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EXECUTIVE SUMMARY

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Catch size frequencies of males, immature females, and mature females obtained from the catch sampling programme are used in stock assessment models to assist in the calculation of stock indicator variables. Recent evaluations of the precision of alternative catch sampling regimes suggested that appropriate target sampling rates were 0.3 trips per vessel per area for the observer programme, and 30% vessel participation rates for the logbook programme. This report reviews the catch sampling programmes to examine coverage relative to fishing activity, and factors affecting the numbers, size, and sex composition of the catch.

Data from the observer programme and logbook programme were collated into individual management areas (CRA 1 to CRA 9 inclusive), and coverage examined by vessel participation and pots lifted as a proportion of the activity of the fishing fleet. Factors affecting the size and sex composition of the catch were investigated by GAM (Generalised Additive Model) analysis. Data from 292 050 potlifts were analysed. The predictor variables were depth, month, year, and statistical area (within a management region). The response variables were total numbers per potlift (NU), average tail width of males (SM), average tail width of females (SF), proportion of males (PM), proportion of mature females (PA), and proportion of mature females that were berried or spent (PO).

Logbook coverage is greater during autumn-winter across all management areas, and no management area receives the target logbook coverage (30% of vessels) during spring-summer. CRA 2 and CRA 5 have appropriate logbook coverage during autumn-winter, but not in spring-summer. Logbook coverage in CRA 8 has declined in recent years and needs to be improved in both autumn-winter and spring-summer to achieve target levels.

Observer coverage is greater in autumn-winter than in spring-summer in most areas. However, at present, no CRA management area experiences the minimum target level of observer coverage of 0.3 trips per vessel per area.

Overall, fishing year was the most important factor contributing to variation in the demographics of *Jasus edwardsii* in New Zealand. It was the highest or second highest contributor to variation in numbers, size, and sex-proportions in 72% of models. The main yearly trend of interest, consistent across most QMAs, but expressed at slightly different years, is an increase in NU, followed by an increase in SM and/or SF (lagged by 1-2 years), and subsequent decreases.

Fishing month was generally more important in explaining size and sex proportions of lobsters, and had less of an effect on numbers. A trend highlighted by the review, but not previously identified, is the occurrence of bi-modal peaks (late autumn and spring) in the proportion of males, which is evident to a greater or lesser degree, in all QMAs. These were correlated with size of males, with the lowest proportion of males occurring at about the same time as the lowest mean size of males. The hypothesis is that this pattern is the result of the moulting cycle of males. As the larger males moult in spring, they 'go off the bite', and consequently the only animals being caught are the smaller males not yet ready to moult.

There were often large differences among statistical areas within each QMA for response variables. Statistical area accounted for most of the variation explained by the model for total numbers in CRA 1, CRA 4, CRA 5, and CRA 8. There was also a large difference in the proportion of males (PM) between statistical areas in CRA 3, CRA 4, CRA 5 and CRA 8.

However, for most QMAs statistical area explained less than 5% of the variation in berried females.

Depth was generally the less influential of factors affecting the demographics of *Jasus edwardsii* in New Zealand, with a few exceptions. In CRA 8, for example, depth was the most influential factor affecting variability in total numbers of lobsters.

The effect of catch sampling programme (logbook, observer) was generally negligible in accounting for variation in numbers, size, and sex composition.

The review highlighted the wealth and volume of information present in the catch sampling data set and confirms and corroborates the need to standardise annual CPUE data by statistical area and month effects.

To complement the annual stock assessments and highlight long-term trends, we recommend an regular examination of year effects on numbers per potlift and average size of lobsters using the analyses developed here.

1. INTRODUCTION

Catch sampling in the New Zealand rock lobster (*Jasus edwardsii*) fishery is done under two separate programmes: an observer programme, and a logbook programme. The observer programme provides the main source of catch composition data for CRA 1 (Northland), CRA 3 (Gisbourne), and CRA 4 (Hawke Bay-Wairarapa). It is an intensive programme carried out by scientific observers who measure characteristics of an entire day's catch on a lobster vessel. It is also used to verify the logbook data in CRA 2 (Bay of Plenty), CRA 5 (Canterbury-Marlborough), and CRA 8 (Southland-Fiordland). The logbook programme is spread over the fishing fleet with many vessels participating (Starr & Vignaux 1997). Each vessel is assigned four experimental pots, from which the number, size, and sex of lobsters is recorded. The observer programme has been running since 1989 in some areas, and the logbook programme began in 1993 (Starr & Vignaux 1997). The sex and size-frequency data from these programmes is incorporated into the annual stock assessment process and population dynamics model in all lobster stocks (Starr and Bentley 2001; Starr et al. 1999).

Catch sampling is intended to sample the commercial catch. The programmes should sample in proportion to the rate of fishing and reflect changes in the targeting of the fleet. Bentley et al. (2002) evaluated the precision of alternative catch sampling regimes in New Zealand rock lobster fisheries. Their simulations suggested that sampling rates of 0.3 trips per vessel per area for the observer programme, and 30% vessel participation rates for the observer programme were desirable targets.

Despite the importance of catch sampling data to the stock assessment models, and the attention given to maximising the value of the information gained, there has been no comprehensive review of the data arising from the catch sampling programmes. This report describes work programme in season i and area j, and T_{ij} is the total number of vessels fishing in season i and area j.

The number of vessels in the fleet (T_{ij}) may be an overestimate – the number comes from the CELR (Catch Effort Logbook Record) data and is a count of the number of vessels that recorded lobster catch in a statistical area/month combination, regardless of the quantity actually caught. It could include some vessels that accidentally caught lobster or recorded it by mistake. We hypothesised that percentage of pots may be a more reliable indicator of logbook participation rates. A target pot participation rate equivalent to the 30% vessel participation proposed by Bentley et al. (2002) was calculated.

$$P_{ij}^{T} = \frac{0.3 \times 4}{P_{ij}^{av}} \times 100 \qquad (2)$$

where P_{ij}^{T} is the target pot participation rate for season i and area j, and P_{ij}^{av} is the average number of pots lifted per vessel per day in season i and area j. 0.3 is the target vessel participation rate, and four is the number of experimental pots used by each vessel to collect data for the logbook programme.

Calculations for the observer catch sampling programme are the same as Eq. (1), but not converted to percentages. The recommended participation rate for the observer programme is 0.3 trips per vessel per area (Bentley et al. 2002).

2.2 Results

2.2.1 Logbook programme

CRA 2 logbook coverage (vessels).

Logbook coverage (potlifts)

Potlift participation rate showed similar patterns to vessel participation rate in most areas (Appendix A; Tables A1-A14), indicating that vessel participation was an adequate indicator of logbook coverage.

2.2.2 Observer programme

CRA 1 observer coverage (trips per vessel per area)

CRA 1 observer coverage began in 1997, and during autumn-winter, averages were 0.1 trip per vessel per area (Figure 5). During spring-summer, however, coverage has been very limited.

CRA 3 observer coverage (trips per vessel per area)

Observer coverage in CRA 3 was initially focused on the spring-summer fishing season, but in 1994 and 1995, fishing effort was transferred to the autumn-winter season and observer coverage reflected this trend (Figure 6). Currently, observer coverage in CRA 3 is less than 0.1 trips per vessel per area during autumn-winter, and zero coverage during spring-summer,

CRA 4 observer coverage (trips per vessel per area)

Observer coverage in CRA 4 follows a similar pattern to CRA 3. Coverage was initially focused on the spring-summer fishing season, in 1994 and 1995, fishing effort was transferred to the autumn-winter season and observer coverage reflected this trend (Figure 7). Currently, observer coverage in CRA 3 is 0.15 trip per vessel per area in areas 913 and 915, and less than 0.1 trip per vessel per area in areas 912 and 914. These figures are for autumn-winter. No coverage is available during spring-summer.

CRA 7 observer coverage (trips per vessel per area)

Observer coverage in CRA7 has oscillated between 0.05 and 0.25 trip per vessel per area since 1989, but currently stands at 0.1 for both autumn-winter and spring-summer (Figure 8).

2.3 Discussion

Coverage of the fishing fleet by the logbook programme varied considerably over time and space. Some areas have exceeded the target sampling rate (30% vessel coverage for the logbook programme), e.g. autumn-winter in areas 906-907 of CRA 2, which have averaged 40 to 50% vessel coverage. Other areas have been consistently below the target, e.g., area 905 in CRA 2. Of all management areas, CRA 2 has received the best coverage of the logbook programme, although in recent years CRA 5 has started to achieve desired levels. Participation rates in CRA 8 have dropped in recent years.

In all areas, logbook participation rates were lower during spring-summer, the season currently with the lowest catches in most QMAs. This may have arisen because participants in the logbook programme continued fishing but did not fill in logbooks during spring-summer, or non-participants tended to continue fishing into the spring-summer season.

At present, no CRA area experiences the minimum desired level of observer coverage of 0.5 trip per vessel per area. Coverage of the observer programme was under the minimum coverage suggested by Bentley et al (2002) (0.3 trip per vessel per area) for all areas and seasons. It was better in autumn-winter, averaging around 0.1 trips per vessel per area, but generally negligible during spring-summer.

Catch sampling effort should be distributed among areas and months in a way that it is most representative of the catch. As discussed above, the coverage of both sampling programmes is variable, some months and/or areas may be over-represented and some may be under-represented when data are aggregated. The effect of this is likely to be minimal, however, since the weighting procedure used in the stock assessment to aggregate catch sampling data incorporates the proportion of catch taken in an area-month stratum (Breen et al. 2002).

3. FACTORS AFFECTING THE SIZE AND SEX COMPOSITION OF CATCHES

3.1 Methods

We compiled catch sampling data from the logbook and observer programmes into a single data set with each record representing a sampled potlift. The collated data set comprised 292050 potlifts from all QMAs (Table 1). A small amount of data from 1975-76 to 1976-77 from CRA 1 and CRA 9 was ignored.

For each potlift we calculated six response variables representing the magnitude, and size and sex-composition, of the catch (Table 2). In the logbook programme, fishers are asked to round down measurements to the nearest millimetre. Thus average tail widths from the logbook programme would be expected to be about 0.5mm lower than the catch sampling programme. To account for this, 0.5 mm was added to the average tail width for pots from the logbook programme.

3.1.1 Generalised additive models

We used Generalised Additive Models (GAM, Hastie & Tibshirani 1990) to examine the relationship between these six characteristics of the catch and a number of independent variables. GAMs are becoming a much-used tool in fisheries science and ecology because the relationship between predictors and response variables modelled by the smoothing functions is only assumed at a localised area, and not for the entire range of data. This data-defined assessment capability (Stoner et al. 2001) allows the data to suggest models with non-linear response shapes, rather than assuming a priori models with specified relationships between predictor and response (Palka & Hammond 2001). Such versatility is reflected in the range of studies for which GAMs are being used. They have been used to investigate the influence of environmental and stock structure on recruitment (Carindale & Arrhenius 2000); develop spatially explicit models of habitat association for juvenile fish (Brosse & Lek 2000, Stoner et al. 2001); correct density estimates of animals moving in response to sighting platforms (Palka & Hammond 2001), and test for density dependent survival in costal *Gadhus morha* (cod) populations (Bjornstad et al. 1999).

A generalised additive model is specified as:

$$Y = g\left(\alpha + \sum_{j=1}^{p} f_j(X_j)\right) + \varepsilon \qquad (3)$$

where α is the intercept, p is the number of independent variables, f_j is an arbitrary univariate function of independent variable X_j, g is the link function and ε are the errors.

As with Generalised Linear Models, GAMs allow alternative assumptions to be made about the error distribution. We assumed different types of error distributions depending upon the type of response variable (Table 2). For the numbers of lobsters caught we used a quasi-Poisson distribution (which allows for greater variation than expected under a standard Poisson, McCullugh & Nelder 1989). For the average size of males and females we used a Guassian distribution and for the response variables that measured proportions we used a quasi-binomial distribution. The quasi-binomial is similar to the quasi-Poison in that it allows for greater variation than expected under a standard binomial distribution. We use the canonical link function of each distribution: log for the quasi-Poisson, identity for the Guassian and logit for the quasi-binomial (McCullugh & Nelder 1989).

Five independent variables were used for each GAM (Table 3). These were considered to be the most important variables determining the magnitude and composition of the catch for which good information was available. Statistical areas were the smallest spatial scale that could be examined. Small scale 'zones' were introduced into the logbook programme during 2000 and could be incorporated into an analysis in the future but at the time of this analysis there was insufficient data at this scale. Most of the independent variables were treated as factors (Table 3), except for depth whose effect was modelled using a cubic regression spline smoothing function (Hastie & Tibshirani 1990). If the effect of depth had been modelled using a linear relationship then our models would be GLMs.

Both the observer and logbook programme have provision for recording swell direction and height and wind direction and speed. However, these variables were available for only between 57 and 62% of potlifts. Furthermore, the effects of these variables, in particular those for wind, are difficult to incorporate into a GAM without considering complex interactions. For example, the effect of wind strength is likely to depend on its direction.

Because of the significant regional differences in apparent settlement variation, morphometry, growth, size at reproduction, pot design, and size limits (Booth & Breen 1994, Bentley & Starr 2001), analysis was undertaken separately for each quota management area. Not all of the independent variables could be used for every QMA. In CRA 6, only observer samples were available so that programme could not be included as a factor. Conversely, in CRA 9 only logbook samples were available. In CRA 1, programme could not be included because although there were both observer and logbook samples available they did not overlap in time. Thus, the programme factor was confounded with the year factor and hence not included.

3.1.2 Model selection

Due to the large number of GAMs (9 areas x 6 variables = 54 models) we did not use a stepwise process to include independent variables into the models. We included all 5 independent variables in all models but provide analysis of deviance tables which show the relative importance of the variables to the model fit. The deviance for a GLM is proportional to twice the difference between its log likelihood and the maximum log likelihood achievable from a saturated model (a model having as many parameters as observations, McCullagh & Nelder 1989). An analysis of deviance is similar to an analysis of variance (ANOVA) but uses deviance, rather than sums of squares, as a measure of discrepency of fit. Because the independent variables used in the GAMs are not orthogonal, the interpretation of the analysis of deviance table is different to the ANOVA. The analysis of deviance table shows the changes in the deviance that result from sequentially adding each independent variable to the model. The change in deviance associated with adding a variable is the variation accounted for by that variable over and above the variation explained by variables already included in the model.

In some QMAs the fitting procedure did not converge when fitting a smooth to the effect of depth. This was usually when depth was insignificant as an independent variable, or contributed a very low proportion of the total deviance explained by the model. In these cases the effects of depth are not shown because they may be spurious.

3.1.3 Diagnostics

For each model we present the adjusted R^2, the estimated scale parameter, the standard deviation of the standardised residuals (s.d.s.r) and the median of standardised residuals (m.a.s.r.). For the quasi-Poisson and the quasi-binomial, the scale parameter represents the 'extra' variation in the error distribution. For the Guassian distribution the scale parameter is the estimated standard deviation of the error distribution.

3.1.4 Presentation of results

GAM smooths are often presented in terms of the linear predictor, but this can make it difficult to understand the magnitude of the effect on the dependent variable. In particular, when using a logit link function, there is no immediately intuitive way of converting the linear predictor into actual proportions since the function is neither multiplicative, nor additive.

To present effects on a meaningful scale, we defined a "standard" level for each of the independent variables. For example, when examining the effect of depth on numbers per potlift, year, month, statistical area and programme were fixed at their standard value, and the predicted numbers per potlift calculated for each depth along a continuum (5, 10, 15,...100m). The predictions were based on the estimated coefficients from the GAM model. This process enabled the effect of an independent variable to be expressed on a meaningful scale such as numbers per potlift, average tail width, or a proportion.

The standard fishing year was set at 2000-01 for all QMAs. The standard month and statistical area were set for each QMA based on those with the greatest number of potlifts during the period 1995-96 to 2000-01 (Table 4). To determine a standard depth we examined the frequency distribution of the depth of potlifts for each QMA in 5 m bins. Most of the sampled potlifts were in the 20 to 25 m or 25 to 30 m category. Thus, we used a standard depth of 25 m for all areas. The logbook programme was used as the standard, except for CRA 6 where there were no logbook samples.

For example, the plot of the effect of fishing year on number of lobsters per potlift in CRA 8 (NU, See Figure 41) shows the predicted number of lobsters from one potlift in the logbook programme at 25 m depth in area 926 during September, for each fishing year. The predicted number of lobsters in 2000-01 of 4.8 lobsters/potlift, is the same as that for September in Figure 42, 926 in Figure 43, and 25 m in Figure 44.

3.2 Results

3.2.1 Model fits

Tables 5 to 14 show the variation in numbers, size, and sex of *Jasus edwardsii* for each QMA, as explained by the independent variables fishing year (FY), fishing month (FM), statistical area (ST), depth (DE), and catch sampling programme (PR). The tables also present diagnostic statistics. Residual diagnostic plots for each model are given in Appendix B.

Variation explained

There was a wide range of variation in the proportion of variation explained by the models (adjusted-R^2, Tables 5 to 14). The model with the highest adjusted-R^2 in each QMA was generally the proportion of the mature females that were berried or spent (PO). This probably arises because this response variable varies markedly within each fishing year and could be explained well by the fishing month (FM) factor. Models for the proportion of males in the catch (PM) often had a low adjusted-R^2: 4% (CRA 7) to 25% (CRA 9). The same was true for models of the number of lobsters per potlift (NU): 5% (CRA 2) and 29% (CRA 5). This suggests that there were other variables that were not included in these models that cause variation in these response variables.

Distributional assumptions

The estimated scale parameter for the quasi-poisson distribution used for models of NU was well above 1 in most QMAs (3.25 – 8.66). This suggests that there is substantial extra-Poisson variation in the data. Residual diagnostic plots indicate deviations from the quasi-Poisson distribution, particularly in the upper 5% of residuals (Appendix B). Although the standard deviation of standardised residuals was 1 in all areas, the median of the absolute value of standardised residuals was less than the expected value of 0.675 (0.45 to 0.65).

In contrast, residual diagnostic plots for the average size of males and females (SM and SF) suggests that the Gaussian distribution was appropriate for these response variables (Appendix B). However, there were some departures from normality in residuals in some areas (e.g., CRA 8).

The poorest residual diagnostics were for models of proportions. These used a quasi-binomial model and the scale parameter was usually estimated to be above 1. The standard deviation of the standardised residuals (s.d.s.r) and median of standardised residuals (m.a.s.r.) were generally very low suggesting that there is less variation in the residuals than expected. This may be related to the high proportion of zeros in these data.

3.2.2 Overview

Fishing year

Overall, fishing year was the most important factor contributing to variation in the catch size and composition. It was the highest or second highest contributor to variation in numbers, size, and sex-proportions in 72% (26/36) of models (Tables 5 to 13).

The main yearly trend of interest, consistent across most QMAs, but expressed at slightly different years, is an increase in NU, followed by an increase in SM and/or females SF (lagged by 1 to 2 years), and subsequent decreases.

Examples of this trend are found in CRA 2 (Figure 17), CRA 3 (Figure 21), CRA 4 (Figure 25) and CRA 5 (Figure 29), CRA 6 (Figure 33), and CRA 7(Figure 37). In CRA 4 the trend appears to have occurred three times. 1) A peak in numbers in 1986, followed by a peak in sizes in 1987 and 1988; 2) a peak in numbers in 1990, followed by a peak in size in 1991,and 3) a peak in numbers in 1997 and 1998, followed by a peak in size of males and females in 1998 and 1999 (Figure 25). In CRA 6, which has sequential data for only 5 years (1993 to 97), it occurred once, a peak in numbers in 1996, followed by an increase in size of males and females in 1997.

Patterns in the proportion of males vary between QMAs. In CRA 4 (Figure 25) and CRA 5 (Figure 29), proportions of males in the catch oscillated over the 1990s, declining in recent years. In CRA 3 (Figure 21), there as been one peak in mid 1990s and declines in recent years. In CRA 6 (Figure 33) and CRA 7 (Figure 37), *proportion of males has remained relatively* constant. In CRA 8, the pattern in proportion of males appears to follow closely the pattern in total numbers (Figure 41), with both variables increasing from a minimum in 1997 until 2000.

Trends in proportions of females that are mature over time can be divided into three distinct groups. The first, and largest group, are those QMAs in which proportion of mature females is consistently high (over 0.95) in all fishing years: CRA 1 (Figure 13), CRA 3 (Figure 21), CRA 4 (Figure 25), CRA 6 (Figure 33), and CRA 9 (Figure 45). In the second group of QMAs, the proportion of mature females was low in the early 1990s, but has increased substantially in recent years: CRA 2 (Figure 17) and CRA 5 (Figure 29). The third group consists of CRA 7 (Figure 37) and CRA 8 (Figure 41), where proportion of females that are mature has been consistently low (under 0.3) over time.

The *proportion of mature females that are berried or spent is generally high over time in all* QMAs.

Fishing month

Fishing month was generally more important in explaining size and sex proportions of lobsters, and had less of an effect on numbers. There were similar patterns in the effect of month on the mean size of males (SM), the proportion of males caught (PM), and the proportion of mature females that were berried or spent (PO).

In CRA 2, CRA 4, and CRA 5 there were two peaks in average male size during the year, one in late autumn (May to July) and one in spring (October to December) (Figure 9). In CRA 3 there is only one peak in SM during summer (December to April). In CRA 1, CRA 6 and CRA 9 there is evidence of similar patterns, although sampling has not been sufficiently distributed over months to confirm this. In CRA 7 there is a clear increase in the mean size of males from the start of the season in June until November.

The pattern in the proportion of males in the catch is similar to that for the mean size of males (Figure 10). In most areas, the lowest proportion of males occurs at about the same time as the lowest mean size of males.

The monthly pattern in the mean size of females shows less variation than for males in most QMAs (Figure 11). In CRA 7, the pattern is similar to that for males.

In QMAs 1,2,3,4,5 and 8 there are clear seasonal peaks in the proportion of mature females that are berried or spent (PO) during the winter months, June to September (Figure 12).

Statistical area

There were often large differences among statistical areas within each QMA for response variables. Statistical area accounted for most of the variation explained by the model for NU in CRA 1, CRA 4, CRA 5, and CRA 8. There was also a large difference in the proportion of males (PM) between statistical areas in CRA 3, CRA 4, CRA 5, and CRA 8. However, for most QMAs, statistical area explained less than 5% of the variation in PO. Statistical area explained little of the variation in the sex and size composition of the catch in CRA 7 (Table 12).

Depth

Depth was generally the less influential of factors affecting the demographics of *Jasus edwardsii* in New Zealand, with a few notable exceptions. It was the most influential factor affecting variability in NU in CRA 8 (Table 13, Figure 44), and the second most influential in determining NU in CRA 2 (Table 7, Figure 20). It was also important in determining size of males and females in CRA 7 (Table 12, Figure 40). Despite this, most QMAs do show distinct trends in some demographic variables with depth.

Programme

The difference between the catch sampling and logbook catch sampling programmes was estimated for those CRA areas were the two programmes had run simultaneously for at least one year - CRA 2, 3, 4, 5, 7, 8. In all these areas, the contribution of the programme factor to the fit of the model was small. Only for the PA response variable in CRA 3 and CRA 5 did the programme factor contribute to more than 5% of the variation explained.

The difference between the programmes was usually small and there was no consistency in the direction of effect across QMAs for most response variables (Table 5). Logbook samples on average had higher numbers per potlift than observer samples in those QMAs where the logbook programme contributes most of the data: CRA 2, CRA 5, and CRA 8. For the other

QMAs, where most of the data come from observer sampling the logbook programme had on average fewer lobsters per potlift.

Differences in average male and female tail widths were less than 1 mm in all QMAs (Table 5). There was very little difference in the proportion of males in the catch from the two programmes, except for CRA 4 where the logbook programme had on average a lower proportion of males.

There were greater differences between the two programmes in the proportion of females that were mature (PA) and the proportion of mature females that were berried or spent (PO). This may be due to differences in the codes used to record the maturity state of females and needs to be investigated further.

3.2.3 Models for each Quota Management Area

Patterns in the size and sex-distribution of *Jasus edwardsii* within each management area were examined. In the results of the model fits, italicised deviances mean that less than 5% of the deviance is explained by the model.

CRA 1

In CRA 1, model fits (adjusted-R^2) varied between 0.66 for proportion of ovigerous females (PO), and 0.12 for size of females (SF, Table 6).

Effect of fishing year.

Numbers remained stable over fishing years, but size of males and females showed an increasing trend from 1995 to 2000 (Figure 13). Proportion of males has oscillated significantly over time, but recent years show a decline. Proportion of mature and ovigerous or spent females is consistently high over time (over 0.95).

Effect of fishing month

Numbers are highest in September/October and decrease in November and December. Size of males decreases from September to October, and then increases again, reaching its peak in March (month 15). Proportion of males in the catch increases from October to January. Proportion of females that are mature is high (over 0.95) in July to October, and March, but decreases to 0.7 during November to February. Proportion of mature females that are ovigerous or spent mature decreases from over 0.9 in July-September to 0 in December-March.

Effect of statistical area.

Numbers are highest in Area 901 and lowest in 904. Average size of males and females is highest in Area 902 and lowest in Area 903. Proportion of males is significantly lower in Area 901 compared with 902. Proportion of females that are mature is also higher in area 901, than in 902, with the other areas overlapping. Proportion of mature females that are ovigerous or spent is high in all areas (over 0.95).

Effect of depth.

No clear trends are discernable for any response variable.

CRA 2

In CRA 2, model fits (Adjusted R^2) varied between 0.49 for proportion of ovigerous females, and 0.05 for total numbers (Table 7). There is no effect of catch sampling programme on any of the variables.

Effect of fishing year

From 1986 to 1991, numbers varied considerably (Figure 17). From 1993 to 2000, year-to-year variation in numbers is reduced, and numbers increase to 1996, and decrease between 1996 and 2000. Size of males and females shows an increasing trend from 1995 to 2000. Proportion of males has oscillated significantly over time, but recent years show a decline. Proportion of mature females increased from 0.75 in 1993 to 0.97 in 1996 to 2000. Proportion of ovigerous or spent females is consistently high from 1993 to 2000 (over 0.95).

Effect of fishing month

Total numbers peak in the middle of the fishing year (July-October), decrease from October to November, and again in February to March (Figure 18). Size of males is relatively constant, except in September and October, when it decreases suddenly (by about 5 mm TW) before increasing again in November and December. The size of females follows a similar pattern to total numbers, highest in June-November and decreasing marginally in December to March. Proportion of males in the catch is constant from April to August, then decreases substantially during September and November, before increasing again in December. The proportion of females that are mature is high (over 0.95) most of the year round, and slightly lower at the beginning (about 0.92) in July to October, and March, but decreases to 0.7 during November to February. The proportion of mature females that are berried or spent exhibit a strong cyclical pattern. In April and May, it is low (under 0.1), with a large increase in June (0.9), declining again during August-December.

Effect of statistical area

Numbers are significantly higher in Area 908, than in 905 (Figure 19). Average size of males and females is about 3 mm larger in Areas 905 and 907, than in 906 and 908. The proportion of males is lower (by about 0.1) in Area 908 than in 905. Proportion of females that are mature is very high across all statistical areas (0.98), as is proportion of mature females that are ovigerous or spent.

Effect of depth

There is a 50% increase (2 to 4 lobsters per pot) in total number of lobsters from 10 m to 70 m, and slight decrease in proportion of male lobsters with depth (by about 0.1 between 10 and 60m) (Figure 20). No effect of depth is evident for any other variables.

CRA 3

In CRA 3, model fits (Adjusted R^2) varied between 0.91 for proportion of ovigerous females, and 0.11 for proportion of males (Table 8). There is minimal effect of catch sampling programme on any of the variables.

Effect of fishing year

Numbers increased substantially from 1992 to 1996, decreased to 1999 and remained stable between 1999 and 2000. Size of males and females showed a similar trend, with the peak (largest sizes), lagging by 1 to 2 years, i.e., 1997 and 1998, instead of 1996. Proportion of males increased from 1990 to 1996 and has oscillated around 0.93 since. Proportion of mature and ovigerous or spent females is consistently high over time (over 0.97).

Effect of fishing month

There is a difference of 13 lobsters per potlift between the month with the highest catch rates (September) and the months with the lowest catch rates (April, August). Total numbers peak in the middle of the fishing year (September-November) and decline from November to March. The size of males and females decreases gradually (by about 1.5 mm) between April and September, before increasing again in November and December. The proportion of males in the catch is constant from April to August, then decreases substantially during September to November, before increasing again through November to March. The proportion of females that are mature is high (over 0.96) all year round. The proportion of mature females that are ovigerous or spent exhibits a strong cyclical pattern. In April it is low (under 0.1), with a large increase in June-August (0.98), and declines to 0 again by November.

Effect of statistical area

Numbers are significantly higher in Area 910 (14 lobsters per pot) than in 911 (6 lobsters per pot). The average size of males and females is about 3 mm and 4 mm higher in Area 911 than in 909 and 910. Proportion of males in Area 911 is 0.7, compared to 0.95 and 0.9 in Areas 909 and 910. The proportion of females that are mature is very high across all statistical areas (0.98), as is proportion of mature females that are ovigerous or spent.

Effect of depth

The highest numbers are found in the 10-30 m depth range, although the difference is not large compare to shallower and deeper depths. A stronger trend is evident with average size of males, which decrease by 2mm from 0 to 20m, then increase by 4 mm from 20 to 50m. A similar trend is seen for average size of females, although not as acute. The proportion of male lobsters increases by a factor of 0.1 between 0 and 50 m. No effect of depth is evident for proportion of mature females, or proportion of mature females that are ovigerous or spent.

CRA 4

In CRA 4, model fits (Adjusted R^2) varied between 0.79 for proportion of ovigerous females, and 0.08 for proportion of mature females (Table 9). There is minimal effect of catch sampling programme on any of the variables.

Effect of fishing year

The number of lobsters peaked in 1986, 1990, and 1997, with a small decline between 1998 and 2000. The size of males and females showed a roughly similar trend, lagged by a couple of years, with peaks (largest sizes) in 1988, 1991, 1994 to 1996, and 1998. The proportion of males oscillated from year to year, peaking in 1996, and declining between 1998 and 2000. The proportion of mature females has been consistently high (0.99) for all years, and proportion of ovigerous or spent females has varied between 0.7 and 0.9.

Effect of fishing month

Total numbers are relatively constant, with a peak in September, and lowest catch rates at the beginning (April) and end (February-March) of the fishing year. The size of males and females oscillates by 2 mm TW during most of the year, with July-October the months of lowest sizes, however, are far lower in April, compared to the rest of the fishing year. The proportion of males in the catch is relatively constant from April – August, then decreases substantially during September – January, before increasing again through February to March. The proportion of females that are mature is high (over 0.98) all year round. The proportion of mature females that are ovigerous or spent is low (under 0.1) in April, with a large increase in May-August (0.98), and declines to 0 again by November.

Effect of statistical area

Statistical area appears to be an important determining variable in CRA 4 and there is a distinct latitudinal trend (Areas 912 to 915 represent increasing latitude) in numbers and sizes. Area 912 is characterised by the largest number, smallest sizes, and highest proportion of males. Conversely, areas 914 and 915 were characterised by the smallest number, largest sizes, and lowest proportion of males. There is a 4 mm and 8 mm difference in average size of males and females respectively, between Area 912 and 915. The proportion of females that are mature is very high across all statistical areas (over 0.95), while proportion of mature females that are ovigerous or spent varies by 0.4 between Area 912 and the other statistical areas.

Effect of depth

There is a trend of increasing numbers with depth, with a difference of 5 lobsters per potlift between 10 and 50 m. No distinct trends are evident for the other response variables.

CRA 5

In CRA 5, model fits (Adjusted R^2) varied between 0.65 for proportion of ovigerous females and 0.08 for proportion of mature females (Table 10). There is minimal effect of catch sampling programme on any of the variables.

Effect of fishing year

Number of lobsters peaked in 1991, 1993, 1997, and 2000. The size of males and females showed a roughly similar trend, lagged by 1 to 2 years, with peaks (largest sizes) in 1992 (males and females) and 1999. The proportion of males oscillated from year to year, peaking in 1992 and 1996, and declining between 1998 and 2000. The Proportion of mature and ovigerous was consistently high between 1997 and 2000 (over 0.97).

Effect of fishing month

Total numbers oscillate slightly throughout the year, with peaks in May, September, and February. The size of males is bi-modal, peaking in May-June and December-January, but the size of females is relatively constant throughout the year. The proportion of males in the catch is also cyclical, constant in May-August, then dropping through September-November, before increasing sharply between November and March. The proportion of females that are mature exhibit two peaks – one in April and May, then again in November to December, with a drop of about 0.1 (relative to the highest months) between August and October. The proportion of mature females has the same cyclical pattern as found in CRA 2, 3, and 4.

Effect of statistical area

Statistical area appears to be an important determining variable in CRA 5 (Table 10). Area 916 is characterised by the largest number, highest proportion of males, and smallest sizes. Conversely, area 918 is characterised by the smallest number and largest size of males and female. For example, there is a 13 mm and 9 mm difference in average size of males between Areas 916 and 918. The proportion of females that are mature is very high across all statistical areas (over 0.95). The proportion of mature females that are ovigerous or spent is generally high (over 0.9), although Area 933 is lower than the other areas (by a factor of 0.3).

Effect of depth

There is a definite effect of depth on total numbers, with a difference of about 7 lobsters per pot between 20 m and 50 m. Average size of males and females is uninfluenced by depth from 0 to70m, after that it increases rapidly, with 5 to 6 mm difference in size of lobsters at 90 m, compared to 70 m. No distinct trends are evident for the other response variables.

CRA 6

In CRA 6, model fits (Adjusted R^2) varied between 0.84 for proportion of ovigerous females, and 0.07 for proportion of males (Table 11).

Effect of fishing year

Data are available only for 6 years (1989, 1993 to 1997). The peak in numbers in 1996 is accompanied by the lowest average size of males and females, but one year later (1997), size of males and females increases significantly (6 mm TW increase for males, 8 mm for females). This pattern (peak in numbers, followed by an increase in size, is similar to that found in CRA 2, 3, 4, and 5. The proportion of males in the catch is very low (about 0.15), and proportions of females that are mature, and ovigerous or spent, are very high (over 0.95).

Effect of fishing month

Number of lobsters per potlift oscillates between one and two. The size of males and females is lowest in August, then increases to a peak in November and December. The proportion of males is bimodal, with peaks in August and January. The proportions of females that are mature, and ovigerous or spent are very high throughout the fishing year (over 0.95). In this respect, CRA 6 differs from other QMAs, which show a strong seasonal trend in ovigerous and spent females.

Effect of statistical area

There is no effect of statistical area on numbers and sex-proportions. Area 941 has significantly smaller males (by 6 mm TW) and females (by 9 mm) than the other three areas.

Effect of depth

There are trends in average numbers and sex-proportion, however the wide confidence bands suggest a cautious interpretation. There is a suggestion that catches of males are proportionally greater in deeper waters (over 90 m) than shallow, but the confidence limits on the GAM plots are wide.

CRA 7

In CRA 7, model fits (Adjusted R^2) varied between 0.53 for proportion of mature females and 0.08 for proportion of males (Table 12). There is minimal effect of catch sampling programme on any of the variables.

Effect of fishing year

Number of lobsters declined between 1987 and 2000, except for an extreme peak in 1993 (an average of 11 per potlift, vs 1 to 2 during other years). The size of males and females varied over time, but not to any large degree, or with any dominant pattern. The proportion of males shows a similar pattern, oscillating between 0.5 and 0.55, and the proportion of mature females has been generally low (under 0.4), although recent years (*1999-2000*) show an increase. The proportion of mature females that are ovigerous or spent varies over time, but has generally been high (over 0.8).

Effect of fishing month

Numbers are constant throughout the fishing year, but size of males and females increases dramatically from October to November. At the same time, proportion of males decreases significantly. The proportion of females that are mature increases substantially between September and November, and proportion of females that are ovigerous or spent is high (over 0.8) for most of the fishing year.

Effect of statistical area

Statistical area is unimportant in determining size and sex proportion of lobsters in CRA 7.

Effect of depth

Depth explains the second largest amount of variation (after fishing year), of sizes of lobster in CRA 7. Largest sizes of females are caught between 10 and 20 m, but size drops rapidly after this.

CRA 8

In CRA 8, model fits (Adjusted R^2) varied between 0.44 for proportion of mature females, and 0.09 for proportion of males (Table 14). There is minimal effect of catch sampling programme.

Effect of fishing year

Numbers increased between 1988 and 1991, dropped substantially between 1991 and 1992, continued to decline between 1993 and 1997, and began to increase between 1997 and 2000. The size of males and females increased between 1990 and 1997, and then decreased between 1997 and 2000. Proportion of males increased between 1987 and 1992, decreased between 1992 and 1997, and increased again between 1997 and 2000. The proportion of mature females increased between 1988 and 1997, then decreased between 1997 and 2000. The proportion of mature females that are ovigerous or spent oscillated between 0.5 and 0.8 between fishing years.

Effect of fishing month

There is a seasonal trend in all response variables. Numbers caught are highest at the beginning (April) and end (March) of the fishing year, but there is also a peak in September. The average size of males and females oscillates between 4 and 5 mm TW throughout the year. There is a decrease between May and August, followed by a peak in December and a decline from December to March. As in other QMAs, the proportion of males in the catch decreases at the time that size of males is increasing (August to December). The proportion of females that are mature has a peak in May-June, and again in November to December, but declines at other parts of the year. The proportion of mature females that are ovigerous or spent shows a similar pattern to other QMAs. It increases rapidly between April and May, remains at almost 100% from May to July, then slowly decreases over the next 6 months (August-January).

Effect of statistical area

Pots in areas 924, 926 and 927 catch, on average, 40% more lobsters (5 vs 3 lobsters per pot) than other areas in CRA 8. The average size of males is about 1 mm TW lower in Area 927, compared to other areas, which are generally similar. There are greater differences in average size of females between areas. The largest females are found in area 927 and 928, and smallest females in Areas 925 and 922. These patterns also reflect a latitudinal trend. Females increase in size from Area 922 to 924, heading south-west down the east coast of Southland and Stewart Island. Females increase in size from Area 926-928, through Foveaux Strait up the west coast of Fiordland. The proportion of females that are mature differs greatly between statistical areas. In Areas 922 to 926, it is generally low (under 0.2), but increases dramatically in Area 927, and is higher still in Area 928. The proportion of mature females that are ovigerous or spent is similar in all areas (0.6 to 0.8), except Area 923, where it is lower (about 0.2).

Effect of depth

CRA 8 is the only QMA where the effect of depth on numbers of lobsters caught is greater than any other variable considered (Table 13). Lowest numbers are caught in shallow areas, numbers double between 20 and 70m, and then double again between 70 and 100m. The size of males is largest in shallower areas, decreases by an average of 4 mm TW to 50 m, and remains constant at greater than 50 m. The size of female also declines with depth, but the trend is more subtle, and the difference less, than for males. There is a minimal effect of depth on sex-composition of lobsters in CRA 8.

CRA 9

In CRA 9, model fits (Adjusted R^2) varied between 0.69 for proportion of ovigerous females, and 0.12 for total numbers (Table 14). There is minimal effect of catch sampling programme on any of the variables.

Effect of fishing year

Numbers and size of males and females have remained stable over fishing years, but the proportion of males has decreased since 1996. Data on proportion of mature and ovigerous or spent females are sketchy and no trends are discernable.

Effect of fishing month

Average numbers caught are highest in September, but the error bars (95% confidence limits) overlap for all months, indicating large variation in the data. There is a declining trend in average size of males (by 7 mm TW) and females (by 5 mm TW) from June to September, but again the error bars for each month overlap. The proportion of males also declines during June-September, and is generally low (under 0.2), however the data are variable. The proportion of females that are mature and oviegerous or spent is very high (over 0.9) all year round.

Effect of statistical area

Numbers caught in area 936 are about 30% higher than in 930, but all other areas have large variation. Clearer differences exist for size. Areas 930 and 936 have lower sizes of males and females (by 10 mm TW for males; 11 mm TW for females) compared to Areas 931 and 935. Area 930 and 931 have a larger proportion of males, compared to 935, 936, and 937. The proportion of females that are mature is over 0.8 in most areas, except 931, where very few mature females were found. The proportion of females that are ovigerous or spent varies greatly between areas, from under 0.05 in area 931, to about 0.99 in area 936.

Effect of depth

The proportion of males shows a sharp decline with depth, from an average of 0.7 in 0 to 10m, to less than 0.1 by 60 m depth. No other patterns are evident due to the wide variation in the data.

3.3 DISCUSSION

The review of factors affecting numbers, size and sex-composition of the commercial catch of *Jasus edwardsii* found a number of trends of importance to the fishery, and highlighted the wealth and volume of information present in the data set.

Recruitment variations appear to have been influential in many of the areas. In CRAs 2, 3, and 4, where data exists since 1986, there were three clear peaks in total numbers of lobsters in 1986, 1990 to 1991, and 1996 to 1997. In CRA 5, where the time series is shorter, there are peaks in 1990 to 1991, 1997, and again in 2000. There is also some evidence of a recruitment pulse (in 1996) in CRA 6, which has a shorter time series of data (1993 to 1997).

There are large differences in average size of males and females between QMAs. In CRA 6 and CRA 9 the average size of males and females was between 70 and 80mm TW. This compares to CRA 3 where the average size of males was 53 mm tail width.

There are also large differences in the proportion of females in the catch that are mature among QMAs. This probably arises because the size of maturity differs substantially among QMAs (Bentley & Starr 2001), but minimum legal length is similar (with the exception of CRA 7).

A trend highlighted by the review, but not previously identified, is the occurence of bi-modal peaks (late autumn and spring) in the seasonal cycle of proportion of males, which is evident to a greater or lesser degree, in all QMAs. The peaks were correlated with size of males, with the lowest proportion of males occurring at about the same time as the lowest mean size of males. We hypothesise that this pattern is the result of the moulting cycle of males. As the larger males moult in spring, they 'go off the bite', and consequently the only animals being caught are the smaller males not yet ready to moult.

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Table 1: Number of potlifts sampled by each catch sampling programme (C: observer, L: logbook).

QMA	1		2		3		4		5		6		7		8		9	
Source	O	L	O	L	O	L	O	L	O	L	O	L	O	L	O	L	O	L
1986			267		157		177											
1987			167				1 280						589		607			
1988							1 280						1 125		385			
1989					1 165		2 734		1 006		1 144		708		4 445			
1990			196		2 045		4 312		1 284				794		7 303			
1991			230		2 195		2 394		1 080				626		6 845			
1992					2 163		2 295		1 850				874		6 904			
1993		129		7 071	5 889	790	2 300		1 652		918		485	73	5 238	5 264		
1994		247		6 245	5 751	1 303	1 379		1 511	3 626	900		1 479	2 554	6 112	5 987		
1995		170		3 934	3 785	798	1 634		1 576	1 884	3 446		1 757		6 342	9 125		
1996				3 492	3 340	621	711		873	2 339	3 964		1 738		8 968	6 847		153
1997	1 252			2 953	2 714	152	4 220	213	566	1 725	2 372		1 411		3 881	6 578		147
1998	668			3 051	2 971	192	3 123	174	885	1 059			1 406		839	5 487		329
1999	1 722		1 437	3 585	2 073	7	4 639	119	2 669	2 054			1 991		693	2 670		153
2000	1 256		1 517	3 589	2 198	153	4 217	23	1 129	3 793			1 619		757	4 105		488

Table 2: Response variables examined and assumed distributions.

Variable	Abbreviation	Assumed distribution
Total number of lobsters caught	NU	Quasi-poisson
Average size (tail width) of males	SM	Gaussian
Average size (tail width) of females	SF	Gaussian
Proportion of lobsters that are male	PM	Binomial
Proportion of females that are mature	PA	Binomial
Proportion of mature females that are ovigerous or spent	PO	Binomial

Table 3: Independent variables examined and their treatment.

Variable	Abbreviation	Variable Type
Fishing year	FY	Factor
Fishing month	FM	Factor
Statistical area	ST	Factor
Depth	DE	Continuous
Programme	PR	Factor

Table 4: Standard statistical area and month for each QMA.

CRA	Stat	Month
1	904	8
2	906	8
3	910	6
4	914	5
5	917	5
6	942	10
7	920	7
8	926	9
9	935	8

Table 5: Estimated effect of programme type on response variables. Values represent the average for the logbook programme relative to the observer programme. They are the inverse of the link function for the logbook coefficient and thus have different interpretations dependent upon the link function: NU-multiplicative; SM, SF-additive; PM,PA,PO-maximum proportional difference. For example, in CRA 2 - NU: 1.22 means 22% greater numbers per potlift for logbooks. SM: –0.16 means that male lobsters measured by the logbook programme are, on average, 0.16 mm less than those measured by the observer programme. PM: 0.03 means that if the observer programme had 50% males, the observer programme would have 53%. Numbers in parentheses are 95% confidence intervals.

	Response variable					
QMA	NU	SM	SF	PM	PA	PO
CRA 2	1.22 (1.14,1.3)	-0.16 (-0.59,0.28)	-0.4 (-0.75,-0.05)	0.03 (0.01,0.04)	0.12 (0.04,0.19)	-0.39 (-0.42,-0.36)
CRA 3	0.93 (0.9,0.96)	0.63 (0.52,0.75)	0.57 (0.31,0.83)	0.02 (0.01,0.04)	0.2 (0.14,0.26)	-0.14 (-0.21,-0.05)
CRA 4	0.96 (0.87,1.06)	-0.46 (-0.89,-0.04)	-0.82 (-1.35,-0.29)	-0.15 (-0.17,-0.12)	-0.05 (-0.21,0.12)	-0.47 (-0.47,-0.45)
CRA 5	1.23 (1.2,1.27)	0.24 (0.04,0.43)	0.48 (0.28,0.69)	-0.01 (-0.02,0)	-0.22 (-0.24,-0.19)	-0.18 (-0.2,-0.16)
CRA 7	0.72 (0.66,0.79)	0.46 (-0.01,0.93)	0.82 (0.28,1.36)	0.02 (0,0.04)	0.42 (0.36,0.46)	-0.27 (-0.39,-0.09)
CRA 8	1.14 (1.12,1.16)	-0.39 (-0.51,-0.27)	-0.36 (-0.48,-0.24)	0.03 (0.02,0.03)	0.01 (0,0.02)	-0.11 (-0.12,-0.1)

Table 6: **Analysis of deviance and diagnostic statistics for CRA 1 models. NU: Number of lobsters; SM: average size (tail width) of males; SF: average size (tail width) of females; PM: proportion of lobsters that are male; PA: proportion of females that are mature; PO: proportion of mature females that are ovigerous or spent. Deviance shows the proportion of variation explained by each of the independent variables. d.f: degrees of freedom; Adj. R^2: adjusted R^2; Scale: estimated scale parameters; s.d.s.r: standard deviation of standardised residuals. m.a.s.r: median of standardised residuals.**

	NU	SM	SF	PM	PA	PO
Deviance						
FY	1 526	14 510	9 143	470	205	2 205
FM	1 113	40 307	1 556	447	260	795
ST	3 782	28 685	2 476	376	180	*141*
DE	711	*2 776*	7 122	*55*	68	*31*
Total	27 461	253 387	177 022	7 904	3 190	4 808
d.f.						
Model	21.4	24.9	23.8	23.3	23.5	22.7
Total	5 444	2 988	2 609	3 666	2 609	2 441
Diagnostics						
Adj. R^2	0.25	0.34	0.11	0.11	0.15	0.66
Scale	4.11	44.17	43.09	1.47	1.23	1.23
s.d.s.r	1.00	1.00	1.00	0.60	0.70	0.74
m.a.s.r	0.59	0.60	0.57	0.50	0.28	0.18

Table 7: **Analysis of deviance and diagnostic statistics for CRA 2 models. See Table 6 for explanations of abbreviations.**

	NU	SM	SF	PM	PA	PO
Deviance						
FY	2 911	75 572	86 786	1 677	4 851	3 324
FM	2 012	26 773	7 824	2 202	750	15 835
ST	1 685	50 979	53 128	683	*174*	*60*
PR	*216*	*9*	*139*	*9*	*13*	*855*
DE	2 835	10 988	*2 368*	648	*293*	*175*
Total	159 250	1 088 854	712 052	51 553	22 490	44 883
d.f.						
Model	34.8	33.5	34.7	34.8	34.9	34.4
Total	37 734	20 473	18509	25864	18509	17609
Diagnostics						
Adj. R^2	0.05	0.15	0.21	0.09	0.12	0.49
Scale	5.10	45.20	30.41	1.42	1.41	2.44
s.d.s.r	1.00	1.00	1.00	0.61	0.72	0.66
m.a.s.r	0.59	0.62	0.59	0.56	0.22	0.18

Table 8: Analysis of deviance and diagnostic statistics for CRA 3 models. See Table 6 for explanations of abbreviations.

	NU	SM	SF	PM	PA	PO
Deviance						
FY	9 851	25 387	10 123	10 601	348	10 776
FM	52 453	17 689	36 302	4 707	394	48 041
ST	33 641	46 814	36 606	10 155	264	*93*
PR	*155*	*1 209*	*419*	*18*	71	*20*
DE	*2 210*	7 474	*2 366*	*1 331*	*55*	*228*
Total	383 883	33 0206	376 651	105 960	12 971	65 480
d.f.						
Model	33.7	34.0	33.8	32.7	31.6	31.9
Total	40 462	28 640	15 414	29 624	15 418	14 837
Diagnostics						
Adj. R^2	0.24	0.30	0.23	0.11	0.04	0.91
Scale	7.40	8.10	18.91	2.73	1.51	2.15
s.d.s.r	1.00	1.00	1.00	0.40	0.75	0.88
m.a.s.r	0.65	0.47	0.56	0.22	0.18	0.09

Table 9: Analysis of deviance and diagnostic statistics for CRA 4 models. See Table 6 for explanations of abbreviations.

	NU	SM	SF	PM	PA	PO
Deviance						
FY	21 035	114 919	163 588	8 875	1 760	47 714
FM	8 703	12 491	*9 409*	4 590	1 159	20 356
ST	46 012	43 615	94 008	12 972	1 077	*1 336*
PR	*31*	*82*	*320*	*117*	*0*	*1 027*
DE	9 637	*3 806*	*2 171*	1 601	*86*	*519*
Total	355 615	485 141	652 082	106 229	18 224	87 134
d.f.						
Model	36.8	37.0	40.8	42.1	37.2	37.0
Total	37 224	22 984	17 993	25 820	17 994	17 472
Diagnostics						
Adj. R^2	0.20	0.36	0.41	0.15	0.08	0.79
Scale	8.25	13.52	21.28	2.66	2.03	2.36
s.d.s.r	1.00	1.00	1.00	0.42	0.69	0.69
m.a.s.r	0.60	0.48	0.54	0.30	0.13	0.12

Table 10: Analysis of deviance and diagnostic statistics for CRA 5 models. See Table 6 for explanations of abbreviations.

	NU	SM	SF	PM	PA	PO
Deviance						
FY	14 567	168 422	182 174	1 612	8 771	6 582
FM	13 565	20 742	*6 929*	7 652	2 155	31 583
ST	32 118	38 216	65 176	11 236	*481*	2 327
PR	*1584*	*206*	*1 181*	*31*	684	*734*
DE	14 103	14 283	*12 455*	*521*	659	*293*
Total	258 691	720 088	832 270	77 669	39 812	69 418
d.f.						
Model	34.9	34.9	34.8	34.4	34.8	33.3
Total	32 548	19 051	19 250	24 180	19 533	18 302
Diagnostics						
Adj. R^2	0.29	0.34	0.32	0.12	0.18	0.65
Scale	6.65	25.15	29.37	1.99	1.94	2.49
s.d.s.r	1.00	1.00	1.00	0.50	0.60	0.63
m.a.s.r	0.58	0.47	0.51	0.38	0.21	0.18

Table 11: Analysis of deviance and diagnostic statistics for CRA 6 models. See Table 6 for explanations of abbreviations.

	NU	SM	SF	PM	PA	PO
Deviance						
FY	4 149	107 496	44 332	89	369	5 760
FM	1 568	39 639	34 591	385	364	1 504
ST	767	32 233	66 220	94	60	*44*
DE	677	*3 899*	*4 176*	225	43	*47*
Total	44 657	532 456	514 588	1 091	2 933	8 966
d.f.						
Model	21.8	19.7	20.5	23.1	19.0	19.7
Total	12 744	3 482	3 463	5 388	3 463	3 348
Diagnostics						
Adj. R^2	0.10	0.34	0.29	0.06	0.15	0.83
Scale	4.35	82.08	94.52	1.47	1.22	0.84
s.d.s.r	1.00	1.00	1.00	0.72	0.78	0.81
m.a.s.r	0.45	0.64	0.65	0.70	0.17	0.17

Table 12: Analysis of deviance and diagnostic statistics for CRA 7 models. See Table 6 for explanations of abbreviations.

	NU	SM	SF	PM	PA	PO
Deviance						
FY	23 055	29 928	35 134	143	1 396	280
FM	2 328	91 632	213 173	553	2 373	30
ST	3 369	*319*	*1 061*	*3*	*10*	*0*
PR	*61*	*157*	*203*	*12*	*101*	*6*
DE	2 663	28 632	46 803	77	555	22
Total	117 216	342 607	549 118	14 020	7 475	781
d.f.						
Model	29.9	30.3	30.0	29.9	29.8	29.2
Total	19 229	7 558	7 836	10 068	7 836	704
Diagnostics						
Adj. R^2	0.28	0.45	0.54	0.04	0.53	0.29
Scale	6.25	24.99	32.38	1.04	2.62	0.78
s.d.s.r	1.00	1.00	1.00	0.70	0.77	0.90
m.a.s.r	0.49	0.51	0.46	0.58	0.06	0.22

Table 13: Analysis of deviance and diagnostic statistics for CRA 8 models. See Table 6 for explanations of abbreviations.

	NU	SM	SF	PM	PA	PO
Deviance						
FY	41 370	124 064	209 296	3 525	7 040	6 103
FM	37 899	157 284	80 183	1 880	15 619	35 851
ST	69 621	29 681	104 210	10 944	78 162	*2 023*
DE	*3 450*	*2 959*	*2 905*	*122*	*7*	*522*
Total	126 554	124 267	77 586	*558*	5 517	*1 346*
d.f.						
Model	39.9	40.0	39.8	39.9	40.0	38.1
Total	105 379	54 290	62 686	73 064	6 2998	43 477
Diagnostics						
Adj. R^2	0.20	0.22	0.18	0.09	0.44	0.37
Scale	8.66	28.68	33.63	1.38	2.27	1.77
s.d.s.r	1.00	1.00	1.00	0.57	0.56	0.68
m.a.s.r	0.53	0.45	0.53	0.42	0.32	0.40

Table 14: Analysis of deviance and diagnostic statistics for CRA 9 models. See Table 6 for details.

	NU	SM	SF	PM	PA	PO
Deviance						
FY	107	12 949	10 000	87	93	390
FM	281	2 559	4 038	161	75	355
ST	128	3 152	3 853	61	26	47
DE	98	1 416	*193*	146	*-11*	*29*
Total	4 011	51 088	41 542	1 656	593	1 062
d.f.						
Model	20.2	19.9	16.5	20.7	15.0	19.6
Total	1 268	569	505	775	505	483
Diagnostics						
Adj. R^2	0.12	0.37	0.42	0.25	0.15	0.69
Scale	3.25	45.16	41.35	1.30	1.65	0.96
s.d.s.r	1.00	0.98	0.98	0.67	0.85	0.77
m.a.s.r	0.56	0.56	0.59	0.57	0.22	0.11

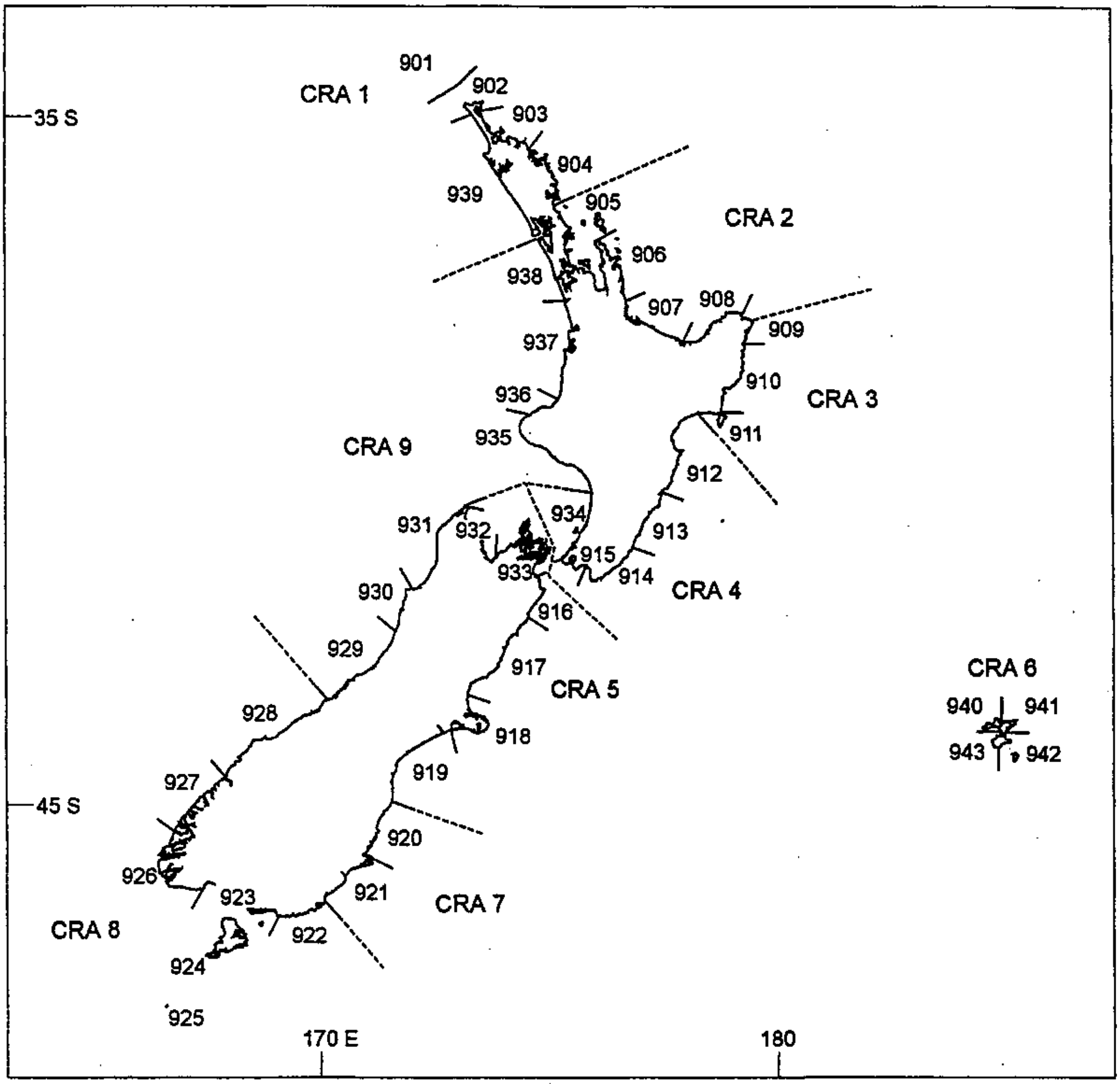

Figure 1: Map of Statistical Areas and Quota Management Areas (QMAs) for the New Zealand *Jasus edwardsii* fishery

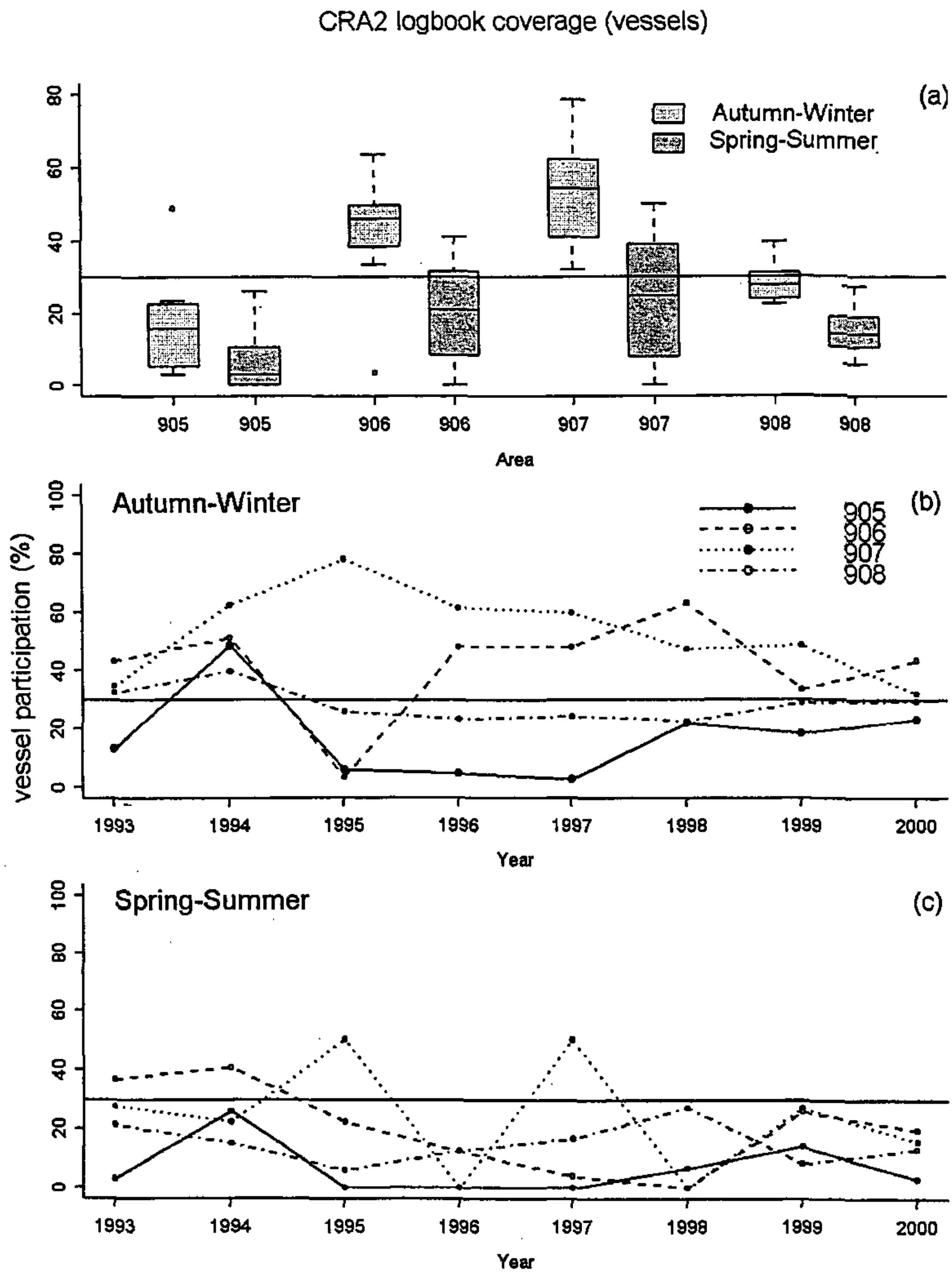

Figure 2: **Percentage vessel participation rate in the logbook scheme for CRA 2 during 1993 to 2000. (a) boxplots of coverage divided into seasons. The middle line is the average coverage, and the length of the boxes represents 75% of values. Plots (b) and (c) are the coverage over time for autumn-winter and spring-summer respectively. The horizontal line at 30% is the recommended participation rate (Bentley et al. 2002).**

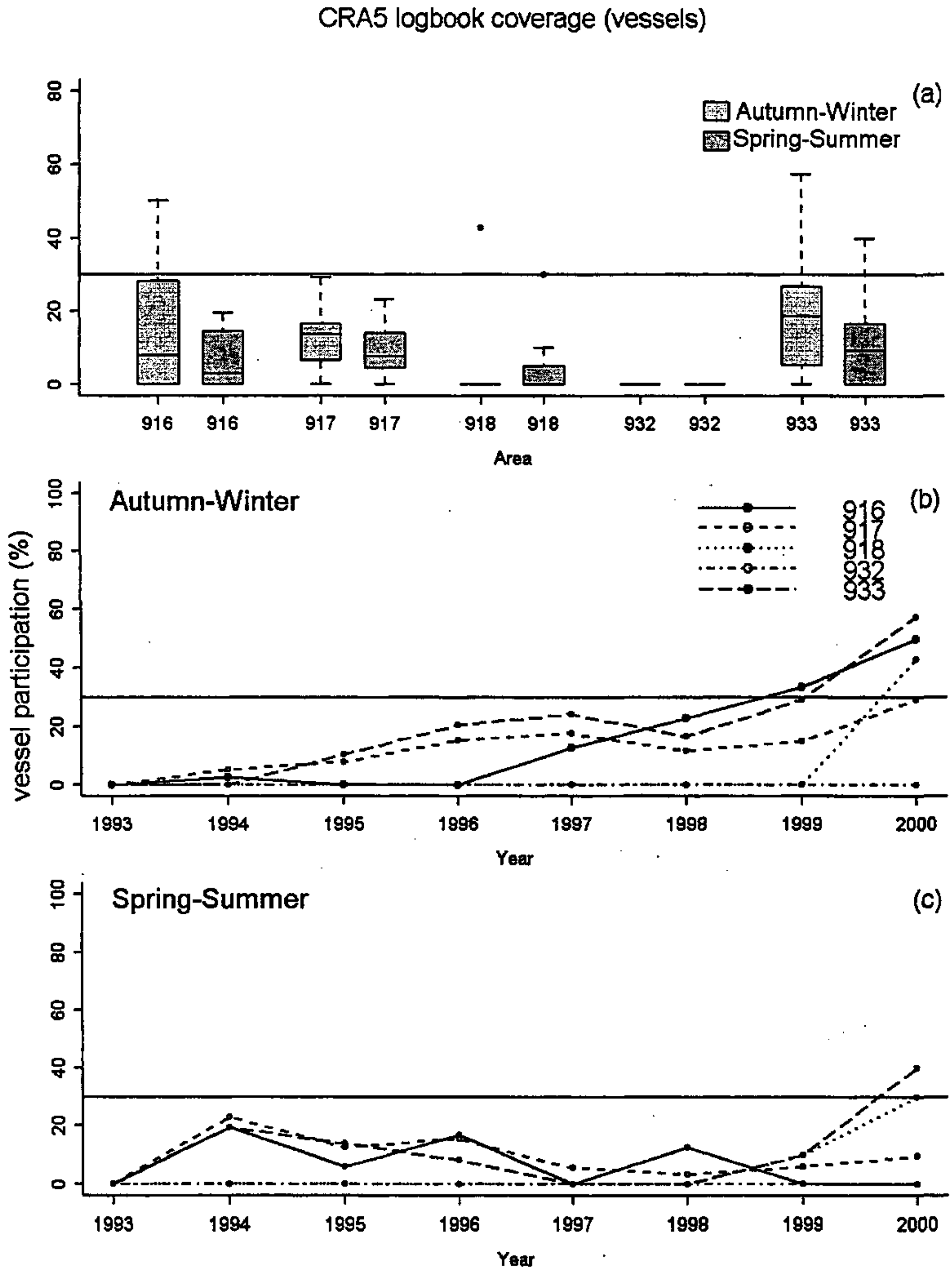

Figure 3: Percentage vessel participation rate in the logbook for CRA5 during 1993 to 2000. Data in (a) are boxplots of coverage divided into seasons. The middle line is the average coverage, and the length of the boxes represents 75% of values. Plots (b) and (c) are the coverage over time for autumn-winter and spring-summer respectively. The horizontal line at 30% is the recommended participation rate (Bentley et al. 2002).

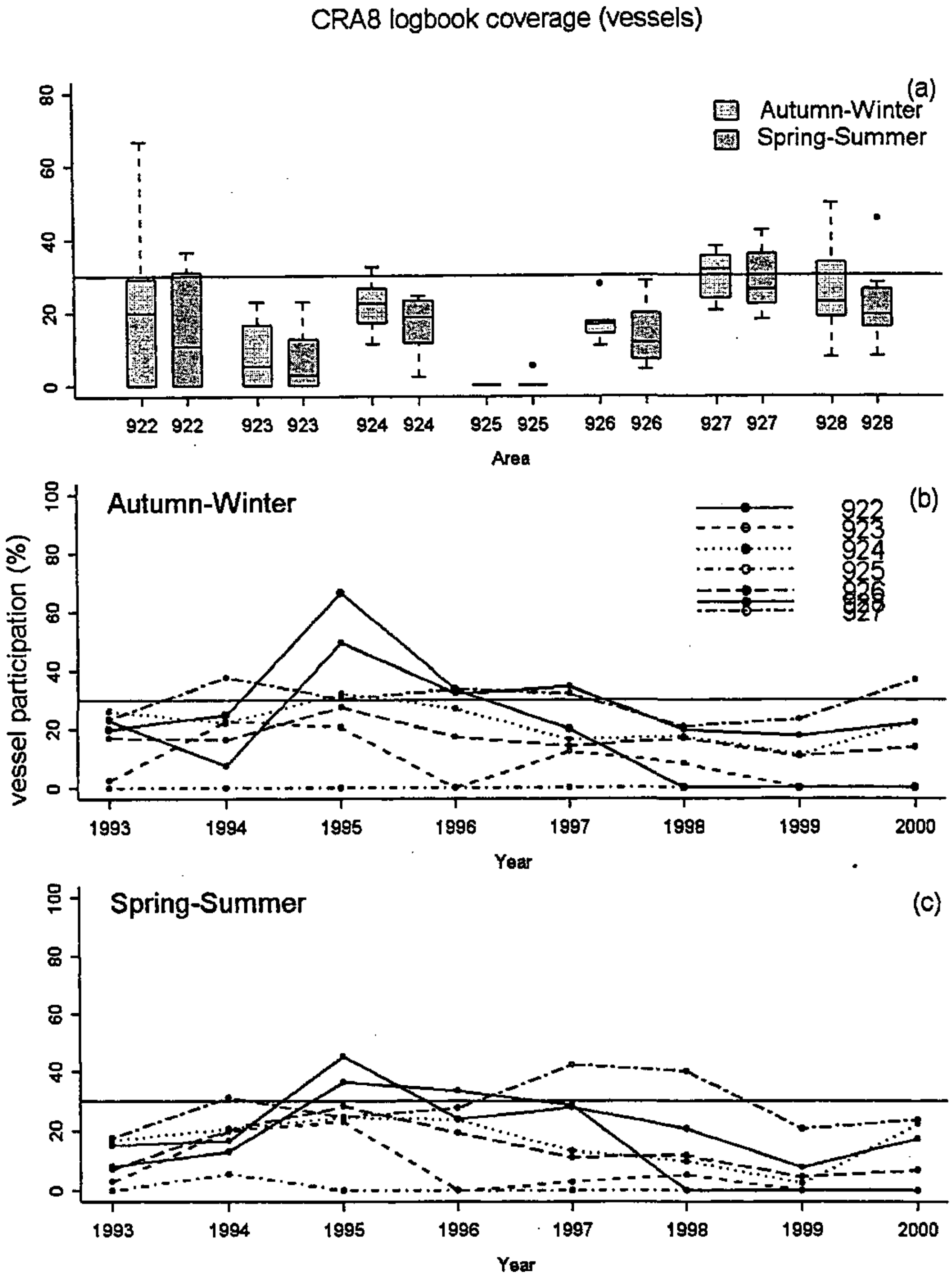

Figure 4: Percentage vessel participation rate in the logbook for CRA8 during 1993 to 2000. Data in (a) are boxplots of coverage divided into seasons. The middle line is the average coverage, and the length of the boxes represents 75% of values. Plots (b) and (c) are the coverage over time for autumn-winter and spring-summer respectively. The horizontal line at 30% is the recommended participation rate (Bentley et al. 2002).

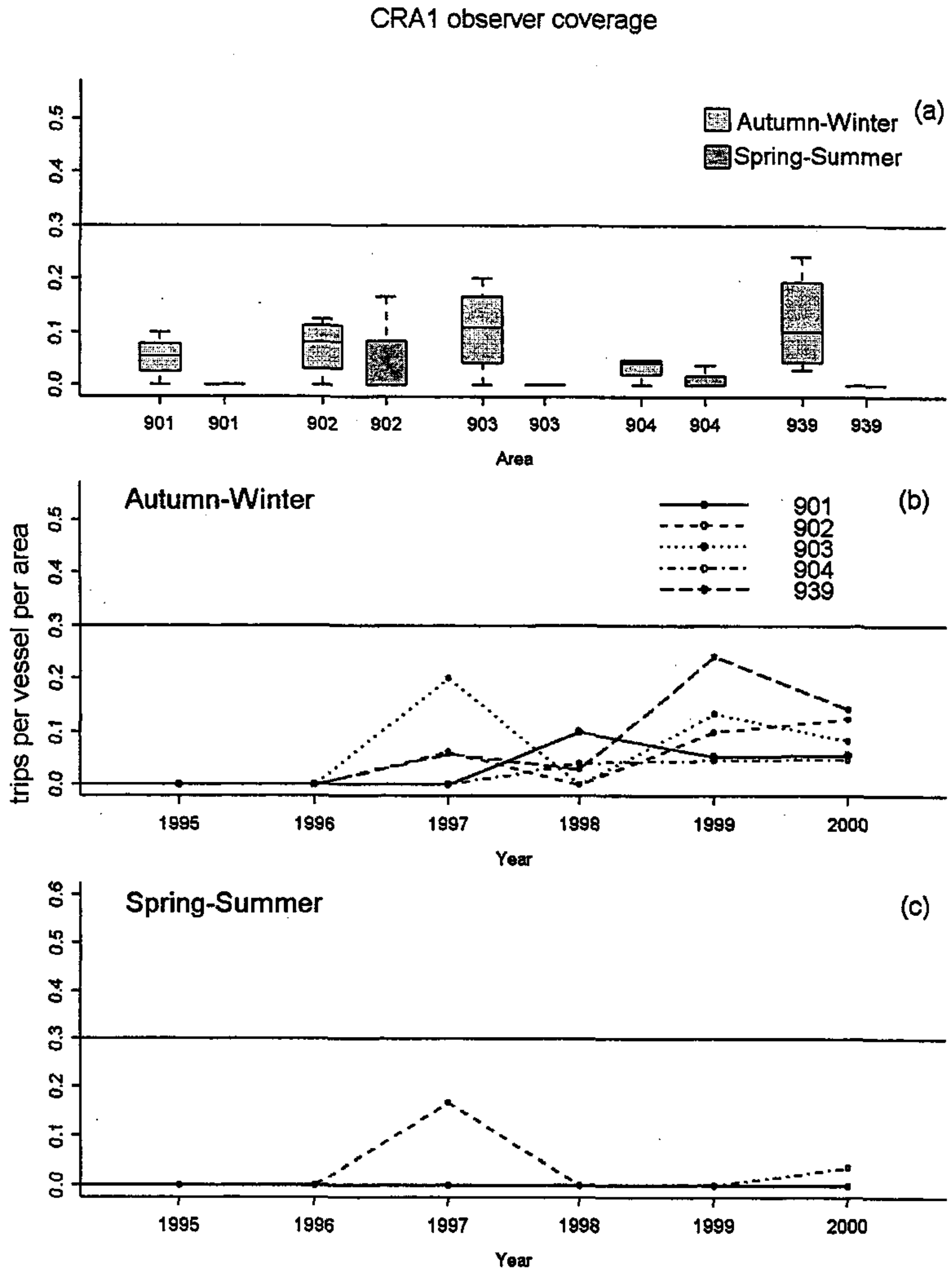

Figure 5: Observer coverage (trips per vessel per area) in CRA1. Data in (a) are boxplots of coverage divided into seasons. The middle line is the average coverage (1997-2000), and the length of the boxes represents 75% of values. Plots (b) and (c) are the coverage over time for autumn-winter and spring-summer respectively. The horizontal line at 0.3 is the recommended minimum sampling rate (Bentley et al., 2002).

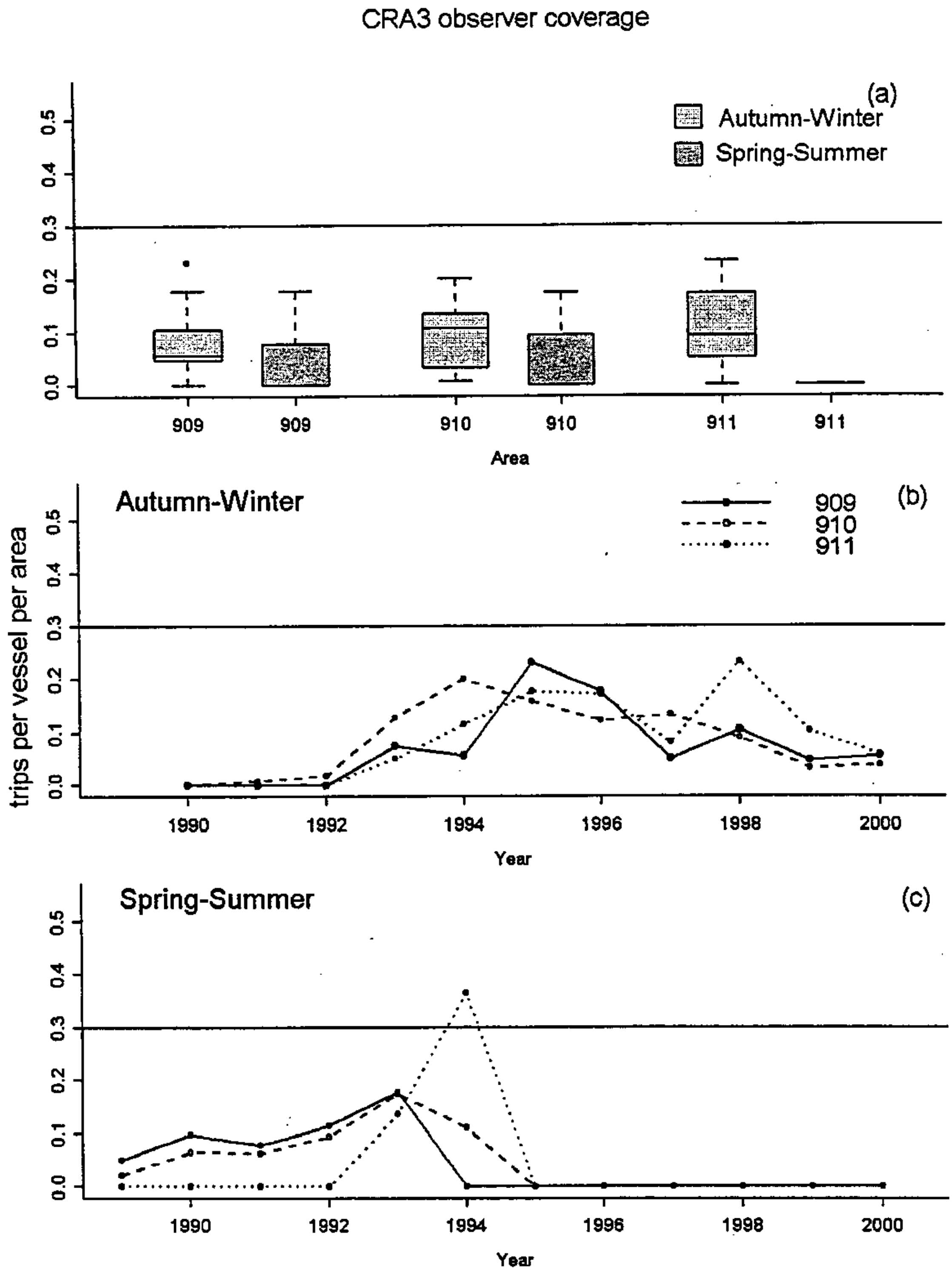

Figure 6: Observer coverage (trips per vessel per area) in CRA3. Data in (a) are boxplots of coverage divided into seasons. The middle line is the average coverage (1997-2000), and the length of the boxes represents 75% of values. Plots (b) and (c) are the coverage over time for autumn-winter and spring-summer respectively. The horizontal line at 0.3 is the recommended minimum sampling rate (Bentley et al., 2002).

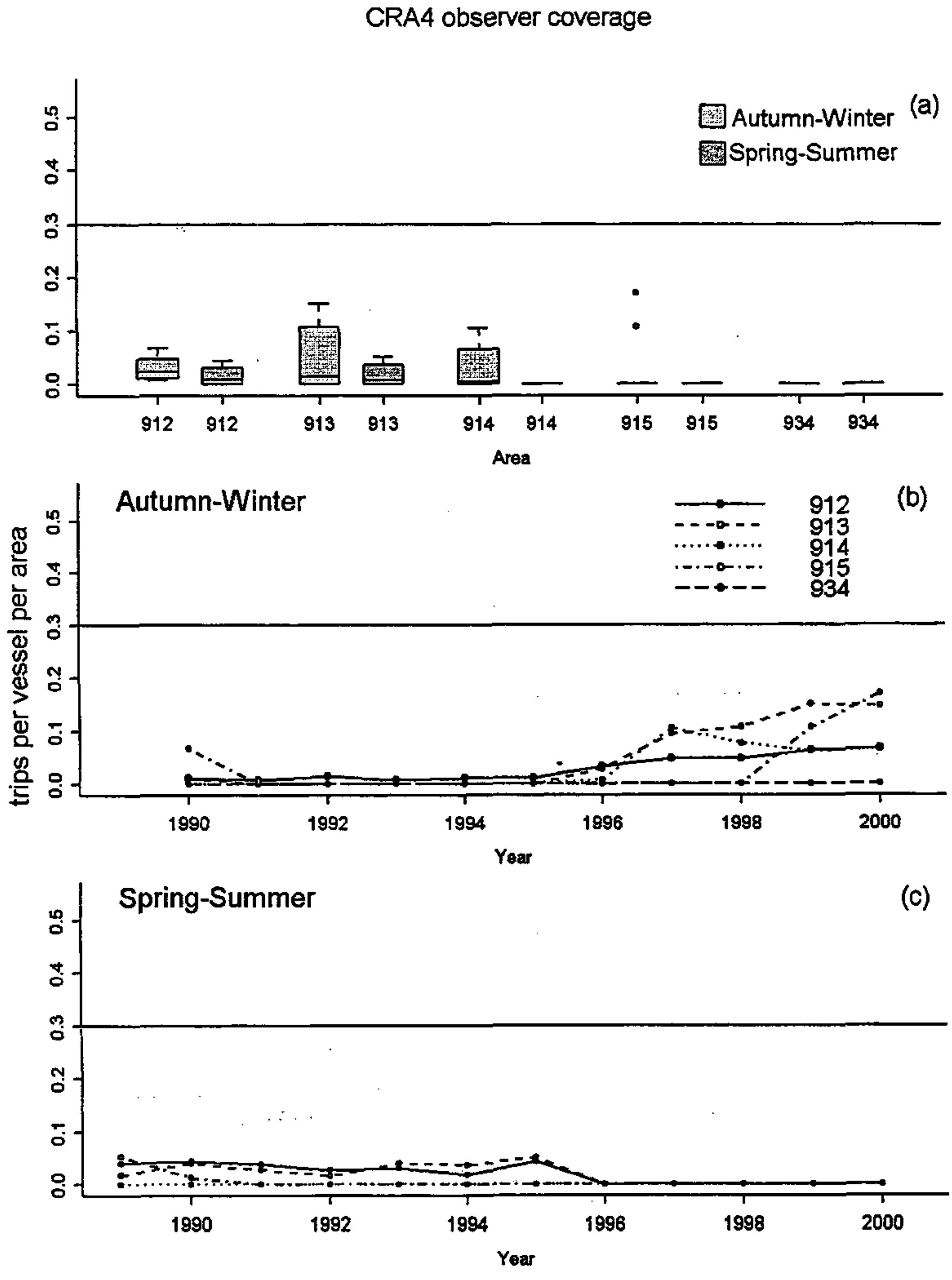

Figure 7: Observer coverage (trips per vessel per area) in CRA4. Data in (a) are boxplots of coverage divided into seasons. The middle line is the average coverage (1997-2000), and the length of the boxes represents 75% of values. Plots (b) and (c) are the coverage over time for autumn-winter and spring-summer respectively. The horizontal line at 0.3 is the recommended minimum sampling rate (Bentley et al., 2002).

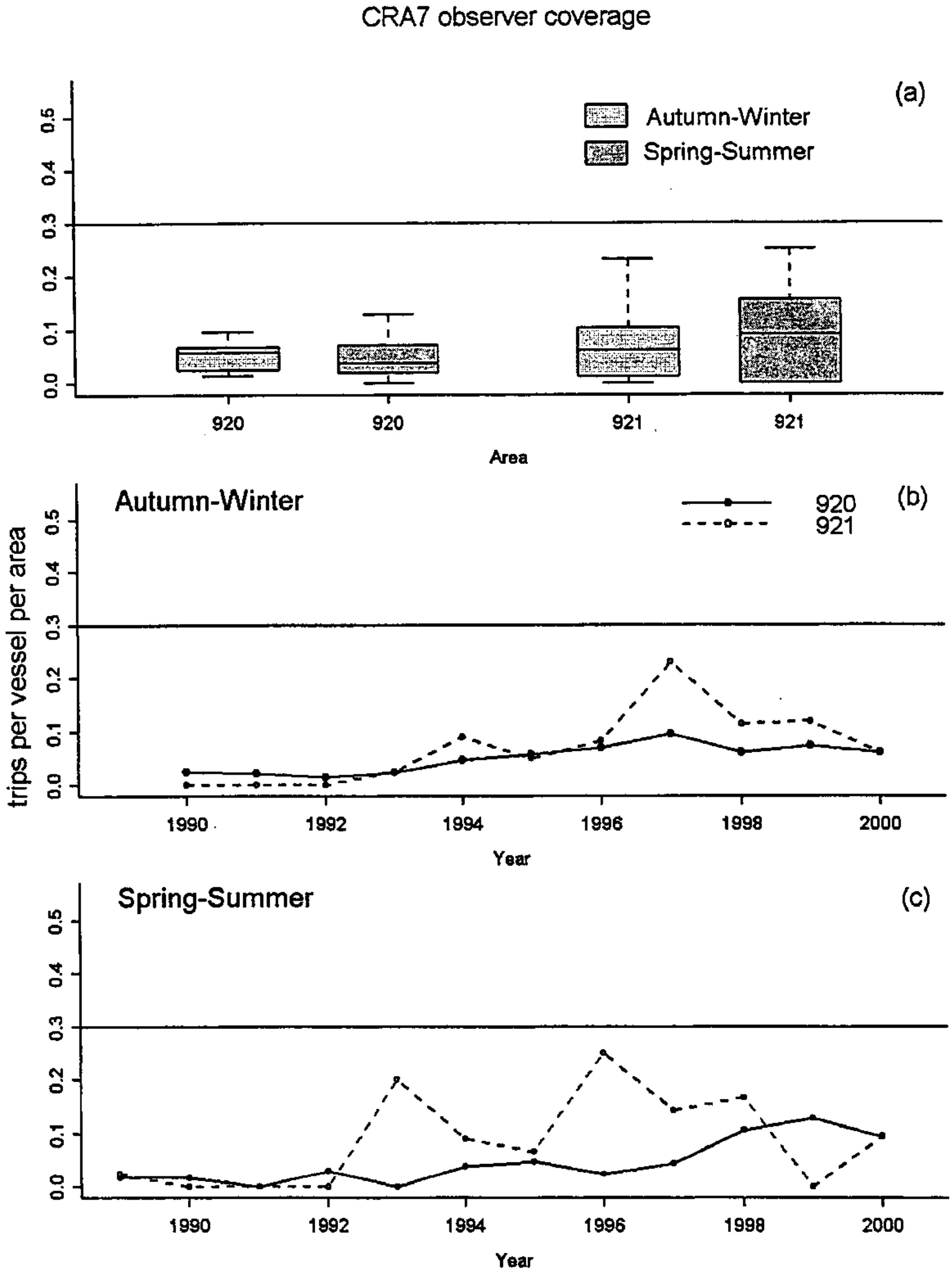

Figure 8: Observer coverage (trips per vessel per area) in CRA7. Data in (a) are boxplots of coverage divided into seasons. The middle line is the average coverage (1997-2000), and the length of the boxes represents 75% of values. Plots (b) and (c) are the coverage over time for autumn-winter and spring-summer respectively. The horizontal line at 0.3 is the recommended minimum sampling rate (Bentley et al., 2002).

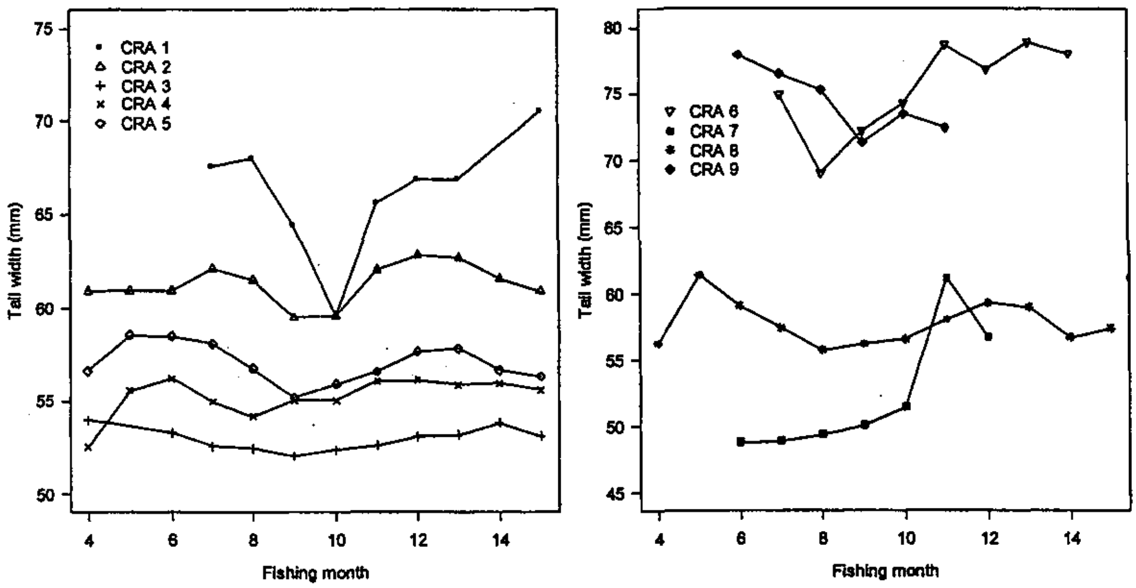

Figure 9: Seasonal patterns in mean size of male lobsters for each CRA area.

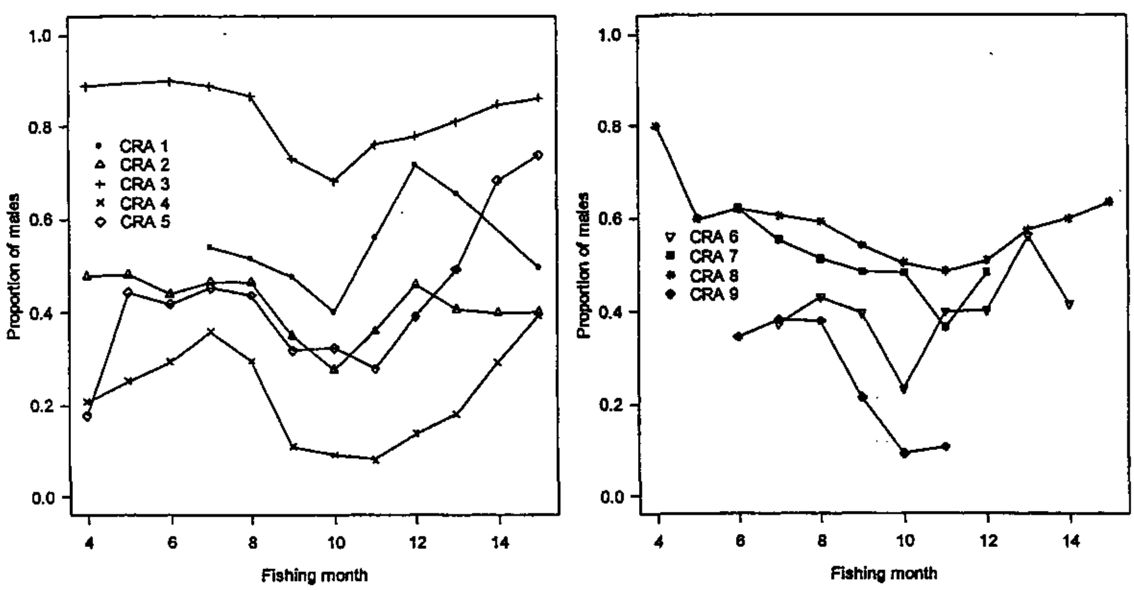

Figure 10: Seasonal patterns in the proportion of male lobsters in the catch for each CRA area.

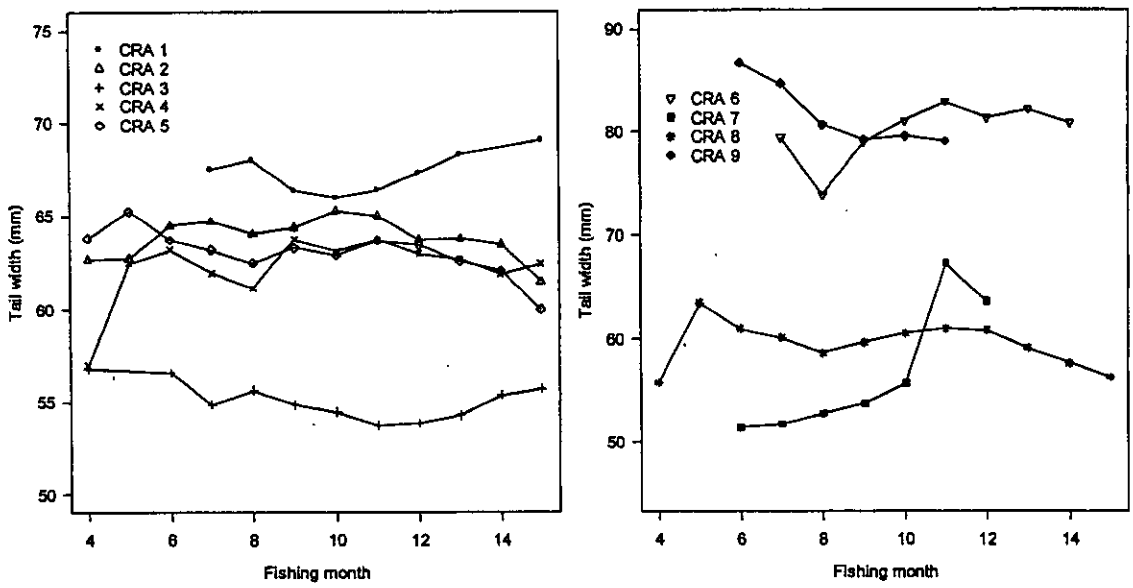

Figure 11: Seasonal patterns in mean size of female lobsters for each CRA area.

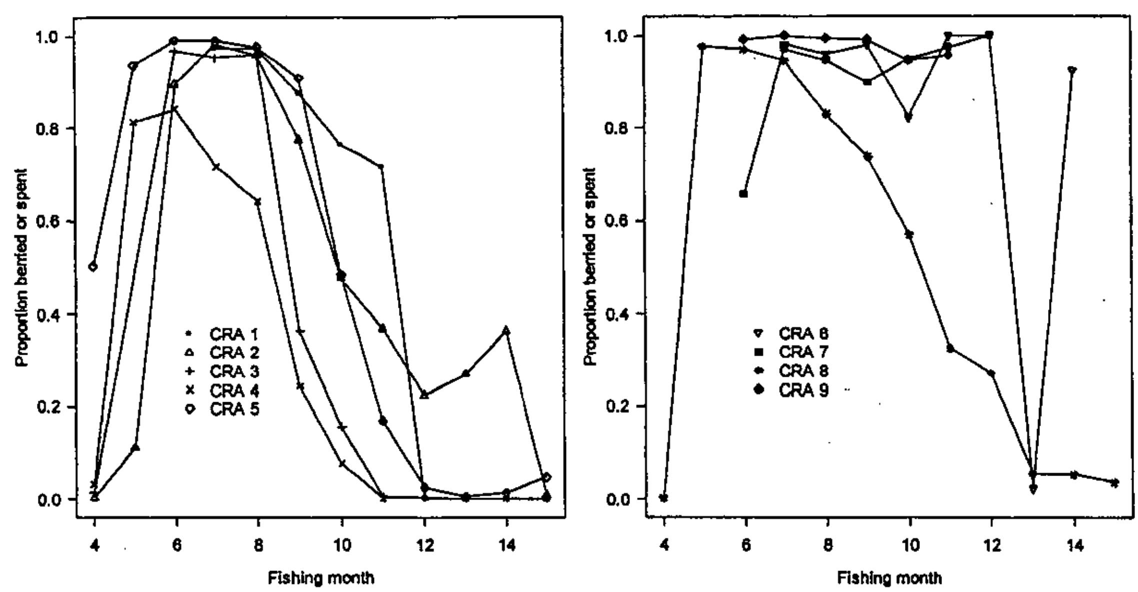

Figure 12: Seasonal patterns in the proportion of mature females that are ovigerous or spent for each CRA area.

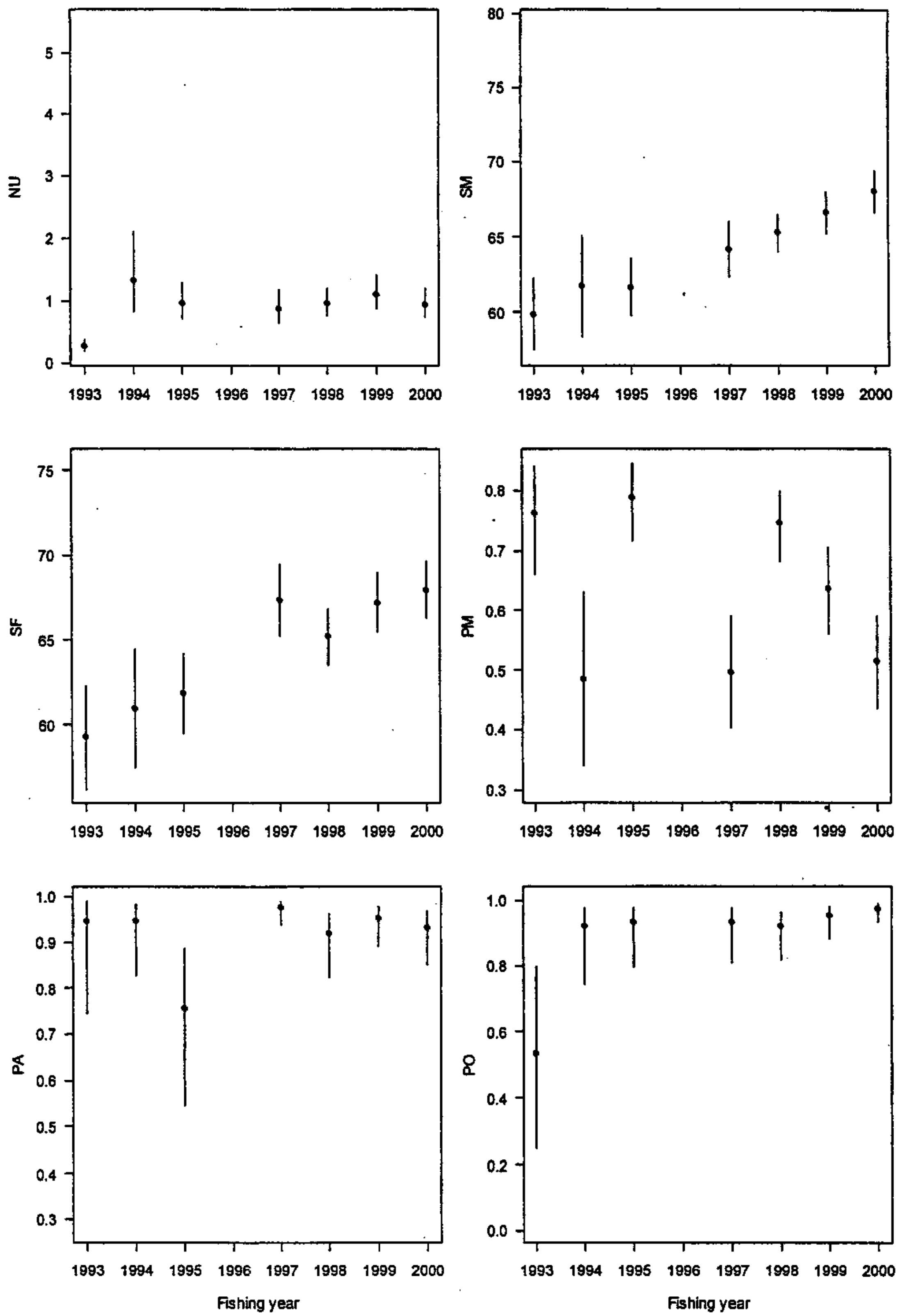

Figure 13: Estimated effect of fishing year on response variables for CRA 1. Vertical lines represent 95% confidence limits. . NU: Number of lobsters; SM: average size (tail width) of males; SF: average size (tail width) of females; PM: proportion of lobsters that are male; PA: proportion of females that are mature; PO: proportion of mature females that are ovigerous or spent.

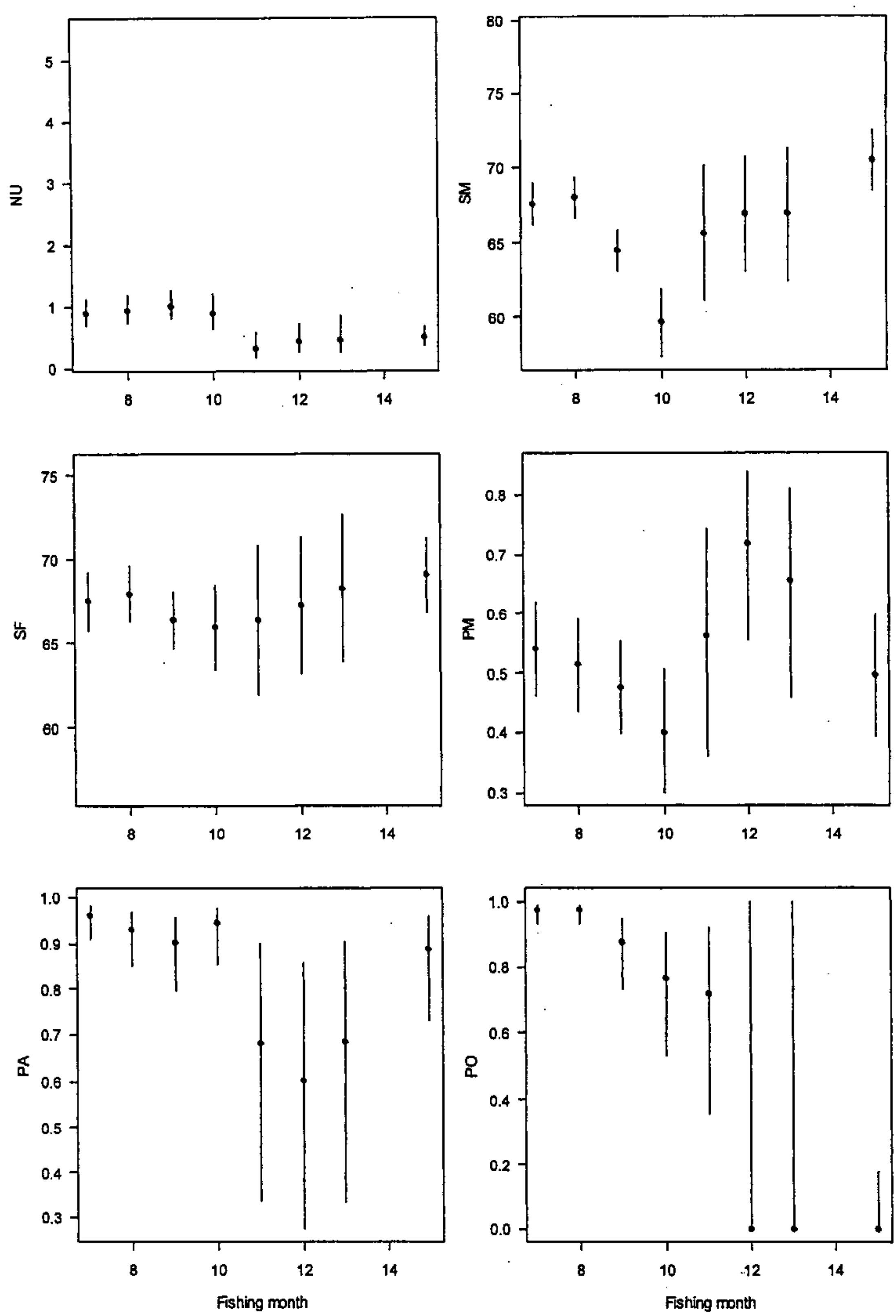

Figure 14: Estimated effect of fishing month on response variables for CRA 1. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

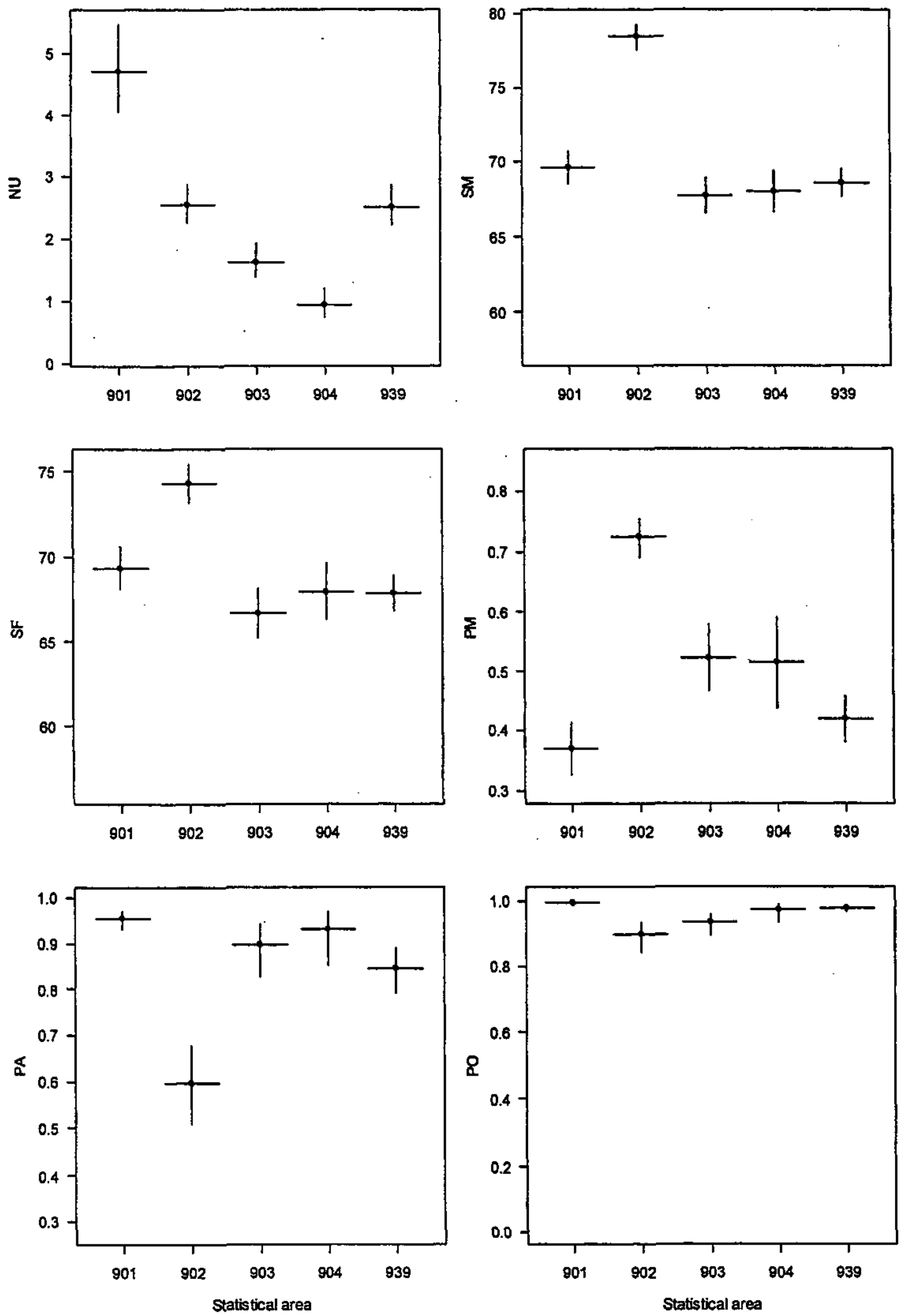

Figure 15: Estimated effect of statistical area on response variables for CRA 1. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

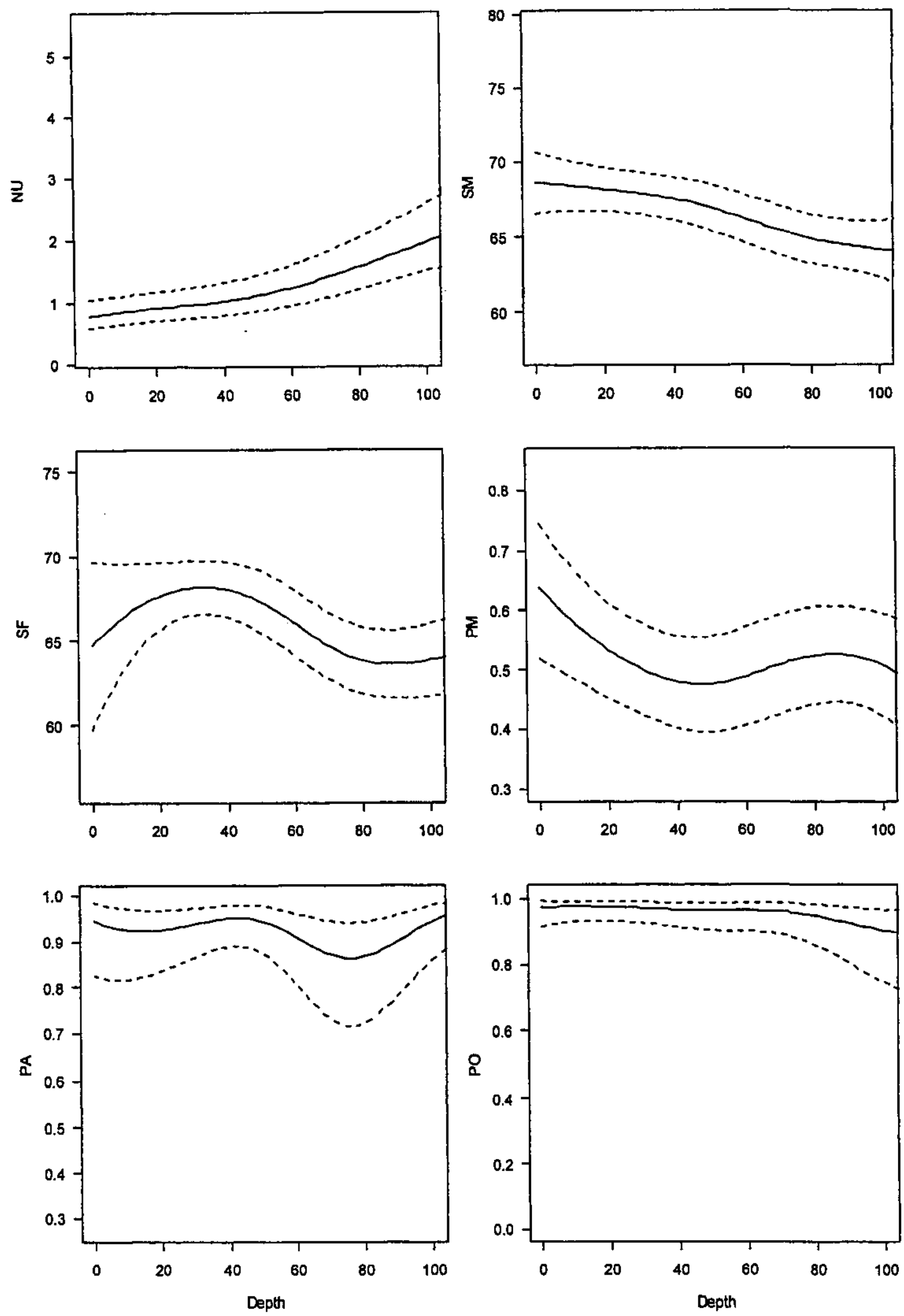

Figure 16: Estimated effect of depth on response variables for CRA 1. Dashed lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

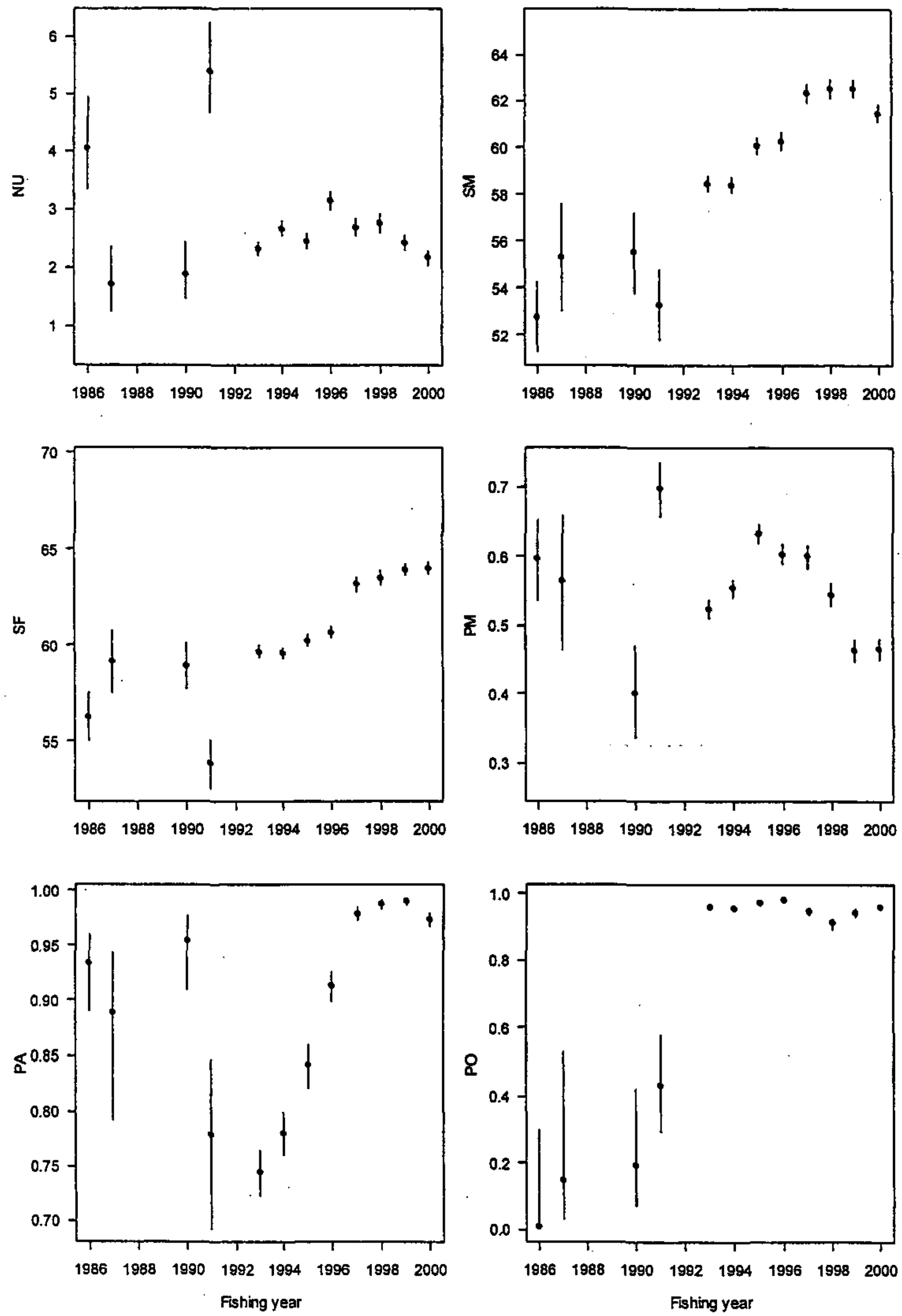

Figure 17: Estimated effect of fishing year on response variables for CRA 2. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

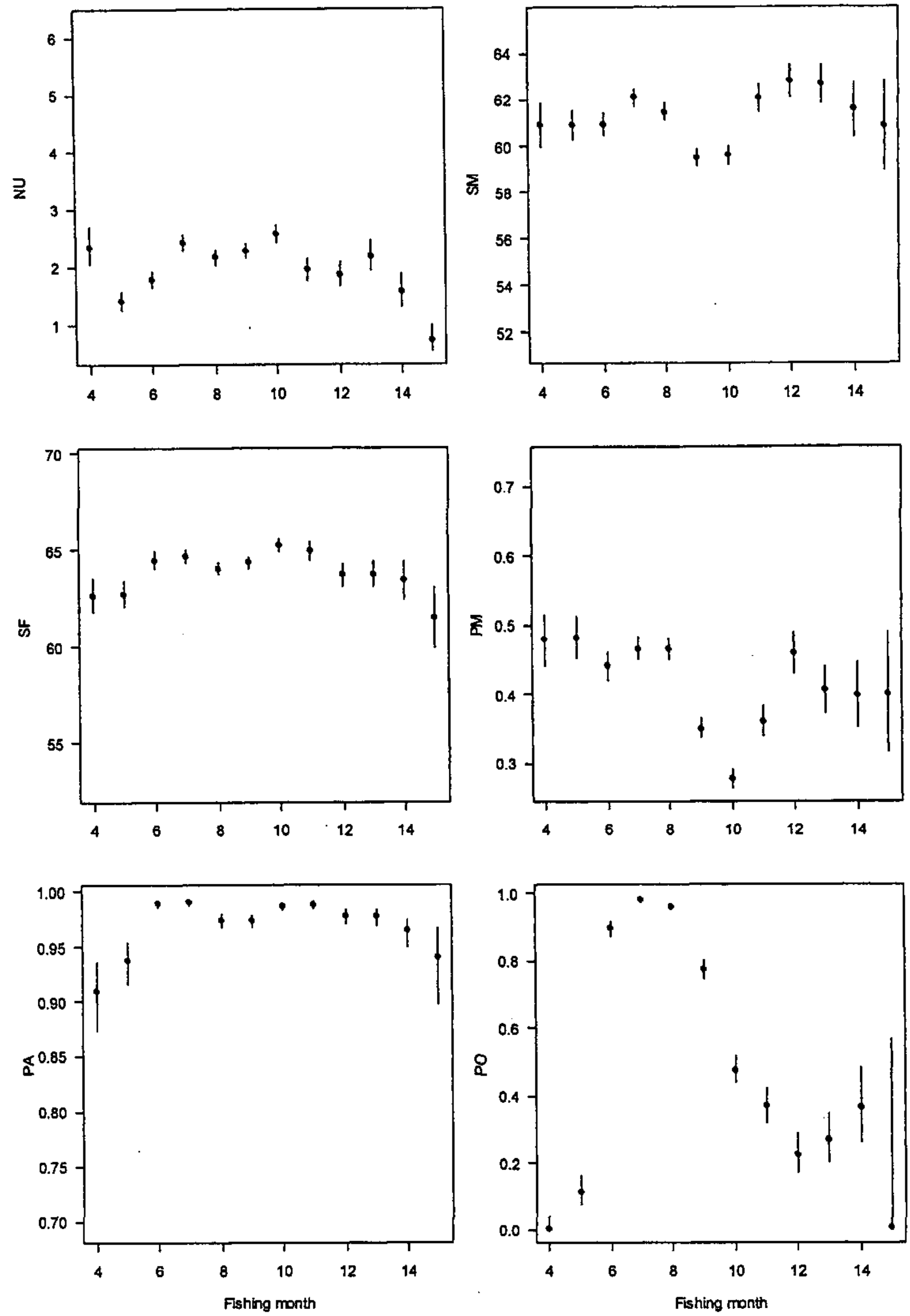

Figure 18: Estimated effect of fishing month on response variables for CRA 2. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

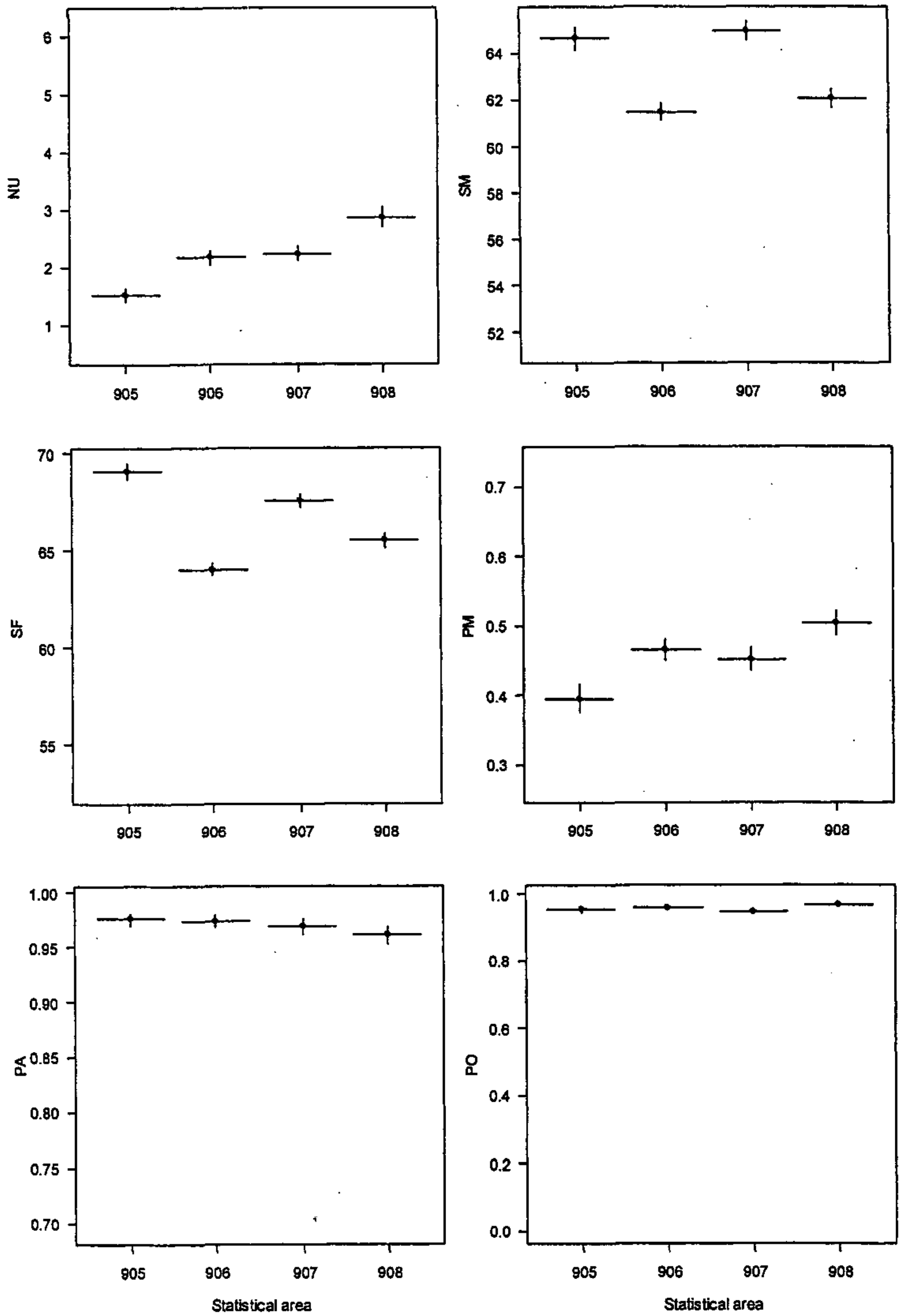

Figure 19: Estimated effect of statistical area on response variables for CRA 2. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

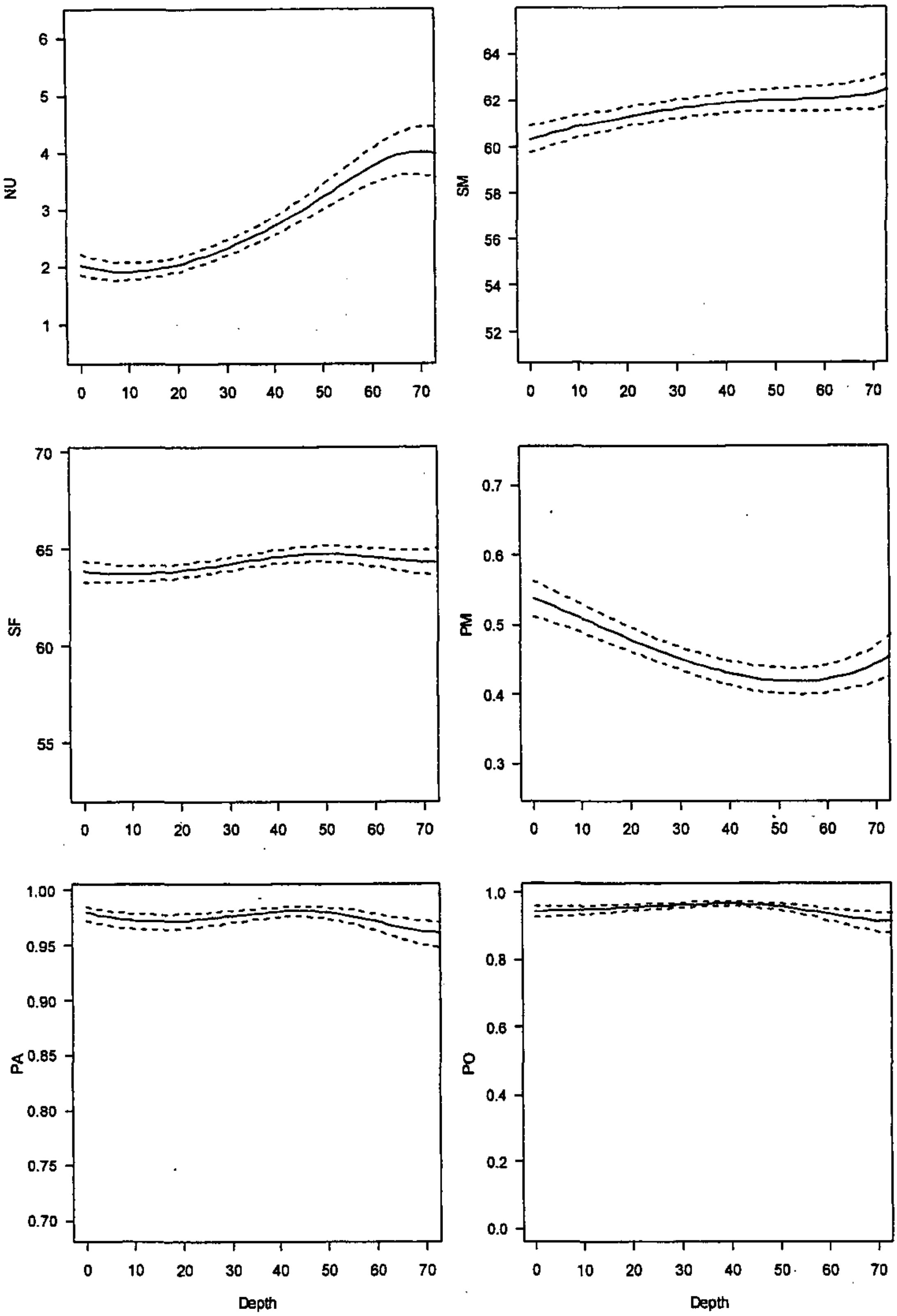

Figure 20: Estimated effect of depth on response variables for CRA 2. Dashed lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

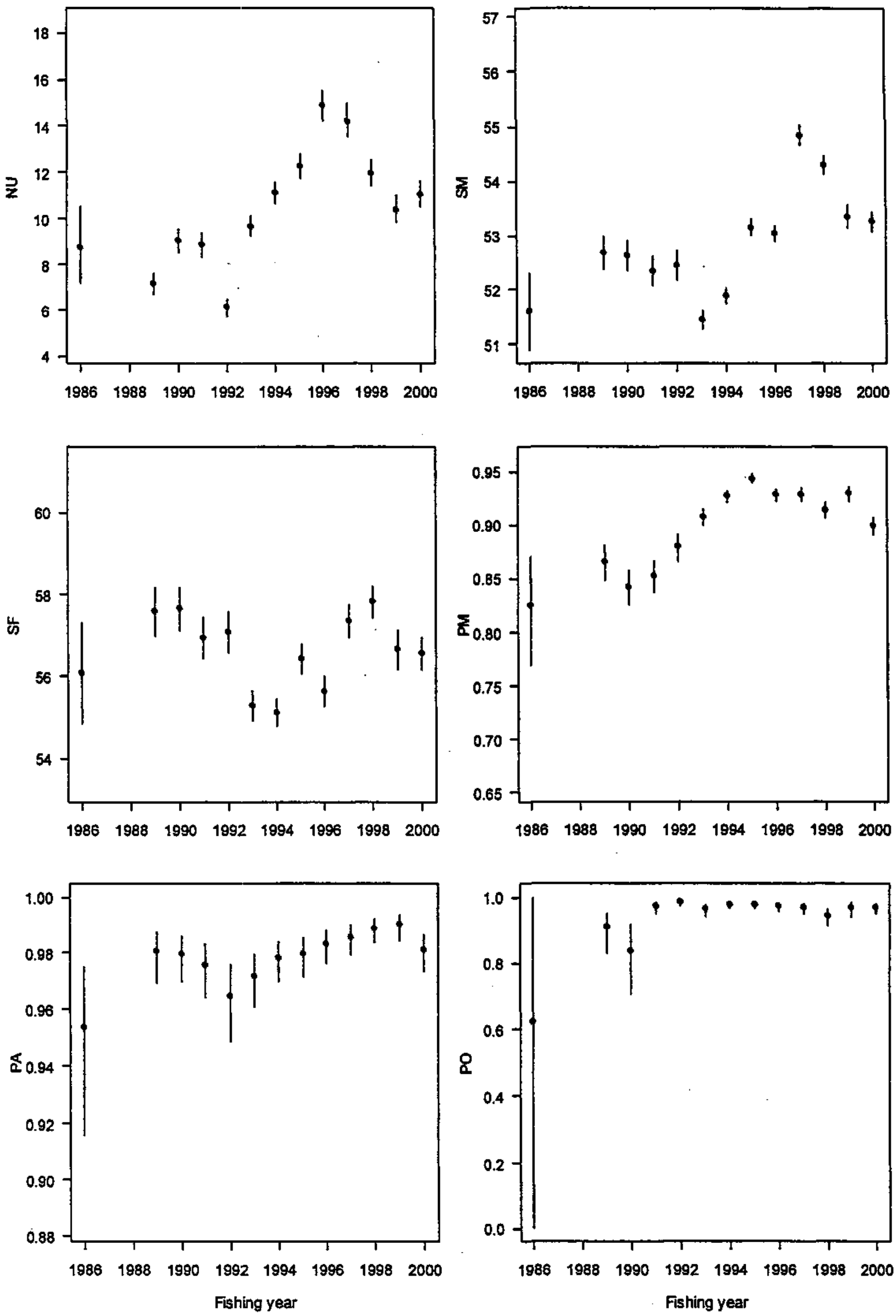

Figure 21: Estimated effect of fishing year on response variables for CRA 3. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

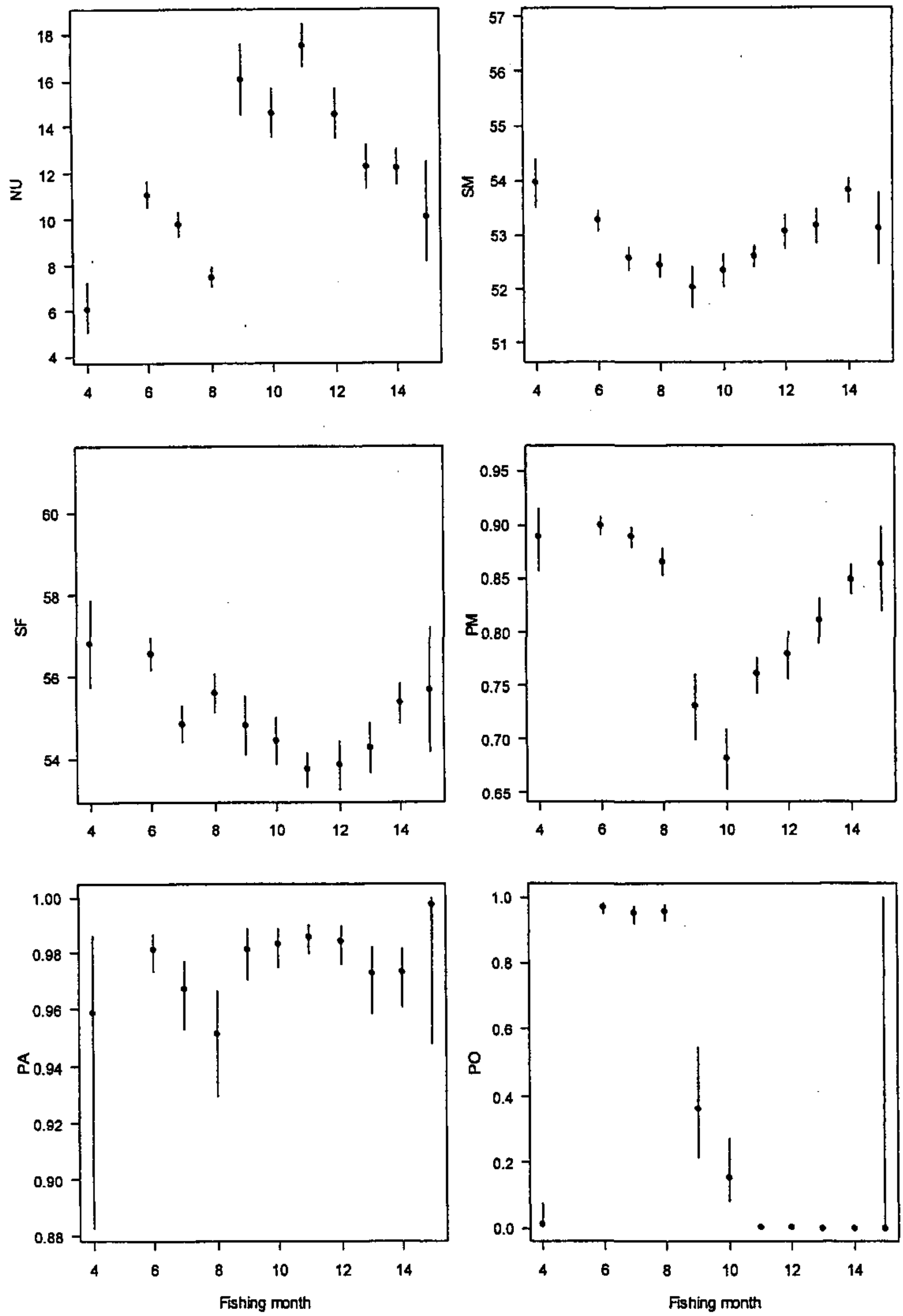

Figure 22: Estimated effect of fishing month on response variables for CRA 3. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

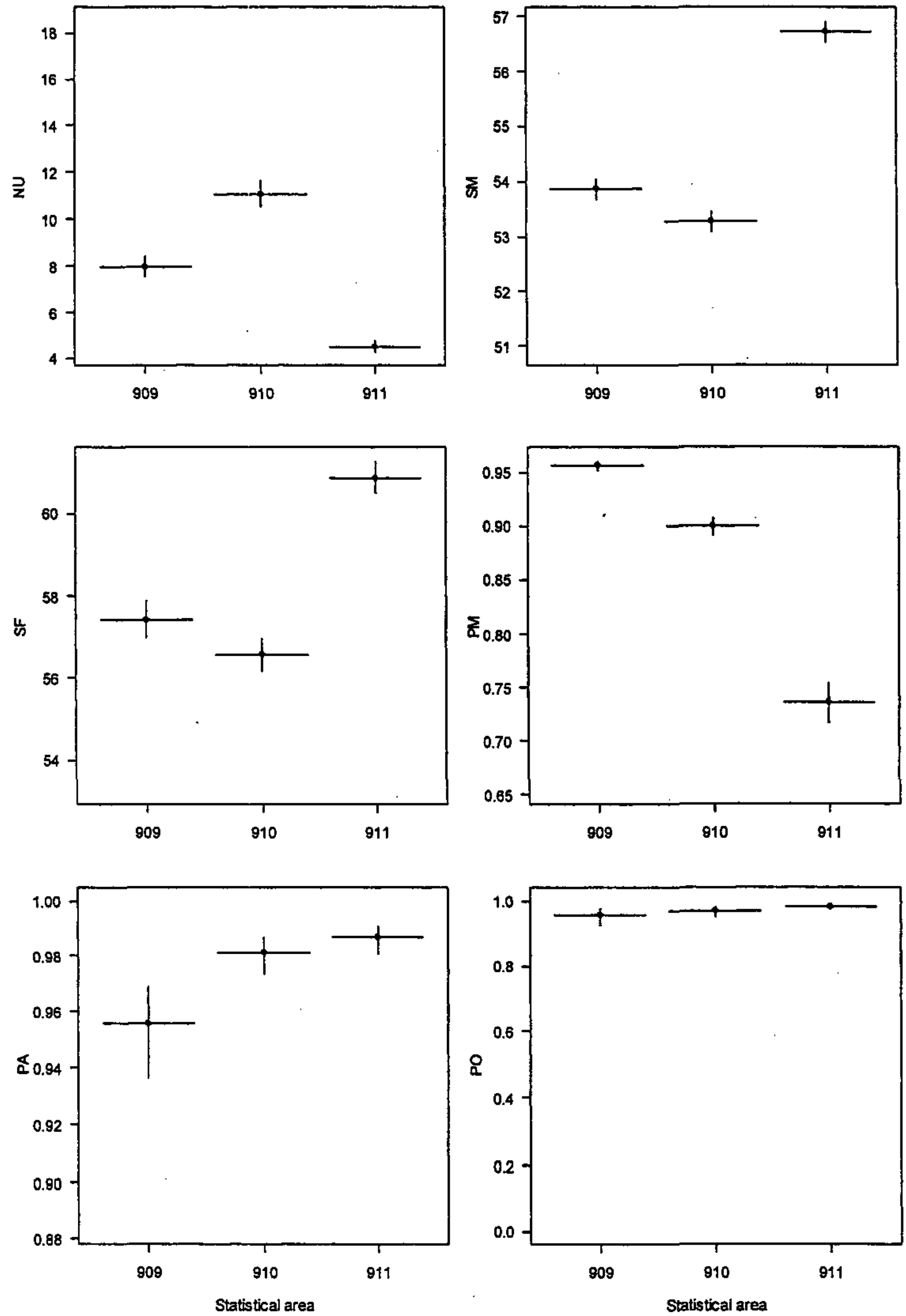

Figure 23: Estimated effect of statistical area on response variables for CRA 3. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

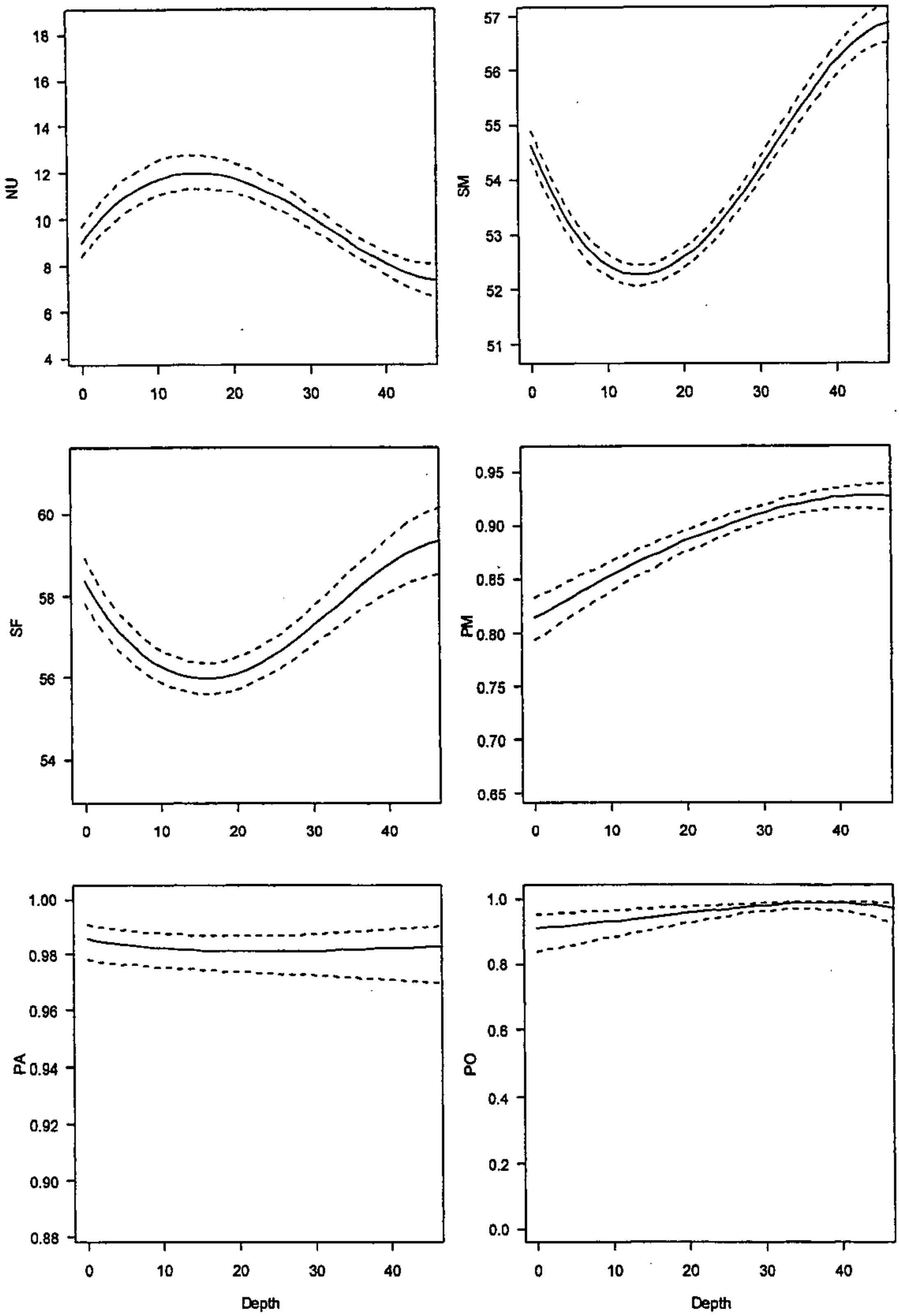

Figure 24: Estimated effect of depth on response variables for CRA 3. Dashed lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

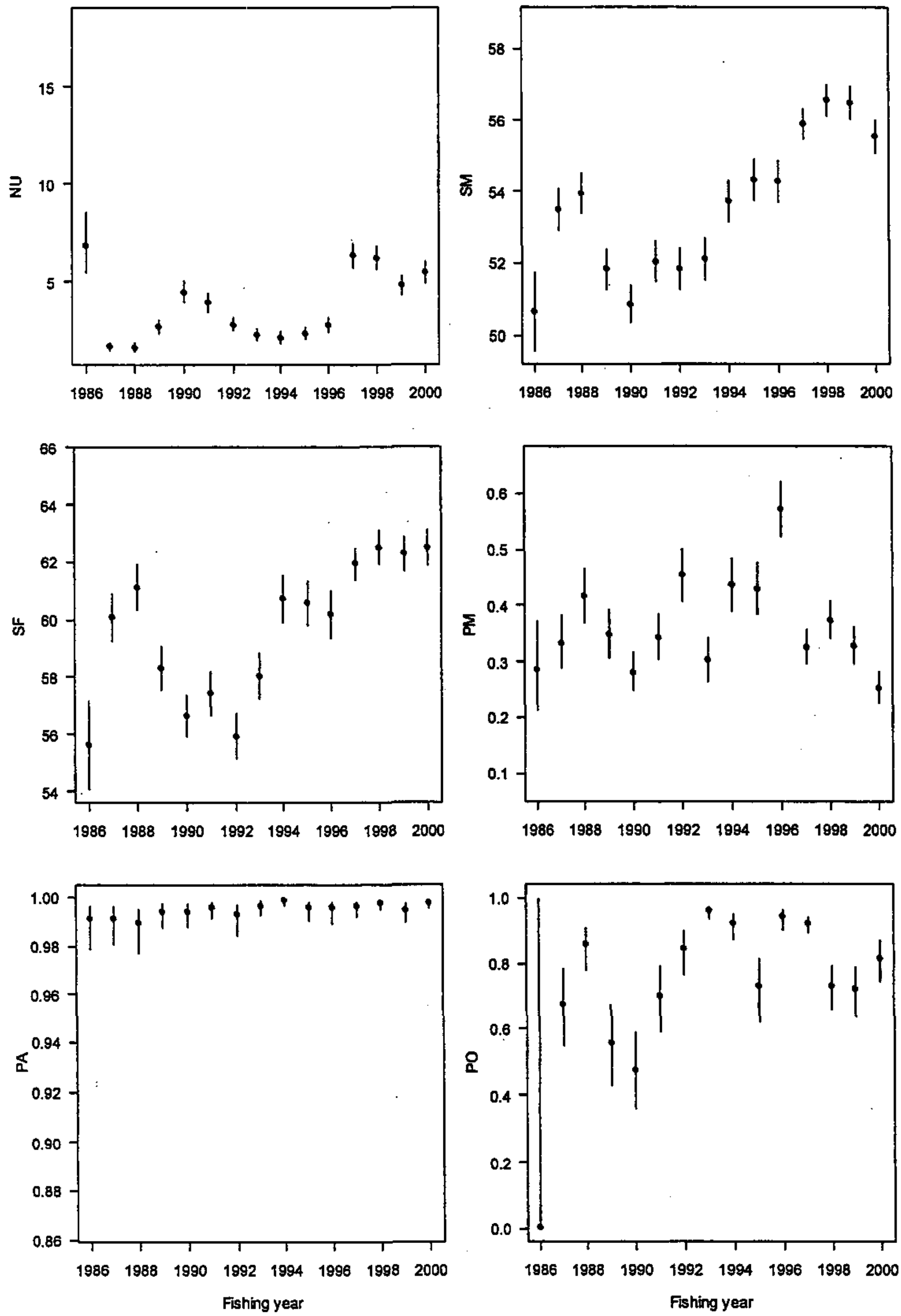

Figure 25: Estimated effect of fishing year on response variables for CRA 4. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

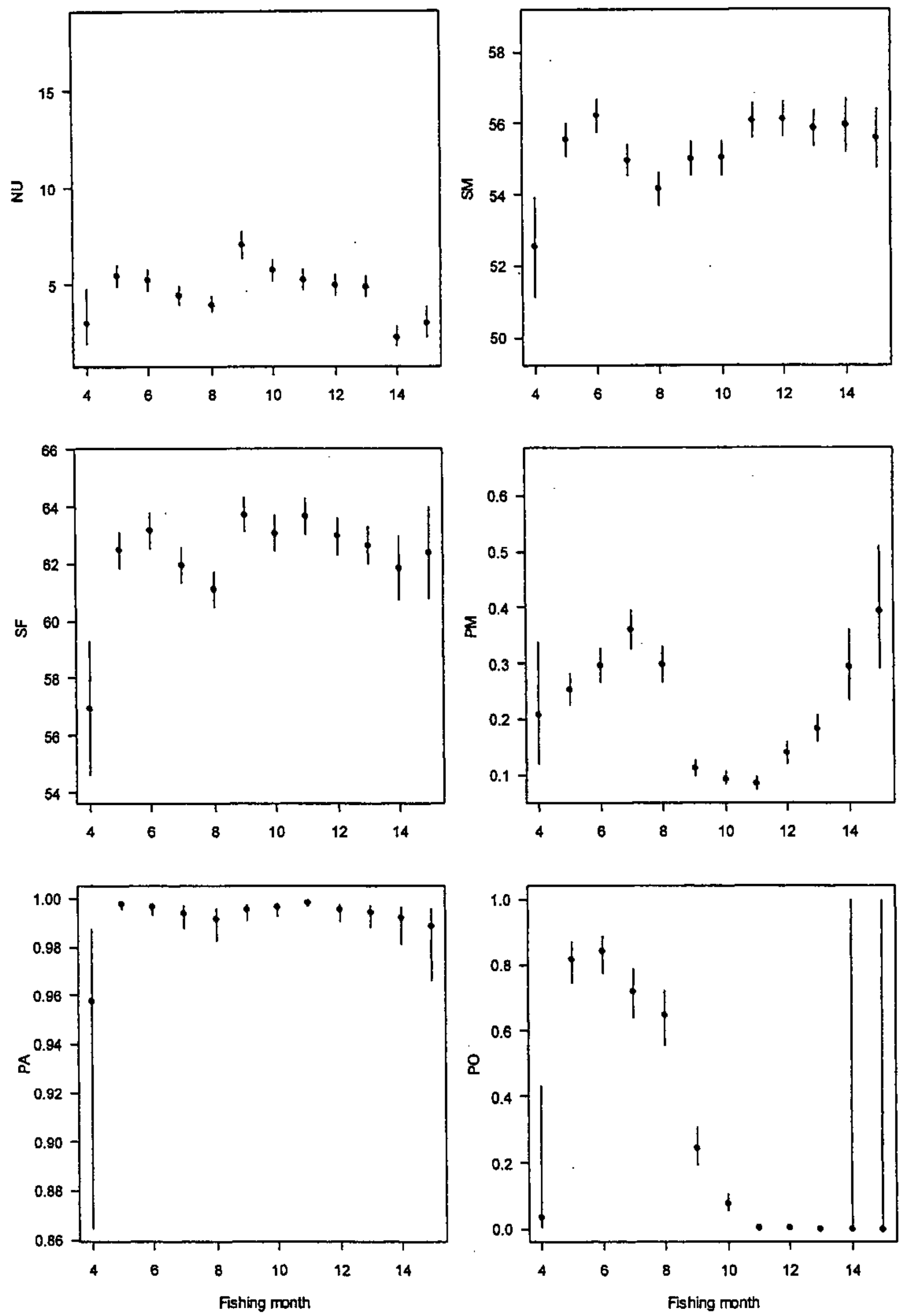

Figure 26: Estimated effect of fishing month on response variables for CRA 4. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

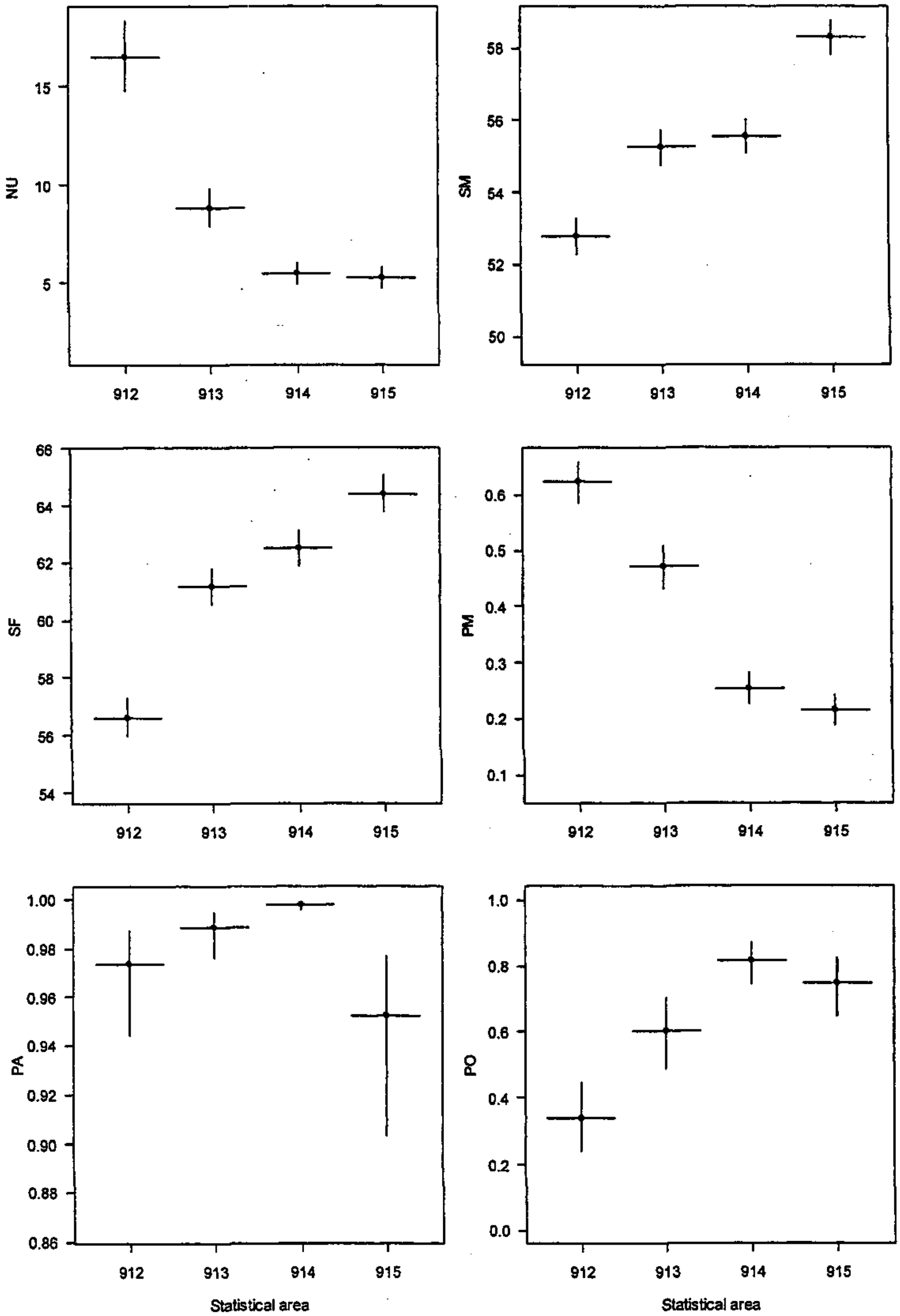

Figure 27: Estimated effect of statistical area on response variables for CRA 4. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

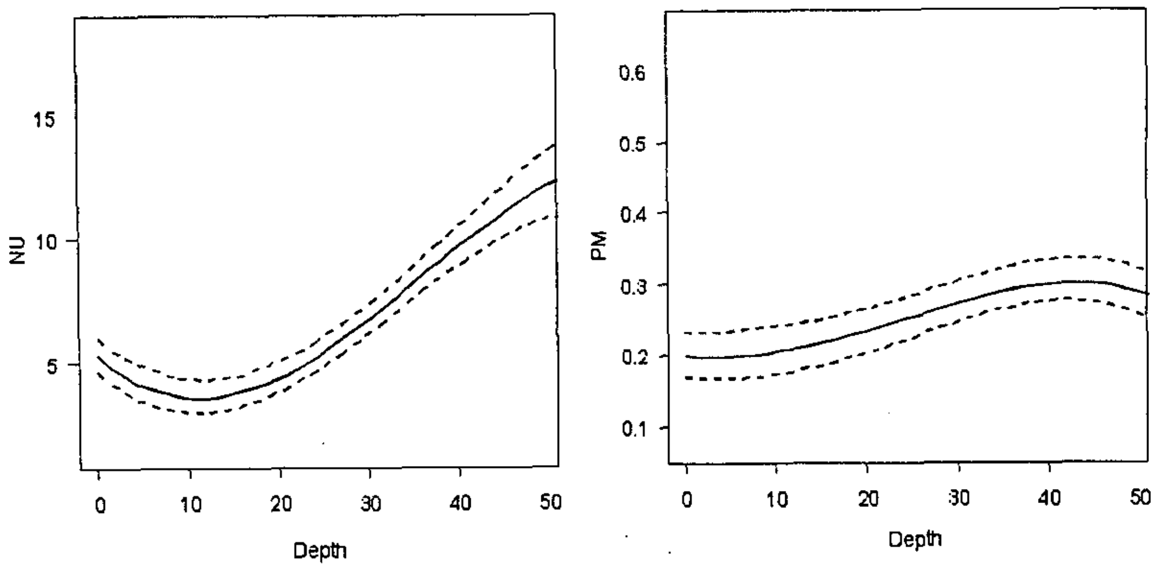

Figure 28: Estimated effect of depth on response variables for CRA 4. Dashed lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

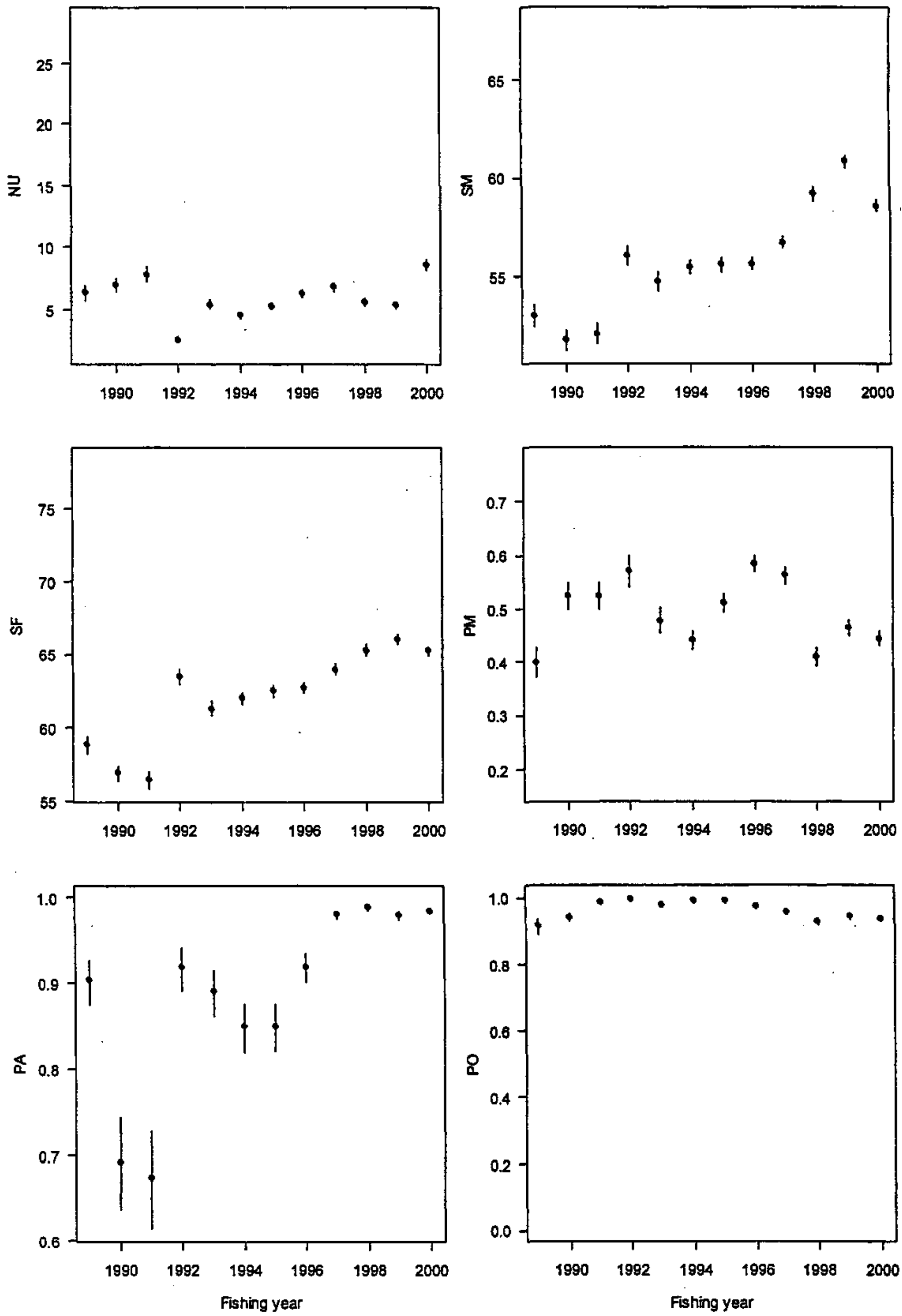

Figure 29: Estimated effect of fishing year on response variables for CRA 5. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

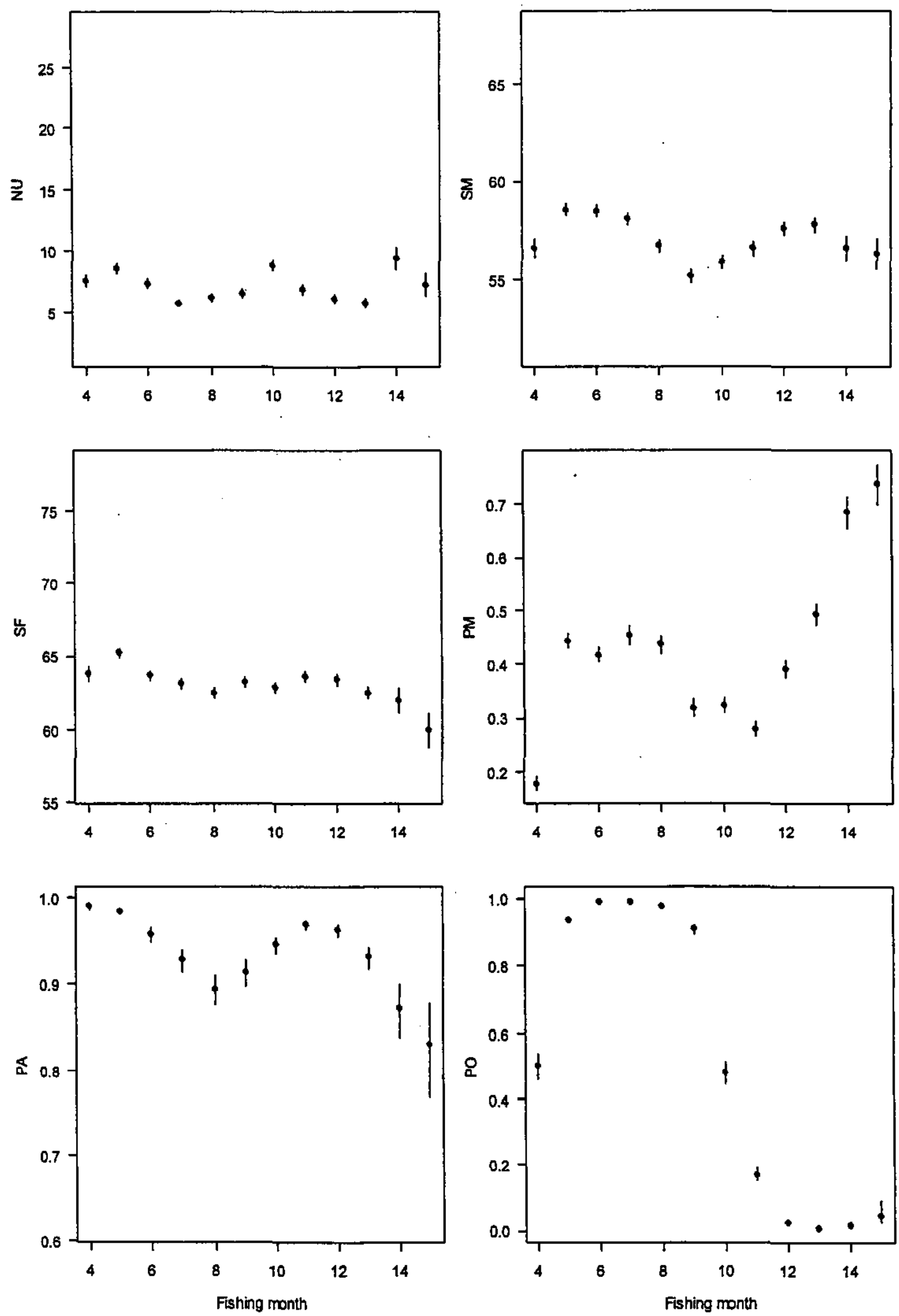

Figure 30: Estimated effect of fishing month on response variables for CRA 5. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

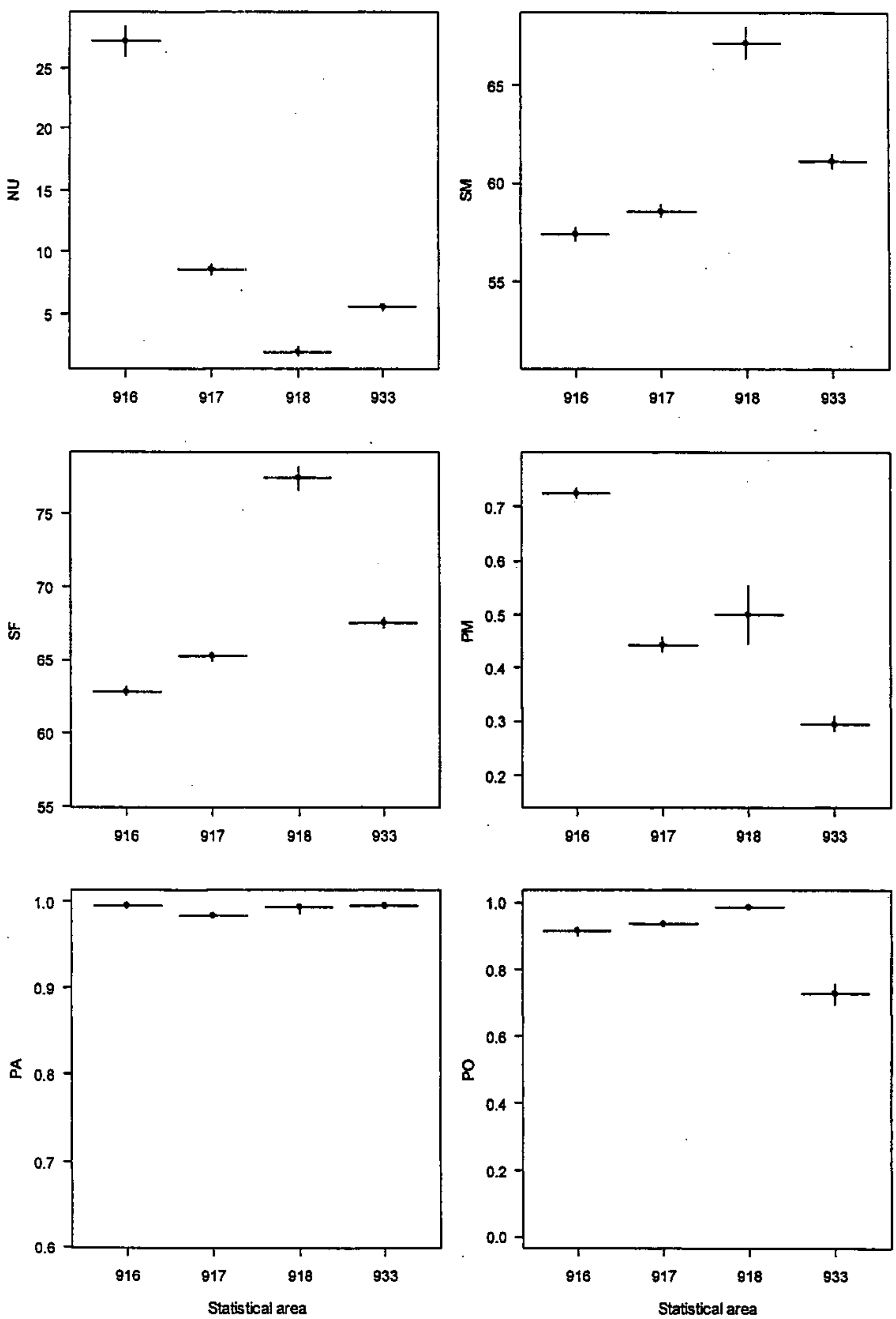

Figure 31: Estimated effect of statistical area on response variables for CRA 5. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

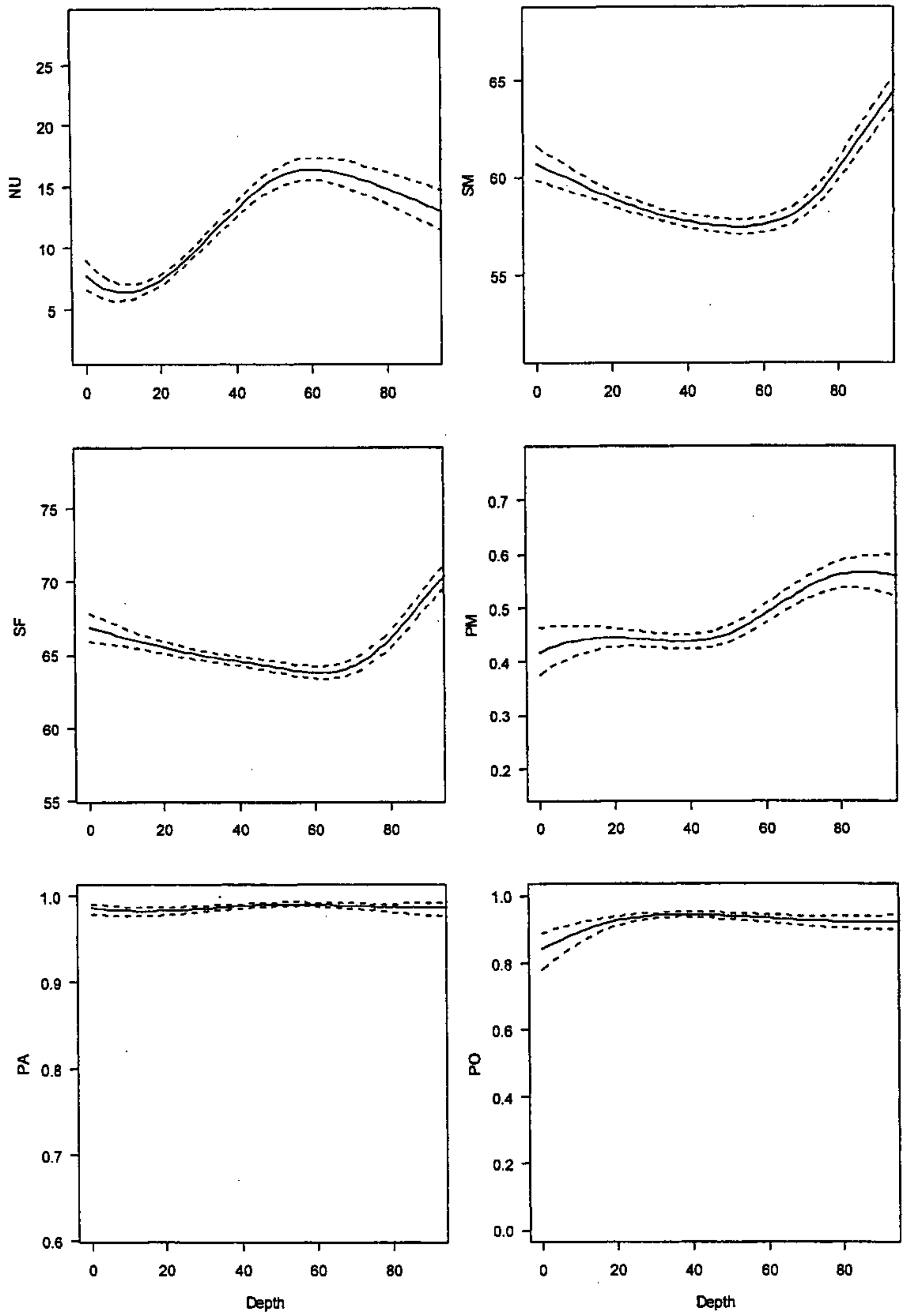

Figure 32: Estimated effect of depth on response variables for CRA 5. Dashed lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

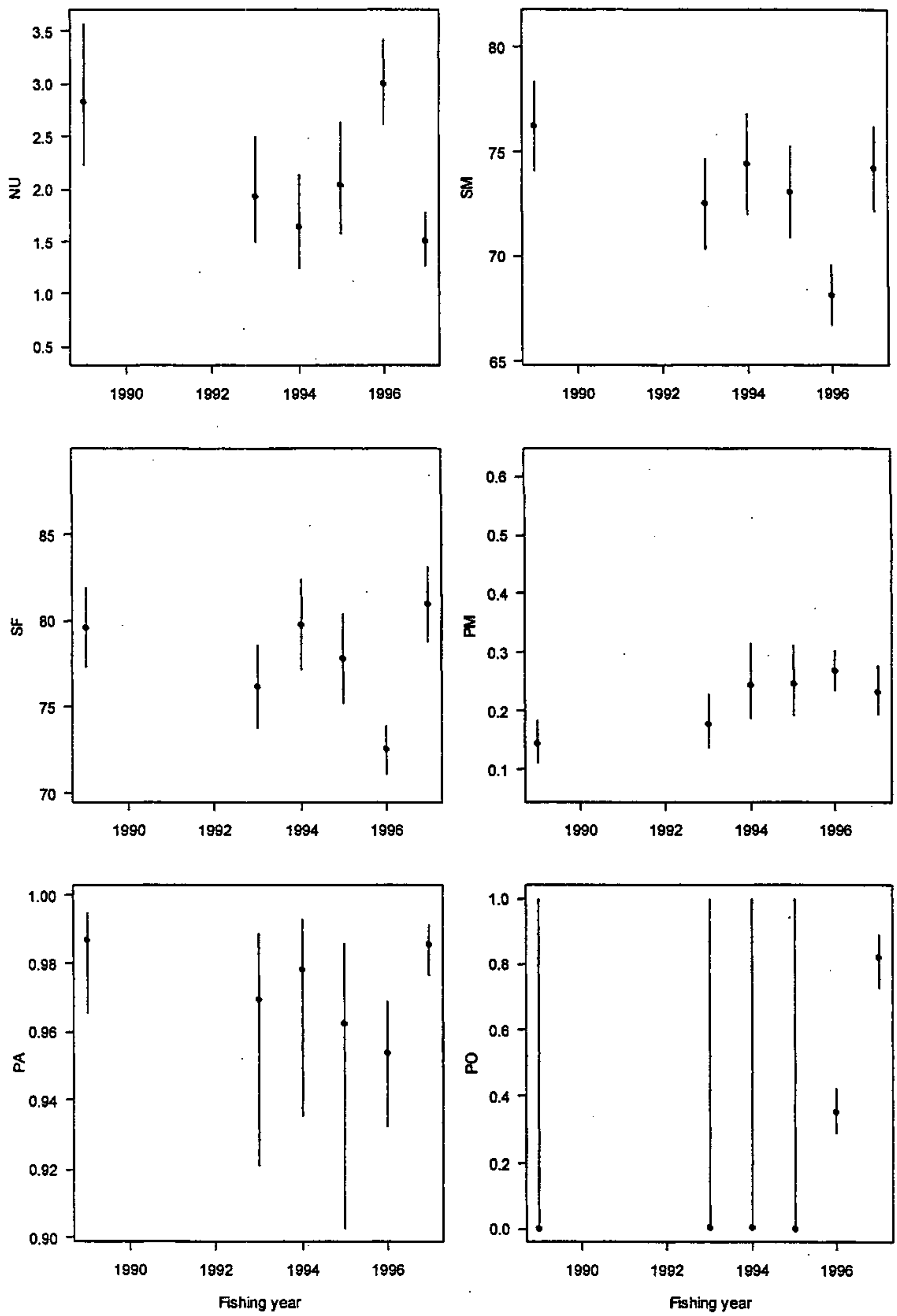

Figure 33: Estimated effect of fishing year on response variables for CRA 6. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

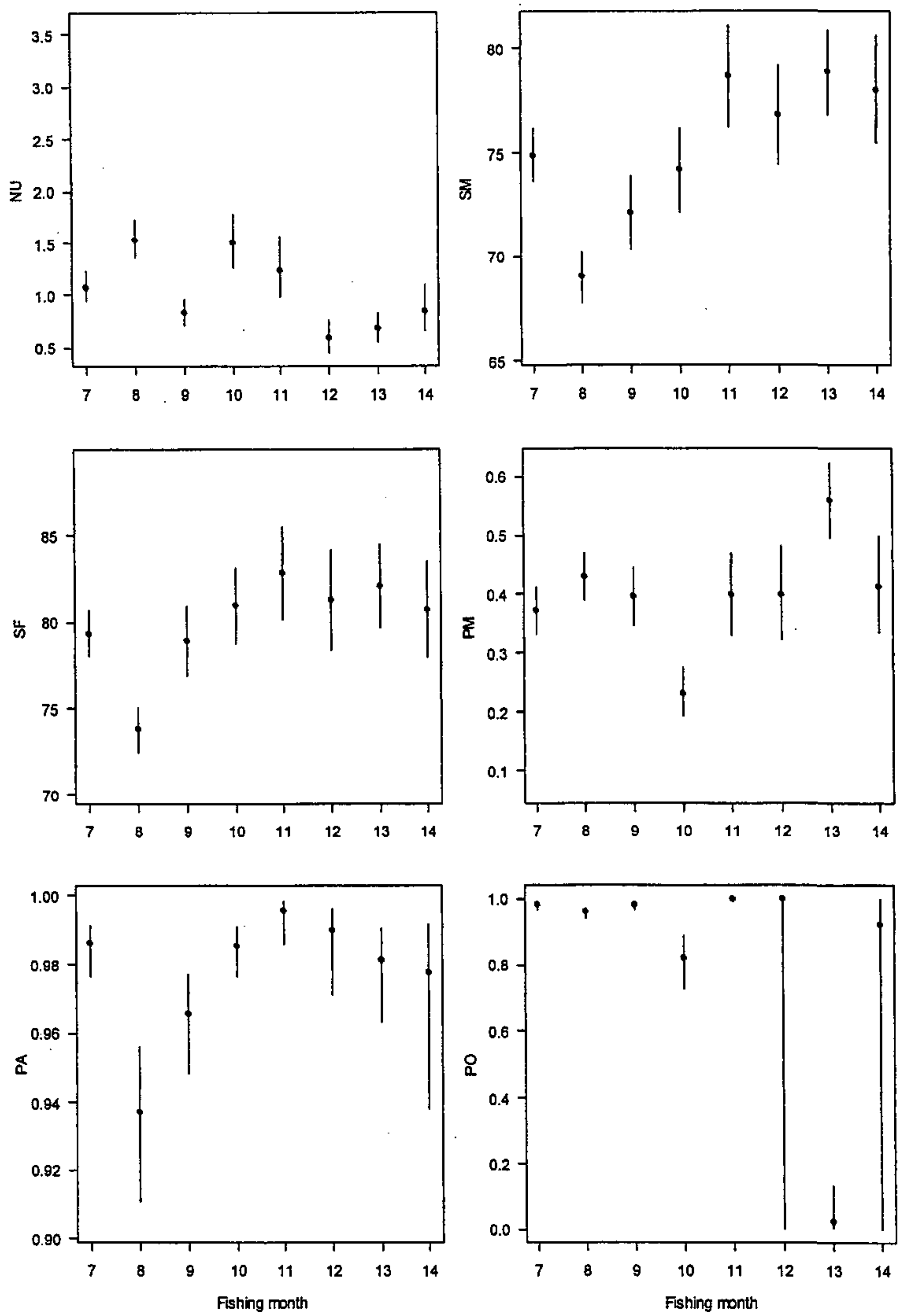

Figure 34: Estimated effect of fishing month on response variables for CRA 6. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

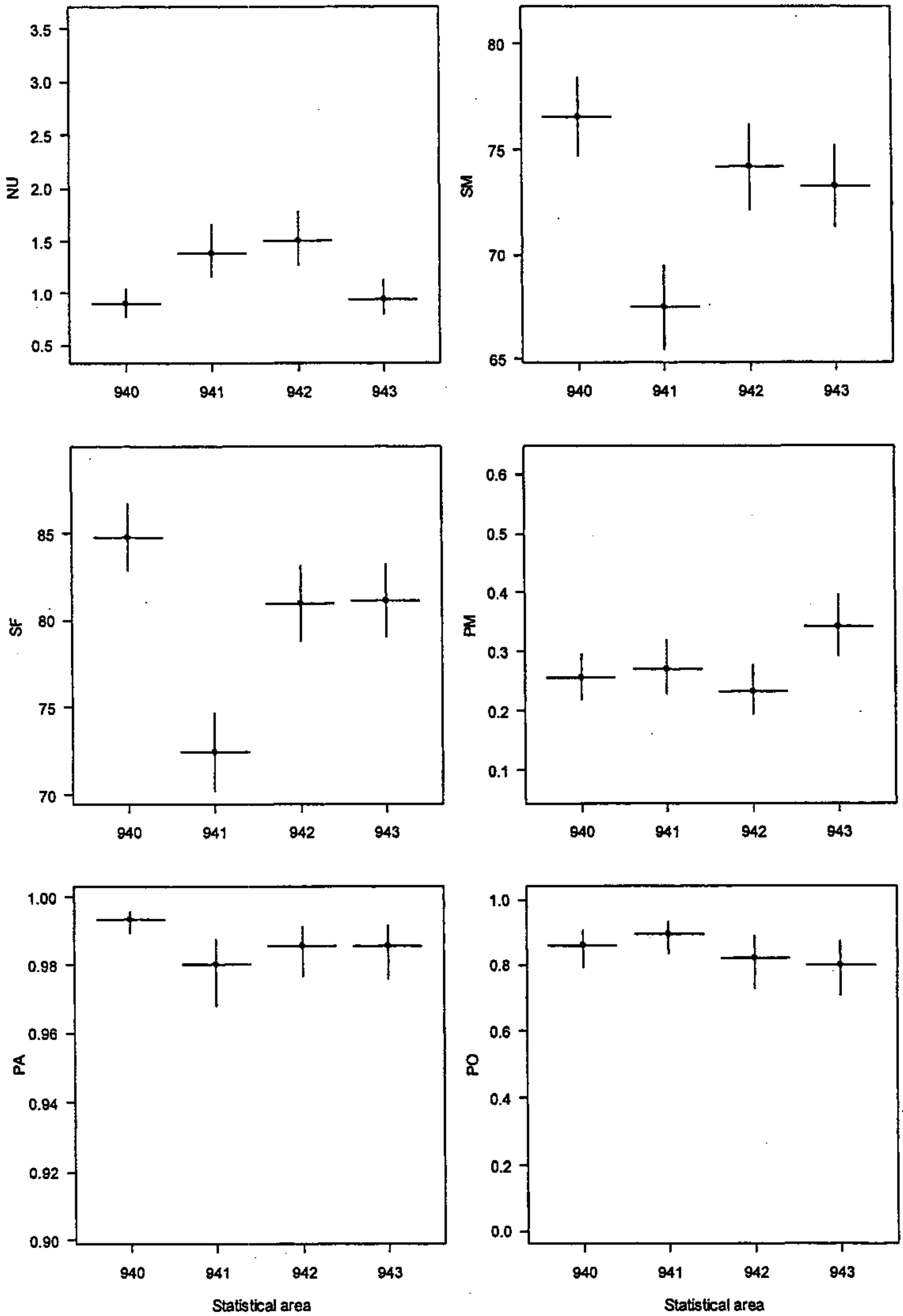

Figure 35: Estimated effect of statistical area on response variables for CRA 6. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

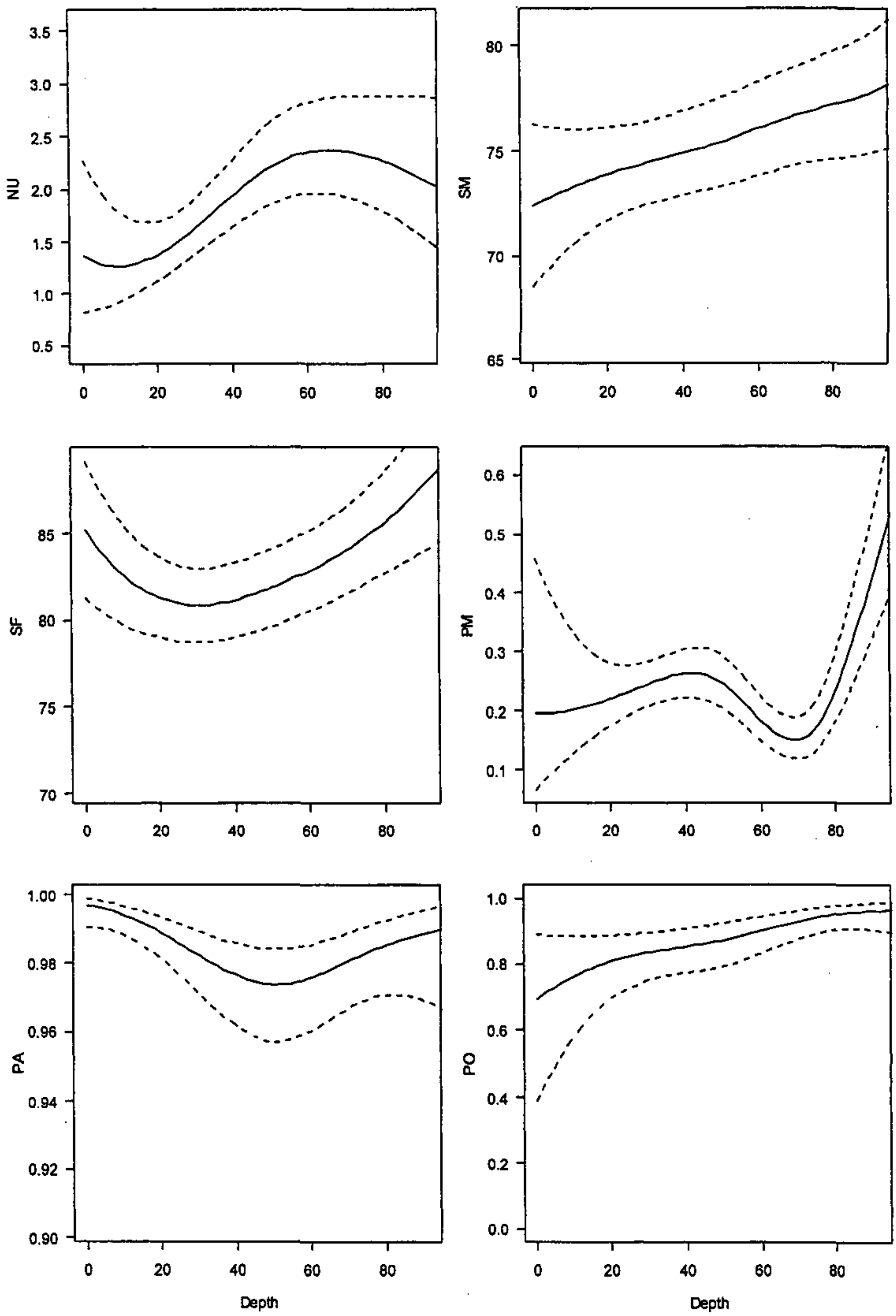

Figure 36: Estimated effect of depth on response variables for CRA 6. Dashed lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

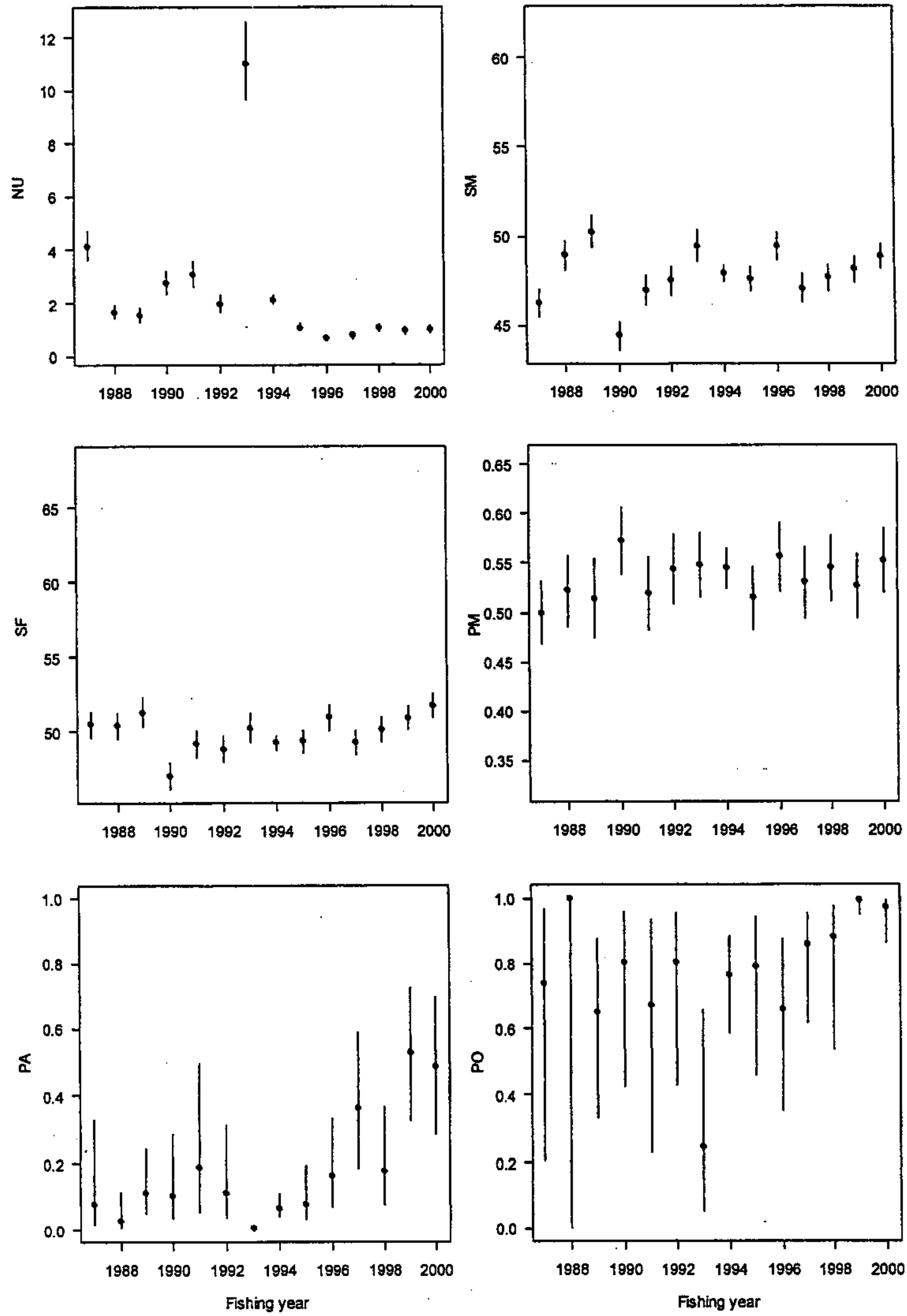

Figure 37: Estimated effect of fishing year on response variables for CRA 7. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

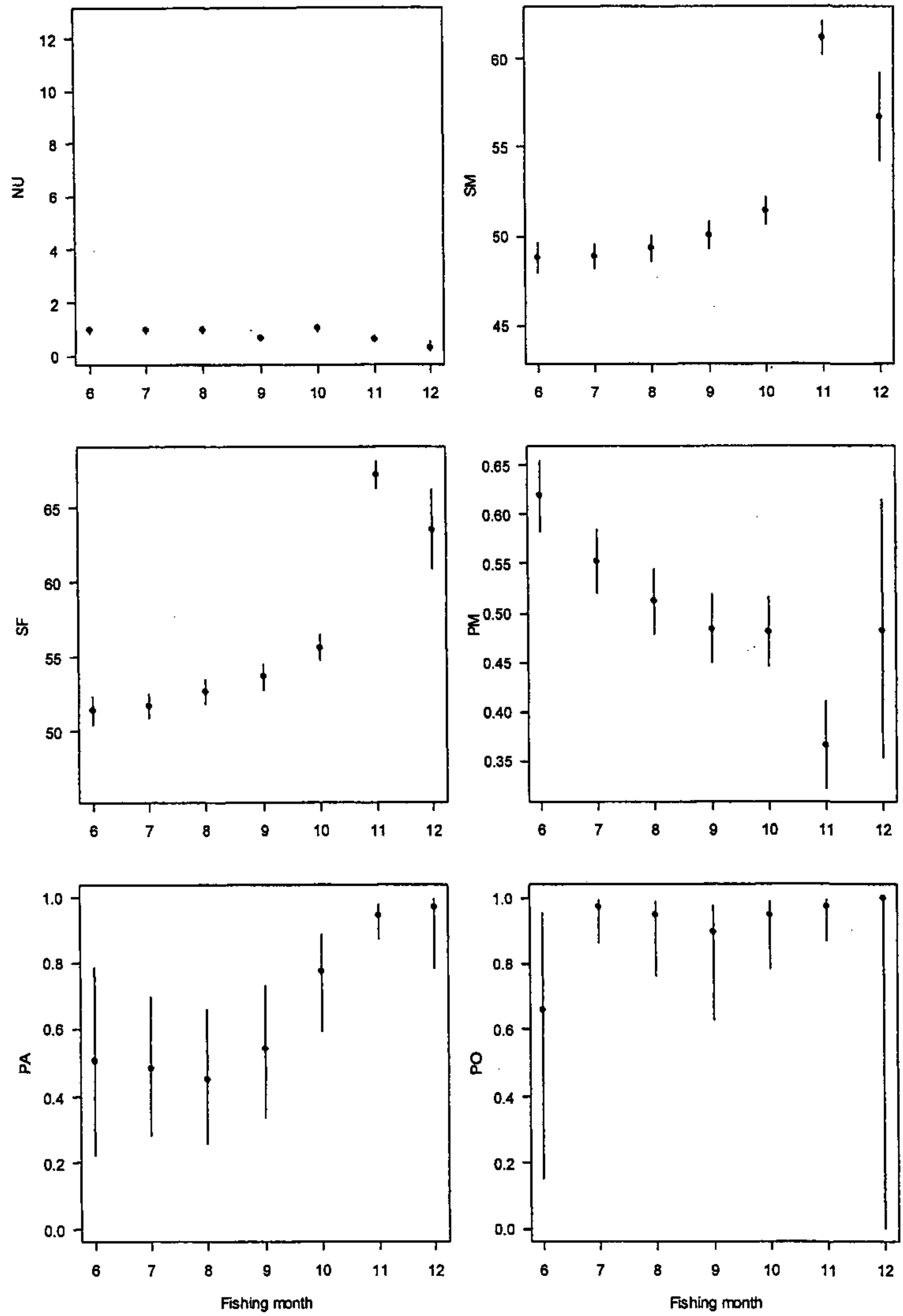

Figure 38: Estimated effect of fishing month on response variables for CRA 7. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

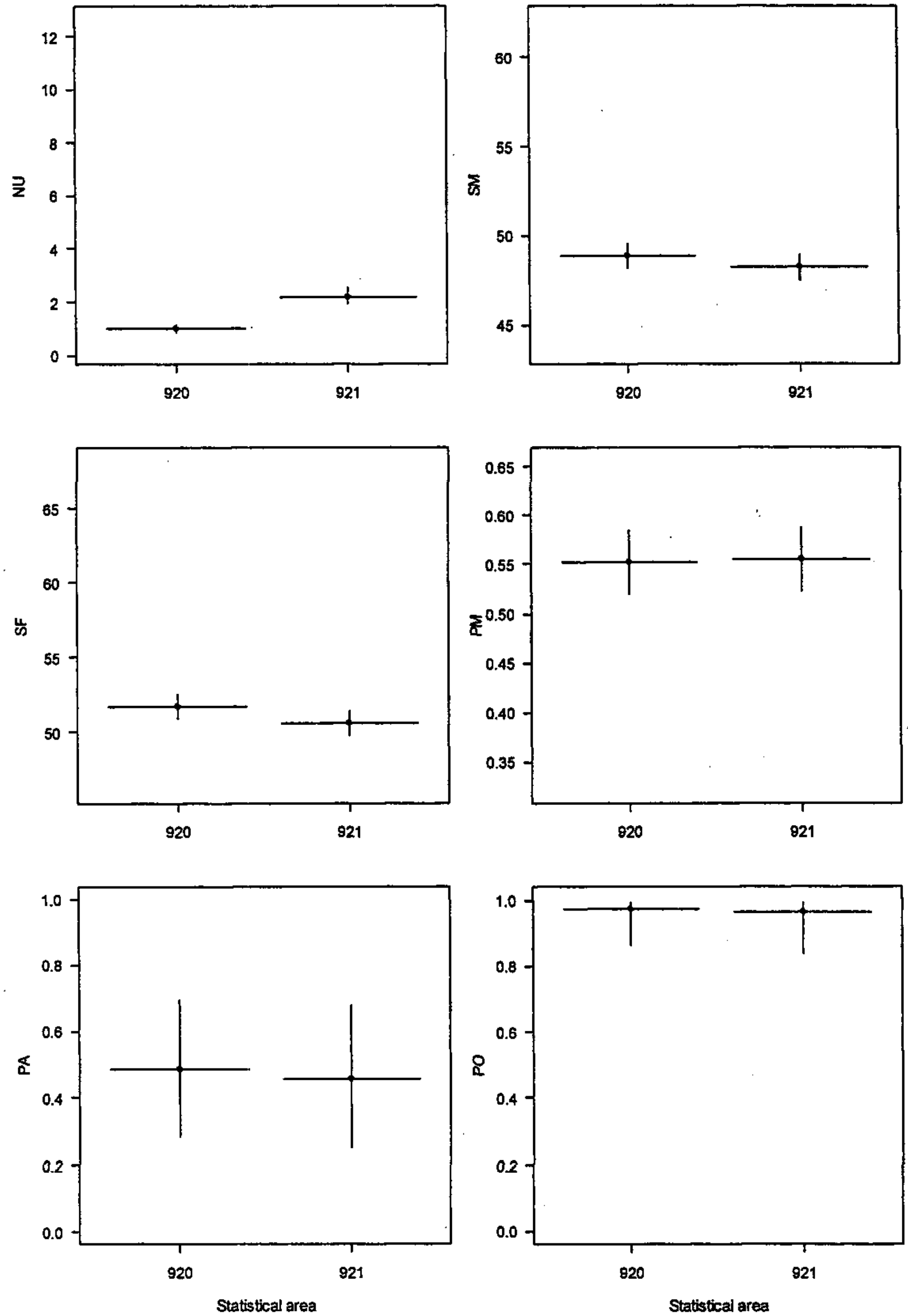

Figure 39: Estimated effect of statistical area on response variables for CRA 7. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

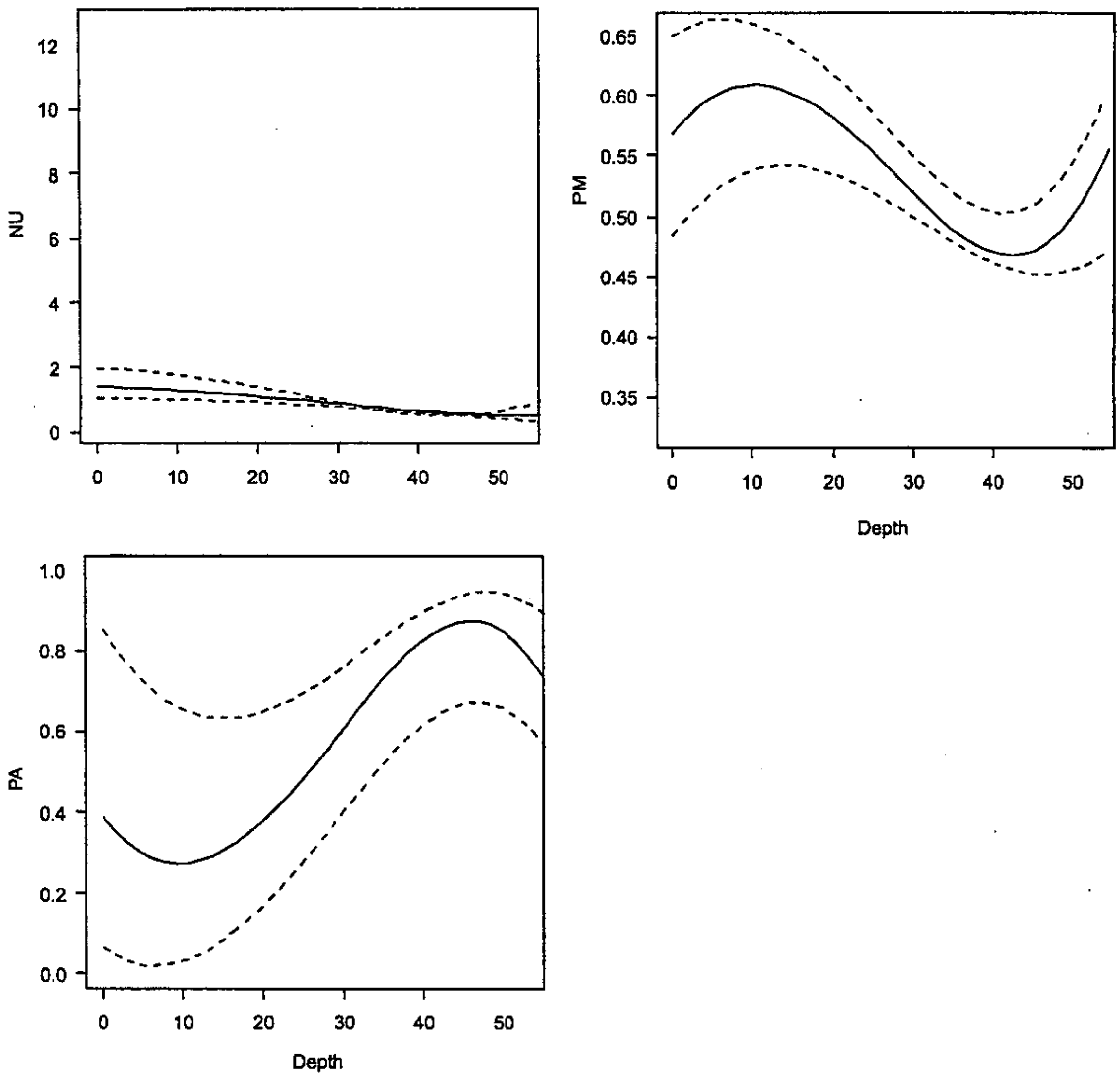

Figure 40: Estimated effect of depth on response variables for CRA 7. Dashed lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

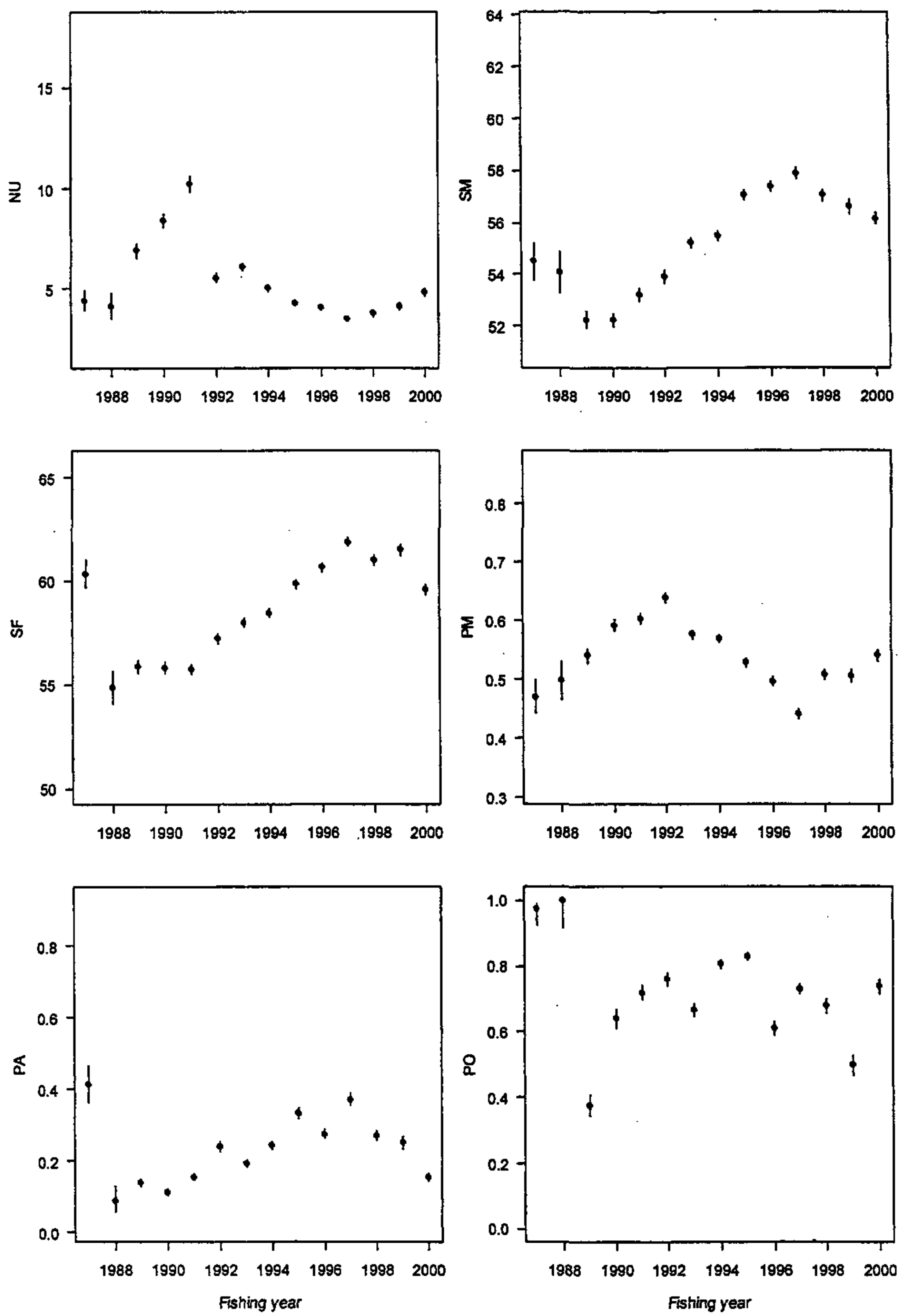

Figure 41: Estimated effect of fishing year on response variables for CRA 8. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

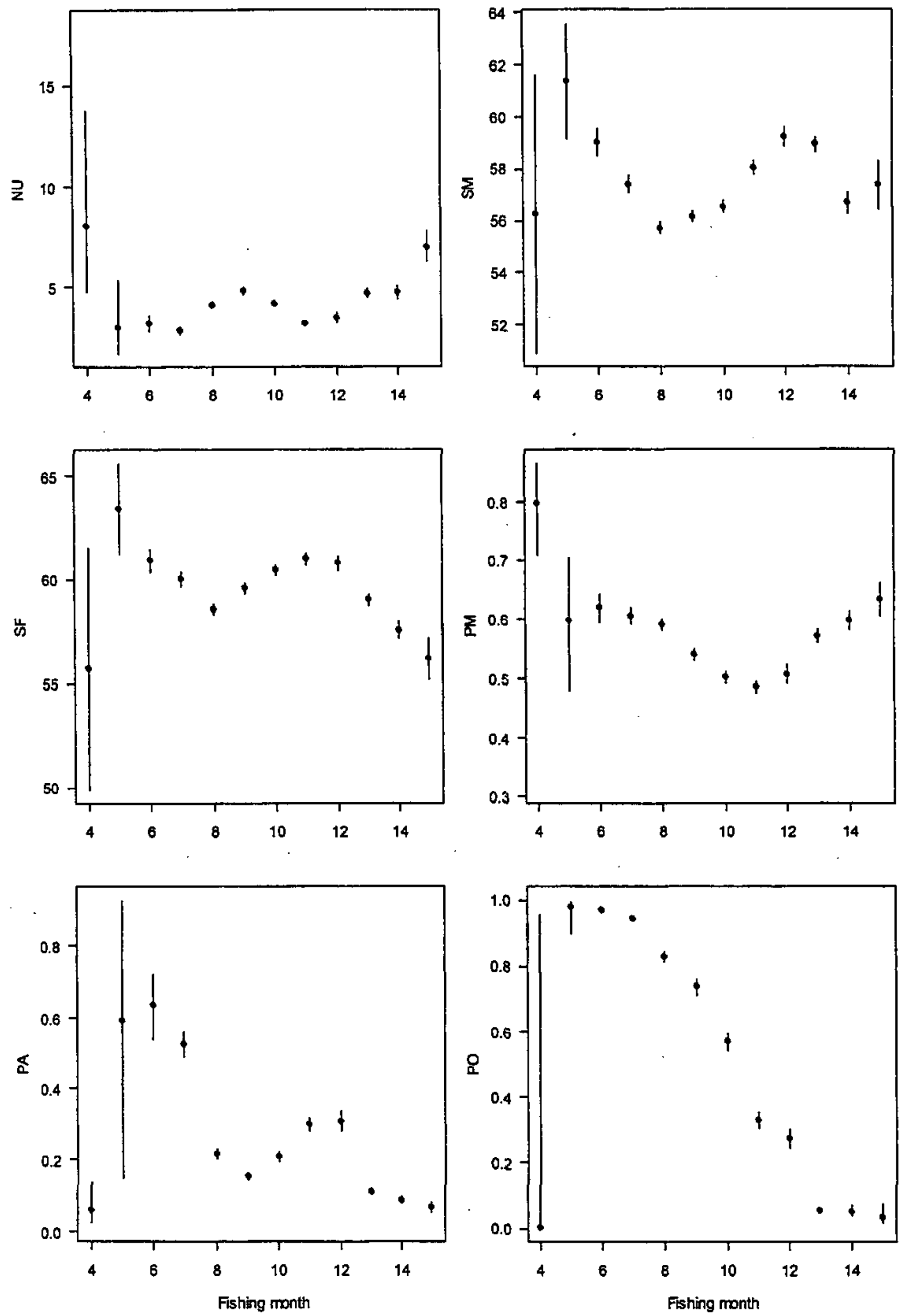

Figure 42: Estimated effect of fishing month on response variables for CRA 8. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

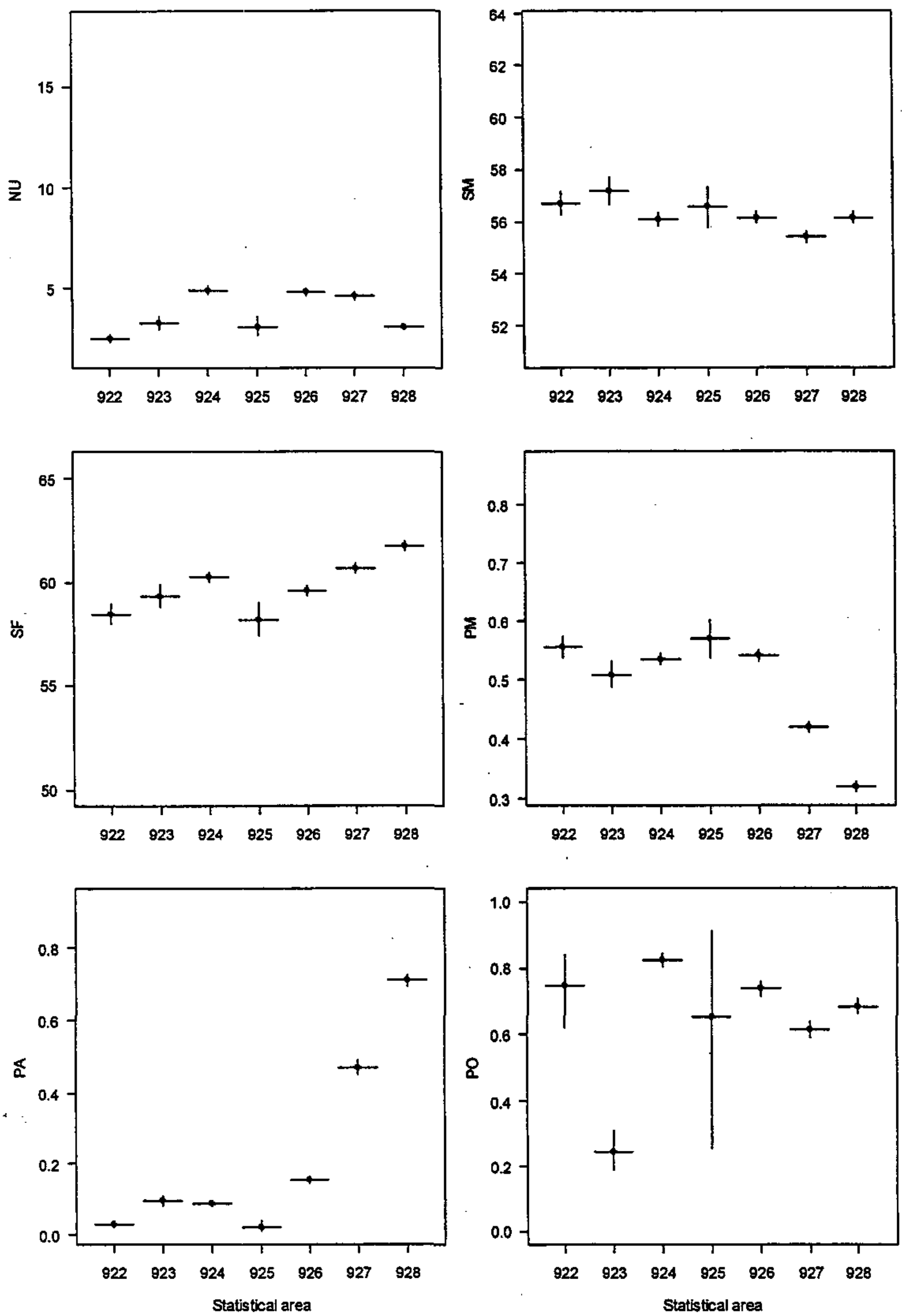

Figure 43: Estimated effect of statistical area on response variables for CRA 8. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

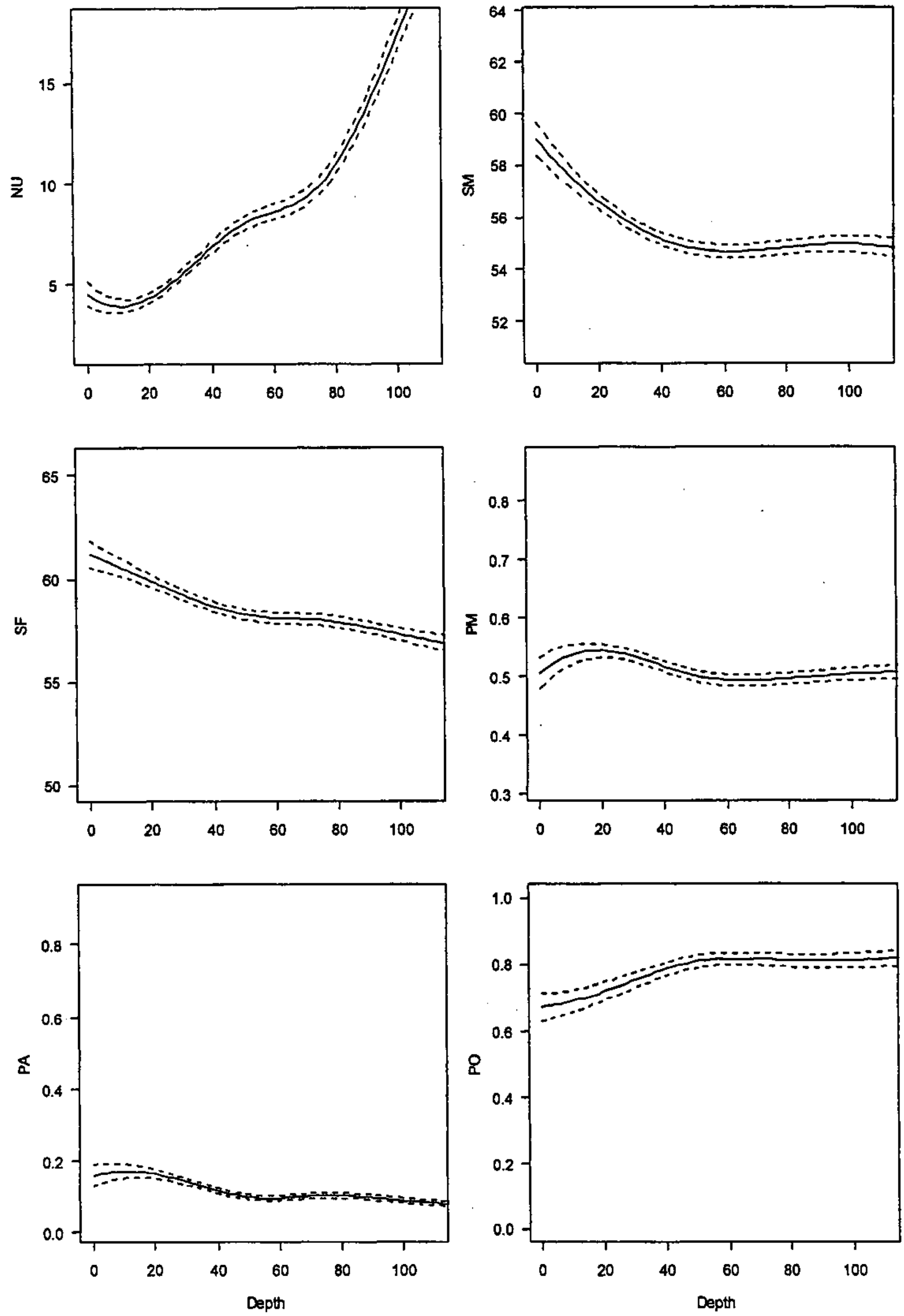

Figure 44: Estimated effect of depth on response variables for CRA 8. Dashed lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

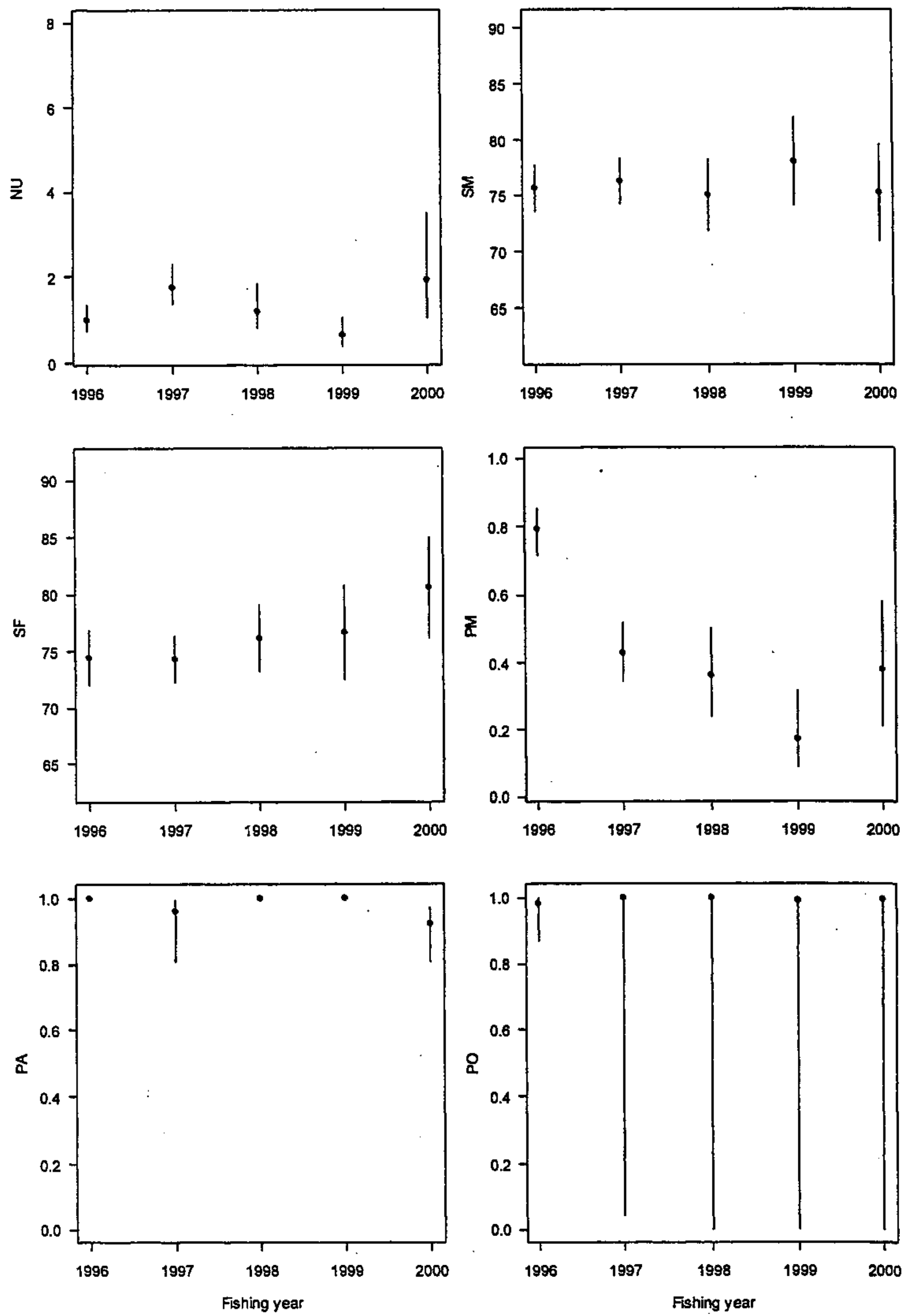

Figure 45: Estimated effect of fishing year on response variables for CRA 9. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

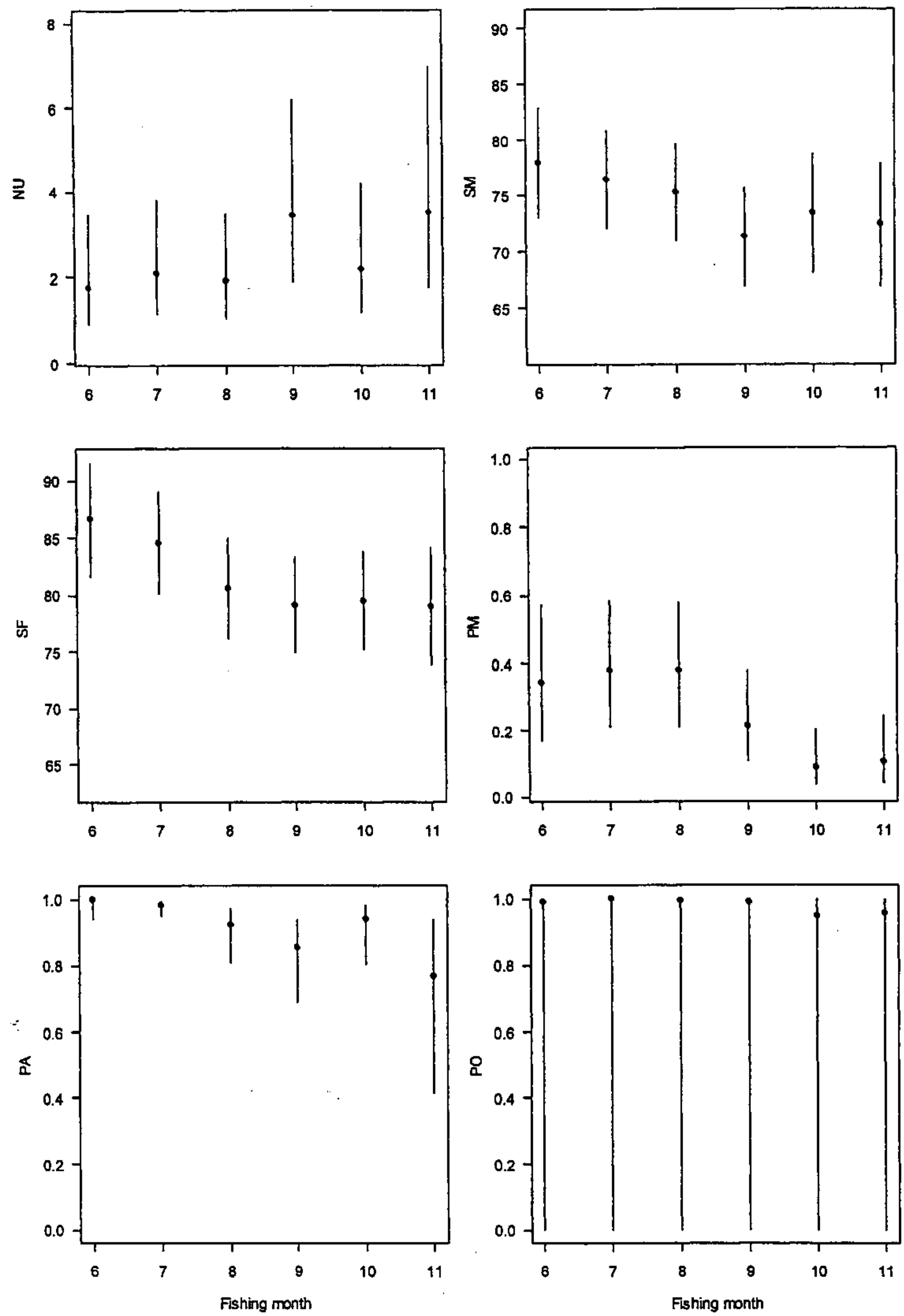

Figure 46: Estimated effect of fishing month on response variables for CRA 9. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

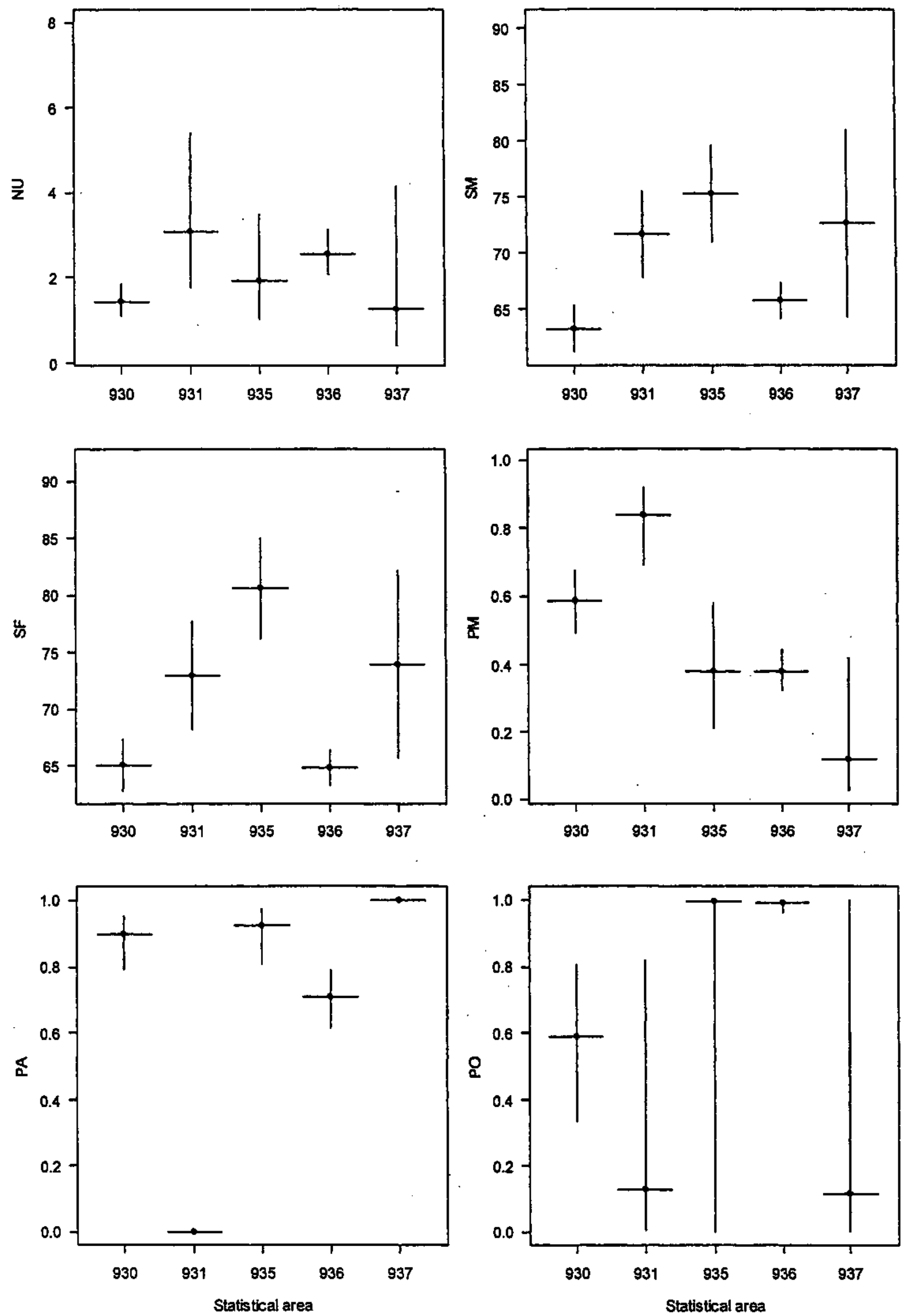

Figure 47: Estimated effect of statistical area on response variables for CRA 9. Vertical lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

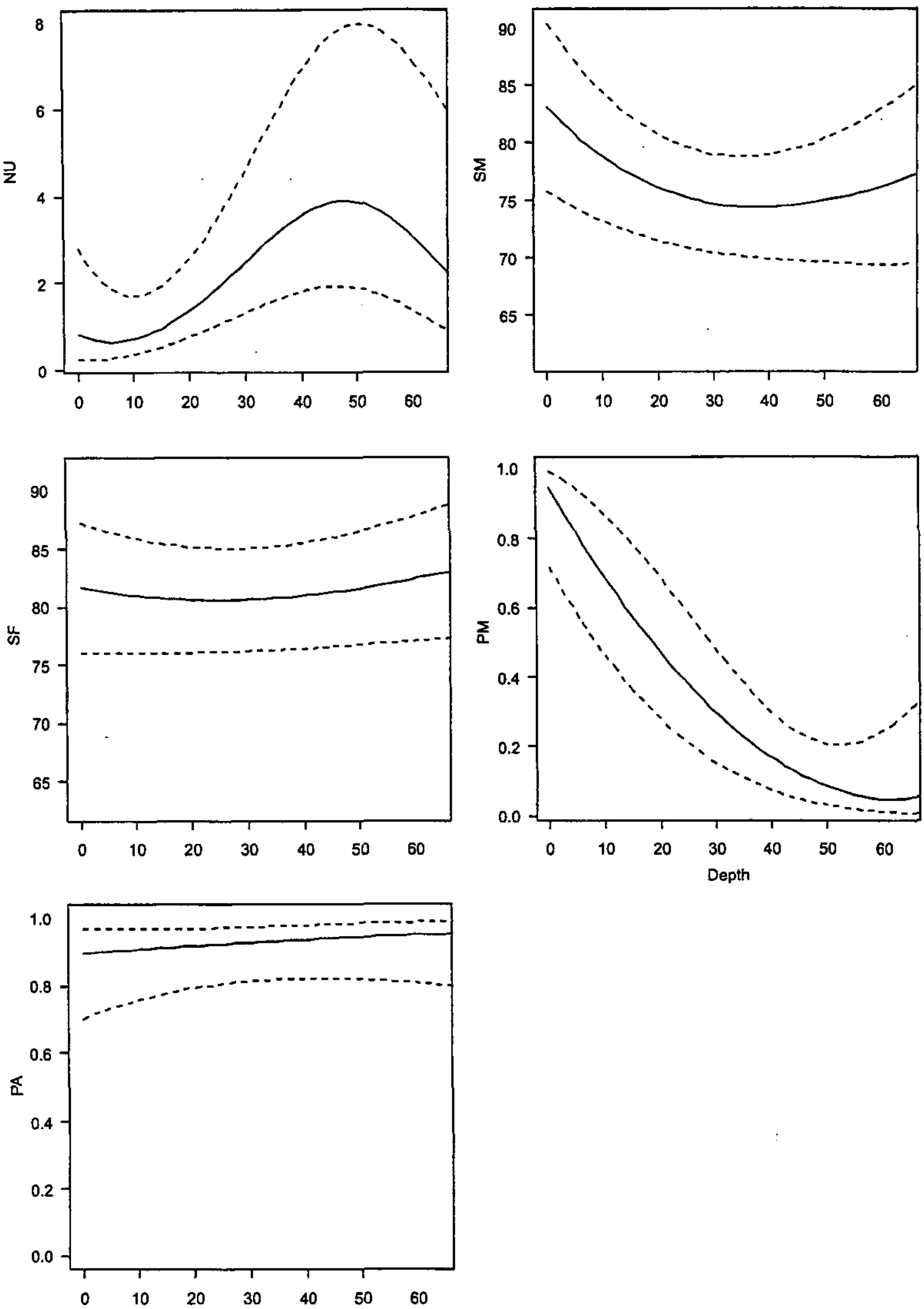

Figure 48: Estimated effect of depth on response variables for CRA 9. Dashed lines represent 95% confidence limits. See Figure 13 for explanation of abbreviations.

Appendix A: Summaries of catch sampling participation rates in the *Jasus edwardsii* fishery

Table A1. Fishing activity (no. of vessels and pots) and logbook coverage (vessels and pots) in CRA 2, Area 905. The shaded areas represent seasons and areas in which the logbook coverage exceeded the target participation rate. See Section 2.1 for formulae definition.

Year	Season	Fishing activity (vessels)	Target (30%) coverage (vessels)	Actual coverage (vessels)	Actual coverage (R_{ij}) (%)	Fishing activity (potlifts)	Average no. potlifts (P_{ij}^{av})	Target potlifts (P_{ij}^{T})(%)	Actual coverage (no. potlifts)	Actual coverage (% pots)
1993	AW	46	14	6	13	43952	87	1.4	269	0.61
1993	SS	33	10	1	3	22525	86	1.4	70	0.31
1994	AW	37	11	18	49	44841	93	1.3	933	2.08
1994	SS	27	8	7	26	18938	85	1.4	190	1.00
1995	AW	33	10	2	6	29953	95	1.3	171	0.57
1995	SS	20	6	0	0	10826	82	1.5	0	0.00
1996	AW	42	13	2	5	33540	92	1.3	174	0.52
1996	SS	9	3	0	0	7132	71	1.7	0	0.00
1997	AW	35	11	1	3	32461	96	1.2	84	0.26
1997	SS	10	3	0	0	4022	67	1.8	0	0.00
1998	AW	41	12	9	22	33798	87	1.4	357	1.06
1998	SS	15	5	1	7	8041	67	1.8	15	0.19
1999	AW	38	11	7	18	30885	94	1.3	252	0.82
1999	SS	21	6	3	14	12848	73	1.6	63	0.49
2000	AW	30	9	7	23	30222	91	1.3	233	0.77
2000	SS	32	10	1	3	23514	80	1.5	15	0.06

Table A2: Fishing activity (no. of vessels and pots) and logbook coverage (vessels and pots) in CRA 2, Area 906. The shaded areas represent seasons and areas in which the logbook coverage exceeded the target participation rate. See methods for formulae definition

Year	Season	Fishing activity (vessels)	Target (30%) coverage (vessels)	Actual coverage (vessels)	Actual coverage (R_{ij}) (%)	Fishing activity (potlifts)	Average no. potlifts (P_{ij}^{av})	Target potlifts (P_{ij}^{T})(%)	Actual coverage (no. potlifts)	Actual coverage (% pots)
1993	AW	88	26	38	43	105077	87	1.4	2117	2.01
1993	SS	103	31	38	37	108449	86	1.4	1997	1.84
1994	AW	86	26	44	51	115231	93	1.3	2092	1.82
1994	SS	49	15	20	41	52052	85	1.4	894	1.72
1995	AW	86	26	3	3	111626	95	1.3	1964	1.76
1995	SS	36	11	8	22	25362	82	1.5	361	1.42
1996	AW	81	24	39	48	116074	92	1.3	1996	1.72
1996	SS	24	7	3	13	11295	71	1.7	84	0.74
1997	AW	81	24	39	48	109699	96	1.2	1643	1.50
1997	SS	24	7	1	4	11104	67	1.8	3	0.03
1998	AW	60	18	38	63	82071	87	1.4	1770	2.16
1998	SS	25	8	0	0	10201	67	1.8	0	0.00
1999	AW	75	23	25	33	101472	94	1.3	1500	1.48
1999	SS	23	7	6	26	26389	73	1.6	322	1.22
2000	AW	71	21	31	44	87487	91	1.3	1419	1.62
2000	SS	46	14	9	20	57060	80	1.5	544	0.95

Table A3: Fishing activity (no. of vessels and pots) and logbook coverage (vessels and pots) in CRA 2, Area 907. The shaded areas represent seasons and areas in which the logbook coverage exceeded the target participation rate. See methods for formulae definition

Year	Season	Fishing activity (vessels)	Target (30%) coverage (vessels)	Actual coverage (vessels)	Actual coverage (R_{ij}) (%)	Fishing activity (potlifts)	Average no. potlifts (P_{ij}^{av})	Target potlifts (P_{ij}^{T})(%)	Actual coverage (no. potlifts)	Actual coverage (% pots)
1993	AW	23	7	8	35	26520	87	1.4	451	1.70
1993	SS	29	9	8	28	28464	86	1.4	416	1.46
1994	AW	24	7	15	63	22895	93	1.3	790	3.45
1994	SS	27	8	6	22	15938	85	1.4	242	1.52
1995	AW	23	7	18	78	22612	95	1.3	738	3.26
1995	SS	2	1	1	50	480	82	1.5	19	3.96
1996	AW	26	8	16	62	16121	92	1.3	592	3.67
1996	SS	1	0	0	0	128	71	1.7	0	0.00
1997	AW	25	8	15	60	19989	96	1.2	685	3.43
1997	SS	2	1	1	50	476	67	1.8	7	1.47
1998	AW	17	5	8	47	17641	87	1.4	257	1.46
1998	SS	4	1	0	0	1832	67	1.8	0	0.00
1999	AW	33	10	16	48	40821	94	1.3	790	1.94
1999	SS	11	3	3	27	5888	73	1.6	85	1.44
2000	AW	28	8	9	32	41473	91	1.3	537	1.29
2000	SS	19	6	3	16	17908	80	1.5	139	0.78

Table A4: Fishing activity (no. of vessels and pots) and logbook coverage (vessels and pots) in CRA 2, Area 908. The shaded areas represent seasons and areas in which the logbook coverage exceeded the target participation rate. See methods for formulae definition.

Year	Season	Fishing activity (vessels)	Target (30%) coverage (vessels)	Actual coverage (vessels)	Actual coverage (R_{ij}) (%)	Fishing activity (potlifts)	Average no. potlifts (P_{ij}^{av})	Target potlifts (P_{ij}^{T})(%)	Actual coverage (no. potlifts)	Actual coverage (% pots)
1993	AW	49	15	16	33	74576	87	1.4	906	1.21
1993	SS	70	21	15	21	71044	86	1.4	845	1.19
1994	AW	43	13	17	40	63941	93	1.3	842	1.32
1994	SS	40	12	6	15	36621	85	1.4	262	0.72
1995	AW	50	15	13	26	70210	95	1.3	587	0.84
1995	SS	34	10	2	6	23144	82	1.5	94	0.41
1996	AW	47	14	11	23	53351	92	1.3	553	1.04
1996	SS	16	5	2	13	8818	71	1.7	93	1.05
1997	AW	37	11	9	24	61971	96	1.2	475	0.77
1997	SS	6	2	1	17	3988	67	1.8	56	1.40
1998	AW	45	14	10	22	58806	87	1.4	496	0.84
1998	SS	11	3	3	27	7850	67	1.8	156	1.99
1999	AW	38	11	11	29	69447	94	1.3	565	0.81
1999	SS	12	4	1	8	6212	73	1.6	8	0.13
2000	AW	34	10	10	29	49715	91	1.3	598	1.20
2000	SS	15	5	2	13	10821	80	1.5	104	0.96

Table A5: Fishing activity (no. of vessels and pots) and logbook coverage (vessels and pots) in CRA 5, Area 916. The shaded areas represent seasons and areas in which the logbook coverage exceeded the target participation rate. See methods for formulae definition.

Year	Season	Fishing activity (vessels)	Target (30%) coverage (vessels)	Actual coverage (vessels)	Actual coverage (R_{ij}) (%)	Fishing activity (potlifts)	Average no. potlifts (P_{ij}^{av})	Target potlifts (P_{ij}^{T})(%)	Actual coverage (no. potlifts)	Actual coverage (% pots)
1993	AW	45	14	0	0	57704	84	1.4	0	0.00
1993	SS	44	13	0	0	113312	102	1.2	0	0.00
1994	AW	35	11	1	3	55534	87	1.4	46	0.08
1994	SS	36	11	7	19	85369	99	1.2	498	0.58
1995	AW	47	14	0	0	62091	97	1.2	0	0.00
1995	SS	34	10	2	6	64692	102	1.2	112	0.17
1996	AW	44	13	0	0	78003	106	1.1	0	0.00
1996	SS	24	7	4	17	30848	93	1.3	80	0.26
1997	AW	31	9	4	13	53784	101	1.2	143	0.27
1997	SS	10	3	0	0	5490	65	1.8	0	0.00
1998	AW	26	8	6	23	29794	92	1.3	172	0.58
1998	SS	8	2	1	13	4962	57	2.1	8	0.16
1999	AW	30	9	10	33	42675	99	1.2	451	1.06
1999	SS	17	5	0	0	3500	56	2.1	0	0.00
2000	AW	26	8	13	50	27543	95	1.3	505	1.83
2000	SS	11	3	0	0	963	58	2.1	0	0.00

Table A6: Fishing activity (no. of vessels and pots) and logbook coverage (vessels and pots) in CRA 5, Area 917. The shaded areas represent seasons and areas in which the logbook coverage exceeded the target participation rate. See methods for formulae definition.

Year	Season	Fishing activity (vessels)	Target (30%) coverage (vessels)	Actual coverage (vessels)	Actual coverage (R_{ij}) (%)	Fishing activity (potlifts)	Average no. potlifts (P_{ij}^{av})	Target potlifts (P_{ij}^{T})(%)	Actual coverage (no. potlifts)	Actual coverage (% pots)
1993	AW	153	46	0	0	162064	84	1.4	0	0.00
1993	SS	178	53	0	0	295633	102	1.2	0	0.00
1994	AW	133	40	7	5	127885	87	1.4	156	0.12
1994	SS	165	50	38	23	285847	99	1.2	2589	0.91
1995	AW	115	35	9	8	112836	97	1.2	295	0.26
1995	SS	143	43	18	13	210154	102	1.2	862	0.41
1996	AW	123	37	19	15	155532	106	1.1	854	0.55
1996	SS	97	29	15	15	97450	93	1.3	696	0.71
1997	AW	95	29	17	18	117706	101	1.2	784	0.67
1997	SS	69	21	4	6	32918	65	1.8	236	0.72
1998	AW	84	25	10	12	92468	92	1.3	407	0.44
1998	SS	62	19	2	3	28650	57	2.1	31	0.11
1999	AW	105	32	16	15	136592	99	1.2	713	0.52
1999	SS	66	20	4	6	39274	56	2.1	110	0.28
2000	AW	86	26	25	29	118938	95	1.3	1064	0.89
2000	SS	53	16	5	9	29373	58	2.1	282	0.96

Table A7: **Fishing activity (no. of vessels and pots) and logbook coverage (vessels and pots) in CRA 5, Area 918. The shaded areas represent seasons and areas in which the logbook coverage exceeded the target participation rate. See methods for formulae definition.**

Year	Season	Fishing activity (vessels)	Target (30%) coverage (vessels)	Actual coverage (vessels)	Actual coverage (R_{ij}) (%)	Fishing activity (potlifts)	Average no. potlifts (P_{ij}^{av})	Target potlifts (P_{ij}^{T})(%)	Actual coverage (no. potlifts)	Actual coverage (% pots)
1993	AW	36	11	0	0	19200	84	1.4	0	0.00
1993	SS	53	16	0	0	31326	102	1.2	0	0.00
1994	AW	36	11	0	0	15810	87	1.4	0	0.00
1994	SS	37	11	0	0	17018	99	1.2	0	0.00
1995	AW	25	8	0	0	11522	97	1.2	0	0.00
1995	SS	34	10	0	0	13272	102	1.2	0	0.00
1996	AW	30	9	0	0	11110	106	1.1	0	0.00
1996	SS	17	5	0	0	4227	93	1.3	0	0.00
1997	AW	21	6	0	0	5115	101	1.2	0	0.00
1997	SS	26	8	0	0	5029	65	1.8	0	0.00
1998	AW	12	4	0	0	1678	92	1.3	0	0.00
1998	SS	13	4	0	0	3528	57	2.1	0	0.00
1999	AW	27	8	0	0	7889	99	1.2	0	0.00
1999	SS	20	6	2	10	8397	56	2.1	92	1.10
2000	AW	14	4	6	43	3737	95	1.3	263	7.04
2000	SS	10	3	3	30	2397	58	2.1	97	4.05

Table A8: **Fishing activity (no. of vessels and pots) and logbook coverage (vessels and pots) in CRA 5, Area 933. The shaded areas represent seasons and areas in which the logbook coverage exceeded the target participation rate. See methods for formulae definition.**

Year	Season	Fishing activity (vessels)	Target (30%) coverage (vessels)	Actual coverage (vessels)	Actual coverage (R_{ij}) (%)	Fishing activity (potlifts)	Average no. potlifts (P_{ij}^{av})	Target potlifts (P_{ij}^{T})(%)	Actual coverage (no. potlifts)	Actual coverage (% pots)
1993	AW	57	17	0	0	67177	84	1.4	0	0.00
1993	SS	45	14	0	0	50790	102	1.2	0	0.00
1994	AW	57	17	0	0	69594	87	1.4	0	0.00
1994	SS	31	9	6	19	32596	99	1.2	337	1.03
1995	AW	56	17	6	11	74431	97	1.2	243	0.33
1995	SS	43	13	6	14	49270	102	1.2	372	0.76
1996	AW	63	19	13	21	90817	106	1.1	627	0.69
1996	SS	24	7	2	8	22351	93	1.3	82	0.37
1997	AW	62	19	15	24	79756	101	1.2	562	0.70
1997	SS	15	5	0	0	8740	65	1.8	0	0.00
1998	AW	54	16	9	17	67689	92	1.3	441	0.65
1998	SS	7	2	0	0	3855	57	2.1	0	0.00
1999	AW	58	17	17	29	88821	99	1.2	668	0.75
1999	SS	10	3	1	10	6936	56	2.1	20	0.29
2000	AW	47	14	27	57	82902	95	1.3	1508	1.82
2000	SS	10	3	4	40	6190	58	2.1	74	1.20

Table A9: **Fishing activity (no. of vessels and pots) and logbook coverage (vessels and pots) in CRA 8, Area 922. The shaded areas represent seasons and areas in which the logbook coverage exceeded the target participation rate. See methods for formulae definition.**

Year	Season	Fishing activity (vessels)	Target (30%) coverage (vessels)	Actual coverage (vessels)	Actual coverage (R_{ij}) (%)	Fishing activity (potlifts)	Average no. potlifts (P_{ij}^{av})	Target potlifts (P_{ij}^{T})(%)	Actual coverage (no. potlifts)	Actual coverage (% pots)
1993	AW	15	5	3	20	8834	91	1.3	156	1.77
1993	SS	12	4	1	8	4069	88	1.4	31	0.76
1994	AW	16	5	4	25	8262	90	1.3	188	2.28
1994	SS	15	5	2	13	6185	89	1.4	71	1.15
1995	AW	6	2	4	67	3331	93	1.3	213	6.39
1995	SS	11	3	4	36	3319	96	1.2	182	5.48
1996	AW	12	4	4	33	4680	95	1.3	188	4.02
1996	SS	12	4	4	33	2984	99	1.2	151	5.06
1997	AW	10	3	2	20	2064	97	1.2	88	4.26
1997	SS	7	2	2	29	1164	102	1.2	32	2.75
1998	AW	< 5								
1998	SS	5	2	0	0	1794	100	1.2	0	0.00
1999	AW	< 5								
1999	SS	< 5								
2000	AW	< 5								
2000	SS	< 5								

Table A10: Fishing activity (no. of vessels and pots) and logbook coverage (vessels and pots) in CRA 8, Area 923. The shaded areas represent seasons and areas in which the logbook coverage exceeded the target participation rate. See methods for formulae definition.

Year	Season	Fishing activity (vessels)	Target (30%) coverage (vessels)	Actual coverage (vessels)	Actual coverage (R_{ij}) (%)	Fishing activity (potlifts)	Average no. potlifts (P_{ij}^{av})	Target potlifts (P_{ij}^{T})(%)	Actual coverage (no. potlifts)	Actual coverage (% pots)
1993	AW	36	11	1	3	29719	91	1.3	31	0.10
1993	SS	33	10	1	3	12650	88	1.4	13	0.10
1994	AW	22	7	5	23	14267	90	1.3	86	0.60
1994	SS	35	11	7	20	20777	89	1.4	140	0.67
1995	AW	24	7	5	21	22705	93	1.3	94	0.41
1995	SS	35	11	8	23	28959	96	1.2	182	0.63
1996	AW	19	6	0	0	23811	95	1.3	0	0.00
1996	SS	35	11	0	0	30750	99	1.2	0	0.00
1997	AW	24	7	3	13	22510	97	1.2	29	0.13
1997	SS	36	11	1	3	18334	102	1.2	1	0.01
1998	AW	24	7	2	8	24117	97	1.2	58	0.24
1998	SS	38	11	2	5	34740	100	1.2	23	0.07
1999	AW	32	10	0	0	29089	106	1.1	0	0.00
1999	SS	32	10	0	0	30499	107	1.1	0	0.00
2000	AW	12	4	0	0	12437	112	1.1	0	0.00
2000	SS	17	5	0	0	8394	109	1.1	0	0.00

Table A11: Fishing activity (no. of vessels and pots) and logbook coverage (vessels and pots) in CRA 8, Area 924. The shaded areas represent seasons and areas in which the logbook coverage exceeded the target participation rate. See methods for formulae definition.

Year	Season	Fishing activity (vessels)	Target (30%) coverage (vessels)	Actual coverage (vessels)	Actual coverage (R_{ij}) (%)	Fishing activity (potlifts)	Average no. potlifts (P_{ij}^{av})	Target potlifts (P_{ij}^{T})(%)	Actual coverage (no. potlifts)	Actual coverage (% pots)
1993	AW	84	25	22	26	81112	91	1.3	784	0.97
1993	SS	66	20	11	17	37828	88	1.4	217	0.57
1994	AW	95	29	21	22	85107	90	1.3	599	0.70
1994	SS	97	29	20	21	75506	89	1.4	529	0.70
1995	AW	62	19	20	32	60068	93	1.3	665	1.11
1995	SS	78	23	19	24	68732	96	1.2	579	0.84
1996	AW	67	20	18	27	71826	95	1.3	697	0.97
1996	SS	80	24	19	24	63840	99	1.2	481	0.75
1997	AW	61	18	10	16	62974	97	1.2	259	0.41
1997	SS	68	20	9	13	55039	102	1.2	137	0.25
1998	AW	57	17	10	18	53804	97	1.2	202	0.38
1998	SS	80	24	8	10	62934	100	1.2	155	0.25
1999	AW	53	16	6	11	68418	106	1.1	62	0.09
1999	SS	42	13	1	2	35265	107	1.1	1	0.00
2000	AW	40	12	9	23	50173	112	1.1	198	0.39
2000	SS	40	12	9	23	39905	109	1.1	242	0.61

Table A12: **Fishing activity (no. of vessels and pots) and logbook coverage (vessels and pots) in CRA 8, Area 926. The shaded areas represent seasons and areas in which the logbook coverage exceeded the target participation rate. See methods for formulae definition.**

Year	Season	Fishing activity (vessels)	Target (30%) coverage (vessels)	Actual coverage (vessels)	Actual coverage (R_{ij}) (%)	Fishing activity (potlifts)	Average no. potlifts (P_{ij}^{av})	Target potlifts (P_{ij}^{T})(%)	Actual coverage (no. potlifts)	Actual coverage (% pots)
1993	AW	140	42	24	17	174799	91	1.3	590	0.34
1993	SS	149	45	11	7	114303	88	1.4	255	0.22
1994	AW	133	40	22	17	146134	90	1.3	592	0.41
1994	SS	138	41	28	20	110926	89	1.4	581	0.52
1995	AW	98	29	27	28	122498	93	1.3	849	0.69
1995	SS	141	42	40	28	118084	96	1.2	1272	1.08
1996	AW	121	36	21	17	149121	95	1.3	594	0.40
1996	SS	135	41	26	19	136265	99	1.2	744	0.55
1997	AW	133	40	19	14	152477	97	1.2	674	0.44
1997	SS	161	48	18	11	156351	102	1.2	447	0.29
1998	AW	95	29	16	17	97764	97	1.2	526	0.54
1998	SS	158	47	19	12	142981	100	1.2	628	0.44
1999	AW	93	28	10	11	136453	106	1.1	329	0.24
1999	SS	110	33	5	5	104490	107	1.1	171	0.16
2000	AW	93	28	13	14	155617	112	1.1	524	0.34
2000	SS	87	26	6	7	74648	109	1.1	144	0.19

Table A13: ***Fishing activity (no. of vessels and pots) and logbook coverage (vessels and pots) in CRA 8, Area 927. The shaded areas represent seasons and areas in which the logbook coverage exceeded the target participation rate. See methods for formulae definition.***

Year	Season	Fishing activity (vessels)	Target (30%) coverage (vessels)	Actual coverage (vessels)	Actual coverage (R_{ij}) (%)	Fishing activity (potlifts)	Average no. potlifts (P_{ij}^{av})	Target potlifts (P_{ij}^{T})(%)	Actual coverage (no. potlifts)	Actual coverage (% pots)
1993	AW	105	32	25	24	129091	91	1.3	977	0.76
1993	SS	118	35	21	18	96841	88	1.4	603	0.62
1994	AW	90	27	34	38	115467	90	1.3	1202	1.04
1994	SS	115	35	36	31	102512	89	1.4	1004	0.98
1995	AW	88	26	27	31	104583	93	1.3	968	0.93
1995	SS	106	32	26	25	112581	96	1.2	803	0.71
1996	AW	83	25	28	34	97386	95	1.3	797	0.82
1996	SS	113	34	31	27	133346	99	1.2	1226	0.92
1997	AW	84	25	27	32	101285	97	1.2	1028	1.01
1997	SS	97	29	41	42	111365	102	1.2	1199	1.08
1998	AW	68	20	14	21	84205	97	1.2	594	0.71
1998	SS	85	26	34	40	105714	100	1.2	1326	1.25
1999	AW	64	19	15	23	90313	106	1.1	659	0.73
1999	SS	82	25	17	21	92415	107	1.1	536	0.58
2000	AW	71	21	26	37	120872	112	1.1	1121	0.93
2000	SS	93	28	22	24	122871	109	1.1	727	0.59

Table A14: Fishing activity (no. of vessels and pots) and logbook coverage (vessels and pots) in CRA 8, Area 928. The shaded areas represent seasons and areas in *which the logbook coverage exceeded the target participation rate. See methods for formulae definition.*

Year	Season	Fishing activity (vessels)	Target (30%) coverage (vessels)	Actual coverage (vessels)	Actual coverage (R_{ij}) (%)	Fishing activity (potlifts)	Average no. potlifts (P_{ij}^{av})	Target potlifts (P_{ij}^{T})(%)	Actual coverage (no. potlifts)	Actual coverage (% pots)
1993	AW	96	29	22	23	116626	91	1.3	857	0.73
1993	SS	159	48	24	15	140502	88	1.4	750	0.53
1994	AW	117	35	9	8	109655	90	1.3	253	0.23
1994	SS	138	41	23	17	127049	89	1.4	673	0.53
1995	AW	105	32	52	50	103190	93	1.3	1509	1.46
1995	SS	119	36	54	45	142457	96	1.2	1809	1.27
1996	AW	100	30	32	32	90311	95	1.3	956	1.06
1996	SS	121	36	29	24	111943	99	1.2	1013	0.90
1997	AW	116	35	40	34	109887	97	1.2	1412	1.28
1997	SS	165	50	46	28	154091	102	1.2	1272	0.83
1998	AW	107	32	21	20	90969	97	1.2	814	0.89
1998	SS	174	52	36	21	172616	100	1.2	1161	0.67
1999	AW	68	20	12	18	81054	106	1.1	499	0.62
1999	SS	112	34	9	8	122850	107	1.1	413	0.34
2000	AW	59	18	13	22	67058	112	1.1	600	0.89
2000	SS	86	26	15	17	84352	109	1.1	549	0.65

Appendix B: Residual diagnostic plots for the GAM models

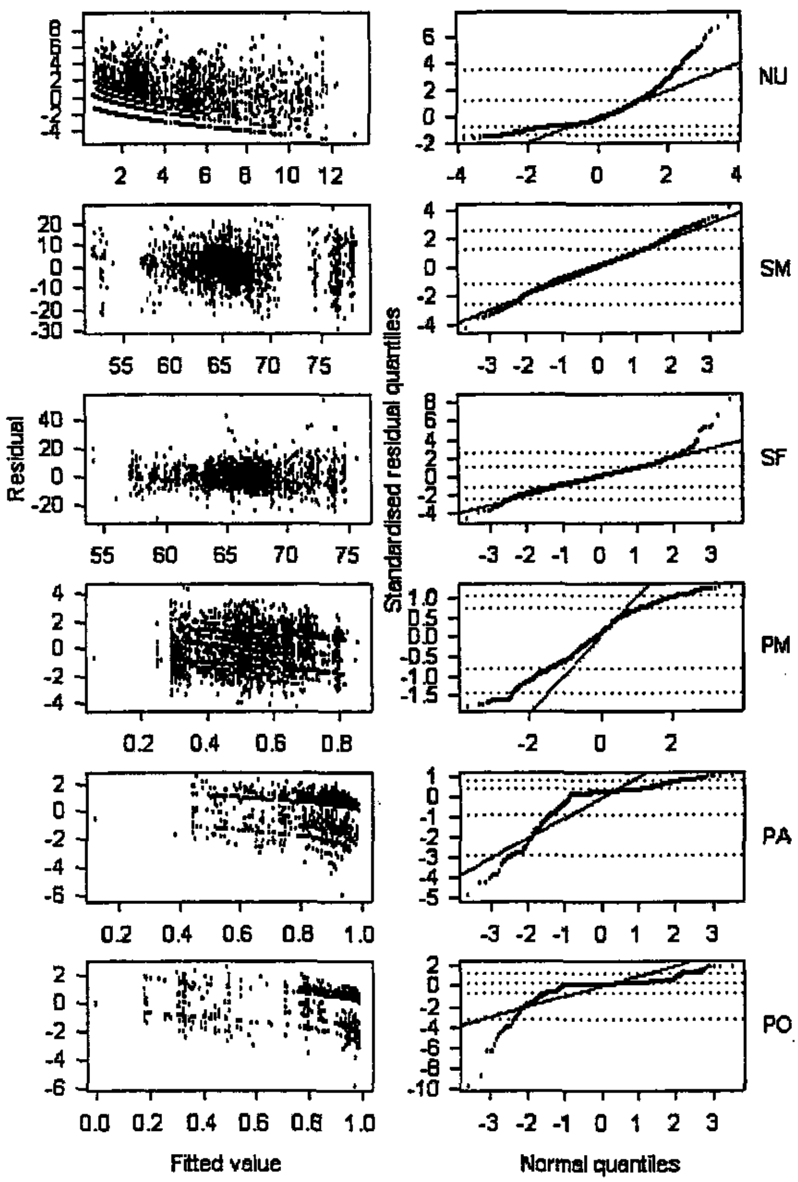

Figure B1: Residual diagnostic plots for CRA 1 models. NU, total number of lobsters; SM, average tail width of males; SF, average tail width of females; PM, proportion of males; PF *proportion of females that are mature; PO, proportion of mature females that are* berried or spent.

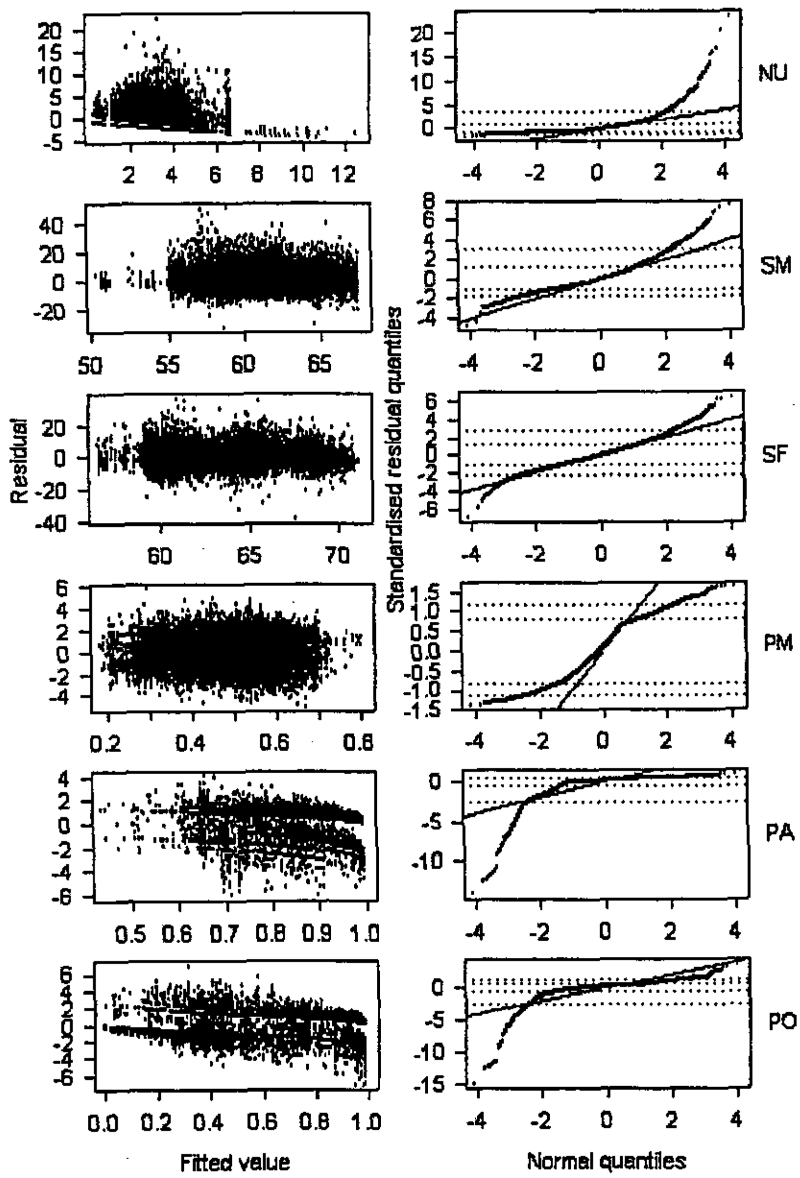

Figure B2: Residual diagnostic plots for CRA 2 models. See Figure B1 for details.

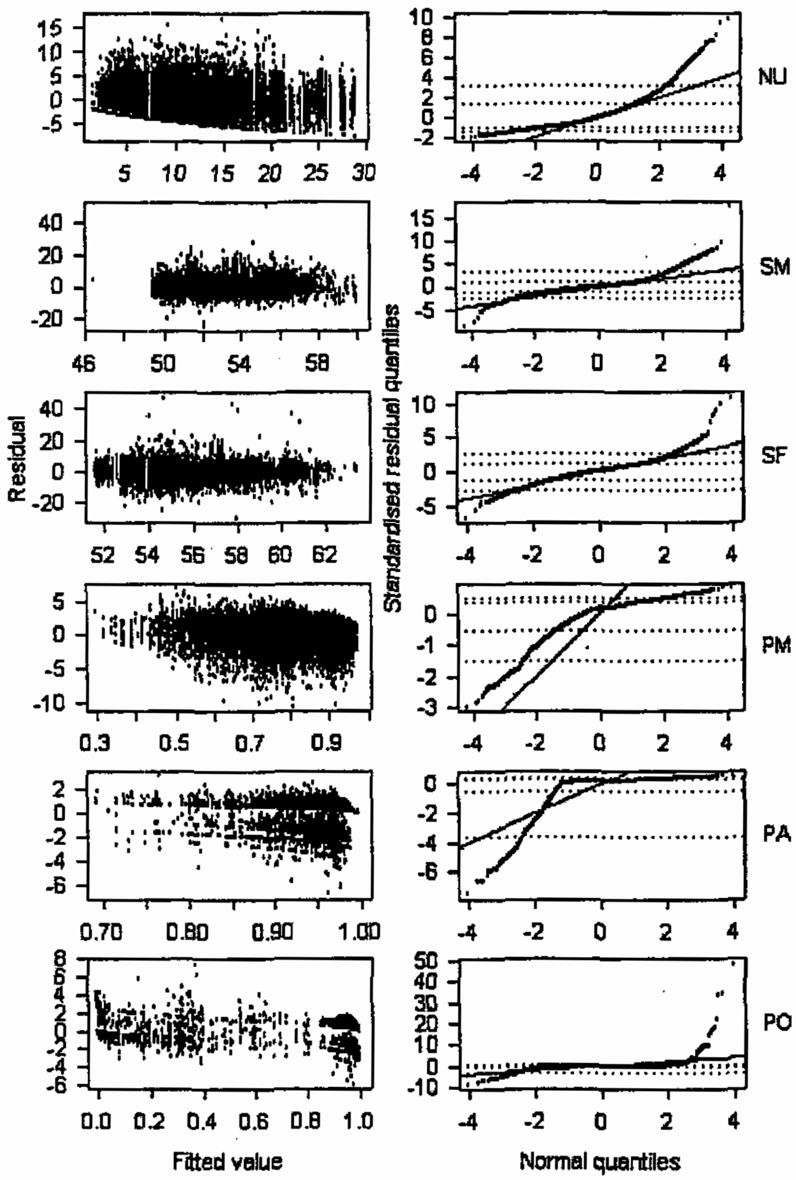

Figure B3: Residual diagnostic plots for CRA 3 models. See Figure B1 for details.

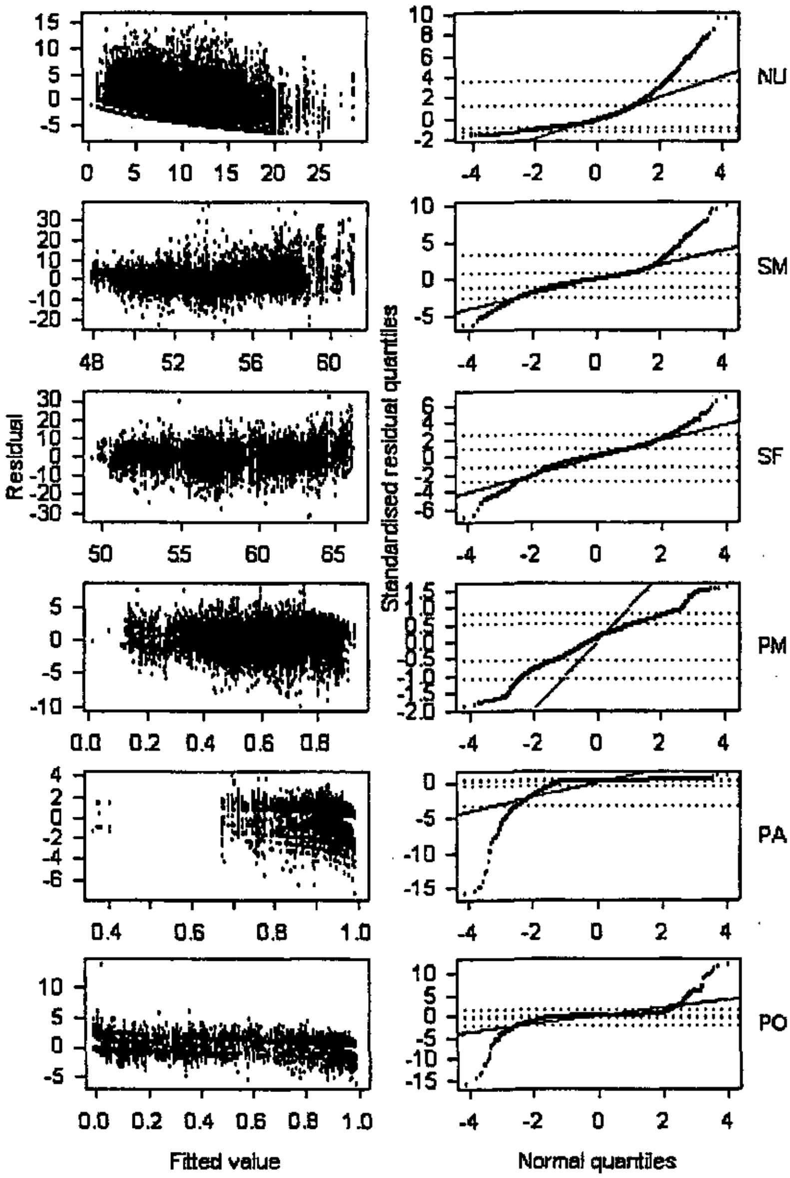

Figure B4: Residual diagnostic plots for CRA 4 models. See Figure B1 for details.

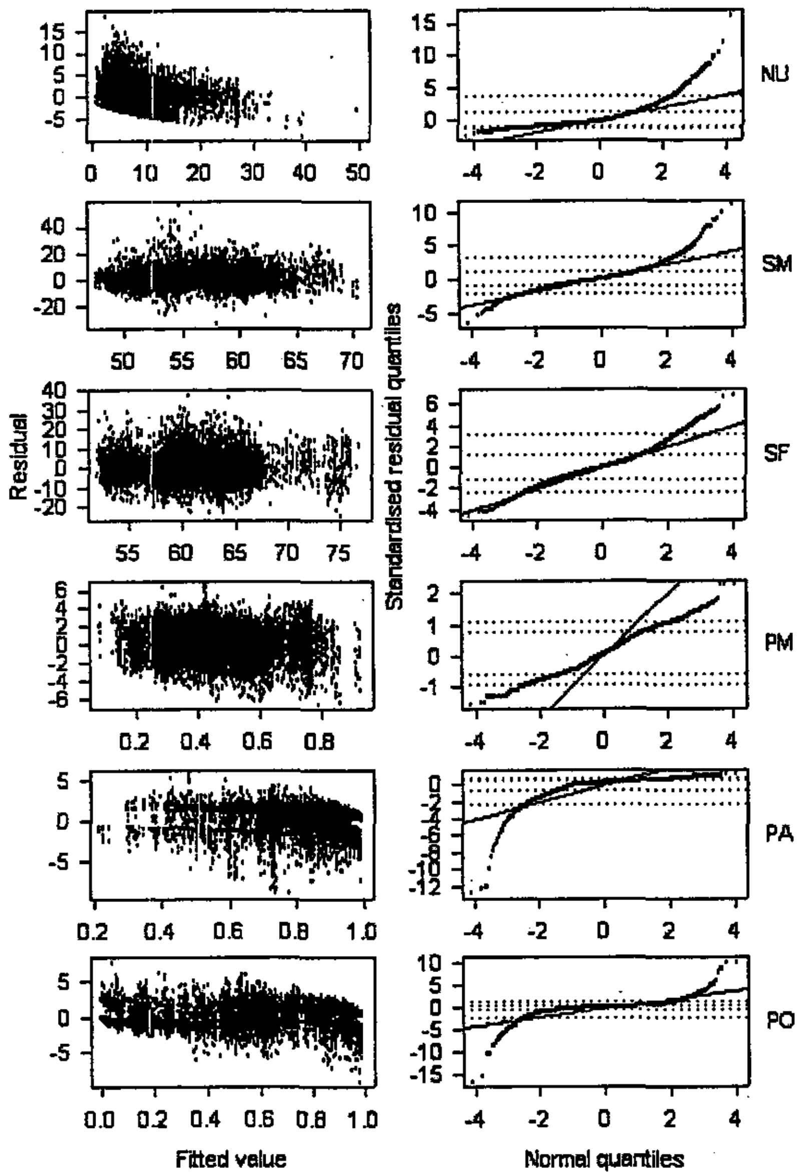

Figure B5: Residual diagnostic plots for CRA 5 models. See Figure B1 for details.

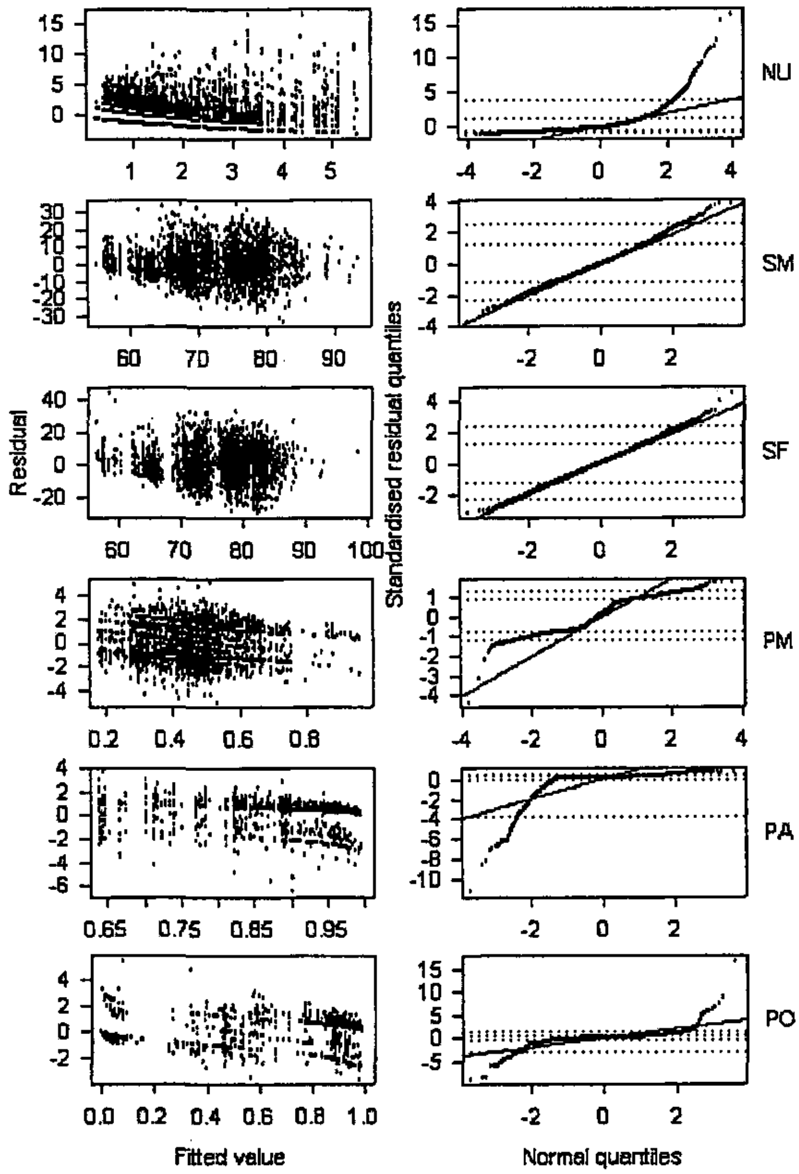

Figure B6: Residual diagnostic plots for CRA 6 models. See Figure B1 for details.

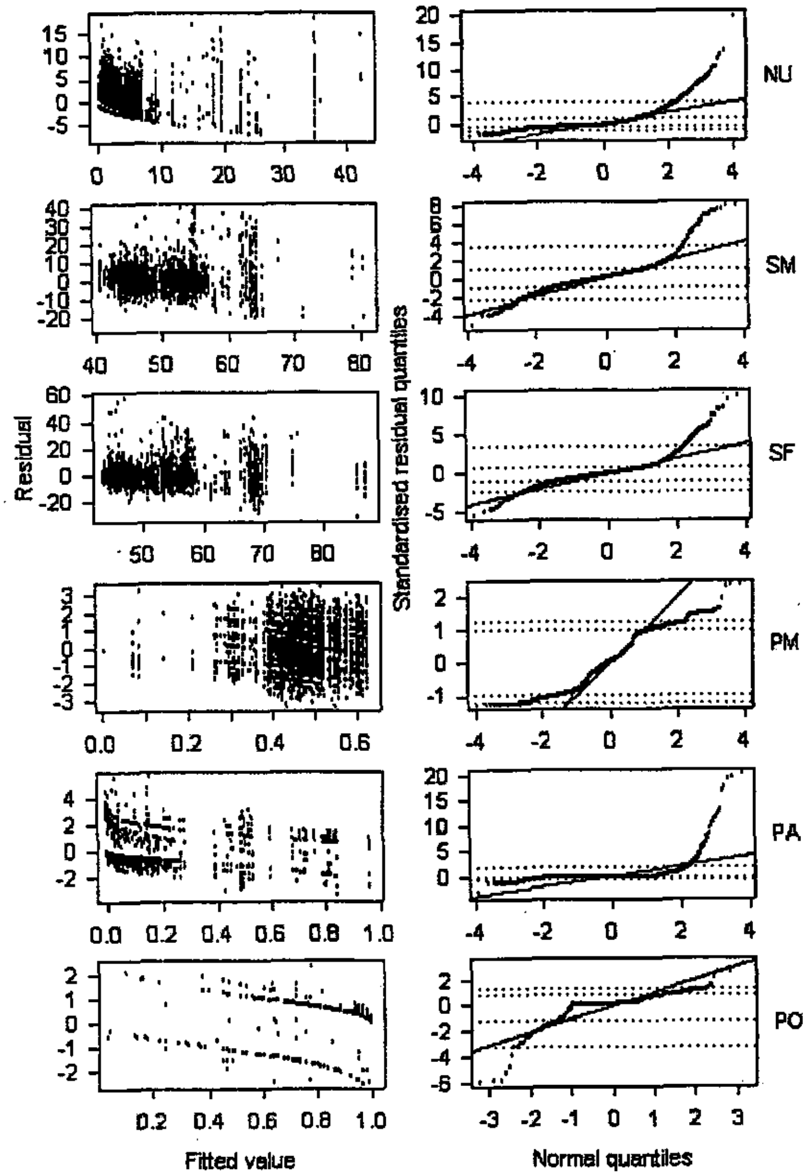

Figure B7: Residual diagnostic plots for CRA 7 models. See Figure B1 for details.

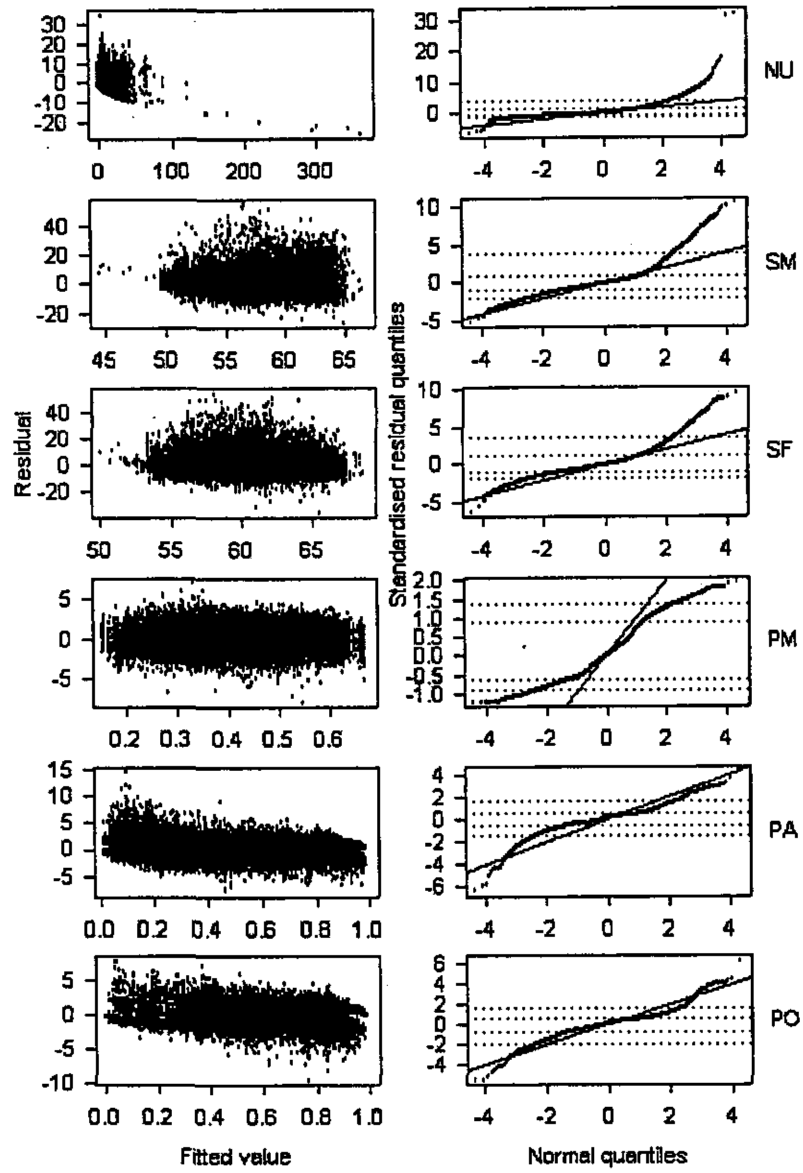

Figure B8: Residual diagnostic plots for CRA 8 models. See Figure B1 for details.

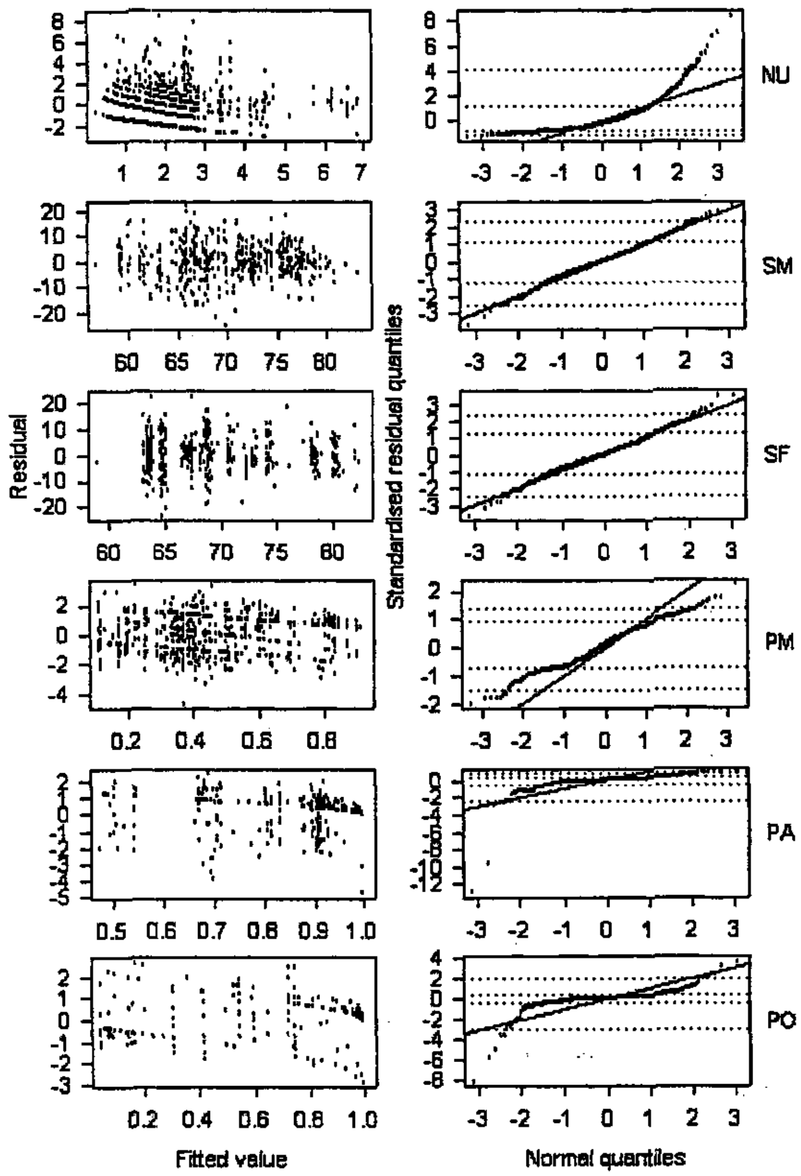

Figure B9: Residual diagnostic plots for CRA 9 models. See Figure B1 for details.