Evaluation of Controlled Fertilization of Acidified Wetlands for Enhancement of Waterfowl Production

Year Two Final Report
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CONTENTS

I. INTRODUCTION

The following represents the year-end report of the second year of a three year project to evaluate the use of controlled fertilization for enhancement of waterfowl production in acidified wetlands. The background and objectives of the study, and a description of the morphology, physics, chemistry and biology of the study sites, have been presented in the first year-end report and are not repeated here. This report concentrates on describing the response of the experimental sites to the addition of fertilizer based on comparisons between pre and post fertilization years and control and experimental sites.

II. FERTILIZATION PROTOCOL

Four of the eight study sites, Jib, Oscar, Perfect and Stump were chosen to serve as experimental sites and receive fertilizer. The remaining four sites, Beaver, Harlow, Menchon and Round, were selected to act as controls.

The fertilization regime employed, in terms of the amount and kind of fertilizer, was based on the results of work carried out at Jordan Lake by Fred Payne and Reg Melanson of the Nova Scotia Department of Natural Resources. In their studies fertilization was carried out using a mixture of triple-super phosphate and urea having a N:P ratio of ten. Their study showed that, upon initial application of the fertilizer, phosphate levels immediately rose to very high levels, but then dropped quickly (within days), and that to produce P levels appropriate to creating eutrophic conditions it was necessary to initially add on the order of 2 mg P l^{-1} of lake water.

Fertilization of the experimental sites was carried out on 27 and 28 April 1991. Perfect and Jib, which are small and reasonably accessible, were fertilized by slowly adding fertilizer by hand into the propeller swash of an outboard motor as the boat traversed the lake (Figure II.1). Oscar, the largest experimental site, and Stump, the least accessible experimental site, were fertilized by helicopter using a water bucket (Figure II.2).

The following amounts of P (added as a triple-super phosphate-urea mix containing a 10:1 ratio of N to P) were added to each experimental site: Oscar - 113.6 Kg; Perfect - 38.9 Kg; Jib - 16.1 Kg; Stump - 10.6 Kg. These quantities represent the amount of fertilizer required to provide 2 mg P l^{-1} of lake water.

III. FIELD SAMPLING PROGRAMME FOR 1991

The 1991 field sampling programme was essentially the same as that used during 1990 except that measurement of suspended particulate matter (SPM) concentration was discontinued and a sediment phosphorous sampling programme added. SPM measurements were discontinued mainly because of the limited information they provided relative to the amount of field and laboratory work required. The addition of the sediment phosphorous sampling

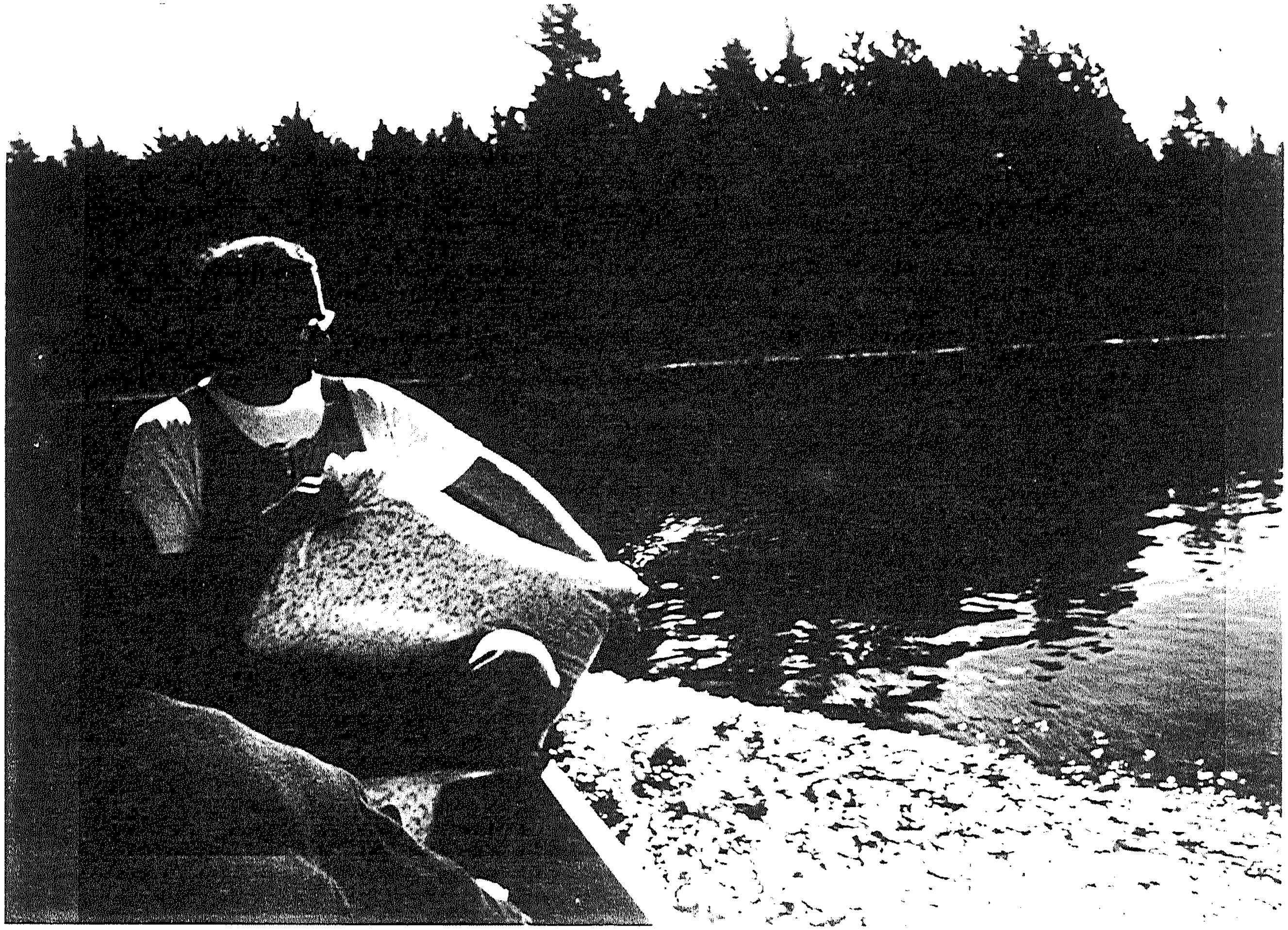


Figure II.1. Fertilization by boat as carried out at Jib and Perfect.

Figure II.2. Fertilization by helicopter and water bucket as carried out at Oscar and Stump.

programme was made possible largely through support provided by a National Research Council IRAP-H grant sponsored by Island Fertilizers of Prince Edward Island. The addition of this programme was considered important in evaluating the fate of added P.

During the same week that fertilization of the experimental sites was carried out, sampling stations, set at the same locations as used during the 1990 field season, were reestablished at each of the study sites. The experimental sites were sampled for water quality parameters immediately before and after fertilization. Thereafter, until 23 June, all sites were sampled for physical, chemical and biological parameters at biweekly intervals. Between 5 July and 10 August the study area was closed to all persons because of a long period of dry weather resulting in a high forest fire index. During this period we were allowed to visit the study area only once, on 23 July. Our visit had to be carried out under the supervision of Nova Scotia Department of Natural Resources personnel and was limited to one day. The time limitation, together with vehicle problems, allowed us to sample only the experimental sites. During the closure we missed one sampling period at the fertilized sites and two sampling periods at the control sites. After 10 August the biweekly sampling programme was resumed until mid-November. On 2 December, at the beginning of ice-up, the 1991 field sampling programme was terminated except for a single winter site visit, to evaluate stratification and water quality under ice cover, on 2-3 March 1992.

IV. VARIATIONS IN ENVIRONMENTAL PARAMETERS

Because of the potential influence that annual variations in precipitation and water temperature may have on the physics, chemistry and biology of the study sites, and to aid in discerning this potential influence from that caused by fertilization, a comparison of average monthly rainfall and water temperature parameters was carried out.

1. Annual Precipitation

Figure IV.1.1 compares the amount of precipitation that occurred during each month of the two study years and the monthly average for the past ten years. Although total annual precipitation was about the same in both years and differed little from the annual average, both 1990 and 1991 were very different from each other in terms of the seasonal variation in precipitation. 1990 was characterized by a wet spring, an average summer and a dry fall whereas 1991 had an average spring, a dry summer and a wet fall.

2. Water Levels

The differences in the seasonal variation of precipitation between 1990 and 1991 resulted in corresponding differences in the water levels at all sites (Figure IV.2.1). The dry summer during 1991 caused water levels to be about 5-20 cm less during June to mid-August. After

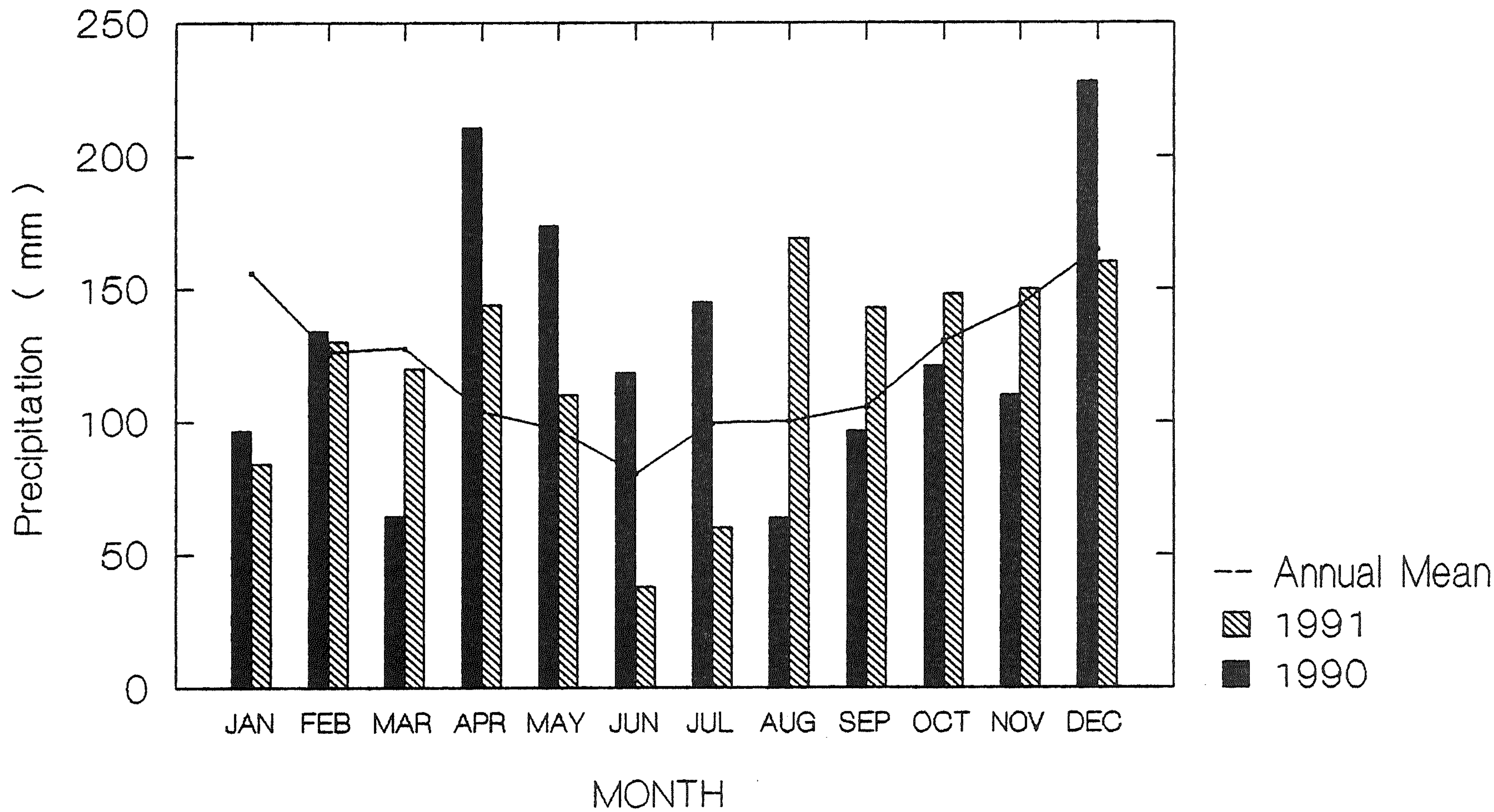


Figure IV.1.1 Total monthly precipitation during 1990 and 1991 compared to the monthly mean for the ten year period between 1981 and 1991 (based on weather data collected at Kejimkujik National Park).

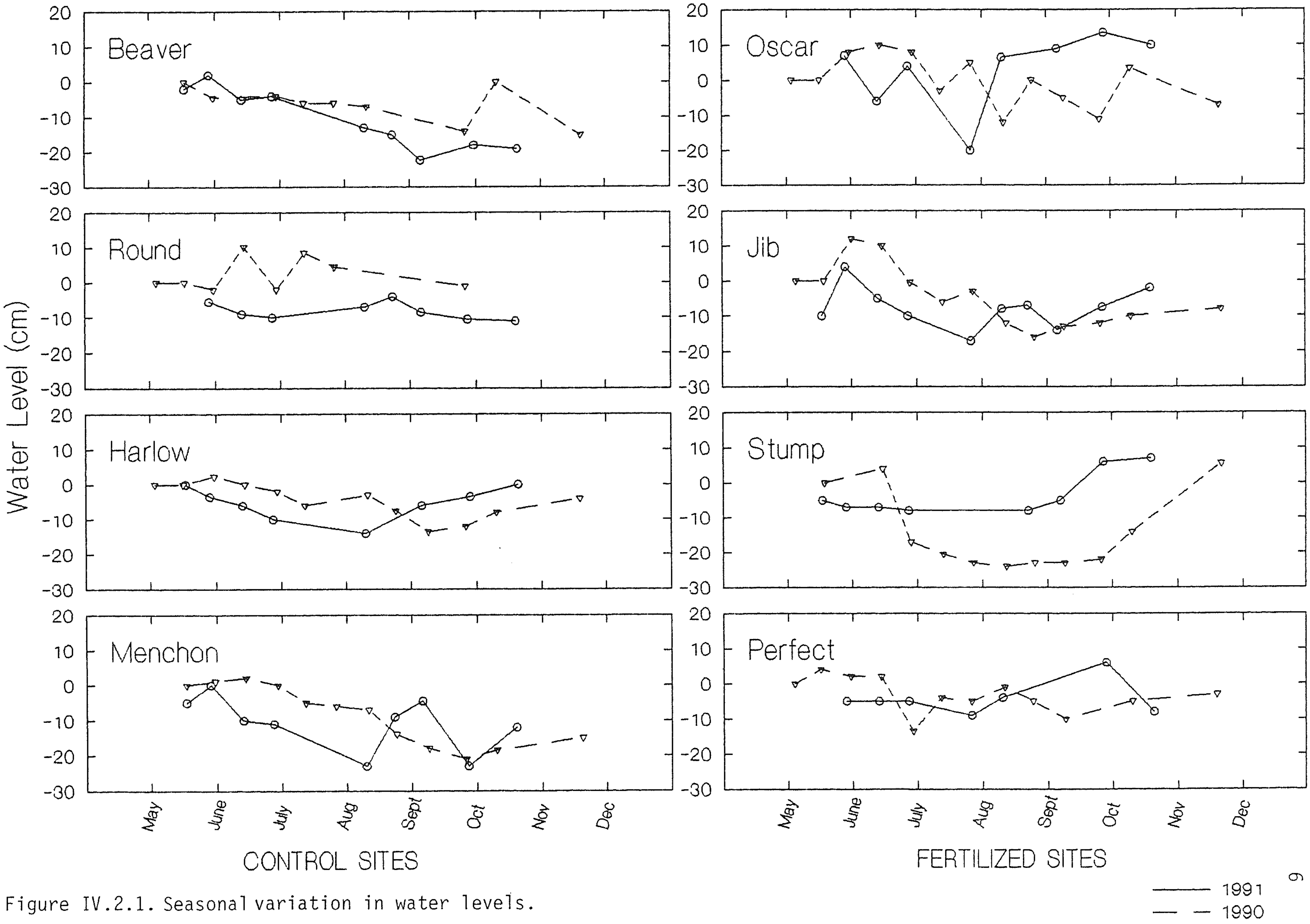


Figure IV.2.1. Seasonal variation in water levels.

mid-August water levels were generally higher during 1991. The greatest variation in water levels during both years occurred at the most shallow sites.

3. Water Temperature

Figure IV.3.1 presents time series data for 1990 and 1991 of surface water temperature, outlet water temperature at those sites having outlets, and bottom water temperature at those sites that thermally stratify. Although there are some differences between years with respect to seasonal variation, the minimum and maximum temperatures at the surface and outlets varied very little. At the stratified sites, however, the bottom water temperatures were slightly lower in 1991, a result of the earlier onset of thermal stratification (see Section IV.4).

4. Thermal Stratification

Contour plots, for both 1990 and 1991, of temperature with depth and time at the four sites exhibiting thermal stratification (Harlow, Jib, Perfect and Round) are presented in Figure IV.4.1. Most sites warmed up on the order of one to two weeks earlier during 1991, but there was little difference in the time of either maximal thermocline development or fall overturn. The earlier onset of thermal stratification during 1991 resulted in bottom waters being isolated earlier which in turn resulted in their having slightly lower temperatures during the summer stratification period.

V. RESPONSE TO FERTILIZATION

The following sections describe the response of the experimental sites to the addition of fertilizer. Interpretation of the changes brought about by the addition of fertilizer was made on the basis of comparisons among the experimental sites between pre and post fertilization years as well as on comparisons between the control and experimental sites after fertilization.

1. Physical Factors

In most cases fertilization would not be expected to have any major effects on physical characteristics of the study sites. One exception is water transparency as measured by Secchi Disk depths. Figure V.1.1 presents time series data comparing Secchi Disk depths at the control and experimental sites during both years. (Menchon and Stump are not included since the bottom was always visible at these sites.) In all cases, Secchi Disk depths were generally lower at both the control and experimental sites during the fertilization year. However, at the experimental sites the reduction was on the order of >50 percent after fertilization, while at the control sites the reduction was usually <10 percent. The reduced Secchi Disk depths at the control sites are probably related to the extremely dry weather during summer which, as a result of evaporation, would tend to increase the concentration of dis-

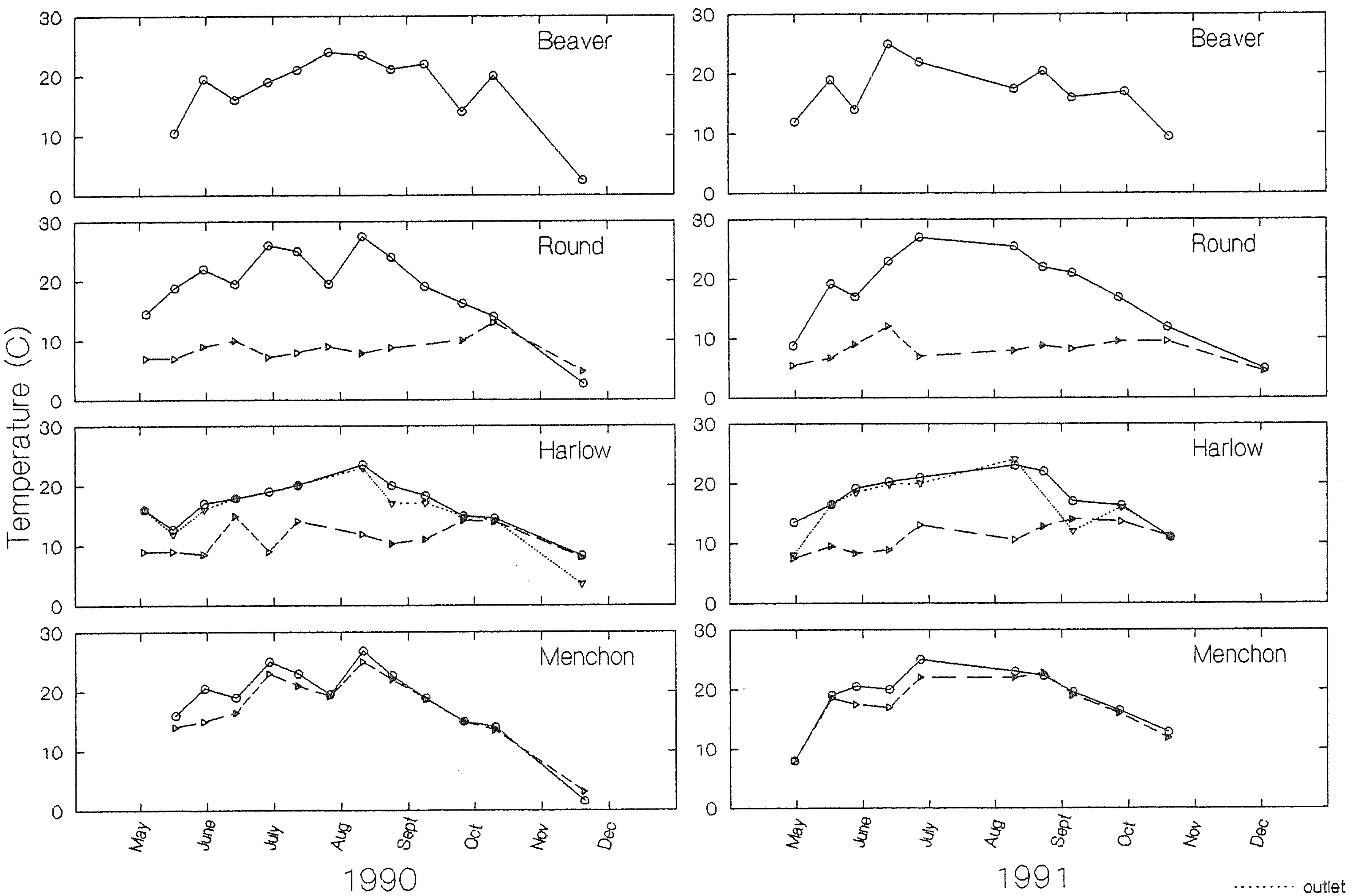


Figure IV.3.1. Seasonal variation in surface and bottom water temperatures.

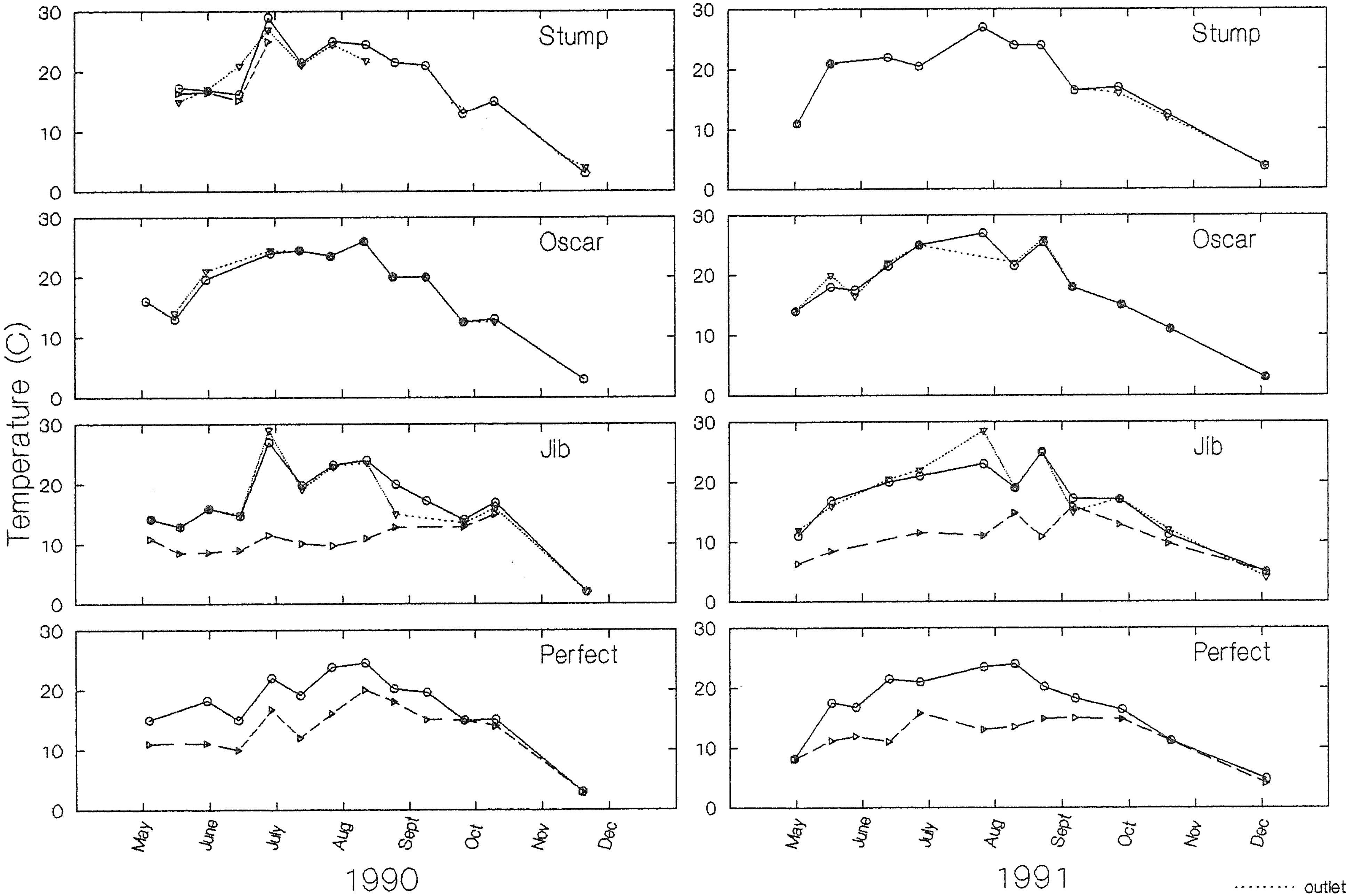


Figure IV.3.1. Continued.

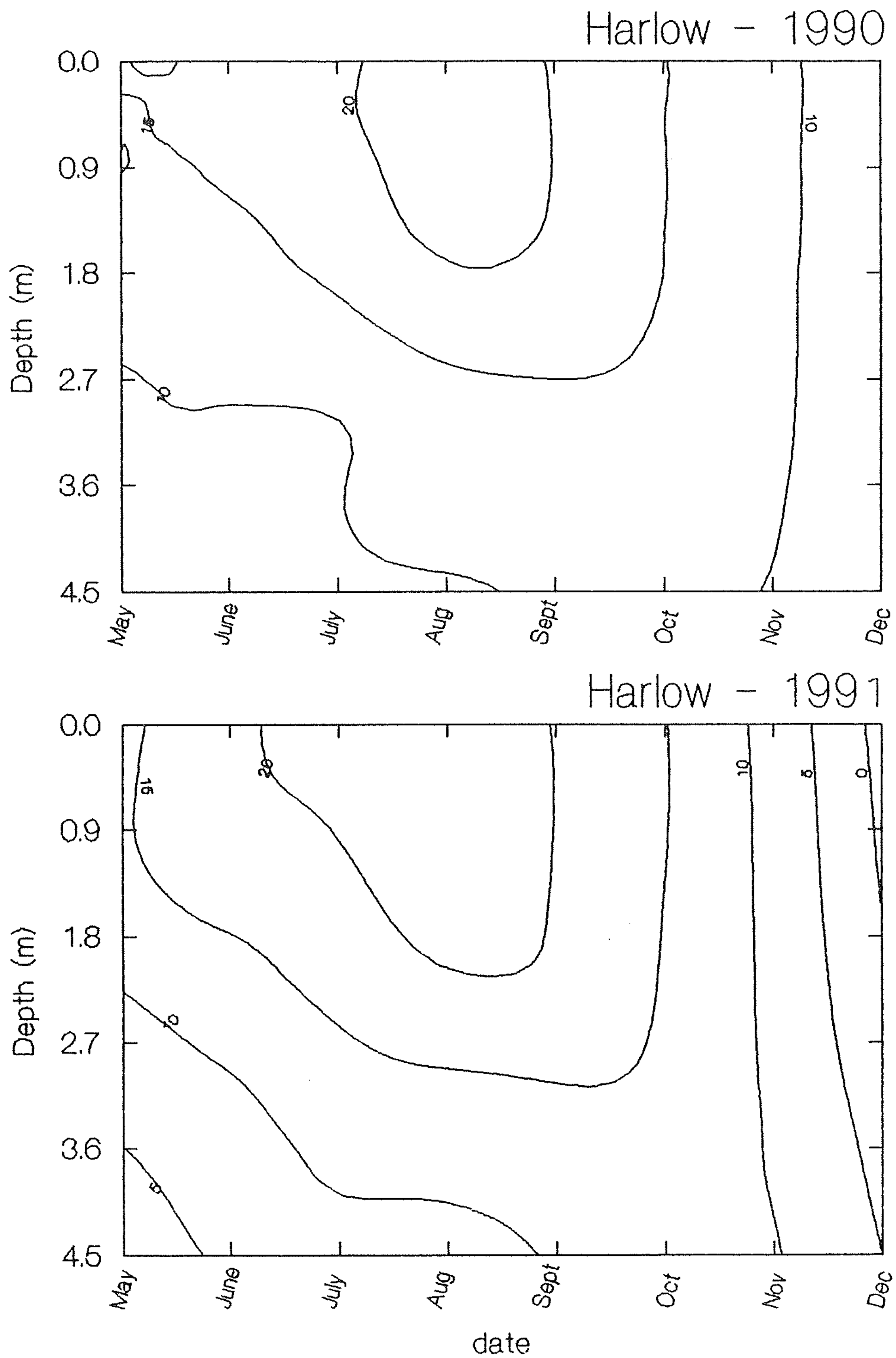


Figure IV.4.1. Contour plots of temperature with time and depth for those sites exhibiting thermal stratification.

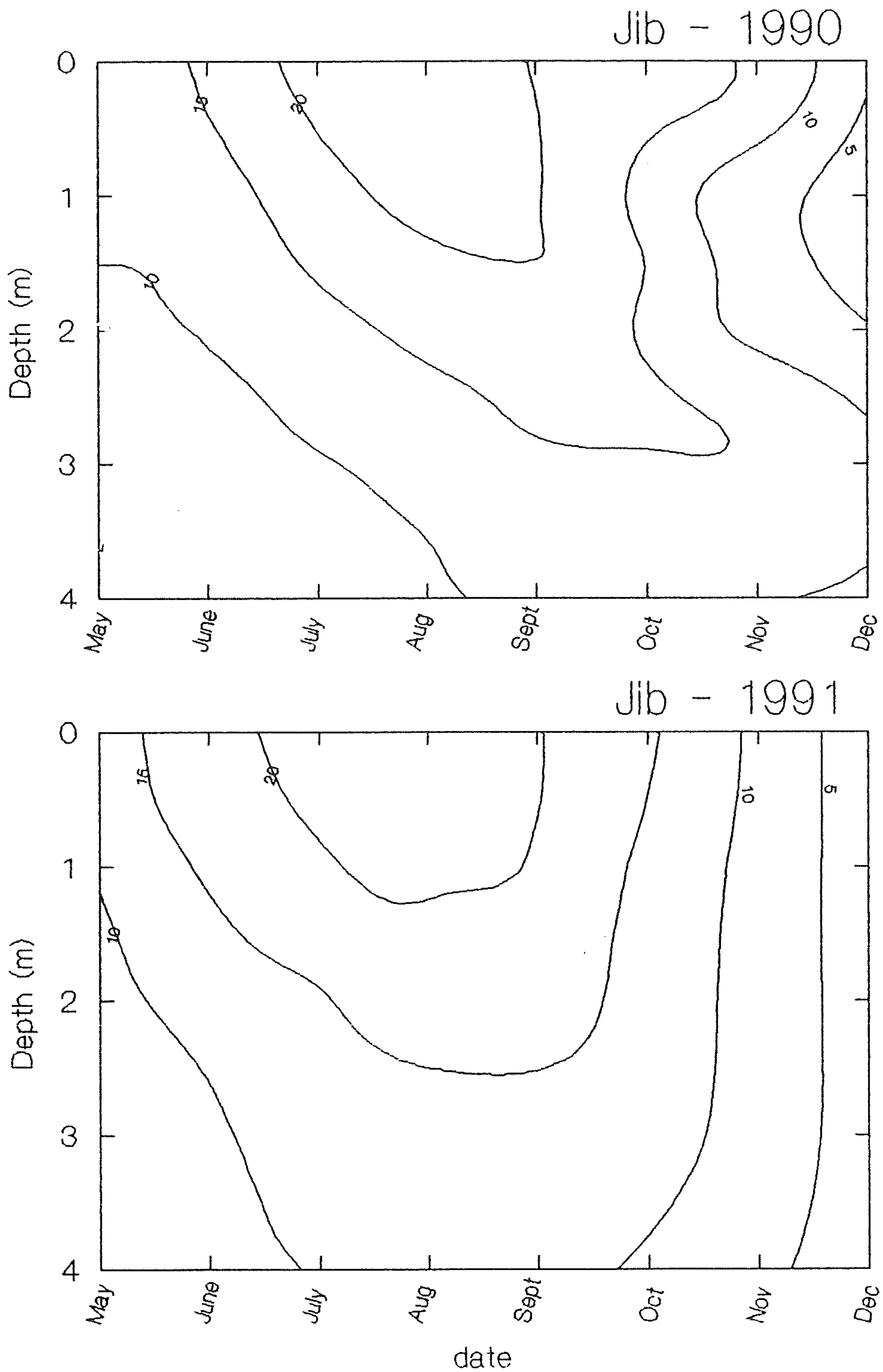
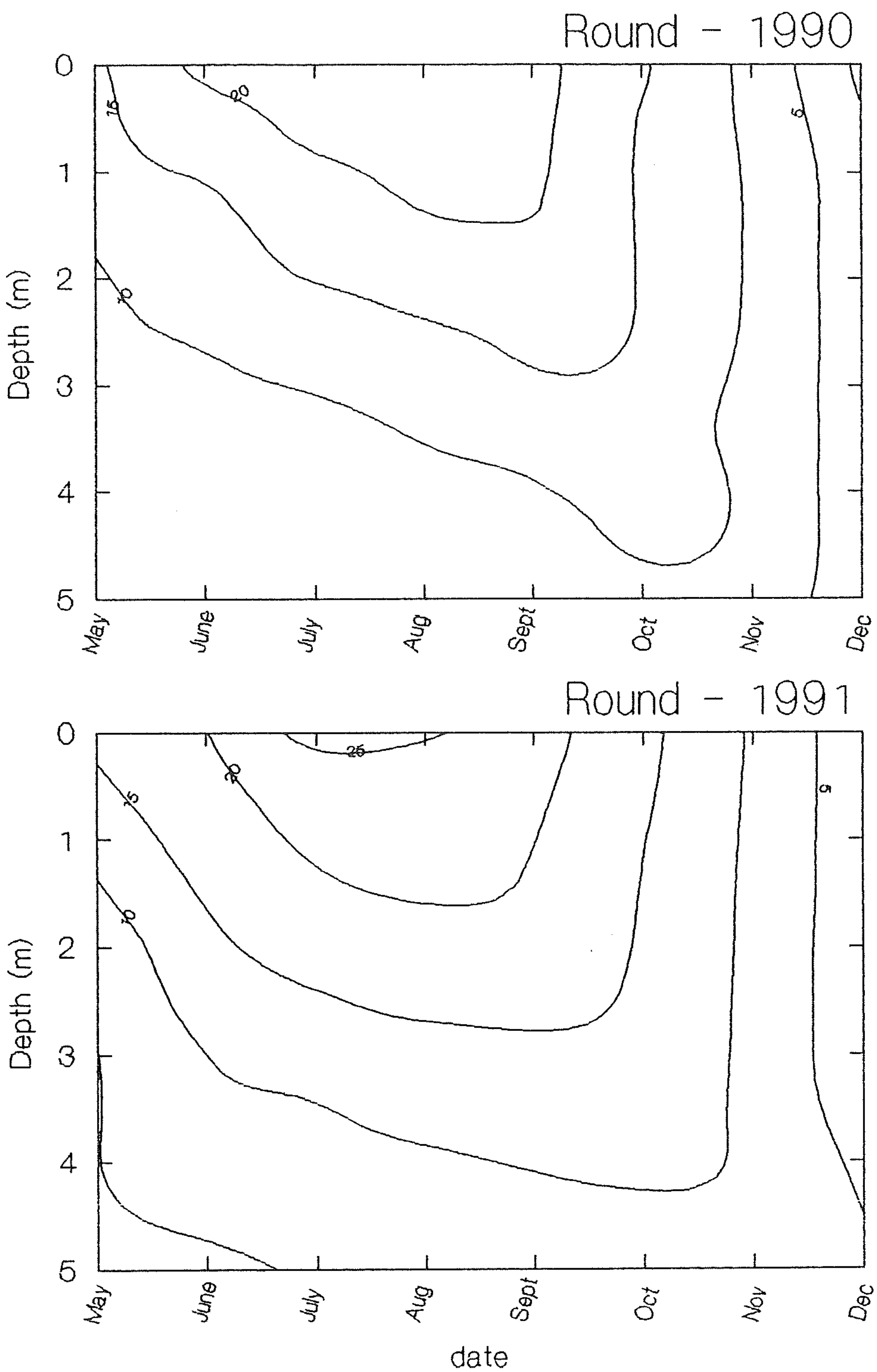


Figure IV.4.1. Continued.



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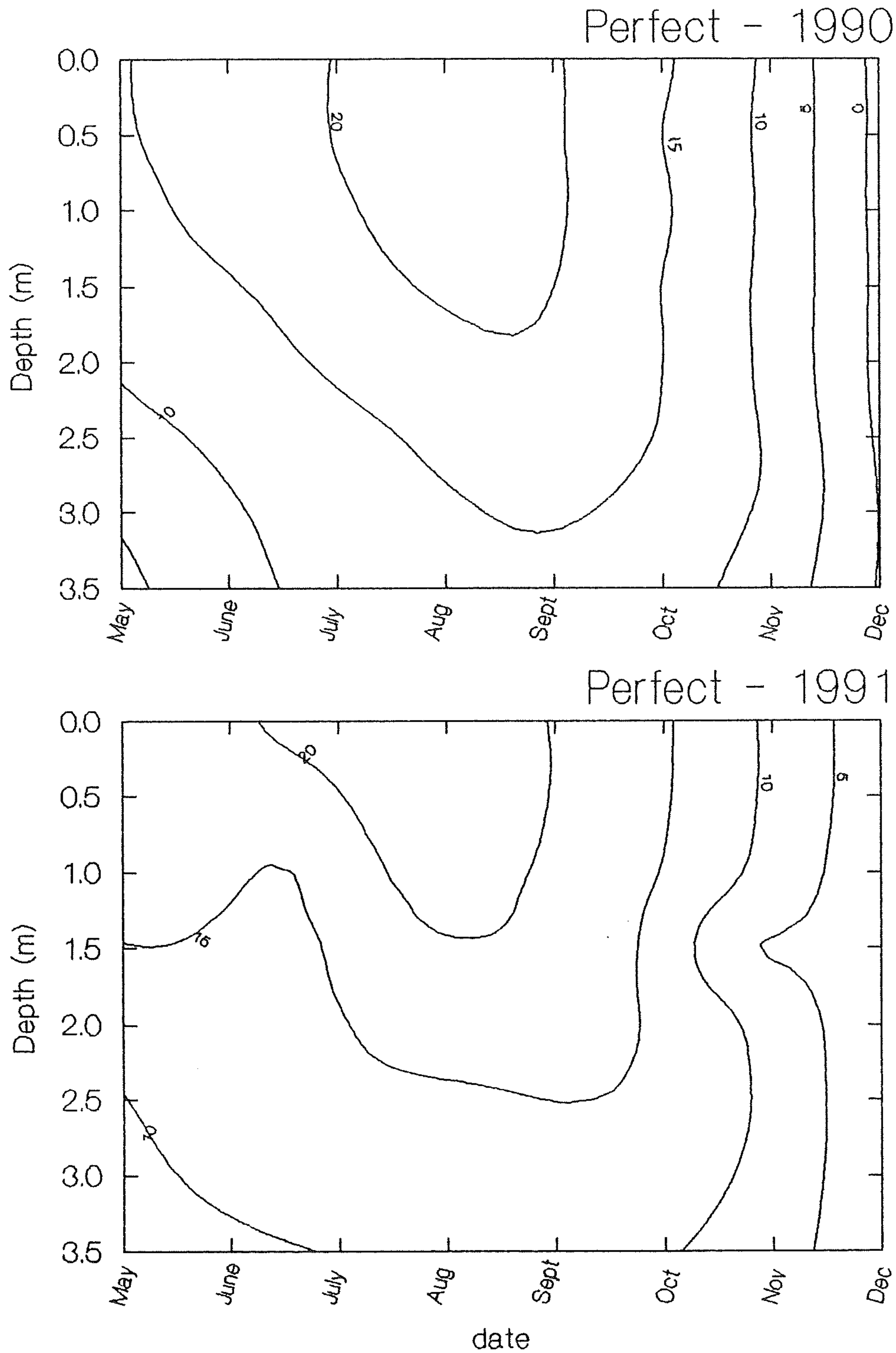

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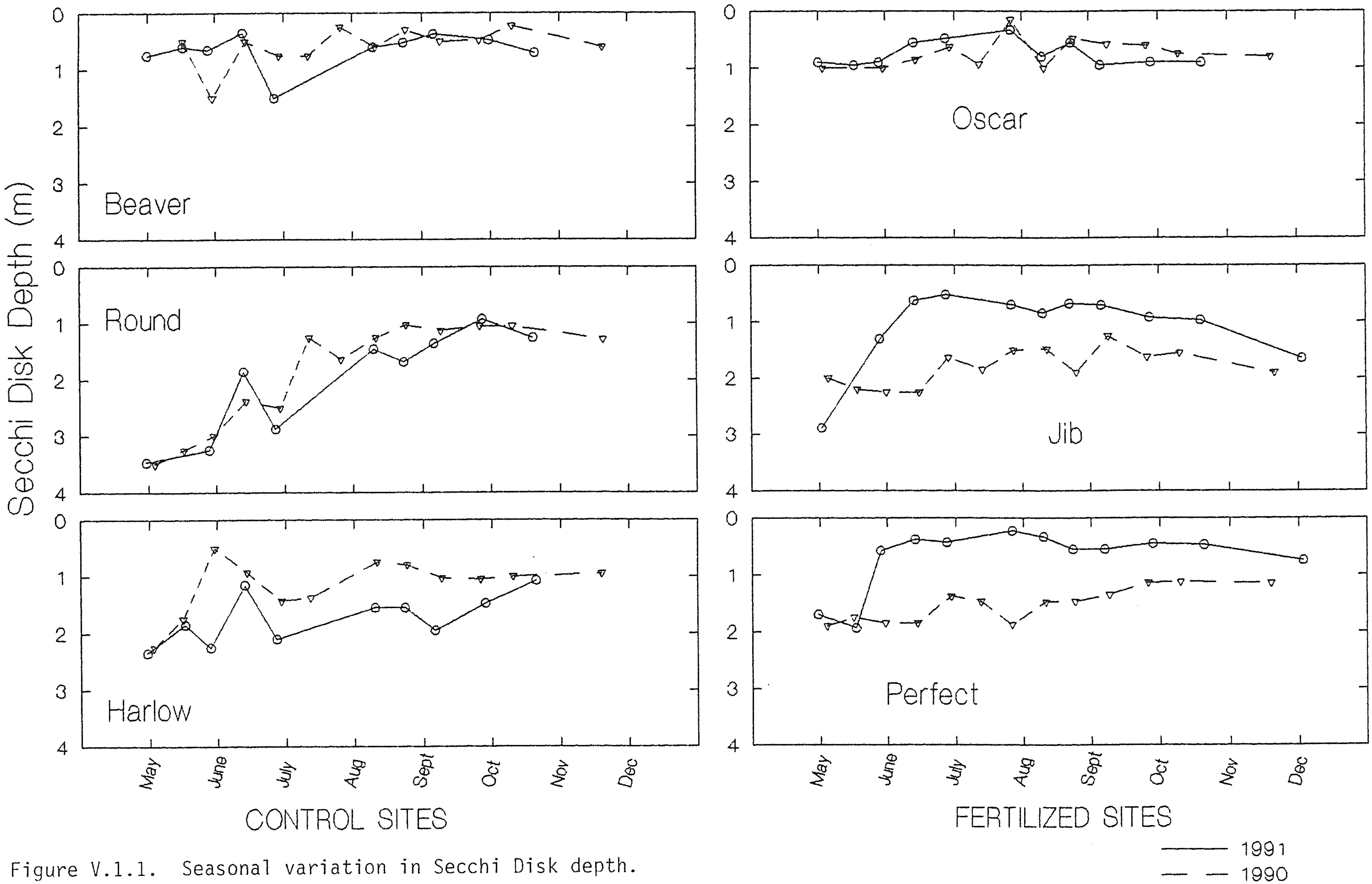


Figure V.1.1. Seasonal variation in Secchi Disk depth.

solved humic acids and other light attenuating substances. The greater reduction in Secchi Disk depths at the experimental sites is undoubtedly related to increased chlorophyll concentrations (see Section V.4).

2. Chemistry

Comparisons of changes in chemistry are based largely on data obtained from chemical analyses carried out by the Acadia Centre for Estuarine Research. Samples collected for subsequent chemical analyses by the Canadian Wildlife Service laboratory at Moncton, N. B. are complete only for the period up to 31 July 1991, limiting their usefulness for determination of seasonal trends. The available CWS data is presented graphically in Appendix A.

2.1 Conductivity

Figure V.2.1.1 illustrates the seasonal trend of surface water conductivity at the control and experimental sites during the 1990 and 1991 field seasons. At most of the study sites conductivities were slightly greater during 1991, particularly during the earlier part of the summer when rainfall was low. At the two stratified experimental sites (Jib and Perfect) fertilization appears to have increased conductivity even more.

2.2 pH

One of the most surprizing changes in chemistry resulting from fertilization was a large increase in pH at the experimental sites (Figure V.2.2.1). This effect was evident at all of the experimental sites, but was most pronounced at Perfect and Jib where the pH reached values of 7.9 and 8.7 respectively. This response, which is most probably a result of the buffering capacity of super-phosphate, gradually increased beginning immediately after fertilization, peaked in early July, and then declined to near normal levels in early August. This trend is very similar to that observed for phosphorous (see Section V.2.4).

2.3 Dissolved Oxygen

Fertilization also appears to have had an influence on dissolved oxygen levels at Jib and Perfect, the two experimental sites that exhibit thermal stratification. During both years a strong thermocline developed during mid-July. Oxygen concentrations in the hypolimnion (Figure V.2.3.1), however, decreased to minimum values approximately two weeks earlier in 1991. In contrast, the two control sites exhibiting thermal stratification, Harlow and Round, attained minimum hypolimnion oxygen concentrations at about the same time during both years.

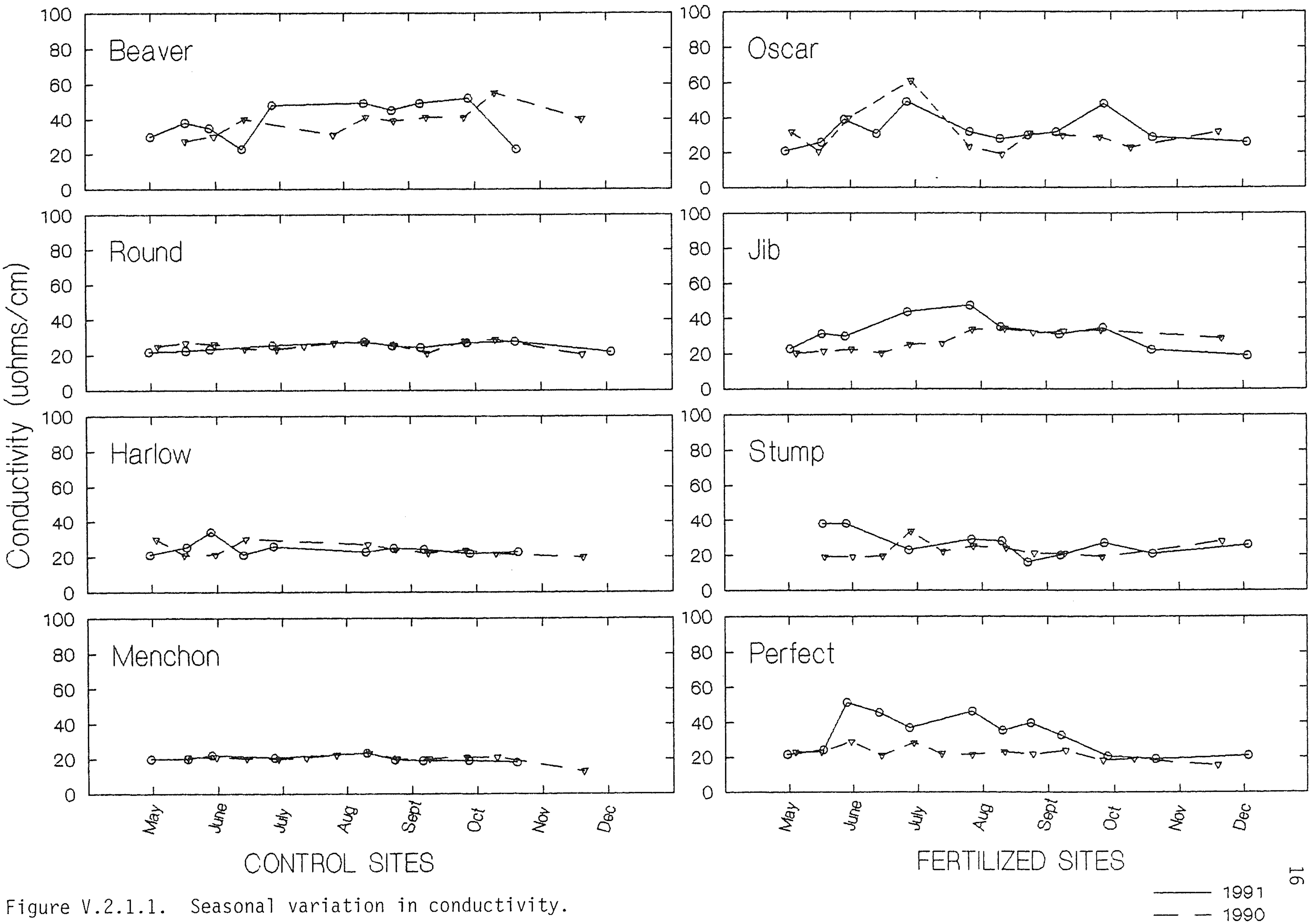


Figure V.2.1.1. Seasonal variation in conductivity.

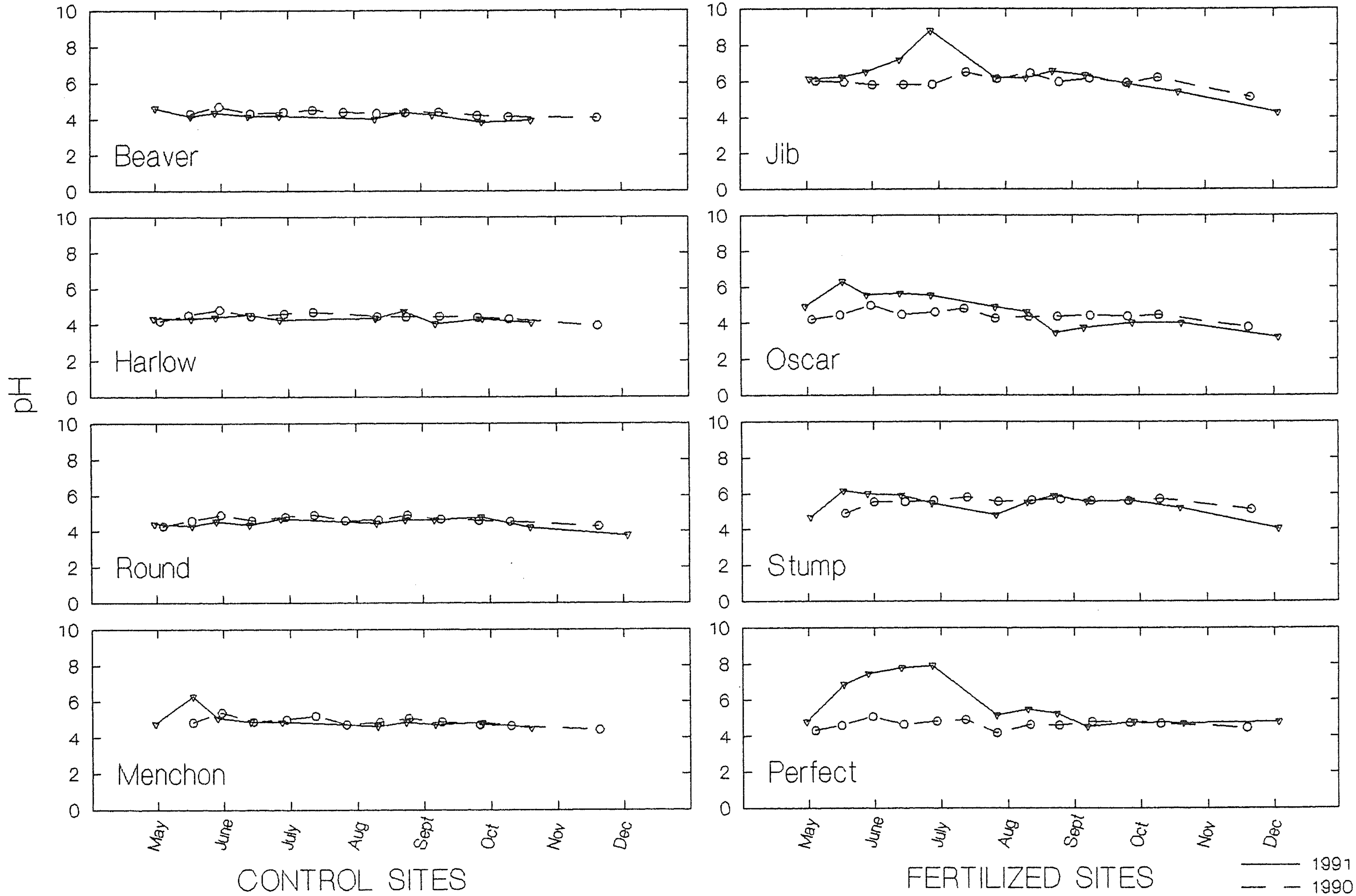


Figure V.2.2.1. Seasonal variation in pH.

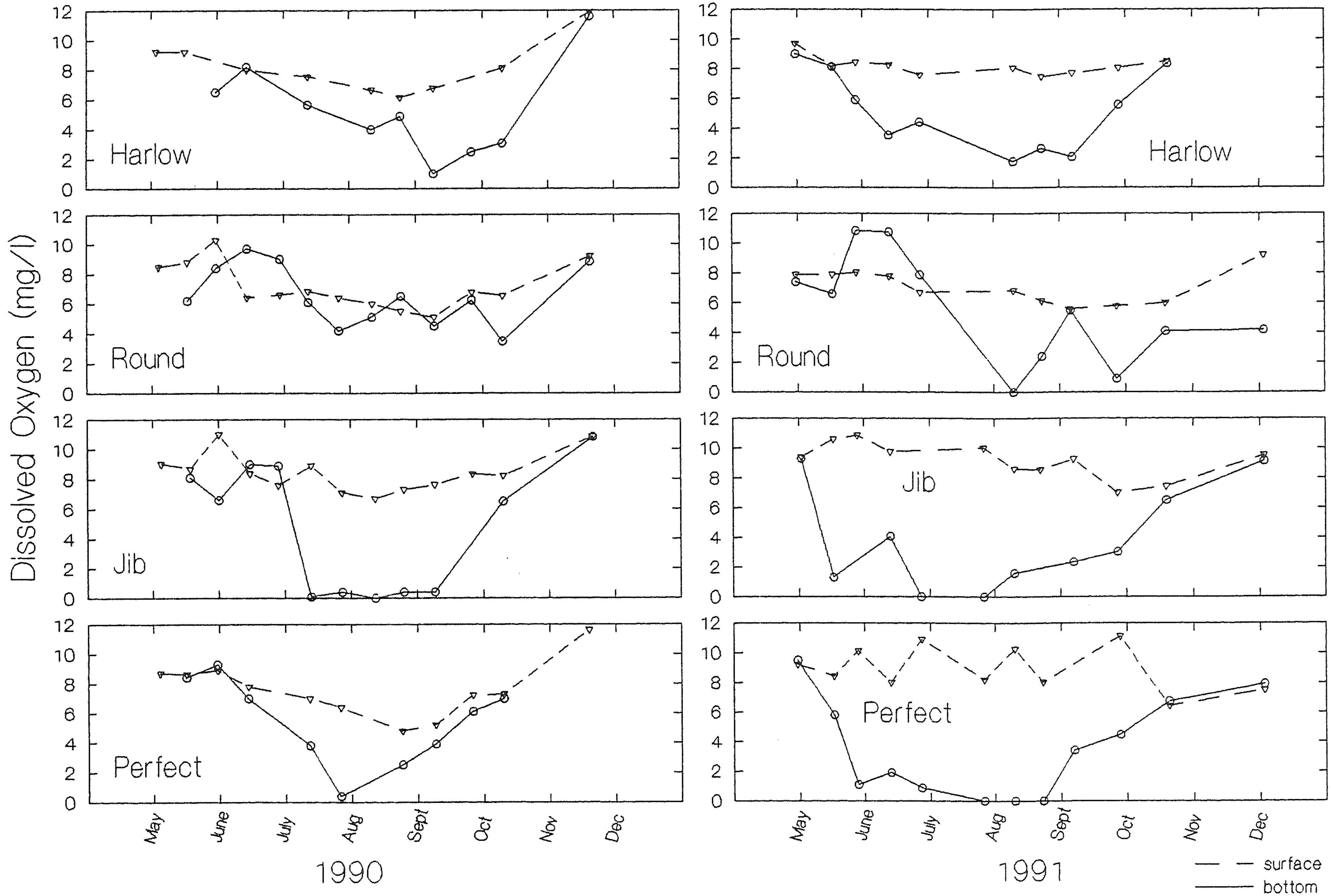


Figure V.2.3.1. Seasonal variation in dissolved oxygen concentrations at those study sites exhibiting thermal stratification.

The decrease in time to deplete hypolimnion oxygen concentrations after stratification at the fertilized sites occurred despite bottom waters being slightly cooler during 1991 and is probably a result of increased primary production in the water column and enhanced degradation of dissolved and particulate detritus. The increased primary productivity would result in an increase in the amount of organic matter settling into the hypolimnion, and the greater availability of nutrients would increase microbial activity. Both of these processes would result in an increase in the hypolimnetic biological oxygen demand.

2.4. Phosphorous

Data on phosphorous concentrations during the 1991 field season is available for surface waters, hypolimnetic waters at the stratified experimental sites, outlet waters at those sites having outlets, and for sediments at the experimental sites.

Figure V.2.4.1 presents time series data on total P concentrations for surface waters at all sites for both years. The control sites showed little year to year variation. At all of the experimental sites total P concentration increased dramatically after fertilization. The seasonal trends, however, differed greatly among sites. At Jib total P in the surface waters increased to very high levels (>250 ug l^{-1}) immediately after fertilization, then declined rapidly over a two week period after which it stabilized at about 60 ug l^{-1}. At Perfect surface water P increased relatively slowly over a period of about six weeks after fertilization, then declined for two weeks, stabilized at about 100 ug l^{-1} for the following two months and then peaked again. This latter peak coincided with the beginning of the fall overturn. Oscar behaved very much like Perfect with two peaks in surface water P, one in mid-July and one in mid-September. At Stump surface water P levels increased gradually for four months after fertilization and then declined.

At the two experimental sites that stratify (Jib and Perfect), total P levels in the hypolimnion were always much greater than those in the surface waters. Apparently a great deal of the added fertilizer became entrained in the hypolimnion once these sites stratified. There was considerable seasonal variation in the hypolimnion total P levels, especially at Jib, which is difficult to explain, particularly since the seasonal trends are not easily related to the onset or breakdown of thermal stratification.

The seasonal variation in total P levels at the outlets, relative to those at the lake centre, also varied among sites. At Jib and Stump total P levels at the lake centre and outlet were always about the same. During mid-June to late September, however, the outlet of Stump was dry. At Oscar, P levels at the outlet were always much less than at the centre.

Sediment P, with respect to both levels and seasonal trends, also behaved differently at the different fertilized sites. At Jib and Perfect sediment P levels were relatively low and showed little seasonal variation. At Oscar and Stump, however, sediment P levels were high and varied a great deal.

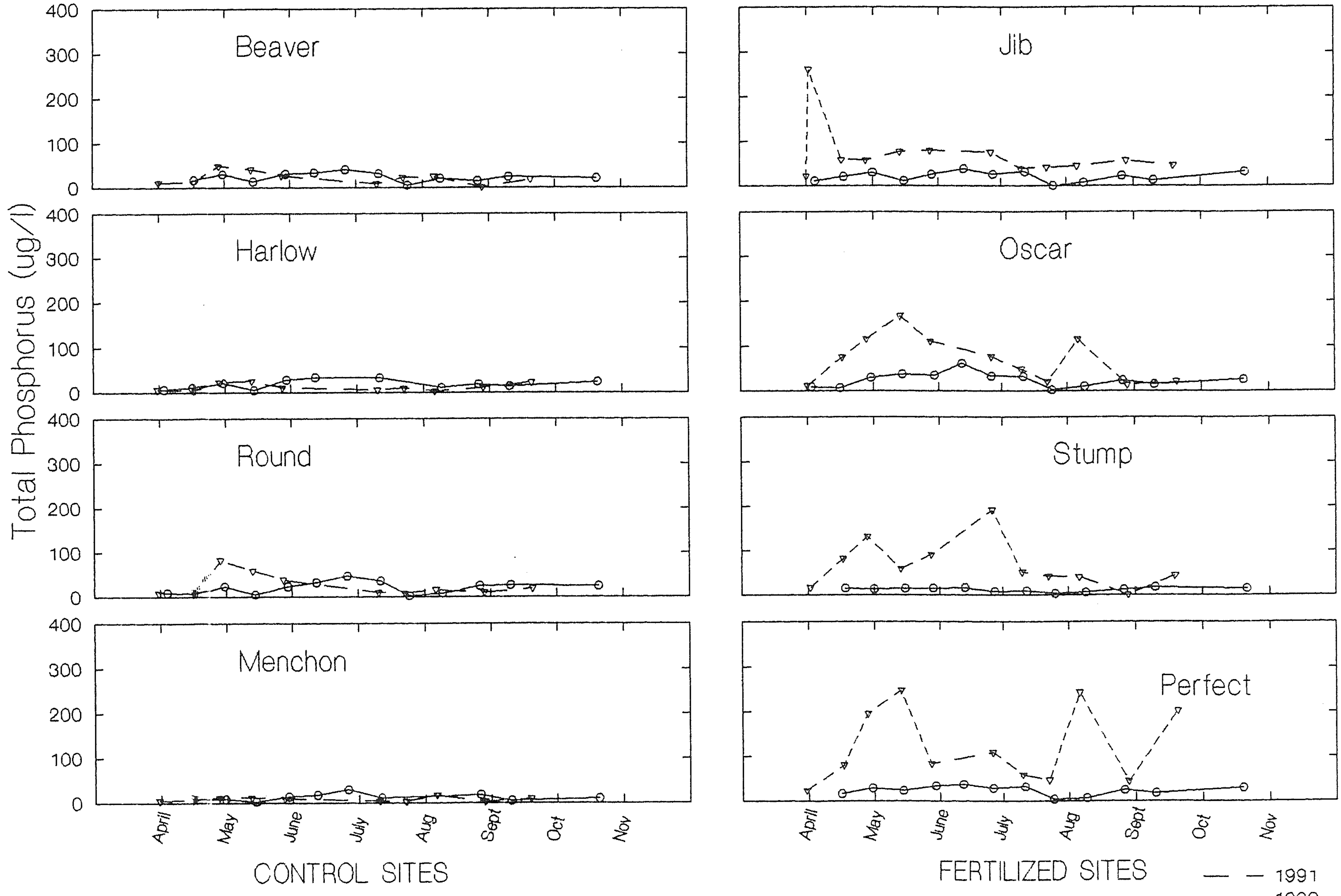


Figure V.2.4.1. Seasonal variation in total phosphorous levels.

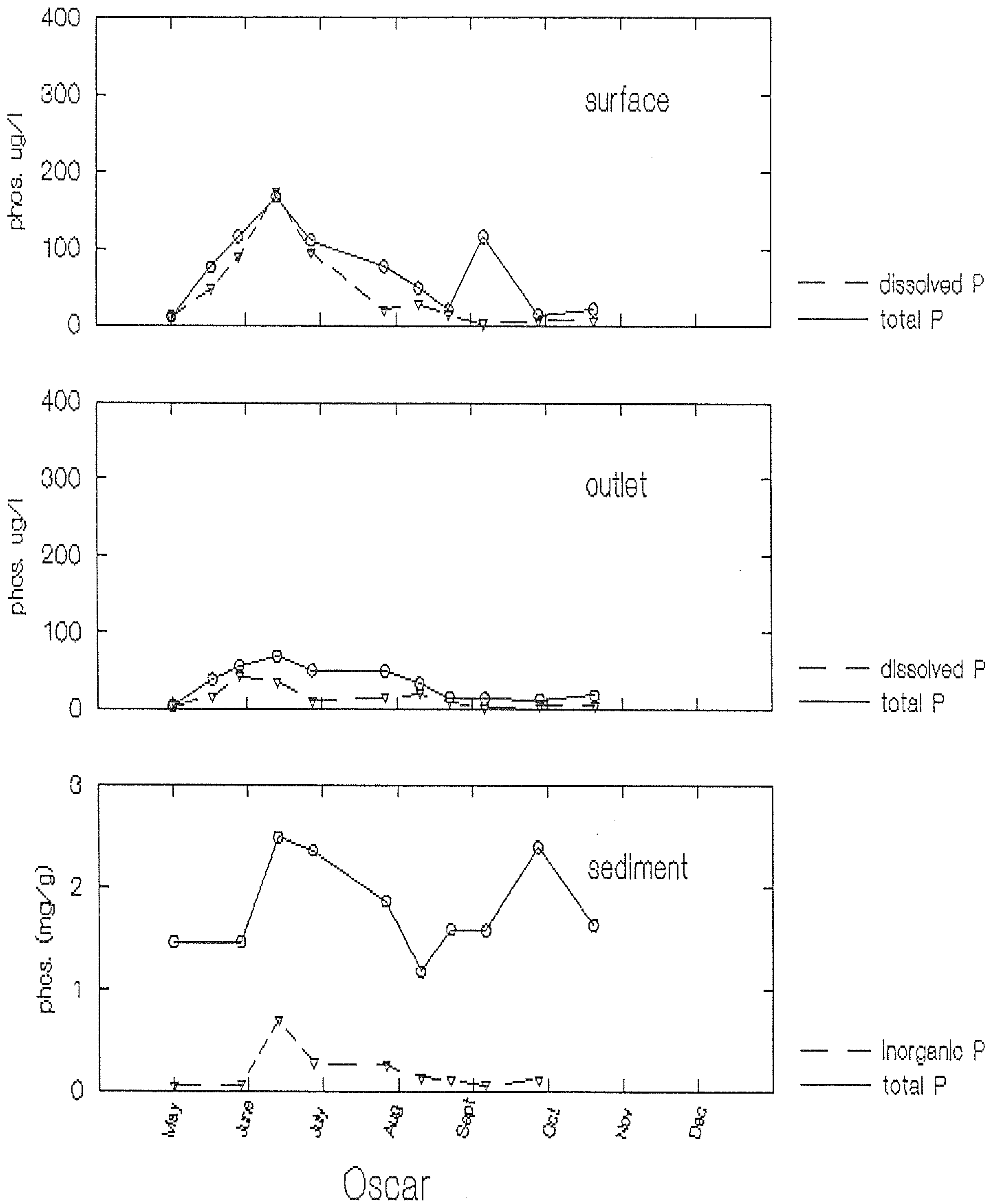


Figure V.2.4.3. Seasonal variation in phosphorous levels at Oscar during 1991.

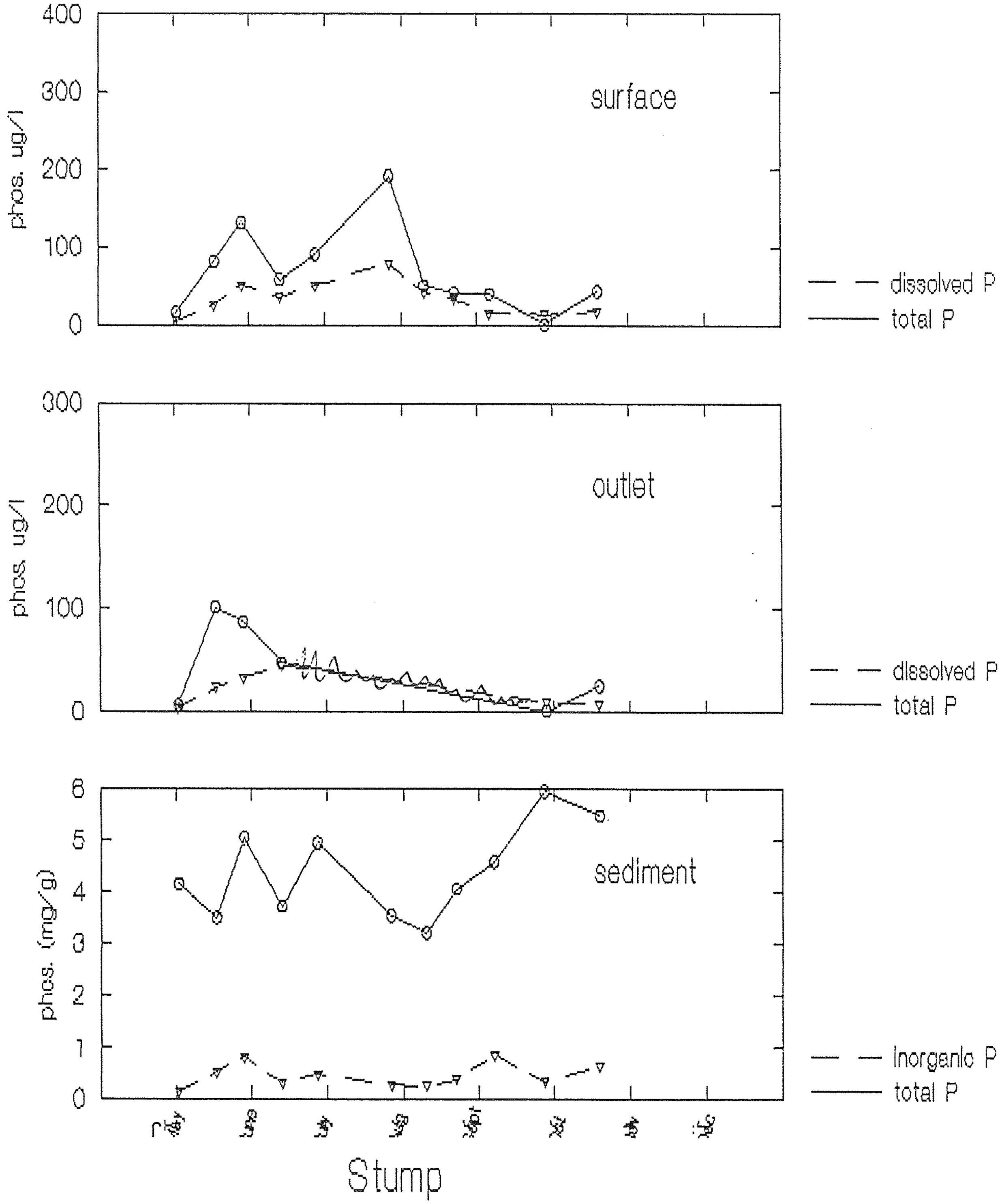


Figure V.2.4.4. Seasonal variation in phosphorous levels at Stump during 1991.

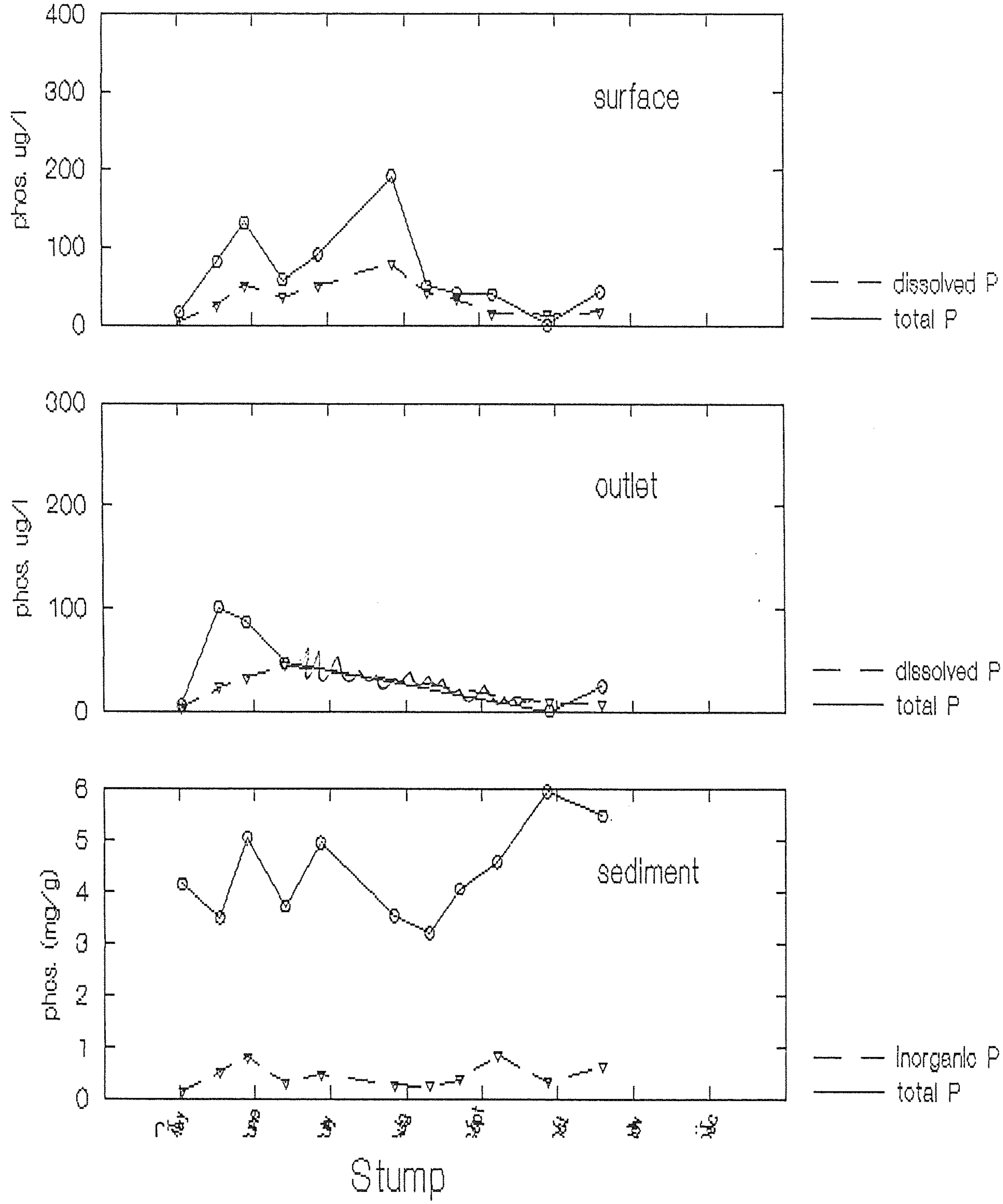


Figure V.2.4.4. Seasonal variation in phosphorous levels at Stump during 1991.

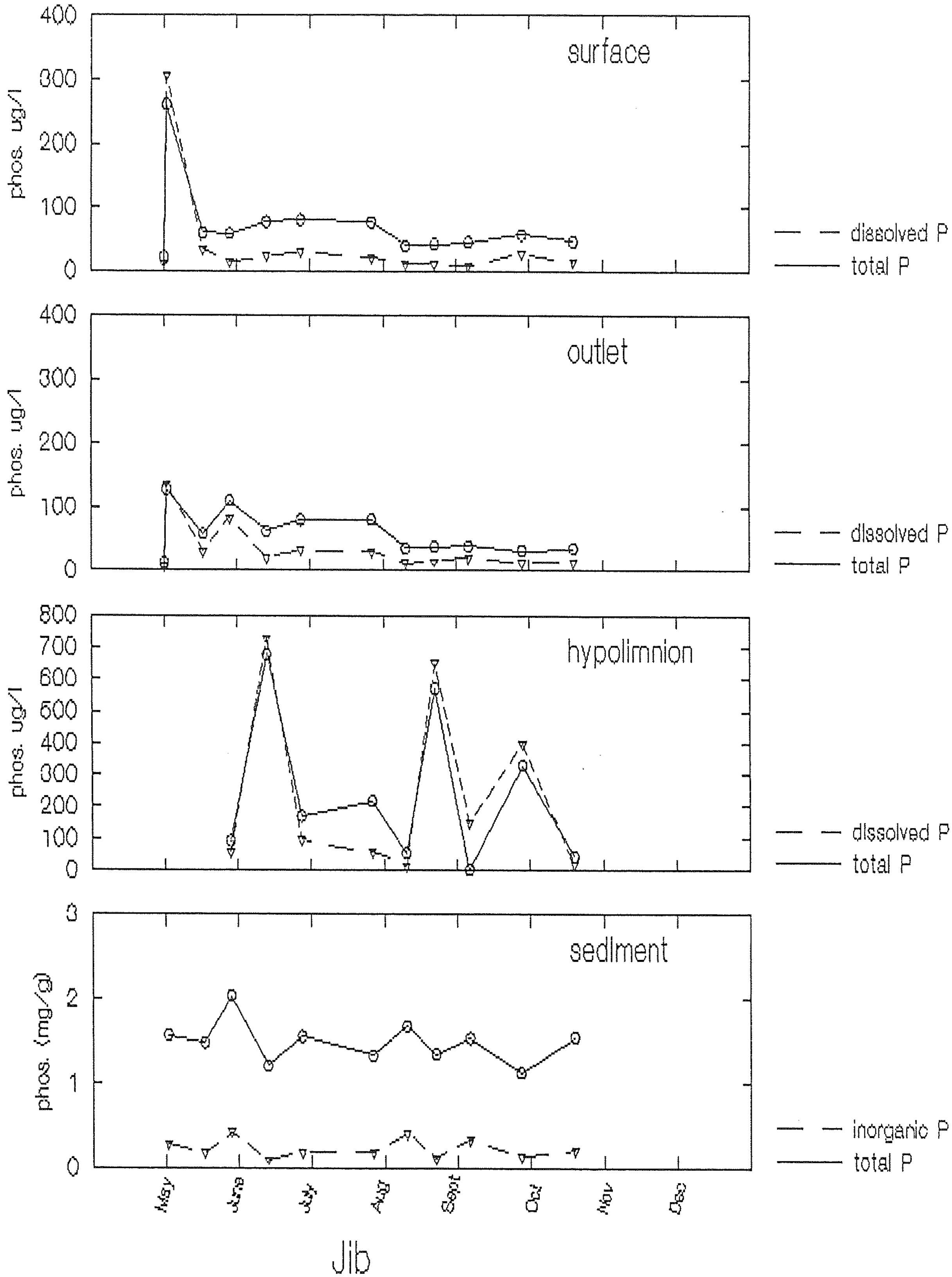


Figure V.2.4.2. Seasonal variation in phosphorous levels at Jib during 1991.

The diversity of responses exhibited by the fertilized sites, in terms of the spatial and temporal partitioning of phosphorous, is not surprizing considering the diversity in morphological and mixing characteristics of the sites. The different methods used to fertilize the sites also may have influenced the behavior of the added nutrients. At Jib and Perfect, the two stratified experimental sites, most of the added phosphorous remained in the water column. These are also the two sites that were fertilized by slowly adding fertilizer into the swash of an outboard motor. This technique would greatly increase the rate at which the fertilizer would dissolve, relative to dumping by helicopter as was done at Stump and Oscar. As a result total P levels within the water column at Jib and Perfect would be expected to be higher, and sediment P lower, than at Stump and Oscar. The longer response time to reach maximum water column total P levels at Oscar and Stump is probably also related to the fertilizer having been largely undissolved immediately after application, and thus having settled into the sediments to be released slowly over time.

The greater depth of Jib and Perfect would also tend to isolate sediment P from water column P and make them behave independently of one another. The opposite would be expected at Stump and Oscar and this is what was observed. At Stump, the seasonal variation of total P in the water column was essentially the reverse of that exhibited by sediment P suggesting that phosphorous was being deposited and resuspended. At Oscar, sediment P and water column P showed similar seasonal trends, perhaps as a result of its exposed nature (unlike Stump), shallow depth and lack of stratification, which makes it subject to wind induced mixing and creates a strong potential for interaction between the water column and sediments.

The differences observed in P levels at the outlets relative to those at the lake centre are probably more closely related to the mixing characteristics of the sites. At Jib and Stump outlet total P levels were about equal which is what would be expected. At Oscar, however, total P at the outlet was much less than at the lake centre which is probably a reflection of the way in which input water flows through this system. The inlet of Oscar is located on the north shore and from there the input water flows along the western shoreline toward an outlet on the south shore. As a result, the inflow does not mix effectively with a large portion of the lake reducing the tendency for phosphorous to be washed out of the system.

Despite these differences in spatial and temporal distribution, peak total P concentrations within the water column were similar at all of the experimental sites and ranged between 125 and 200 ug l^{-1}, a factor of about one order of magnitude greater than that required to achieve eutrophic conditions.

2.5. Nitrogen

Data on nitrogen for the 1991 field season is available only for the period up to the end of July. The initial temporal trends of total N in the surface waters of the experimental sites are very similar to those observed for phosphorous (Figure V.2.5.1). In most cases maximum nitrogen levels occurred about one month after fertilization and then began to gradually

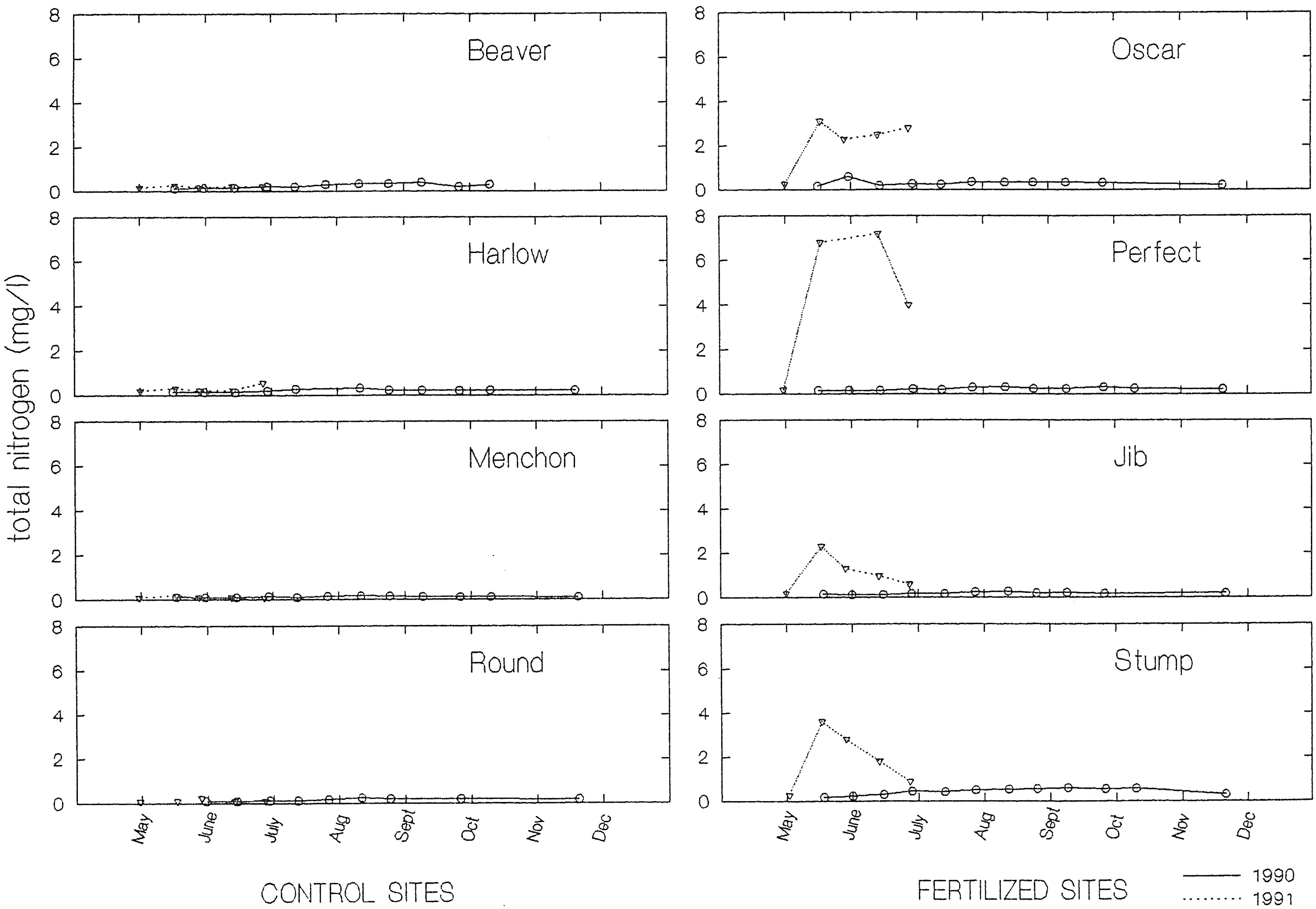


Figure V.2.5.1. Seasonal variation in total nitrogen levels.

decline. Peak levels were on the order of 3 to 8 mg l^{-1}. N:P ratios shortly after the addition of fertilizer varied greatly but were on the order of about 25:1. The greater N:P ratios within the water relative to that of the fertilizer (10:1) probably reflects a greater solubility of the nitrogen fertilizer.

3. Biology

3.1. Phytoplankton

The response of phytoplankton to fertilization was dramatic. Annual mean phytoplankton chlorophyll *a* levels (Figure V.3.1.1.) increased by more than an order of magnitude at all of the fertilized sites except Oscar, and were well above levels that would classify these sites as eutrophic. The highest levels attained were on the order of 300 ug l^{-1} at Perfect. At Stump and Jib, levels of 50 and 90 ug l^{-1} respectively were reached. At Oscar the maximum chlorophyll *a* level attained was about 20 ug l^{-1}. The control sites, in contrast, exhibited slightly lower chlorophyll *a* levels during 1991.

The seasonal variation in phytoplankton chlorophyll *a* varied considerably among the different experimental sites (Figure V.3.1.2). At all sites except Oscar the response was immediate with a strong increase within the first two weeks after addition of the fertilizer. At Jib and Stump chlorophyll *a* levels remained high throughout most of the summer and early fall. At Perfect, there was an initial increase in chlorophyll *a* immediately after fertilization, followed by a decline during the summer, and then a very large and rapid increase during fall. The latter increase corresponded to the fall overturn which began in early September. The response at Oscar was much less than at the other experimental sites. Phytoplankton chlorophyll *a* levels did not substantially increase until late July, nearly two months after the addition of fertilizer and, as noted earlier, the highest level reached was only on the order of 20 ug l^{-1}.

Phytoplankton chlorophyll *a* levels at the outlets of Jib and Stump (Figure V.3.1.3) showed the same seasonal trend as at the lake centre. At Stump the levels at the outlet were about equal to those at the centre. At Jib and Oscar, however, they were only about half as great. At Oscar, the seasonal trend at the lake centre and outlet differed, the peak at the outlet occurring about one month earlier than at the centre.

There is an obvious relationship between the flushing rates of the experimental sites and the levels of chlorophyll *a* attained. Figure V.3.1.4 shows average chlorophyll *a* concentration plotted against flushing rate. For those sites with outlets (all except Perfect), there is an inverse relationship between the two, those sites with the highest flushing rates having the lowest chlorophyll *a* levels. This probably simply reflects that phytoplankton are being flushed from these sites. This is further supported by the high levels of chlorophyll *a* attained at Perfect, which does not have a surface outlet, and thus no opportunity for phytoplankton to be flushed out of the system.

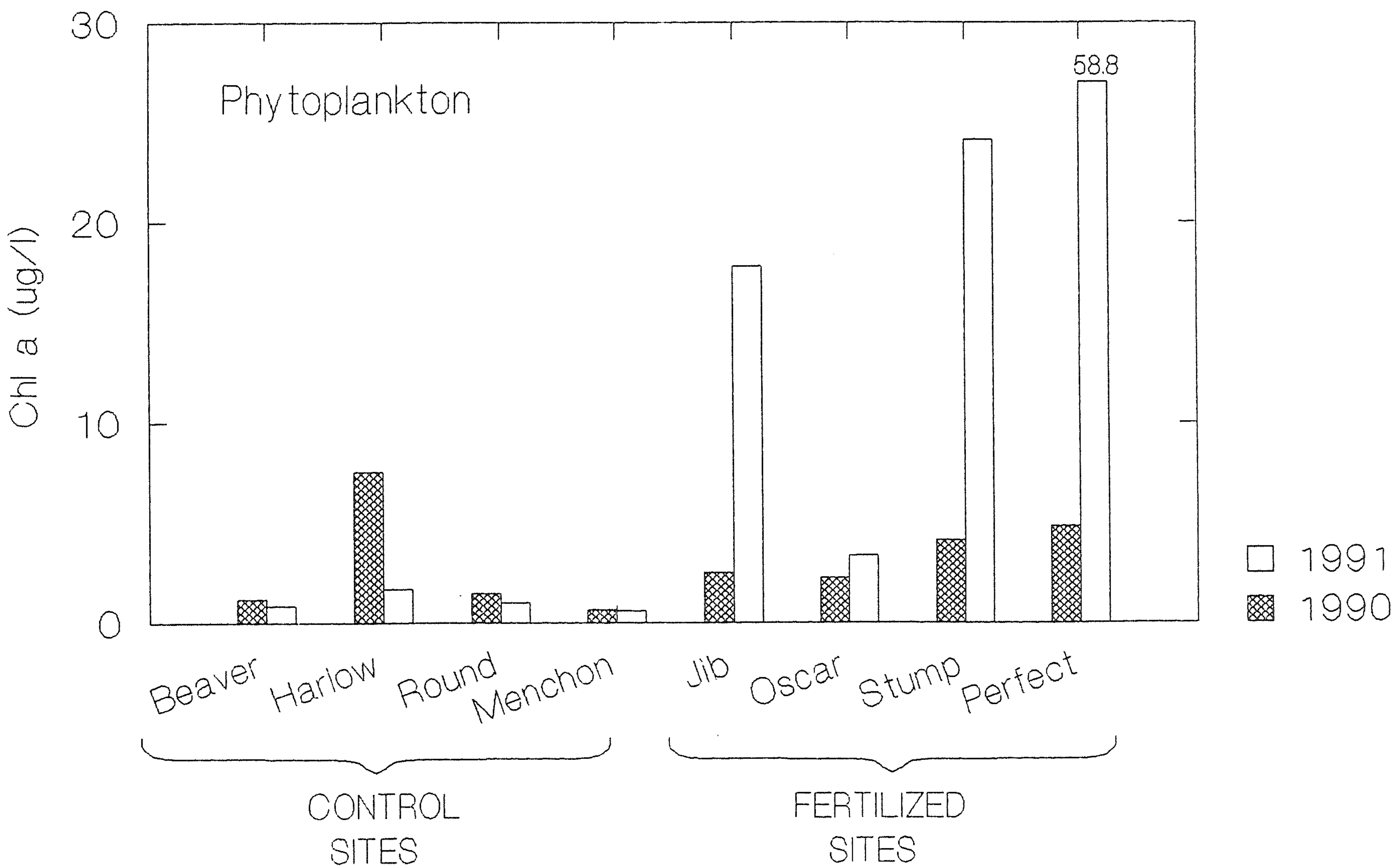
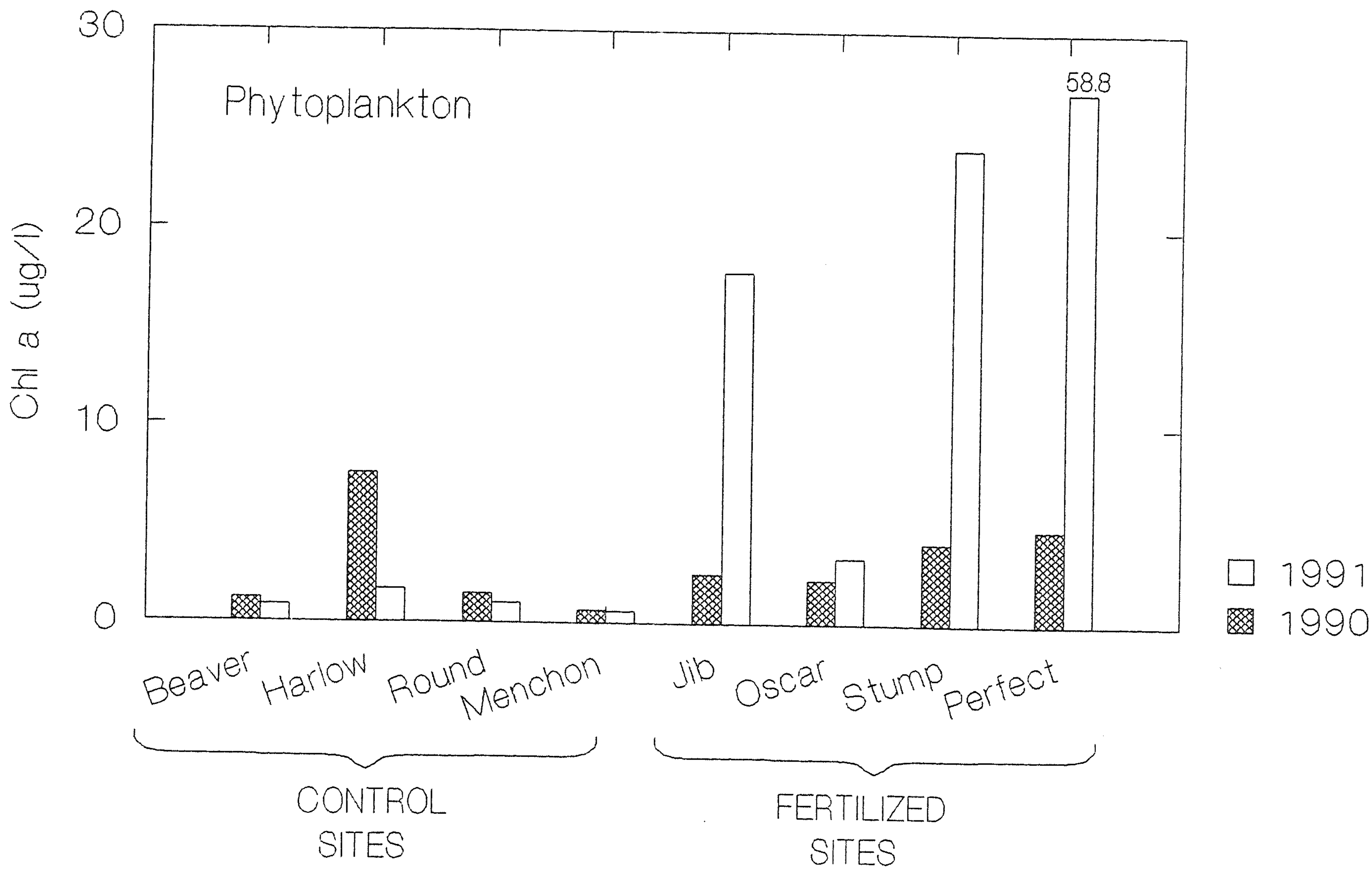


Figure V.3.1.1. Annual mean phytoplankton chlorophyll a levels.



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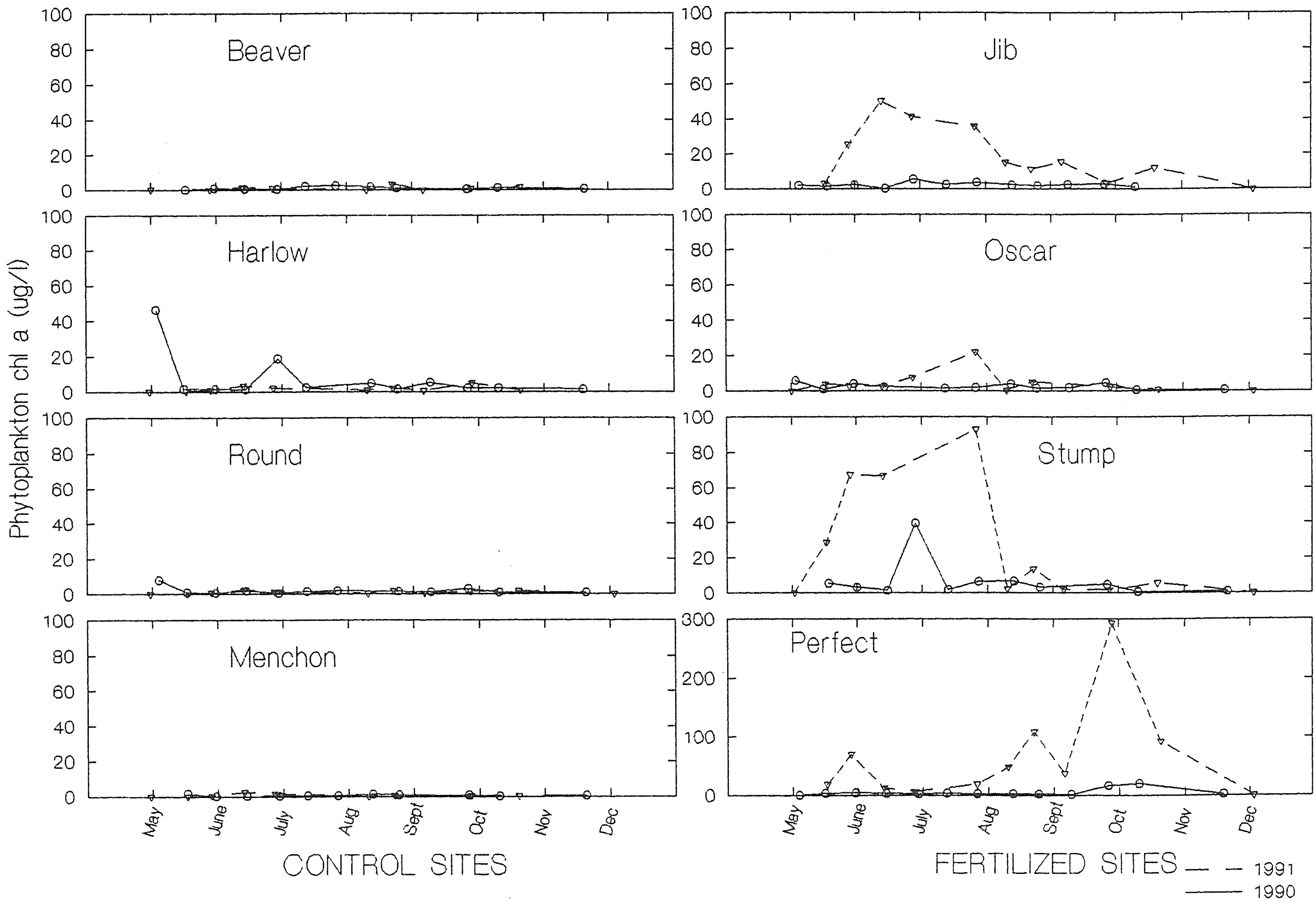


Figure V.3.1.2. Seasonal variation in chlorophyll a values at the centre of each site.

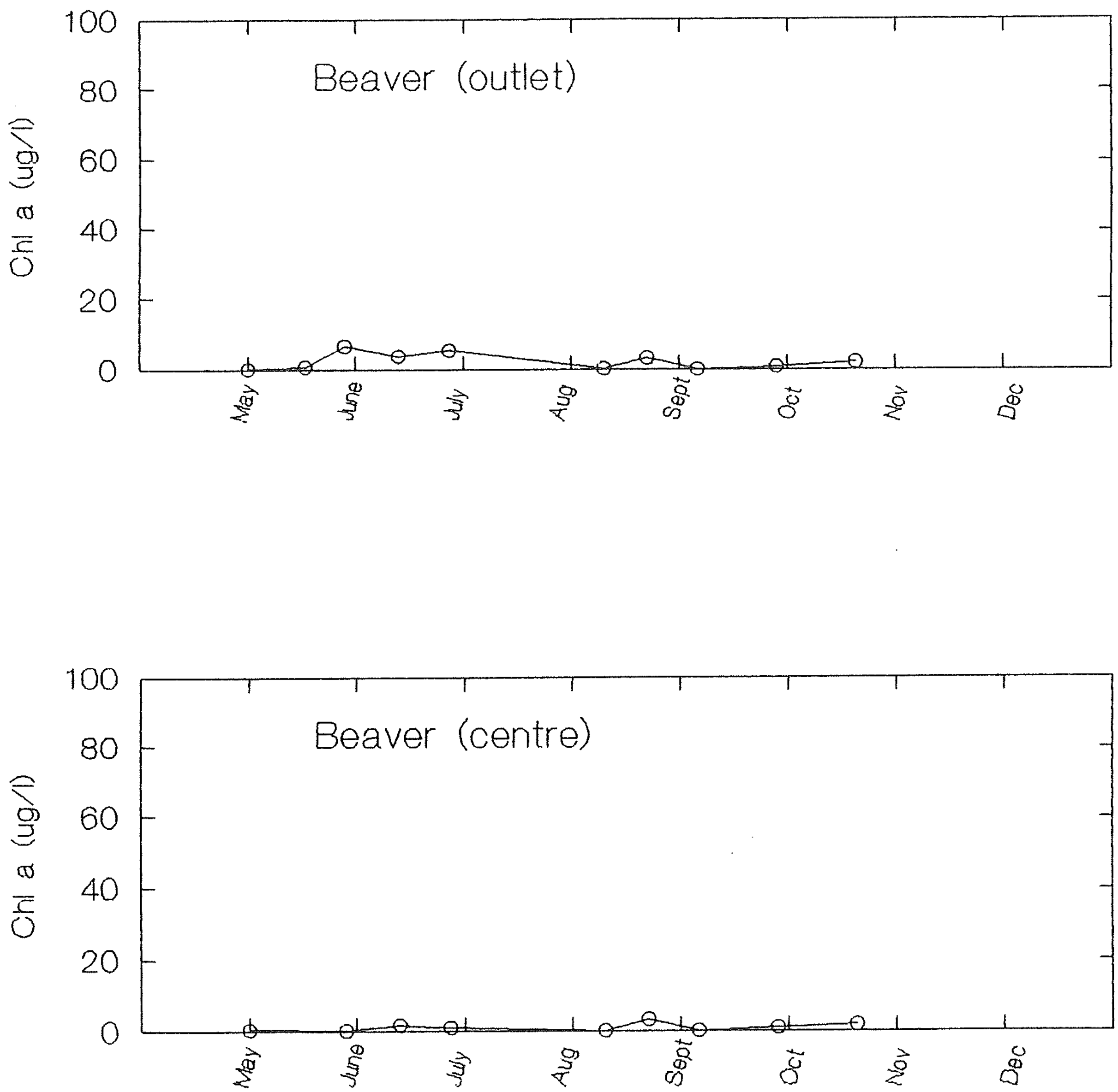
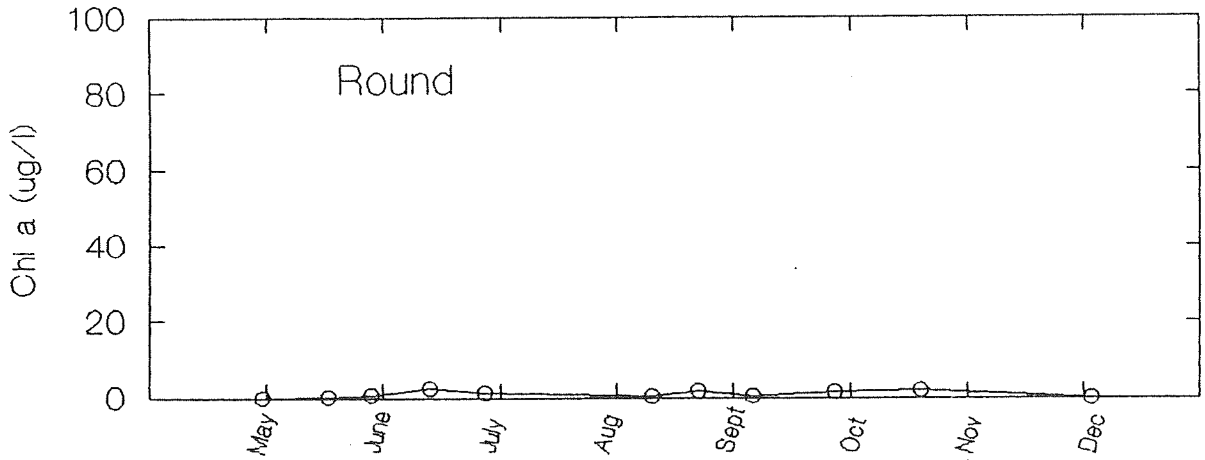


Figure V.3.1.3. Seasonal variation in phytoplankton chlorophyll a during 1991.



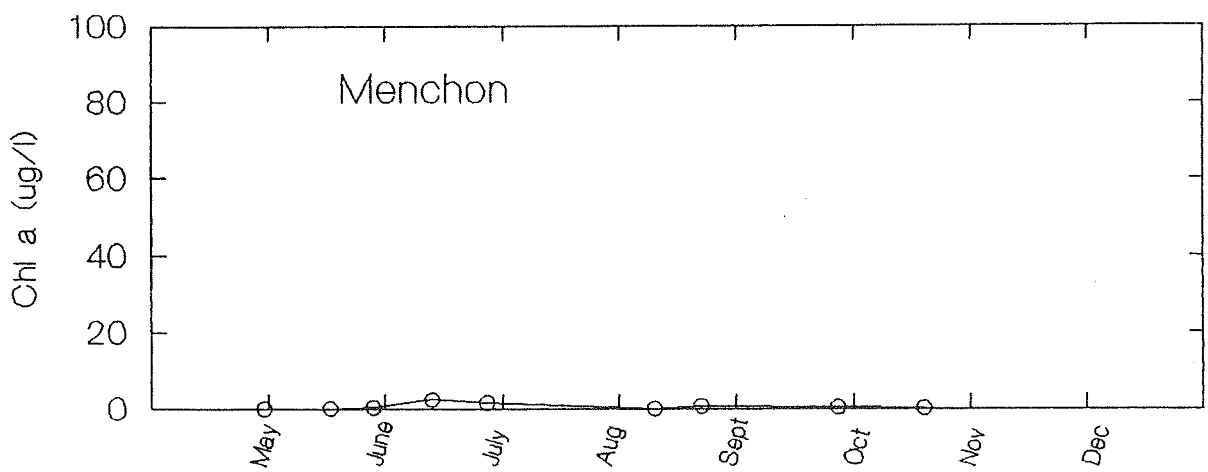
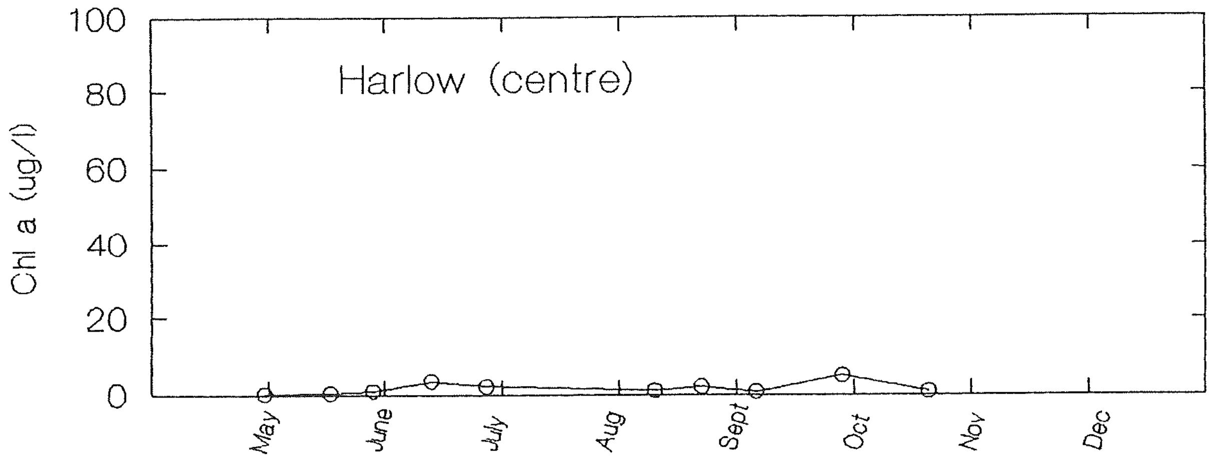
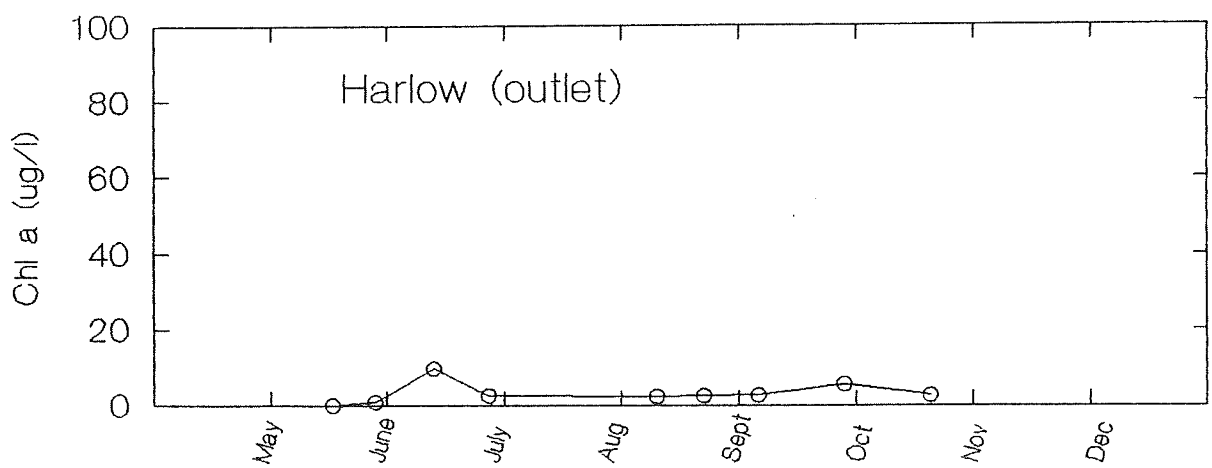


Figure V.3.1.3. Continued.





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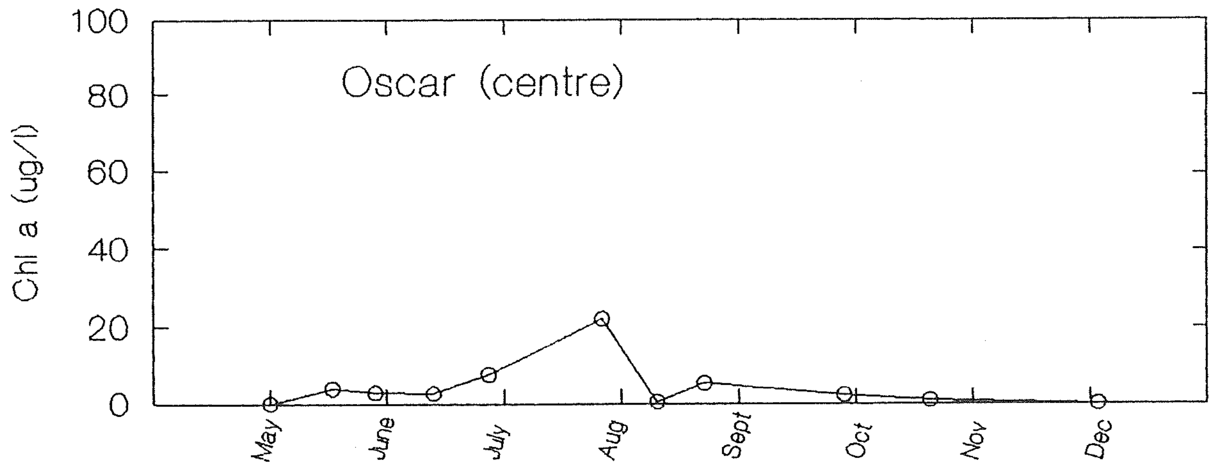

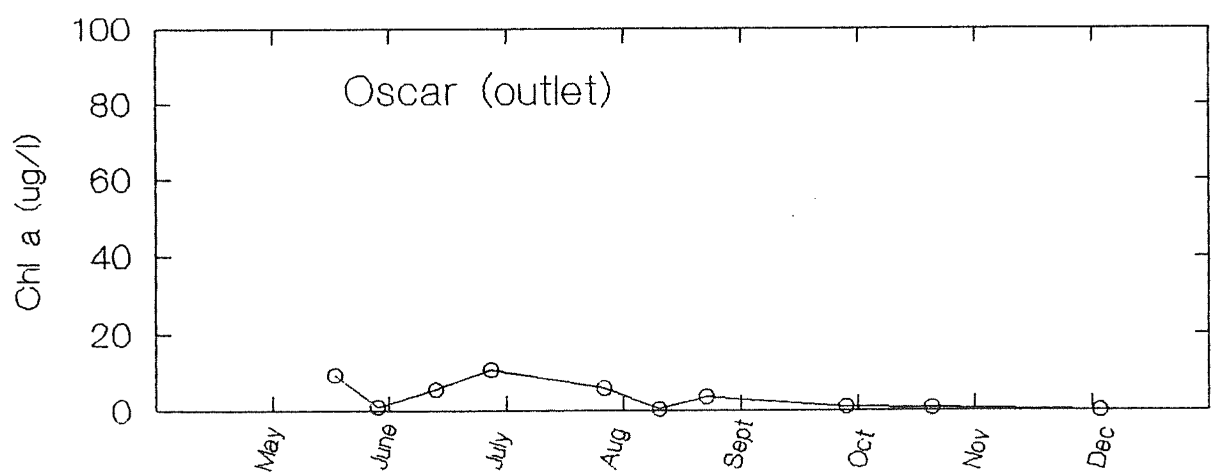

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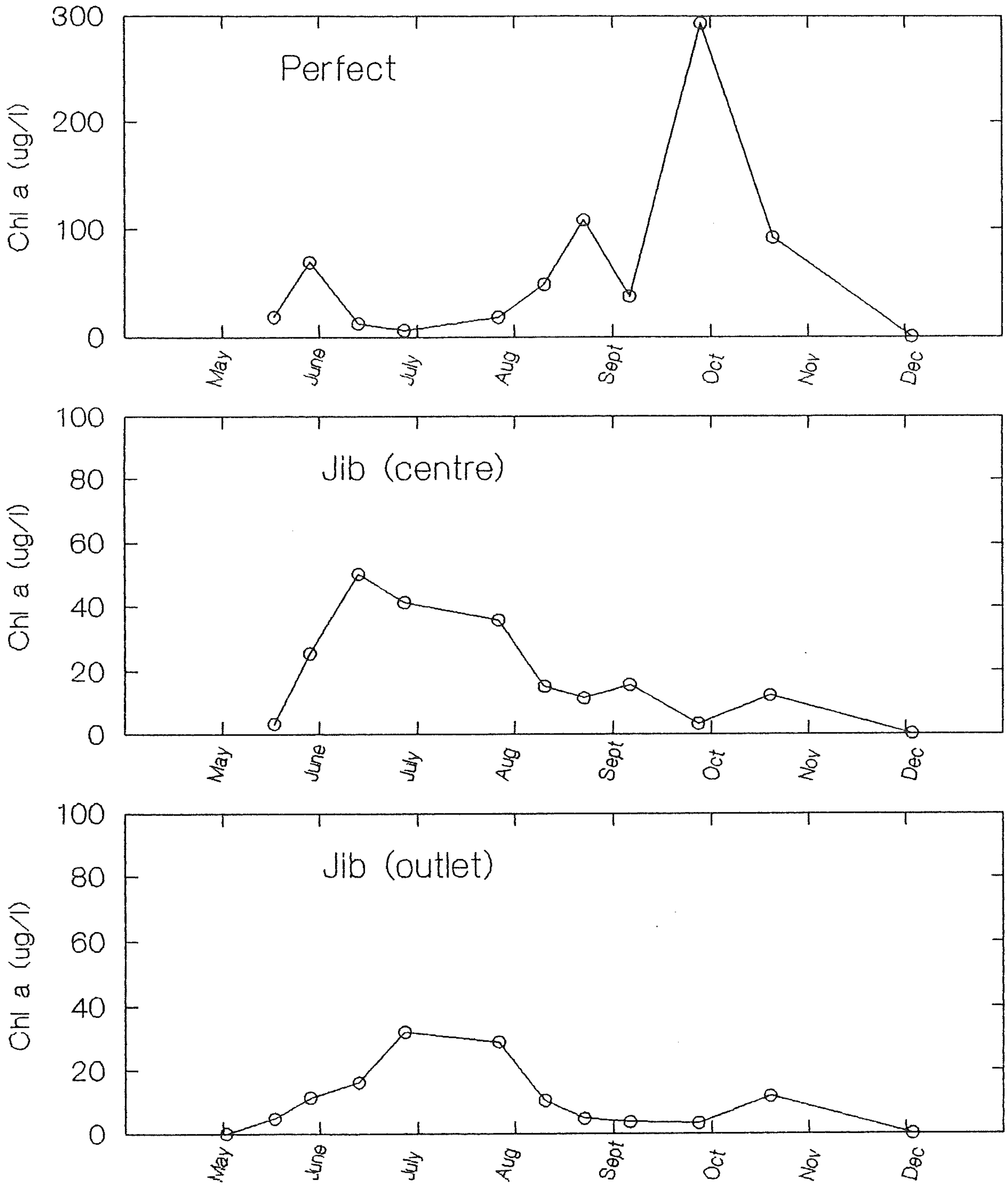

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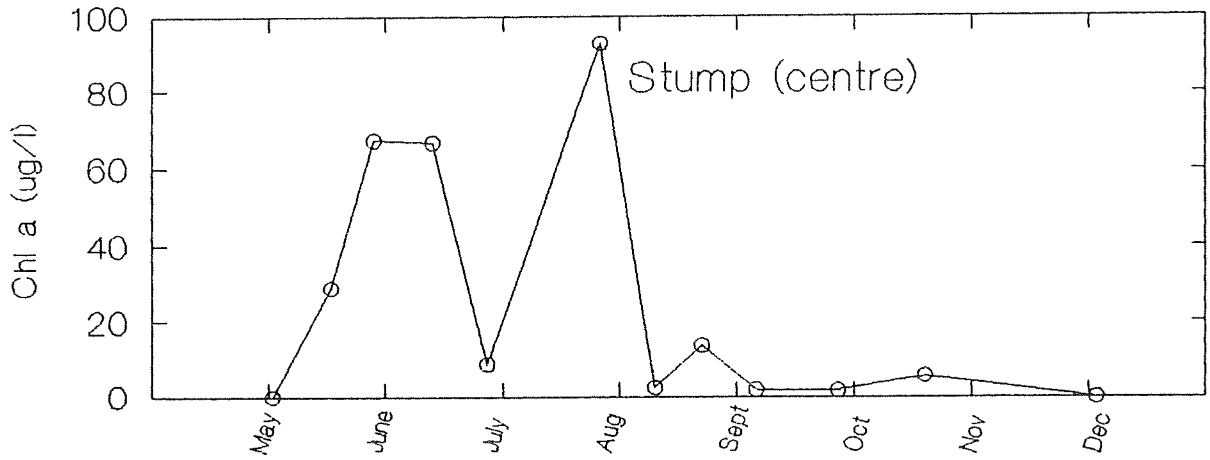


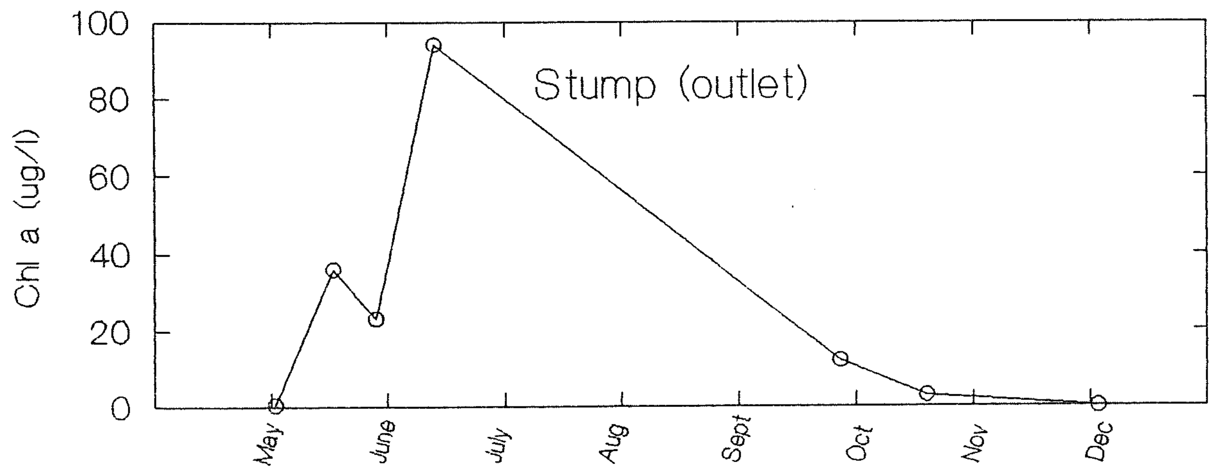


Figure V.3.1.3. Continued.

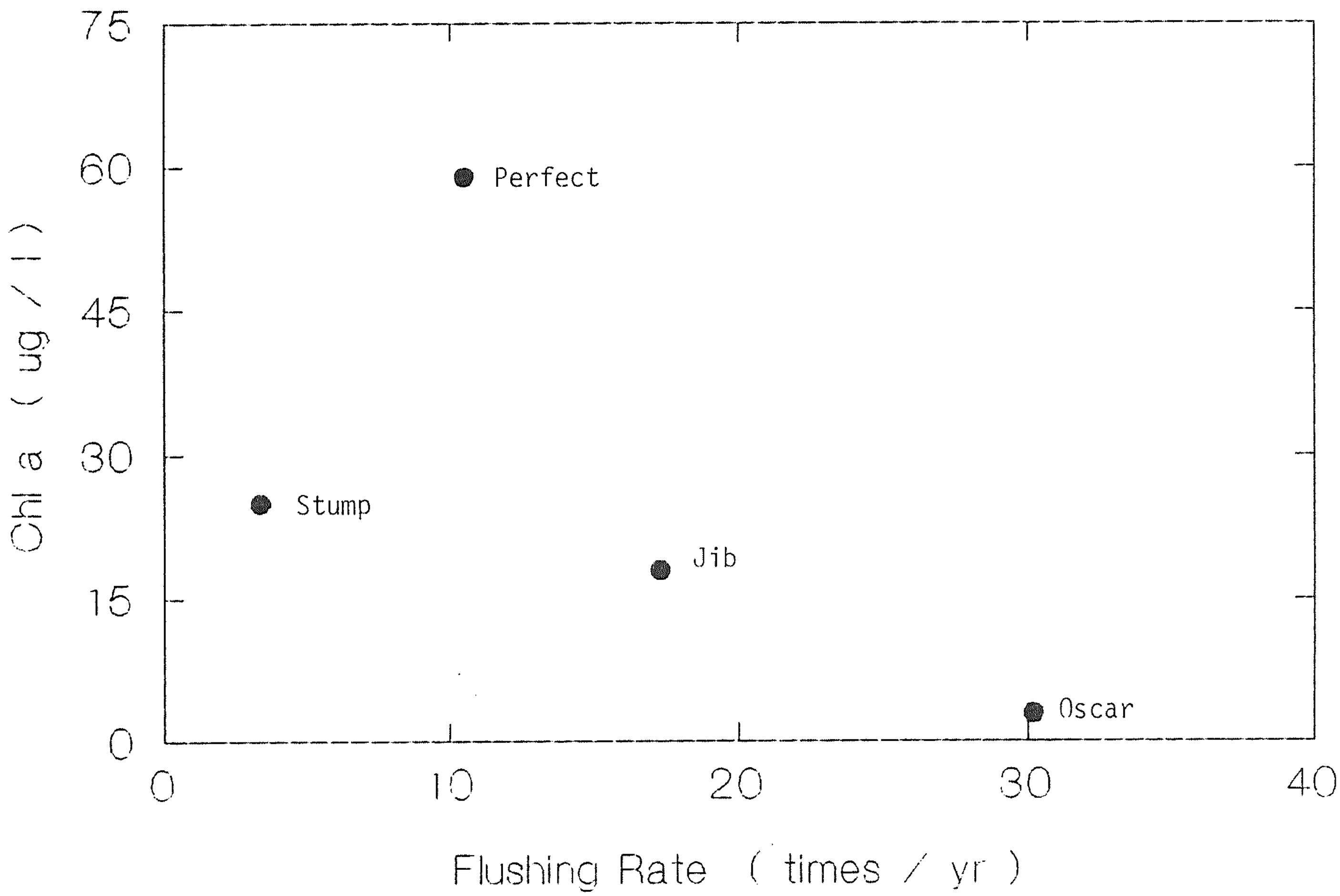


Figure V.3.1.4. Relationship of chlorophyll a levels to flushing rates (see text for explanation).

3.2. Periphyton

Mean periphyton growth at each site, as measured by monthly accumulation of chlorophyll *a* on glass slides, is illustrated in Figure V.3.2.1. Periphyton growth also showed a dramatic increase at the fertilized sites. The greatest increase was at Stump, and the least at Perfect.

The fertilized sites exhibited an inverse relationship between phytoplankton and periphyton growth. Perfect, which attained the highest phytoplankton chlorophyll *a* levels, had the lowest periphyton growth, and Oscar, which had the lowest phytoplankton chlorophyll *a* levels, had the second highest periphyton growth. This same inverse trend also occurred on a seasonal basis and was particularly obvious at Jib and Stump where the period of greatest periphyton growth coincided with the lowest phytoplankton chlorophyll *a* levels (Figure V.3.2.2). This inverse relationship is often observed in freshwater systems and is attributed to competition for light between the two groups.

3.3. Macrophytes

A macrophyte survey was carried out during mid-August of 1991 and compared to a similar survey performed during 1990. Because nutrients were obviously being lost via the outputs of the experimental sites, a particular effort was made to document any changes in macrophyte growth within the outlet streams. Comparison of species composition and abundance between the 1990 and 1991 survey showed little difference in either the distribution or abundance of macrophytes within the lakes or at their outlets. The macrophytes at the fertilized sites did, however, appear more robust and healthier as evidenced by their large size and dark green color.

3.4. Zooplankton

Mean annual zooplankton numbers at each site during 1990 and 1991 are illustrated in Figure V.3.4.1. At all sites except Beaver, the mean zooplankton numbers were greater during 1991. Most of the experimental sites, however, showed considerably larger increases than did the controls. At Stump and Perfect, the relative increase in mean zooplankton numbers was on the order of 5 and 20 times respectively, similar to the relative increase in chlorophyll *a*. The difference between years at Jib and Oscar was much less, on the order of 1.5 and 2 times respectively, and showed little relationship to the relative increase of chlorophyll *a*. As with phytoplankton, the difference in zooplankton numbers between sites may also be related to the flushing characteristics of these systems, although the relationship for zooplankton is not nearly as clear as it is for phytoplankton.

There was, surprisingly, no obvious relationship between the relative increase in zooplankton and the number of potential fish predators (see Sections V.3.7 and VI). Of the four experimental sites, only Jib and Perfect have fish populations substantial enough to

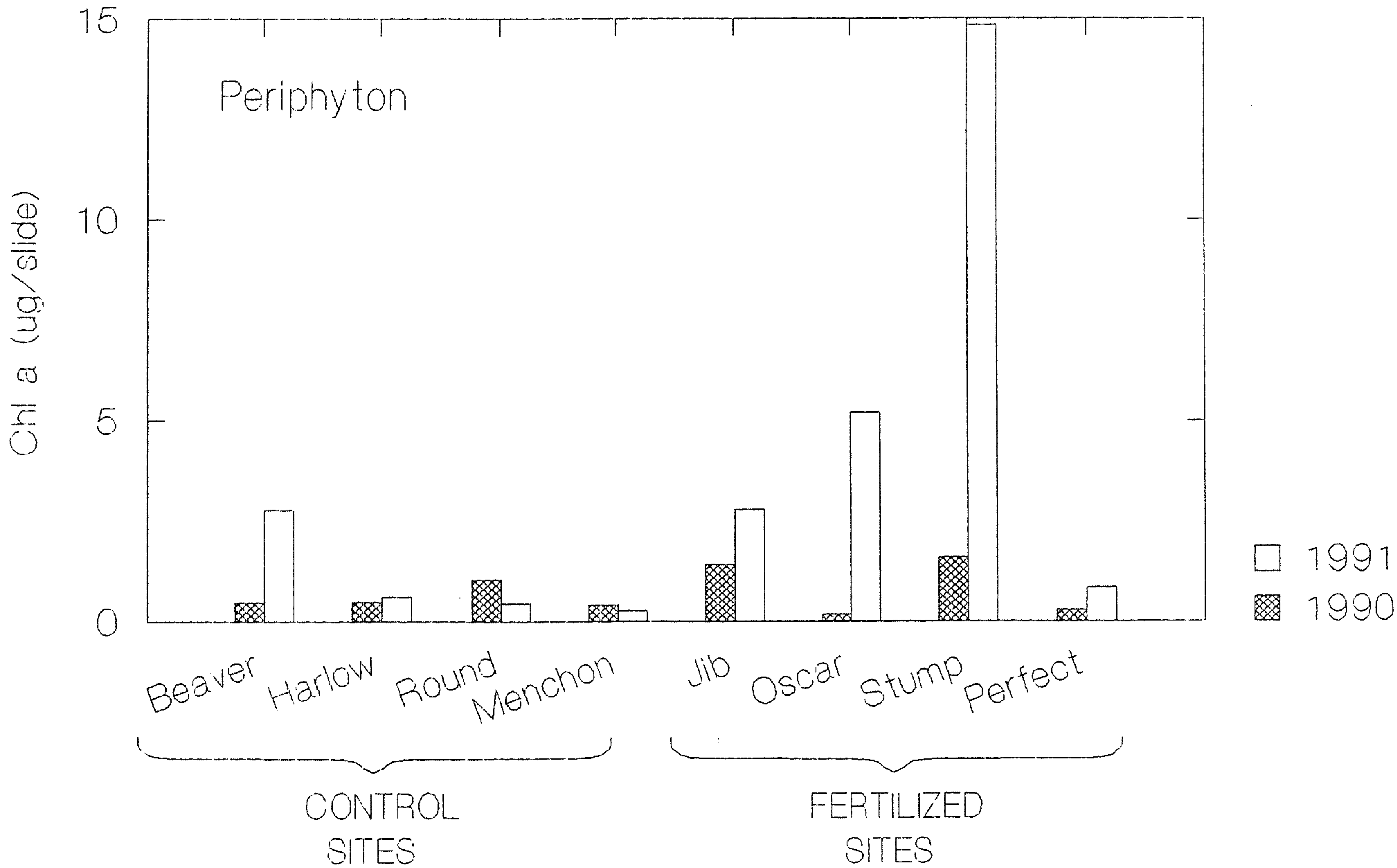


Figure V.3.2.1. Annual mean periphyton growth.

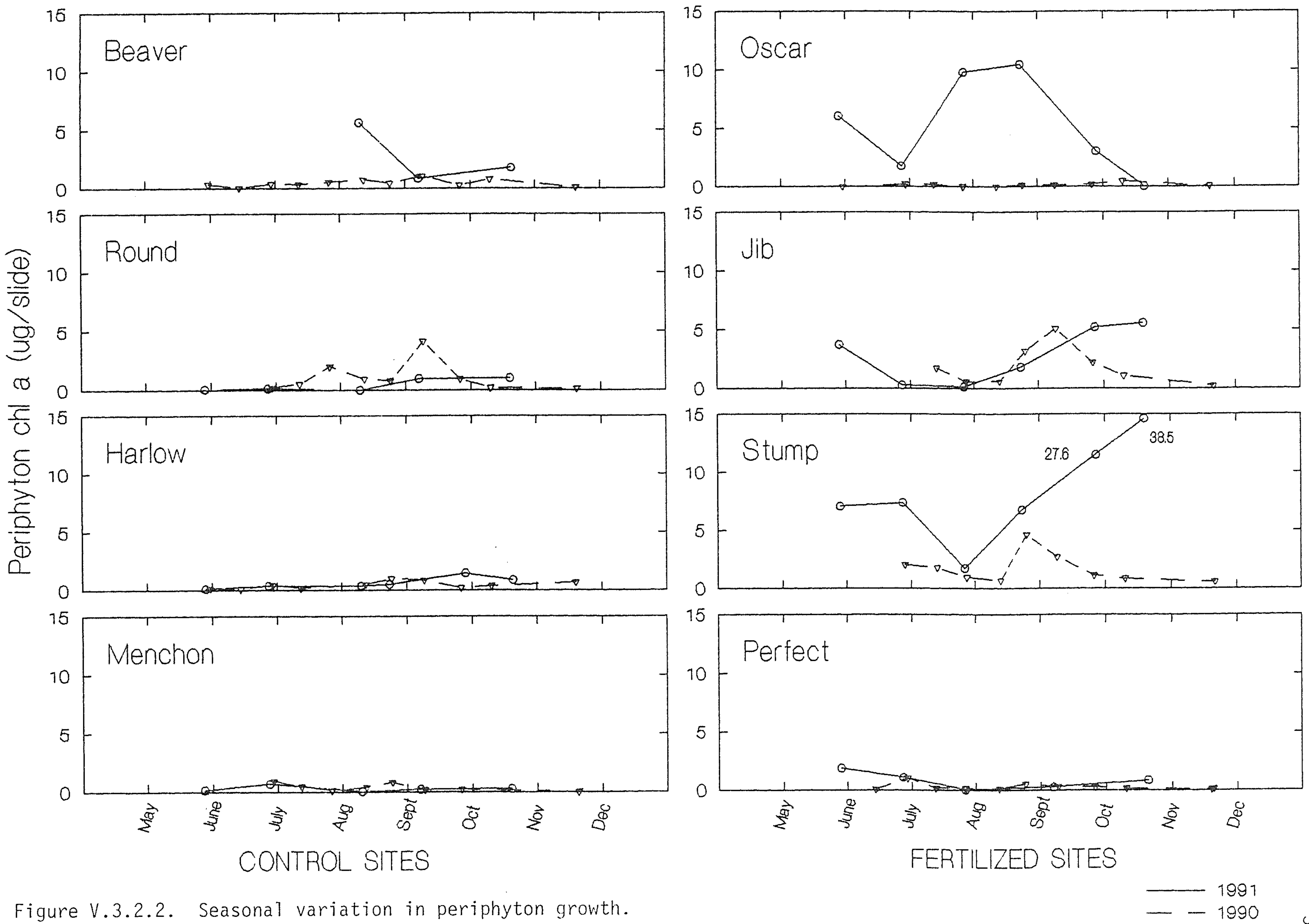


Figure V.3.2.2. Seasonal variation in periphyton growth.

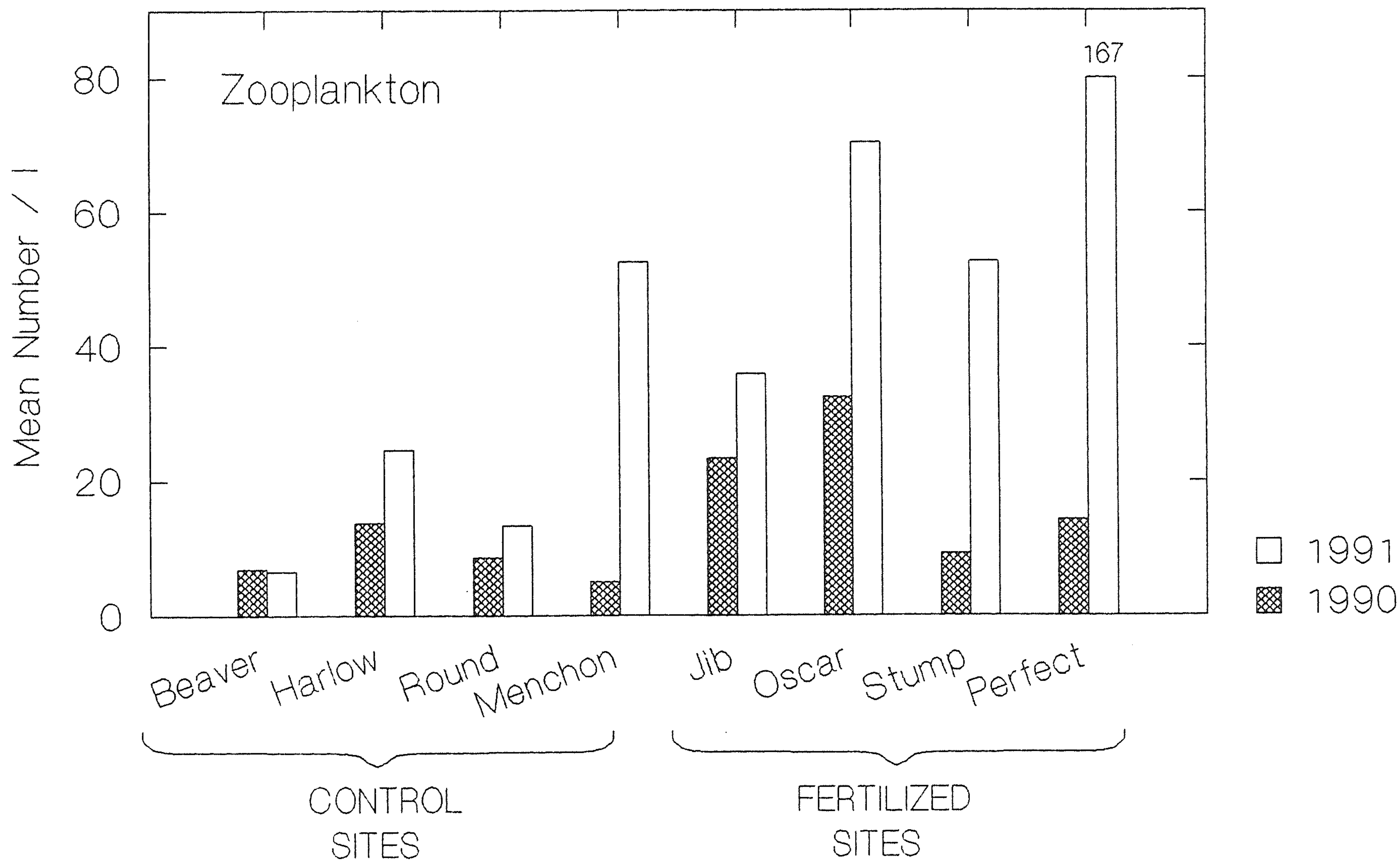


Figure V.3.4.1. Between year comparison of mean zooplankton numbers at the control and experimental sites.

potentially impose significant predation pressure. The increase in zooplankton was, however, greatest at Perfect and least at Jib.

With one exception, the relative proportions of the major zooplankton groups at the fertilized sites changed little between years (Figure V.3.4.2), indicating that most zooplankton groups benefited from the increase in phytoplankton biomass. The one exception is Jib which showed a large increase in the relative proportion of rotifers. This also occurred at Menchon, one of the control sites, suggesting that it may reflect normal year to year variation rather than a response to fertilization. A comparison of percent similarity of zooplankton groups at each site between years (Figure V.3.4.3) further illustrates that, with the exception of Jib and Menchon, there was little difference either between or among control and experimental sites with respect to the relative abundance of the different zooplankton groups between years.

3.5. Emergent Insects

The number of emergent insects collected in emergence traps was considerably greater in 1991 than in 1990 (Figure V.3.5.1). The relative increase in numbers, however, was about the same at both control and experimental sites indicating that fertilization did not have a significant influence on emergent insect numbers.

Most of the increase in emergent insect numbers was due to an increase in dipterans. Percent similarities based on between year comparisons of the major emergent insect groups at each site (Figure V.3.5.2) indicates considerable variation among control sites but very little variation among fertilized sites. The variation among control sites is due to the lower proportion of tricopterans at Beaver and coleopterans at Round, and the greater number of dipterans, collected during 1991.

3.6. Benthic Invertebrates

Benthic invertebrate numbers differed very little between years (Figure V.3.6.1). The small differences observed are probably a result of normal year to year variation. The relative proportion of each major taxonomic group also remained about the same between years and there was little variation in percent similarity between years either among or between the control and experimental sites (Figure V.3.6.2).

3.7 Minnow Trap Collections

A comparison of between year variation in minnow trap collections, which consist of amphibians and large insects as well as small fish, is shown in Figure V.3.7.1. Although the sampling is limited and the number of organisms collected is low, in most cases the difference between years is minor. The largest difference occurred at Perfect where a greater

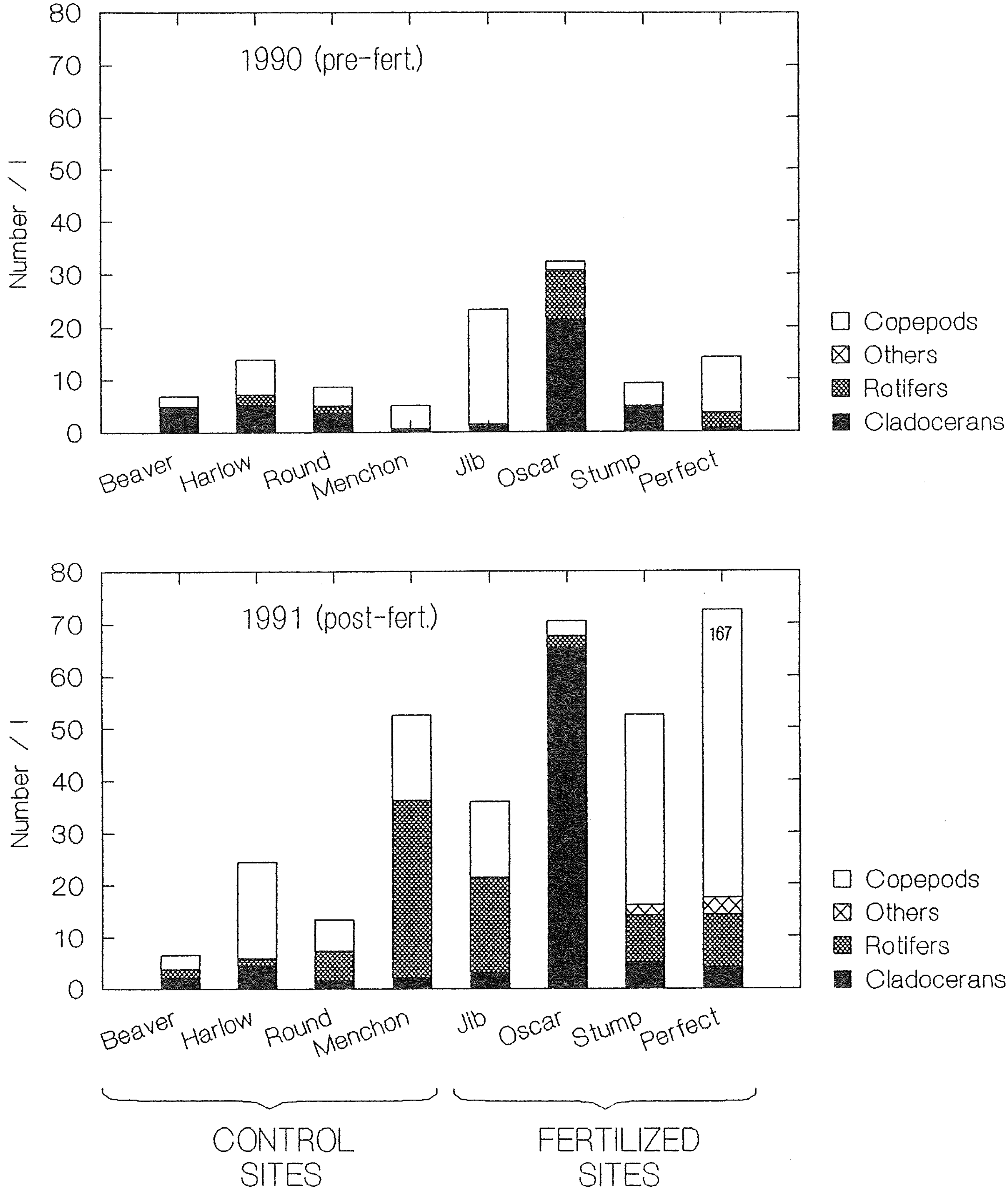


Figure V.3.4.2. Between year comparison of zooplankton community at each site.

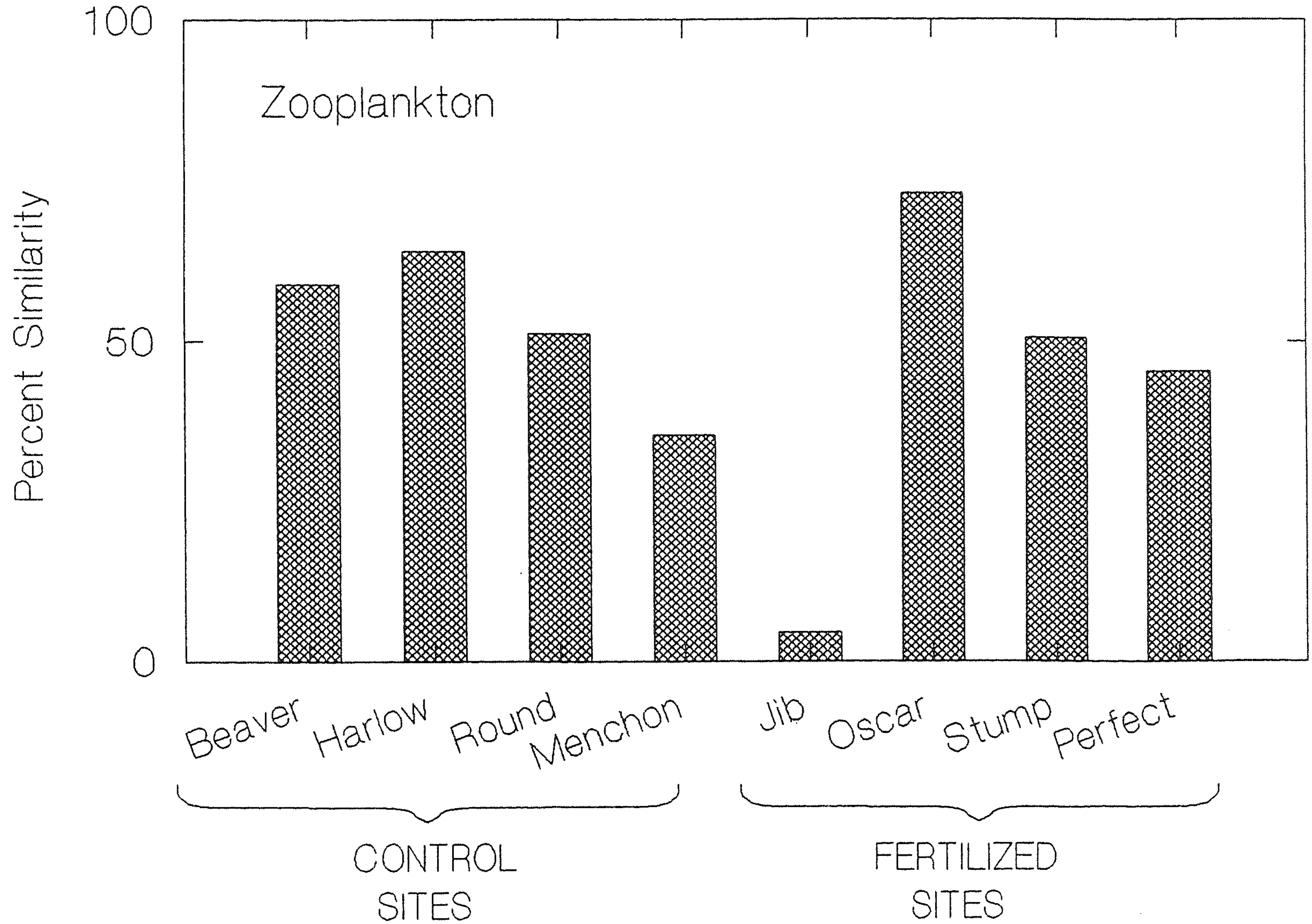


Figure V.3.4.3. Between year comparison of zooplankton community, in terms of similarity, at each site.

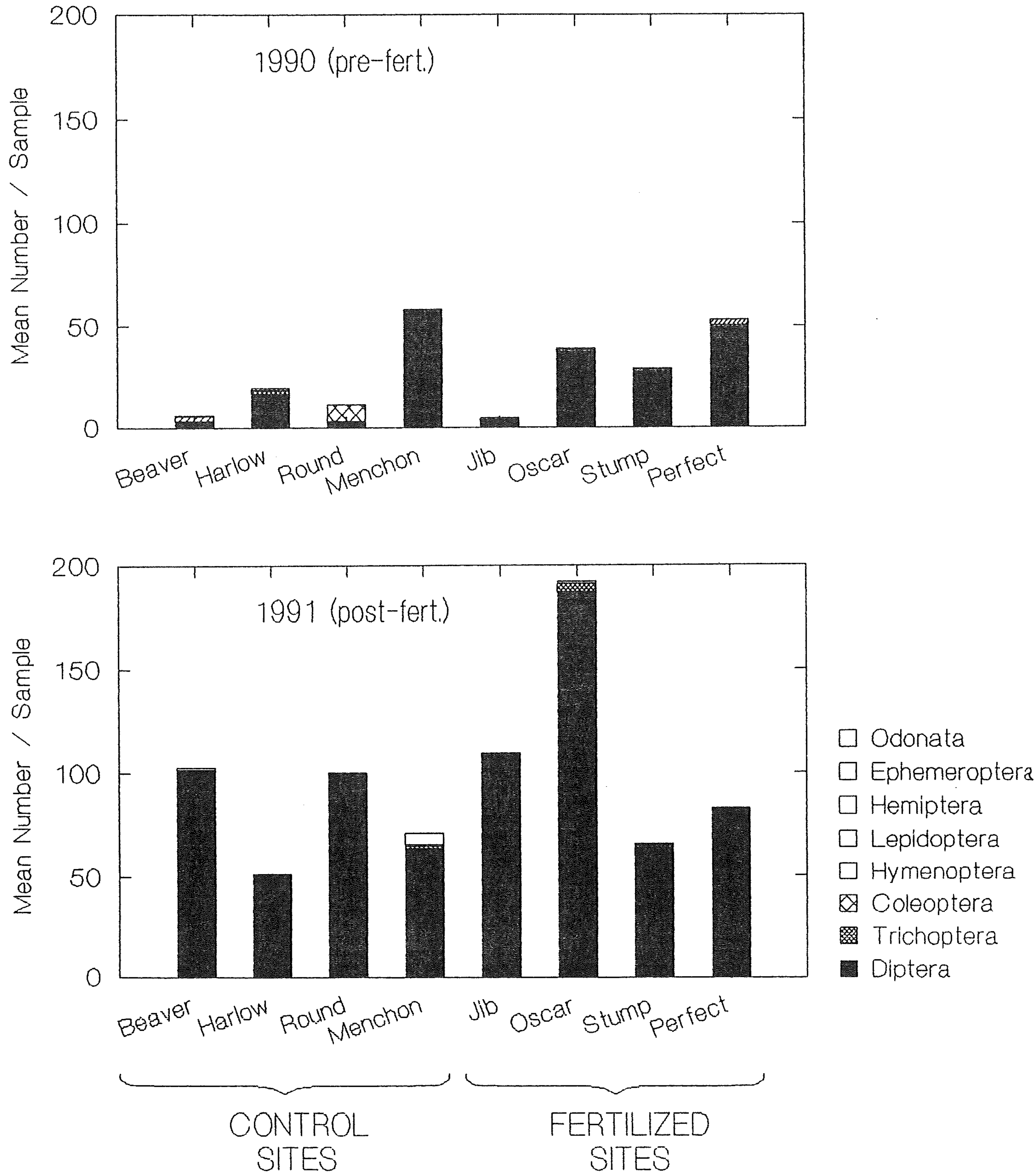


Figure V.3.5.1. Between year comparison of emergence trap collections at each site.

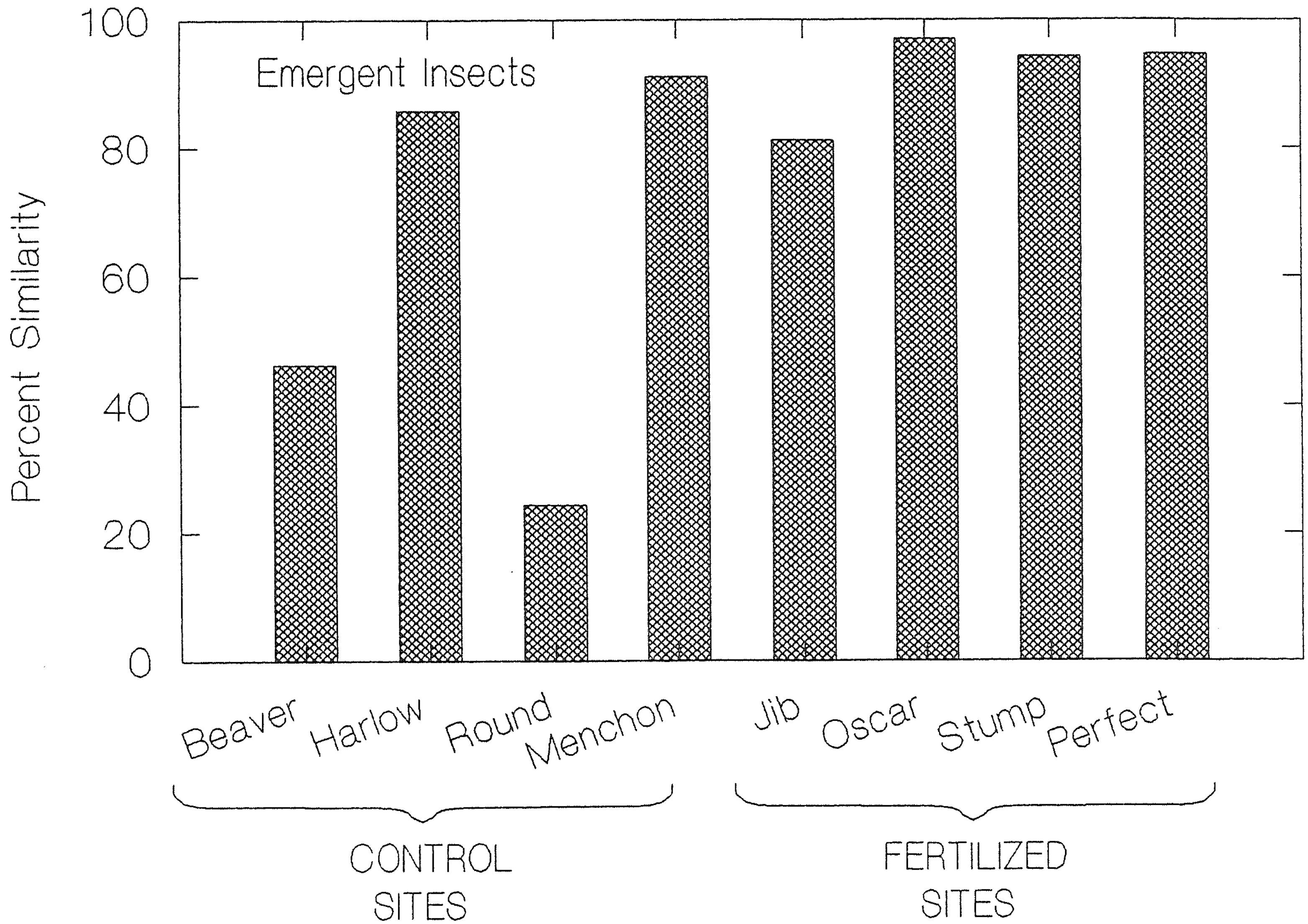


Figure V.3.5.2. Between year comparison of emergence trap collections, in terms of similarity, at each site.

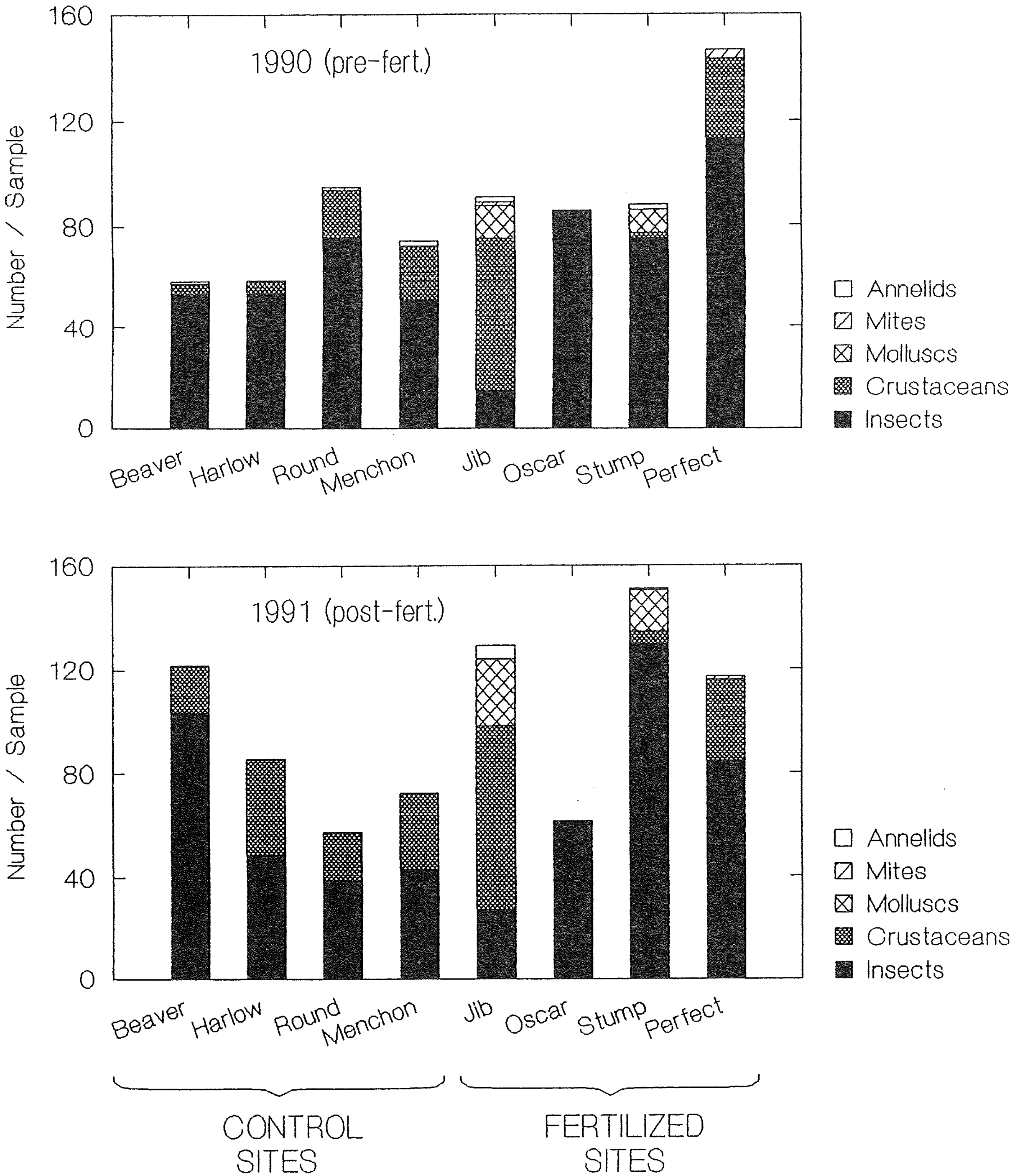


Figure V.3.6.1. Between year comparison of benthic invertebrate collections at each site.

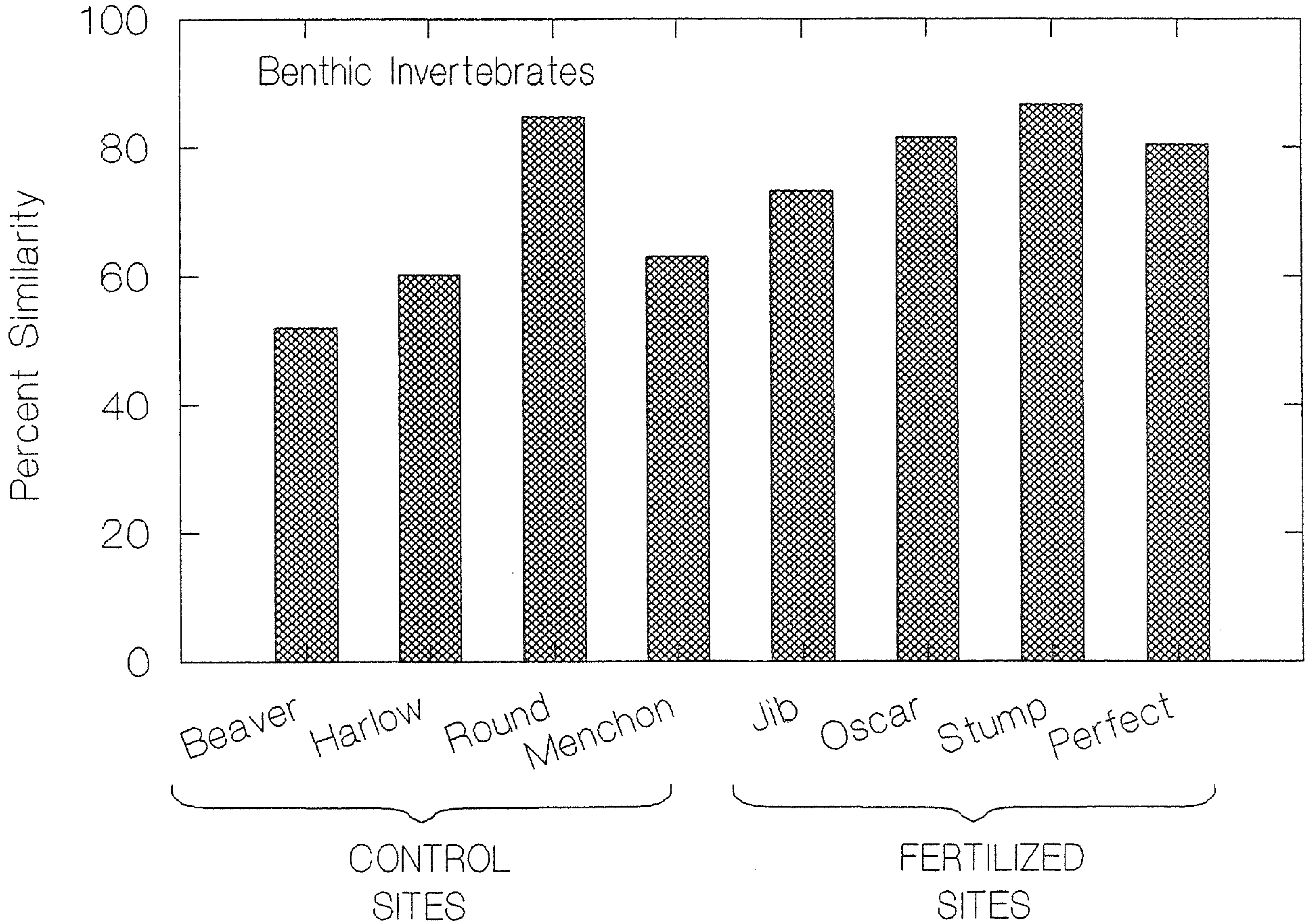


Figure V.3.6.2. Between year comparison of benthic invertebrate collections, in terms of similarity, at each site.

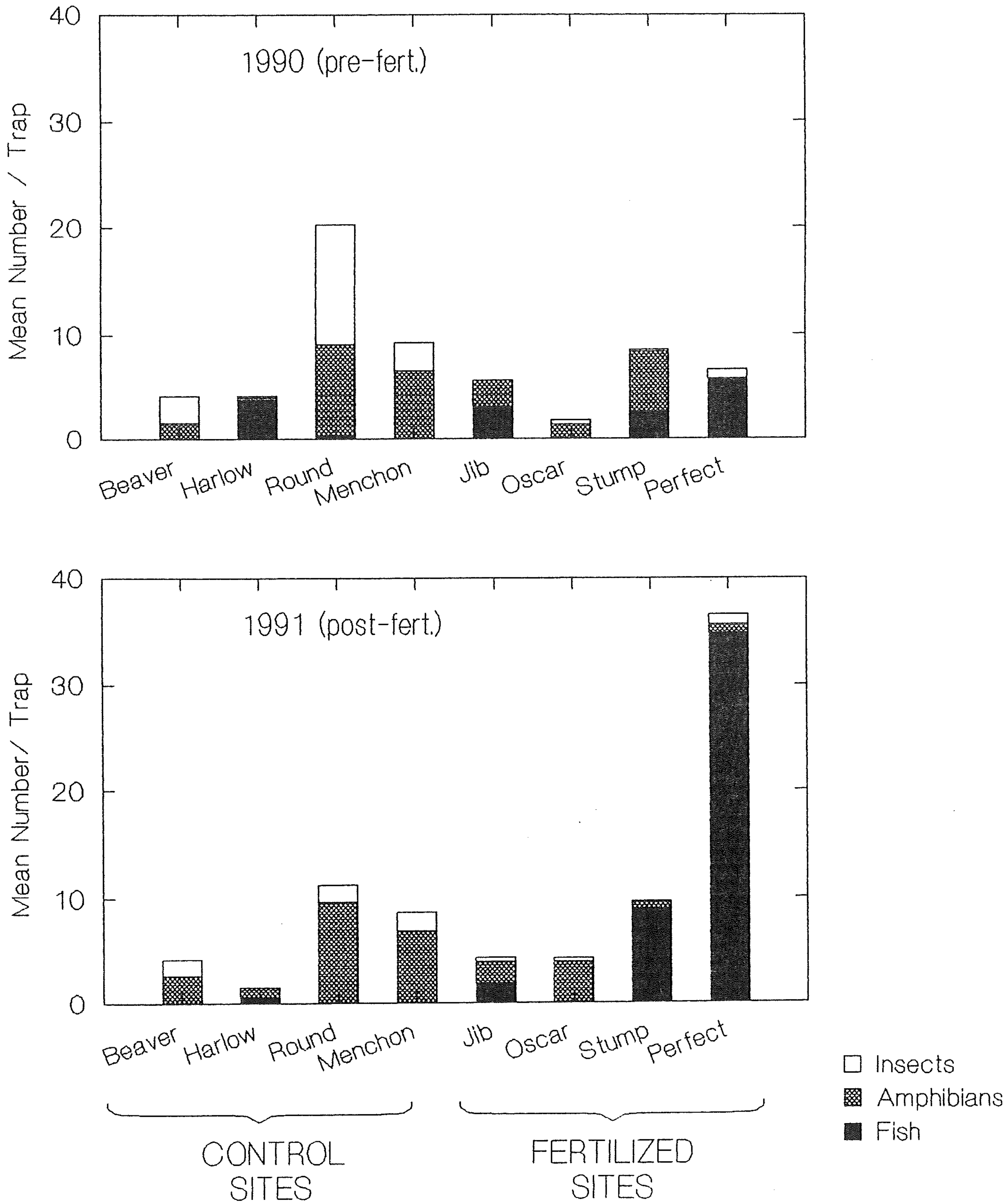


Figure V.3.7.1. Between year comparison of minnow trap collections at each site.

number of fish were trapped during 1991. Figure V.3.7.2 illustrates the major fish groups collected at each site during the two study years and indicates that the increase at Perfect was largely due to the golden shiner (*Notemigonus crysoleucas*), a species which for some reason was not recorded at all at any site during 1990.

VI. WATERFOWL OBSERVATIONS

The mean number of duck sightings per visit at each site during 1990 and 1991 is illustrated in Figure VI.1. A greater number of ducks, which were mostly black and ringnecks, were observed at both Beaver and Oscar during 1991.

VII. FISH SURVEY

Between 28 April and 1 May, 1991 a fish survey, similar to that performed during the fall of 1990, was carried out at each of the study sites. A 100 meter long multipanel experimental gill net, having mesh sizes of 0.5, 1.0, 1.5 and 2.0 inches, was placed in the centre of each site and allowed to remain overnight. Fish were captured at only three of the eight study sites. The greatest number (64) were caught at Harlow, all of the same species, yellow perch (*Perca fontinalis*; average size 10.2 cm). At Jib 18 brown bullheads (*Ictalurus nebulosus*; average size 14.6 cm), 23 yellow perch (*Perca fontinalis*; average size 13.8 cm) and 13 white suckers (*Catastomus commerson*; average size 20.5 cm) were caught, and at Perfect 5 brown bullheads (average size 12.4 cm) and 22 golden shiners (*Notemigonius crysolucas*; average size 10.0 cm) were caught.

VIII. SUMMARY

Despite the acidic nature of the study sites, the response of the experimental sites to the addition of fertilizers, in terms of increased biological activity, is impressive. Those organisms with short generation times, i.e. phytoplankton, periphyton, and zooplankton, showed an almost immediate response to the addition of fertilizer and increased in biomass substantially over the growing season. Organisms having longer generation times, such as emergent insects and benthic invertebrates, showed little response to fertilization during this first year, but will probably also show an increase in biomass during subsequent years and there is little doubt that fertilization will increase the overall productivity of these systems.

On the basis of the nutrient levels achieved, the fertilization regime employed certainly appears to have been adequate and, if anything, may have used more fertilizer than was required to maximize production. The variation in response among the sites, particularly with regard to the nutrient levels attained, suggests that future fertilization protocols should consider factors other than lake volume alone. Predicting the level of P that would be attained for a particular system is complex but appears to depend largely on lake depth, flushing rate, mixing type and the technique used to apply the fertilizer.

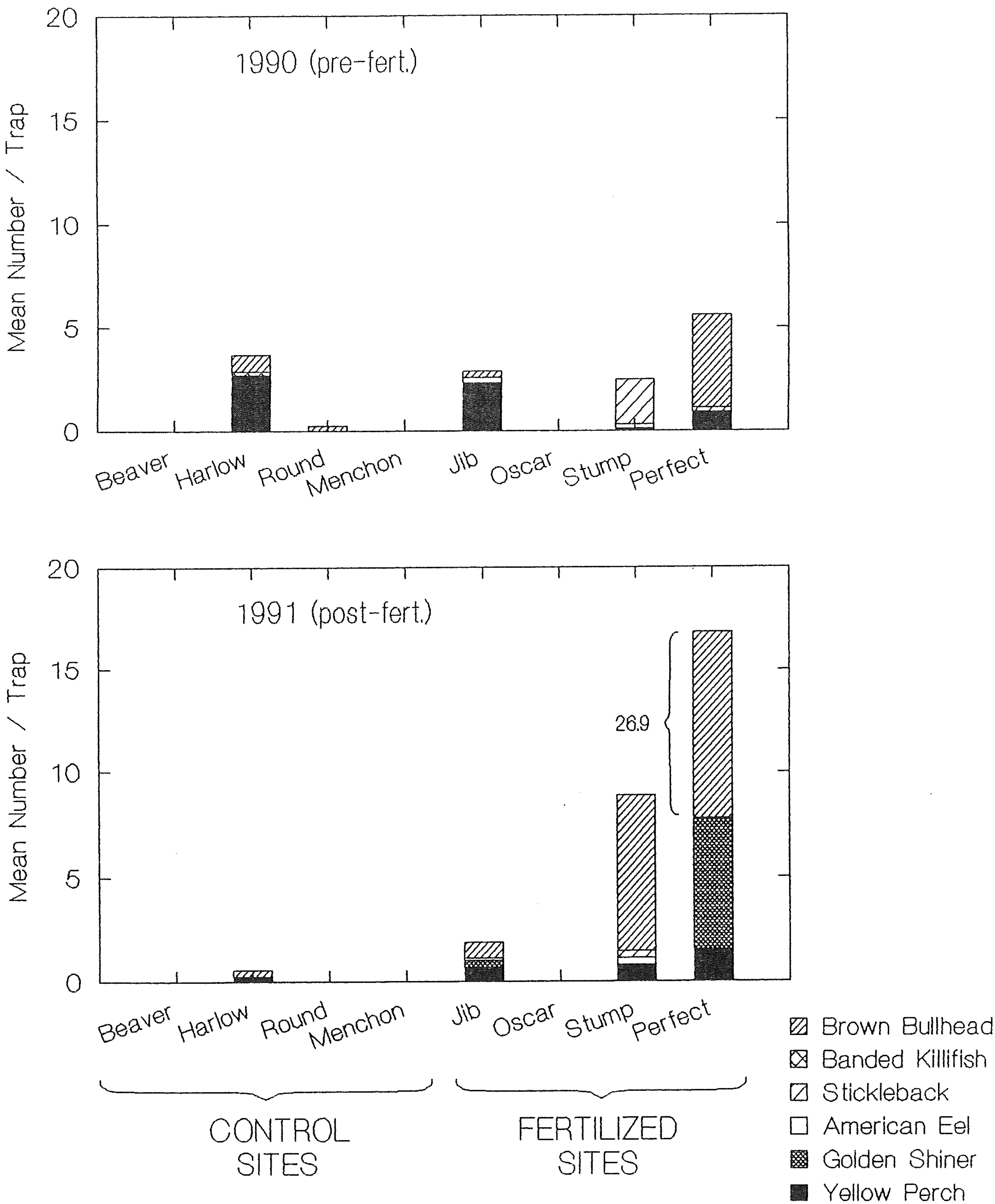


Figure V.3.7.2. Between year comparison of fish collected in minnow traps at each site.

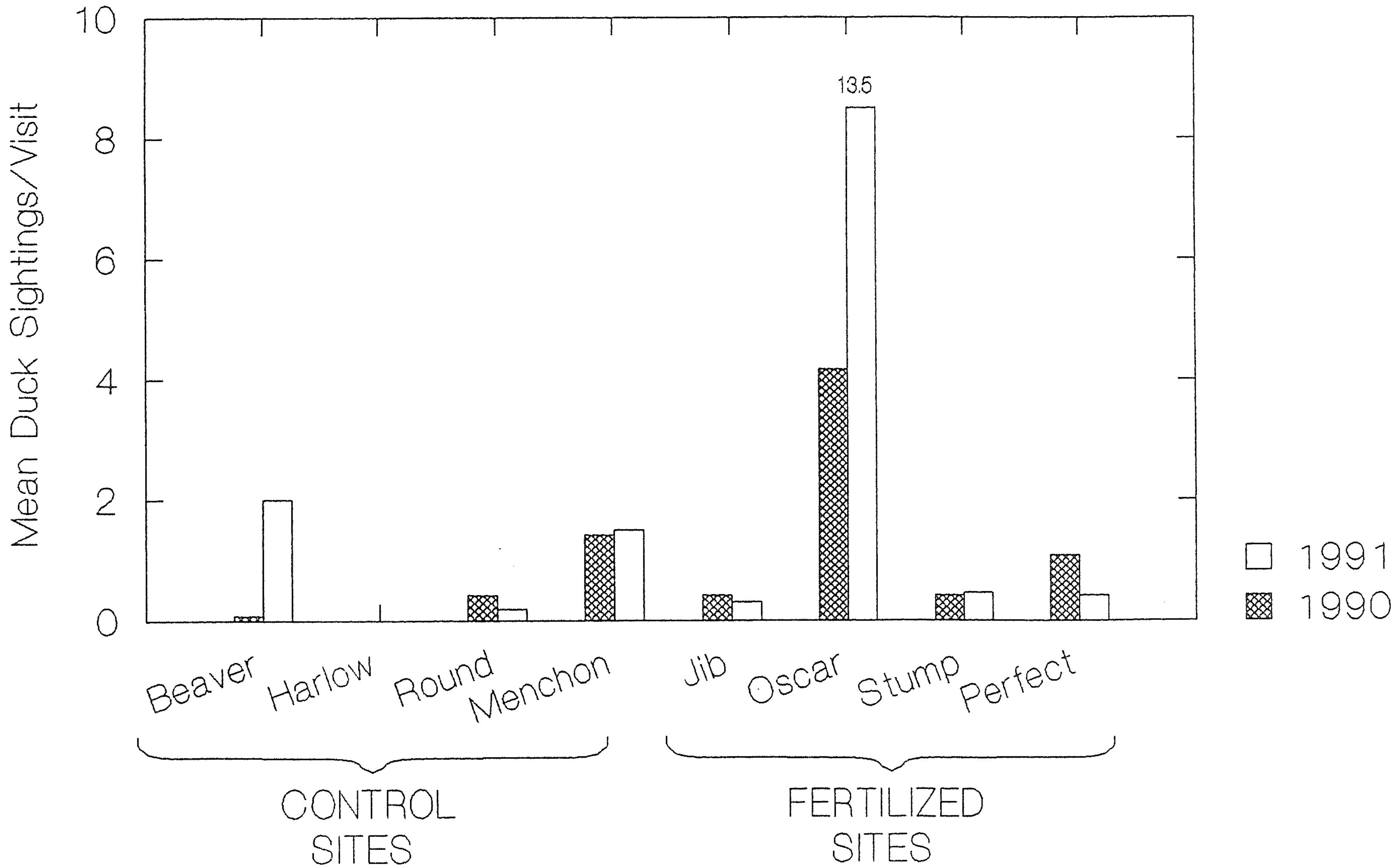


Figure VI.1. Between year comparison of duck sightings at each site.

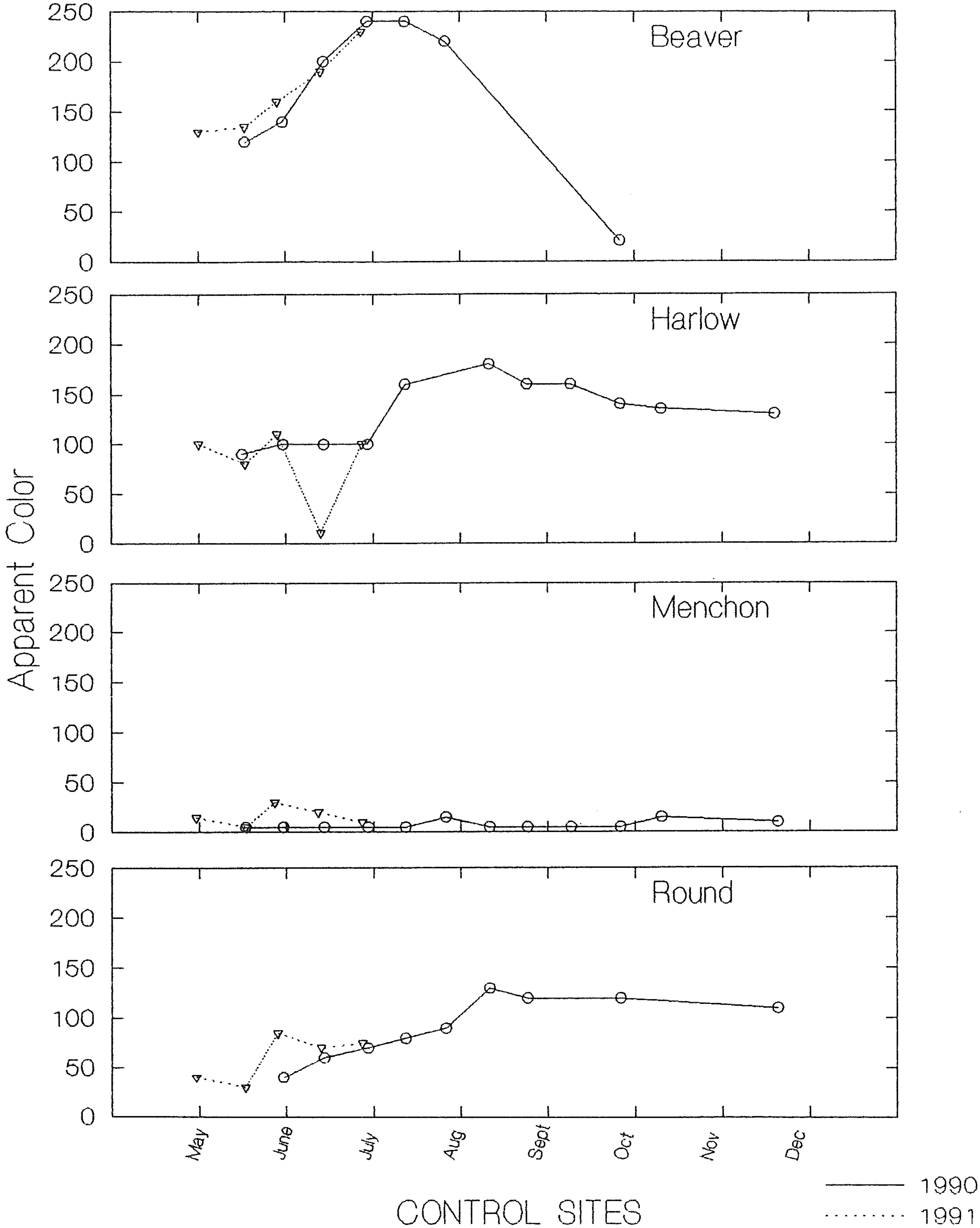
With respect to the potentially negative aspects of fertilization and its resulting eutrophication, a more complete evaluation will have to wait for at least another year of study. However, based on the results of the first year of fertilization, the negative impact appears to be minor. No obnoxious algal blooms were created and the downstream effects of nutrient export were unnoticeable. The only potentially negative impact identified was that the experimental sites may become anaerobic a short time sooner than if they were not fertilized but, since none of these sites appear to be important as feeding or breeding habitat for fishes requiring high oxygen levels (e.g., salmonids), this appears to be of minor significance.

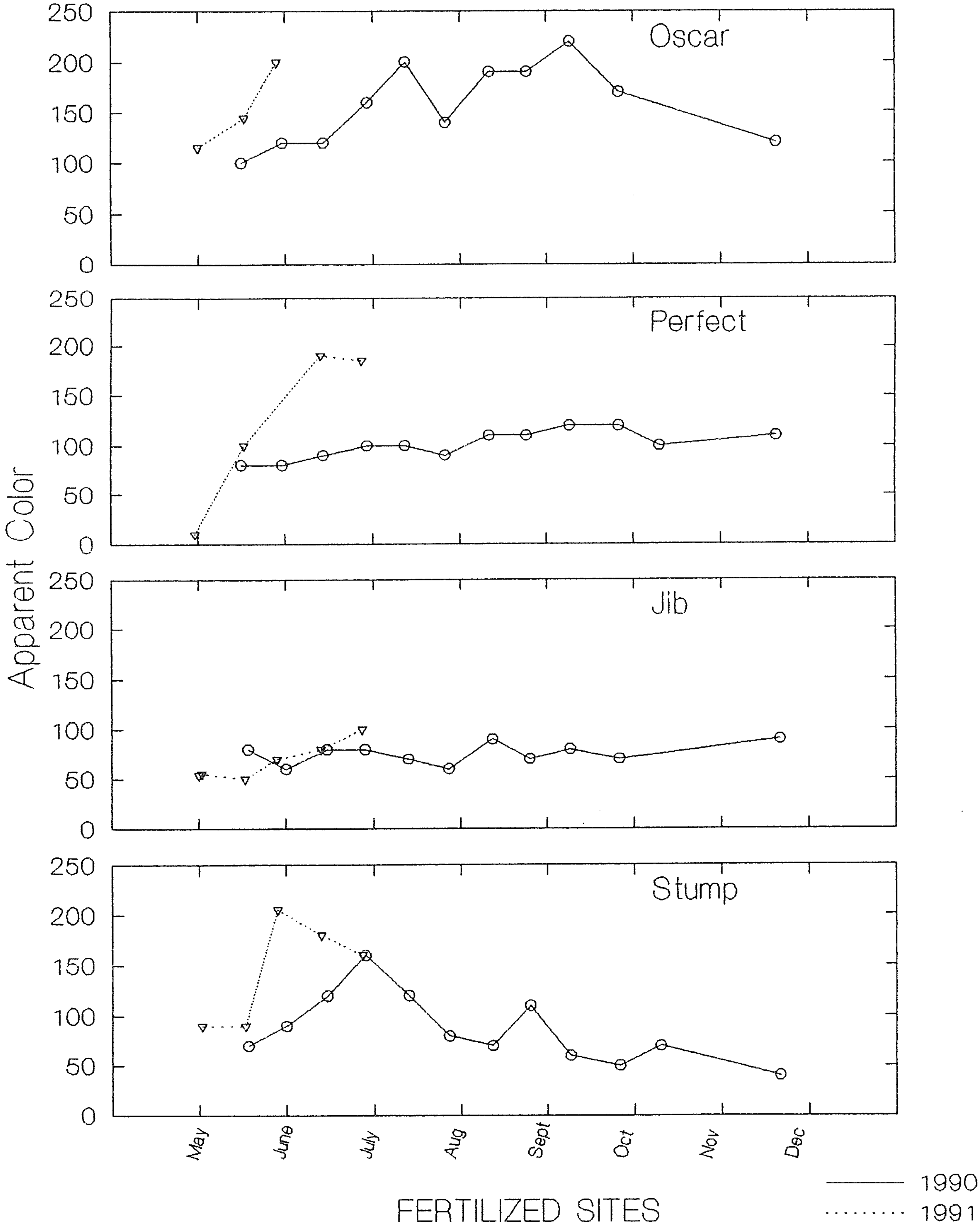
IX. ACKNOWLEDGEMENTS

This report was prepared with the help of Darlene Feener. The 1991 field crew was supervised by Nancy House and consisted of Jamie Gibson, Kuflom Kuflu, Sarah Richard and Michelle Walters. Reg Melanson and Fred Payne of the Nova Scotia Department of Natural Resources provided valuable logistic support throughout the year. Dr. Joseph Kerekes of the Canadian Wildlife Service arranged for the chemical analyses of water samples which was carried out by the Inland Waters Branch of the Canadian Department of Environment at Moncton, N.B.

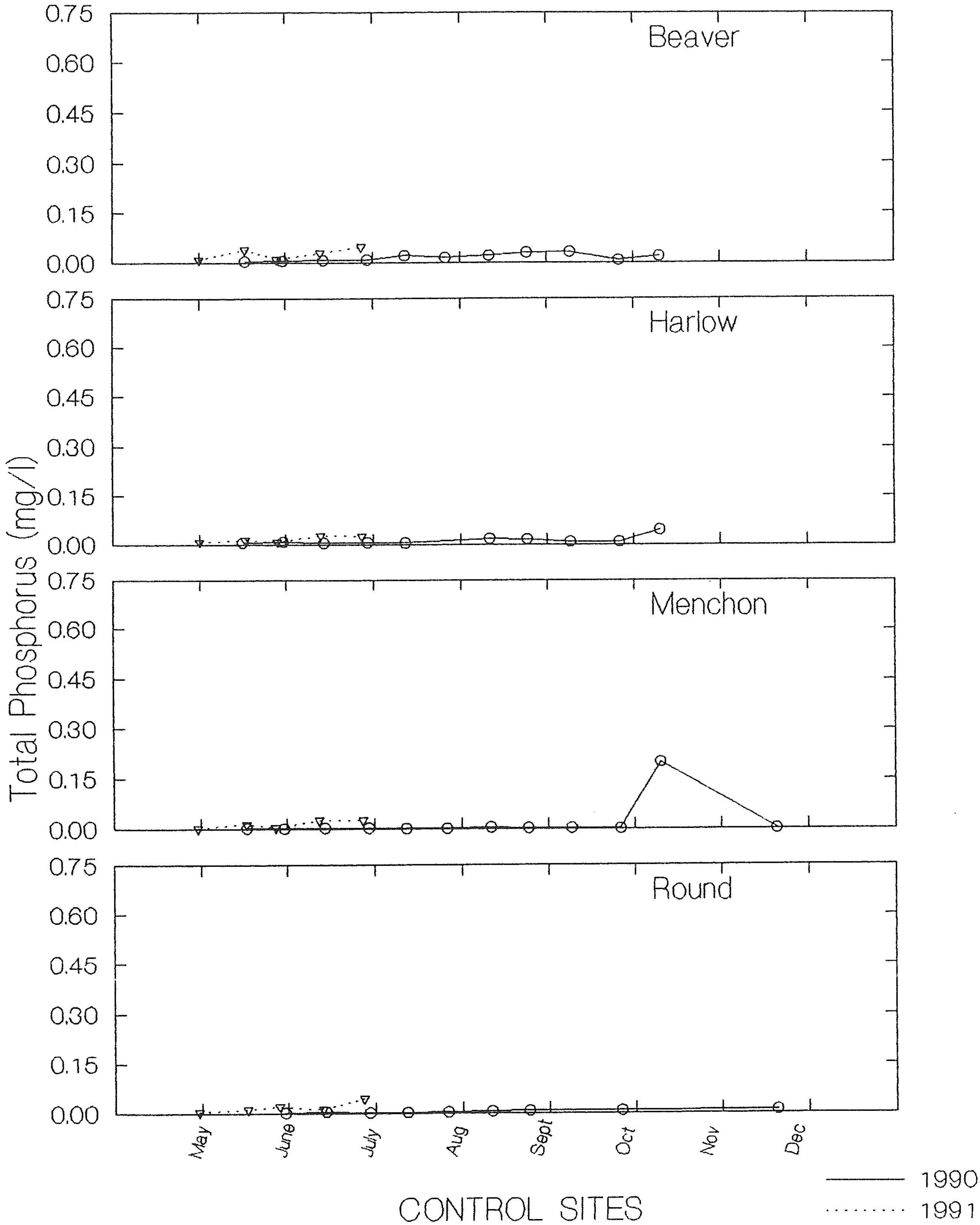
X. APPENDIX

A. Graphical Summary of CWS Data

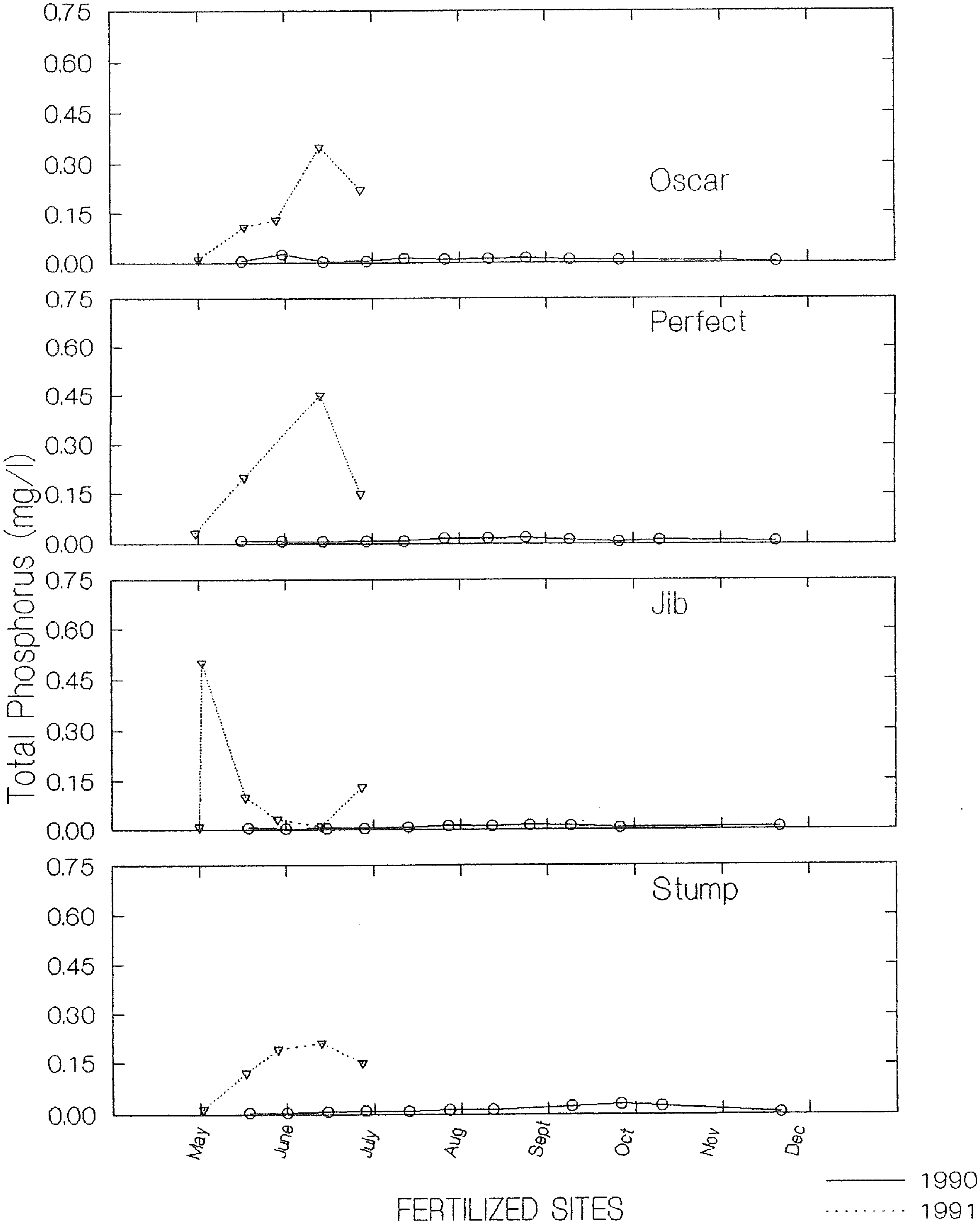

Beaver
Harlow
Menchon
Round
Apparent Color
250
200
150
100
50
0
May
June
July
Aug
Sept
Oct
Nov
Dec
CONTROL SITES
1990
1991



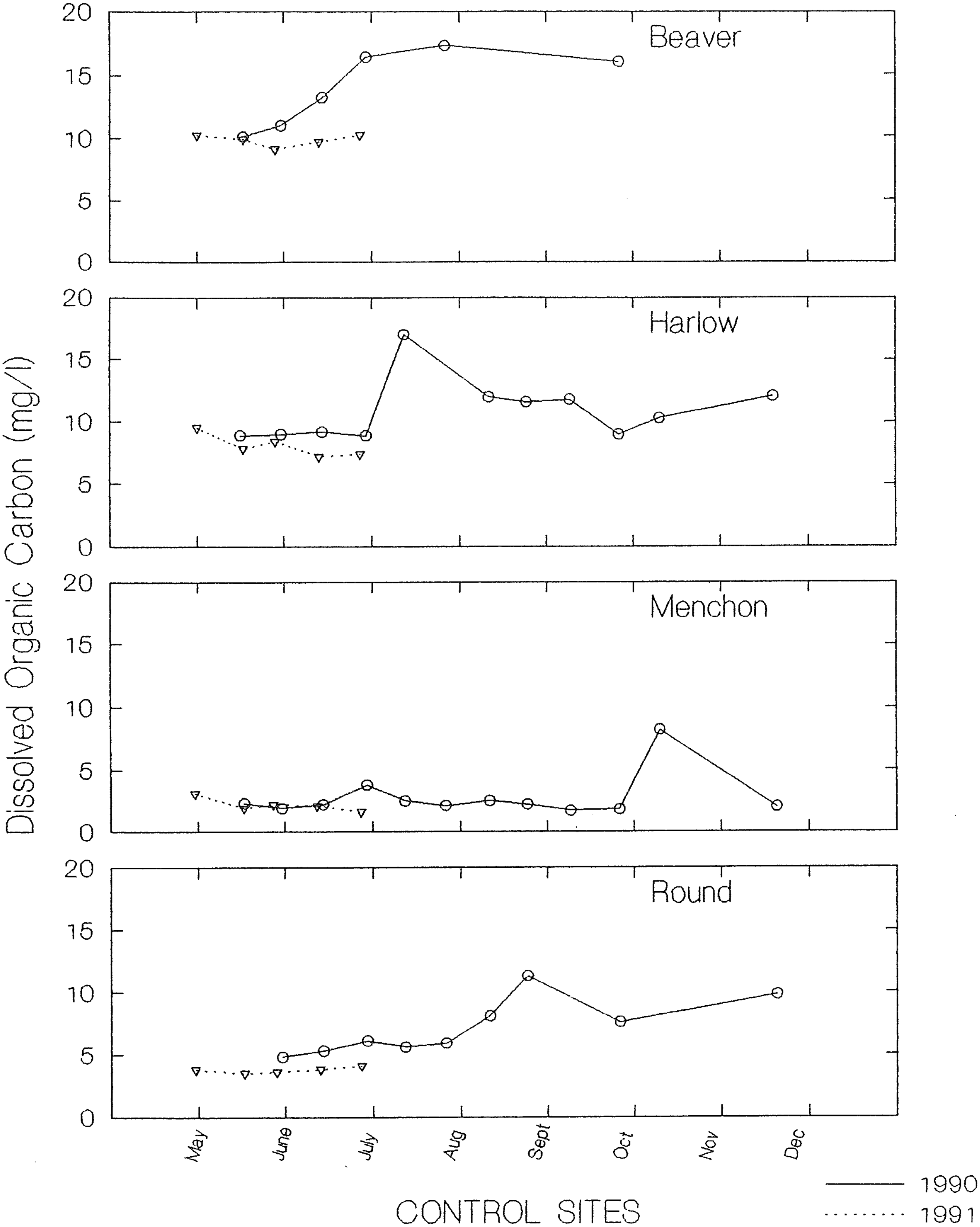
FERTILIZED SITES



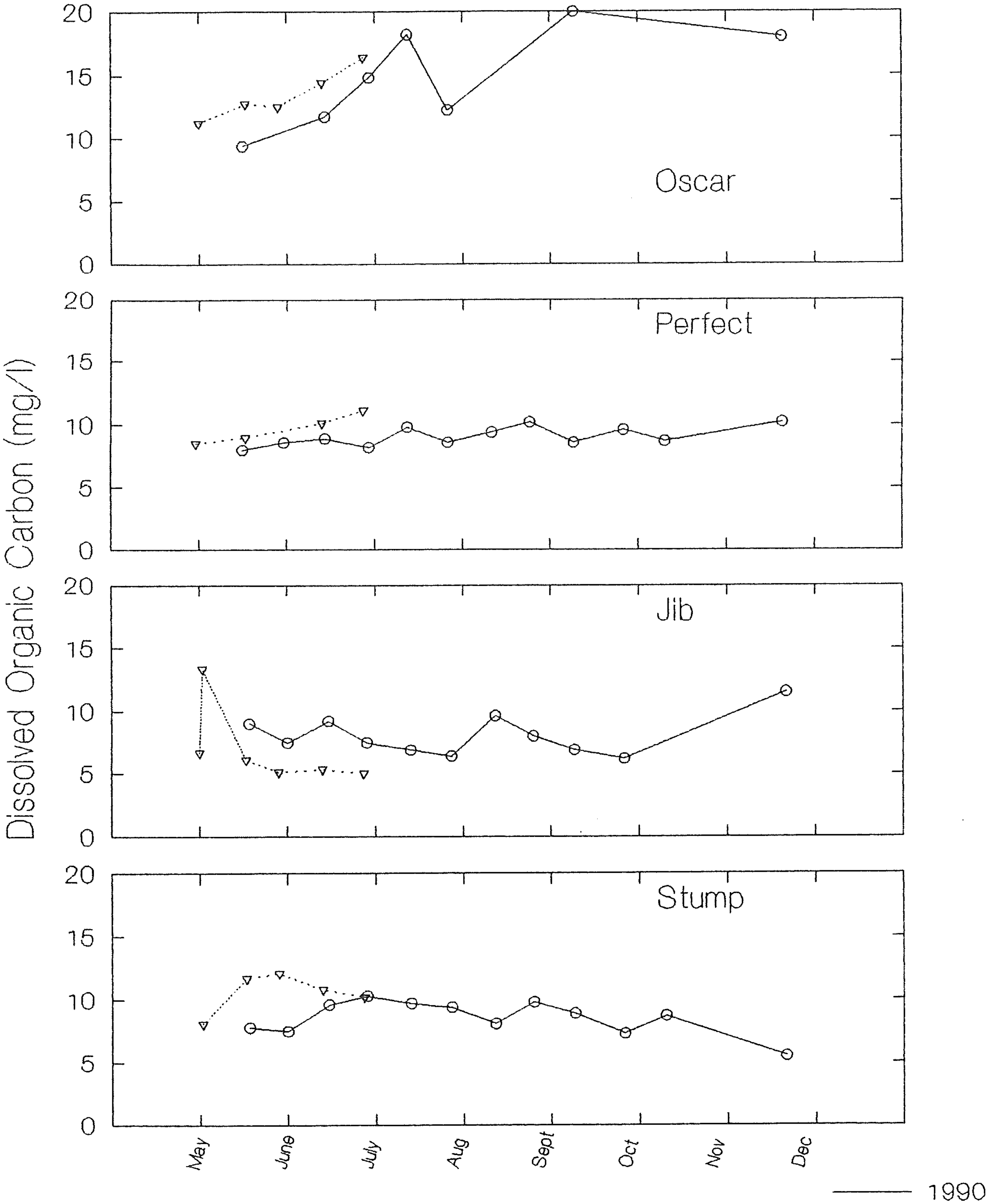
Beaver
Harlow
Menchon
Round
Total Phosphorus (mg/l)
0.75
0.60
0.45
0.30
0.15
0.00
May
June
July
Aug
Sept
Oct
Nov
Dec
CONTROL SITES
1990
1991



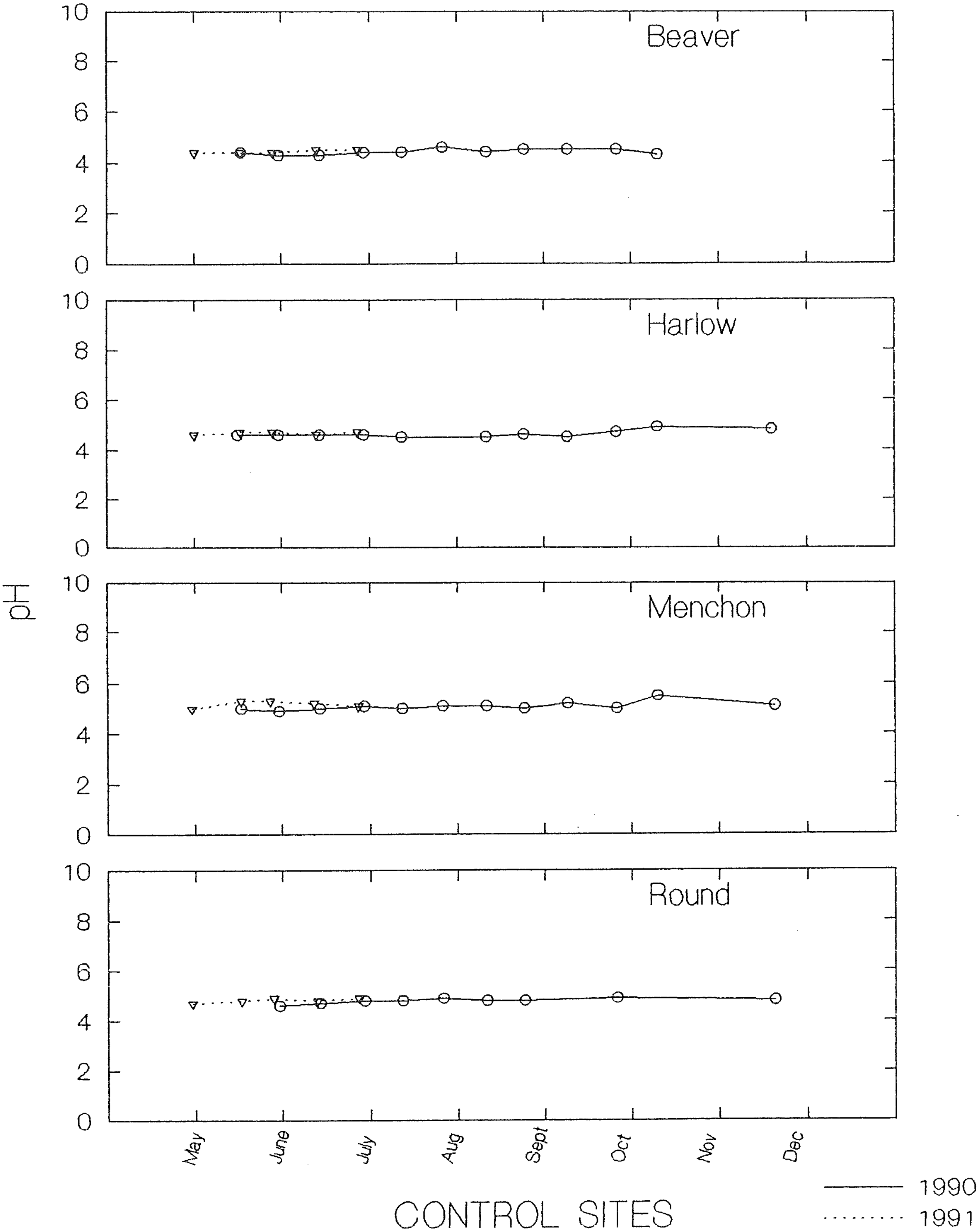
Oscar
Perfect
Jib
Stump
0.75
0.60
0.45
0.30
0.15
0.00
Total Phosphorus (mg/l)
May
June
July
Aug
Sept
Oct
Nov
Dec
FERTILIZED SITES
1990
1991



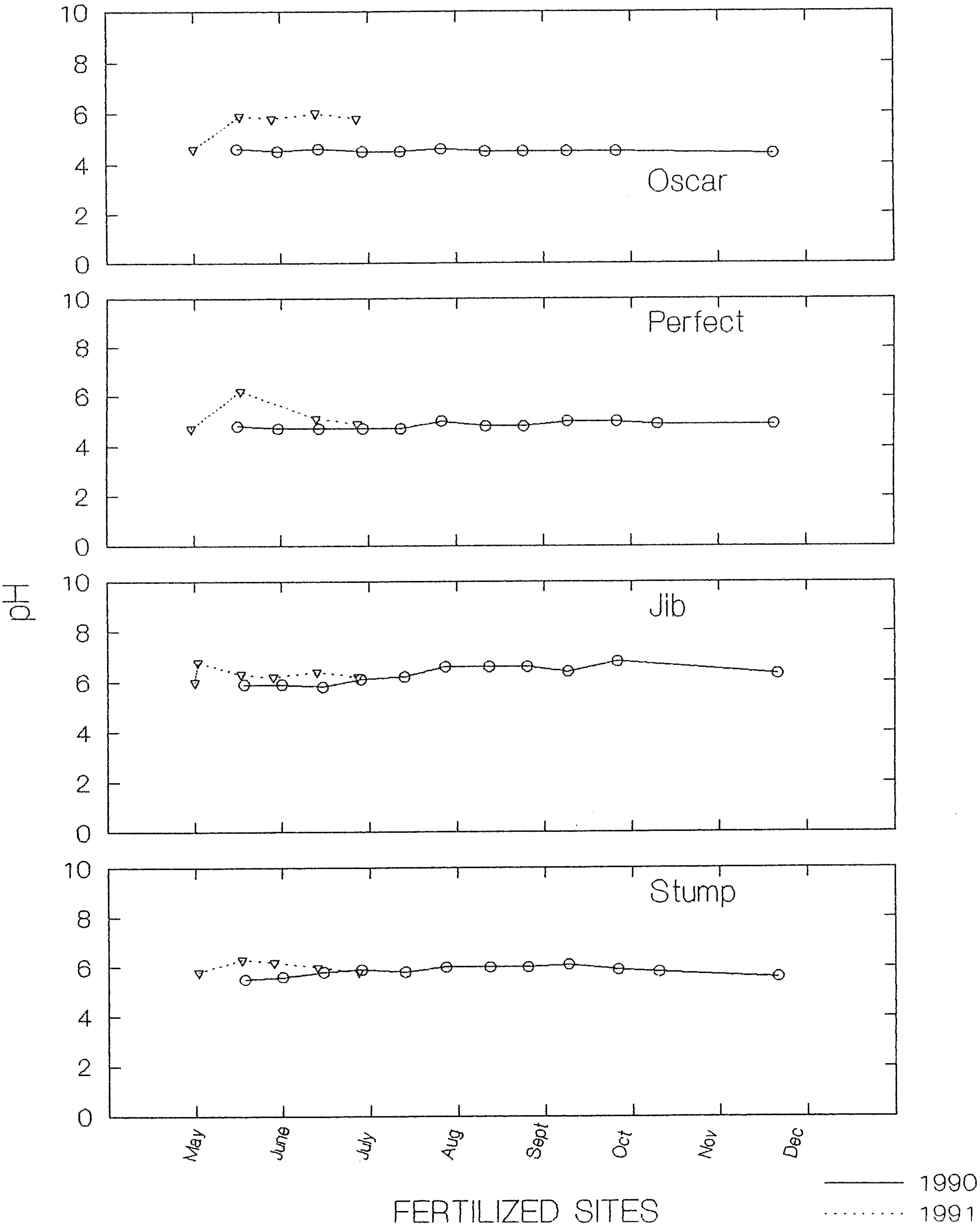
CONTROL SITES



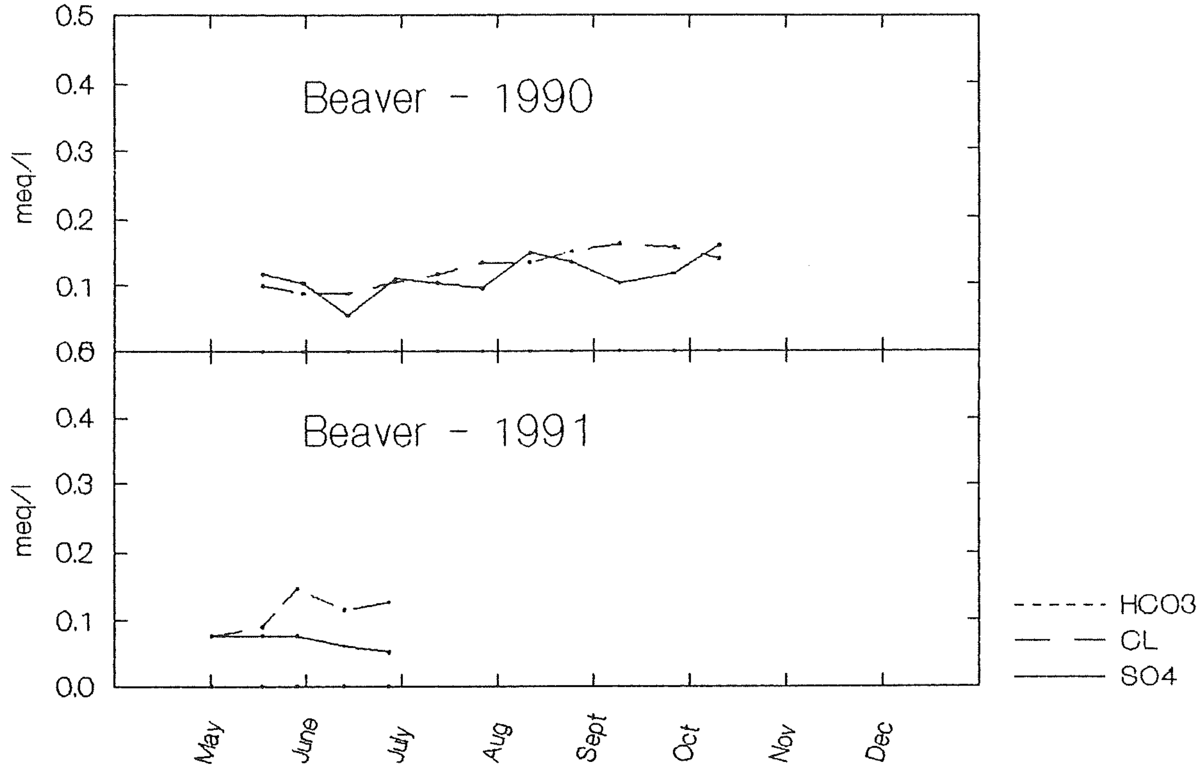
FERTILIZED SITES

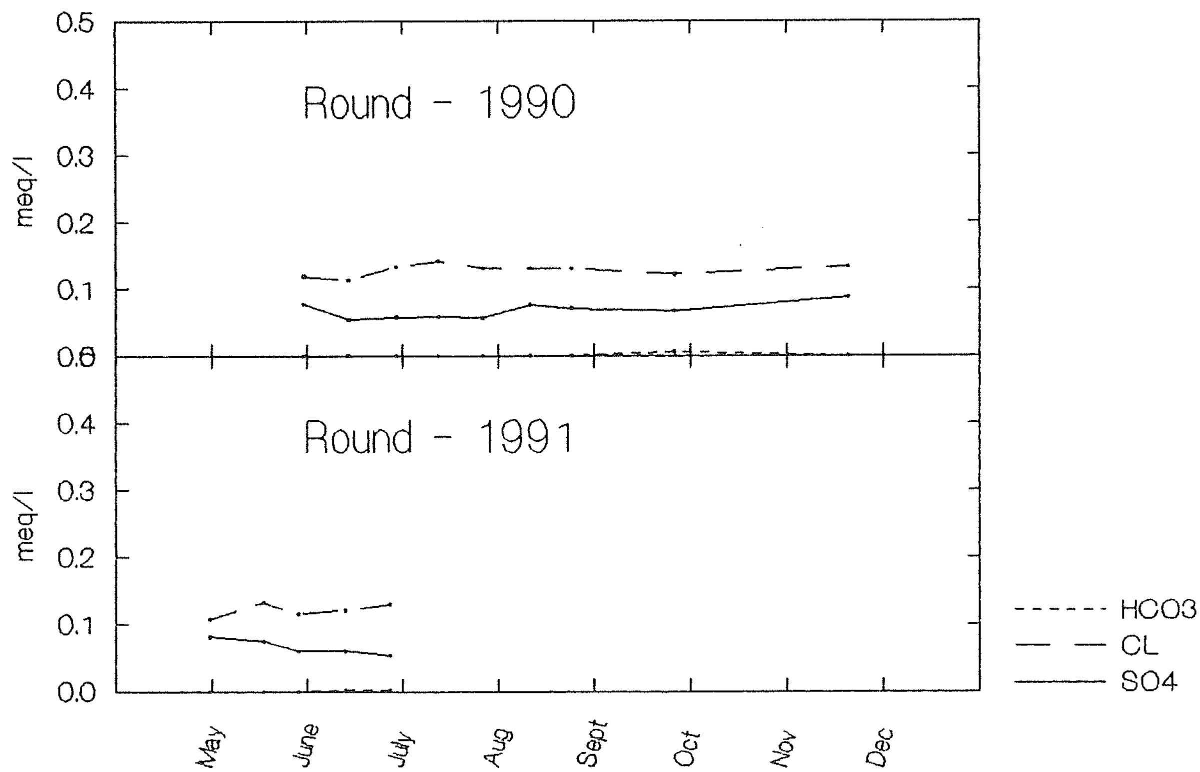


CONTROL SITES



10
8
6
4
2
0
Oscar
Perfect
Jib
Stump
pH
May
June
July
Aug
Sept
Oct
Nov
Dec
FERTILIZED SITES
1990
1991


Beaver - 1990
Beaver - 1991
meq/l
0.5
0.4
0.3
0.2
0.1
0.0
HCO3
CL
SO4
May
June
July
Aug
Sept
Oct
Nov
Dec


Round - 1990
Round - 1991
meq/l
0.5
0.4
0.3
0.2
0.1
0.0
HCO3
CL
SO4
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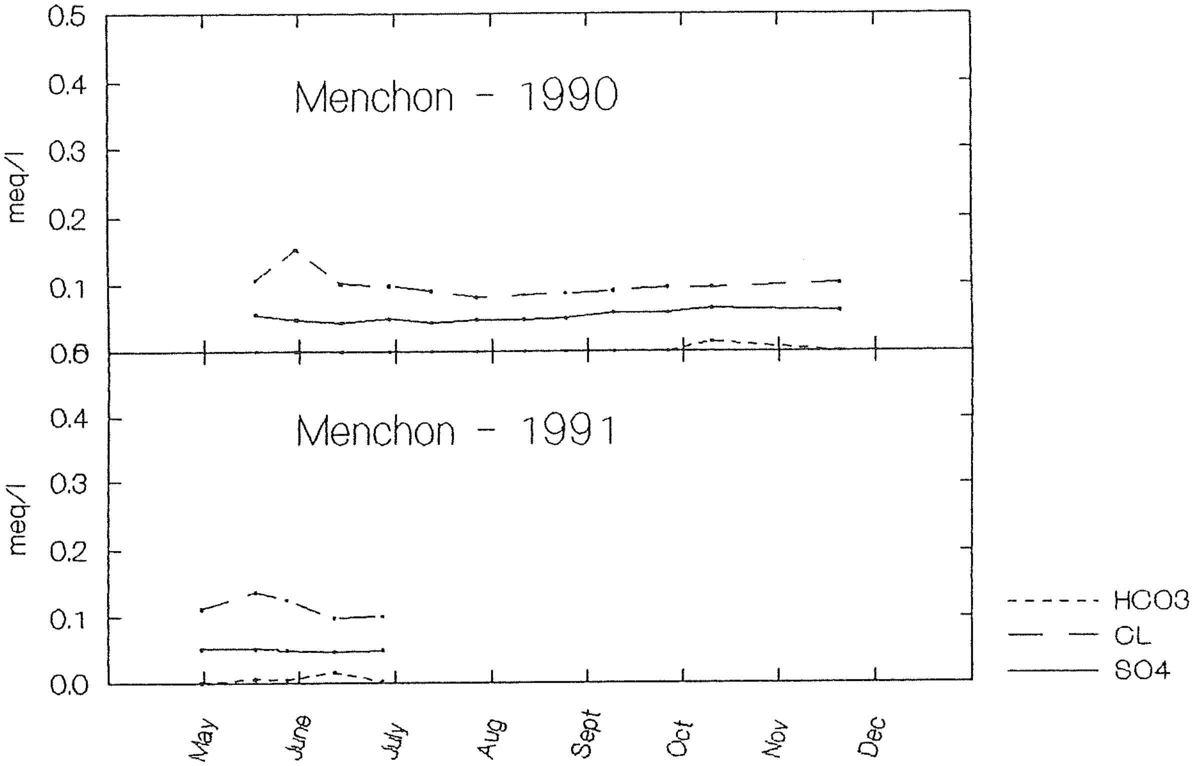
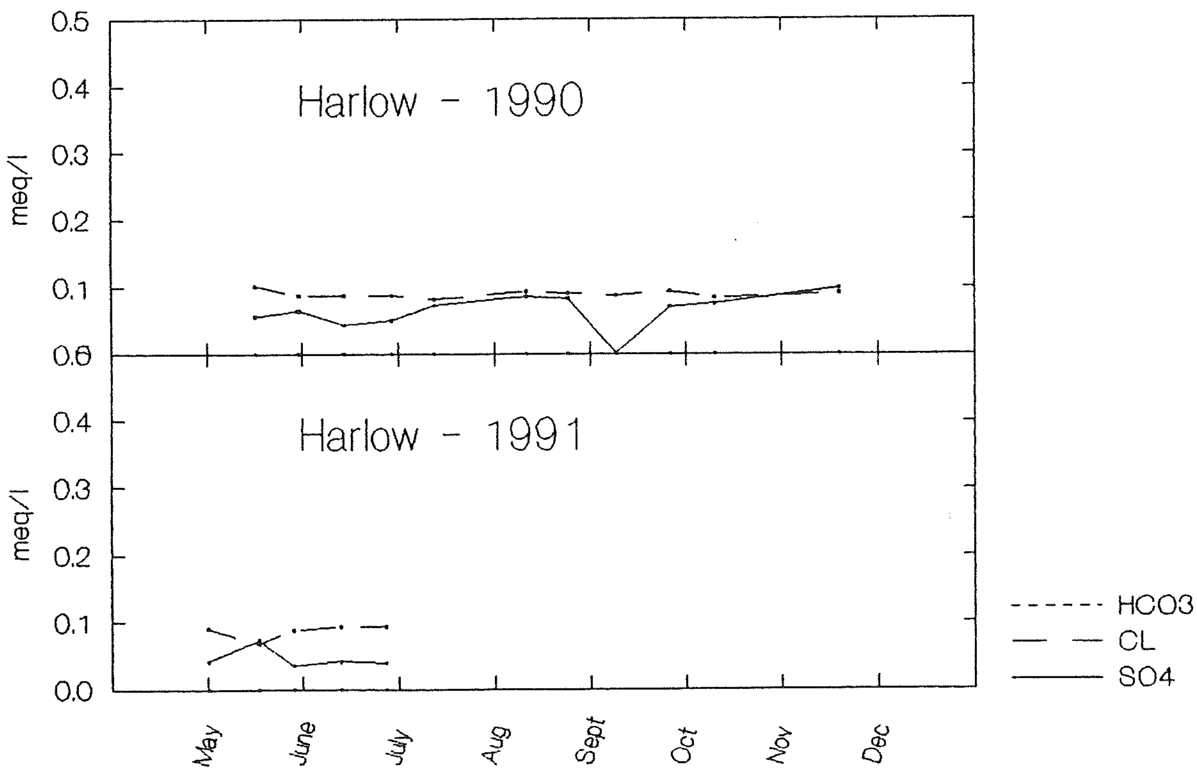
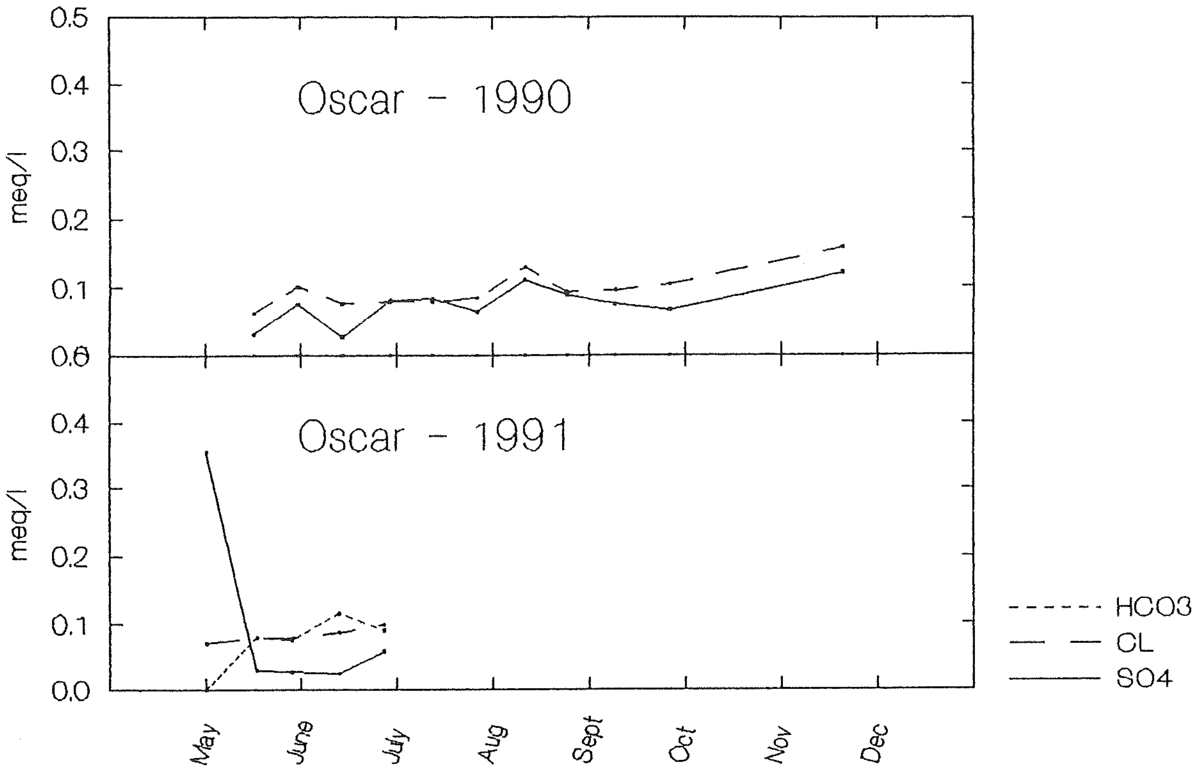
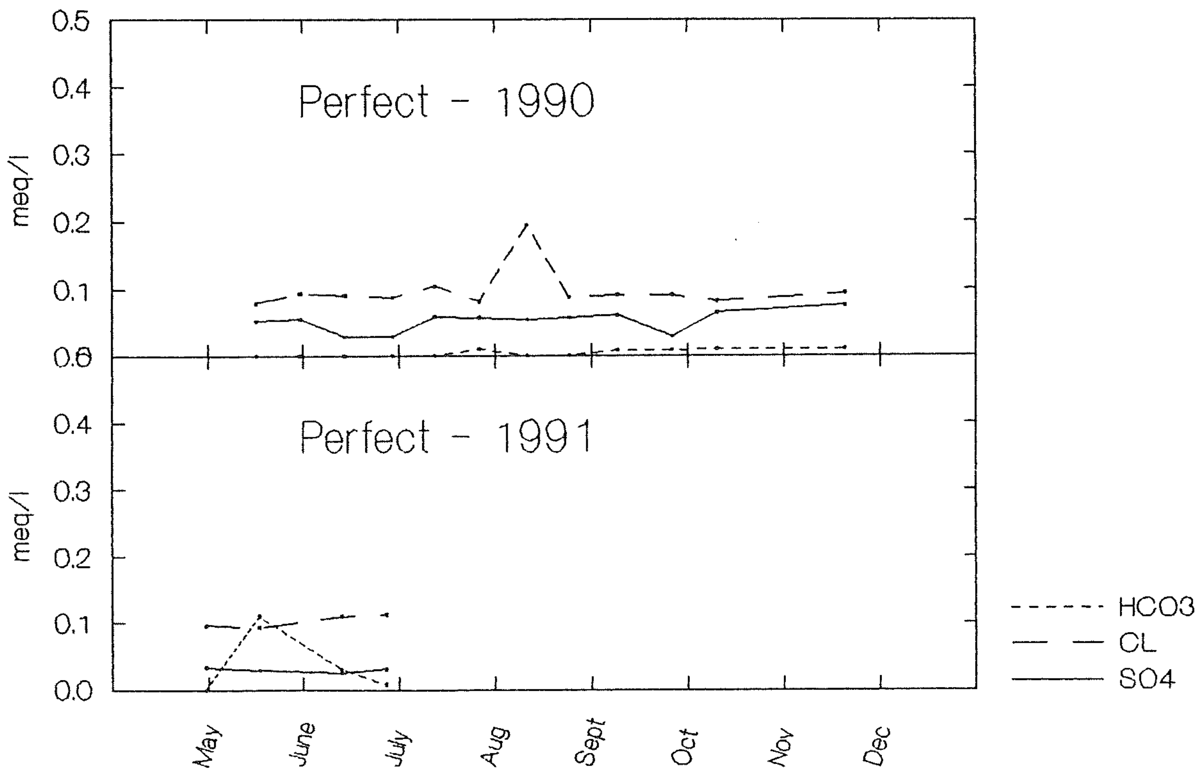
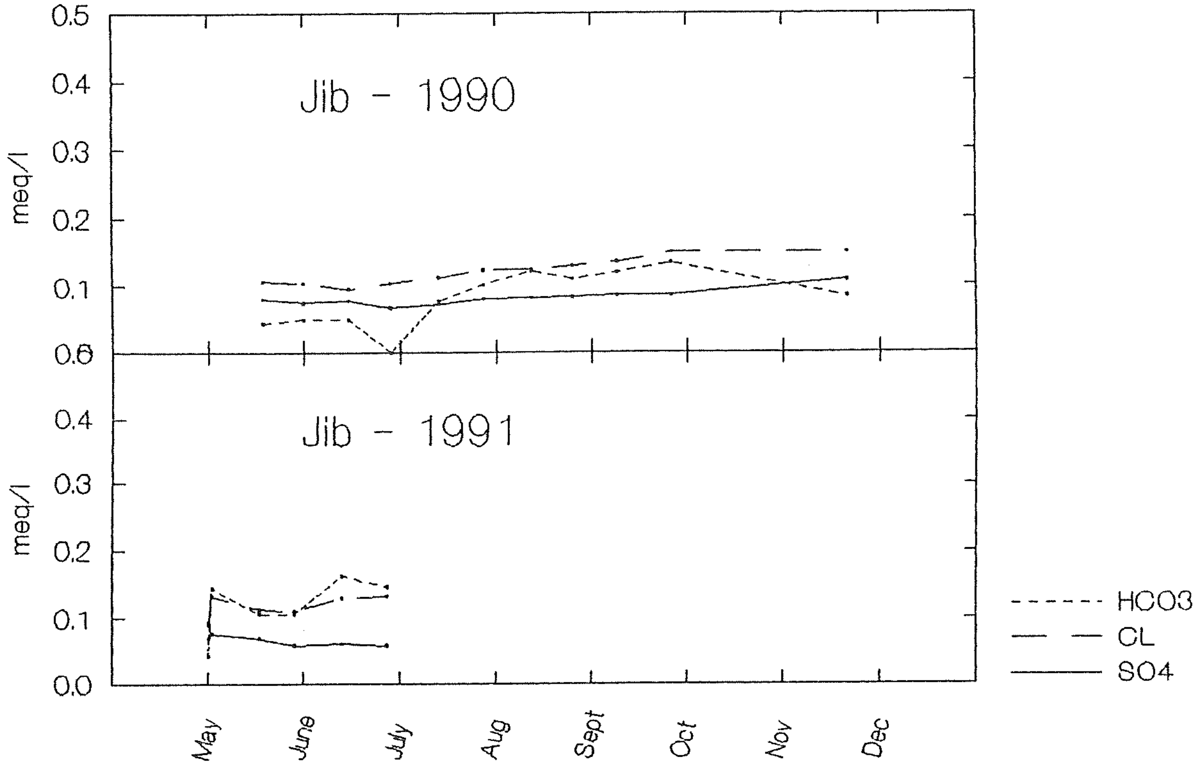
June
July
Aug
Sept
Oct
Nov
Dec

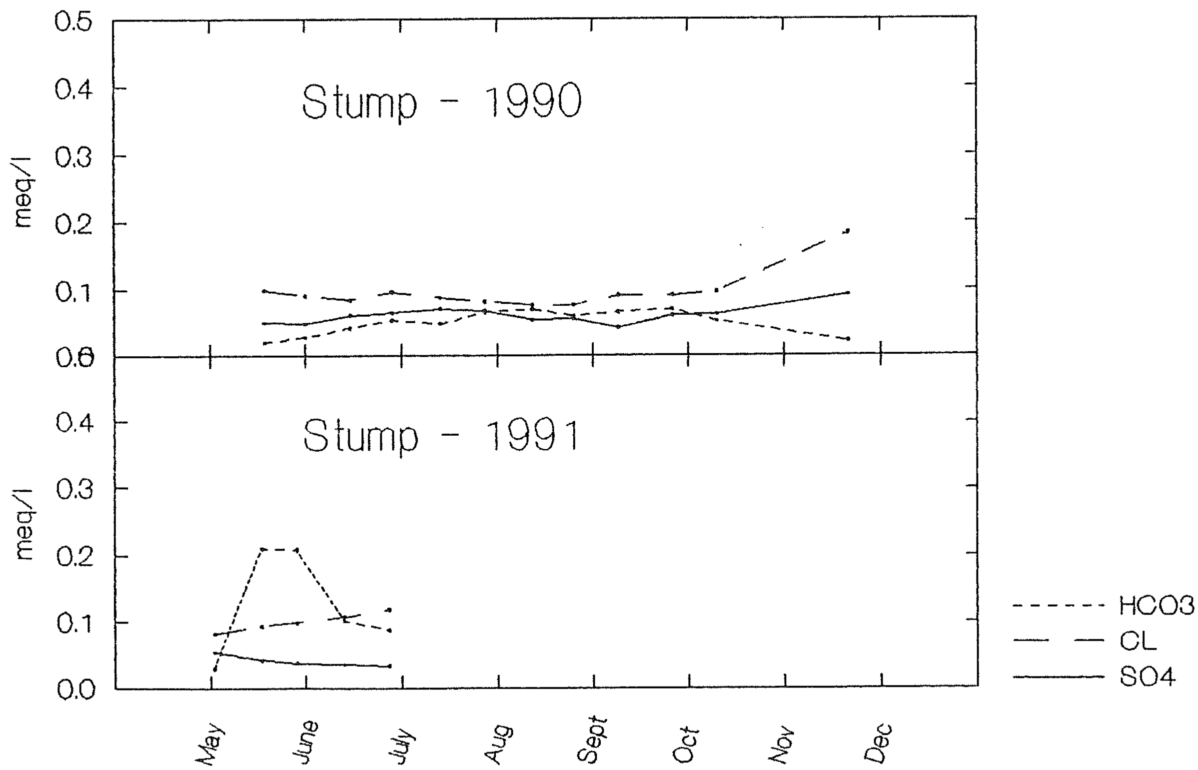

Menchon - 1990
Menchon - 1991
meq/l
meq/l
0.5
0.4
0.3
0.2
0.1
0.0
0.4
0.3
0.2
0.1
0.0
May
June
July
Aug
Sept
Oct
Nov
Dec
HCO3
CL
SO4

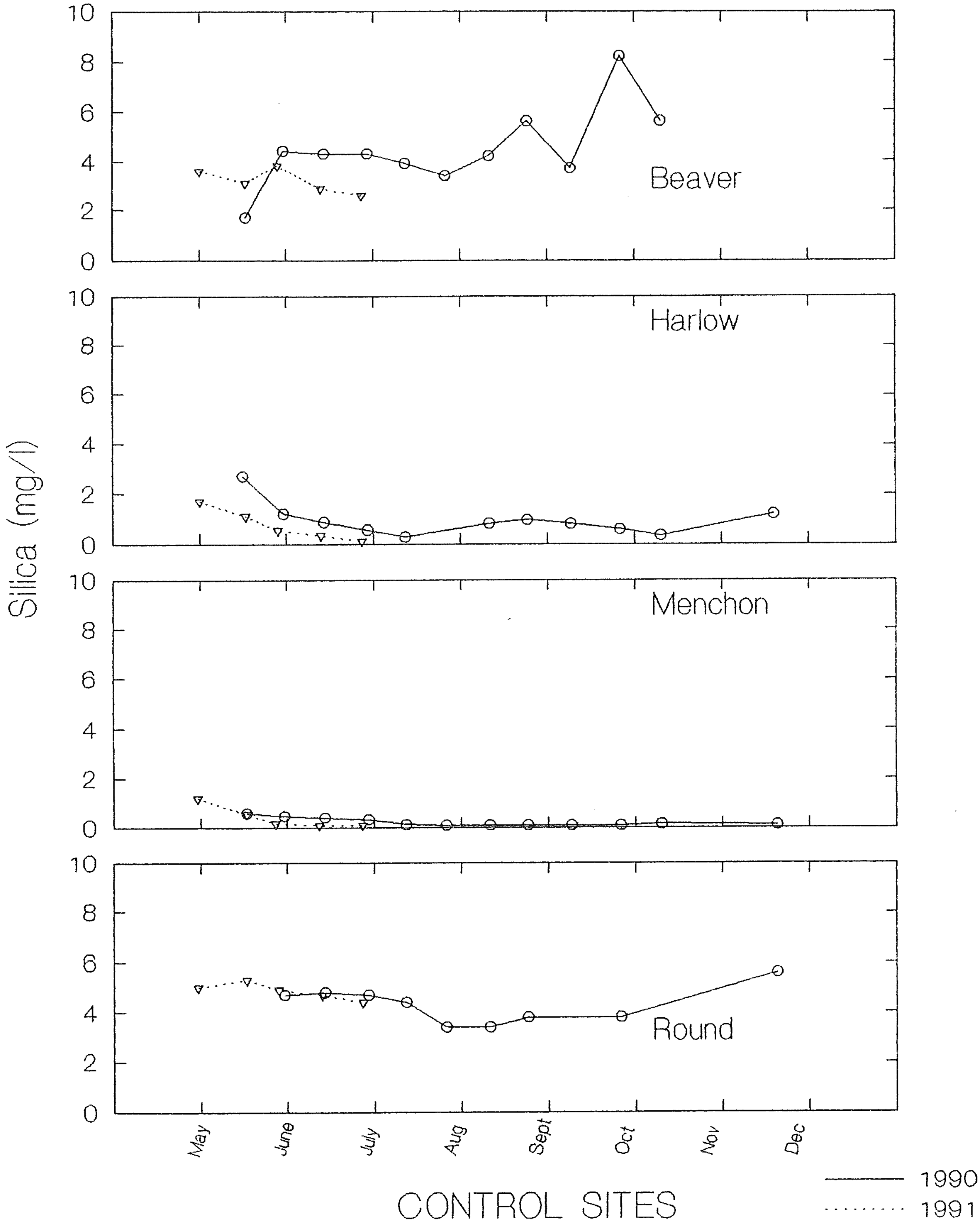

Harlow - 1990
Harlow - 1991
meq/l
meq/l
0.5
0.4
0.3
0.2
0.1
0.0
0.4
0.3
0.2
0.1
0.0
May
June
July
Aug
Sept
Oct
Nov
Dec
HCO3
CL
SO4

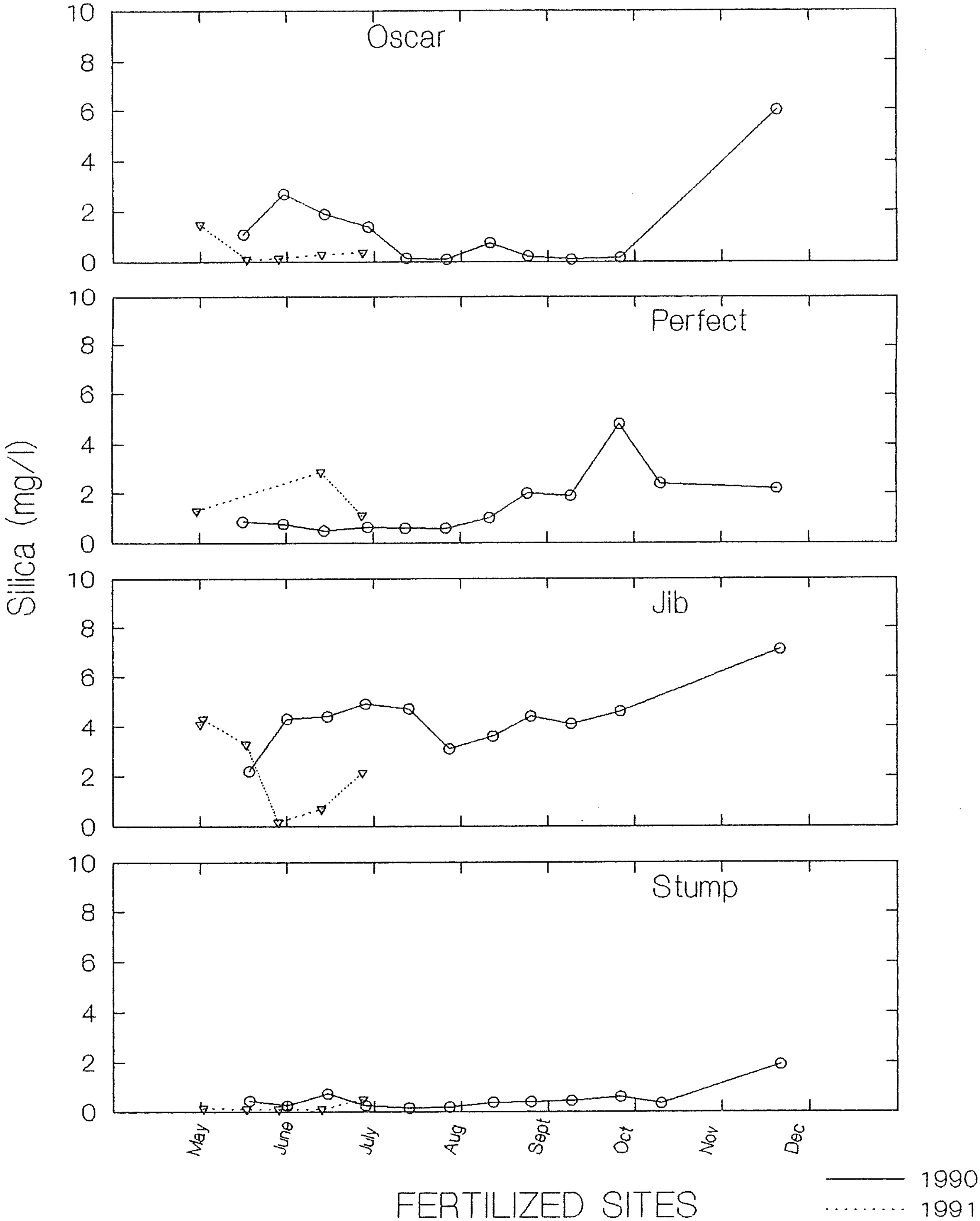

Oscar - 1990
Oscar - 1991
meq/l
0.5
0.4
0.3
0.2
0.1
0.0
HCO3
CL
SO4
May
June
July
Aug
Sept
Oct
Nov
Dec


Perfect - 1990
Perfect - 1991
meq/l
0.5
0.4
0.3
0.2
0.1
0.0
HCO3
CL
SO4
May
June
July
Aug
Sept
Oct
Nov
Dec


Jib - 1990
Jib - 1991
meq/l
0.5
0.4
0.3
0.2
0.1
0.0
HCO3
CL
SO4
May
June
July
Aug
Sept
Oct
Nov
Dec


Stump - 1990
Stump - 1991
meq/l
0.5
0.4
0.3
0.2
0.1
0.0
HCO3
CL
SO4
May
June
July
Aug
Sept
Oct
Nov
Dec


Silica (mg/l)
Beaver
Harlow
Menchon
Round
0
2
4
6
8
10
May
June
July
Aug
Sept
Oct
Nov
Dec
CONTROL SITES
1990
1991


Oscar
Perfect
Jib
Stump
Silica (mg/l)
0
2
4
6
8
10
May
June
July
Aug
Sept
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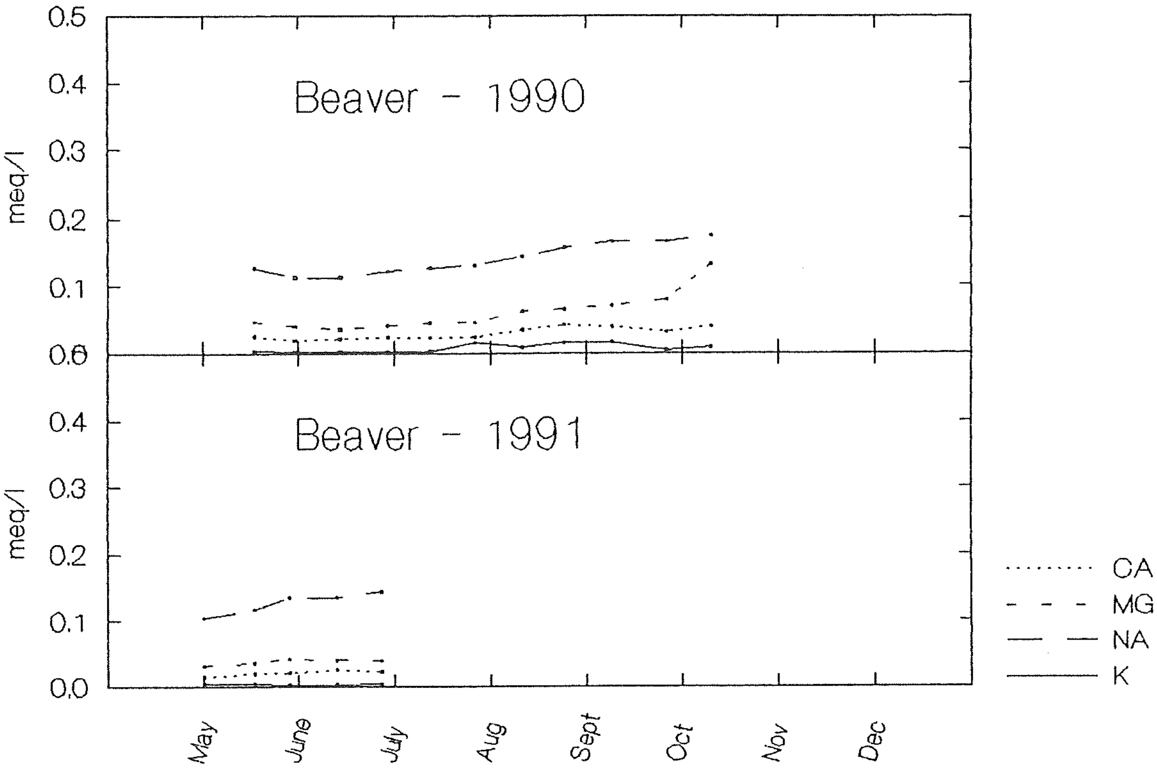
Nov
Dec
FERTILIZED SITES
1990
1991


Beaver - 1990
Beaver - 1991
meq/l
0.5
0.4
0.3
0.2
0.1
0.0
May
June
July
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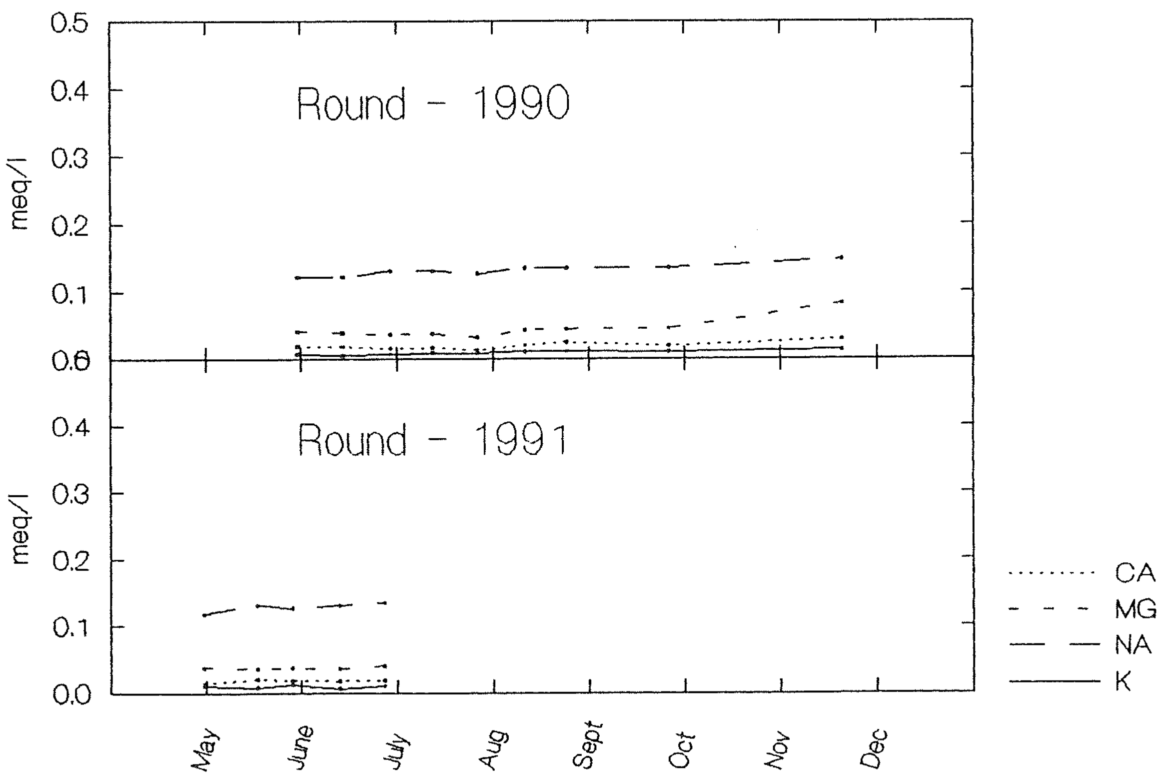
Nov
Dec
CA
MG
NA
K


Round - 1990
Round - 1991
meq/l
0.5
0.4
0.3
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0.1
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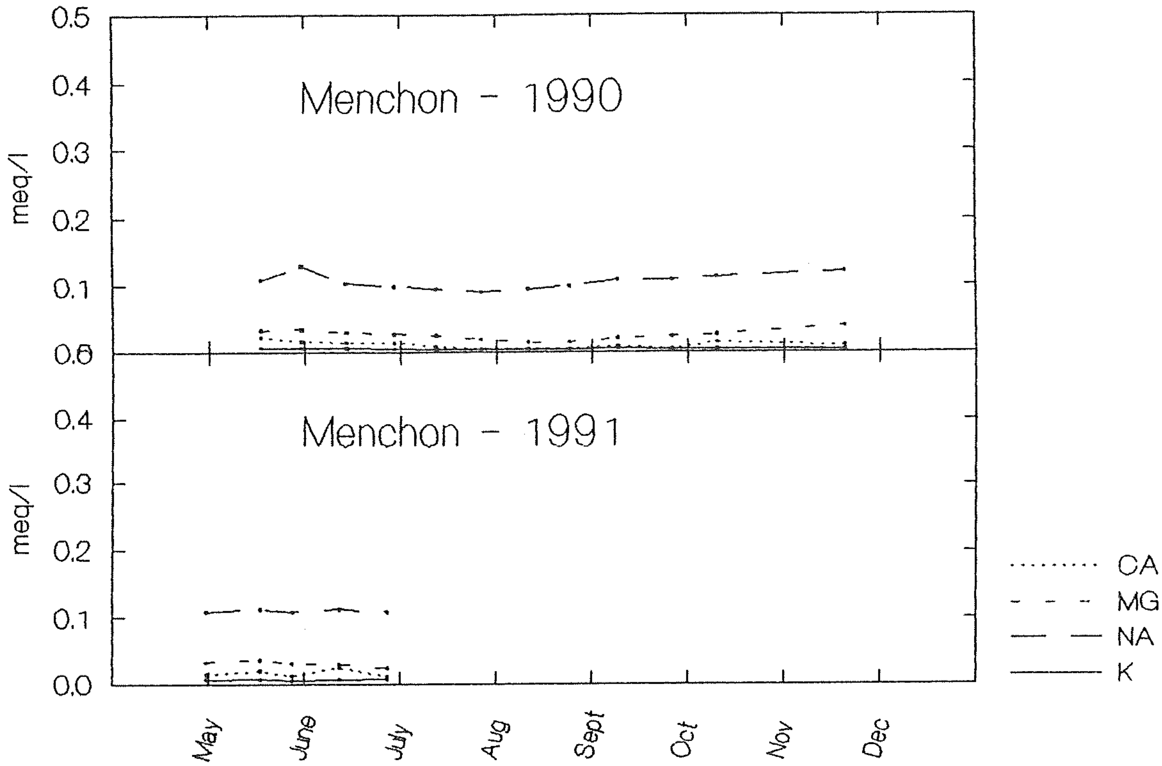
May
June
July
Aug
Sept
Oct
Nov
Dec
CA
MG
NA
K


Menchon - 1990
Menchon - 1991
meq/l
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0.2
0.1
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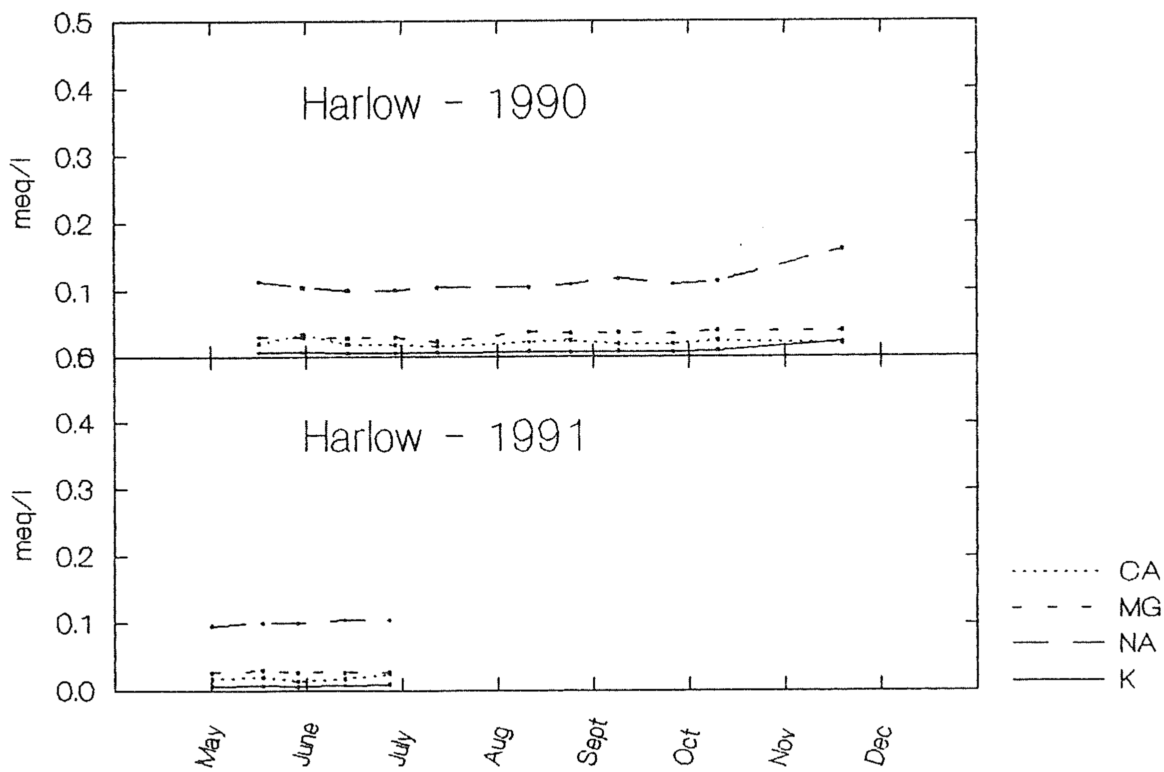
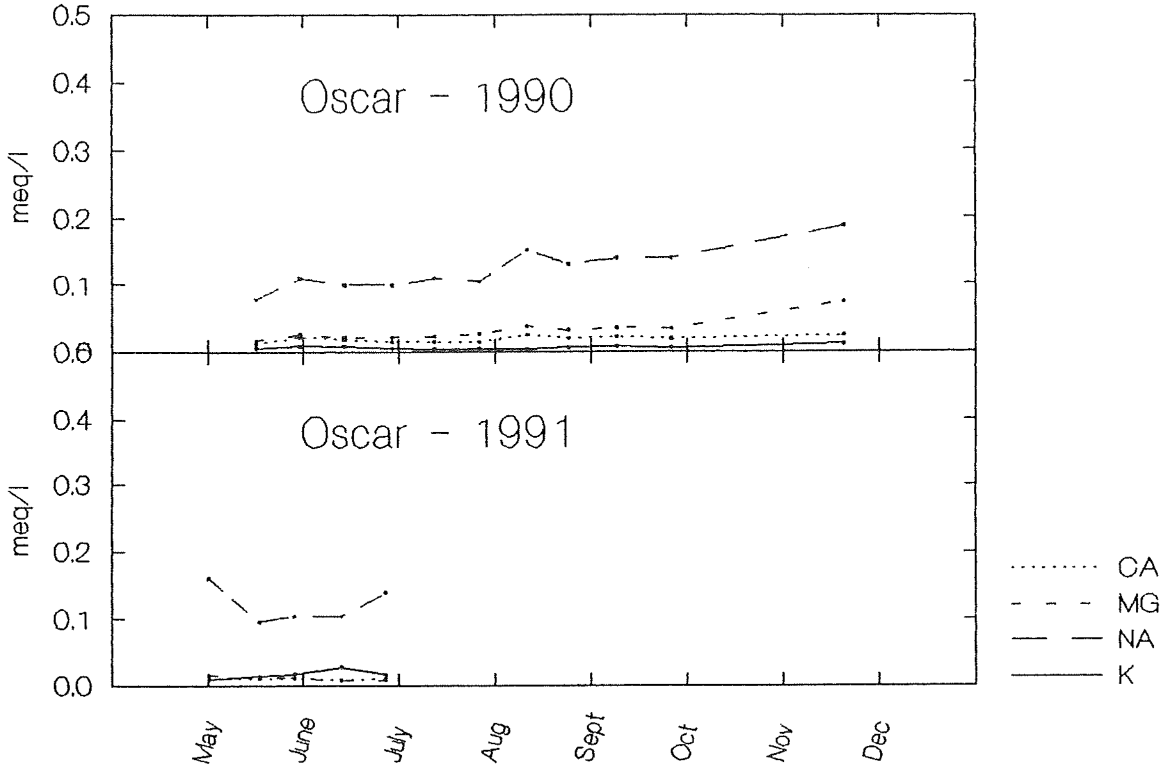
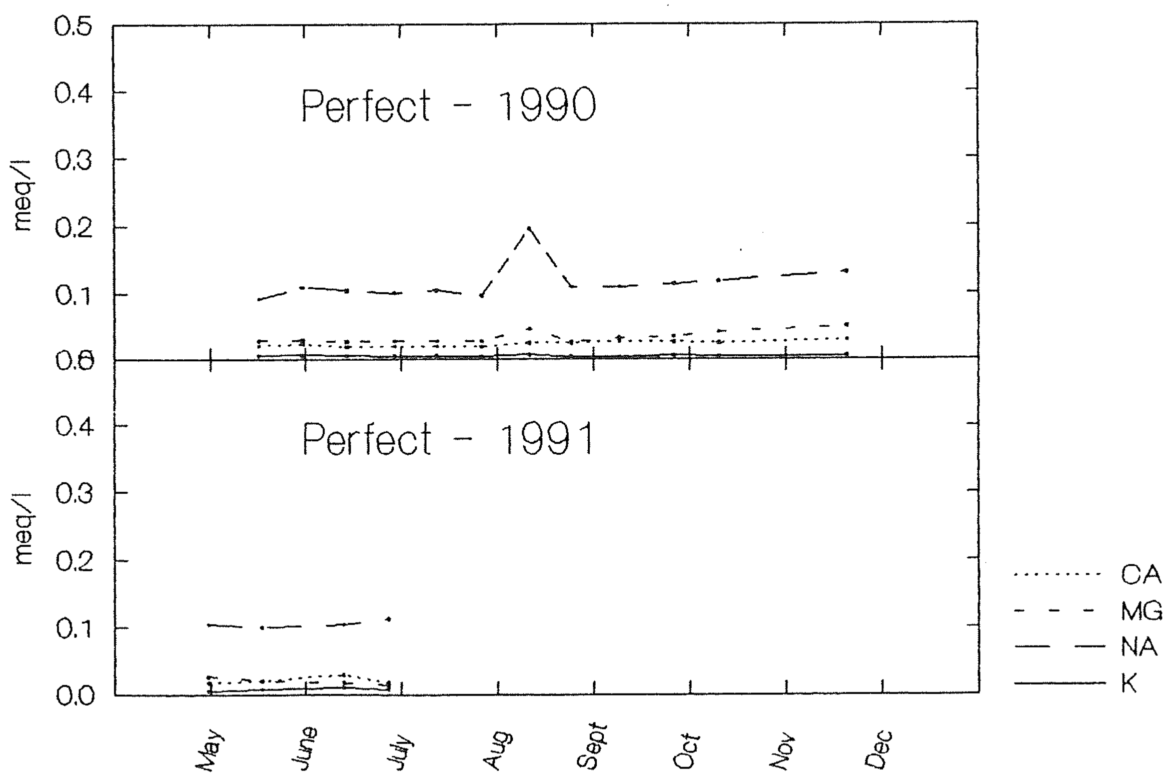
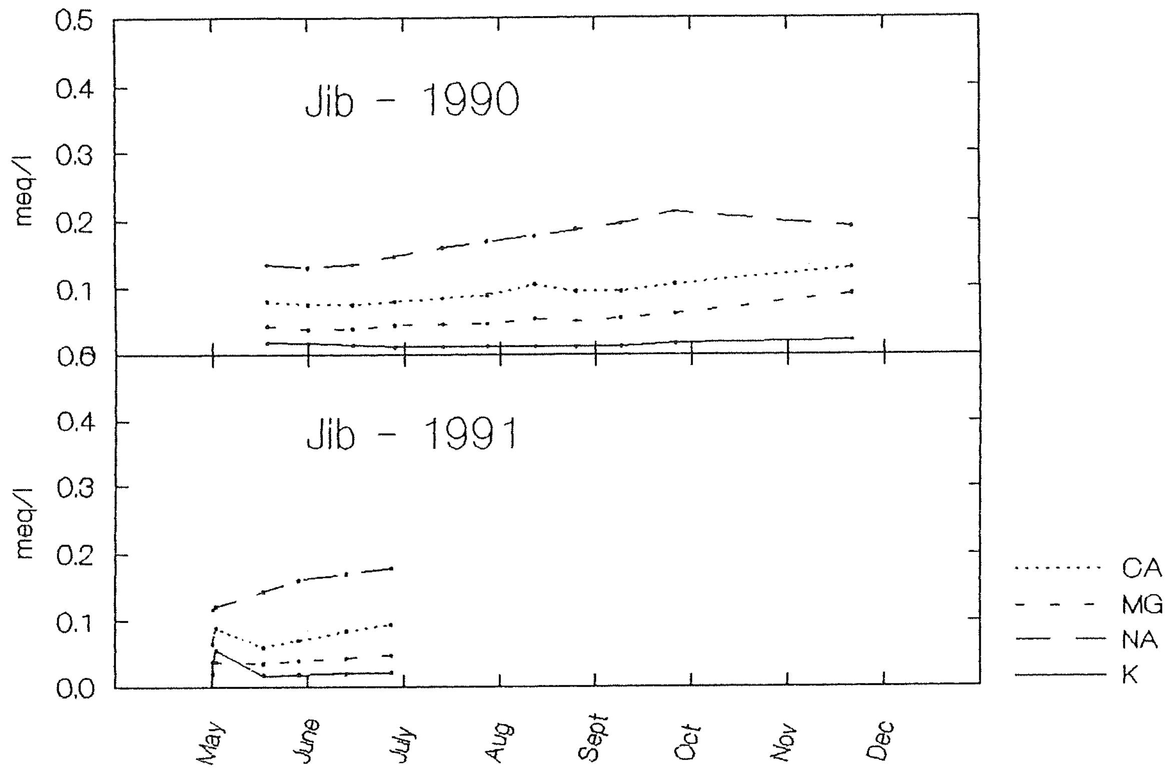
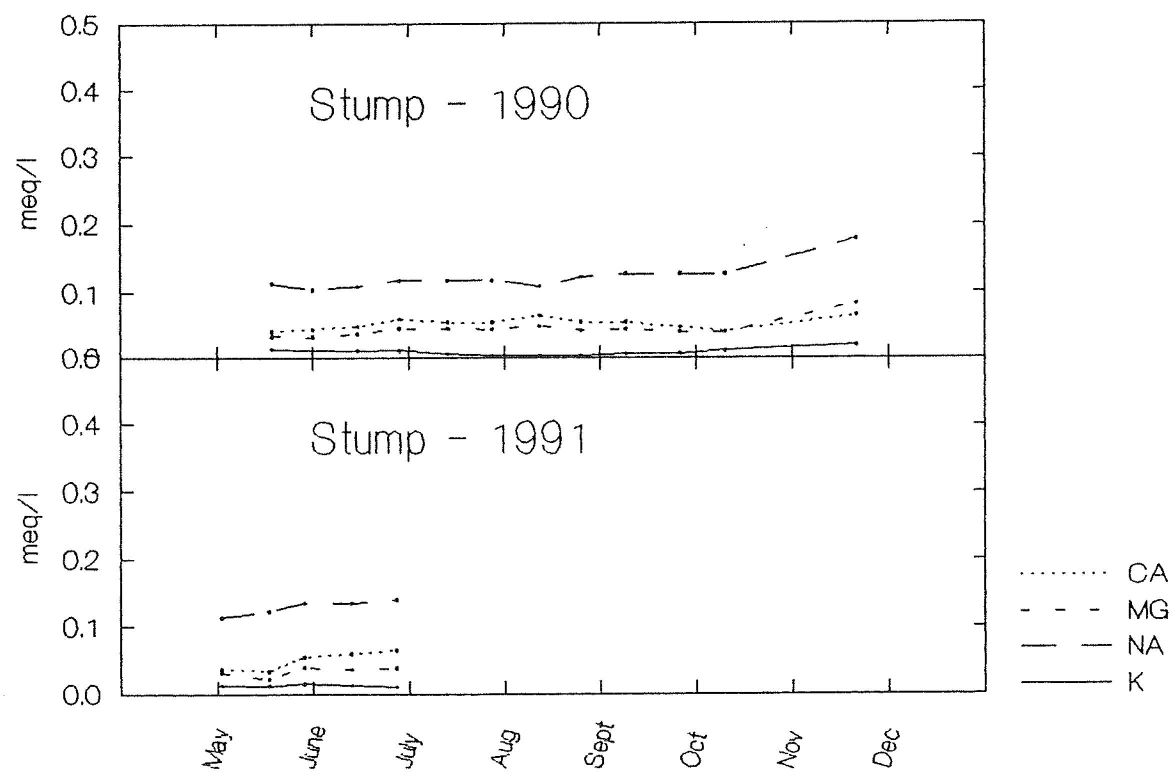
CA
MG
NA
K
May
June
July
Aug
Sept
Oct
Nov
Dec

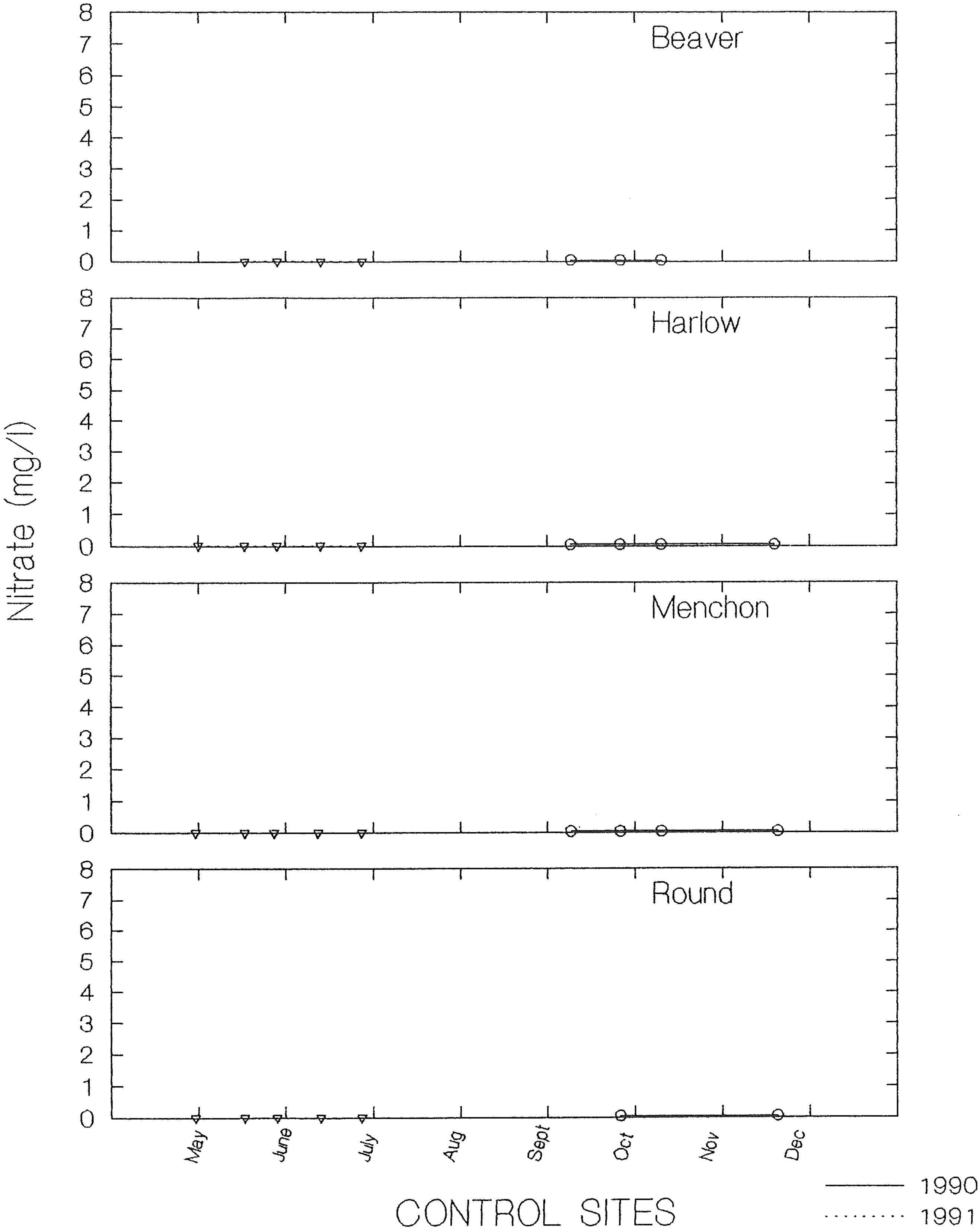

Harlow - 1990
Harlow - 1991
meq/l
0.5
0.4
0.3
0.2
0.1
0.0
CA
MG
NA
K
May
June
July
Aug
Sept
Oct
Nov
Dec


Oscar - 1990
Oscar - 1991
meq/l
0.5
0.4
0.3
0.2
0.1
0.0
CA
MG
NA
K
May
June
July
Aug
Sept
Oct
Nov
Dec

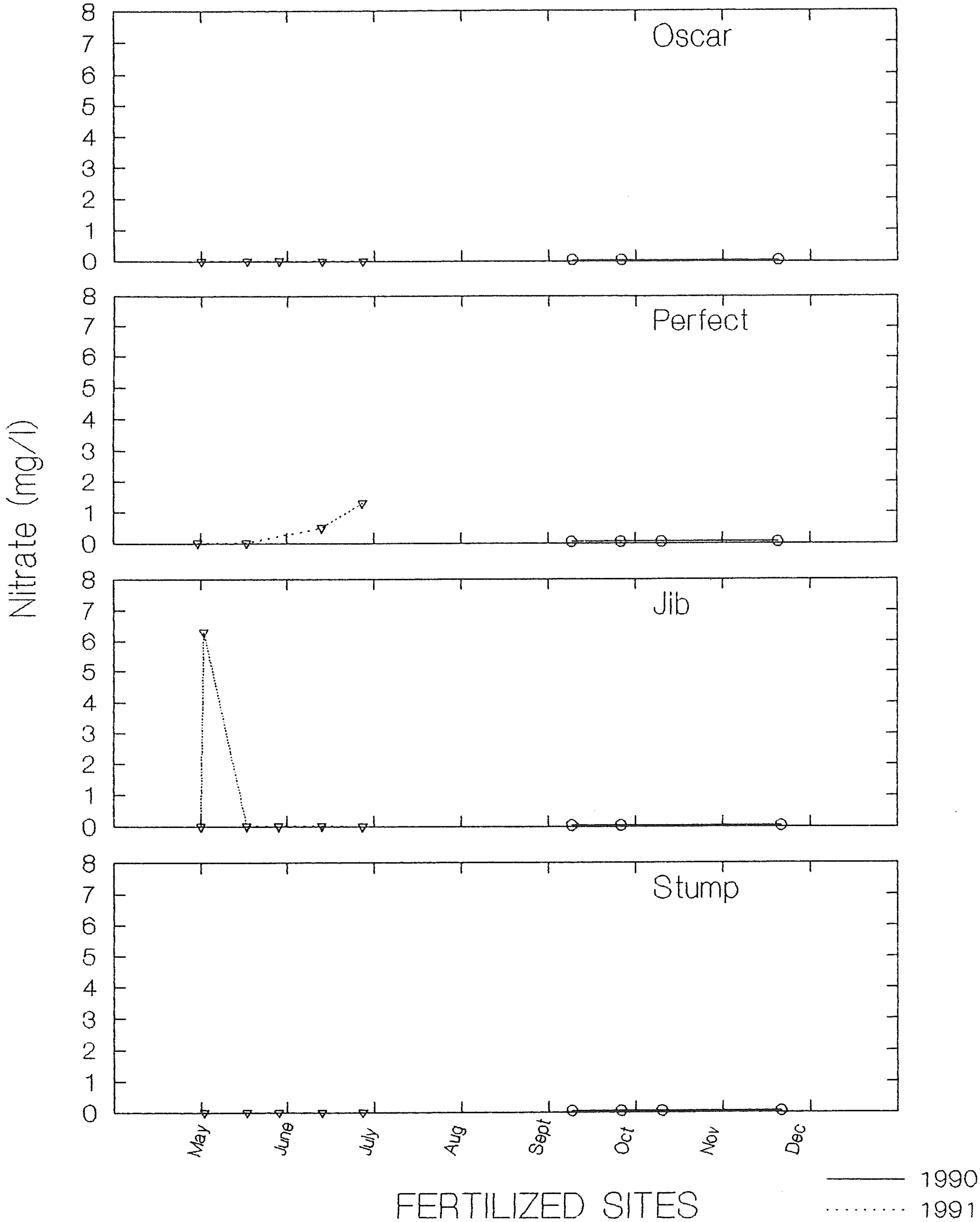

Perfect - 1990
Perfect - 1991
meq/l
0.5
0.4
0.3
0.2
0.1
0.0
CA
MG
NA
K
May
June
July
Aug
Sept
Oct
Nov
Dec


Jib - 1990
Jib - 1991
meq/l
0.5
0.4
0.3
0.2
0.1
0.0
May
June
July
Aug
Sept
Oct
Nov
Dec
CA
MG
NA
K


Stump - 1990
Stump - 1991
meq/l
0.5
0.4
0.3
0.2
0.1
0.0
May
June
July
Aug
Sept
Oct
Nov
Dec
CA
MG
NA
K



CONTROL SITES



Oscar
Perfect
Jib
Stump
Nitrate (mg/l)
0
1
2
3
4
5
6
7
8
May
June
July
Aug
Sept
Oct
Nov
Dec
FERTILIZED SITES
1990
1991