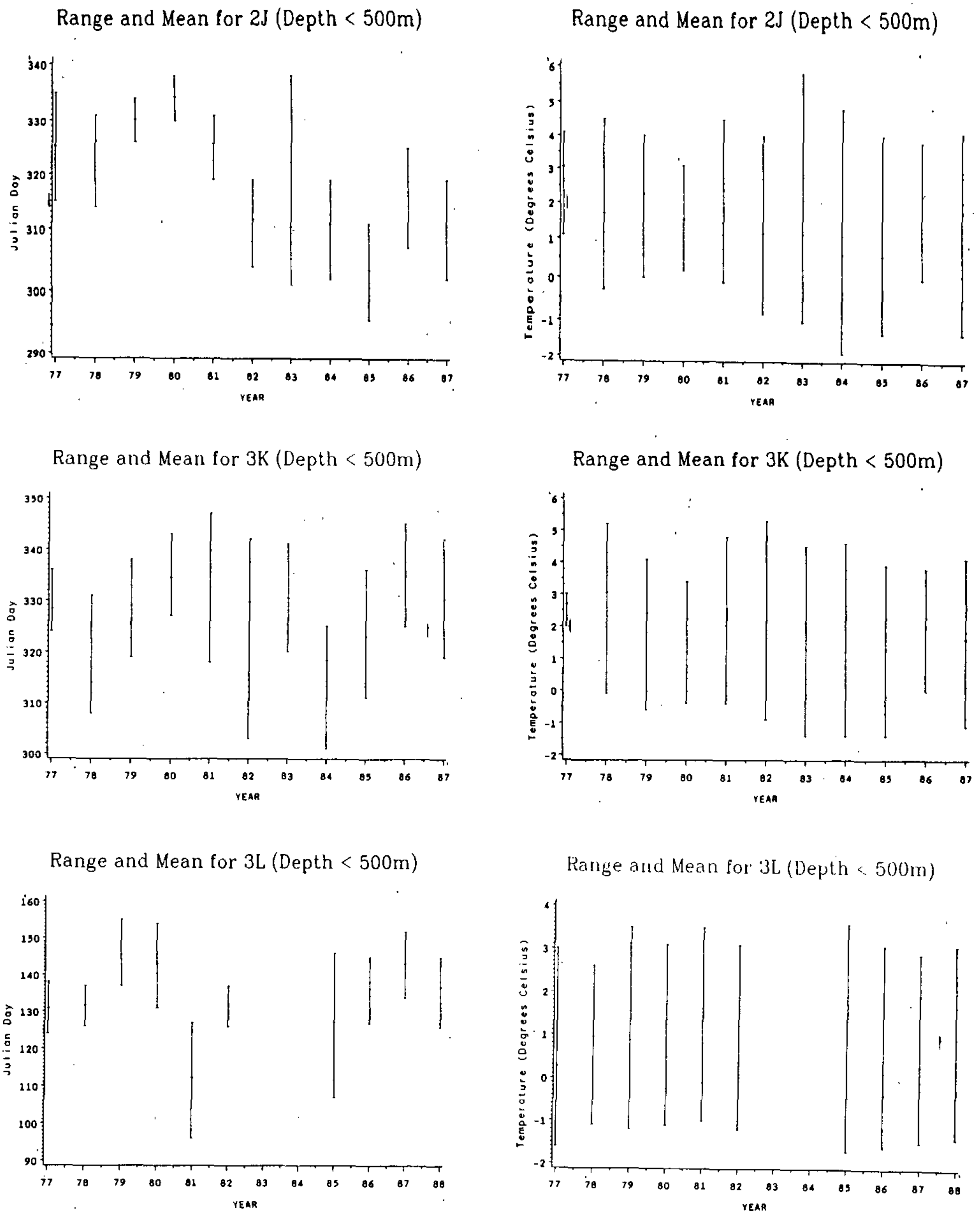


Fig. 2. Range and mean of the timing and bottom temperature for the reserch vessel surveys in 2J, 3K, and 3L(spring).

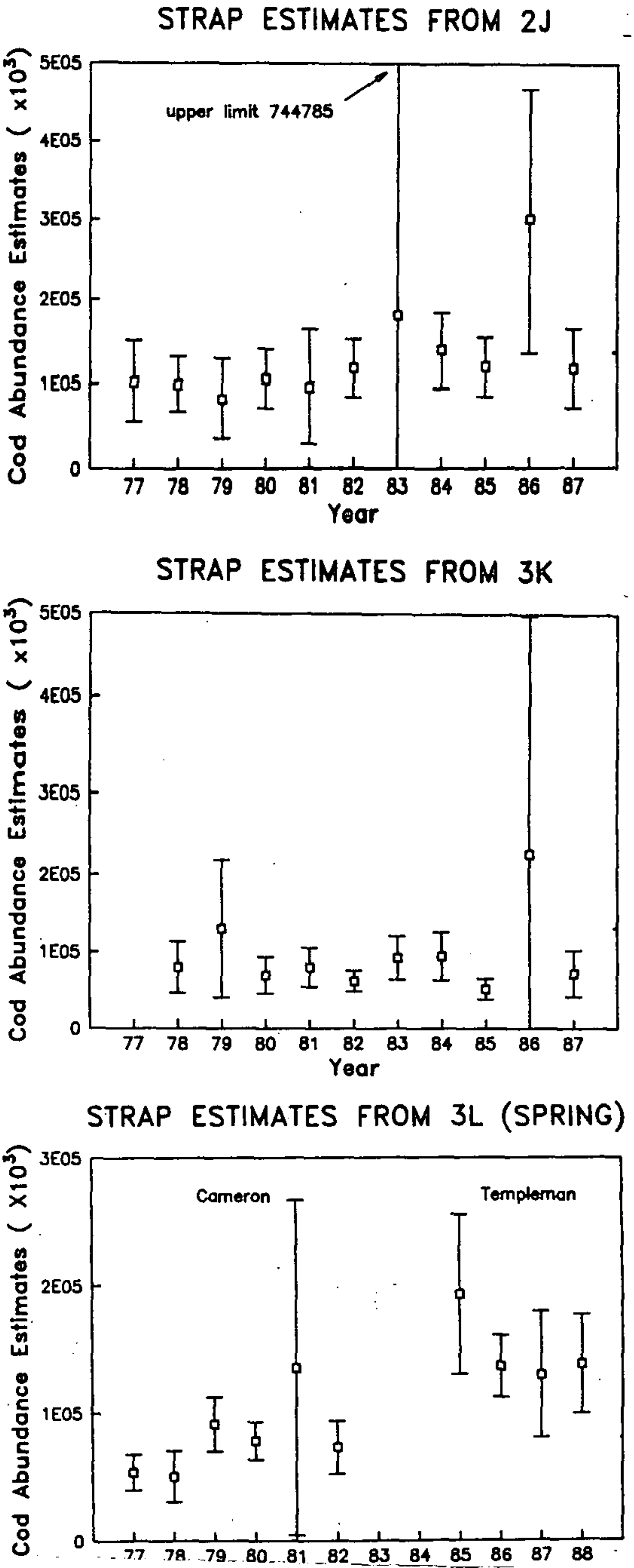


Fig. 3. Stratified random analysis of the 2J, 3K, and 3L (spring surveys) with estimated 95% confidence intervals.

Fig. 4a. Cod, 2J, Depth <500, Oct Nov Dec, Yr*Strata Model.

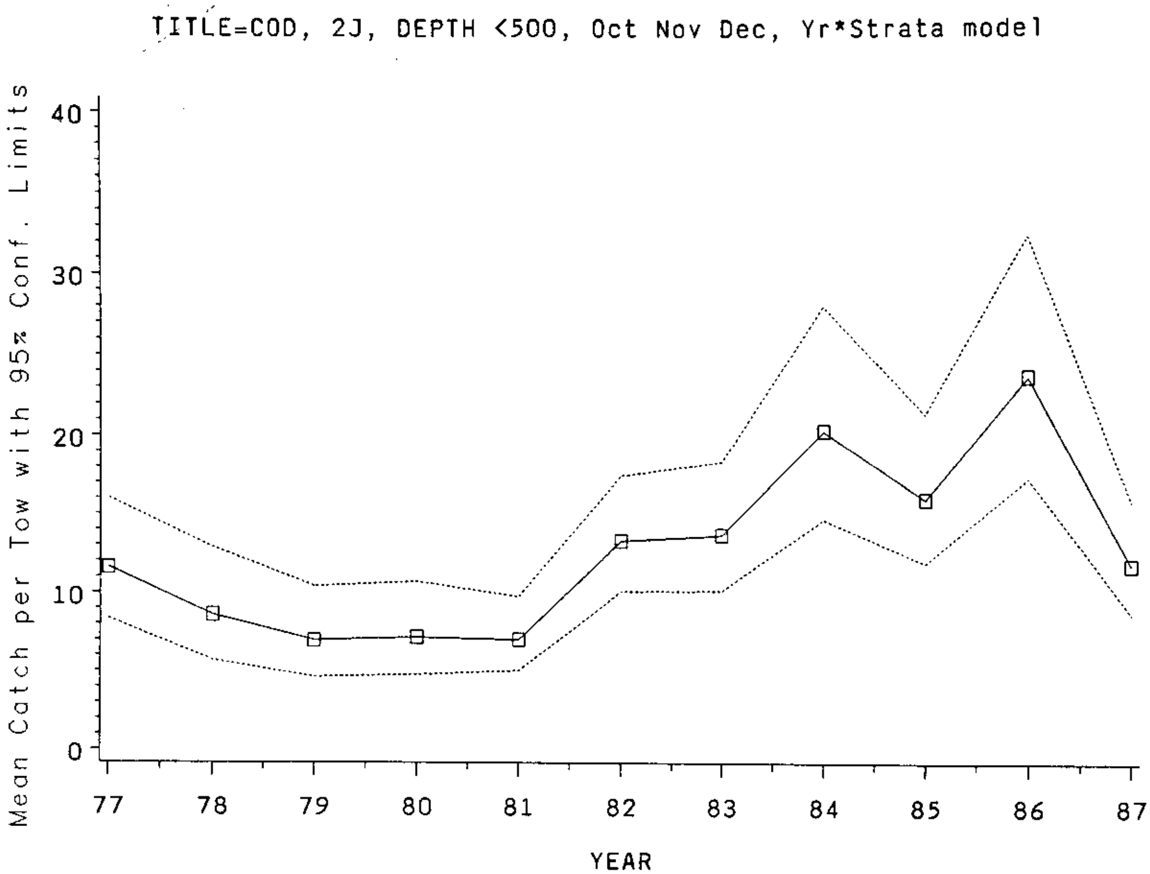


Fig. 4b. Cod, 2J, Depth <500, Oct Nov Dec, Yr*Strata, Julian, temp model.

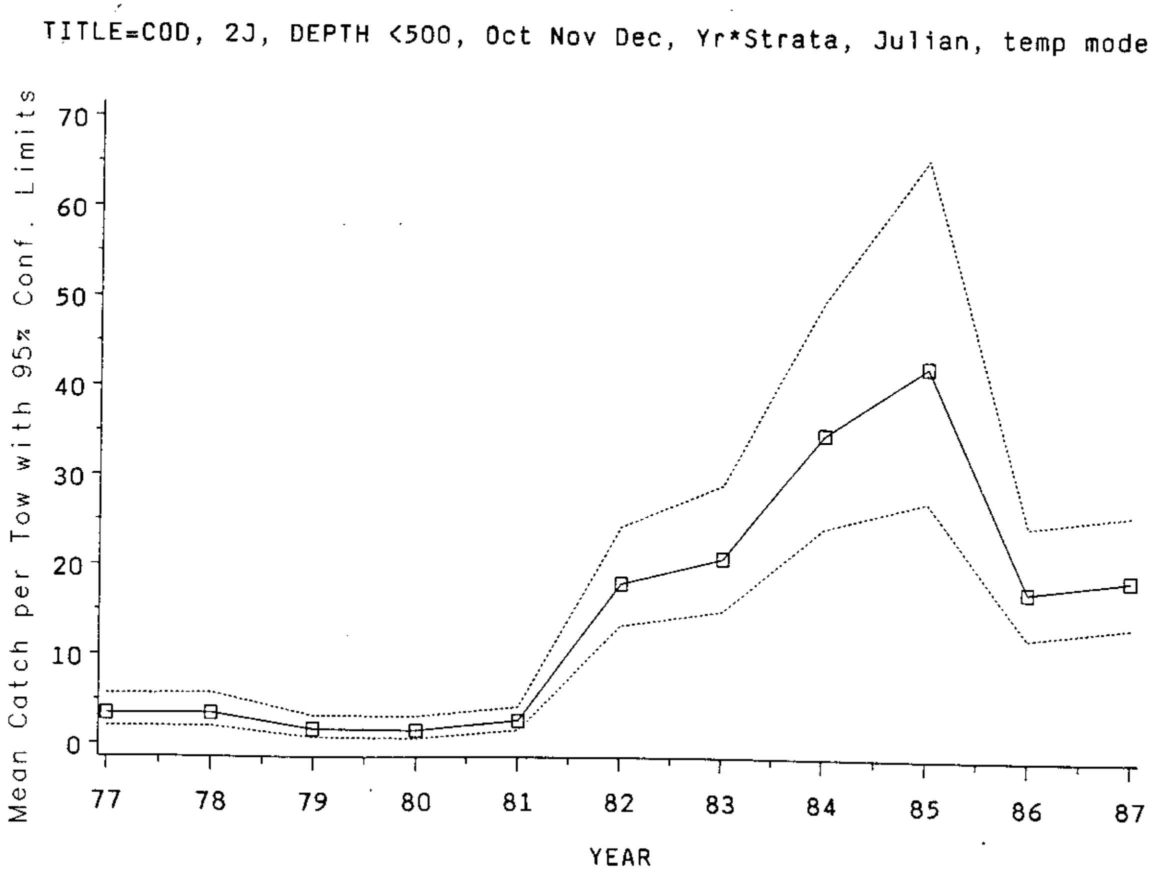


Fig. 4c. Cod, 2J, Depth <500, Nov Dec, Yr, Strata.

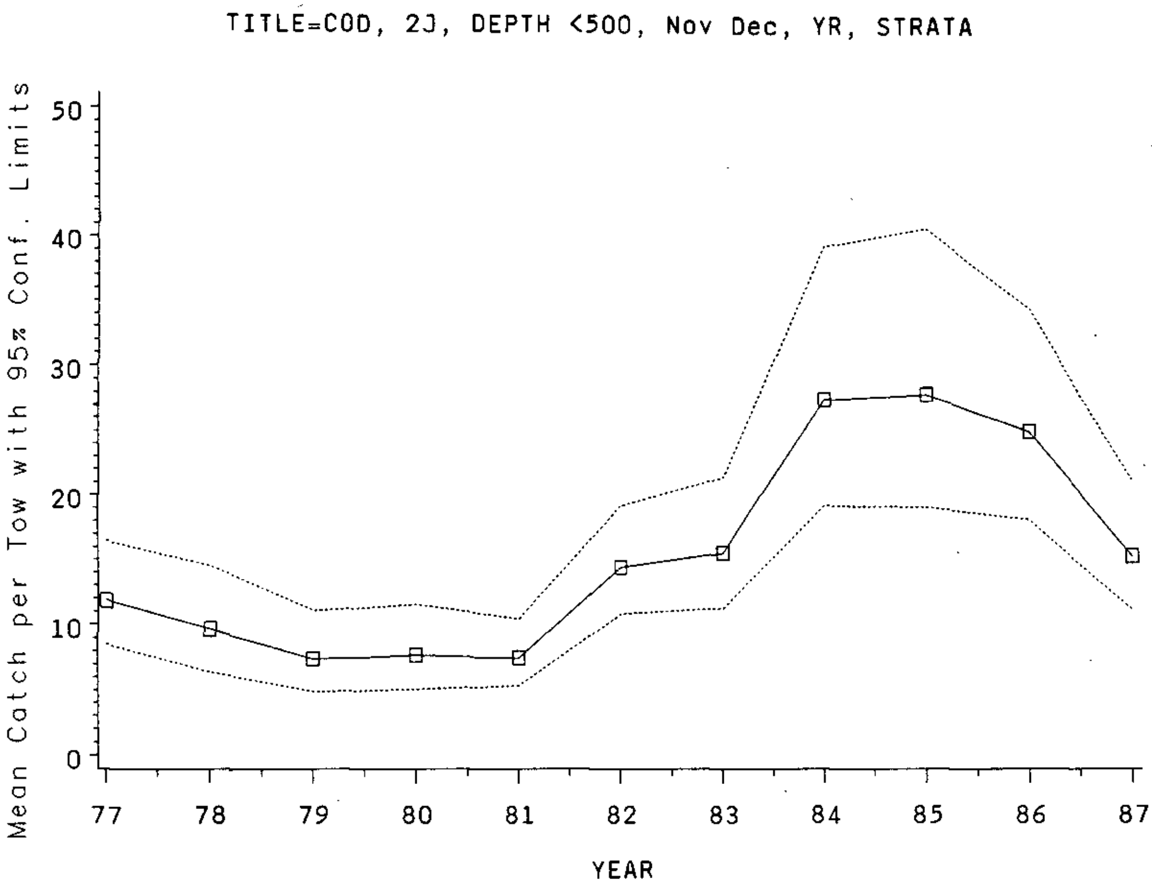


Fig. 4d. Cod, 2J, Depth <500, Day Nov10, Yr, Strata Model.

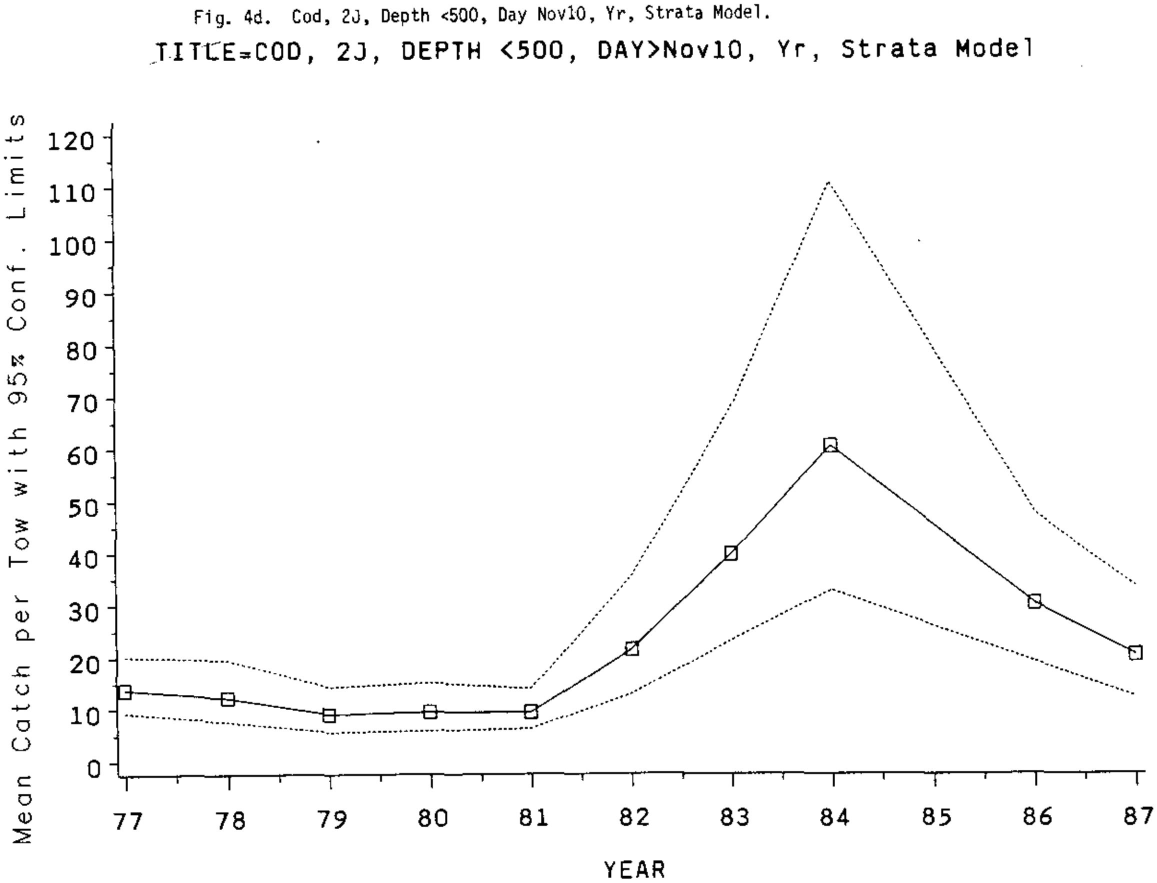


Fig. 4e. Cod, 2J, Depth <500, Oct Nov Dec, Yr*Strata Julian model.

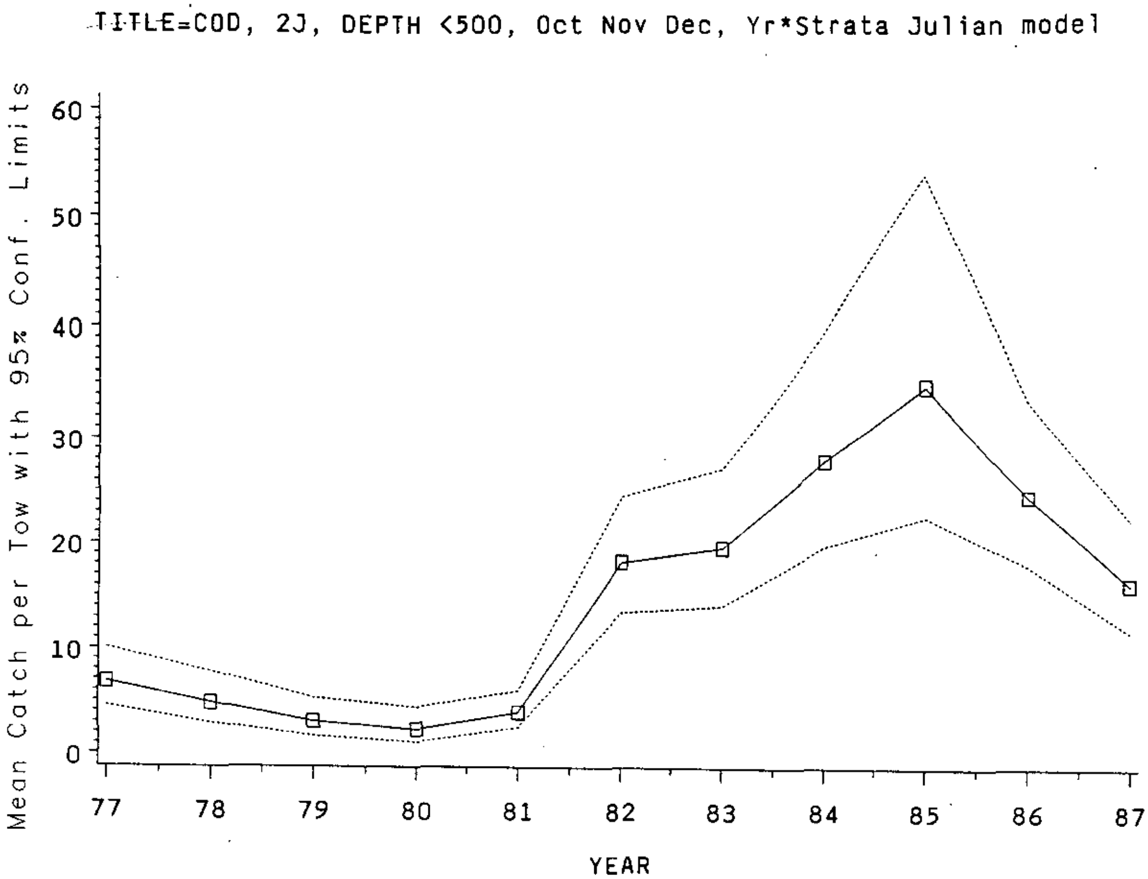


Fig. 5a. Cod, 3K, Depth <500, Oct Nov Dec, Yr*Strata model.

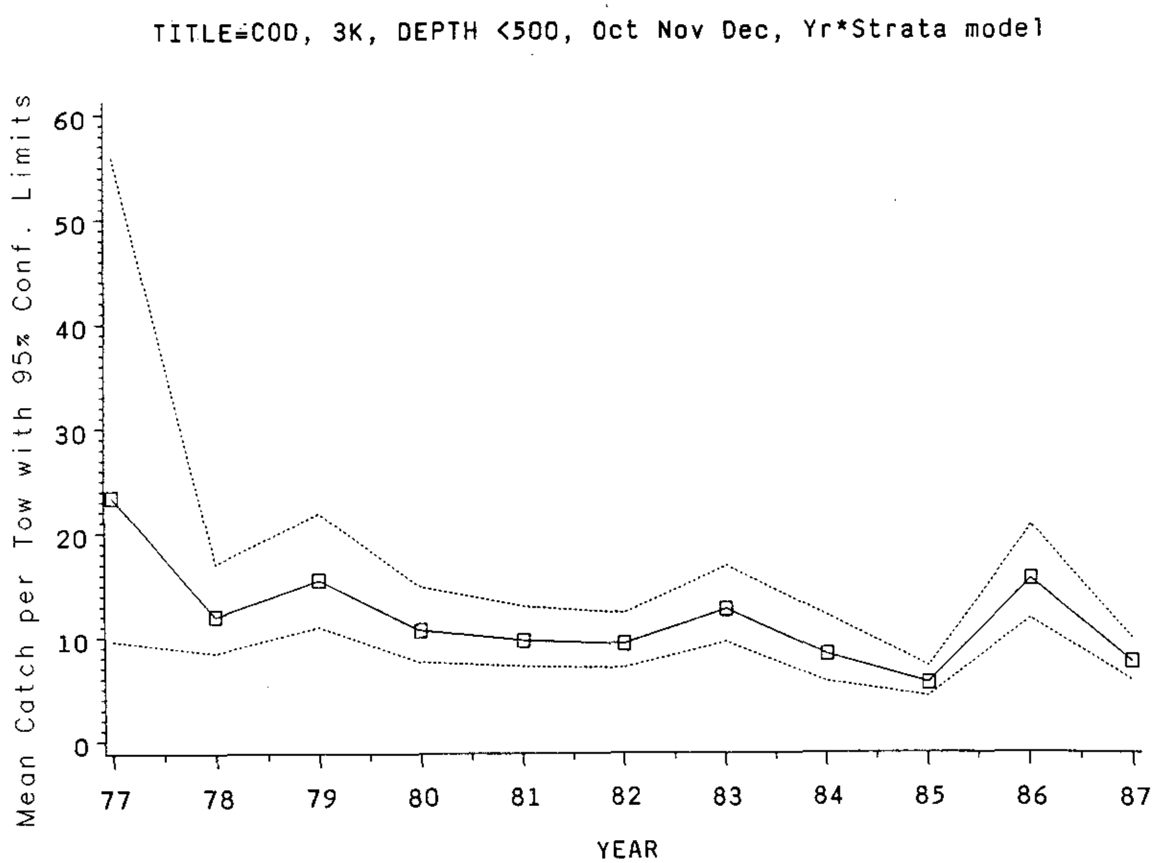


Fig. 5b. Cod, 3K, Depth <500, Nov Dec, Yr*Strata, Julian, temp model.

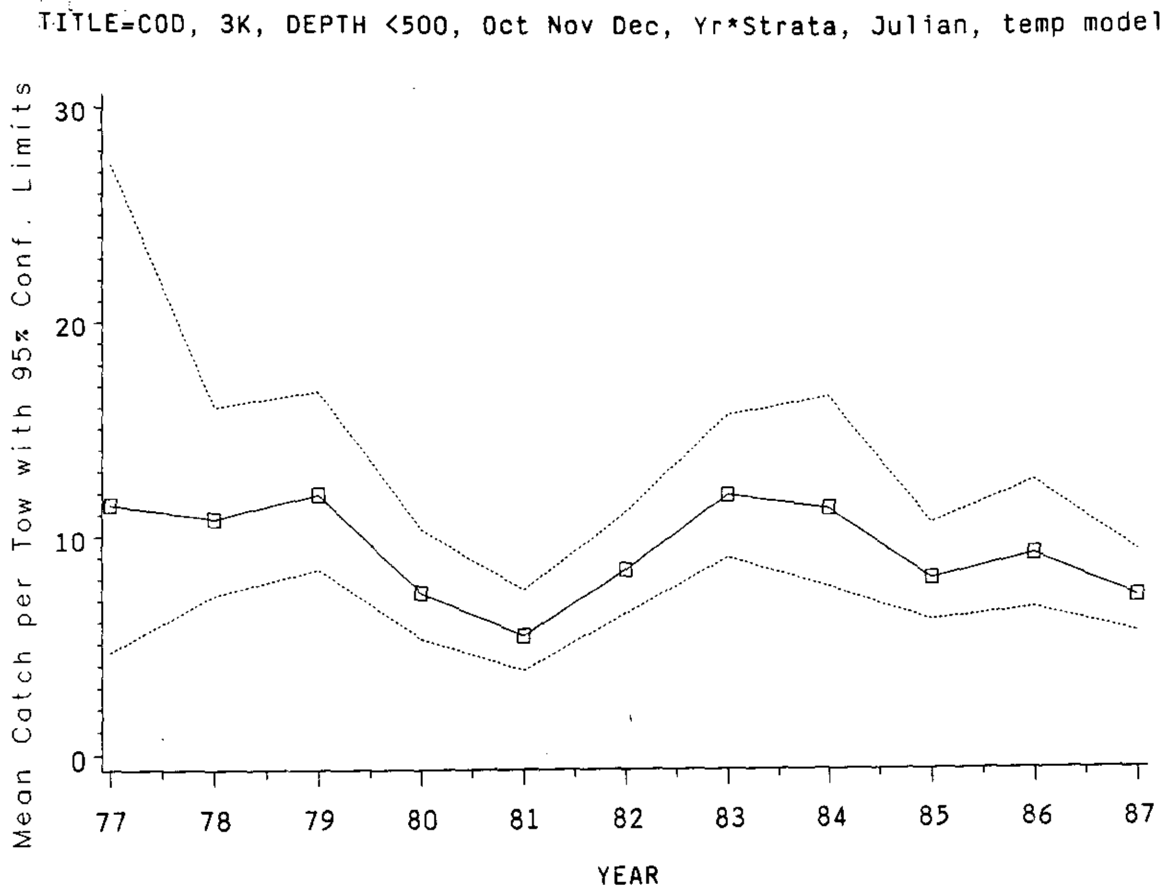


Fig. 6a. Cod, 3L(spring), Depth <500, Yr*Strata model.

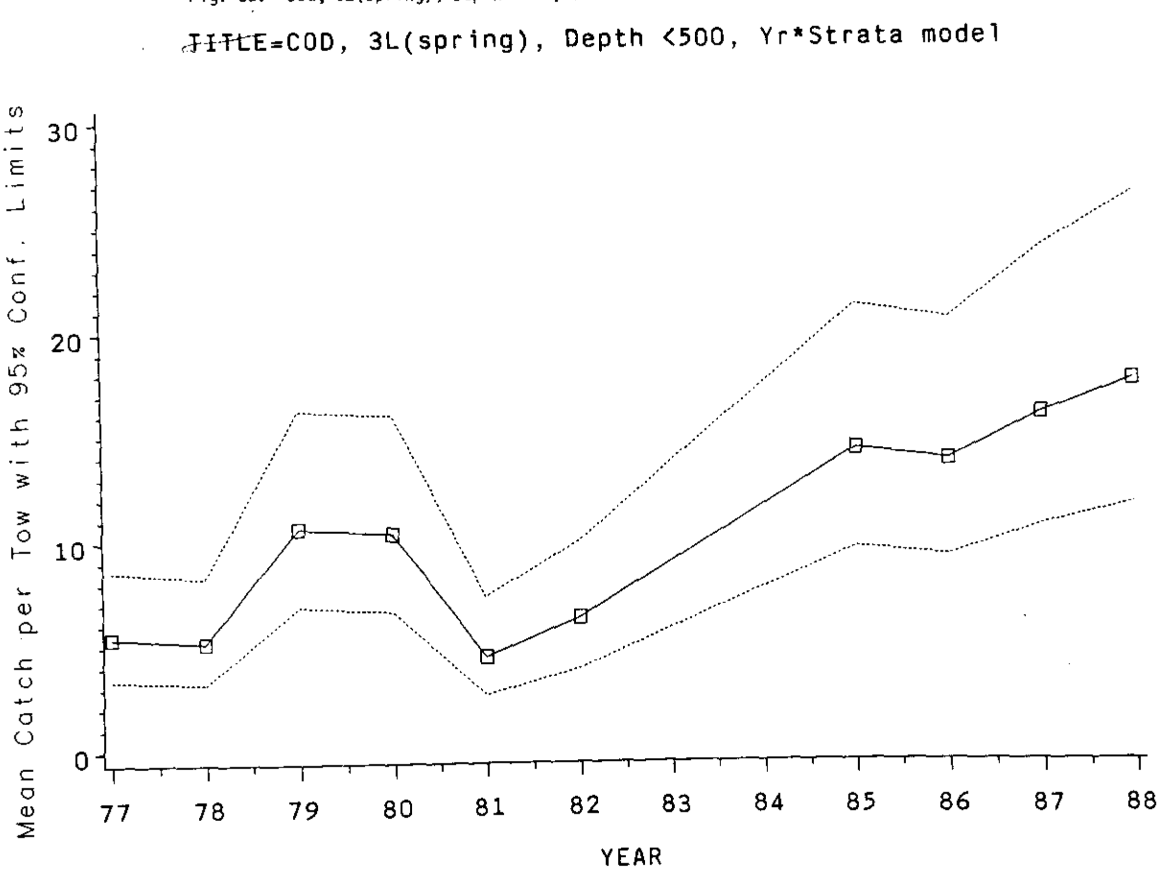


Fig. 6b. Cod, 3L(spring), Depth <500, Yr*Strata, Julian temp model.

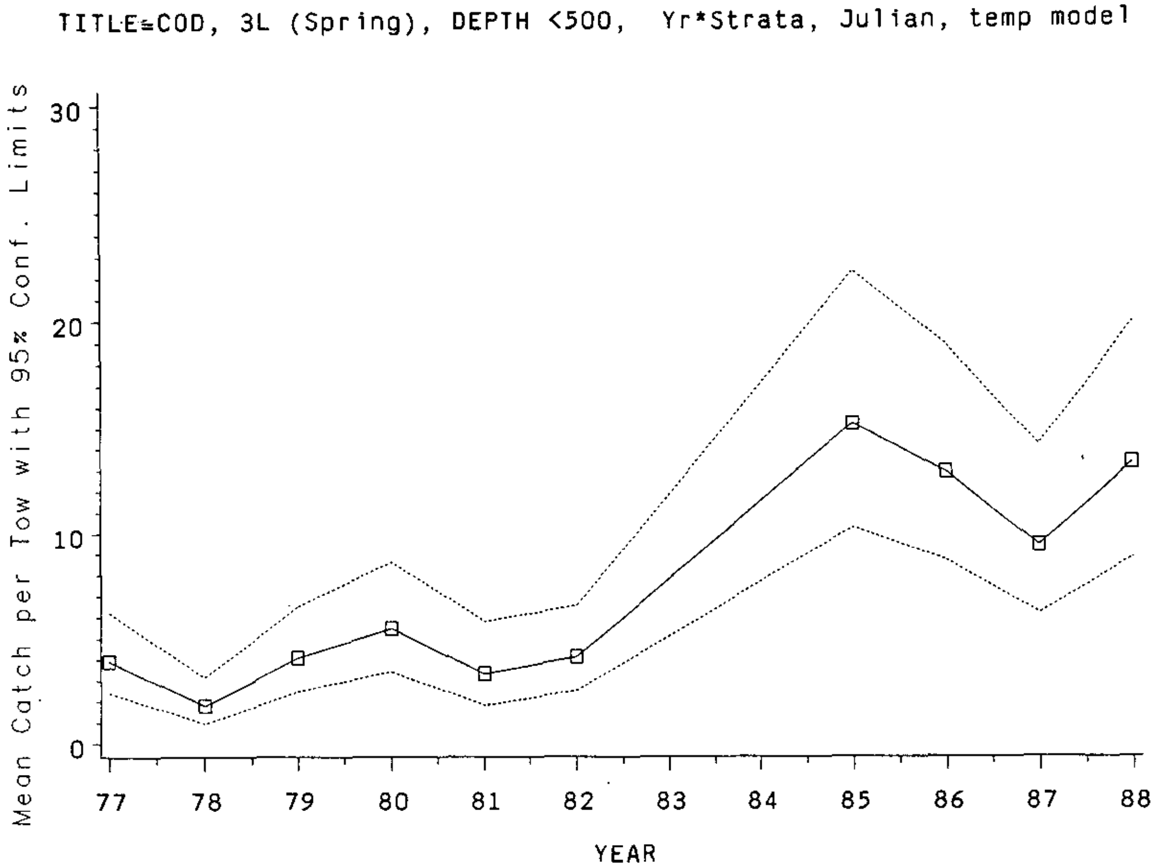


Fig. 6c. Cod, 3L(spring), Depth <500, Yr*Strata model, before June.

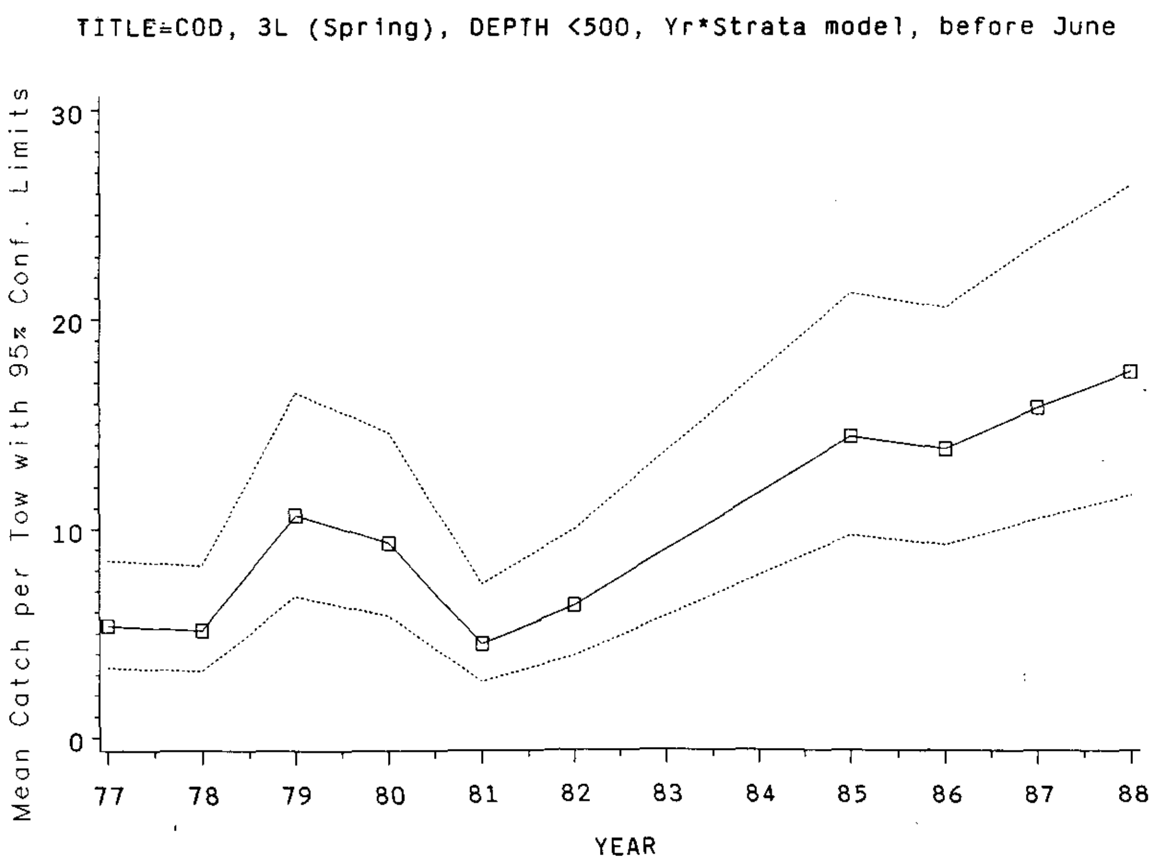


Fig. 6d, Cod, 3L(spring), Depth <500, Yr*Strata model, before May 20.

TITLE=COD, 3L (Spring), DEPTH <500, Yr*Strata model, before May 20

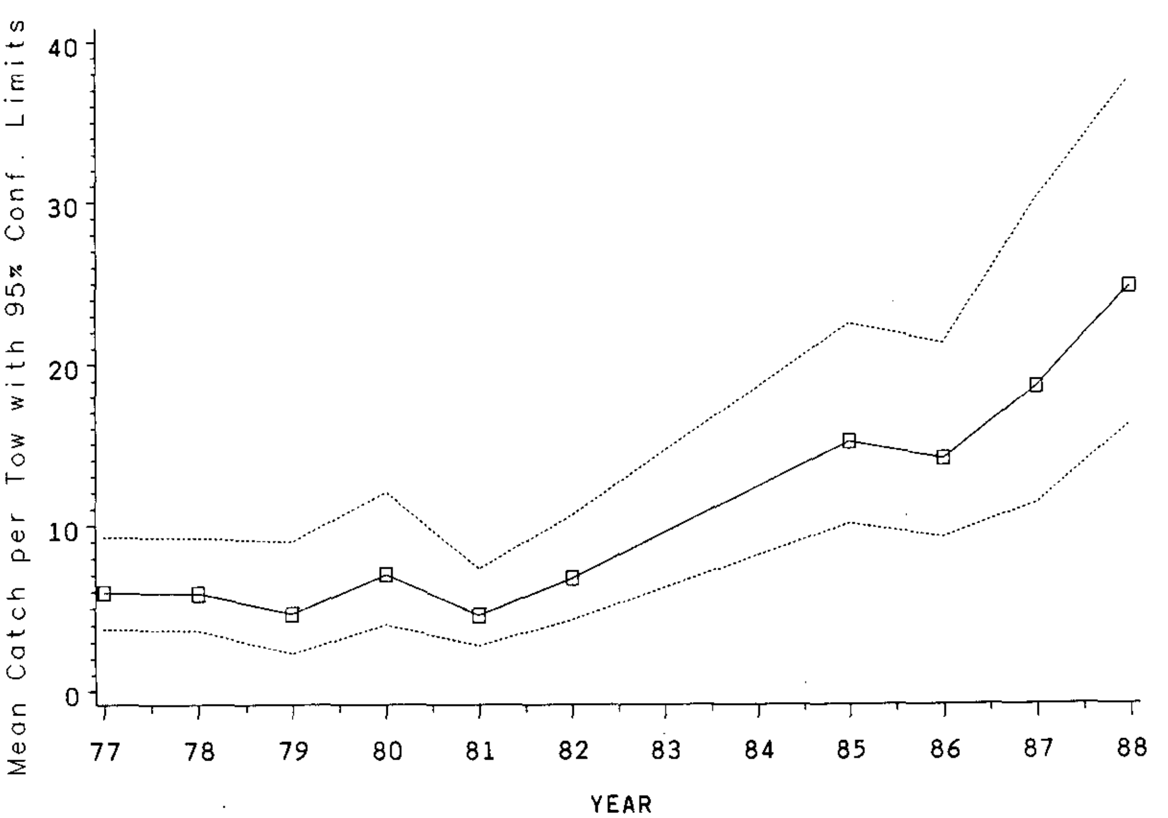


Fig. 6e. Cod, 3L(spring), Depth <500, Yr*Strata, Julian model.

TITLE=COD, 3L (Spring), DEPTH <500, Yr*Strata, Julian model

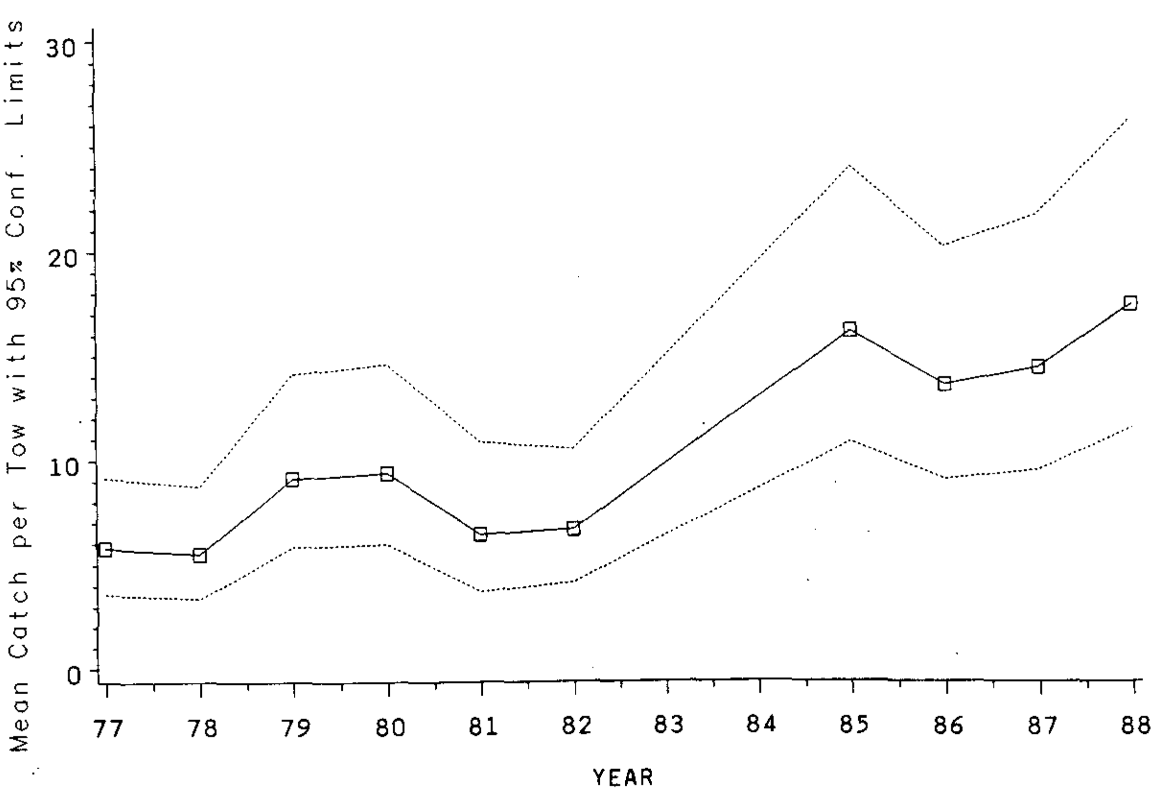


Fig. 7a. Cod, 2J, Depth <500, Oct Nov Dec, Yr*Strata model.

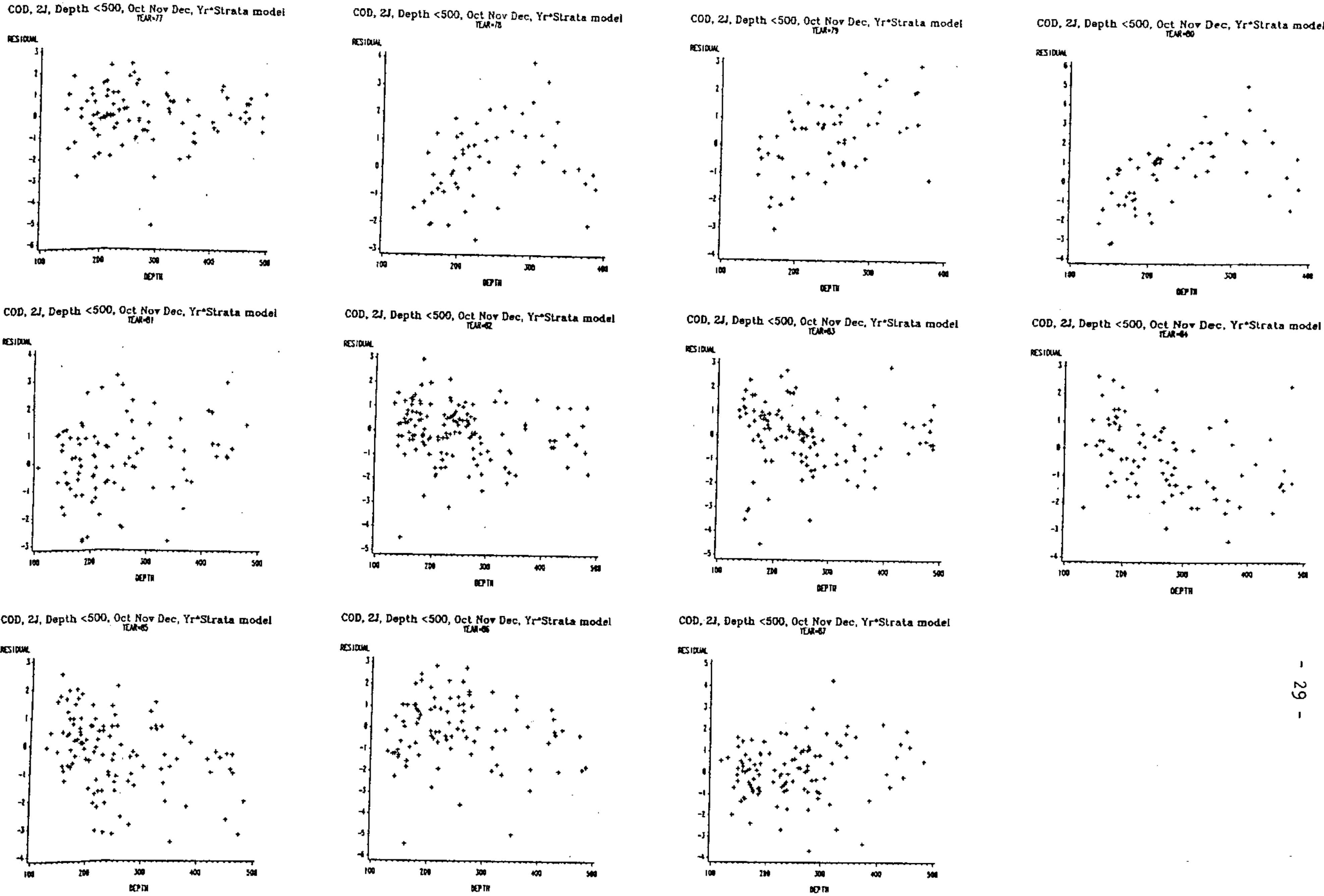


Fig. 7a. (cont'd)

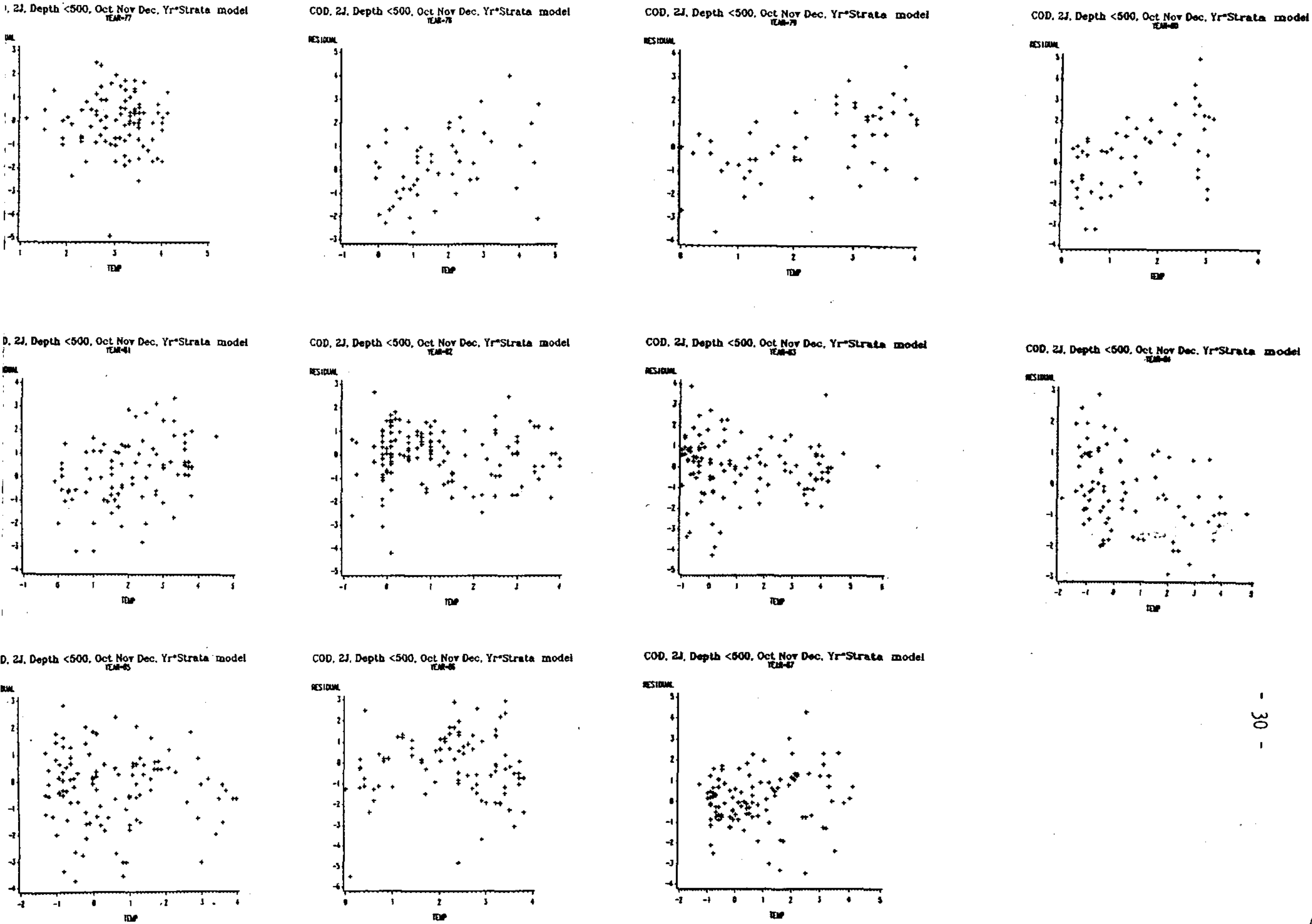


Fig. 7b. Cod, 2J, Depth 500, Oct Nov Dec, Hr*Strata Julian, temp model.

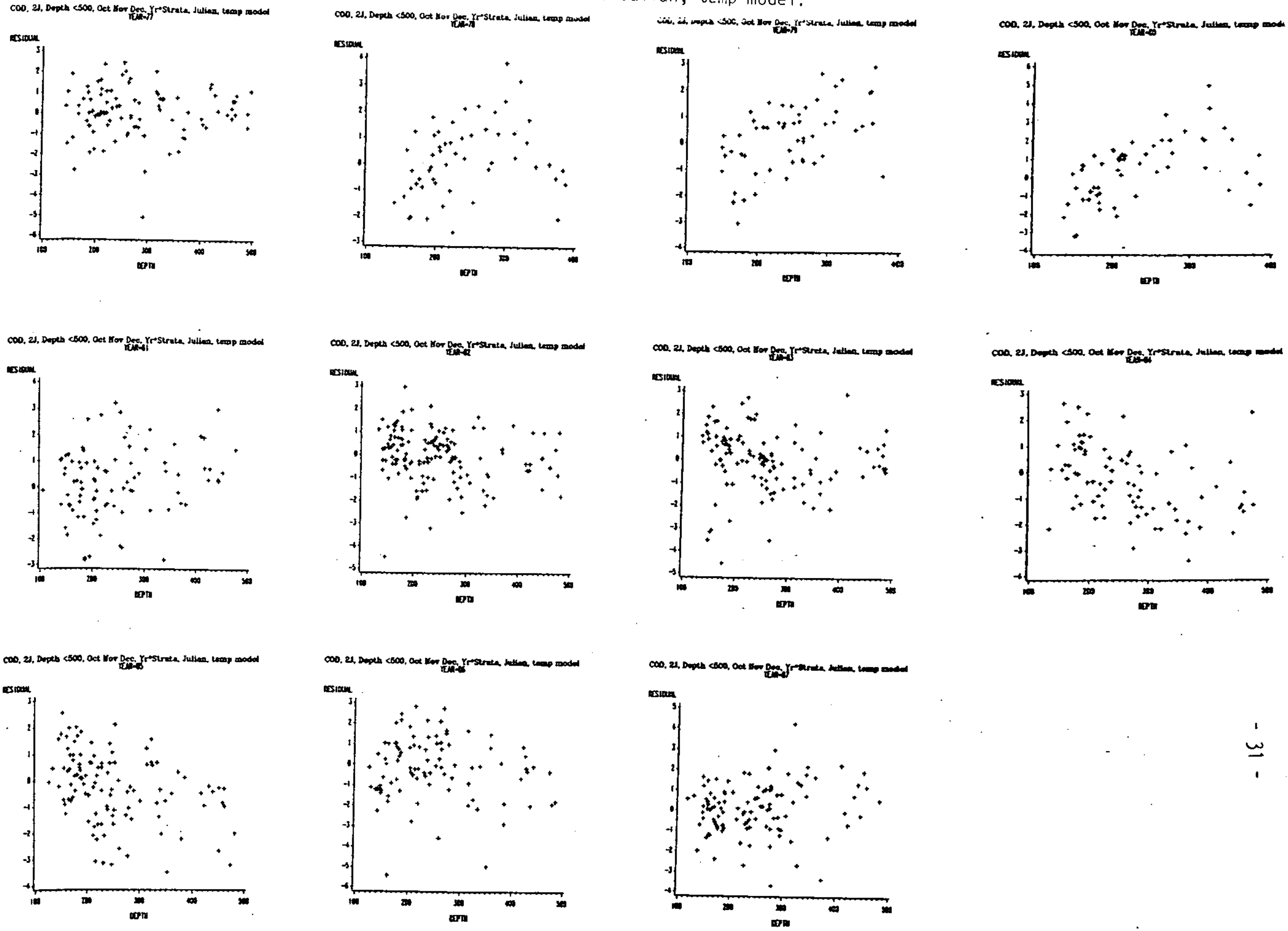


Fig. 7c. Cod, 2J, Depth <500, Nov Dec, Yr*Strata model.

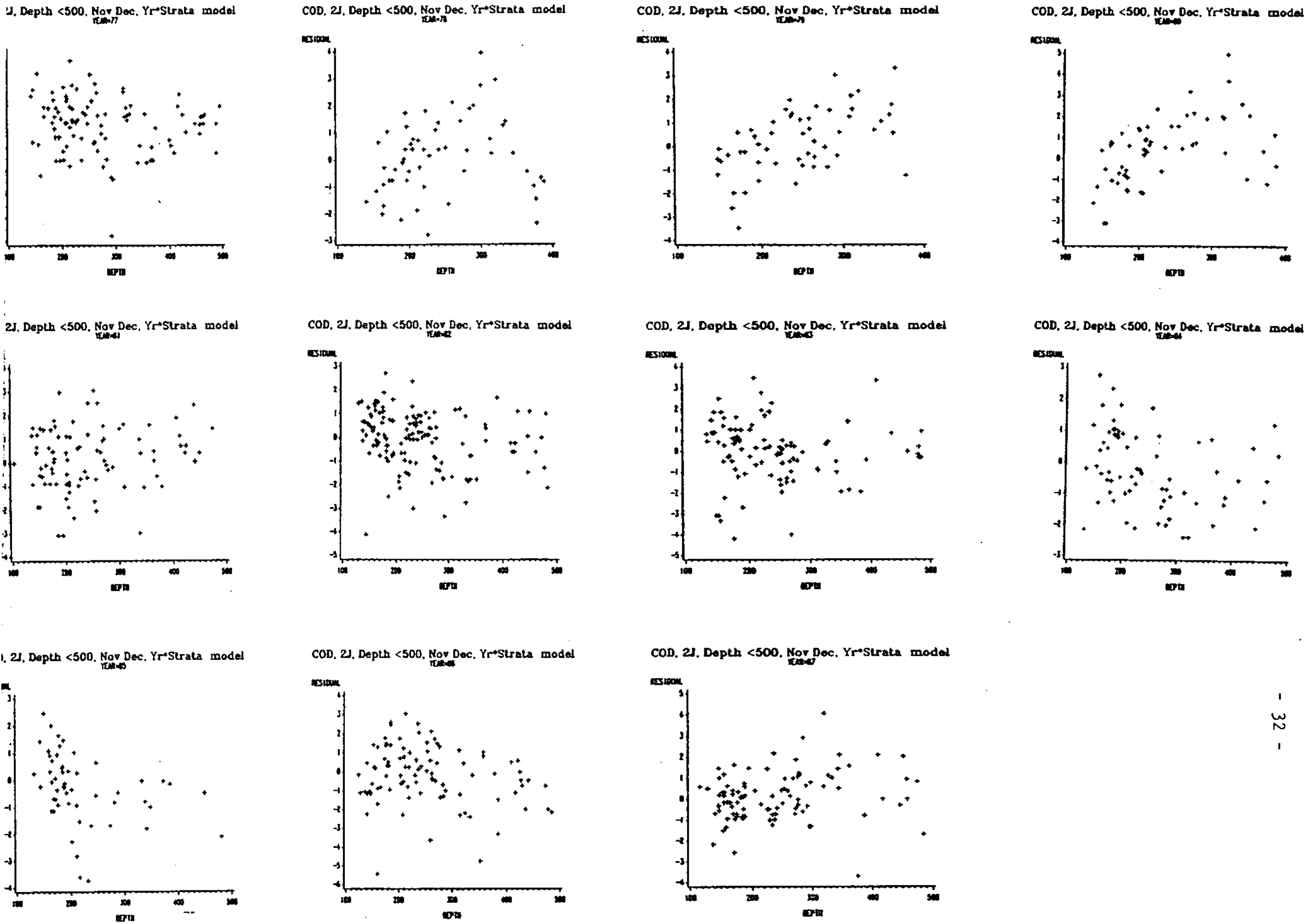


Fig. 7d. Cod, 2J, Depth <500, Date <Nov 10, Yr*Strata model.

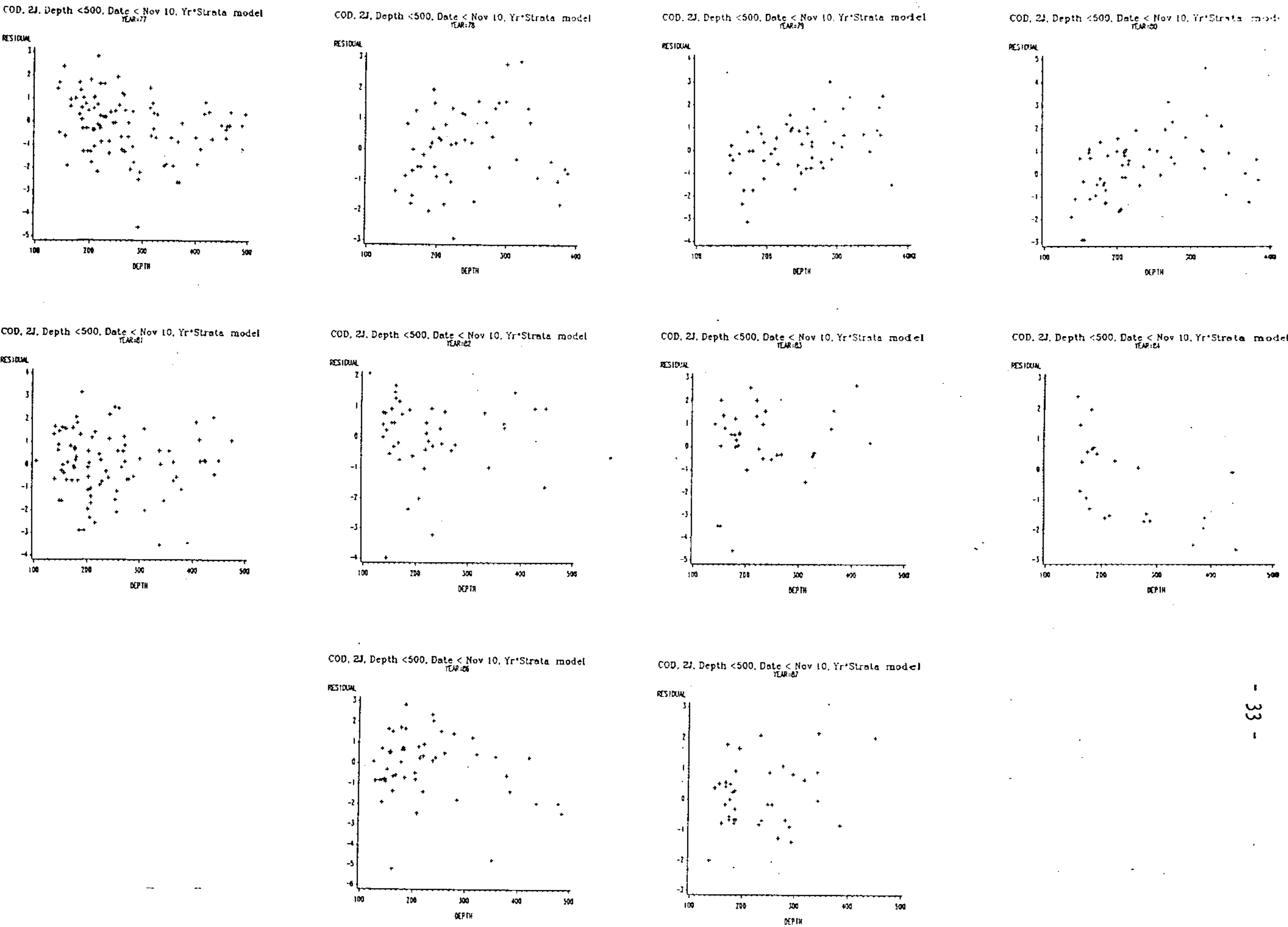


Fig. 8. Cod, 3K, Depth <500, Oct Nov Dec, Yr*Strata model.

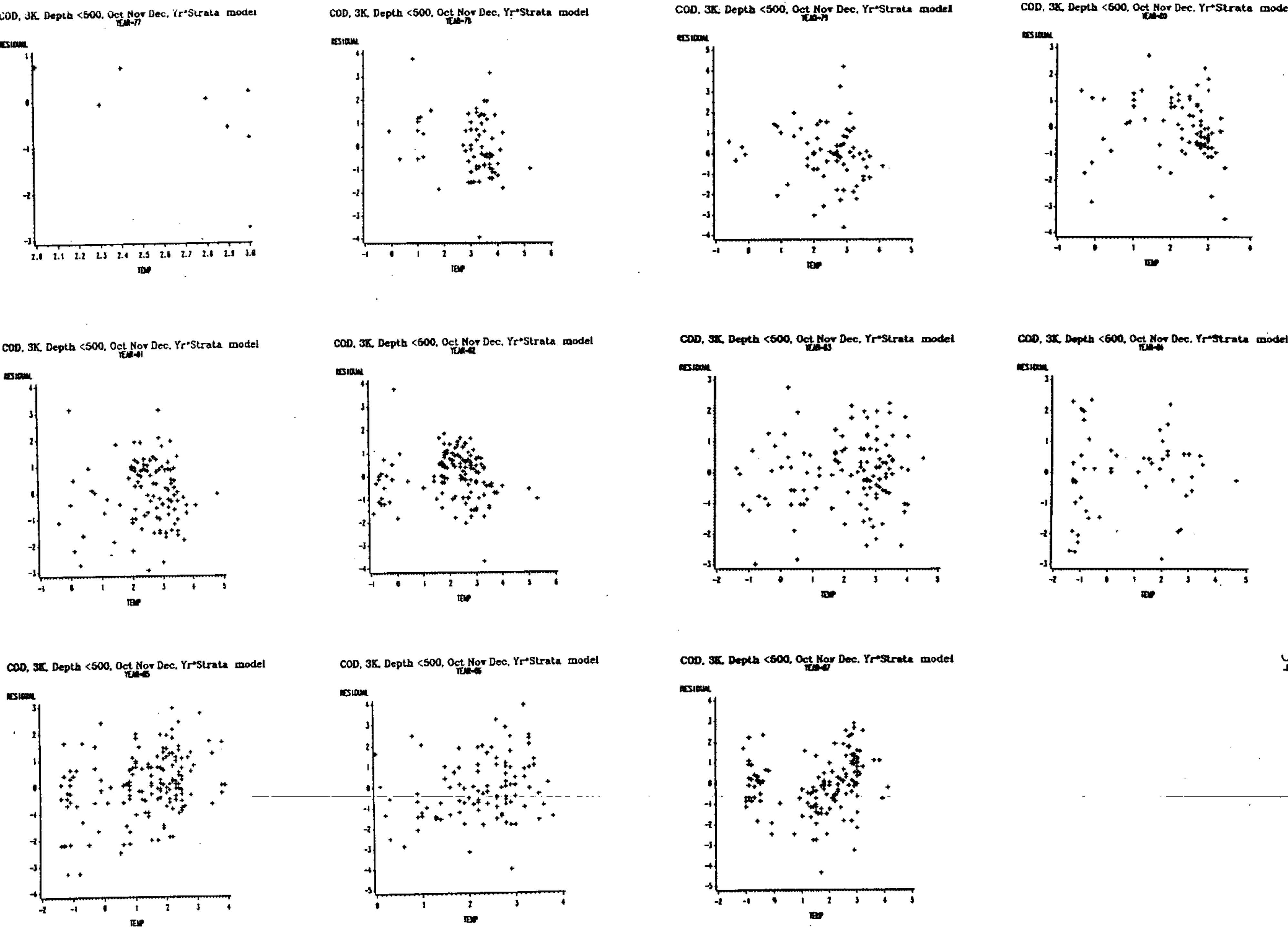


Fig. 9a. Cod, 3L(spring), Depth <500, Yr*Strata model

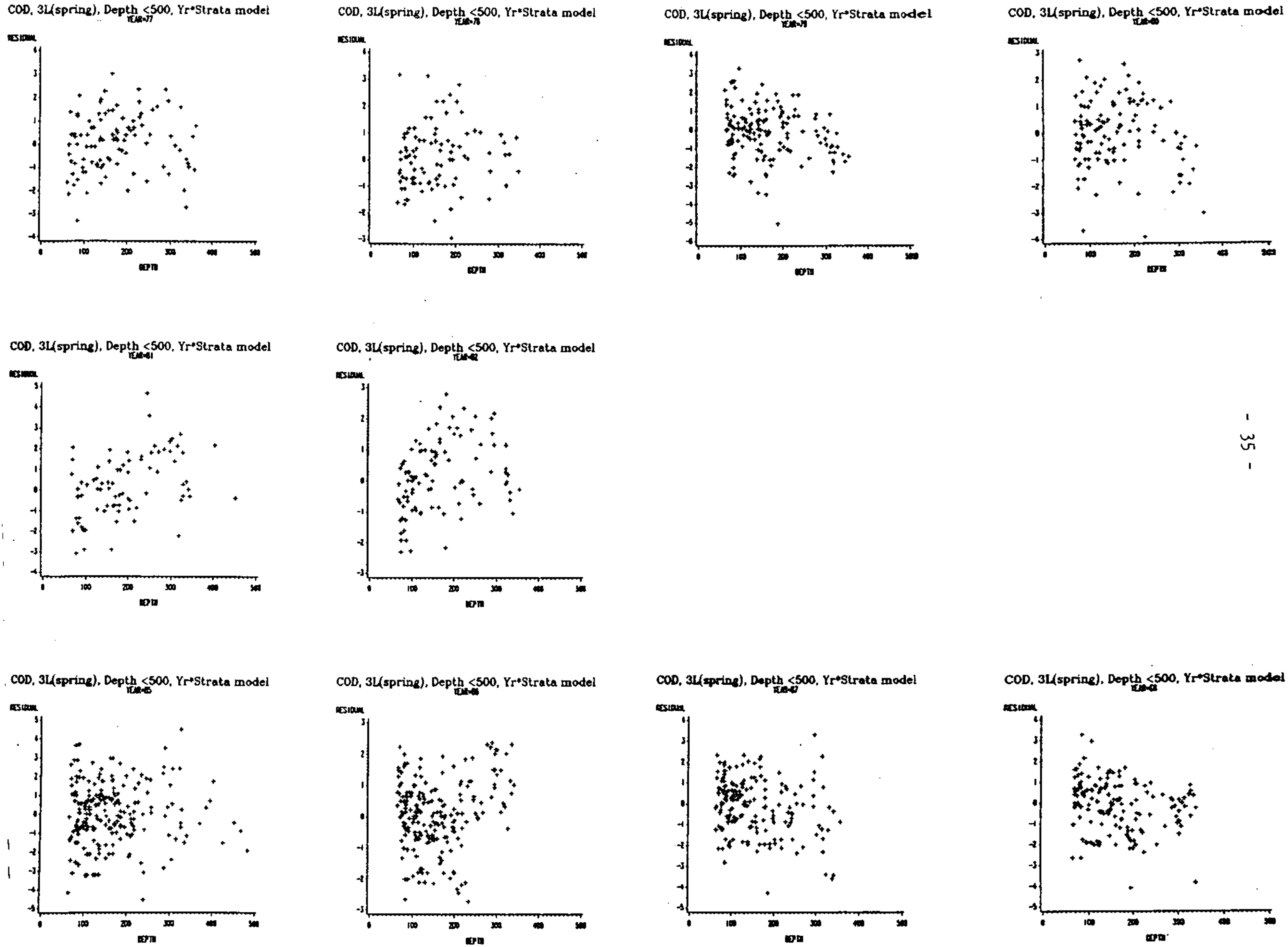
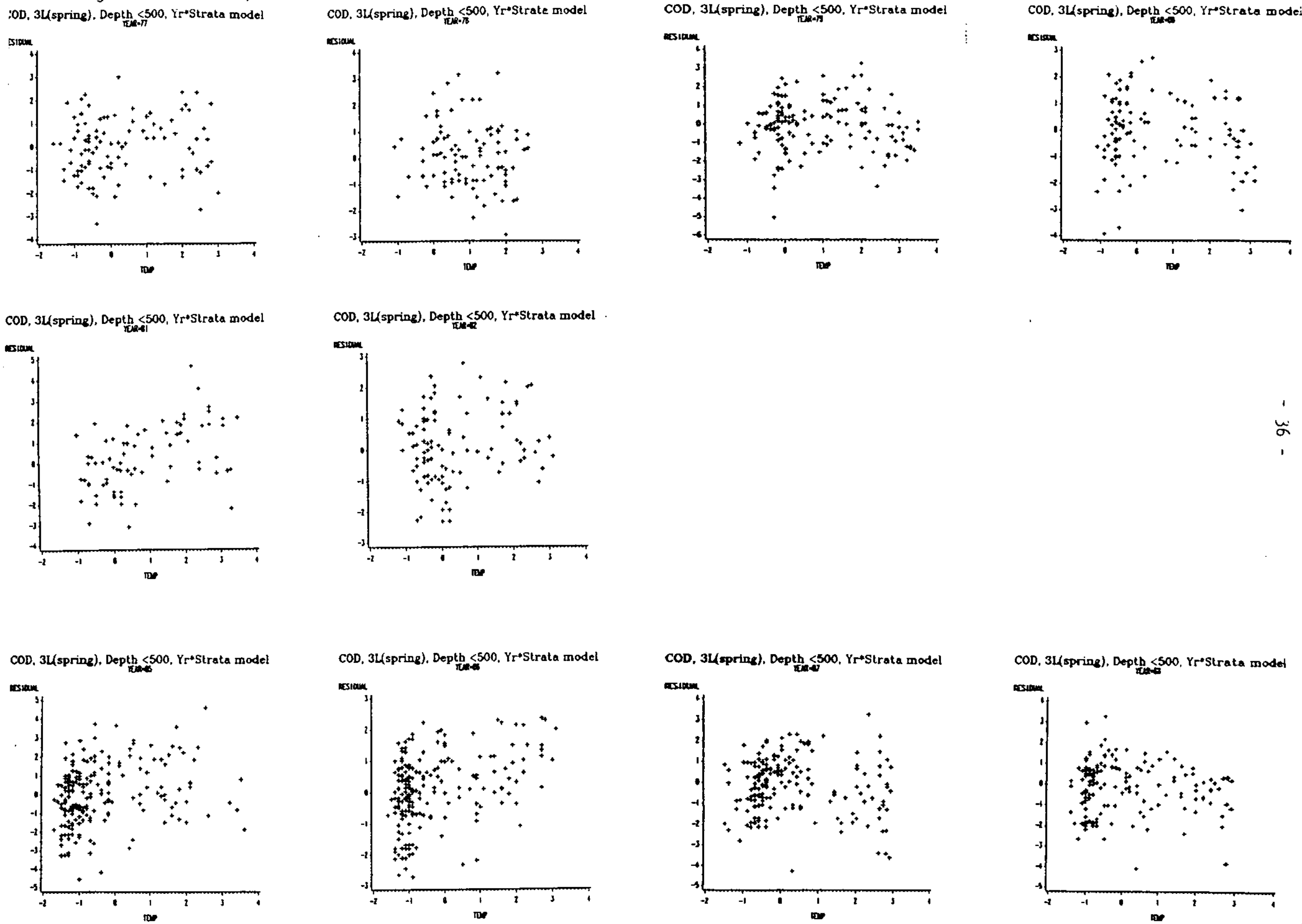


Fig. 9a. (cont'd)


COD, 3L(spring), Depth <500, Yr*Strata model
RESIDUAL
TEMP
COD, 3L(spring), Depth <500, Yr*Strate model
RESIDUAL
TEMP
COD, 3L(spring), Depth <500, Yr*Strata model
RESIDUAL
TEMP
COD, 3L(spring), Depth <500, Yr*Strata model
RESIDUAL
TEMP
COD, 3L(spring), Depth <500, Yr*Strata model
RESIDUAL
TEMP
COD, 3L(spring), Depth <500, Yr*Strata model
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COD, 3L(spring), Depth <500, Yr*Strata model
RESIDUAL
TEMP
COD, 3L(spring), Depth <500, Yr*Strata model
RESIDUAL
TEMP
COD, 3L(spring), Depth <500, Yr*Strata model
RESIDUAL
TEMP
COD, 3L(spring), Depth <500, Yr*Strata model
RESIDUAL
TEMP