ACADIA CENTRE FOR ESTUARINE RESEARCH

# AN ANALYSIS OF DATA ON MUSSEL PERFORMANCE

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For

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## ABSTRACT

As part of a programme to determine the sampling regime most appropriate for obtaining representative samples from a cultured blue mussel (*Mytilus edulis*) population, the Fish Health Unit of the Atlantic Veterinary College of the University of Prince Edward Island carried out an extensive field sampling programme at two mussel grow-out sites in Prince Edward Island. The data collected on morphological characteristics, growth rates, and related parameters was examined statistically to determine the nature and extent of variation between sites and among and within individual blocks at each site.

The results indicate that despite the potential for variation as a result of differences in environmental conditions and management procedures, there was little variation between or within blocks at each site. This suggests that, for the time period over which this study was carried out, mussels performed equally well both among and within blocks, and that sampling programmes need not be overly concerned with insuring that samples be taken over a widely distributed area. However, during years of unusually low food quantity or quality, or under conditions of high stocking densities, spatial variations resulting from competition for food resources may be more significant.

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## I. INTRODUCTION

The following report presents the results of a study carried out by the Acadia Centre for Estuarine Research of Acadia University under contract from the Fish Health Unit of the Atlantic Veterinary College of the University of Prince Edward Island. The general objective of the study was to provide a statistical analysis of an extensive data base on performance of the cultivated blue mussel, *Mytilus edulis*, collected at two distinct sites in Prince Edward Island. Specific objectives of the study were to:

(1) determine if significant differences exist between mussel performance at each site;

(2) determine the nature and extent of differences in mussel performance among individual blocks at each site;

(3) determine the nature and extent of differences in mussel performance within individual mussel blocks at each site; and

(4) use the information obtained to make recommendations as to the most appropriate methodology for obtaining a representative sample of a cultured mussel population.

The report is presented in three parts. The first deals with a description of the data base collected and tabulated by the Atlantic Veterinary College. The second part presents the results of the statistical data analysis and the third part summarizes the findings and makes recommendations with regard to sampling protocols.

# II. CHARACTERISTICS OF THE DATA SET

## 1. Introduction

The data set tabulated by the Atlantic Veterinary College was developed from an extensive field sampling programme conducted at two mussel grow-out sites. One site, consisting of four distinct mussel blocks, is located in the Murray River estuary at a lease held by W. Sommers. The other, consisting of seven distinct mussel blocks, is located in the Boughton River estuary at a lease held by R. Dockendorf.

A total of 882 samples, each consisting of five mussels, were collected (632 at the Murray River site and 250 at the Boughton River site). The majority of samples consisted of five individual mussels and in total, over 4400 individual mussels were sampled. The location of each sample collected was recorded as to site, block number, line number, position along the line and level. Line number and position along the line served to locate samples in two directions horizontally within a block, and level corresponded to the vertical depth of the sample. Three levels were sampled corresponding to depths of zero, two and four meters.

A variety of statistical procedures were used to analyze the data set. These included Pearson correlation analysis, cluster analysis, linear and non-linear regression analysis, analysis of variance (ANOVA) and analysis of covariance (ANCOVA). When using ANOVA procedures site and block were considered discrete variables and treated as categories. ANCOVA was used primarily to evaluate differences in the variation of parameters over time using Julian Day as the covariate. In the case of level, which represents depth and is in reality a continuous variable, samples were collected at three discrete depths which allowed it to be treated as either a categorical variable in ANOVA or as continuous variable and covariate in ANCOVA. For ANOVA analyses pairwise mean difference and comparison probability matrices (based on Bonferroni probability levels) are presented to facilitate interpretation of results.

## 2. Sampling Times and Locations

Sampling at the Murray River site began on 12 June 1987 and continued, at approximately weekly intervals, until 4 November 1987. It was then resumed for a shorter period between 30 May and 15 June during 1988. At the Boughton River site, sampling initially began on 17 July 1987 and continued at irregular intervals until 20 October 1987. During 1988 the Boughton River site was sampled between 31 May and 9 June. Figure II.2.1 presents a frequency distribution of the number of samples taken at each sampling time at each site. During 1987 the number of samples taken at each date was relatively uniform until early October when sampling increased. During 1988 sampling occurred over a much shorter time period and accounted for about one-third of the total samples taken at each site.

During 1987 samples were collected randomly at each block. To evaluate the long-term changes in mussel performance more precisely, samples collected during the spring of 1988

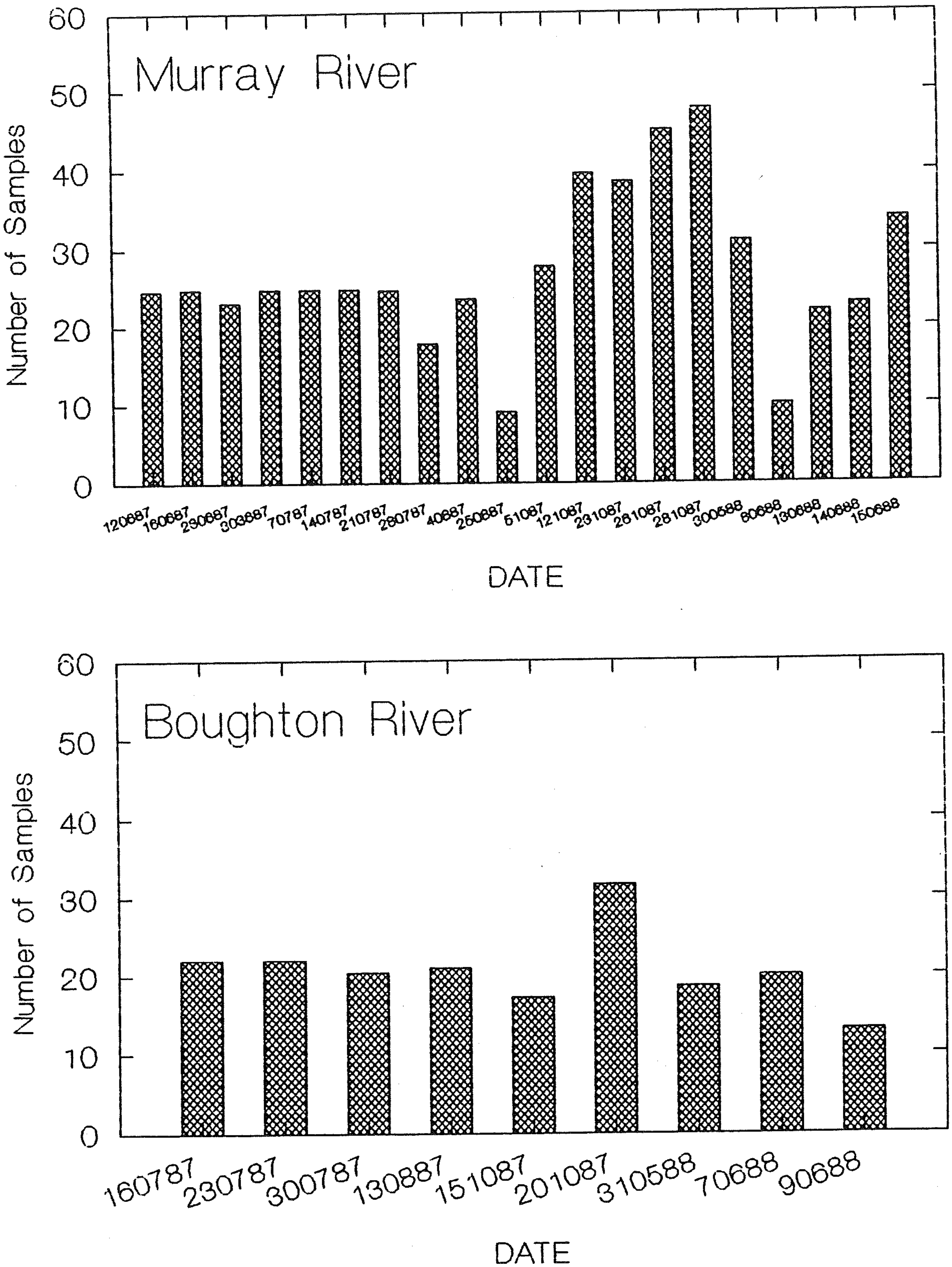



Figure II.2.1. Number of samples taken on each sampling date at each site.

were taken at the same specific locations within each block as those collected during 1987. However, because some mussel lines had been harvested prior to the 1988 sampling period, a larger number of mussels was collected during the 1987 sampling season.

Figure II.2.2 presents the distribution of samples among the individual blocks at each site. Sampling at the Murray River site was concentrated at Blocks I and II, a result of the much larger size of these blocks compared to the remaining two. At the Boughton River site, although all blocks were of about equal size, Block IV was sampled more frequently and Block VII less frequently than the remaining blocks.

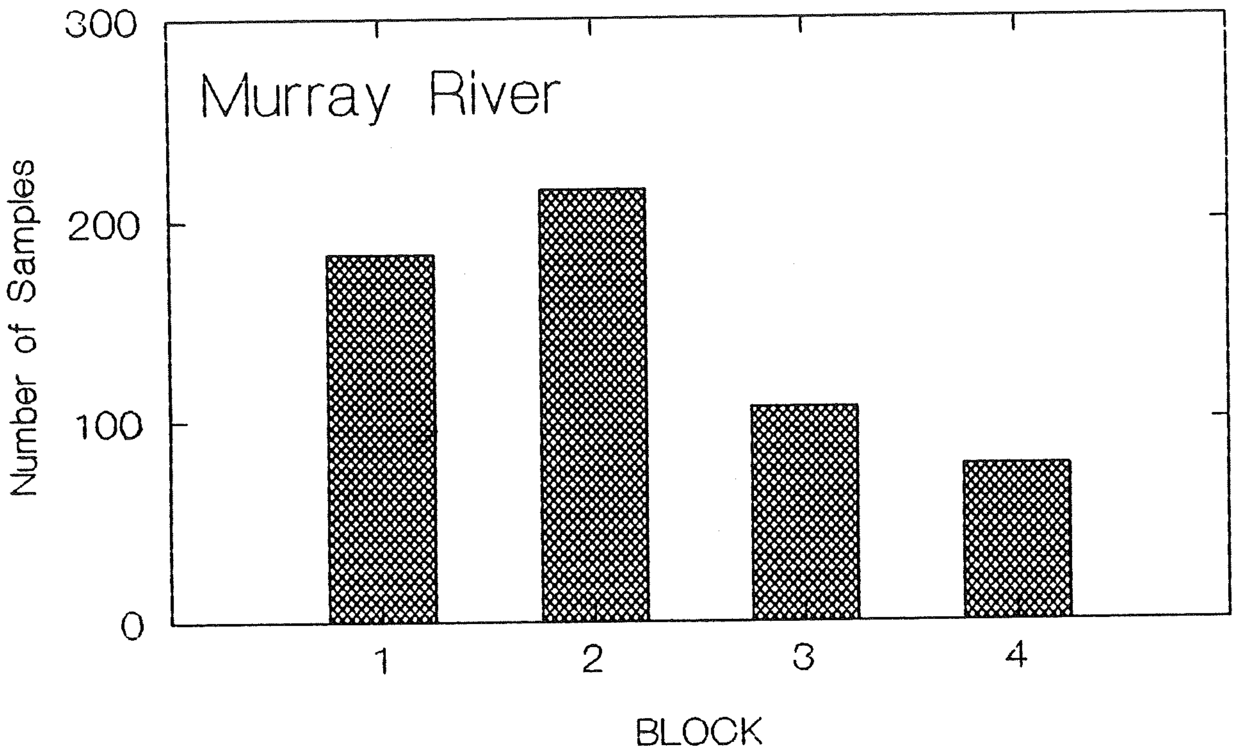
The distribution of samples among blocks at each sampling date is illustrated in Figure II.2.3. At the Murray River site the number of samples taken at each block was consistent until early October when sampling was concentrated at Block I and, toward the end of October, at Block II. Block I had been harvested prior to the 1988 sampling season and all samples during 1988 were taken from Blocks II, III and IV. Sampling at the Boughton River site exhibited the same trend except that the two October samplings included all blocks. During 1988 sampling occurred at all blocks although the intensity of sampling at each block varied.

### 3. Variables Measured

Table II.3.1 lists the variables measured at each site and the parameters measured on each mussel sample. Although some information was collected on environmental conditions, most of the data base consists of standard morphometric parameters commonly used to characterize the allometry of mussels. Additional variables, associated with growth rates and condition indices, were calculated from these parameters. Two indices of condition, both relating shell weight to meat weight, were calculated. One was based on steamed meat weight and was expressed as a percentage calculated as the ratio of the steamed meat weight to the weight of the sum of steamed meat weight and steamed shell weight. The second was based on the dry meat weight and was calculated in the same manner except that dry meat weight was used in place of steamed meat weight.

Also included in the data base were measurements of mussel density at each sampling location, and an estimate of the number dead in each density sample. From these measurements the proportion dead was calculated. These indices can be interpreted as being a measure of either mortality or drop-off. A decrease in density could be a result of either process, and an increase in the proportion of a sample dead should be a direct index of mortality.

Not all parameters were measured on all samples. Salinity and temperature measurements were made only for short periods during the spring of each year and allometric variables related to dry weights were determined for less than half of the samples collected. Figures II.3.1 and II.3.2 summarize the number of observations made on each variable at each site.



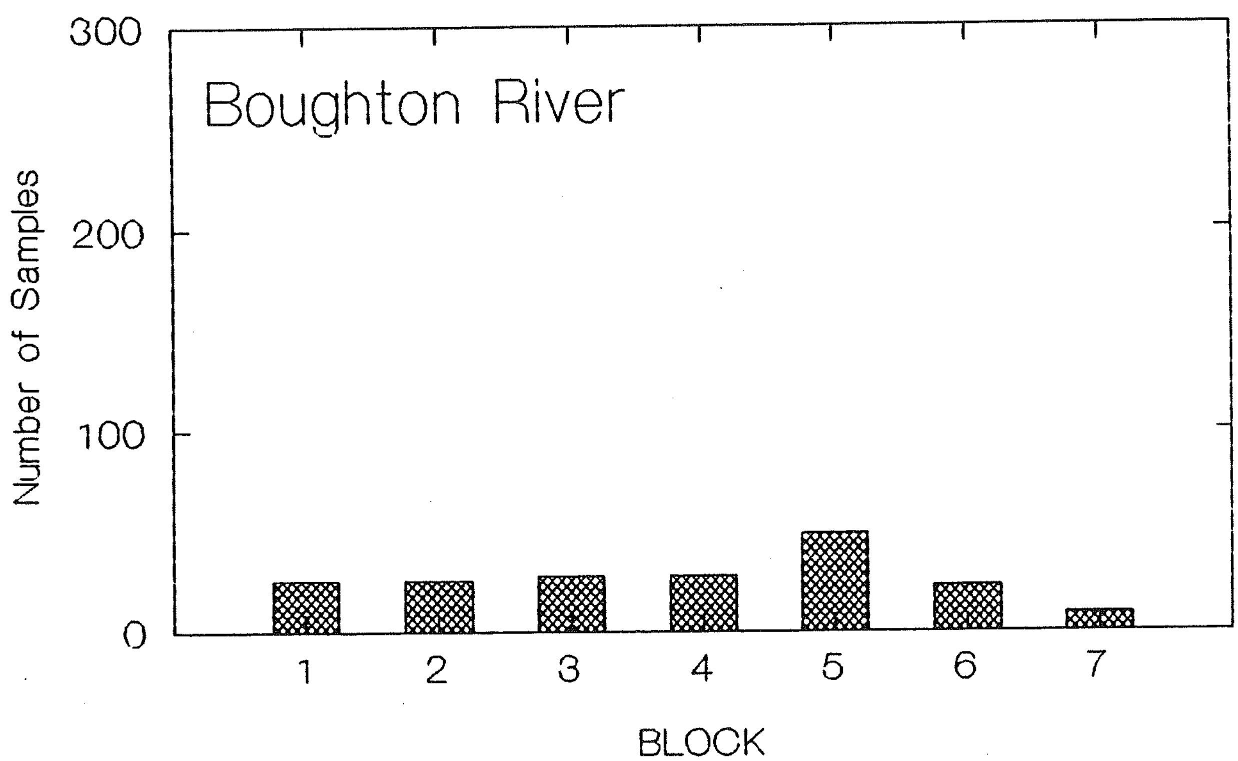




Figure II.2.2. Distribution of samples among the individual blocks at each site.

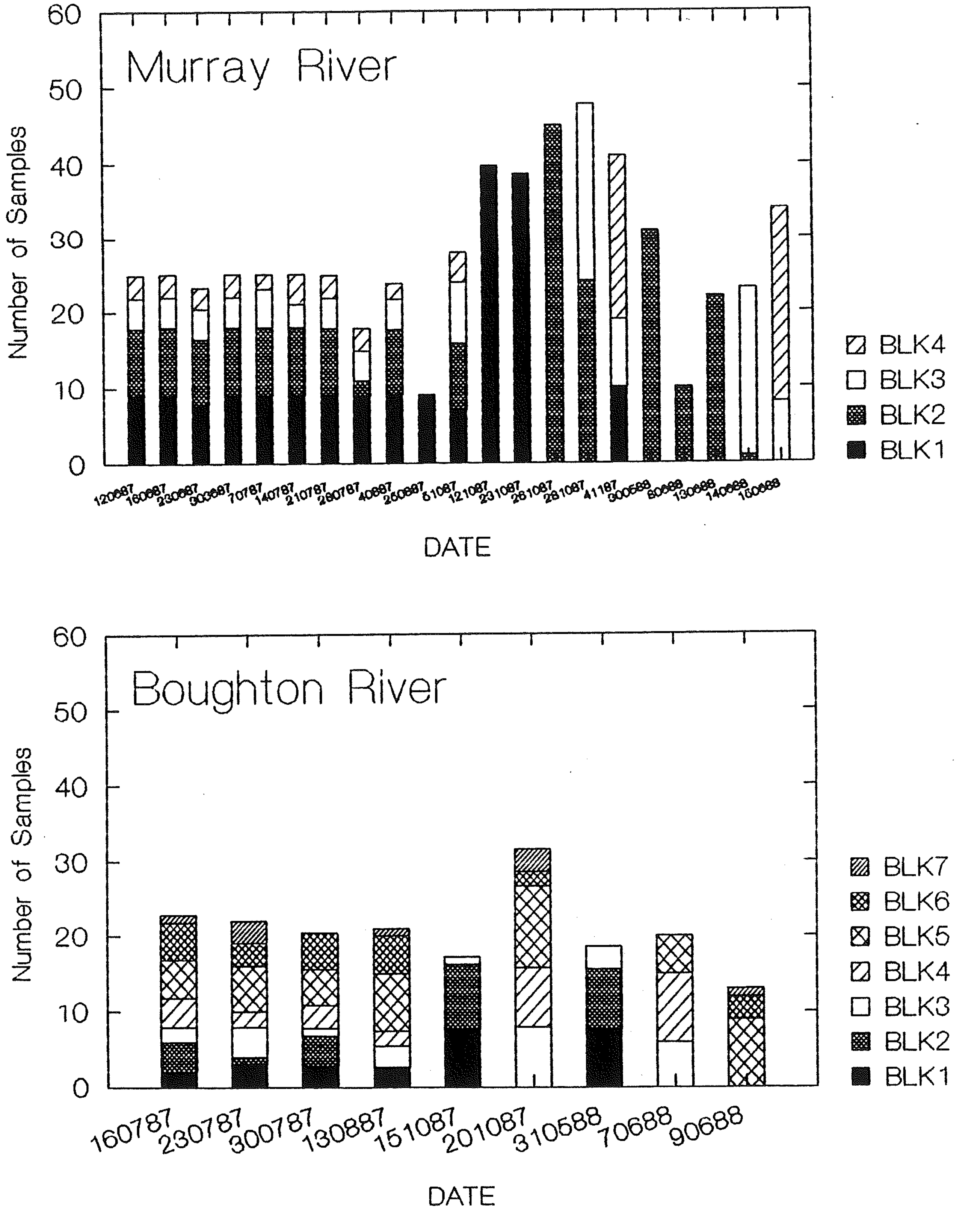



Figure II.2.3. Distribution of samples among blocks at each sampling date.

Table II.3.1 Variables measured at each site.

| | Units |
|---|---|
| Environmental Variables: | |
| Temperature (TEMP) | C |
| Salinity (SALINITY) | ppt |
| Allometric Variables: | |
| Length (LENGTH) | cm |
| Width (WIDTH) | cm |
| Steamed Shell Weight (STSHWT) | gms |
| Dryshell Weight (DRYSHWT) | gms |
| Wet Weight (WETWT) | gms |
| Steamed Meat Weight (STMWT) | gms |
| Dry Meat Weight (DRYMWT) | gms |
| Biological Variables: | |
| Density (DENSITY) | number |
| Number Dead (NDEAD) | number |
| Calculated Variables: | |
| Steamed Meat Condition Index (STCI) | % |
| Dry Meat Condition Index (DRYCI) | % |
| Proportion Dead (PDEAD) | - |

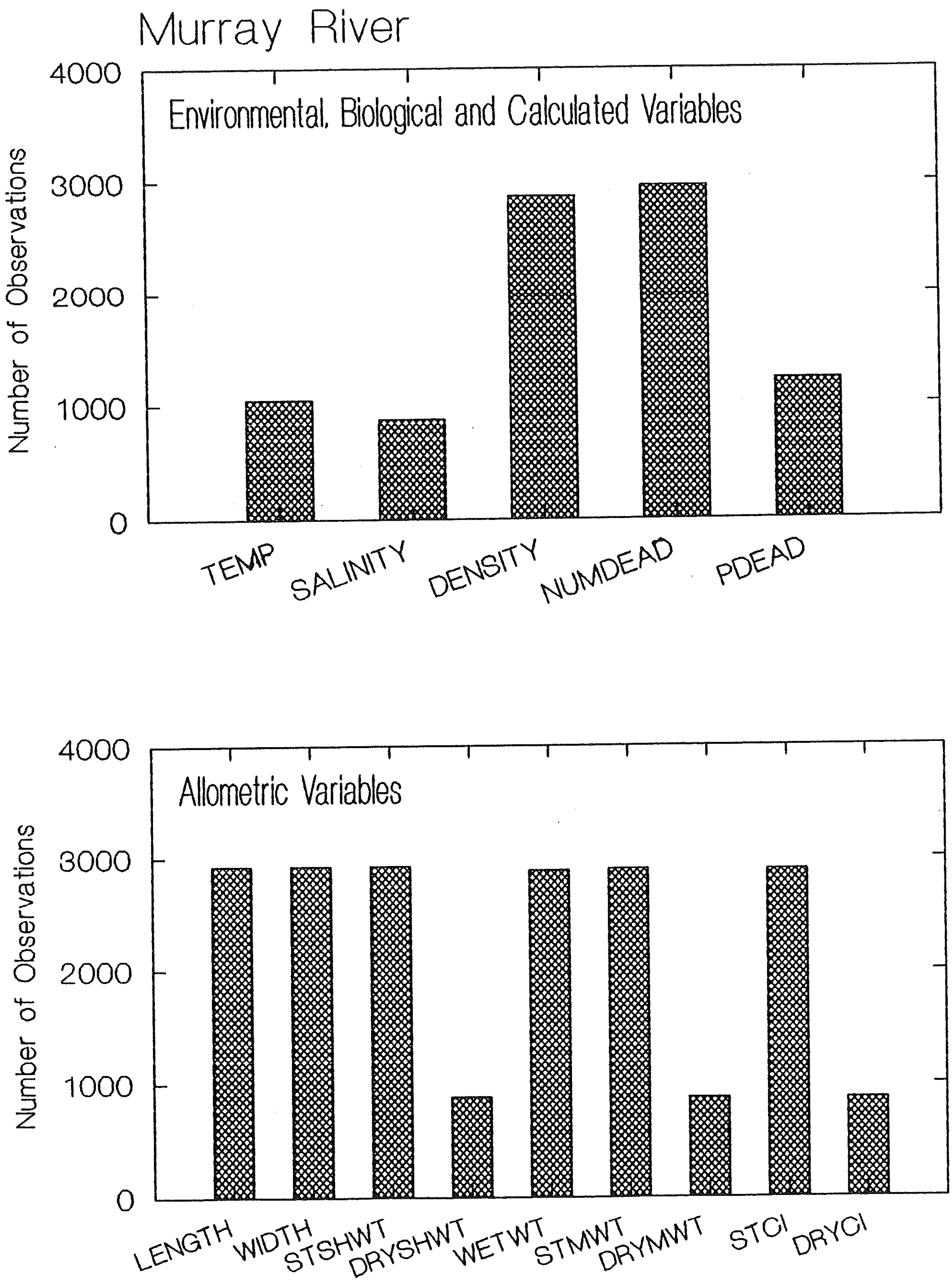



Figure II.3.1. Number of individual observations on each variable at the Murray River site.

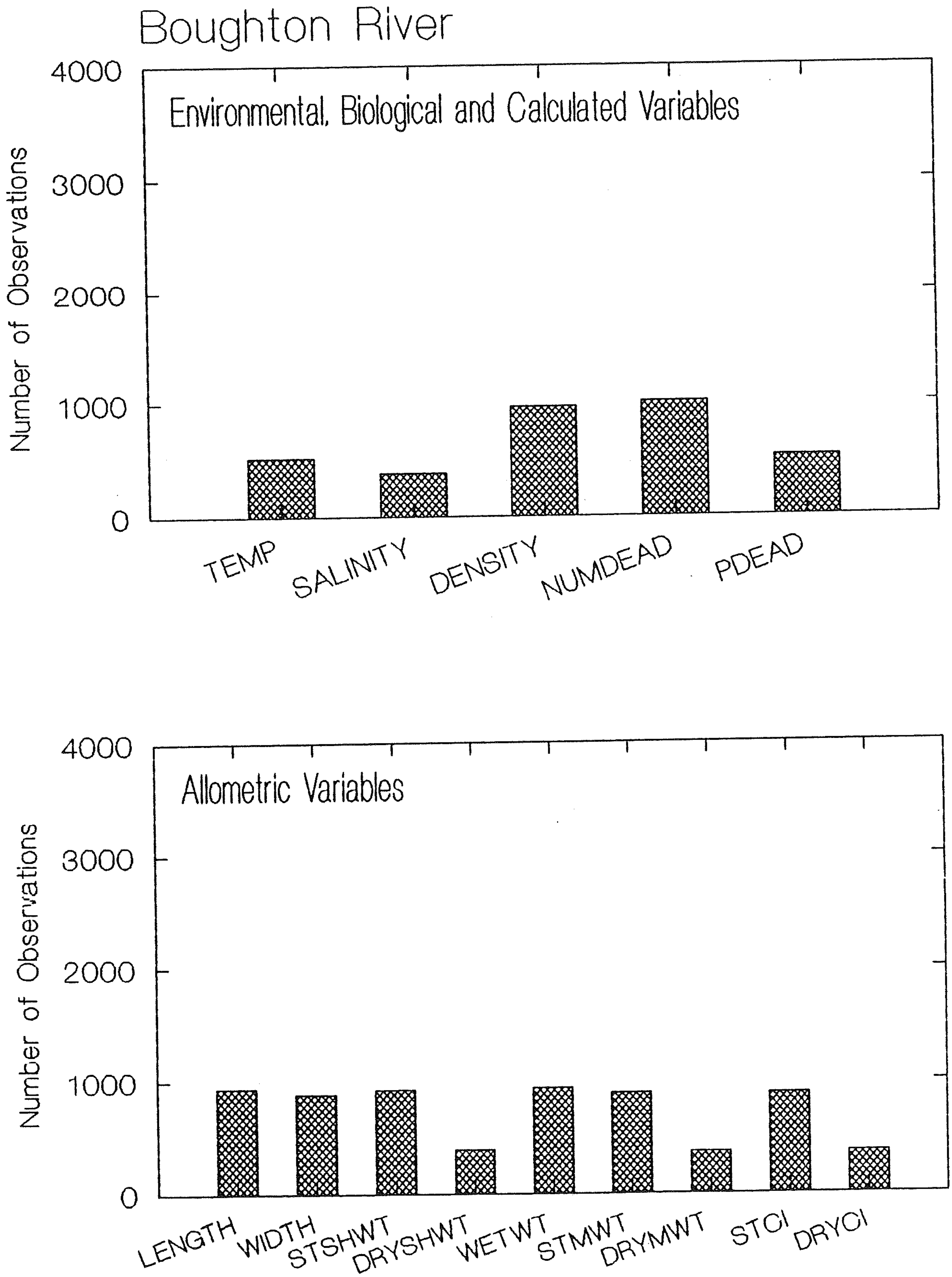



Figure II.3.2. Number of individual observations on each variable at the Boughton River site.

# III. ANALYSIS OF THE DATA BASE

## 1. Relationships Between Variables

Figure III.1.1 illustrates, based on a nearest neighbor cluster analysis, the degree of correlation between variables. Figures III.1.2 and III.1.3 present matrices of scatterplots of the allometric variables using the data on each individual site, and Tables III.1.1 and III.1.2 present the corresponding Pearson correlation coefficients.

With the exception of the two condition indices, the allometric variables are highly correlated ($r>0.8$) with each other. The lowest correlations are between pairs of variables relating shell size to meat size and is a result of two factors; (1) the rate of change of shell size differs from the rate of change of meat size and; (2) shell size always changes positively with time while meat size may either increase or decrease depending on environmental conditions (e.g., temperature and food availability or quality). This also explains why condition indices are poorly correlated with allometric variables.

Examination of the scatterplots indicates that many of the relationships between variables are non-linear. For the same reasons mentioned above, this is especially true of relationships between shell size and meat size. Figure III.1.4 presents non-linear regressions of steamed meat weight on shell length for each site. The non-linear model used is of the form $y = a(x)^b$, a model commonly used to describe non-linear allometric relationships. Table III.1.3 presents additional non-linear regressions between shell length and other variables related to meat weight. In all cases, the non-linear correlations are significantly greater than the corresponding linear correlations.

Also evident from the scatterplots is that the relationship between shell length and shell weight is non-linear. Figure III.1.5 presents non-linear regressions of steamed shell weight on shell length for each site.

## 2. Comparisons Between Sites and Blocks

Table III.2.1 presents basic statistics on each variable for each site (a more detailed statistical summary is presented in Appendix A) and Table III.2.2 presents the same on selected variables for each block at each site. In the following discussion, comparisons dealing with allometric variables are limited to shell length, steamed meat weight and steamed condition indices. These particular variables were chosen partly because they are highly correlated with other allometric variables which allows the trends they exhibit to be generalized to other allometric variables, but mainly because they represent the variables that best describe mussel quality and are therefore of most concern to mussel growers.

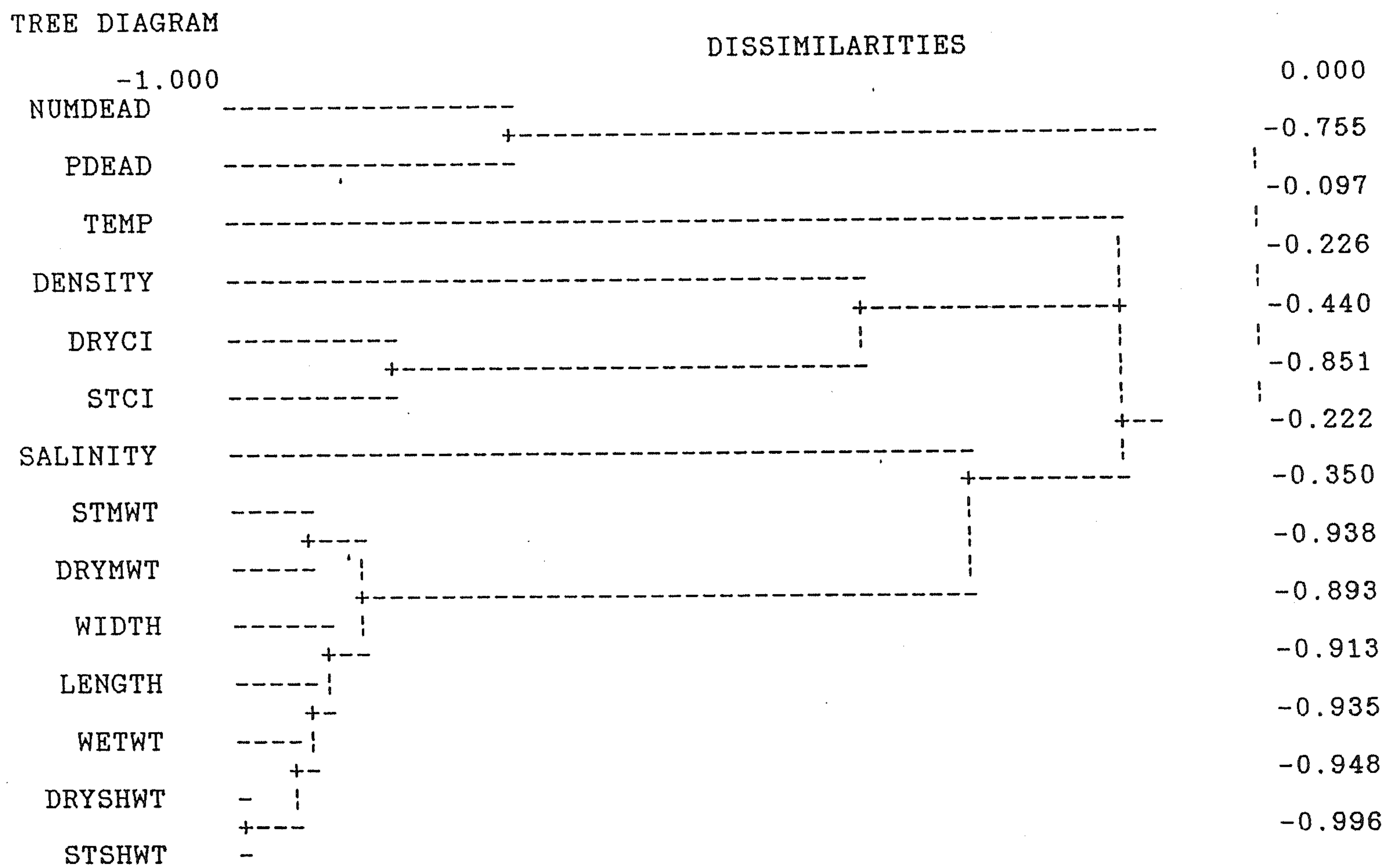



Figure III.1.1. Results of nearest neighbor cluster analysis illustrating the degree of correlation between variables.

Murray River

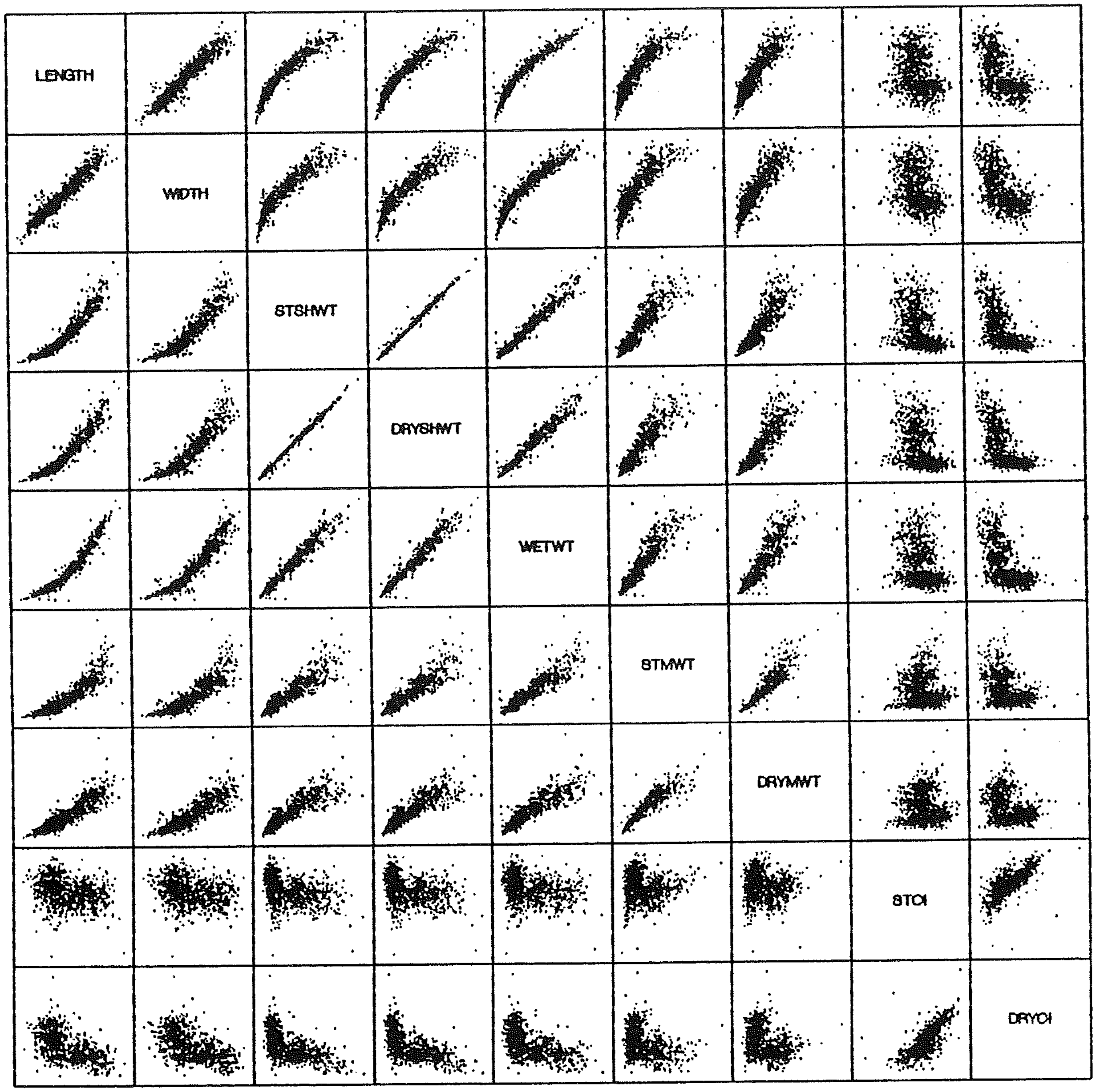



Figure III.1.2. Matrice of scatterplots of allometric variables for the Murray River site.

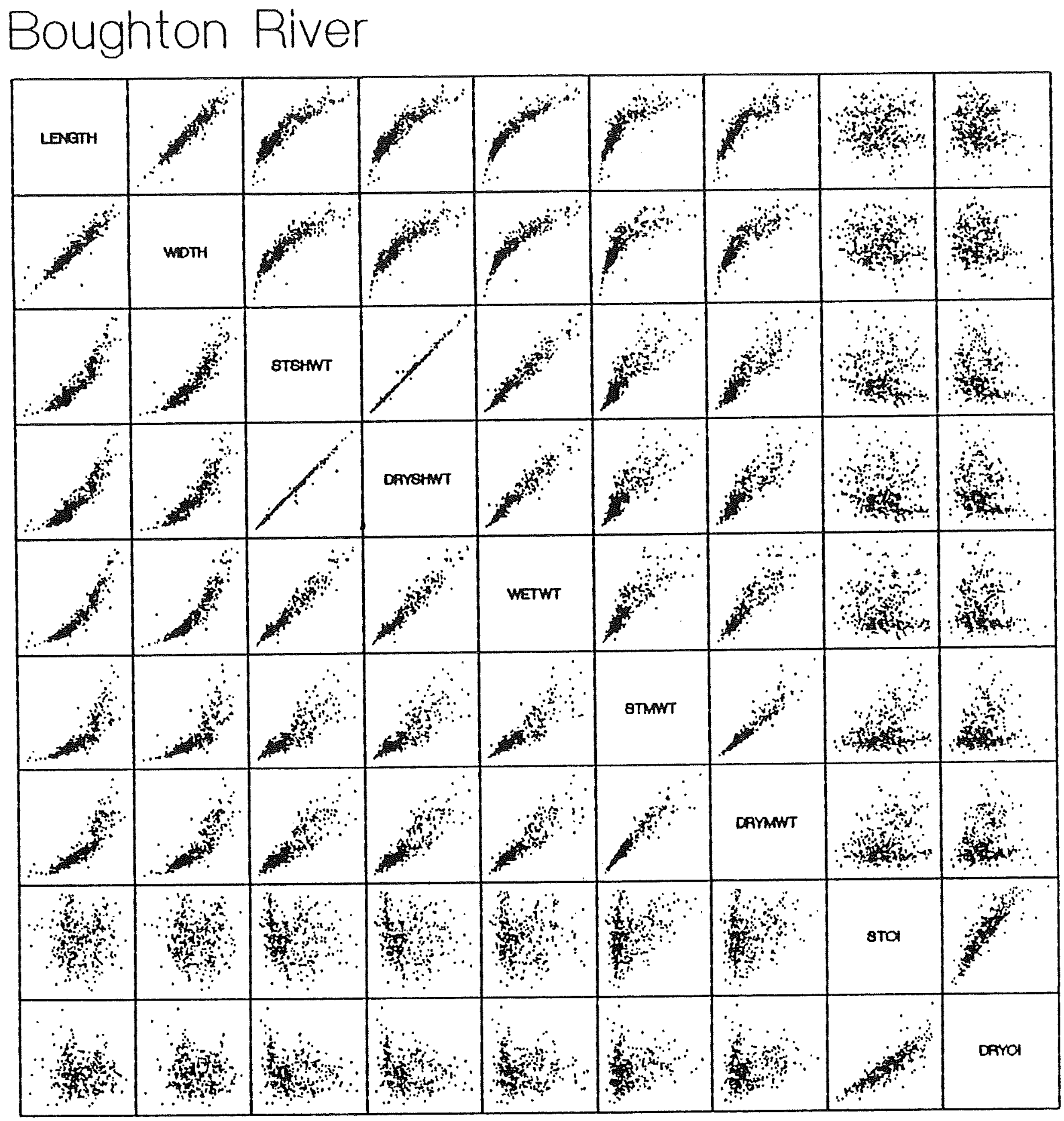



Figure III.1.3. Matrice of scatterplots of allometric variables for the Boughton River site.

Table III.1.1. Pearson correlation coefficients on allometric variables for the Murray River site.

| | LENGTH | WIDTH | STSHWT | DRYSHWT | WETWT | STMWT | DRYMWT | STCI | DRYCI |
|---|---|---|---|---|---|---|---|---|---|
| LENGTH | 1.000 | | | | | | | | |
| WIDTH | 0.899 | 1.000 | | | | | | | |
| STSHWT | 0.909 | 0.850 | 1.000 | | | | | | |
| DRYSHWT | 0.932 | 0.883 | 0.994 | 1.000 | | | | | |
| WETWT | 0.940 | 0.890 | 0.928 | 0.953 | 1.000 | | | | |
| STMWT | 0.851 | 0.799 | 0.868 | 0.897 | 0.875 | 1.000 | | | |
| DRYMWT | 0.868 | 0.844 | 0.889 | 0.890 | 0.888 | 0.953 | 1.000 | | |
| STCI | -0.043 | -0.033 | -0.156 | -0.252 | -0.020 | 0.305 | 0.085 | 1.000 | |
| DRYCI | -0.413 | -0.359 | -0.467 | -0.477 | -0.403 | -0.161 | -0.073 | 0.793 | 1.000 |

MATRIX OF PROBABILITIES

| | LENGTH | WIDTH | STSHWT | DRYSHWT | WETWT | STMWT | DRYMWT | STCI | DRYCI |
|---|---|---|---|---|---|---|---|---|---|
| LENGTH | 0.000 | | | | | | | | |
| WIDTH | 0.000 | 0.000 | | | | | | | |
| STSHWT | 0.000 | 0.000 | 0.000 | | | | | | |
| DRYSHWT | 0.000 | 0.000 | 0.000 | 0.000 | | | | | |
| WETWT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | |
| STMWT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | |
| DRYMWT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | |
| STCI | 0.042 | 0.113 | 0.000 | 0.000 | 0.332 | 0.000 | 0.028 | 0.000 | |
| DRYCI | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.059 | 0.000 | 0.000 |

FREQUENCY TABLE

| | LENGTH | WIDTH | STSHWT | DRYSHWT | WETWT | STMWT | DRYMWT | STCI | DRYCI |
|---|---|---|---|---|---|---|---|---|---|
| LENGTH | 2330 | | | | | | | | |
| WIDTH | 2329 | 2333 | | | | | | | |
| STSHWT | 2321 | 2324 | 2330 | | | | | | |
| DRYSHWT | 679 | 682 | 682 | 682 | | | | | |
| WETWT | 2293 | 2295 | 2288 | 666 | 2297 | | | | |
| STMWT | 2300 | 2303 | 2305 | 673 | 2268 | 2310 | | | |
| DRYMWT | 671 | 674 | 674 | 673 | 658 | 674 | 674 | | |
| STCI | 2296 | 2299 | 2305 | 673 | 2263 | 2305 | 674 | 2305 | |
| DRYCI | 670 | 673 | 673 | 673 | 657 | 673 | 673 | 673 | 673 |

Table III.1.2. Pearson correlation coefficients on allometric variables for the Boughton River site.

| | LENGTH | WIDTH | STSHWT | DRYSHWT | WETWT | STMWT | DRYMWT | STCI | DRYCI |
|---|---|---|---|---|---|---|---|---|---|
| LENGTH | 1.000 | | | | | | | | |
| WIDTH | 0.879 | 1.000 | | | | | | | |
| STSHWT | 0.879 | 0.824 | 1.000 | | | | | | |
| DRYSHWT | 0.902 | 0.896 | 0.998 | 1.000 | | | | | |
| WETWT | 0.892 | 0.827 | 0.924 | 0.940 | 1.000 | | | | |
| STMWT | 0.812 | 0.752 | 0.769 | 0.823 | 0.822 | 1.000 | | | |
| DRYMWT | 0.888 | 0.852 | 0.877 | 0.873 | 0.896 | 0.946 | 1.000 | | |
| STCI | 0.058 | 0.011 | -0.182 | -0.380 | -0.010 | 0.422 | 0.009 | 1.000 | |
| DRYCI | -0.174 | -0.229 | -0.365 | -0.371 | -0.240 | 0.032 | 0.038 | 0.885 | 1.000 |

MATRIX OF PROBABILITIES

| | LENGTH | WIDTH | STSHWT | DRYSHWT | WETWT | STMWT | DRYMWT | STCI | DRYCI |
|---|---|---|---|---|---|---|---|---|---|
| LENGTH | 0.000 | | | | | | | | |
| WIDTH | 0.000 | 0.000 | | | | | | | |
| STSHWT | 0.000 | 0.000 | 0.000 | | | | | | |
| DRYSHWT | 0.000 | 0.000 | 0.000 | 0.000 | | | | | |
| WETWT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | |
| STMWT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | |
| DRYMWT | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | |
| STCI | 0.145 | 0.789 | 0.000 | 0.000 | 0.798 | 0.000 | 0.874 | 0.000 | |
| DRYCI | 0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.574 | 0.508 | 0.000 | 0.000 |

FREQUENCY TABLE

| | LENGTH | WIDTH | STSHWT | DRYSHWT | WETWT | STMWT | DRYMWT | STCI | DRYCI |
|---|---|---|---|---|---|---|---|---|---|
| LENGTH | 680 | | | | | | | | |
| WIDTH | 628 | 629 | | | | | | | |
| STSHWT | 672 | 623 | 673 | | | | | | |
| DRYSHWT | 329 | 328 | 329 | 329 | | | | | |
| WETWT | 678 | 627 | 672 | 328 | 679 | | | | |
| STMWT | 634 | 584 | 634 | 308 | 633 | 634 | | | |
| DRYMWT | 309 | 308 | 309 | 307 | 308 | 308 | 309 | | |
| STCI | 634 | 584 | 634 | 308 | 633 | 634 | 308 | 634 | |
| DRYCI | 306 | 305 | 306 | 306 | 305 | 306 | 306 | 306 | 306 |

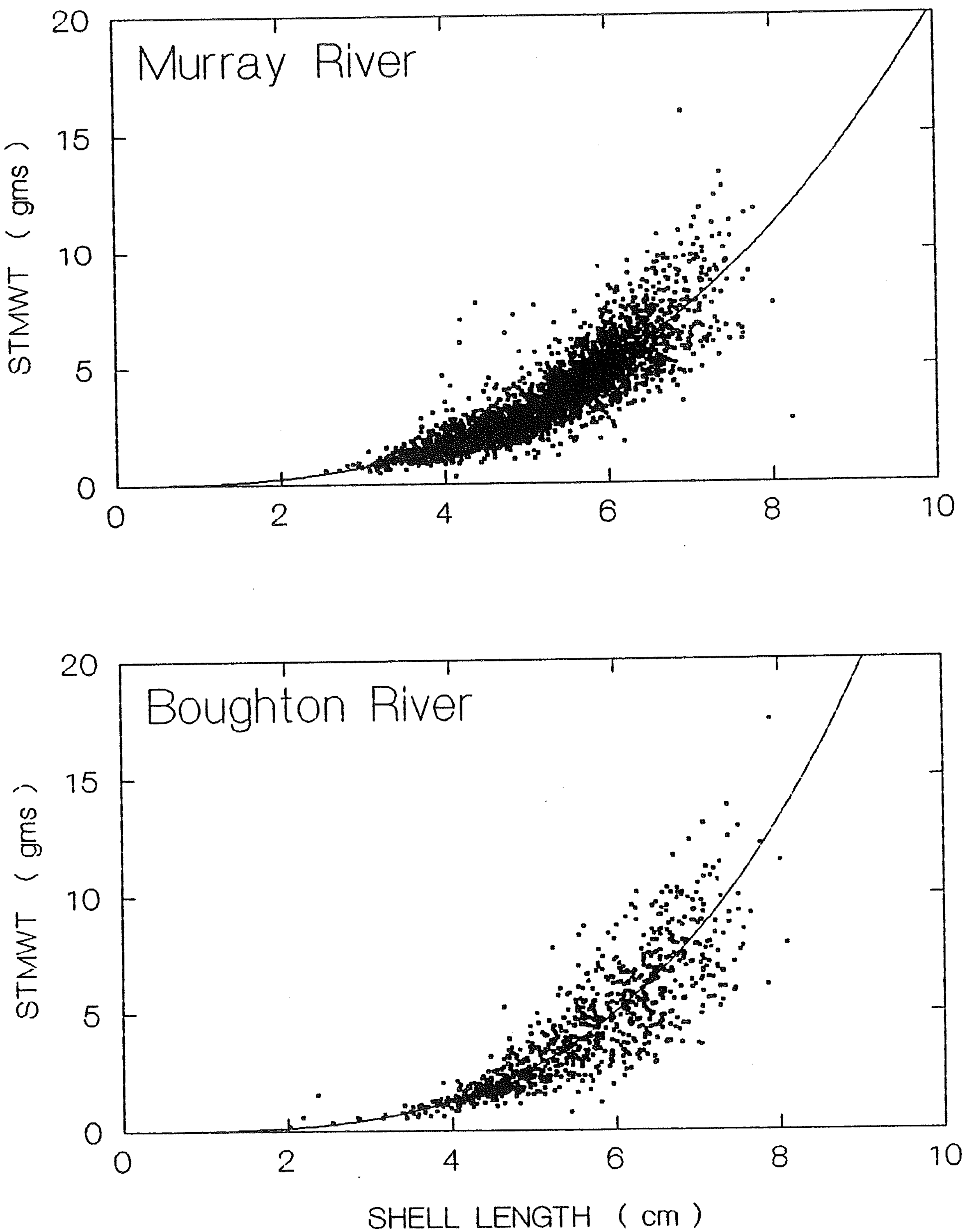



Figure III.1.4. Non-linear relationship between shell length and steamed meat weight (see Table III.1.3 for regression statistics).

Table III.1.3 Non-linear regressions of weight related variables on shell length.* The model used is $y = ax^b$.

| Dependent Variable | Site | N | a (95% CI) | b (95% CI) | $r^2$ |
|---|---|---|---|---|---|
| STSHWT | Both | 780 | 0.020 (0.017-0.024) | 3.185 (3.082-3.288) | .856 |
| | Boughton | 194 | 0.036 (0.024-0.049) | 2.958 (2.771-3.146) | .865 |
| | Murray | 586 | 0.025 (0.022-0.028) | 3.016 (2.949-3.084) | .942 |
| DRYSHWT | Both | 254 | 0.024 (0.017-0.030) | 3.091 (2.941-3.240) | .903 |
| | Boughton | 79 | 0.025 (0.015-0.036) | 3.145 (2.923-3.367) | .933 |
| | Murray | 175 | 0.023 (0.019-0.027) | 3.046 (2.955-3.136) | .973 |
| WETWT | Both | 774 | 0.065 (0.059-0.070) | 3.162 (3.112-3.212) | .959 |
| | Boughton | 195 | 0.058 (0.046-0.071) | 3.246 (3.132-3.359) | .949 |
| | Murray | 579 | 0.082 (0.076-0.089) | 3.017 (2.972-3.061) | .974 |
| STMWT | Both | 780 | 0.024 (0.020-0.029) | 2.979 (2.870-3.081) | .835 |
| | Boughton | 194 | 0.012 (0.006-0.018) | 3.368 (3.118-3.619) | .809 |
| | Murray | 586 | 0.035 (0.029-0.042) | 2.766 (2.665-2.866) | .858 |
| DRYMWT | Both | 254 | 0.013 (0.010-0.016) | 2.389 (2.265-2.512) | .877 |
| | Boughton | 79 | 0.003 (0.002-0.005) | 3.180 (2.901-3.460) | .899 |
| | Murray | 175 | 0.022 (0.018-0.026) | 2.104 (1.996-2.212) | .909 |

*Because of the extraordinary computing power required to compute non-linear regression coefficients, the regressions were calculated using sample means rather than individual measurements.

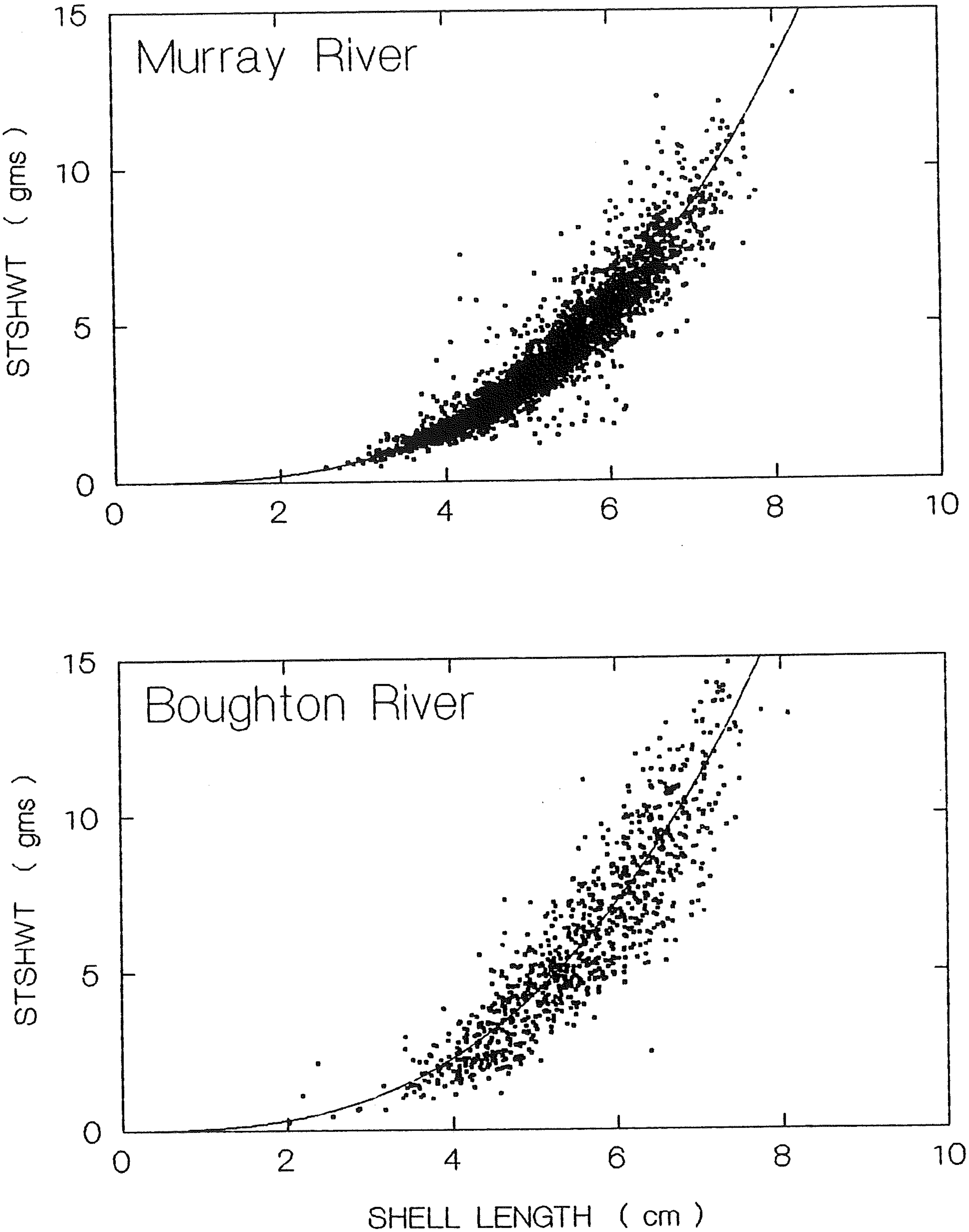



Figure III.1.5. Non-linear relationship between shell length and steamed shell weight (see Table III.1.3 for regression statistics).

Table III.2.1 Basic statistics.

| | Murray River | | | | Boughton River | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | N | Mean (SD) | Min | Max | N | Mean (SD) | Min | Max |
| TEMP | 1048 | 16.98 (3.74) | 9.00 | 21.30 | 518 | 19.21 (3.26) | 9.80 | 21.70 |
| SALINITY | 873 | 25.78 (0.66) | 24.00 | 27.00 | 383 | 25.32 (1.13) | 22.00 | 27.20 |
| DENSITY | 2872 | 10.06 (2.82) | 0.00 | 31.00 | 959 | 7.62 (3.18) | 0.00 | 16.00 |
| NUMDEAD | 2967 | 0.12 (0.58) | 0.00 | 12.00 | 1003 | 0.28 (0.64) | 0.00 | 4.00 |
| PDEAD | 2861 | 0.01 (0.07) | 0.00 | 1.00 | 935 | 0.05 (0.14) | 0.00 | 1.00 |
| LENGTH | 2920 | 5.25 (0.95) | 2.54 | 8.24 | 933 | 5.55 (1.01) | 2.02 | 9.03 |
| WIDTH | 2923 | 1.93 (0.38) | 0.09 | 4.93 | 882 | 2.06 (0.43) | 0.69 | 3.69 |
| STSHWT | 2920 | 4.04 (2.15) | 0.45 | 13.78 | 920 | 6.09 (3.16) | 0.26 | 17.05 |
| DRYSHWT | 876 | 3.56 (3.56) | 0.41 | 13.04 | 384 | 5.18 (3.23) | 0.24 | 16.25 |
| WETWT | 2886 | 13.21 (13.21) | 0.76 | 42.79 | 932 | 16.58 (9.19) | 0.77 | 70.13 |
| STMWT | 2900 | 3.71 (3.71) | 0.33 | 15.91 | 888 | 4.33 (2.71) | 0.20 | 30.05 |
| DRYMWT | 866 | 0.68 (0.68) | 0.09 | 2.77 | 364 | 0.69 (0.46) | 0.02 | 2.44 |
| STCI | 2895 | 47.78 (47.78) | 16.10 | 74.52 | 882 | 40.19 (8.06) | 11.62 | 73.51 |
| DRYCI | 865 | 17.74 (17.74) | 8.10 | 40.64 | 360 | 11.91 (3.22) | 4.95 | 25.46 |

Table III.2.2 Statistical comparison of blocks at each site.

| BLOCK | LENGTH N | LENGTH Mean (SD) | STMWT N | STMWT Mean (SD) | STCI N | STCI Mean (SD) | DENSITY N | DENSITY Mean (SD) | PDEAD N | PDEAD Mean (SD) |
|---|---|---|---|---|---|---|---|---|---|---|
| Murray River | | | | | | | | | | |
| I | 918 | 5.02 (0.79) | 907 | 3.20 (1.53) | 906 | 48.23 (5.82) | 860 | 10.75 (2.44) | 860 | 0.16 (0.08) |
| II | 1074 | 5.26 (0.97) | 1073 | 3.62 (1.97) | 1070 | 47.07 (6.42) | 1086 | 10.02 (3.19) | 1081 | 0.02 (0.08) |
| III | 534 | 5.49 (0.99) | 529 | 4.37 (2.37) | 529 | 48.21 (6.05) | 534 | 9.20 (2.67) | 530 | 0.01 (0.03) |
| IV | 389 | 5.46 (1.02) | 386 | 4.23 (2.22) | 385 | 48.10 (6.56) | 392 | 9.85 (2.30) | 390 | 0.02 (0.05) |
| Boughton River | | | | | | | | | | |
| I | 128 | 5.82 (1.15) | 125 | 4.82 (3.63) | 120 | 40.37 (7.36) | 141 | 6.77 (3.78) | 130 | 0.09 (0.21) |
| II | 128 | 5.40 (1.04) | 126 | 3.80 (2.15) | 126 | 41.45 (8.31) | 127 | 8.71 (2.33) | 126 | 0.01 (0.07) |
| III | 139 | 5.75 (0.96) | 132 | 4.80 (2.35) | 131 | 40.17 (6.00) | 145 | 7.55 (2.64) | 145 | 0.04 (0.07) |
| IV | 138 | 5.40 (1.09) | 136 | 4.69 (3.03) | 136 | 42.20 (8.48) | 135 | 7.92 (2.66) | 135 | 0.03 (0.07) |
| V | 241 | 5.46 (0.93) | 223 | 4.25 (2.60) | 223 | 40.03 (8.20) | 245 | 7.53 (3.30) | 244 | 0.06 (0.16) |
| VI | 114 | 5.61 (0.87) | 106 | 3.80 (2.16) | 106 | 35.51 (8.09) | 121 | 6.65 (2.83) | 115 | 0.09 (0.22) |
| VII | 45 | 5.29 (0.93) | 40 | 3.50 (2.11) | 40 | 42.30 (8.13) | 45 | 9.55 (4.40) | 40 | 0.05 (0.11) |

## 2.1. Environmental Conditions

Although the data set is limited with respect to measurements of water temperature and salinity, the Boughton River, when compared to the Murray, appears to be influenced more by freshwater inputs as evidenced by its higher mean temperature and greater salinity range (Table III.2.1).

## 2.2. Mussel Density and Proportion Dead

The variation in mussel density and proportion of mussels dead among sites and blocks is illustrated in Figure III.2.2.1. ANOVA results (Tables III.2.2.1 and III.2.2.2) revealed a significant difference between sites in both mussel density and proportion of mussels dead. Mussel densities at the Murray River site averaged about ten per density sample and were slightly greater than at the Boughton River site. At the latter, average density among blocks ranged between about six and nine mussels per density sample.

The proportion of mussels dead at each site showed considerably more variation than density, and is generally greater at the Boughton River site. At both sites there was little relationship between the proportion of mussels dead and mussel density suggesting that high densities were not related to high mortalities. Correlations between the proportion dead and allometric variables are generally low (<.100) indicating that mussel size is also not directly related to mortality.

Tables III.2.2.3 and III.2.2.4 present ANOVA results of block effects on density for each site. At the Murray River site there is very little variation within each block and the difference between blocks is small, but in all cases the differences are statistically significant. At the Boughton site there is much greater variability both within and between blocks but no one block is significantly different than all others and no obvious trends are evident.

The proportion of mussels dead was considerably lower at the Murray River site and, like density, varied much less than at the Boughton River site. An ANOVA (Table III.2.2.5) showed only Block III to be significantly different from other blocks. At the Boughton site the large variation among blocks obscured detection of any trends (Table III.2.2.6).

## 2.3. Mussel Allometry

Comparisons of average shell length, steamed meat weight and steamed condition index for the entire sampling period revealed that these parameters differ significantly between sites. ANOVA results are presented in Tables III.2.3.1-III.2.3.3. The differences, however, are mostly small. Mussels at the Boughton River site had slightly larger shell lengths and steamed meat weights and lower condition indices than those at the Murray River site.

The non-linear regressions presented in Table III.1.3 and discussed in Section III.1 indicate that the relationship between shell length and shell weight is different for each site. Mussels at

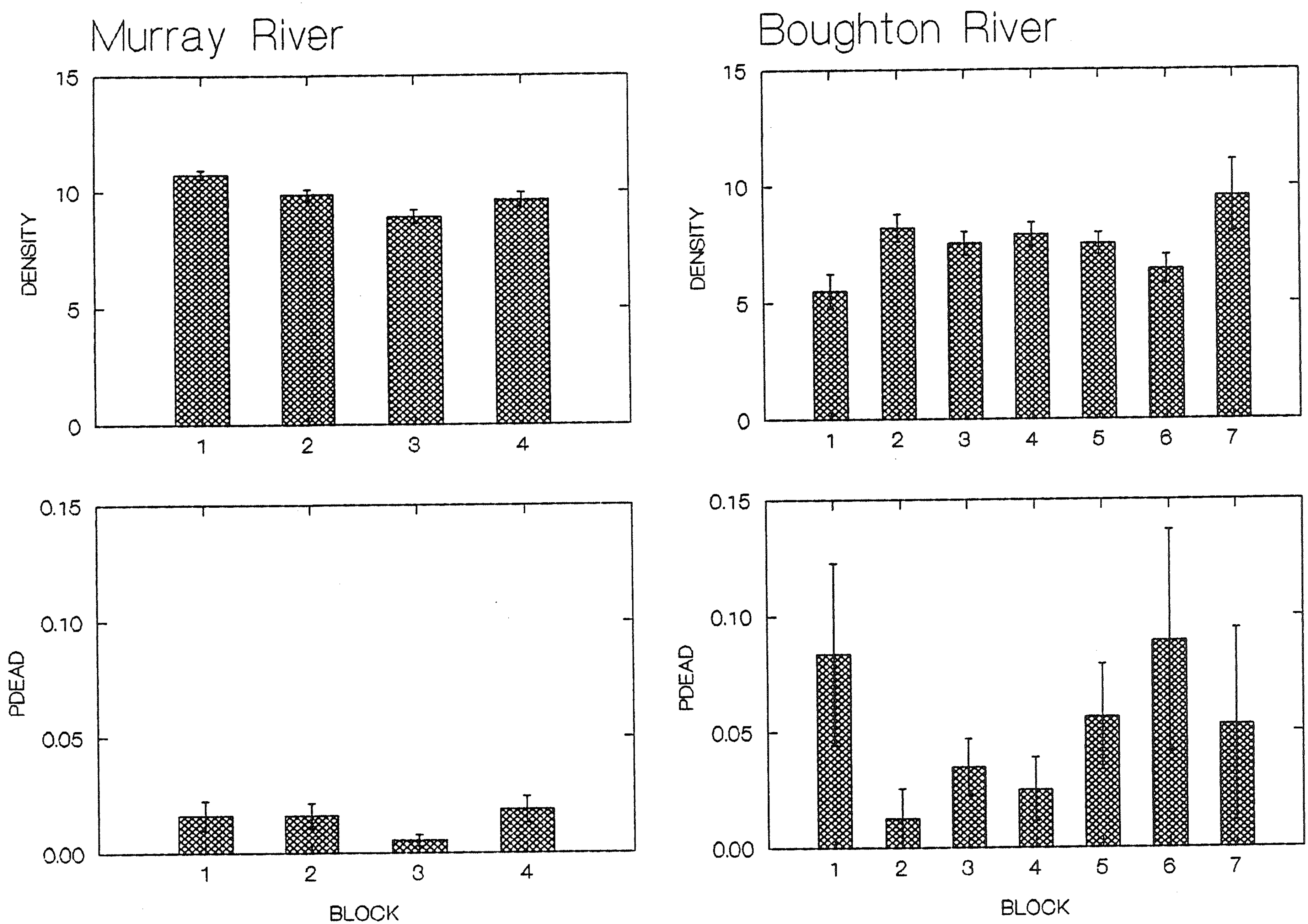



Figure III.2.2.1. Variation in mussel density and proportion of mussels dead among sites and blocks (error bars are one standard error of the mean).

**Table III.2.2.1. ANOVA OF SITE EFFECT ON DENSITY**

**DEP VAR: DENSITY** N: 3831 SQUARED MULTIPLE R: 0.117

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 4295.439 | 1 | 4295.439 | 505.524 | 0.000 |
| ERROR | 32535.036 | 3829 | 8.497 | | |

POST HOC TEST OF DENSITY

USING MODEL MSE OF 8.497 WITH 3829. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| SITE | Boughton | Murray |
|---|---|---|
| Boughton | 0.000 | |
| Murray | 2.444 | 0.000 |

BONFERRONI ADJUSTMENT.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| SITE | Boughton | Murray |
|---|---|---|
| Boughton | 1.000 | |
| Murray | 0.000 | 1.000 |

**Table III.2.2.2. ANOVA OF SITE EFFECT ON PROPORTION DEAD**

**DEP VAR: PDEAD** N: 3796 SQUARED MULTIPLE R: 0.027

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 0.960 | 1 | 0.960 | 105.019 | 0.000 |
| ERROR | 34.678 | 3794 | 0.009 | | |

POST HOC TEST OF PDEAD

USING MODEL MSE OF .009 WITH 3794. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| SITE | Boughton | Murray |
|---|---|---|
| Boughton | 0.000 | |
| Murray | -0.037 | 0.000 |

BONFERRONI ADJUSTMENT.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| SITE | Boughton | Murray |
|---|---|---|
| Boughton | 1.000 | |
| Murray | 0.000 | 1.000 |

**Table III.2.2.3. ANOVA OF BLOCK EFFECT ON DENSITY (Murray River)**

**DEP VAR: DENSITY** N: 2872 SQUARED MULTIPLE R: 0.036

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQRS | DF | MEAN-SQR | F-RATIO | P |
|---|---|---|---|---|---|
| BLOCK | 828.483 | 3 | 276.161 | 35.919 | 0.000 |
| ERROR | 22050.236 | 2868 | 7.688 | | |

POST HOC TEST OF DENSITY
USING MODEL MSE OF 7.688 WITH 2868. DF.

MATRIX OF PAIRWISE MEAN DIFFERENCES:

| BLOCK | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 0.000 | | | |
| 2 | -0.727 | 0.000 | | |
| 3 | -1.555 | -0.828 | 0.000 | |
| 4 | -0.903 | -0.176 | 0.652 | 0.000 |

BONNFRRONI ADJUSTED.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| BLOCK | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 1.000 | | | |
| 2 | 0.000 | 1.000 | | |
| 3 | 0.000 | 0.000 | 1.000 | |
| 4 | 0.000 | 1.000 | 0.002 | 1.000 |

**Table III.2.2.4. ANOVA OF BLOCK EFFECT ON DENSITY (Boughton River)**

**DEP VAR: DENSITY** N: 959 SQUARED MULTIPLE R: 0.057

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQRS | DF | MEAN-SQR | F-RATIO | P |
|---|---|---|---|---|---|
| BLOCK | 548.685 | 6 | 91.447 | 9.559 | 0.000 |
| ERROR | 9107.632 | 952 | 9.567 | | |

POST HOC TEST OF DENSITY

USING MODEL MSE OF 9.567 WITH 952. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| BLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 0.000 | | | | | | |
| 2 | 1.936 | 0.000 | | | | | |
| 3 | 0.779 | -1.157 | 0.000 | | | | |
| 4 | 1.153 | -0.783 | 0.374 | 0.000 | | | |
| 5 | 0.758 | -1.178 | -0.021 | -0.395 | 0.000 | | |
| 6 | -0.120 | -2.056 | -0.899 | -1.273 | -0.878 | 0.000 | |
| 7 | 2.783 | 0.847 | 2.004 | 1.630 | 2.025 | 2.903 | 0.000 |

BONFERRONI ADJUSTED.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| BLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1.000 | | | | | | |
| 2 | 0.000 | 1.000 | | | | | |
| 3 | 0.705 | 0.045 | 1.000 | | | | |
| 4 | 0.042 | 0.859 | 1.000 | 1.000 | | | |
| 5 | 0.435 | 0.011 | 1.000 | 1.000 | 1.000 | | |
| 6 | 1.000 | 0.000 | 0.388 | 0.022 | 0.227 | 1.000 | |
| 7 | 0.000 | 1.000 | 0.003 | 0.048 | 0.001 | 0.000 | 1.000 |

**Table III.2.2.5. ANOVA OF BLOCK EFFECT ON PROPORTION DEAD (Murray River)**

**DEP VAR: PDEAD** N: 2861 SQUARED MULTIPLE R: 0.004

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQRS | DF | MEAN-SQR | F-RATIO | P |
|---|---|---|---|---|---|
| BLOCK | 0.056 | 3 | 0.019 | 3.789 | 0.010 |
| ERROR | 14.126 | 2857 | 0.005 | | |

POST HOC TEST OF PDEAD

USING MODEL MSE OF .005 WITH 2857. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| BLOCK | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 0.000 | | | |
| 2 | 0.000 | 0.000 | | |
| 3 | -0.011 | -0.011 | 0.000 | |
| 4 | 0.003 | 0.003 | 0.013 | 0.000 |

BONFERRONI ADJUSTED.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| BLOCK | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 1.000 | | | |
| 2 | 1.000 | 1.000 | | |
| 3 | 0.037 | 0.022 | 1.000 | |
| 4 | 1.000 | 1.000 | 0.027 | 1.000 |

**Table III.2.2.6. ANOVA OF BLOCK EFFECT ON PROPORTION DEAD (Boughton River)**

**DEP VAR: PDEAD** N: 935 SQUARED MULTIPLE R: 0.033

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQRS | DF | MEAN-SQR | F-RATIO | P |
|---|---|---|---|---|---|
| BLOCK | 0.680 | 6 | 0.113 | 5.307 | 0.000 |
| ERROR | 19.816 | 928 | 0.021 | | |

POST HOC TEST OF PDEAD

USING MODEL MSE OF .021 WITH 928. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| BLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 0.000 | | | | | | |
| 2 | -0.077 | 0.000 | | | | | |
| 3 | -0.055 | 0.022 | 0.000 | | | | |
| 4 | -0.065 | 0.012 | -0.010 | 0.000 | | | |
| 5 | -0.033 | 0.043 | 0.022 | 0.031 | 0.000 | | |
| 6 | -0.001 | 0.076 | 0.054 | 0.064 | 0.033 | 0.000 | |
| 7 | -0.037 | 0.040 | 0.018 | 0.028 | -0.004 | -0.036 | 0.000 |

BONFERRONI ADJUSTED.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| BLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1.000 | | | | | | |
| 2 | 0.001 | 1.000 | | | | | |
| 3 | 0.040 | 1.000 | 1.000 | | | | |
| 4 | 0.007 | 1.000 | 1.000 | 1.000 | | | |
| 5 | 0.766 | 0.144 | 1.000 | 0.944 | 1.000 | | |
| 6 | 1.000 | 0.001 | 0.063 | 0.012 | 1.000 | 1.000 | |
| 7 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |

**Table III.2.3.1. ANOVA OF SITE EFFECT ON SHELL LENGTH**

**DEP VAR: LENGTH** N: 3853 SQUARED MULTIPLE R: 0.017

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 60.554 | 1 | 60.554 | 65.498 | 0.000 |
| ERROR | 3560.297 | 3851 | 0.925 | | |

POST HOC TEST OF LENGTH
USING MODEL MSE OF .925 WITH 3851. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| SITE | Boughton | Murray |
|---|---|---|
| Boughton | 0.000 | |
| Murray | -0.293 | 0.000 |

BONFERRONI ADJUSTMENT.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| SITE | Boughton | Murray |
|---|---|---|
| Boughton | 1.000 | |
| Murray | 0.000 | 1.000 |

**Table III.2.3.2. ANOVA OF SITE EFFECT ON STEAMED MEAT WEIGHT**

**DEP VAR: STMWT** N: 3788 SQUARED MULTIPLE R: 0.014

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 265.480 | 1 | 265.480 | 55.169 | 0.000 |
| ERROR | 18218.618 | 3786 | 4.812 | | |

POST HOC TEST OF STMWT
USING MODEL MSE OF 4.812 WITH 3786. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| SITE | Boughton | Murray |
|---|---|---|
| Boughton | 0.000 | |
| Murray | -0.625 | 0.000 |

BONFERRONI ADJUSTMENT.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| SITE | Boughton | Murray |
|---|---|---|
| Boughton | 1.000 | |
| Murray | 0.000 | 1.000 |

**Table III.2.3.3. ANOVA OF SITE EFFECT ON STEAMED CONDITION INDEX**

**DEP VAR:** **STCI** N: 3777 SQUARED MULTIPLE R: 0.187

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 38911.411 | 1 | 38911.411 | 870.768 | 0.000 |
| ERROR | 168690.778 | 3775 | 44.686 | | |

POST HOC TEST OF STCI
USING MODEL MSE OF 44.686 WITH 3775. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| SITE | Boughton | Murray |
|---|---|---|
| Boughton | 0.000 | |
| Murray | 7.587 | 0.000 |

BONFERRONI ADJUSTMENT.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| SITE | Boughton | Murray |
|---|---|---|
| Boughton | 1.000 | |
| Murray | 0.000 | 1.000 |

the Boughton River site tend to have heavier shells than those at the Murray River site and, since the relationship between shell weight and meat weight appears to be linear, the same is true of steamed meat weight (Figure III.1.3), the Boughton River site having a larger meat weight per unit shell length. This suggests that the same factors influencing shell weight also influence meat weight.

Comparison of differences in shell length among blocks at each site (Figure III.2.3.1) revealed a surprizing uniformity. At the Murray River site the difference between blocks is very small, but because the variability within blocks is also small, an ANOVA (Table III.2.3.4) indicated that the differences are statistically significant. At the Boughton site an ANOVA (Table III.2.3.5) showed only Block I to be significantly different from all other blocks.

Steamed meat weight shows considerably more variation among blocks. At the Murray River site it is lower for the two blocks located near the river channel as opposed to the shore-line and all blocks are significantly different from one another (Table III.2.3.6). The slightly lower average values of both shell length and steamed meat weight for Block I at the Murray River site is partially a result of this block having been harvested prior to the 1988 sampling period with the result that the averages do not include the older mussels. At the Boughton River site the differences between blocks are equally pronounced, but because the variability within blocks is greater none of the differences are statistically significant (Table III.2.3.7). The trend, however, appears to be toward higher values for blocks located downriver.

Steamed condition indices are also relatively homogeneous among blocks at both sites. At the Murray River site the variation both between and within blocks is exceptionally small. An ANOVA (Table III.2.3.8) showed only Block II to significantly differ from Blocks I and III. The variability at the Boughton site is greater, both between and among blocks, but only Block VI differs from all other blocks (Table III.2.3.9).

## 3. Variations With Depth

### 3.1. Mussel Density and Proportion Dead

Figure III.3.1.1 compares the average density and proportion of mussels dead at each site for the three levels sampled. At both sites the variation in mussel density with level is small, but the variation in the average proportion dead is considerable. An initial ANOVA (Table III.3.1.1) of the effect of level on both of these variables indicated that the relationship differed significantly between sites and further ANOVA were carried out on each site separately.

At both sites the variation in density both within and between levels was small. At the Murray River site only level one, which had the highest density, was significantly different from the other levels (Table III.3.1.2). At the Boughton site the only significant difference was between level one and two, but at this site level one had the lowest density (Table III.3.1.3).

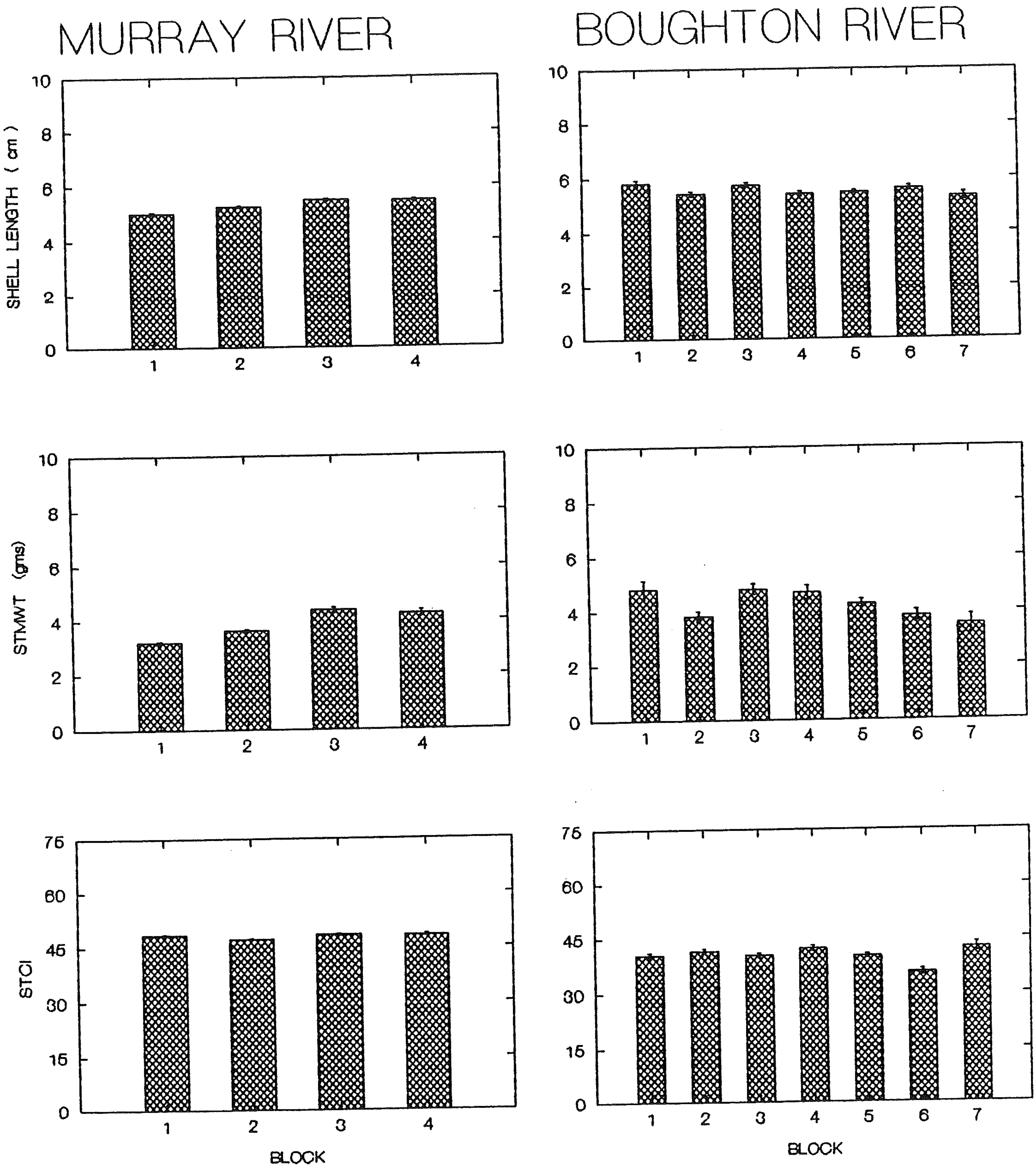



Figure III.2.3.1. Comparison of shell length, steamed meat weight and steamed condition index among blocks at each site (error bars one standard error of the mean).

**Table III.2.3.4. ANOVA OF BLOCK EFFECT ON SHELL LENGTH (Murray River)**

**DEP VAR: LENGTH** N: 2915 SQUARED MULTIPLE R: 0.037

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQRS | DF | MEAN-SQR | F-RATIO | P |
|---|---|---|---|---|---|
| BLOCK | 96.371 | 3 | 32.124 | 37.192 | 0.000 |
| ERROR | 2514.275 | 2911 | 0.864 | | |

POST HOC TEST OF LENGTH
USING MODEL MSE OF .864 WITH 2911. DF.

MATRIX OF PAIRWISE MEAN DIFFERENCES:

| BLOCK | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 0.000 | | | |
| 2 | 0.233 | 0.000 | | |
| 3 | 0.468 | 0.234 | 0.000 | |
| 4 | 0.443 | 0.210 | -0.025 | 0.000 |

BONFERRONI ADJUSTMENT.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| BLOCK | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 1.000 | | | |
| 2 | 0.000 | 1.000 | | |
| 3 | 0.000 | 0.000 | 1.000 | |
| 4 | 0.000 | 0.001 | 1.000 | 1.000 |

**Table III.2.3.5. ANOVA OF BLOCK EFFECT ON SHELL LENGTH (Boughton River)**

**DEP VAR: LENGTH** N: 933 SQUARED MULTIPLE R: 0.027

ANALYSIS OF VARIANCE

| SOURCE | SUMS-OF-SQRS | DF | MEAN-SQR | F-RATIO | P |
|---|---|---|---|---|---|
| BLOCK | 25.604 | 6 | 4.267 | 4.282 | 0.000 |
| ERROR | 922.883 | 926 | 0.997 | | |

POST HOC TEST OF LENGTH
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| BLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 0.000 | | | | | | |
| 2 | -0.414 | 0.000 | | | | | |
| 3 | -0.071 | 0.343 | 0.000 | | | | |
| 4 | -0.415 | -0.001 | -0.344 | 0.000 | | | |
| 5 | -0.356 | 0.057 | -0.286 | 0.058 | 0.000 | | |
| 6 | -0.210 | 0.203 | -0.139 | 0.204 | 0.146 | 0.000 | |
| 7 | -0.529 | -0.116 | -0.459 | -0.115 | -0.173 | -0.319 | 0.000 |

BONFERRONI ADJUSTED.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| BLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1.000 | | | | | | |
| 2 | 0.020 | 1.000 | | | | | |
| 3 | 1.000 | 0.108 | 1.000. | | | | |
| 4 | 0.016 | 1.000 | 0.090 | 1.000 | | | |
| 5 | 0.024 | 1.000 | 0.155 | 1.000 | 1.000 | | |
| 6 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | |
| 7 | 0.048 | 1.000 | 0.158 | 1.000 | 1.000 | 1.000 | 1.000 |

**Table III.2.3.6. ANOVA OF BLOCK EFFECT ON STEAMED MEAT WEIGHT (Murray River)**

DEP VAR: STMWT N: 2895 SQUARED MULTIPLE R: 0.049

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQRS | DF | MEAN-SQR | F-RATIO | P |
|---|---|---|---|---|---|
| BLOCK | 577.412 | 3 | 192.471 | 49.975 | 0.000 |
| ERROR | 11134.312 | 2891 | 3.851 | | |

POST HOC TEST OF STMWT
USING MODEL MSE OF 3.851 WITH 2891. DF.

MATRIX OF PAIRWISE MEAN DIFFERENCES:

| BLOCK | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 0.000 | | | |
| 2 | 0.414 | 0.000 | | |
| 3 | 1.167 | 0.753 | 0.000 | |
| 4 | 1.027 | 0.613 | -0.140 | 0.000 |

BONFERRONI ADJUSTMENT.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| BLOCK | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 1.000 | | | |
| 2 | 0.000 | 1.000 | | |
| 3 | 0.000 | 0.000 | 1.000 | |
| 4 | 0.000 | 0.000 | 1.000 | 1.000 |

**Table III.2.3.7. ANOVA OF BLOCK EFFECT ON STEAMED MEAT WEIGHT (Boughton River)**

**DEP VAR: STMWT** N: 888 SQUARED MULTIPLE R: 0.026

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQRS | DF | MEAN-SQR | F-RATIO | P |
|---|---|---|---|---|---|
| BLOCK | 171.020 | 6 | 28.503 | 3.967 | 0.001 |
| ERROR | 6329.303 | 881 | 7.184 | | |

POST HOC TEST OF STMWT
USING MODEL MSE OF 7.184 WITH 881. DF.

MATRIX OF PAIRWISE MEAN DIFFERENCES:

| BLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 0.000 | | | | | | |
| 2 | -1.021 | 0.000 | | | | | |
| 3 | -0.021 | 1.001 | 0.000 | | | | |
| 4 | -0.137 | 0.884 | -0.116 | 0.000 | | | |
| 5 | -0.570 | 0.451 | -0.549 | -0.433 | 0.000 | | |
| 6 | -1.023 | -0.002 | -1.003 | -0.887 | -0.453 | 0.000 | |
| 7 | -1.324 | -0.303 | -1.304 | -1.187 | -0.754 | -0.301 | 0.000 |

BONFERRONI ADJUSTED.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| BLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1.000 | | | | | | |
| 2 | 0.055 | 1.000 | | | | | |
| 3 | 1.000 | 0.059 | 1.000 | | | | |
| 4 | 1.000 | 0.163 | 1.000 | 1.000 | | | |
| 5 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | | |
| 6 | 0.082 | 1.000 | 0.089 | 0.228 | 1.000 | 1.000 | |
| 7 | 0.140 | 1.000 | 0.151 | 0.294 | 1.000 | 1.000 | 1.000 |

**Table III.2.3.8. ANOVA OF BLOCK EFFECT ON STEAMED CONDITION INDEX (Murray River)**

**DEP VAR:** **STCI** N: 2890 SQUARED MULTIPLE R: 0.008

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQRS | DF | MEAN-SQR | F-RATIO | P |
|---|---|---|---|---|---|
| BLOCK | 868.636 | 3 | 289.545 | 7.558 | 0.000 |
| ERROR | 110559.777 | 2886 | 38.309 | | |

POST HOC TEST OF STCI
USING MODEL MSE OF 38.309 WITH 2886. DF.

MATRIX OF PAIRWISE MEAN DIFFERENCES:

| BLOCK | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 0.000 | | | |
| 2 | -1.165 | 0.000 | | |
| 3 | -0.016 | 1.149 | 0.000 | |
| 4 | -0.134 | 1.031 | -0.117 | 0.000 |

BONFRRONI ADJUSTED.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| BLOCK | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1 | 1.000 | | | |
| 2 | 0.000 | 1.000 | | |
| 3 | 1.000 | 0.003 | 1.000 | |
| 4 | 1.000 | 0.031 | 1.000 | 1.000 |

**Table III.2.3.9. ANOVA OF BLOCK EFFECT ON STEAMED CONDITION INDEX (Boughton River)**

**DEP VAR:** **STCI** N: 882 SQUARED MULTIPLE R: 0.057

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQRS | DF | MEAN-SQR | F-RATIO | P |
|---|---|---|---|---|---|
| BLOCK | 3254.315 | 6 | 542.386 | 8.800 | 0.000 |
| ERROR | 53933.258 | 875 | 61.638 | | |

POST HOC TEST OF STCI

USING MODEL MSE OF 61.638 WITH 875. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| BLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 0.000 | | | | | | |
| 2 | 1.083 | 0.000 | | | | | |
| 3 | -0.198 | -1.281 | 0.000 | | | | |
| 4 | 1.829 | 0.746 | 2.027 | 0.000 | | | |
| 5 | -0.342 | -1.426 | -0.144 | -2.171 | 0.000 | | |
| 6 | -4.854 | -5.937 | -4.656 | -6.683 | -4.512 | 0.000 | |
| 7 | 1.936 | 0.852 | 2.134 | 0.107 | 2.278 | 6.790 | 0.000 |

BONFERRONI ADJUSTED.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| BLOCK | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| 1 | 1.000 | | | | | | |
| 2 | 1.000 | 1.000 | | | | | |
| 3 | 1.000 | 1.000 | 1.000 | | | | |
| 4 | 1.000 | 1.000 | 0.740 | 1.000 | | | |
| 5 | 1.000 | 1.000 | 1.000 | 0.235 | 1.000 | | |
| 6 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 | |
| 7 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.000 | 1.000 |

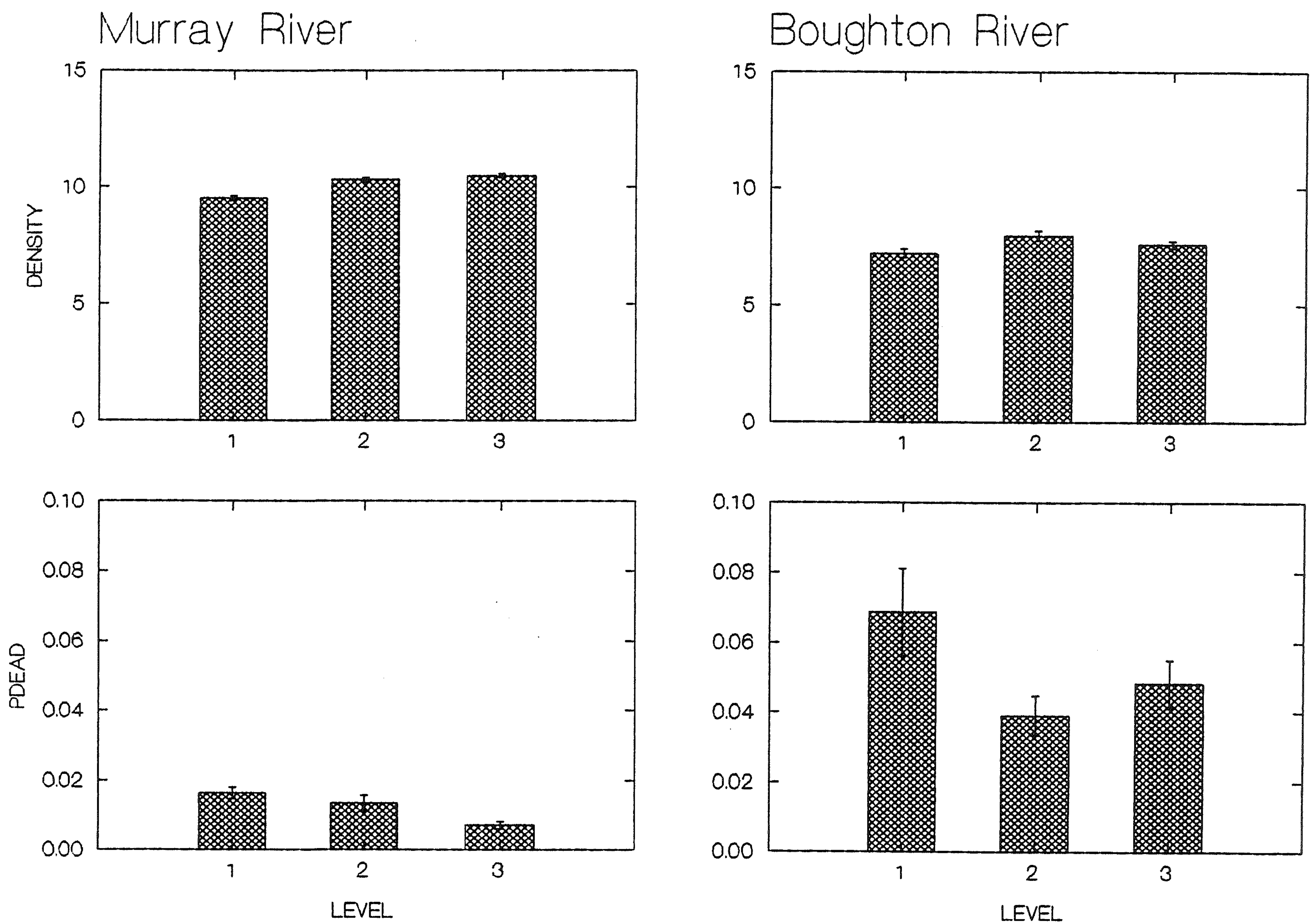



Figure III.3.1.1. Comparison of average density and proportion of mussels dead at each site for the three levels sampled (error bars are one standard error of the mean).

**Table III.3.1.1. ANCOVA OF LEVEL EFFECT BETWEEN SITES**

**DEP VAR: LENGTH** N: 3838 SQUARED MULTIPLE R: 0.018

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 60.619 | 1 | 60.619 | 65.399 | 0.000 |
| LEVEL | 2.360 | 2 | 1.180 | 1.273 | 0.280 |
| SITE*LEVEL | 3.797 | 2 | 1.898 | 2.048 | 0.129 |
| ERROR | 3551.893 | 3832 | 0.927 | | |

**DEP VAR: STMWT** N: 3773 SQUARED MULTIPLE R: 0.015

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 255.334 | 1 | 255.334 | 53.069 | 0.000 |
| LEVEL | 1.606 | 2 | 0.803 | 0.167 | 0.846 |
| SITE*LEVEL | 10.425 | 2 | 5.213 | 1.083 | 0.339 |
| ERROR | 18124.523 | 3767 | 4.811 | | |

**DEP VAR: STCI** N: 3762 SQUARED MULTIPLE R: 0.193

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 37258.420 | 1 | 37258.420 | 837.103 | 0.000 |
| LEVEL | 786.686 | 2 | 393.343 | 8.837 | 0.000 |
| SITE*LEVEL | 88.589 | 2 | 44.295 | 0.995 | 0.370 |
| ERROR | 167174.899 | 3756 | 44.509 | | |

**DEP VAR: DENSITY** N: 3826 SQUARED MULTIPLE R: 0.135

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 4320.652 | 1 | 4320.652 | 523.336 | 0.000 |
| LEVEL | 312.008 | 2 | 156.004 | 18.896 | 0.000 |
| SITE*LEVEL | 52.520 | 2 | 26.260 | 3.181 | 0.042 |
| ERROR | 31537.853 | 3820 | 8.256 | | |

**DEP VAR: PDEAD** N: 3791 SQUARED MULTIPLE R: 0.039

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 1.071 | 1 | 1.071 | 136.713 | 0.000 |
| LEVEL | 0.139 | 2 | 0.070 | 8.895 | 0.000 |
| SITE*LEVEL | 0.075 | 2 | 0.037 | 4.776 | 0.008 |
| ERROR | 29.653 | 3785 | 0.008 | | |

**Table III.3.1.2. ANOVA OF LEVEL EFFECT ON DENSITY (Murray River)**

**DEP VAR: DENSITY** N: 2867 SQUARED MULTIPLE R: 0.023

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| LEVEL | 507.084 | 2 | 253.542 | 33.066 | 0.000 |
| ERROR | 21960.258 | 2864 | 7.668 | | |

POST HOC TEST OF DENSITY
USING MODEL MSE OF 7.668 WITH 2864. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| Level | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 0.000 | | |
| 2 | 0.801 | 0.000 | |
| 3 | 0.967 | 0.166 | 0.000 |

BONFERRONI ADJUSTMENT.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| Level | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 1.000 | | |
| 2 | 0.000 | 1.000 | |
| 3 | 0.000 | 0.602 | 1.000 |

**Table III.3.1.3. ANOVA OF LEVEL EFFECT ON DENSITY (Boughton River)**

**DEP VAR: DENSITY** N: 959 SQUARED MULTIPLE R: 0.008

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| LEVEL | 78.722 | 2 | 39.361 | 3.929 | 0.020 |
| ERROR | 9577.595 | 956 | 10.018 | | |

POST HOC TEST OF DENSITY
USING MODEL MSE OF 10.018 WITH 956. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| Level | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 0.000 | | |
| 2 | 0.758 | 0.000 | |
| 3 | 0.384 | -0.374 | 0.000 |

BONFERRONI ADJUSTMENT.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| Level | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 1.000 | | |
| 2 | 0.016 | 1.000 | |
| 3 | 0.375 | 0.377 | 1.000 |

The variation in proportion of mussels dead at each level at each site was much greater than that of density, particularly at the Boughton site. However, because the variation within levels was also greater the differences were not significant at all levels. An ANOVA for the Murray River site (Table III.3.1.4) showed that level one differed from level three, but that level two did not differ from either one or three. At the Boughton site, although the average values were quite different, the variation within levels was so large an ANOVA revealed no significant differences between levels (Table III.3.1.5).

The variation in density and proportion dead at each level among blocks at each site is illustrated in Figure III.3.1.2. The variation is greater at the Boughton site but neither variable exhibits any obvious trend in terms of differences between levels among blocks.

### 3.2. Mussel Allometry

The variation of all allometric variables with level is small (Figure III.3.2.1). An ANOVA of variation in shell length and steamed meat weight with level between sites indicated that the differences between sites was not significant and subsequent ANOVA's were performed using combined data from both sites. These are presented in Tables III.3.2.1 and III.3.2.2 and indicate no significant difference existed between levels for these variables.

Variations in shell length and steamed meat weight between levels among blocks are illustrated in Figures III.3.2.2 and III.3.2.3. As was the case with shell length, the variation among blocks is small and no obvious trends are evident.

### 3.3. Steamed Condition Index

An ANOVA of variation in steamed condition index with level between sites indicated that site differences were not significant so data from both sites was combined. An ANOVA (Table III.3.3.1) indicated that level two was significantly different from one and three, but that levels one and three did not differ significantly from one another.

Variations between levels among blocks for each site are illustrated in Figure III.3.3.1. No obvious trends are evident.

## 4. Variations Over Time

The variation in each parameter over time was analyzed using ANCOVA, with Julian Day as the covariate, and multiple regression procedures. An initial ANCOVA (Table III.4.1) showed that the interaction between site and Julian Day was significant for all variables indicating that the variations over time differed significantly between sites. As a result, the data for each site was analyzed separately.

**Table III.3.1.4. ANOVA OF LEVEL EFFECT ON PROPORTION DEAD (Murray River)**

**DEP VAR: PDEAD** N: 2856 SQUARED MULTIPLE R: 0.004

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| LEVEL | 0.039 | 2 | 0.019 | 5.959 | 0.003 |
| ERROR | 9.278 | 2853 | 0.003 | | |

POST HOC TEST OF PDEAD
USING MODEL MSE OF .003 WITH 2853. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| Level | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 0.000 | | |
| 2 | -0.003 | 0.000 | |
| 3 | -0.009 | -0.006 | 0.000 |

BONFERRONI ADJUSTMENT.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| Level | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 1.000 | | |
| 2 | 0.698 | 1.000 | |
| 3 | 0.002 | 0.056 | 1.000 |

**Table III.3.1.5. ANOVA OF LEVEL EFFECT ON PROPORTION DEAD (Boughton River)**

**DEP VAR: PDEAD** N: 935 SQUARED MULTIPLE R: 0.006

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| LEVEL | 0.122 | 2 | 0.061 | 2.783 | 0.062 |
| ERROR | 20.375 | 932 | 0.022 | | |

POST HOC TEST OF PDEAD
USING MODEL MSE OF .022 WITH 932. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| Level | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 0.000 | | |
| 2 | -0.030 | 0.000 | |
| 3 | -0.020 | 0.009 | 0.000 |

BONFERRONI ADJUSTMENT.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| Level | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 1.000 | | |
| 2 | 0.066 | 1.000 | |
| 3 | 0.248 | 1.000 | 1.000 |

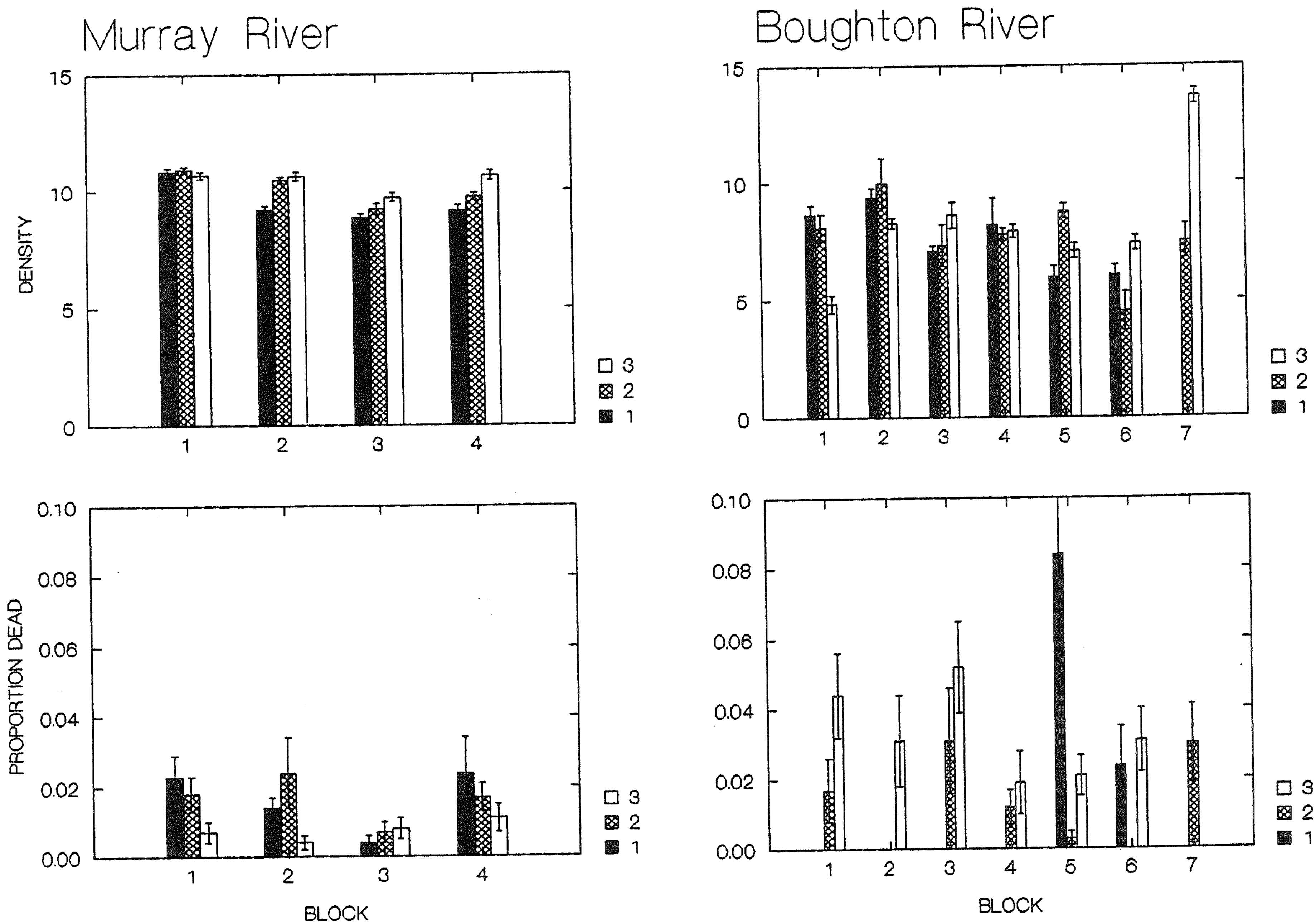



Figure III.3.1.2. Variation in density and proportion of mussels dead at each level among blocks at each site.

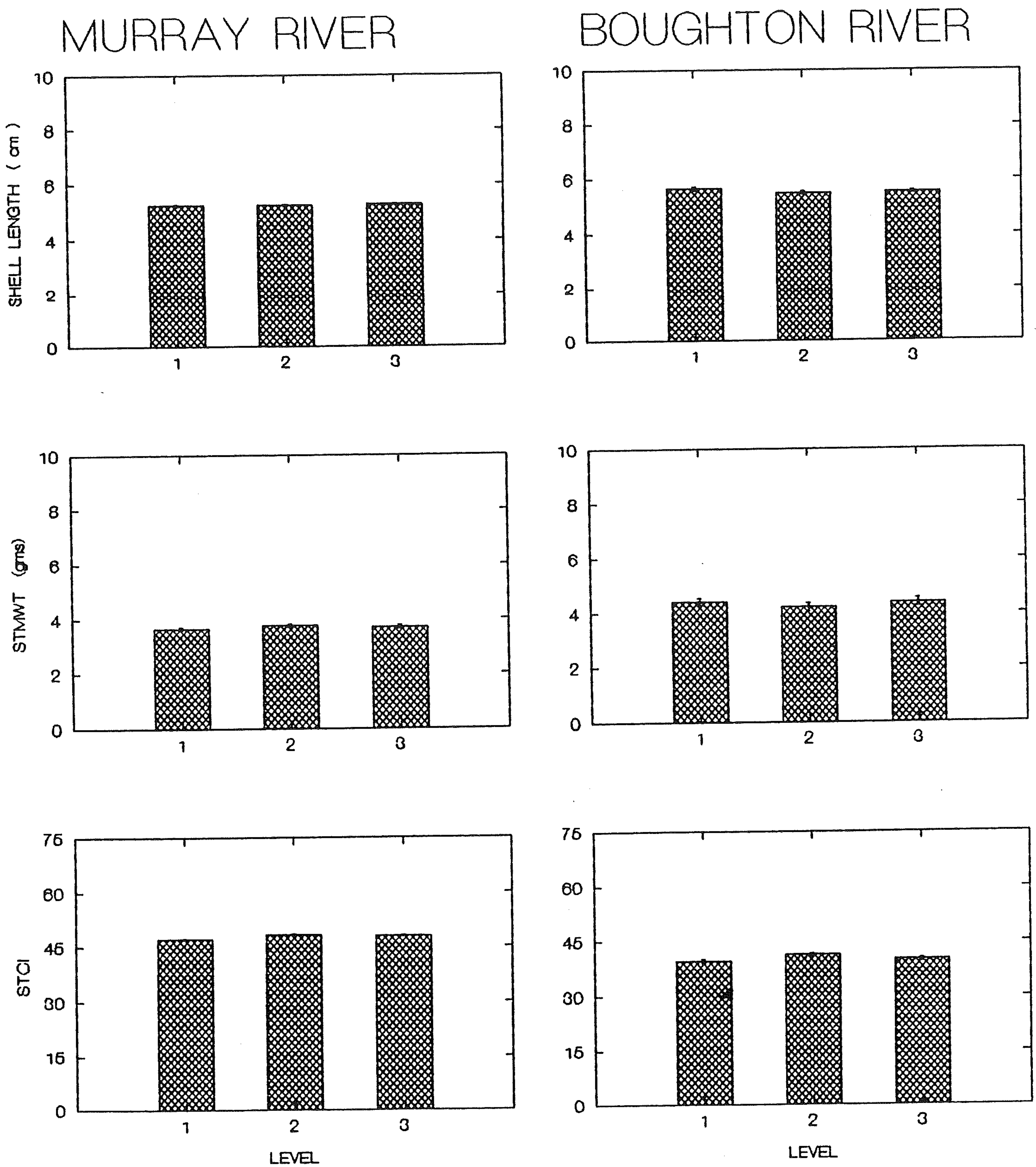



Figure III.3.2.1. Variation in shell length, steamed meat weight and condition index at each level at each site (error bars are one standard error of the mean).

**Table III.3.2.1. ANOVA OF LEVEL EFFECT ON SHELL LENGTH (Both Sites)**

**DEP VAR: LENGTH** N: 3838 SQUARED MULTIPLE R: 0.001

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| LEVEL | 2.358 | 2 | 1.179 | 1.251 | 0.286 |
| ERROR | 3614.731 | 3835 | 0.943 | | |

POST HOC TEST OF LENGTH
USING MODEL MSE OF .943 WITH 3835. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| Level | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 0.000 | | |
| 2 | -0.021 | 0.000 | |
| 3 | 0.039 | 0.060 | 0.000 |

BONFERRONI ADJUSTMENT.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| Level | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 1.000 | | |
| 2 | 1.000 | 1.000 | |
| 3 | 0.953 | 0.351 | 1.000 |

**Table III.3.2.2. ANOVA OF LEVEL EFFECT ON STEAMED MEAT WEIGHT (Both Sites)**

**DEP VAR: STMWT** N: 3773 SQUARED MULTIPLE R: 0.000

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| LEVEL | 9.045 | 2 | 4.522 | 0.927 | 0.396 |
| ERROR | 18396.290 | 3770 | 4.880 | | |

POST HOC TEST OF STMWT
USING MODEL MSE OF 4.880 WITH 3770. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| Level | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 0.000 | | |
| 2 | 0.047 | 0.000 | |
| 3 | 0.121 | 0.074 | 0.000 |

BONFERRONI ADJUSTMENT.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| Level | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 1.000 | | |
| 2 | 1.000 | 1.000 | |
| 3 | 0.528 | 1.000 | 1.000 |

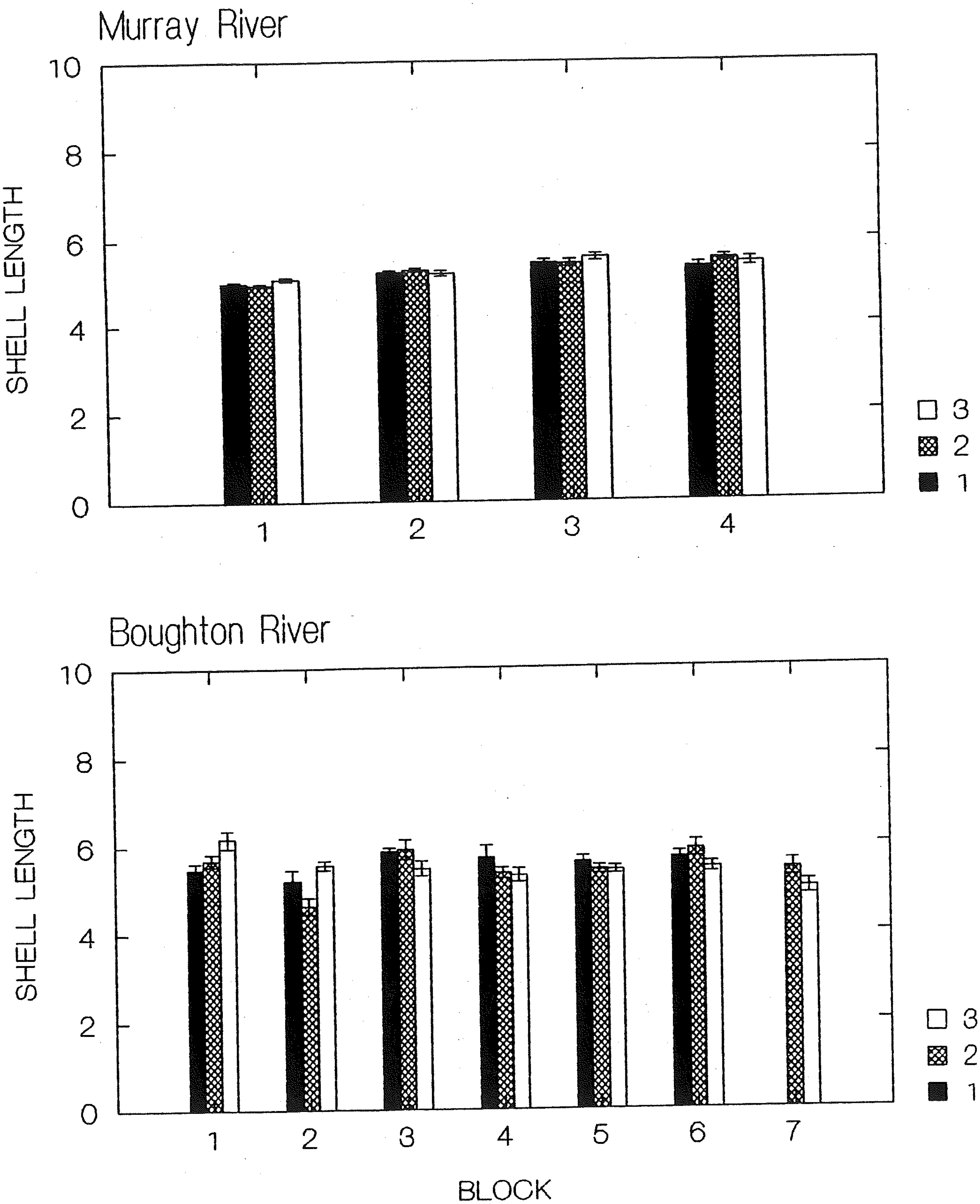



Figure III.3.2.2. Variations in shell length between levels among blocks (error bars are one standard error of the mean).

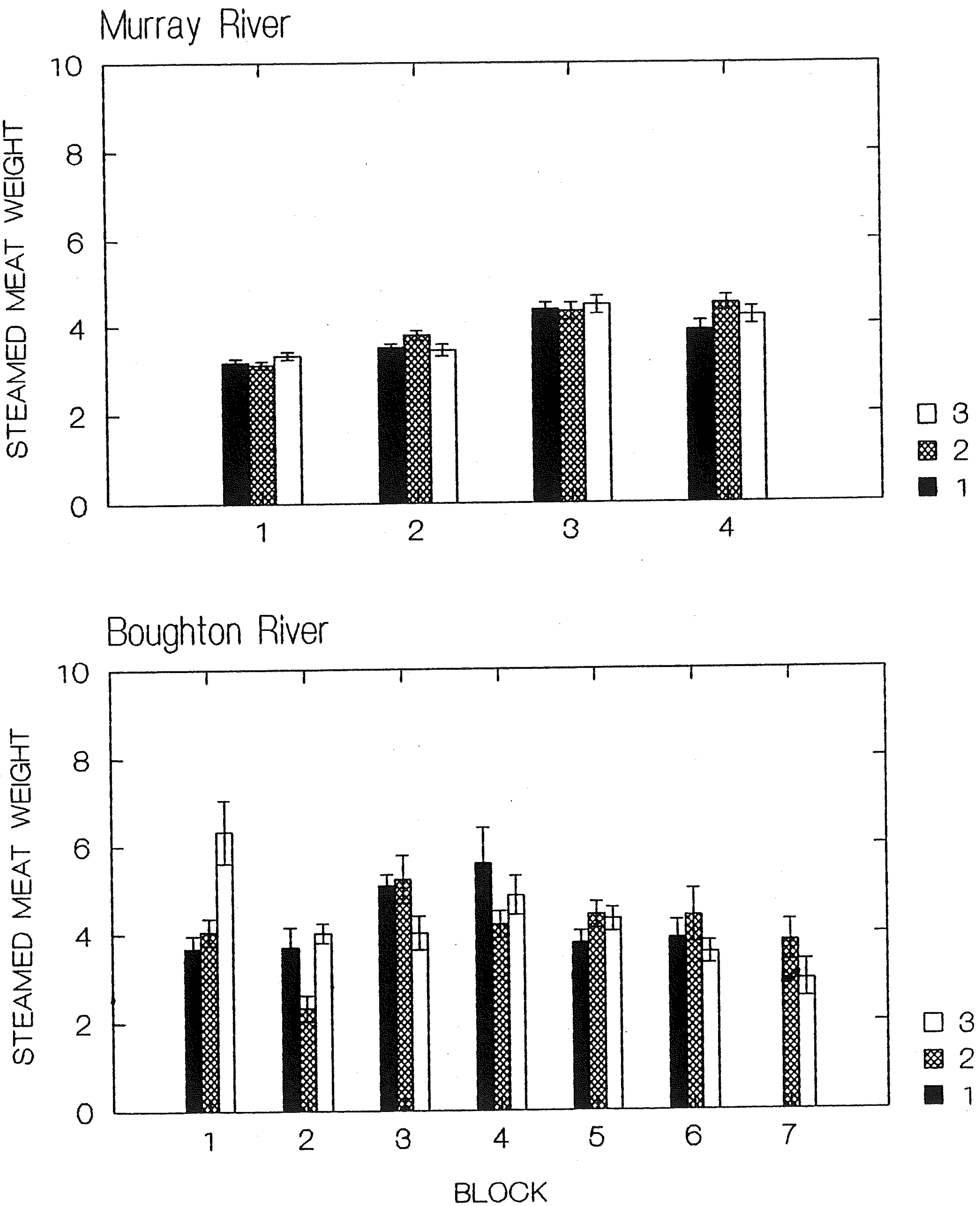



Figure III.3.2.3. Variations in steamed meat weight between levels among blocks (error bars are one standard error of the mean).

**Table III.3.3.1. ANOVA OF LEVEL EFFECT ON STEAMED CONDITION INDEX (Both Sites)**

**DEP VAR:** **STCI** N: 3762 SQUARED MULTIPLE R: 0.008

ANALYSIS OF VARIANCE

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| LEVEL | 1723.460 | 2 | 861.730 | 15.776 | 0.000 |
| ERROR | 205328.142 | 3759 | 54.623 | | |

POST HOC TEST OF STCI
USING MODEL MSE OF 54.623 WITH 3759. DF.
MATRIX OF PAIRWISE MEAN DIFFERENCES:

| Level | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 0.000 | | |
| 2 | 1.226 | 0.000 | |
| 3 | -0.334 | -1.560 | 0.000 |

BONFERRONI ADJUSTMENT.
MATRIX OF PAIRWISE COMPARISON PROBABILITIES:

| Level | 1 | 2 | 3 |
|---|---|---|---|
| 1 | 1.000 | | |
| 2 | 0.000 | 1.000 | |
| 3 | 0.796 | 0.000 | 1.000 |

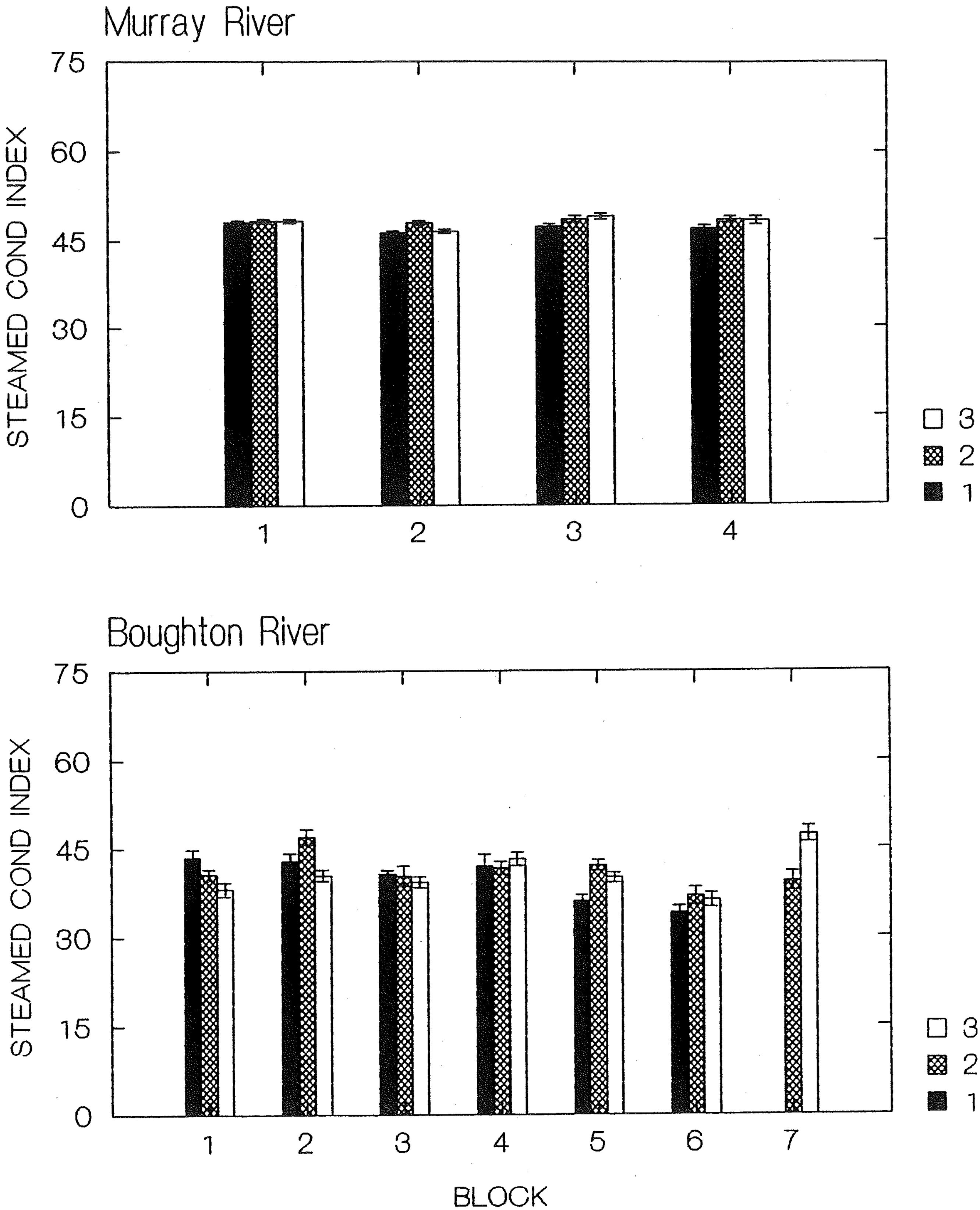



Figure III.3.3.1. Variation in steamed condition index between levels among blocks (error bars are one standard error of the mean).

Table III.4.1. ANCOVA OF SITE AND JULIAN DAY FOR ALL VARIABLES

**DEP VAR: LENGTH** N: 3853 SQUARED MULTIPLE R: 0.519

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 36.070 | 1 | 36.070 | 79.759 | 0.000 |
| JD | 1255.200 | 1 | 1255.200 | 2775.494 | 0.000 |
| SITE*JD | 17.175 | 1 | 17.175 | 37.978 | 0.000 |
| ERROR | 1740.687 | 3849 | 0.452 | | |

**DEP VAR: STMWT** N: 3788 SQUARED MULTIPLE R: 0.437

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 0.711 | 1 | 0.711 | 0.259 | 0.611 |
| JD | 6393.109 | 1 | 6393.109 | 2325.755 | 0.000 |
| SITE*JD | 29.413 | 1 | 29.413 | 10.700 | 0.001 |
| ERROR | 10401.581 | 3784 | 2.749 | | |

**DEP VAR: STCI** N: 3777 SQUARED MULTIPLE R: 0.231

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 25236.575 | 1 | 25236.575 | 596.133 | 0.000 |
| JD | 494.704 | 1 | 494.704 | 11.686 | 0.001 |
| SITE*JD | 8320.865 | 1 | 8320.865 | 196.554 | 0.000 |
| ERROR | 159725.477 | 3773 | 42.334 | | |

**DEP VAR: DENSITY** N: 3831 SQUARED MULTIPLE R: 0.220

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 294.168 | 1 | 294.168 | 39.207 | 0.000 |
| JD | 3269.639 | 1 | 3269.639 | 435.785 | 0.000 |
| SITE*JD | 51.185 | 1 | 51.185 | 6.822 | 0.009 |
| ERROR | 28713.519 | 3827 | 7.503 | | |

**DEP VAR: PDEAD** N: 3796 SQUARED MULTIPLE R: 0.043

| SOURCE | SUM-OF-SQUARES | DF | MEAN-SQUARE | F-RATIO | P |
|---|---|---|---|---|---|
| SITE | 0.632 | 1 | 0.632 | 70.310 | 0.000 |
| JD | 0.567 | 1 | 0.567 | 63.051 | 0.000 |
| SITE*JD | 0.206 | 1 | 0.206 | 22.905 | 0.000 |
| ERROR | 34.104 | 3792 | 0.009 | | |

## 4.1. Mussel Density and Proportion Dead

Variations in the density and proportion of mussels dead with time were considerable (Figure III.4.1.1) and the two variables behaved very differently. At both sites density tended to decrease with time during the 1987 sampling period. However, the change in density over the winter period, between the last sampling dates in October 1987 and the first sampling dates in May 1988, was very small.

The change in proportion of mussels dead with time showed different trends at each site. During 1987 this varied erratically at the Murray River site, but at the Boughton site there was an obvious increase. During 1988 the proportion of mussels dead at both sites was very low.

The combination of little change in density over the winter period and low proportion of mussels dead during the spring of 1988 indicates that overwintering had little influence on either mortality or drop-off.

## 4.2. Shell Length

Figure III.4.2.1 presents the average size of mussels, in terms of shell length, for each block at each site over the entire sampling period (Appendix B presents the same for each individual block at each site). The results of multiple regression analyses of shell length with time are presented in Table III.4.2.1. The differences in shell growth between sites was minor, but was slightly greater (0.06 mm $day^{-1}$) at the Boughton site compared to the Murray site (0.05 mm $day^{-1}$). Surprizingly, at both sites shell growth over the winter period appeared to about equal that occurring during the previous summer and fall.

## 4.3. Steamed Meat Weight

Growth data for steamed meat weight at each site is presented in Figure III.4.3.1, Table III.4.3.1 and Appendix C. As was the case for shell growth, steamed meat weight increased slightly faster (13 mg $day^{-1}$) at the Boughton site than at the Murray River site (11 mg $day^{-1}$), and winter growth rates equalled that occurring during the summer.

## 4.4. Condition Indices

The variation in steamed condition index with time (Figure III.4.4.1, Table III.4.4.1 and Appendix D) differed between sites. At the Murray River site the initial values were the highest recorded for either site at any time. These gradually decreased during the early summer after which there was very little change, either during the summer or over the winter. In contrast, at the Boughton site the initial values were among the lowest recorded and these increased over the summer. Values at the end of winter were about equal to those of the previous fall indicating that little change occurred over the winter period.

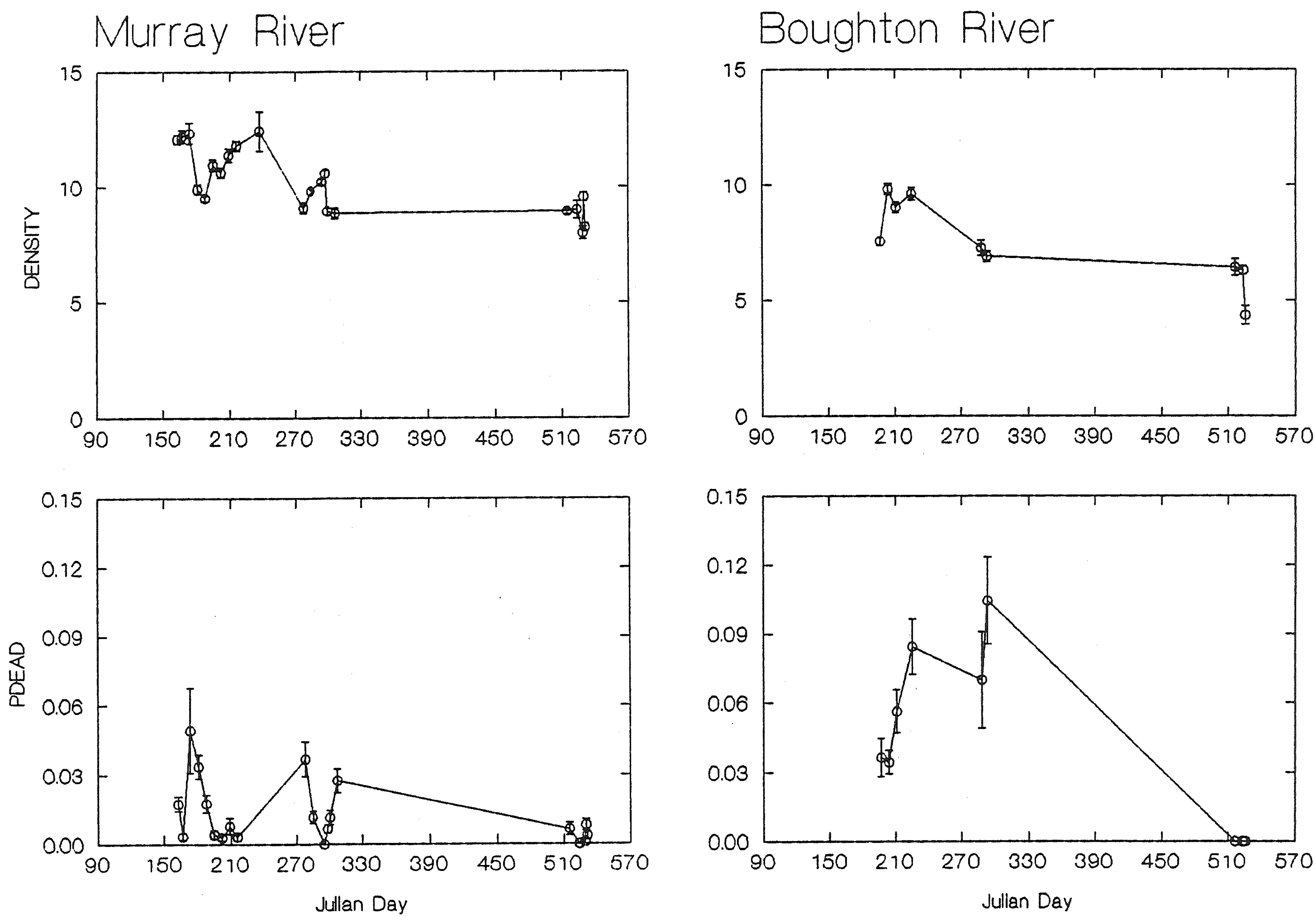



Figure III.4.1.1. Variation in density and proportion of mussels dead with time (error bars are one standard error of the mean).

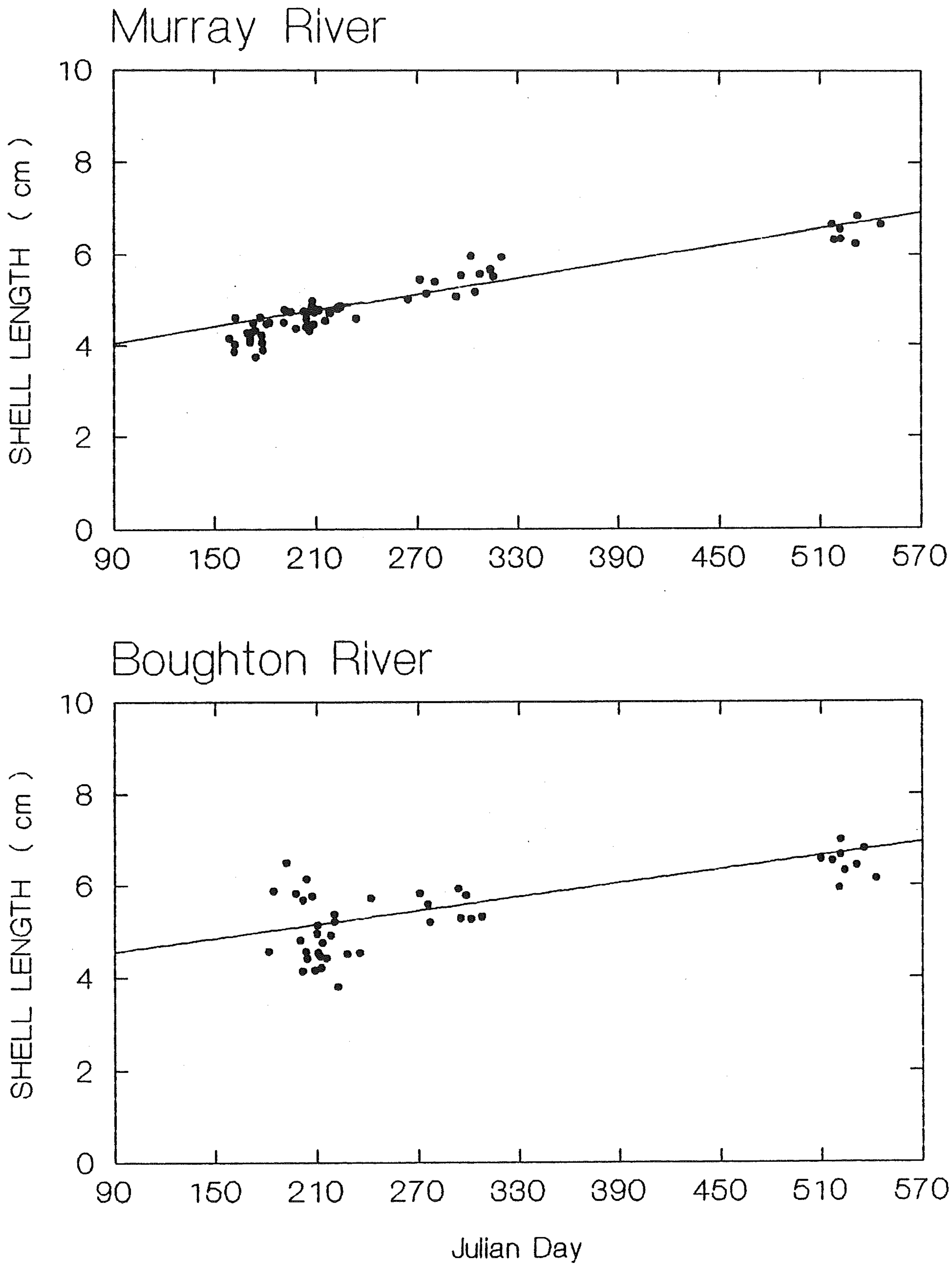



Figure III.4.2.1. Average shell length at each block at each site for each sampling date (see Table III.4.2.1 for regression statistics).

**Table III.4.2.1. MULTIPLE REGRESSION ANALYSIS OF SHELL LENGTH ON JULIAN DAY**

**MURRAY RIVER**

**DEP VAR: LENGTH** N: 2920 MULTIPLE R: 0.755 SQUARED MULTIPLE R: 0.570 ADJUSTED SQUARED MULTIPLE R: .569
STANDARD ERROR OF ESTIMATE: 0.621

| VARIABLE | COEFFICIENT | STD ERROR | P(2 TAIL) |
|---|---|---|---|
| CONSTANT | 3.509 | 0.030 | 0.000 |
| JD | 0.006 | 0.000 | 0.000 |

**BOUGHTON RIVER**

**DEP VAR: LENGTH** N: 933 MULTIPLE R: 0.592 SQUARED MULTIPLE R: 0.350 ADJUSTED SQUARED MULTIPLE R: .349
STANDARD ERROR OF ESTIMATE: 0.814

| VARIABLE | COEFFICIENT | STD ERROR | P(2 TAIL) |
|---|---|---|---|
| CONSTANT | 4.101 | 0.070 | 0.000 |
| JD | 0.005 | 0.000 | 0.000 |

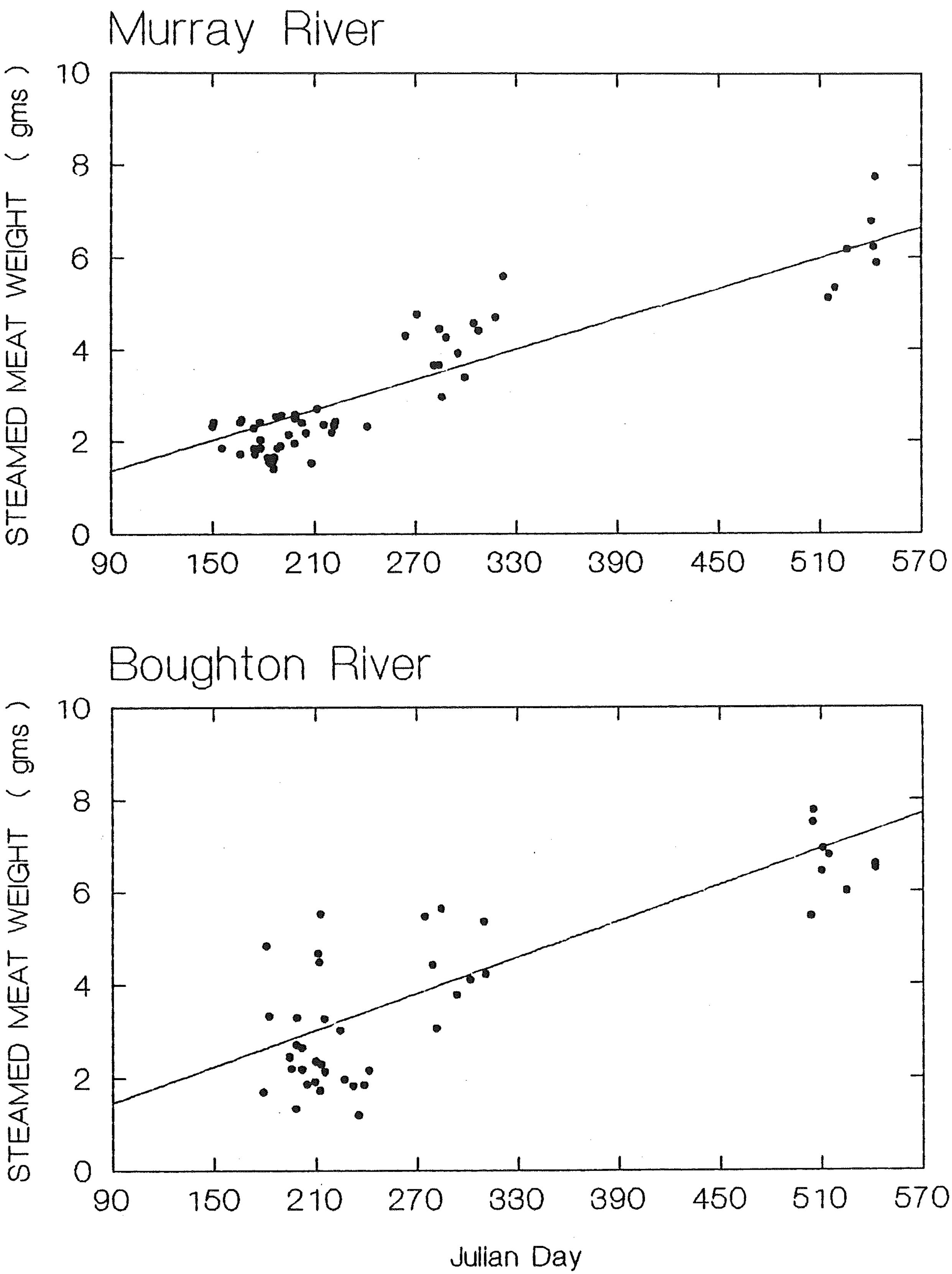



Figure III.4.3.1. Average steamed meat weight at each block at each site for each sampling date (see Table III.4.3.1 for regression statistics).

III.4.3.1

**Table III.4.3.1. MULTIPLE REGRESSION ANALYSIS OF STEAMED MEAT WEIGHT ON JULIAN DAY**

**MURRAY RIVER**

**DEP VAR: STMWT** N: 2900 MULTIPLE R: 0.676 SQUARED MULTIPLE R: 0.457 ADJUSTED SQUARED MULTIPLE R: .457
STANDARD ERROR OF ESTIMATE: 1.482

| VARIABLE | COEFFICIENT | STD ERROR | P(2 TAIL) |
|---|---|---|---|
| CONSTANT | 0.378 | 0.073 | 0.000 |
| JD | 0.011 | 0.000 | 0.000 |

**BOUGHTON RIVER**

**DEP VAR: STMWT** N: 888 MULTIPLE R: 0.615 SQUARED MULTIPLE R: 0.378 ADJUSTED SQUARED MULTIPLE R: .378
STANDARD ERROR OF ESTIMATE: 2.135

| VARIABLE | COEFFICIENT | STD ERROR | P(2 TAIL) |
|---|---|---|---|
| CONSTANT | 0.293 | 0.188 | 0.119 |
| JD | 0.013 | 0.001 | 0.000 |

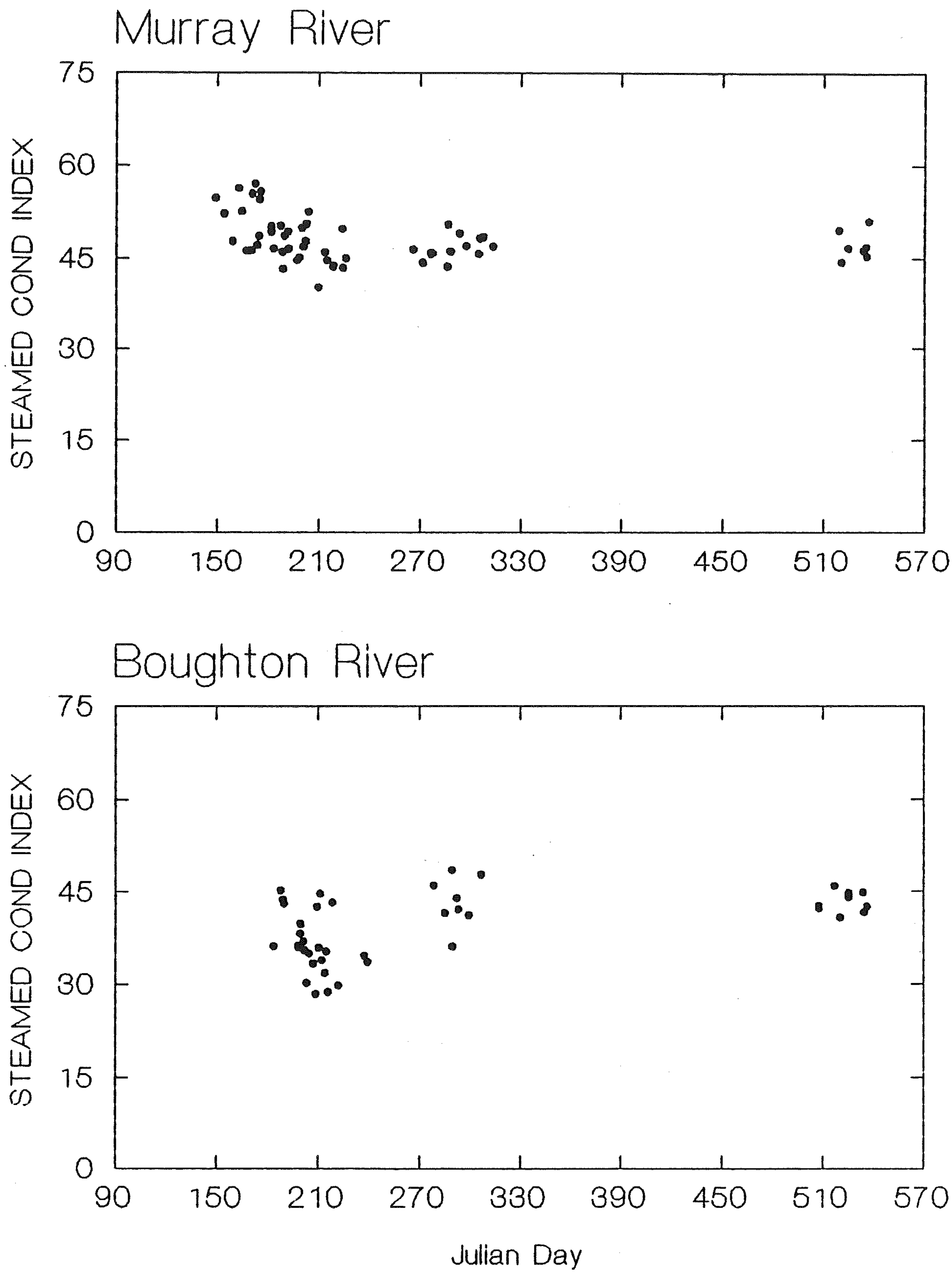



Figure III.4.4.1. Average steamed condition index at each block at each site for each sampling date (see Table III.4.4.1 for regression statistics).

**Table III.4.4.1. MULTIPLE REGRESSION ANALYSIS OF STEAMED CONDITION INDEX ON JULIAN DAY**

**MURRAY RIVER**

**DEP VAR: STCI** N: 2895 MULTIPLE R: 0.204 SQUARED MULTIPLE R: 0.042 ADJUSTED SQUARED MULTIPLE R: .041
STANDARD ERROR OF ESTIMATE: 6.078

| VARIABLE | COEFFICIENT | STD ERROR | P(2 TAIL) |
|---|---|---|---|
| CONSTANT | 50.876 | 0.299 | 0.000 |
| JD | -0.010 | 0.001 | 0.000 |

**BOUGHTON RIVER**

**DEP VAR: STCI** N: 882 MULTIPLE R: 0.275 SQUARED MULTIPLE R: 0.076 ADJUSTED SQUARED MULTIPLE R: .075
STANDARD ERROR OF ESTIMATE: 7.750

| VARIABLE | COEFFICIENT | STD ERROR | P(2 TAIL) |
|---|---|---|---|
| CONSTANT | 34.820 | 0.685 | 0.000 |
| JD | 0.017 | 0.002 | 0.000 |

## 5. Variations within Blocks

An important question with regard to the performance of cultured mussels deals with the degree of variation that occurs within a mussel block. Because food materials are delivered by water currents that enter at the margins of the blocks, mussels located within the interior of a block may be subject to lower food availability, as a result of competition for food between mussels, than those located near the outer margins. The proximity to oceanic as opposed to river water, as well as to shoreline or river channel, may also influence food availability.

Analysis of the data base to determine differences in performance within individual blocks at each site proved difficult. Although the total sample size is large, the number of observations on any particular day for any particular block is relatively small, and the variables associated with describing the location of a sample are continuous as opposed to discrete making traditional analysis of variance procedures impractical. Multiple regression analysis also proved difficult since, not knowing the relative contribution of river and oceanic water with respect to food resources, there is no obvious criteria for locating the position of a sample relative to some index of potential food availability.

As an alternative to either analysis of variance or multiple regression procedures, the approach used to make comparisons was to produce a series of contour plots illustrating the variations in mussel performance among blocks in terms of shell length, steamed meat weight and steamed condition index. The shortcoming of this approach is that statistical analysis to test the significance of differences is difficult, if not impossible, to perform, and it therefore becomes difficult to discern small but possibly significant differences.

In order to maximize the number of data points used to construct each contour plot, the data collected during 1987 was standardized to eliminate differences resulting from changes in size or condition index over time. For the 1987 data this was accomplished by calculating the mean value of each parameter for each block on each day and then expressing the value of each sample as a proportion of the deviation from this mean. Thus each contour plot is based on all of the data collected during 1987 for a particular block.

For the Murray River site contour plots were calculated only for Blocks I and II. The remaining blocks either had too few data or were too small in size to produce meaningful contour plots. For the Boughton site, the linear arrangement of the blocks made it possible to combine all data on all blocks. This allowed the spatial variation in all blocks to be illustrated on a single contour plot.

The overall variation in shell length, steamed meat weight and steamed condition index, as a percentage of the mean deviation, among each site and among each block at each site is summarized in Table III.5.1. Shell length shows the least variation and steamed meat weight the most. Steamed condition indices are intermediate. The range of variation is slightly greater at the Boughton River site.

Table III.5.1 Range in deviation (as percent) from mean.

| | Shell Length | | Steamed Meat Weight | | Steamed Condition Index | |
|---|---|---|---|---|---|---|
| | Min | Max | Min | Max | Min | Max |
| Between Sites: | | | | | | |
| Murray River | -23.0 | 18.0 | -58.7 | 81.3 | -28.4 | 21.3 |
| Boughton River | -26.0 | 31.1 | -62.3 | 101.4 | -35.0 | 29.7 |
| Among Blocks: | | | | | | |
| Murray River | | | | | | |
| Block I | -13.4 | 16.2 | -45.3 | 63.1 | -17.1 | 17.2 |
| Block II | -23.0 | 18.0 | -58.7 | 81.3 | -28.4 | 21.3 |
| Boughton River | | | | | | |
| Block I | -21.8 | 31.1 | -57.2 | 101.4 | -21.3 | 15.7 |
| Block II | -26.0 | 16.6 | -37.0 | 49.1 | -23.9 | 24.4 |
| Block III | -20.8 | 16.6 | -62.3 | 51.3 | -21.8 | 13.4 |
| Block IV | -24.3 | 21.5 | -56.4 | 64.9 | -15.2 | 29.7 |
| Block V | -21.2 | 26.3 | -59.9 | 62.5 | -24.6 | 24.2 |
| Block VI | -21.2 | 16.9 | -51.6 | 56.6 | -32.0 | 29.3 |
| Block VII | -6.6 | 4.4 | -22.3 | 21.5 | -35.0 | 21.3 |

Figures III.5.1-III.5.9 present contour plots of the spatial variation of each variable within each block at each site (the same contour plots are presented in three dimensional form in Appendix E). In almost every case the zero isopleth appears near the centre of the block. The direction of deviation from the centre to the edges of the block relative to the proximity of river, ocean, shoreline or river channel, however, differs among sites and blocks. At the Murray River site, Block I shows an increase in shell length and steamed meat weight as one moves toward the ocean edge. Steamed condition indices, however, tend to decrease in the same direction indicating that the relative changes in these variables differ. At Block II the highest values of shell length and steamed meat weight tend to be near the centre of the block and decrease toward both the river and ocean edges. Condition indices, however, tend to increase toward the river edge and decrease toward the ocean edge.

At the Boughton River site the zero isopleth tends to cut diagonally across the blocks from the ocean-river to the river-shoreline corner. Both shell length and steamed meat weight tended to be greater at the river-shoreline and ocean-river channel corners. Steamed condition indices were greatest along the river channel edge.

These results suggest that although there are some evident trends at both sites with respect to the spatial variation of size and condition index, the trends show no consistent relationship to the orientation of mussels with respect to their proximity to ocean, river, shoreline or river channel. In addition, since mussels located within the interior of the blocks show no evidence of lower than average size or condition index, it is doubtful that food shortage was a serious limiting factor during the period this study was carried out, and it is unlikely that the carrying capacity of these systems was being exceeded.

# SHELL LENGTH ( Murray River, Block I )

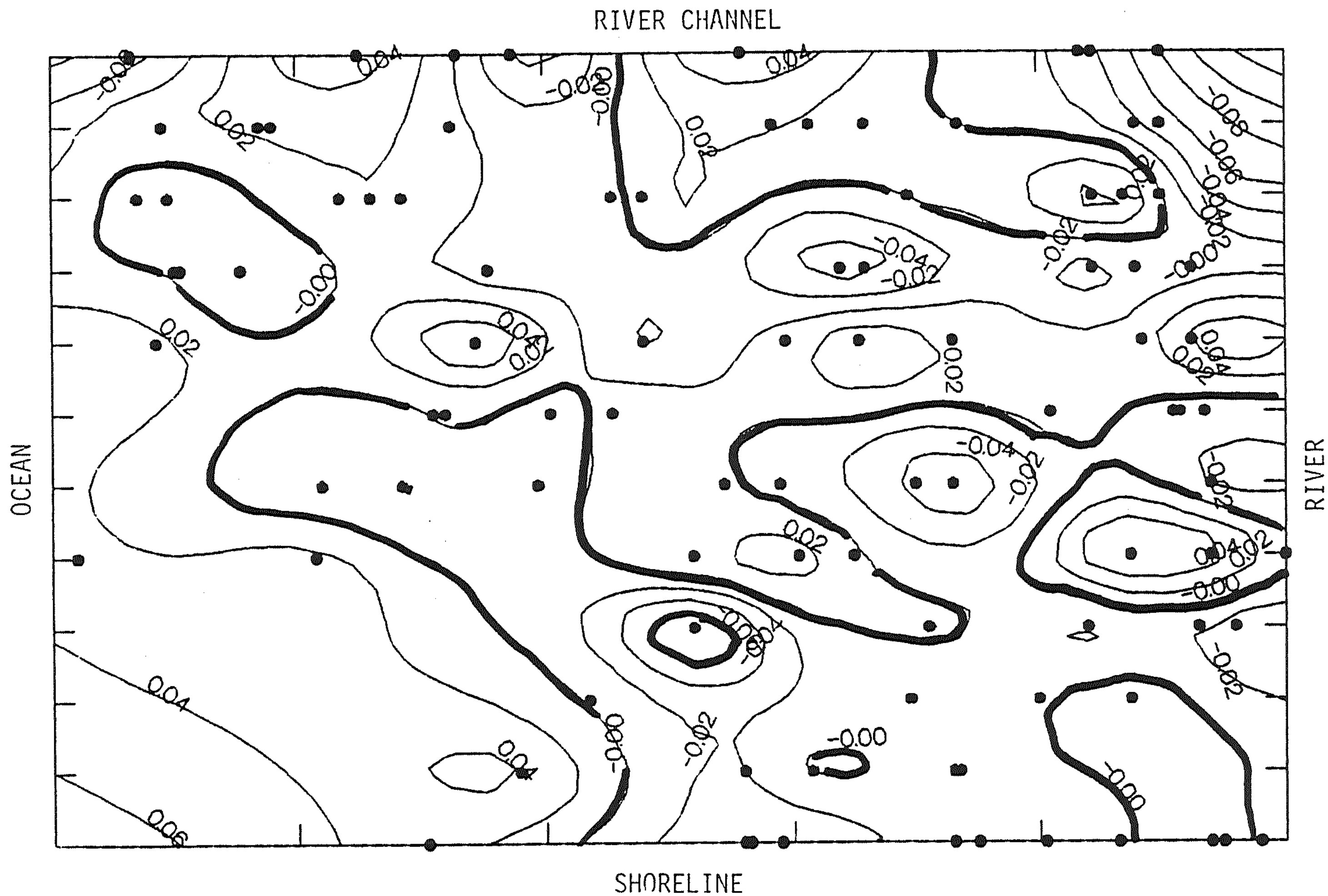



Figure III.5.1. Contour plot of shell length, as deviation from the mean, for Block I at the Murray River site (heavy lines are zero isopleths; filled circles represent the locations from which samples were collected).

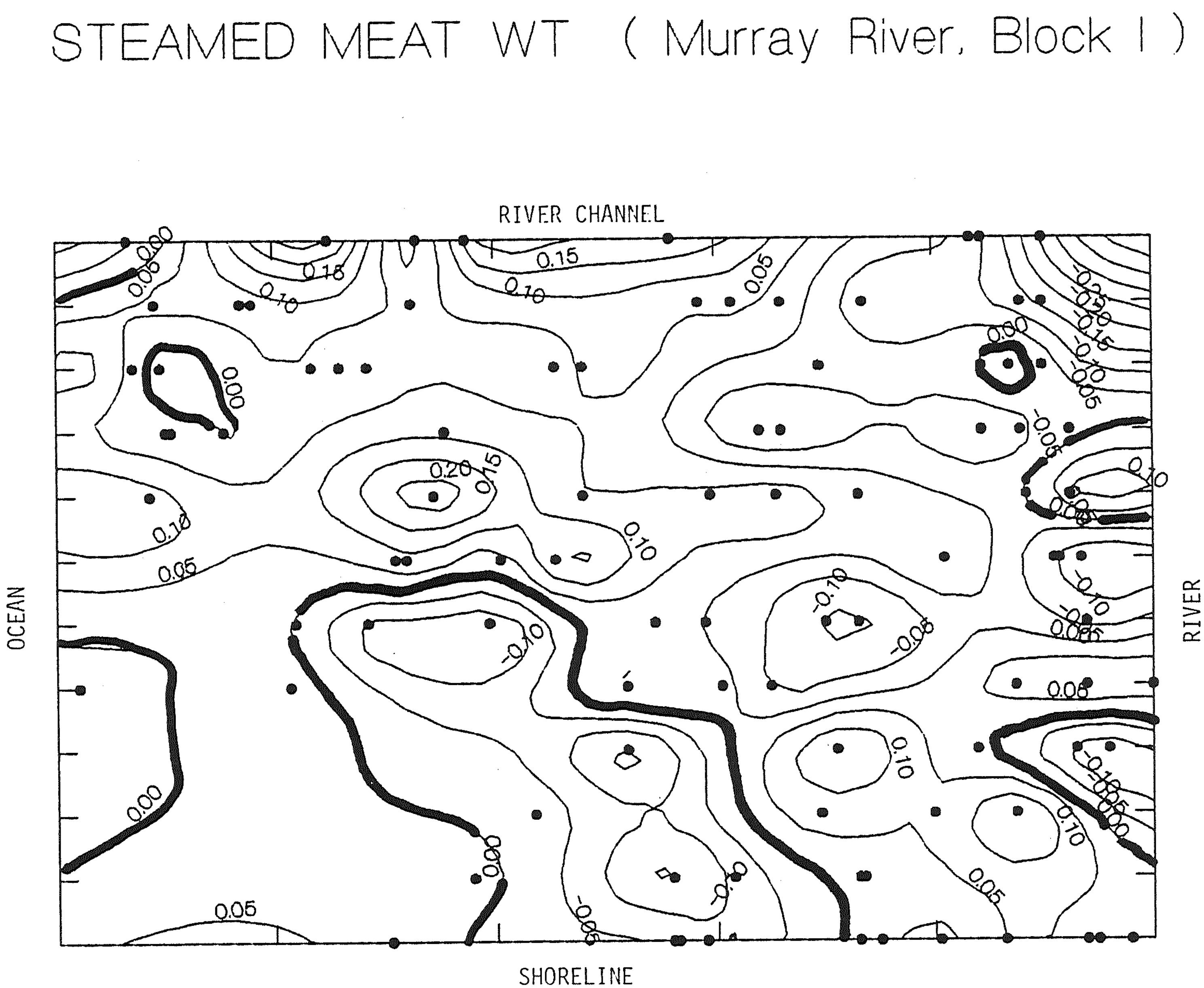



Figure III.5.2. Contour plot of steamed meat weight, as deviation from the mean, for Block I at the Murray River site (heavy lines are zero isopleths; filled circles represent the locations from which samples were collected).

# STEAMED COND INDEX ( Murray River, Block I )

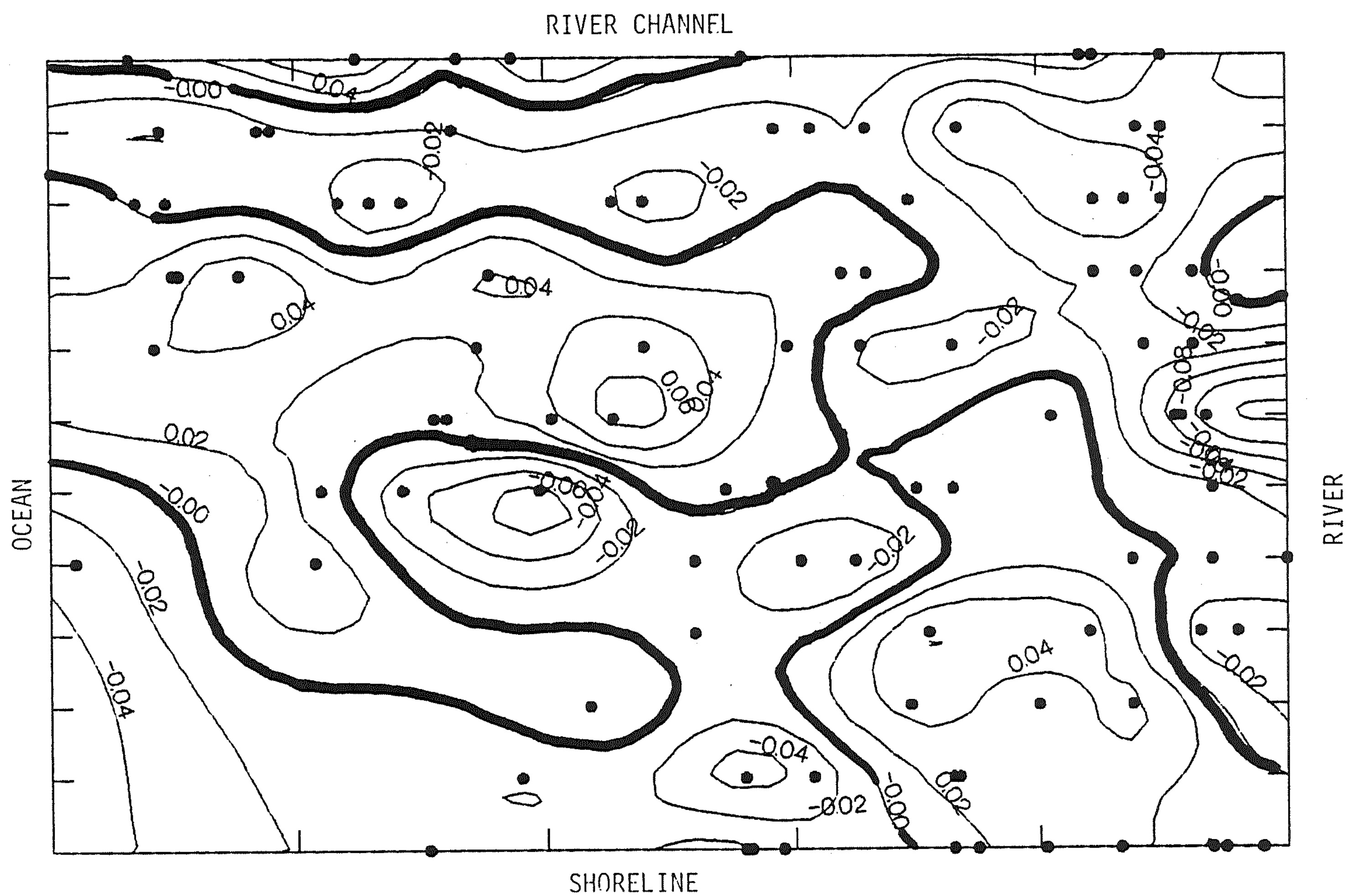



Figure III.5.3. Contour plot of steamed condition index, as deviation from the mean, for Block I at the Murray River site (heavy lines are zero isopleths; filled circles represent the locations from which samples were collected).

# SHELL LENGTH ( Murray River, Block II )

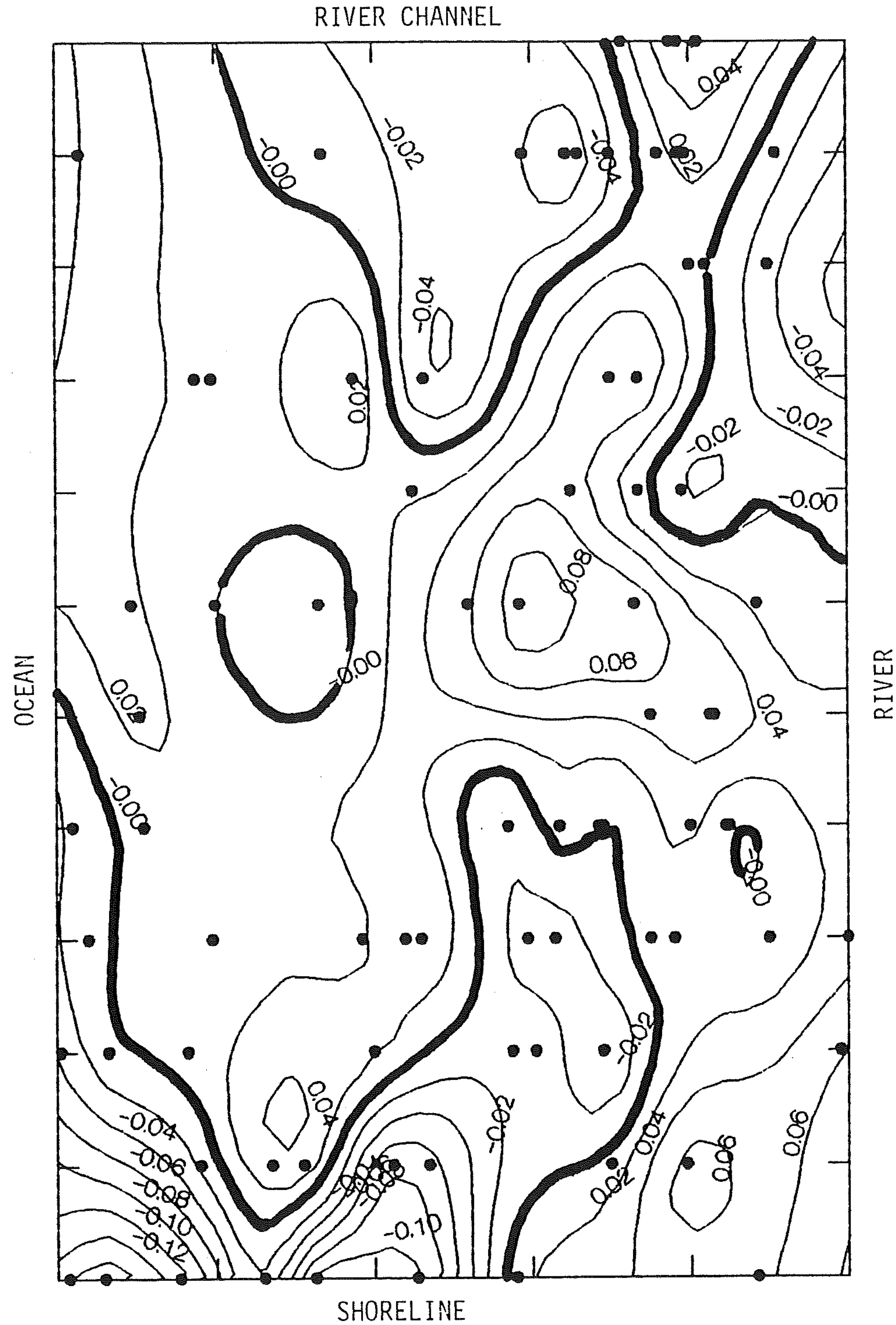



Figure III.5.4. Contour plot of shell length, as deviation from the mean, for Block II at the Murray River site (heavy lines are zero isopleths; filled circles represent the locations from which samples were collected).

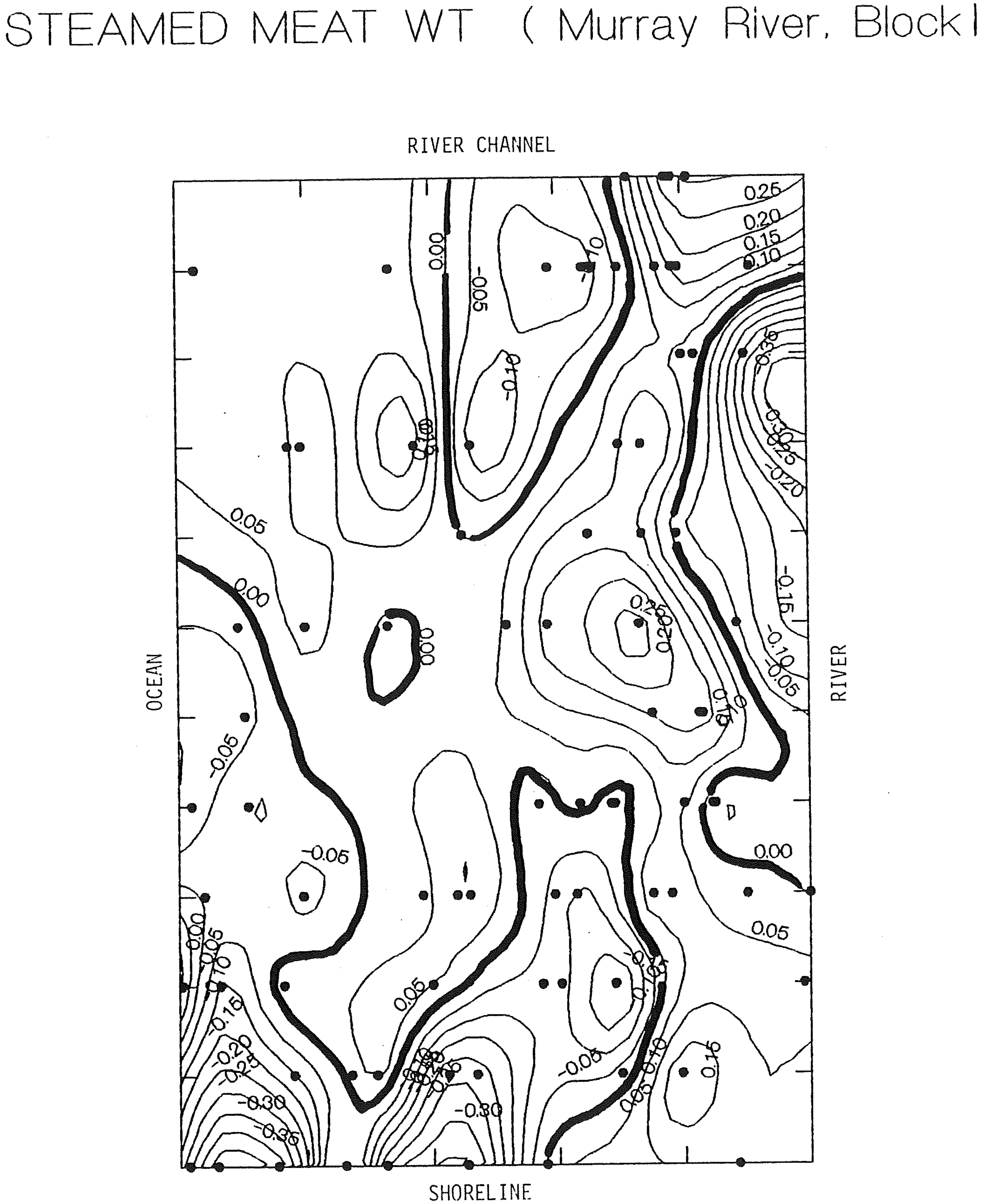



Figure III.5.5. Contour plot of steamed meat weight, as deviation from the mean, for Block II at the Murray River site (heavy lines are zero isopleths; filled circles represent the locations from which samples were collected).

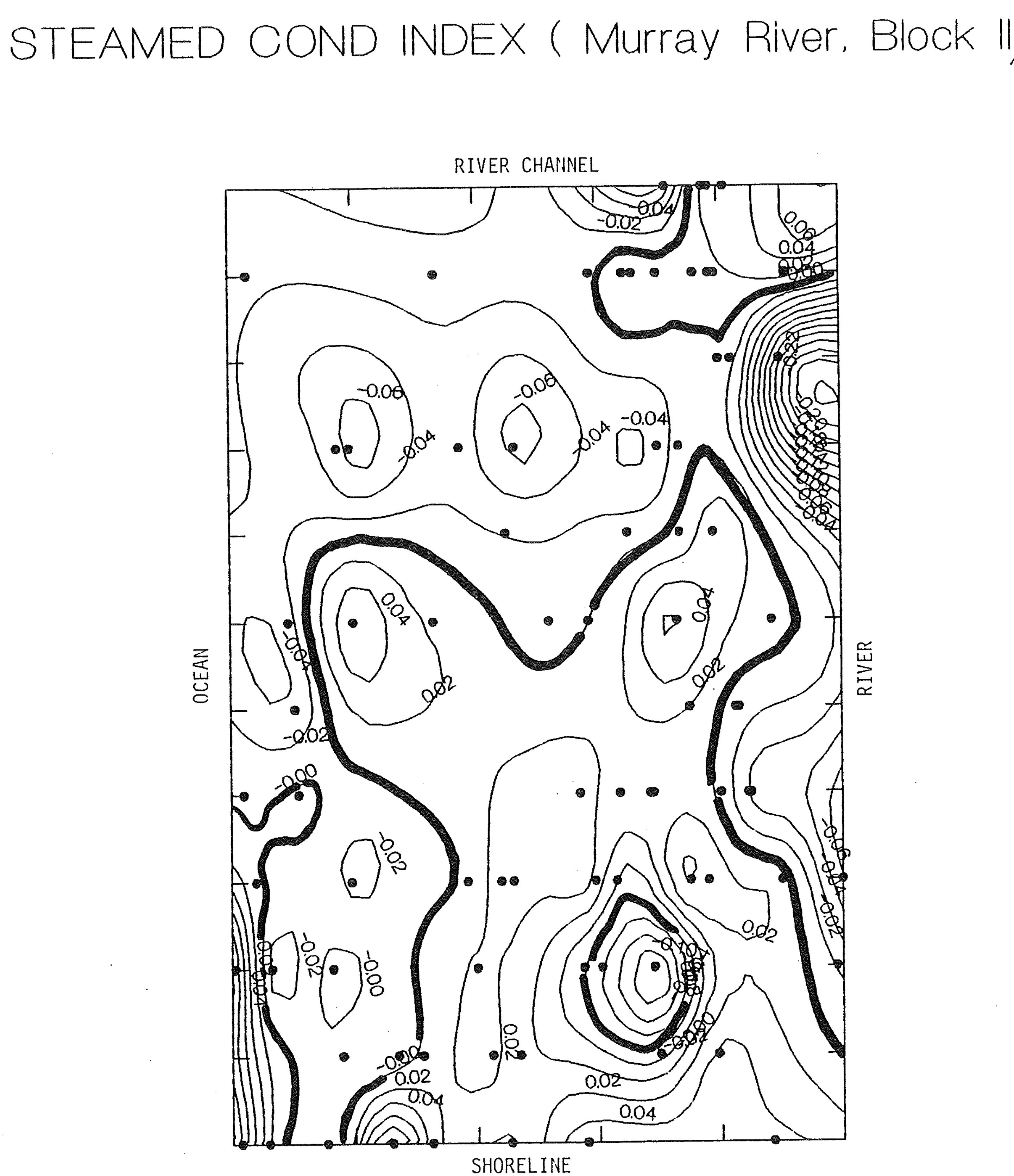



Figure III.5.6. Contour plot of steamed condition index, as deviation from the mean, for Block II at the Murray River site (heavy lines are zero isopleths; filled circles represent the locations from which samples were collected).

# SHELL LENGTH ( Boughton River )

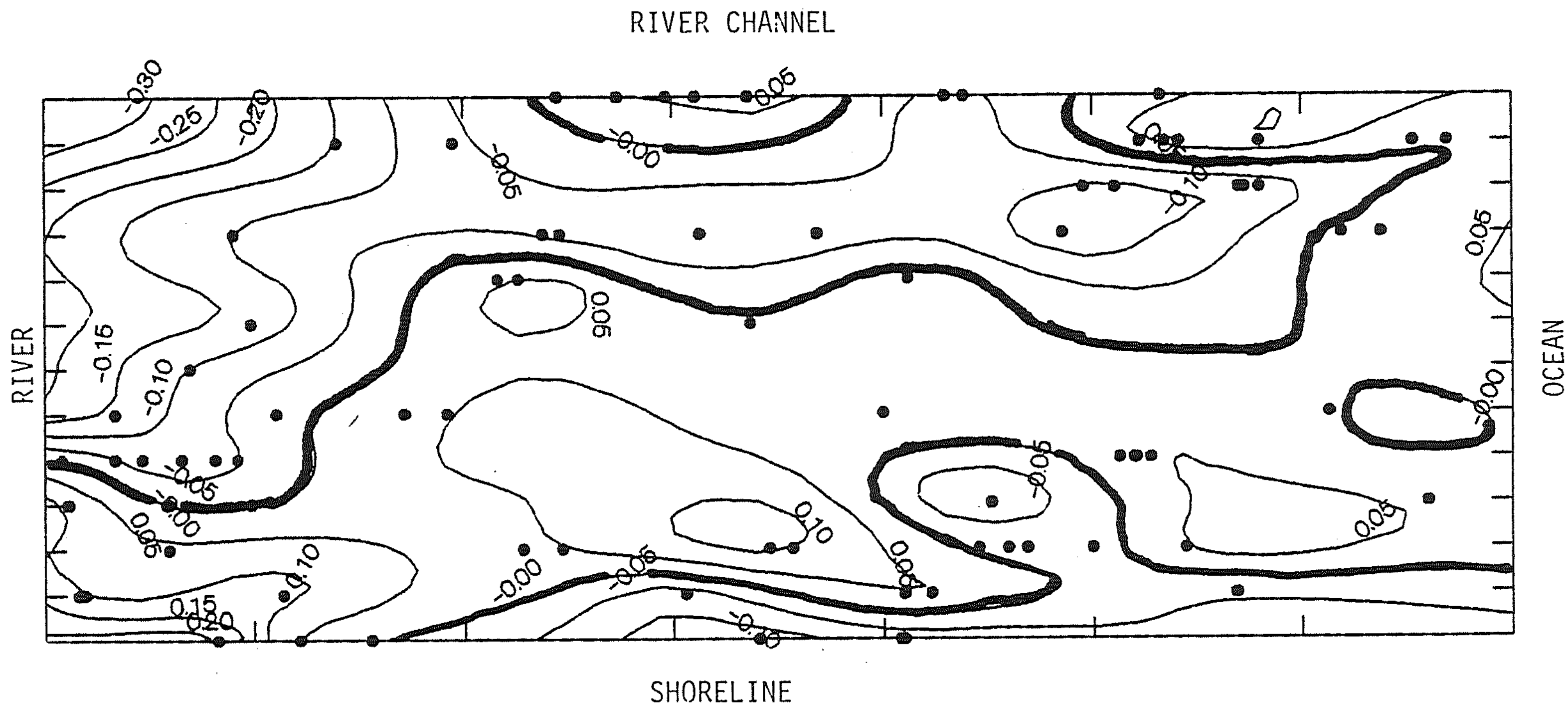



Figure III.5.7. Contour plot of shell length as deviation from the mean for all blocks at the Boughton River site (heavy lines are zero isopleths; filled circles represent the locations from which samples were collected).

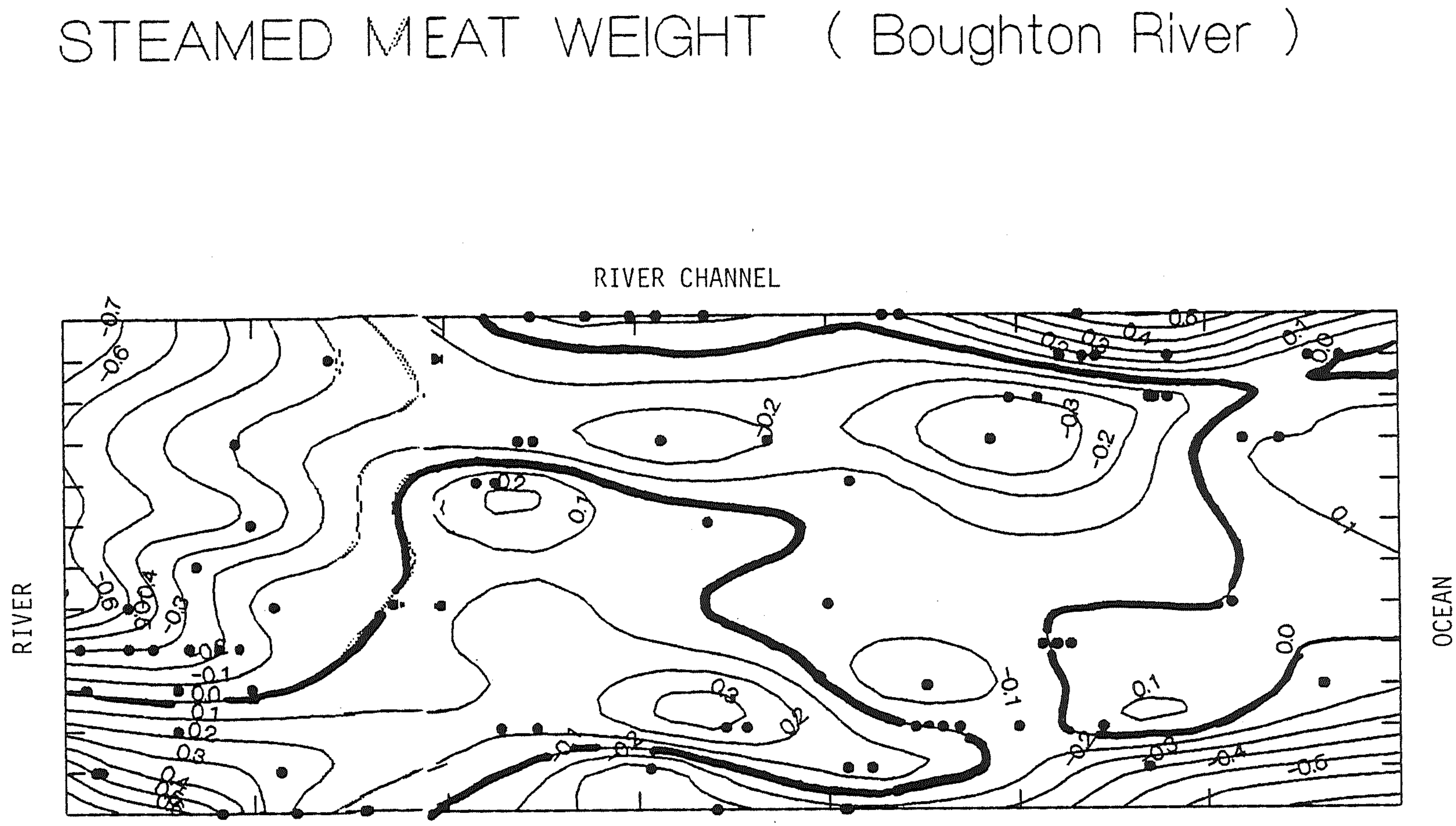



Figure III.5.8. Contour plot of steamed meat weight as deviation from the mean for all blocks at the Boughton River site (heavy lines are zero isopleths; filled circles represent the locations from which samples were collected).

STEAMED COND INDEX ( Boughton River )

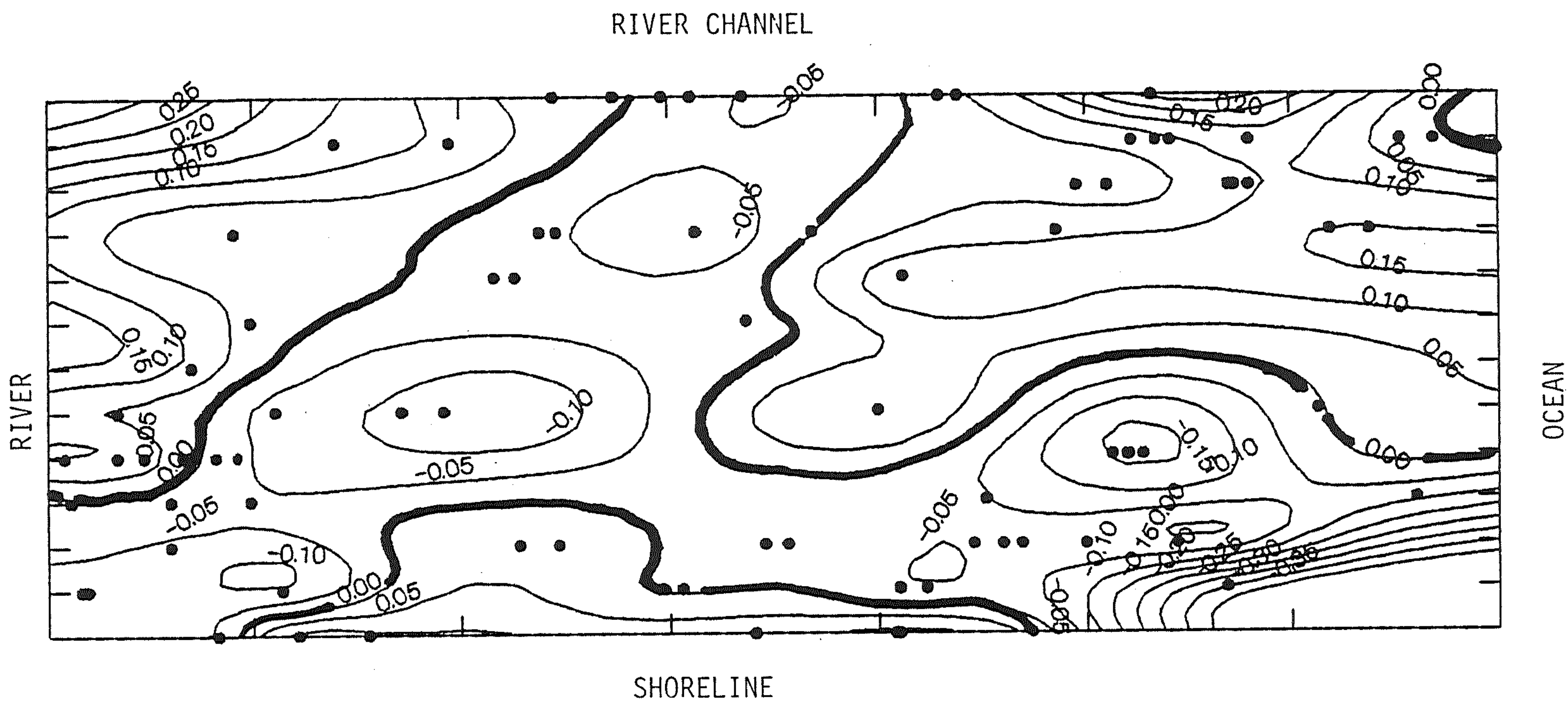



Figure III.5.9. Contour plot of steamed condition index as deviation from the mean for all blocks at the Boughton River site (heavy lines are zero isopleths; filled circles represent the locations from which samples were collected).

## IV. SUMMARY

The overwhelming conclusion that can be drawn from this analysis is that despite potential environmental differences resulting from two different estuarine systems, and operational differences with respect to stocking densities and the spatial configuration of site design, there was a tremendous uniformity, on both temporal and spatial scales, in the performance of mussels as measured by growth characteristics, condition indices and mortality indices.

Although statistically significant differences were noted between sites, the differences were small. Within a particular site the variation was particularly low for almost all variables measured. The greatest variation, both between and within sites, was in the density of mussels (a factor determined by stocking densities and therefore initially under the control of growers), and the proportion of mussels dead. But even in this instance the differences were relatively small.

The observed uniformity of mussel performance within blocks is particularly surprizing since it suggests growth conditions within the interior of a block are no less favorable than near the edges, and that food availability within the interior of a block never reaches levels low enough to limit growth. This implies that competition for food between mussels is not a serious limiting factor and that a higher stocking density could be employed allowing for more intensive culture. It should be noted, however, that the data base did not include any direct measures of food availability and there is no basis for determining if food availability was particularly high or low during the study period. Estuarine systems can vary greatly in food availability on an annual basis, especially with respect to phytoplankton production, and it may be that the uniformity of mussel performance observed in this study applies only during years in which food materials are particularly abundant, and that this may have been the case during the period of this study.

Based on the results of this study it appears that in obtaining representative samples of a cultured mussel population there is little need to be overly concerned with insuring that samples are collected from all areas within an individual mussel block, and indeed it may not even be necessary to insure that all blocks at a particular site are sampled. This conclusion, however, is probably appropriate only under conditions of a non-limiting food resource. Alternatively, determining the uniformity of growth characteristics within or between mussel blocks through a systematic sampling programme could be used as an index of potential food availability and, if it is assumed that any observed differences result solely from differences in the amount of food available, the degree to which a system has reached its carrying capacity.

# APPENDIX A

## Basic Statistics

Table A.1. Basic statistics on data for both sites combined.

| | DAY | JD | BLOCK | LINE | LEVEL | PERCENT | TEMP | SALINITY | DENSITY |
|---|---|---|---|---|---|---|---|---|---|
| N OF CASES | 3515 | 3515 | 3510 | 3510 | 3500 | 3510 | 1355 | 1045 | 2980 |
| MINIMUM | 4.000 | 163.000 | 1.000 | 1.000 | 1.000 | 0.000 | 16.200 | 22.000 | 1.000 |
| MAXIMUM | 30.000 | 308.000 | 7.000 | 27.000 | 3.000 | 97.000 | 21.700 | 27.200 | 31.000 |
| RANGE | 26.000 | 145.000 | 6.000 | 26.000 | 2.000 | 97.000 | 5.500 | 5.200 | 30.000 |
| MEAN | 18.026 | 247.728 | 2.574 | 8.595 | 2.004 | 47.154 | 19.156 | 25.441 | 9.893 |
| VARIANCE | 67.663 | 2604.575 | 2.587 | 35.661 | 0.656 | 823.439 | 2.202 | 0.682 | 9.149 |
| STANDARD DEV | 8.226 | 51.035 | 1.608 | 5.972 | 0.810 | 28.696 | 1.484 | 0.826 | 3.025 |
| STD. ERROR | 0.139 | 0.861 | 0.027 | 0.101 | 0.014 | 0.484 | 0.040 | 0.026 | 0.055 |
| SKEWNESS(G1) | -0.313 | -0.262 | 0.926 | 0.501 | -0.008 | 0.001 | -0.211 | -1.084 | 0.487 |
| KURTOSIS(G2) | -1.082 | -1.608 | -0.035 | -0.677 | -1.475 | -1.216 | -1.065 | 2.059 | 4.158 |
| SUM | 63360.000 | 870765.000 | 9035.000 | 30170.000 | 7015.000 | 165510.000 | 25957.000 | 26586.000 | 29480.000 |
| C.V. | 0.456 | 0.206 | 0.625 | 0.695 | 0.404 | 0.609 | 0.077 | 0.032 | 0.306 |

| | NUMDEAD | PDEAD | TAGNUMBE | LENGTH | WIDTH | STSHWT | DRYSHWT | WETWT | STMWT |
|---|---|---|---|---|---|---|---|---|---|
| N OF CASES | 3125 | 915 | 3515 | 3010 | 2962 | 3003 | 1011 | 2976 | 2944 |
| MINIMUM | 0.000 | 0.000 | 2701.000 | 2.020 | 0.090 | 0.260 | 0.240 | 0.760 | 0.200 |
| MAXIMUM | 12.000 | 1.000 | 932910.000 | 8.090 | 4.930 | 17.050 | 16.250 | 45.270 | 12.840 |
| RANGE | 12.000 | 1.000 | 930209.000 | 6.070 | 4.840 | 16.790 | 16.010 | 44.510 | 12.640 |
| MEAN | 0.202 | 0.029 | 343684.697 | 5.016 | 1.834 | 3.711 | 3.144 | 11.342 | 3.187 |
| VARIANCE | 0.488 | 0.009 | .901131E+11 | 0.685 | 0.109 | 4.109 | 4.842 | 32.253 | 2.907 |
| STANDARD DEV | 0.698 | 0.092 | 300188.517 | 0.828 | 0.331 | 2.027 | 2.200 | 5.679 | 1.705 |
| STD. ERROR | 0.012 | 0.003 | 5063.274 | 0.015 | 0.006 | 0.037 | 0.069 | 0.104 | 0.031 |
| SKEWNESS(G1) | 9.239 | 7.093 | 0.710 | 0.000 | 0.473 | 1.421 | 1.793 | 0.980 | 1.064 |
| KURTOSIS(G2) | 134.519 | 66.181 | -0.356 | -0.323 | 3.126 | 4.132 | 4.617 | 2.058 | 1.371 |
| SUM | 630.000 | 26.241 | .120805E+10 | 15096.670 | 5432.930 | 11143.160 | 3178.760 | 33752.760 | 9383.160 |
| C.V. | 3.463 | 3.222 | 0.873 | 0.165 | 0.180 | 0.546 | 0.700 | 0.501 | 0.535 |

| | DRYMWT | STCI | DRYCI |
|---|---|---|---|
| N OF CASES | 983 | 2939 | 979 |
| MINIMUM | 0.020 | 11.618 | 4.950 |
| MAXIMUM | 2.100 | 74.516 | 40.642 |
| RANGE | 2.080 | 62.898 | 35.691 |
| MEAN | 0.554 | 46.318 | 16.614 |
| VARIANCE | 0.090 | 58.276 | 27.036 |
| STANDARD DEV | 0.300 | 7.634 | 5.200 |
| STD. ERROR | 0.010 | 0.141 | 0.166 |
| SKEWNESS(G1) | 1.389 | -0.409 | 0.242 |
| KURTOSIS(G2) | 2.181 | 0.763 | -0.293 |
| SUM | 544.139 | 136127.674 | 16265.061 |
| C.V. | 0.542 | 0.165 | 0.313 |

Table A.2. Basic statistics on data for the Murray River site.

| | DAY | JD | BLOCK | LINE | LEVEL | PERCENT | TEMP | SALINITY | DENSITY |
|---|---|---|---|---|---|---|---|---|---|
| N OF CASES | 2560 | 2560 | 2555 | 2555 | 2545 | 2555 | 885 | 710 | 2265 |
| MINIMUM | 4.000 | 163.000 | 1.000 | 1.000 | 1.000 | 0.000 | 16.200 | 24.000 | 1.000 |
| MAXIMUM | 30.000 | 308.000 | 4.000 | 27.000 | 3.000 | 97.000 | 21.300 | 27.000 | 31.000 |
| RANGE | 26.000 | 145.000 | 3.000 | 26.000 | 2.000 | 97.000 | 5.100 | 3.000 | 30.000 |
| MEAN | 17.443 | 246.971 | 2.018 | 8.575 | 1.931 | 45.779 | 18.553 | 25.585 | 10.428 |
| VARIANCE | 82.283 | 2919.751 | 1.043 | 39.998 | 0.626 | 816.304 | 2.003 | 0.351 | 8.041 |
| STANDARD DEV | 9.071 | 54.035 | 1.021 | 6.324 | 0.791 | 28.571 | 1.415 | 0.592 | 2.836 |
| STD. ERROR | 0.179 | 1.068 | 0.020 | 0.125 | 0.016 | 0.565 | 0.048 | 0.022 | 0.060 |
| SKEWNESS(G1) | -0.235 | -0.278 | 0.660 | 0.598 | 0.123 | 0.097 | 0.304 | 0.133 | 0.902 |
| KURTOSIS(G2) | -1.456 | -1.646 | -0.727 | -0.700 | -1.393 | -1.202 | -1.031 | -0.343 | 6.221 |
| SUM | 44655.000 | 632245.000 | 5155.000 | 21910.000 | 4915.000 | 116965.000 | 16419.000 | 18165.000 | 23620.000 |
| C.V. | 0.520 | 0.219 | 0.506 | 0.738 | 0.410 | 0.624 | 0.076 | 0.023 | 0.272 |

| | NUMDEAD | PDEAD | TAGNUMBE | LENGTH | WIDTH | STSHWT | DRYSHWT | WETWT | STMWT |
|---|---|---|---|---|---|---|---|---|---|
| N OF CASES | 2365 | 618 | 2560 | 2330 | 2333 | 2330 | 682 | 2297 | 2310 |
| MINIMUM | 0.000 | 0.000 | 2701.000 | 2.540 | 0.090 | 0.450 | 0.410 | 0.760 | 0.330 |
| MAXIMUM | 12.000 | 1.000 | 932910.000 | 7.490 | 4.930 | 10.100 | 8.320 | 31.780 | 10.970 |
| RANGE | 12.000 | 1.000 | 930209.000 | 4.950 | 4.840 | 9.650 | 7.910 | 31.020 | 10.640 |
| MEAN | 0.135 | 0.023 | 340288.895 | 4.964 | 1.819 | 3.323 | 2.524 | 10.808 | 3.140 |
| VARIANCE | 0.417 | 0.010 | .123214E+12 | 0.634 | 0.102 | 2.503 | 2.377 | 25.022 | 2.555 |
| STANDARD DEV | 0.646 | 0.098 | 351018.637 | 0.796 | 0.320 | 1.582 | 1.542 | 5.002 | 1.598 |
| STD. ERROR | 0.013 | 0.004 | 6937.615 | 0.016 | 0.007 | 0.033 | 0.059 | 0.104 | 0.033 |
| SKEWNESS(G1) | 13.562 | 8.229 | 0.633 | -0.086 | 0.465 | 0.592 | 1.191 | 0.497 | 0.884 |
| KURTOSIS(G2) | 238.710 | 77.046 | -1.043 | -0.685 | 4.087 | -0.203 | 0.587 | -0.338 | 0.538 |
| SUM | 320.000 | 14.375 | .871140E+09 | 11566.280 | 4244.590 | 7742.720 | 1721.340 | 24824.960 | 7252.980 |
| C.V. | 4.775 | 4.221 | 1.032 | 0.160 | 0.176 | 0.476 | 0.611 | 0.463 | 0.509 |

| | DRYMWT | STCI | DRYCI |
|---|---|---|---|
| N OF CASES | 674 | 2305 | 673 |
| MINIMUM | 0.090 | 16.098 | 8.095 |
| MAXIMUM | 1.690 | 74.516 | 40.642 |
| RANGE | 1.600 | 58.419 | 32.546 |
| MEAN | 0.551 | 48.253 | 18.899 |
| VARIANCE | 0.081 | 38.448 | 17.997 |
| STANDARD DEV | 0.285 | 6.201 | 4.242 |
| STD. ERROR | 0.011 | 0.129 | 0.164 |
| SKEWNESS(G1) | 1.254 | 0.062 | 0.394 |
| KURTOSIS(G2) | 1.374 | 0.753 | 0.273 |
| SUM | 371.639 | 111224.140 | 12718.803 |
| C.V. | 0.516 | 0.129 | 0.224 |

Table A.3. Basic statistics on data for the Boughton River site.

| | DAY | JD | BLOCK | LINE | LEVEL | PERCENT | TEMP | SALINITY | DENSITY |
|---|---|---|---|---|---|---|---|---|---|
| N OF CASES | 955 | 955 | 955 | 955 | 955 | 955 | 470 | 335 | 715 |
| MINIMUM | 13.000 | 197.000 | 1.000 | 1.000 | 1.000 | 0.000 | 18.800 | 22.000 | 1.000 |
| MAXIMUM | 30.000 | 293.000 | 7.000 | 17.000 | 3.000 | 94.000 | 21.700 | 27.200 | 16.000 |
| RANGE | 17.000 | 96.000 | 6.000 | 16.000 | 2.000 | 94.000 | 2.900 | 5.200 | 15.000 |
| MEAN | 19.586 | 249.759 | 4.063 | 8.649 | 2.199 | 50.832 | 20.294 | 25.137 | 8.196 |
| VARIANCE | 25.169 | 1756.210 | 3.675 | 24.085 | 0.684 | 824.794 | 0.598 | 1.251 | 8.883 |
| STANDARD DEV | 5.017 | 41.907 | 1.917 | 4.908 | 0.827 | 28.719 | 0.773 | 1.119 | 2.980 |
| STD. ERROR | 0.162 | 1.356 | 0.062 | 0.159 | 0.027 | 0.929 | 0.036 | 0.061 | 0.111 |
| SKEWNESS(G1) | 0.732 | -0.052 | -0.326 | -0.083 | -0.384 | -0.256 | 0.277 | -0.804 | -0.011 |
| KURTOSIS(G2) | -0.132 | -1.891 | -1.148 | -1.183 | -1.432 | -1.128 | -1.017 | -0.142 | 0.324 |
| SUM | 18705.000 | 238520.000 | 3880.000 | 8260.000 | 2100.000 | 48545.000 | 9538.000 | 8421.000 | 5860.000 |
| C.V. | 0.256 | 0.168 | 0.472 | 0.567 | 0.376 | 0.565 | 0.038 | 0.045 | 0.364 |

| | NUMDEAD | PDEAD | TAGNUMBE | LENGTH | WIDTH | STSHWT | DRYSHWT | WETWT | STMWT |
|---|---|---|---|---|---|---|---|---|---|
| N OF CASES | 760 | 297 | 955 | 680 | 629 | 673 | 329 | 679 | 634 |
| MINIMUM | 0.000 | 0.000 | 350002.000 | 2.020 | 0.690 | 0.260 | 0.240 | 0.770 | 0.200 |
| MAXIMUM | 5.000 | 0.400 | 850259.000 | 8.090 | 3.350 | 17.050 | 16.250 | 45.270 | 12.840 |
| RANGE | 5.000 | 0.400 | 500257.000 | 6.070 | 2.660 | 16.790 | 16.010 | 44.500 | 12.640 |
| MEAN | 0.408 | 0.040 | 352787.581 | 5.192 | 1.889 | 5.053 | 4.430 | 13.148 | 3.360 |
| VARIANCE | 0.650 | 0.006 | .130409E+10 | 0.820 | 0.132 | 7.357 | 7.516 | 52.552 | 4.160 |
| STANDARD DEV | 0.806 | 0.078 | 36112.175 | 0.906 | 0.364 | 2.712 | 2.741 | 7.249 | 2.040 |
| STD. ERROR | 0.029 | 0.005 | 1168.563 | 0.035 | 0.014 | 0.105 | 0.151 | 0.278 | 0.081 |
| SKEWNESS(G1) | 2.676 | 2.477 | 13.708 | 0.063 | 0.398 | 1.153 | 1.375 | 1.110 | 1.242 |
| KURTOSIS(G2) | 8.948 | 7.034 | 185.945 | 0.155 | 0.819 | 2.101 | 2.245 | 1.950 | 1.738 |
| SUM | 310.000 | 11.867 | .336912E+09 | 3530.390 | 1188.340 | 3400.440 | 1457.420 | 8927.800 | 2130.180 |
| C.V. | 1.977 | 1.952 | 0.102 | 0.174 | 0.192 | 0.537 | 0.619 | 0.551 | 0.607 |

| | DRYMWT | STCI | DRYCI |
|---|---|---|---|
| N OF CASES | 309 | 634 | 306 |
| MINIMUM | 0.020 | 11.618 | 4.950 |
| MAXIMUM | 2.100 | 73.511 | 25.455 |
| RANGE | 2.080 | 61.893 | 20.504 |
| MEAN | 0.558 | 39.280 | 11.589 |
| VARIANCE | 0.110 | 67.288 | 10.191 |
| STANDARD DEV | 0.332 | 8.203 | 3.192 |
| STD. ERROR | 0.019 | 0.326 | 0.182 |
| SKEWNESS(G1) | 1.538 | 0.058 | 0.789 |
| KURTOSIS(G2) | 2.850 | 0.085 | 1.151 |
| SUM | 172.500 | 24903.534 | 3546.257 |
| C.V. | 0.595 | 0.209 | 0.275 |

# APPENDIX B

Variations in shell length with time for each block at each site

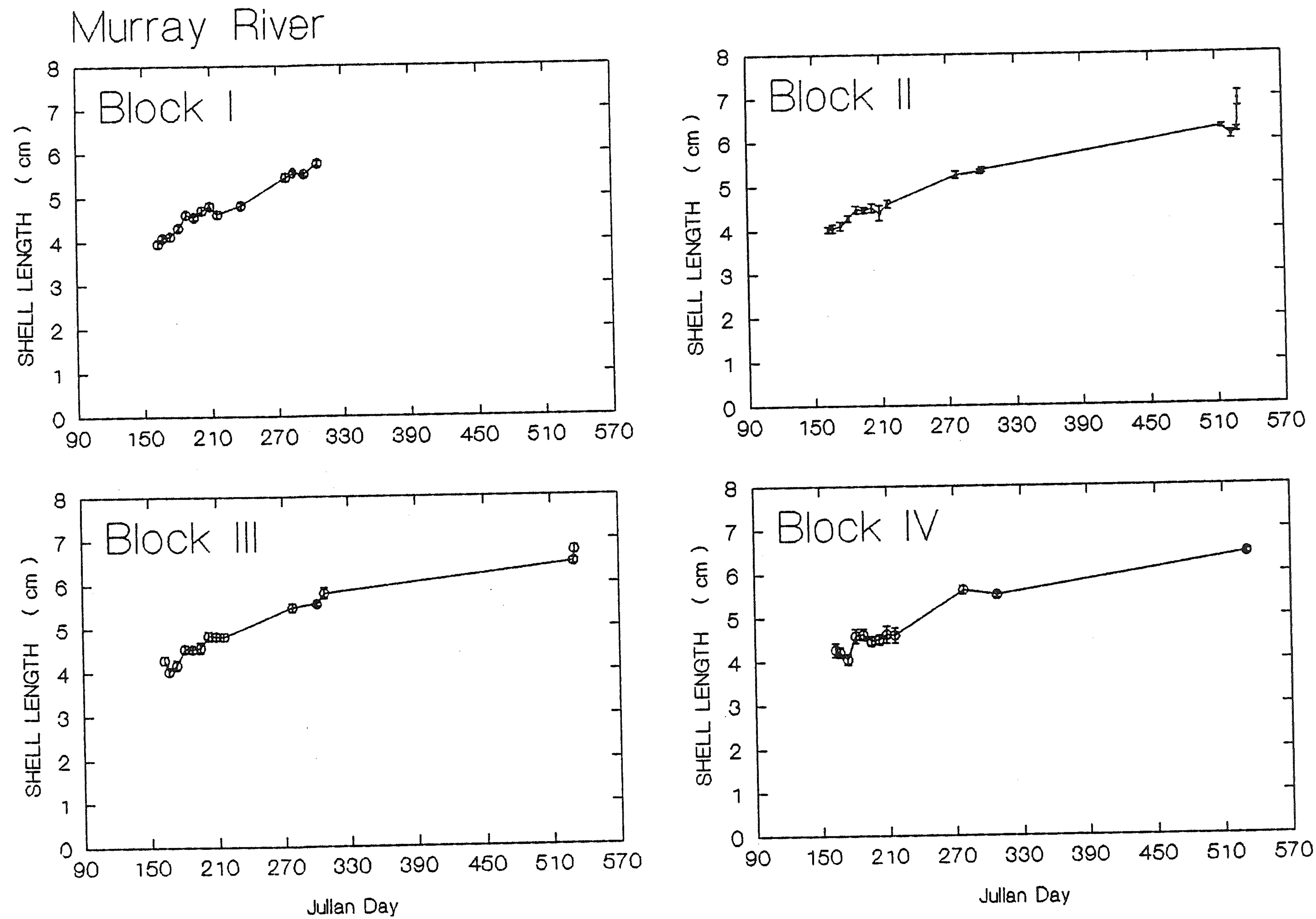



Figure B.1. Time series of shell length for each block at the Murray River site (error bars are one standard error of the mean).

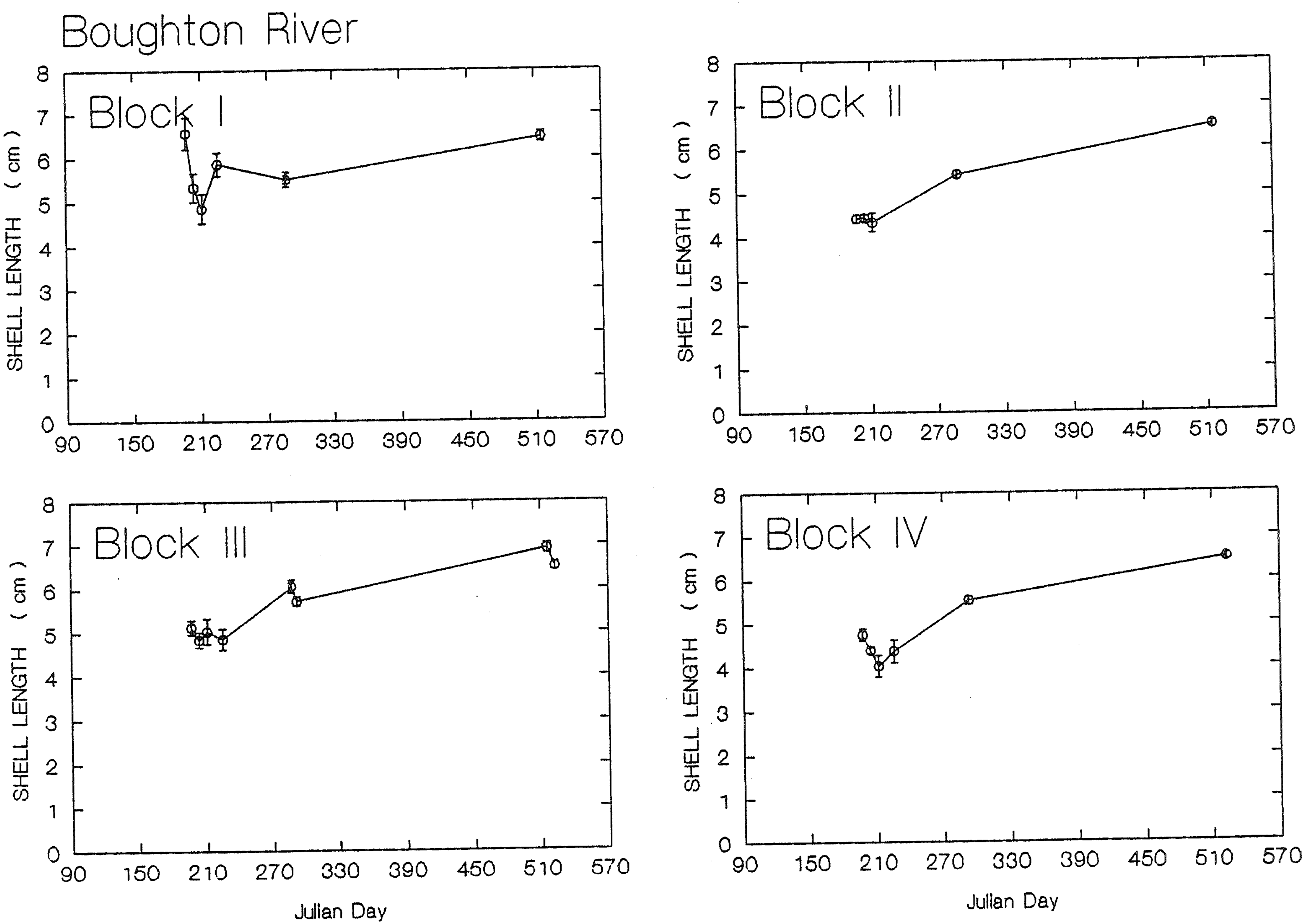



Figure B.2. Time series of shell length for each block at the Boughton River site (error bars are one standard error of the mean).

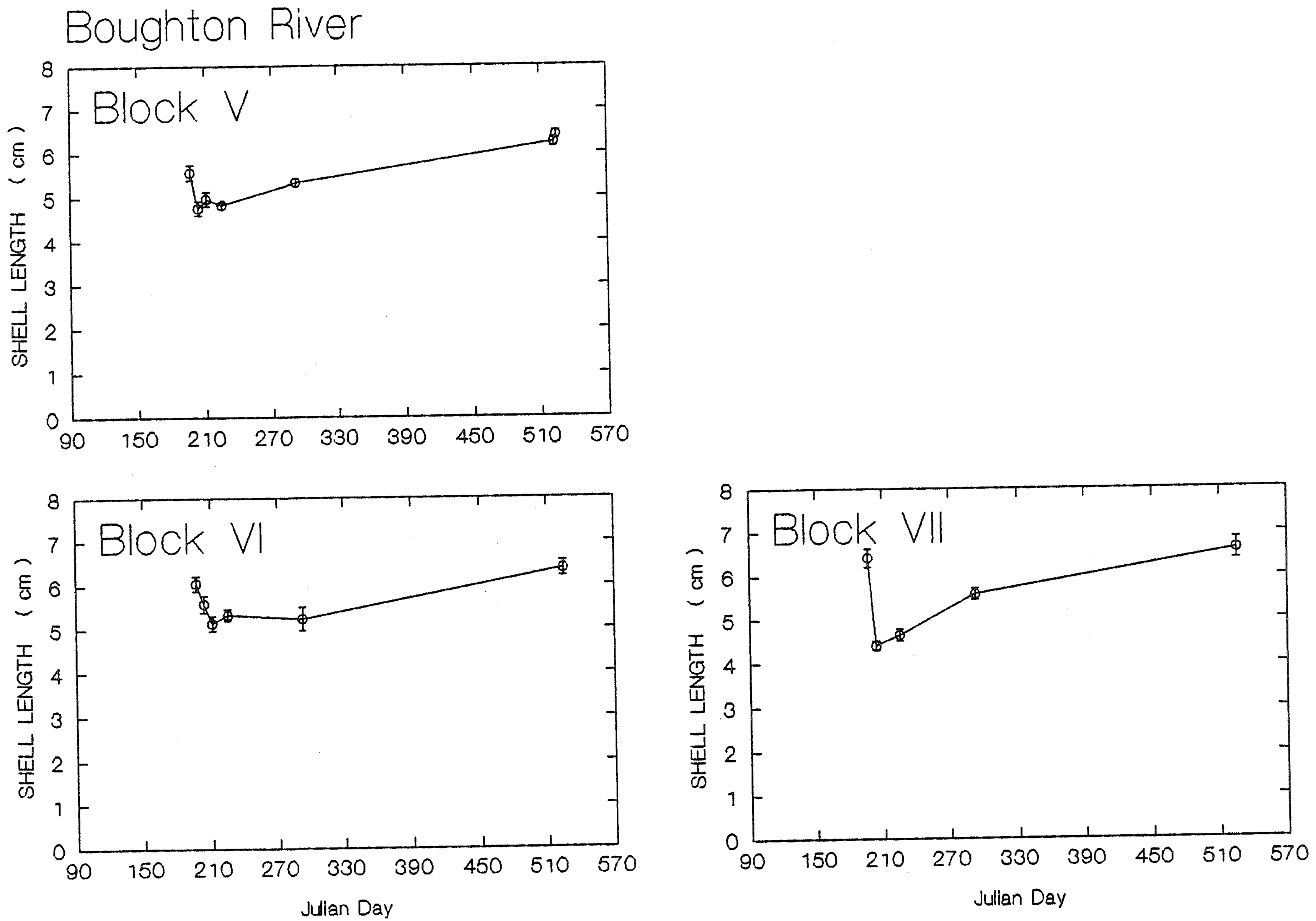



Figure B.2. Continued.

# APPENDIX C

Variations in steamed meat weight with time for each block at each site

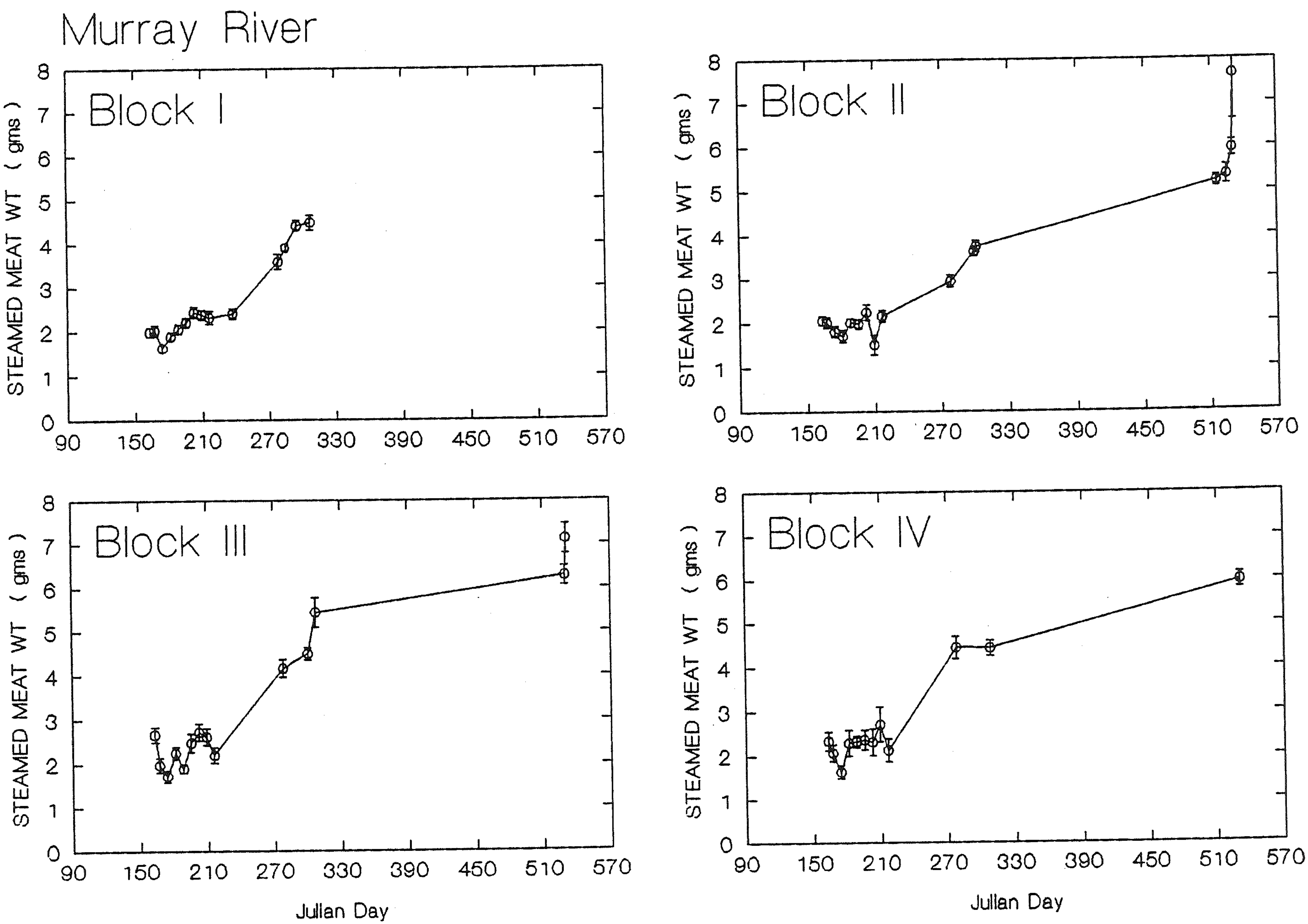



Figure C.1. Time series of steamed meat weight at each block for the Murray River site (error bars are one standard error of the mean).

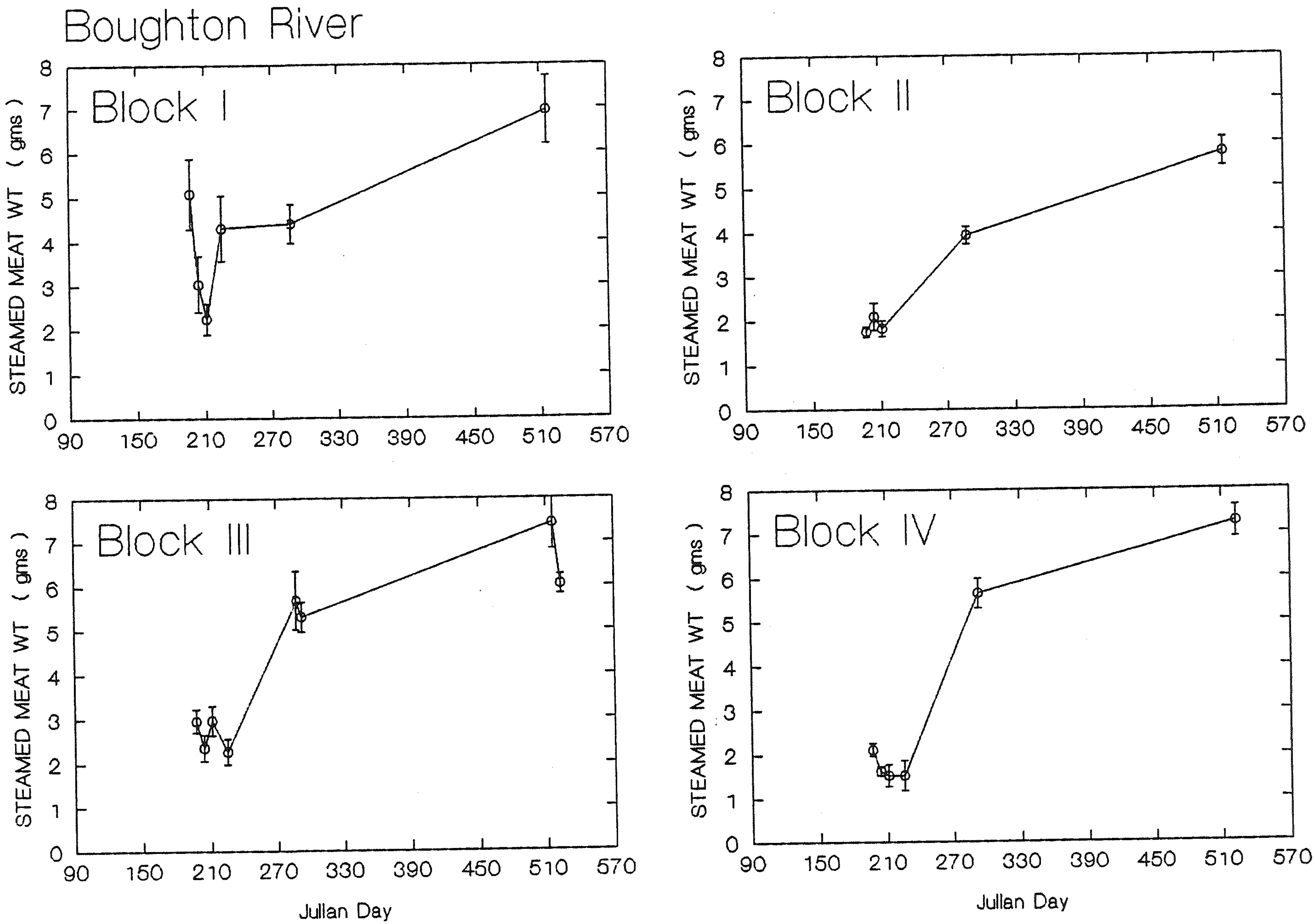



Figure C.2. Time series of steamed meat weight at each block for the Boughton River site (error bars are one standard error of the mean).

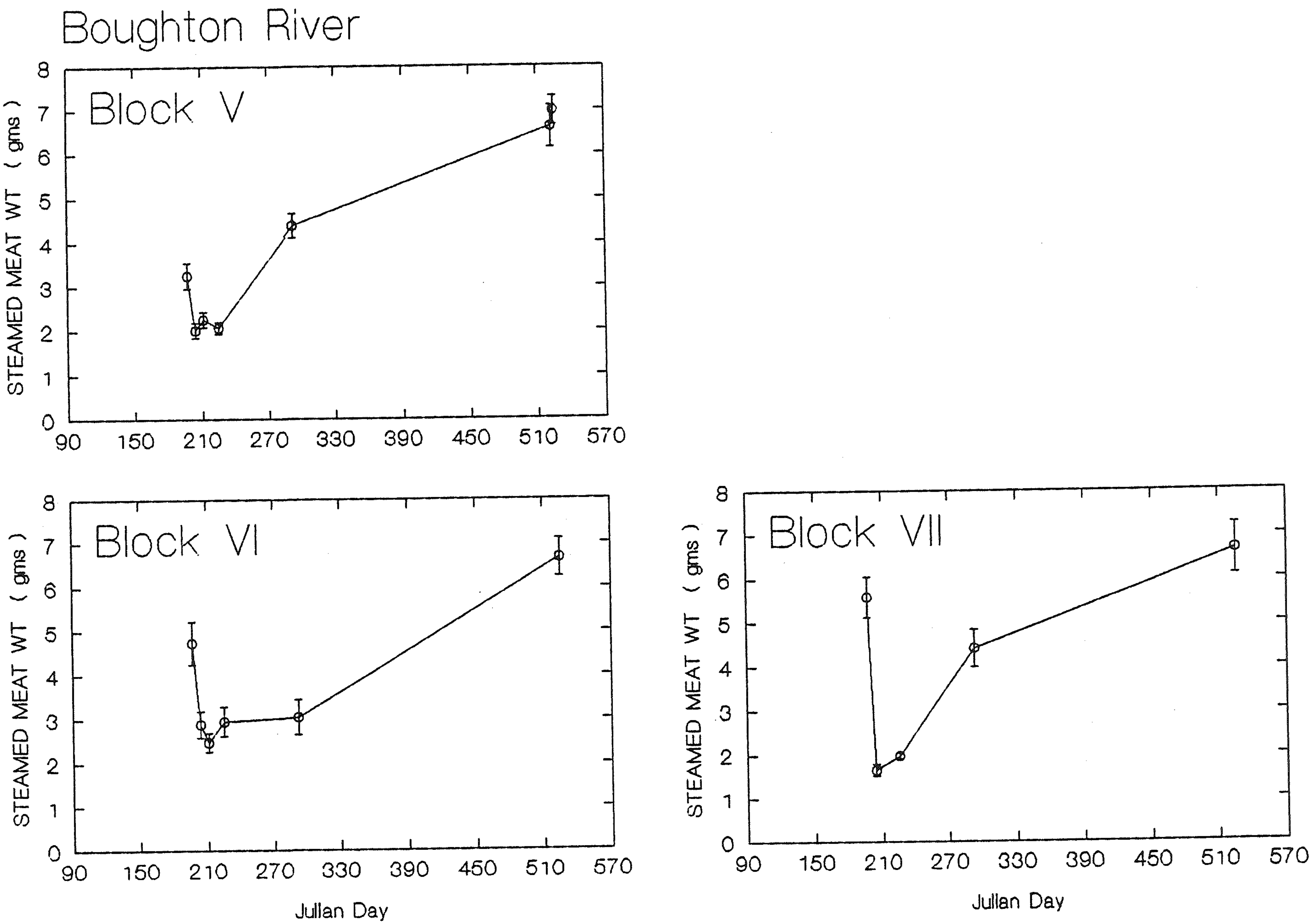



Figure C.2. Continued.

# APPENDIX D

Variations in steamed condition index with time for each block at each site

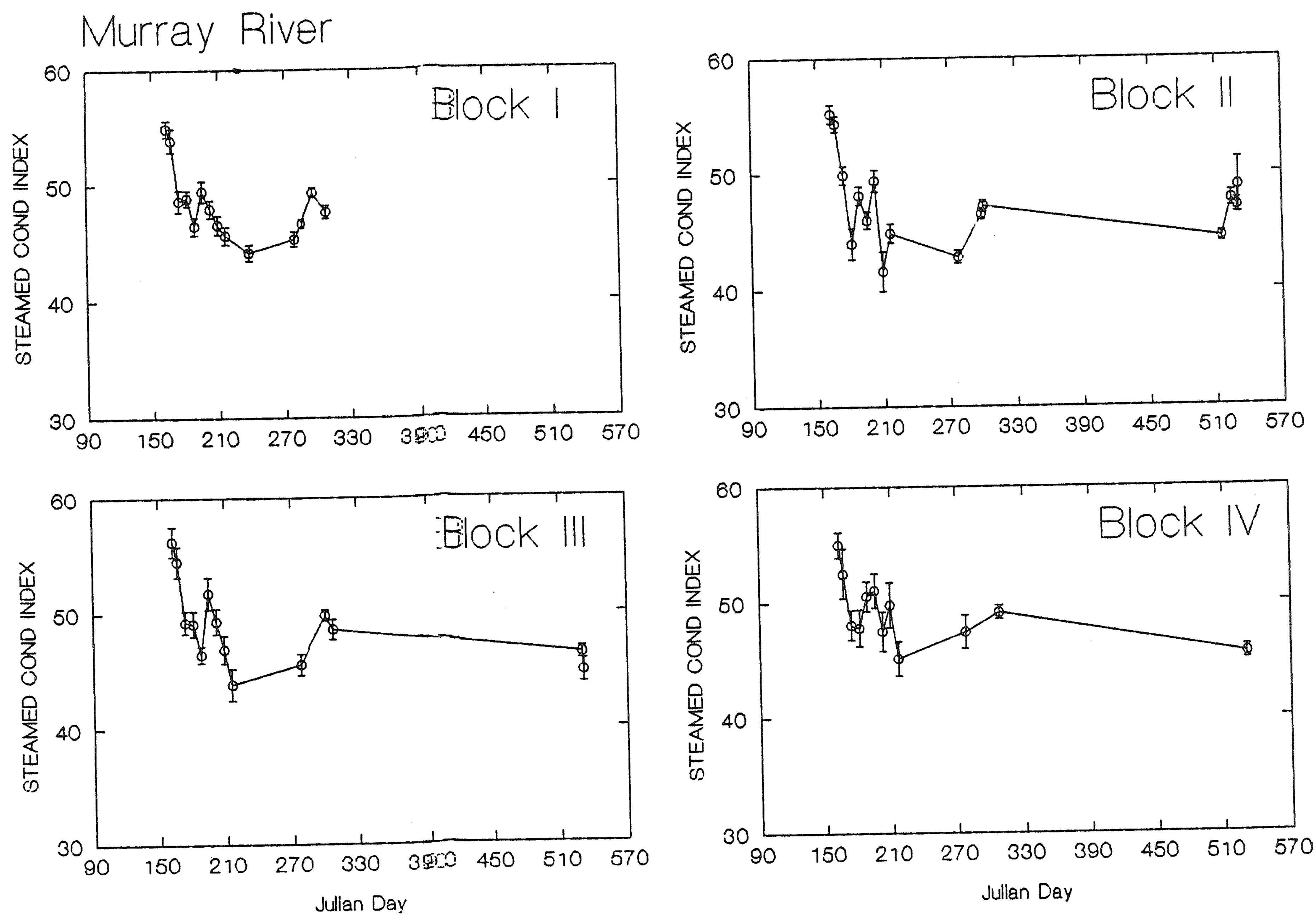



Figure D.1. Time series of steamed condition index for each block at the Murray River site (error bars are one standard error of the mean).

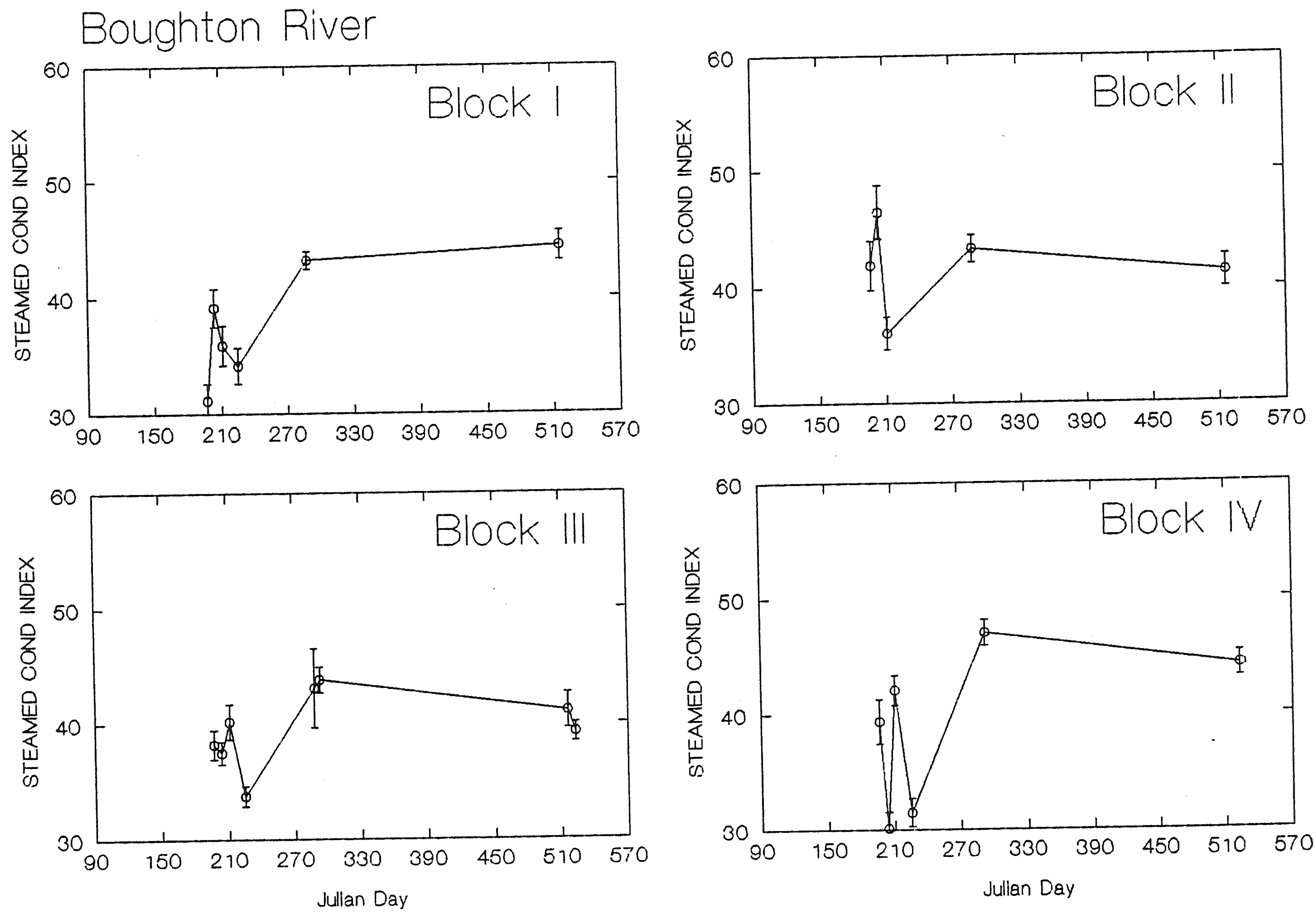



Figure D.2. Time series of steamed condition index for each block at the Boughton River site (error bars are one standard error of the mean).

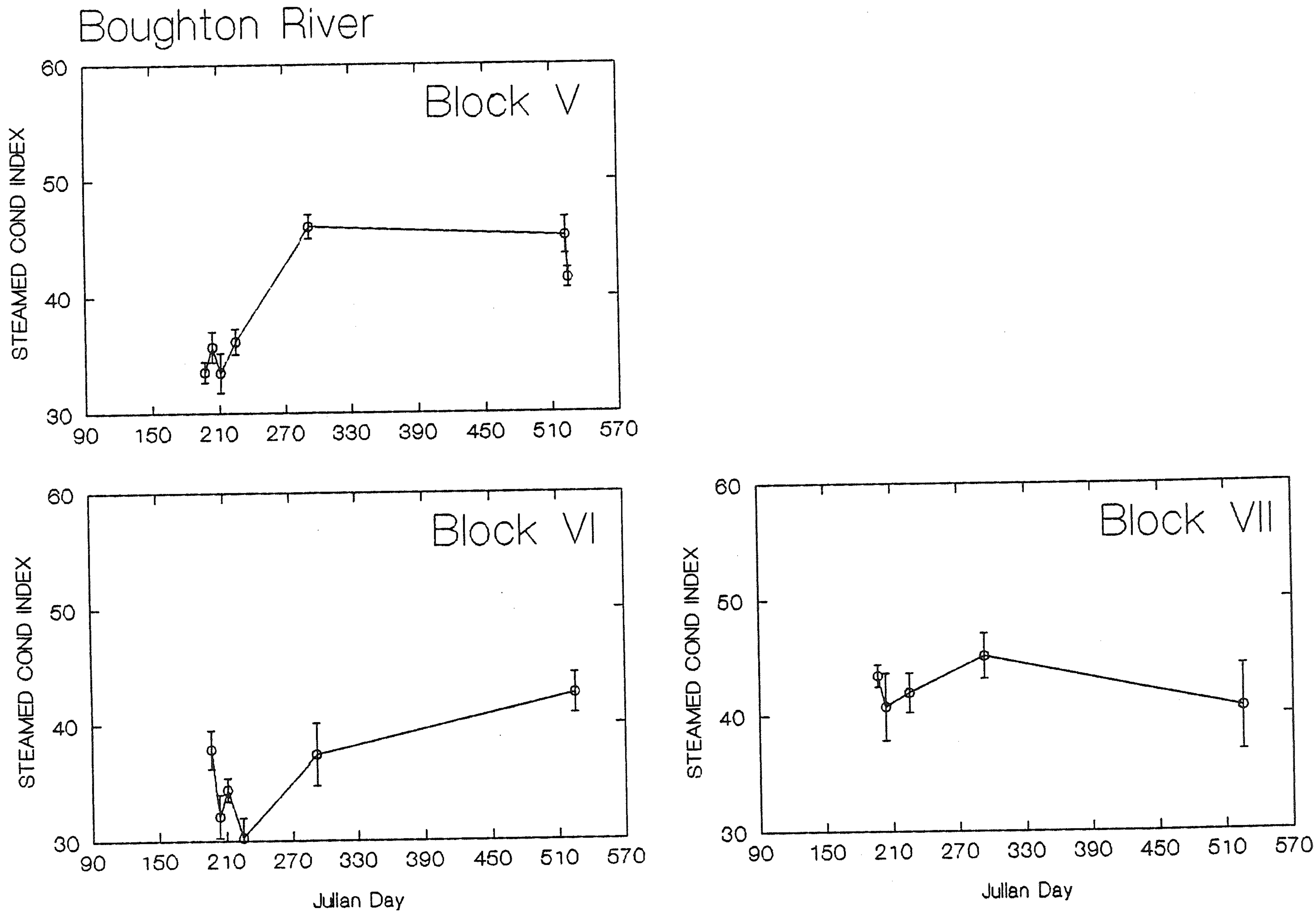



Figure D.2.  Continued.

# APPENDIX E

Contour plots of variations within blocks at each site

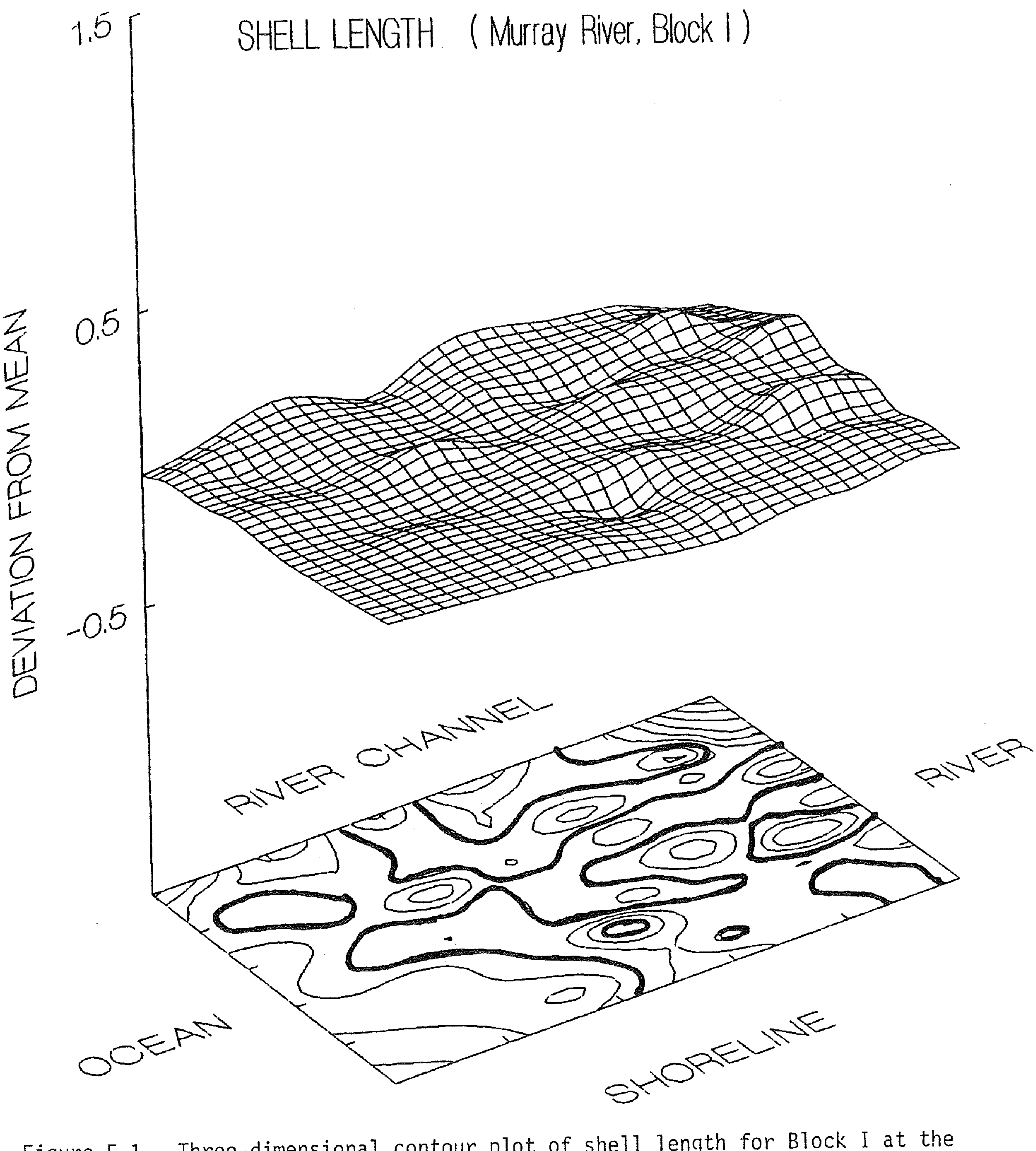



Figure E.1. Three-dimensional contour plot of shell length for Block I at the Murray River site (heavy lines are zero isopleths).

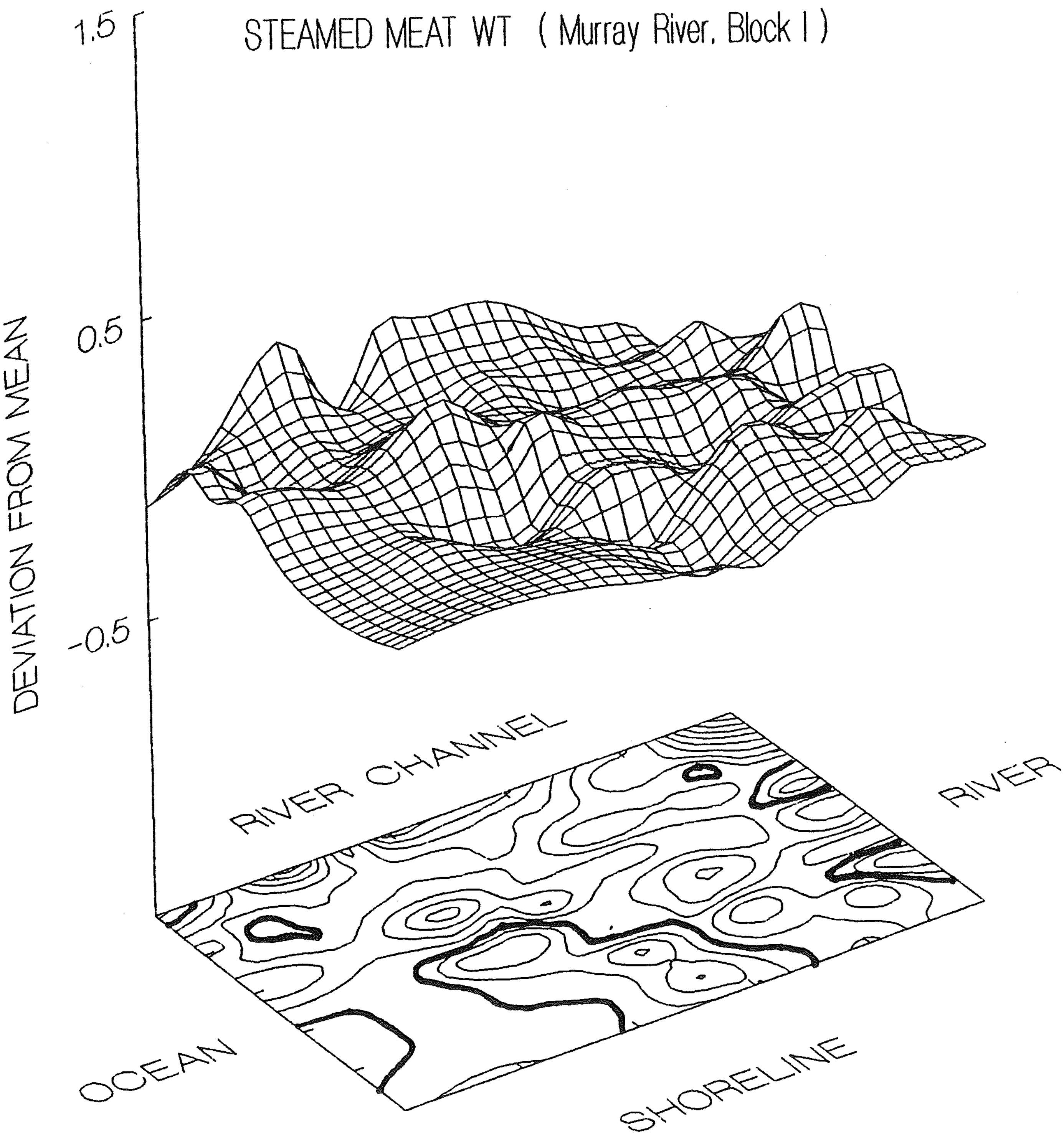



Figure E.2. Three-dimensional contour plot of steamed meat weight at Block I of the Murray River site (heavy lines are zero isopleths).

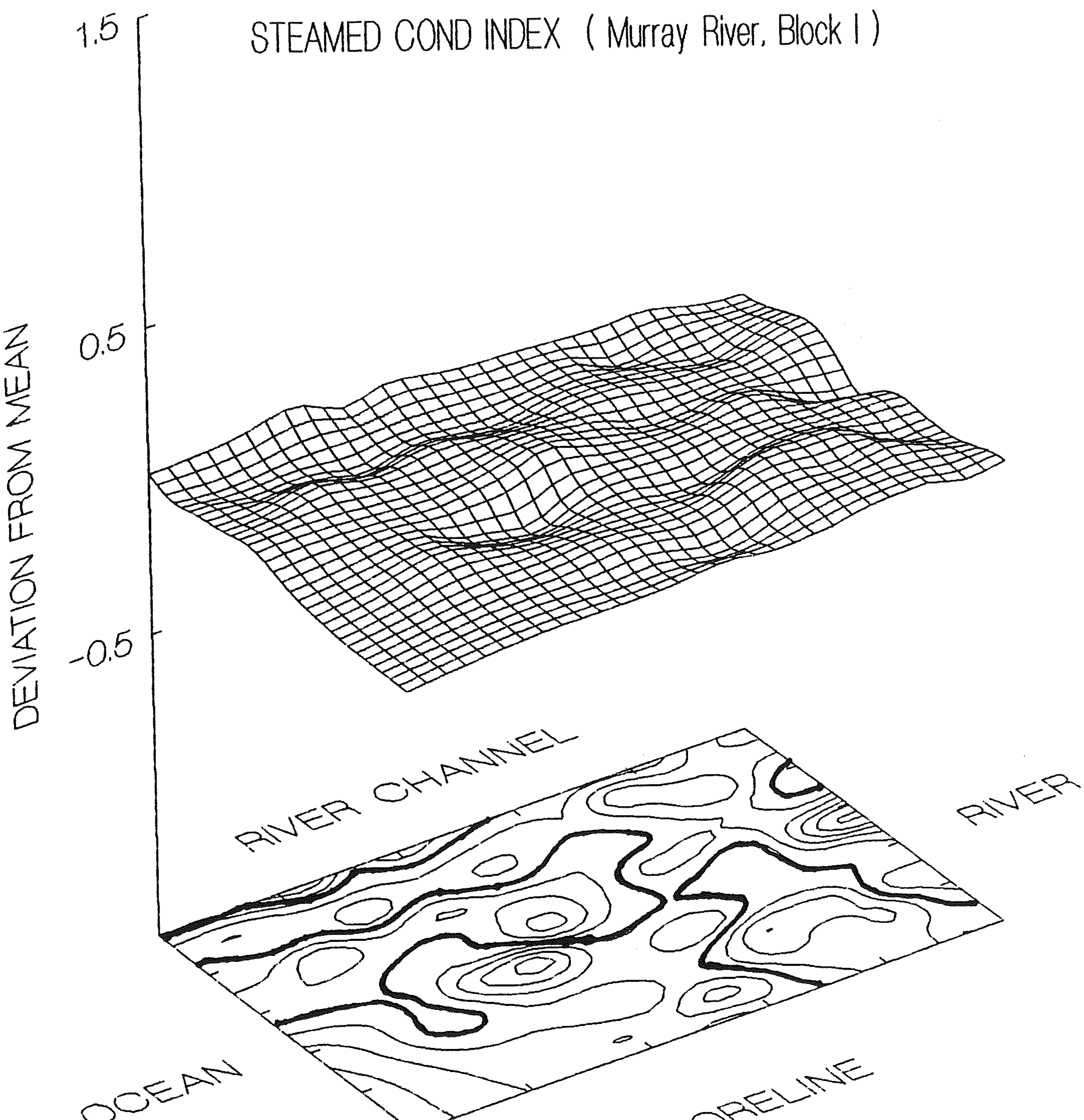



Figure E.3. Three-dimensional contour plot of steamed condition index at Block I of the Murray River site (heavy lines are zero isopleths).

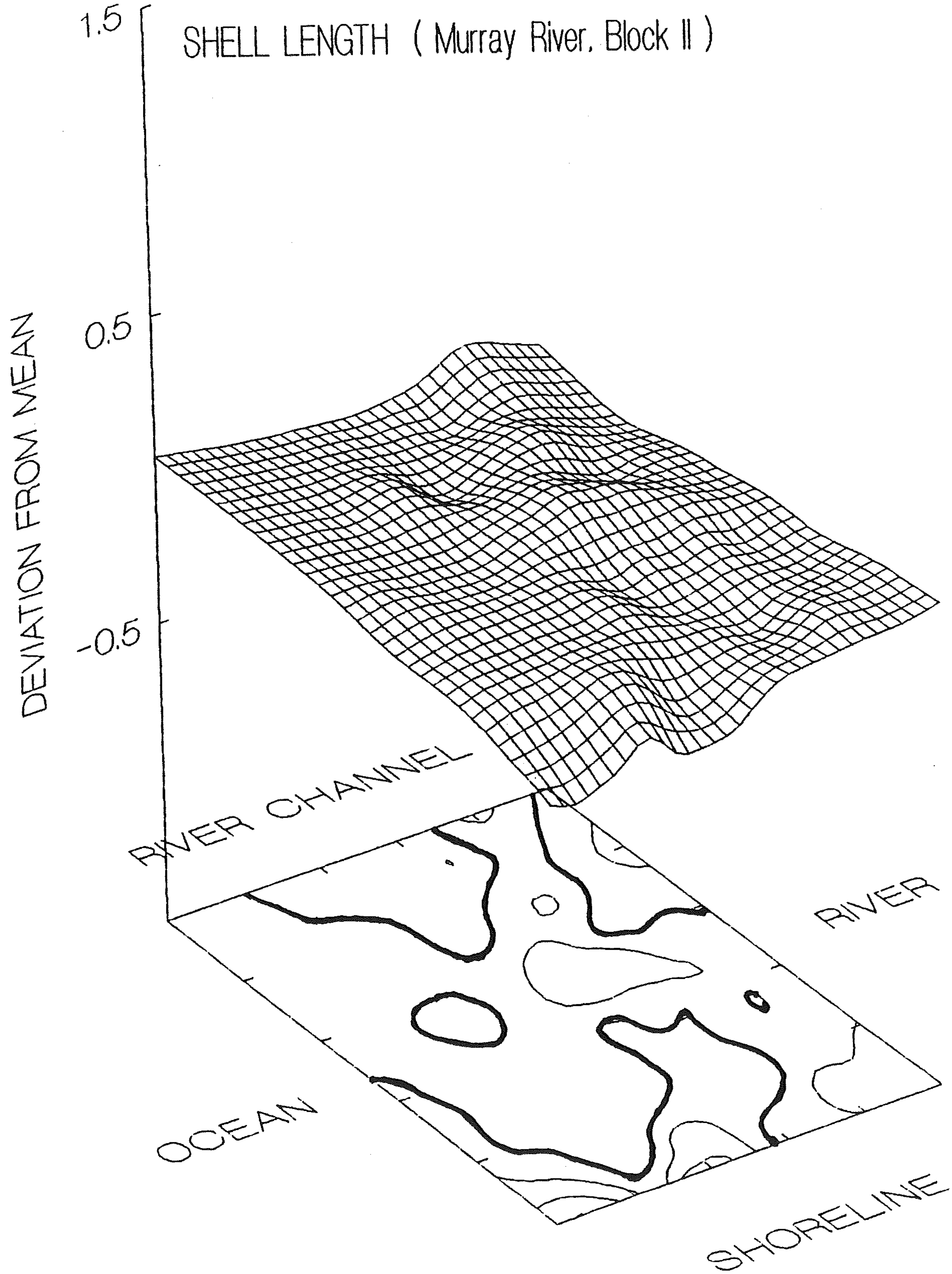



Figure E.4. Three-dimensional contour plot of shell length at Block II of the Murray River site (heavy lines are zero isopleths).

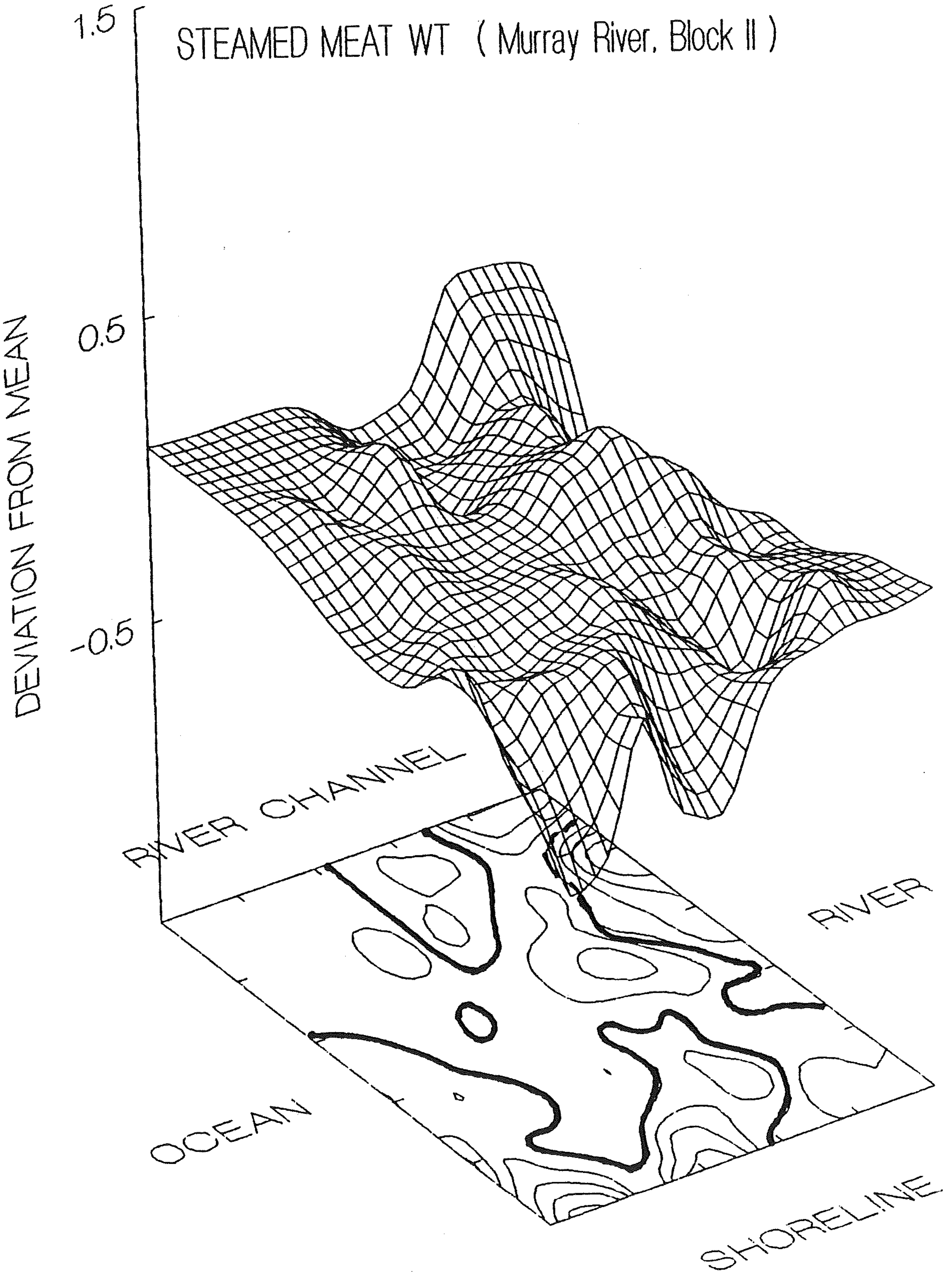



Figure E.5. Three-dimensional contour plot of steamed meat weight at Block II of the Murray River site (heavy lines are zero isopleths).

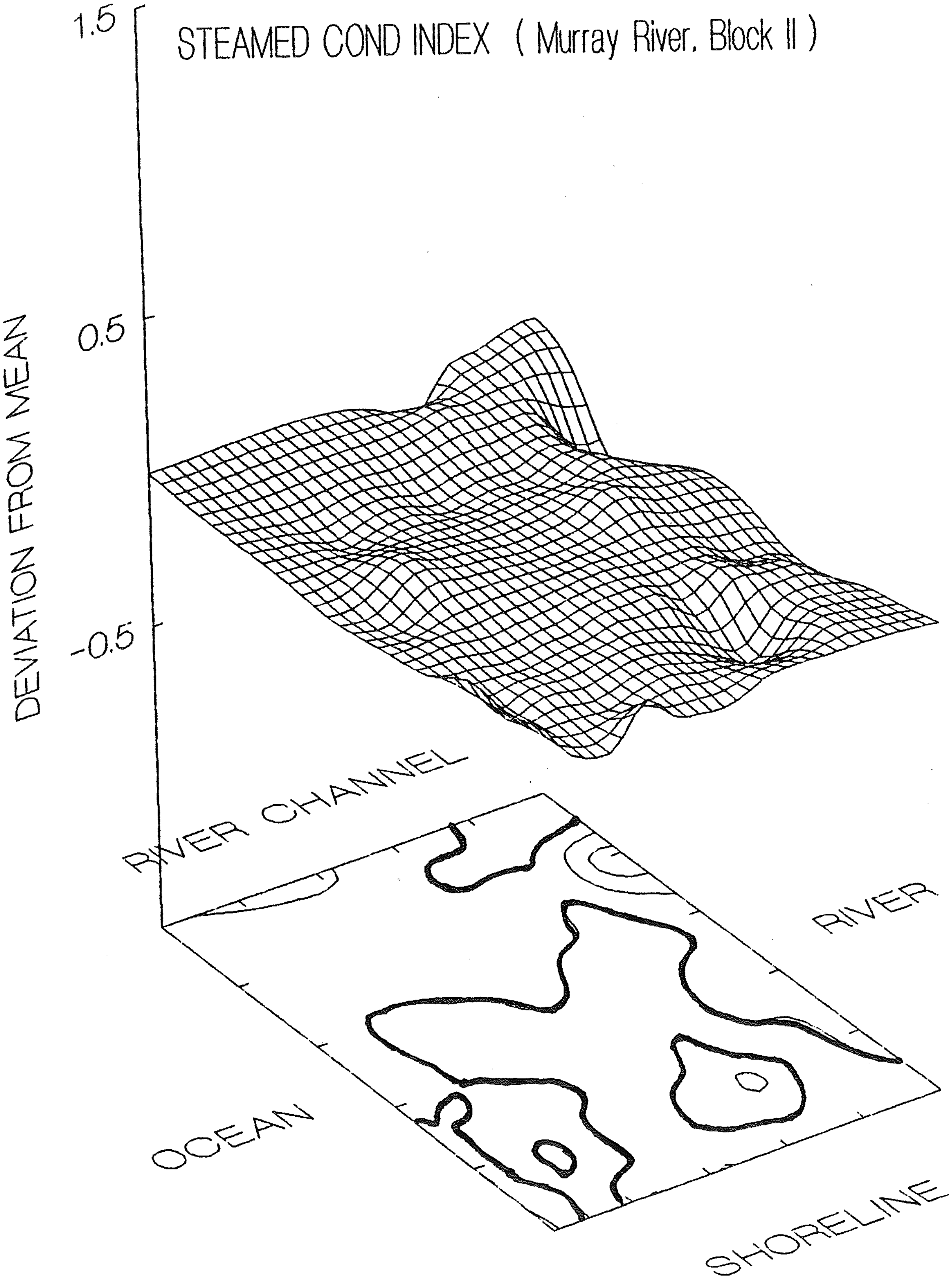



Figure E.6. Three-dimensional contour plot of steamed condition index at Block II of the Murray River site (heavy lines are zero isopleths).

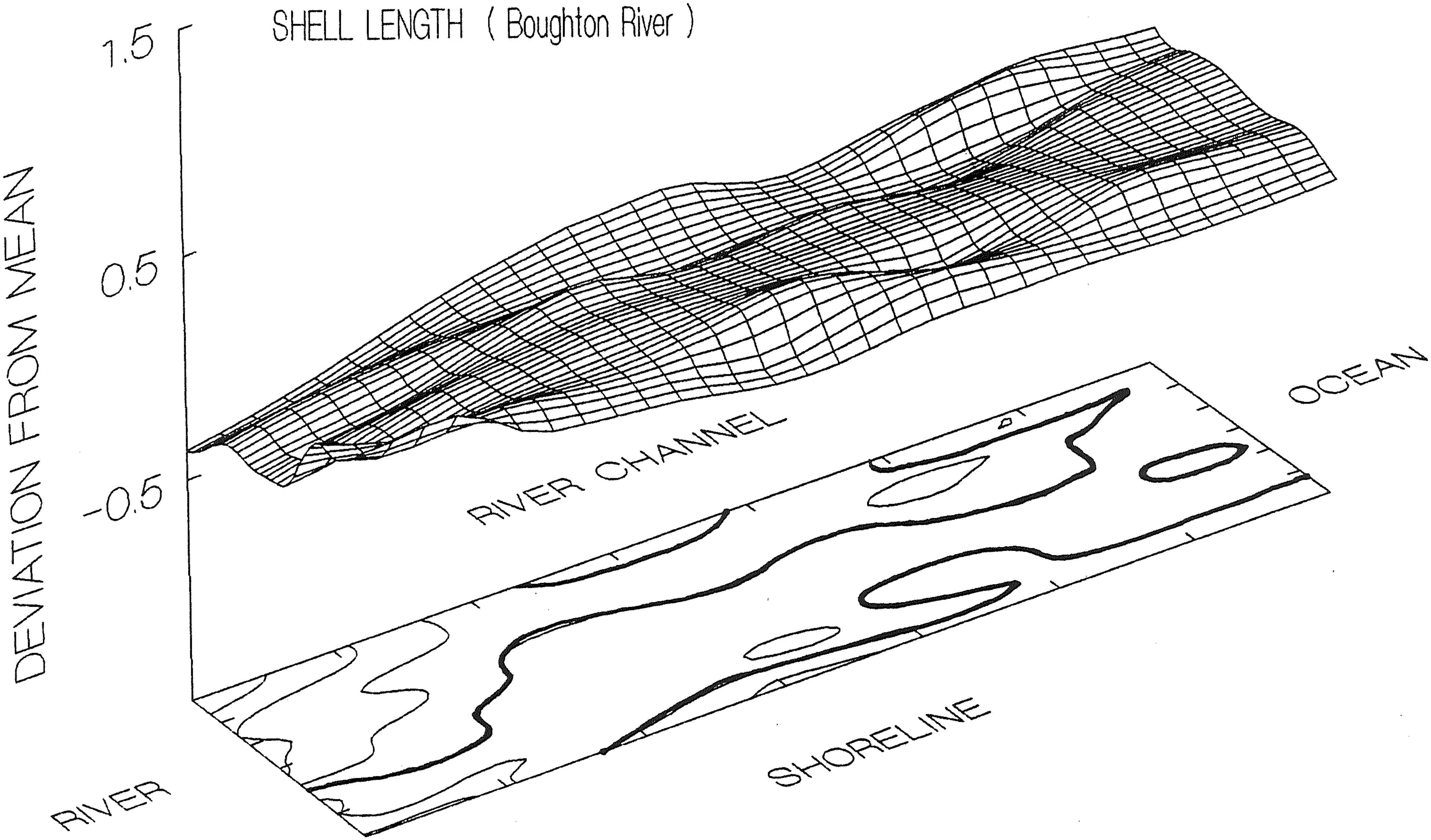



Figure E.7. Three-dimensional contour plot of shell length at all blocks at the Boughton River site (heavy lines are zero isopleths).

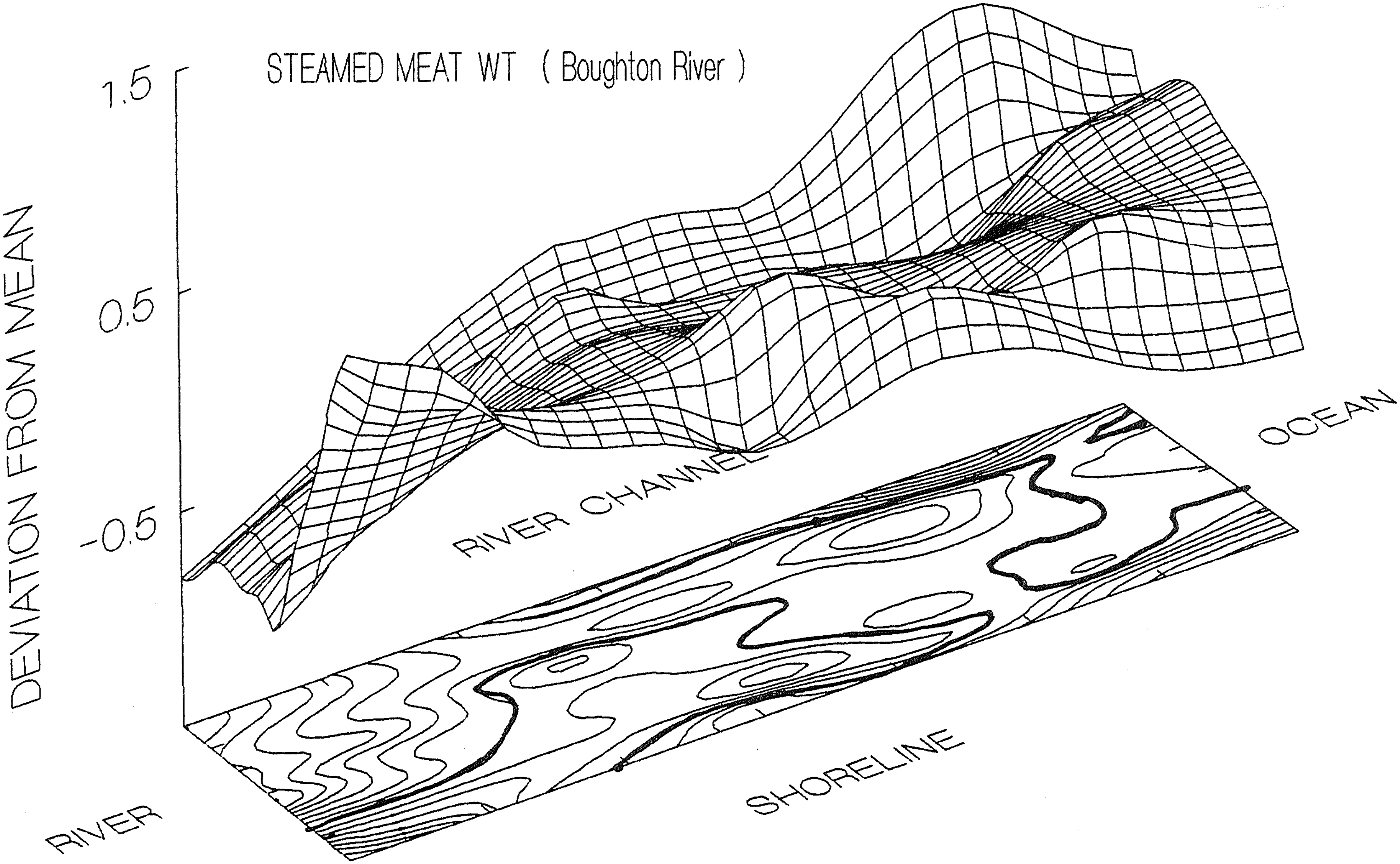



Figure E.8. Three-dimensional contour plot of steamed meat weight at all blocks at the Boughton River site (heavy lines are zero isopleths).

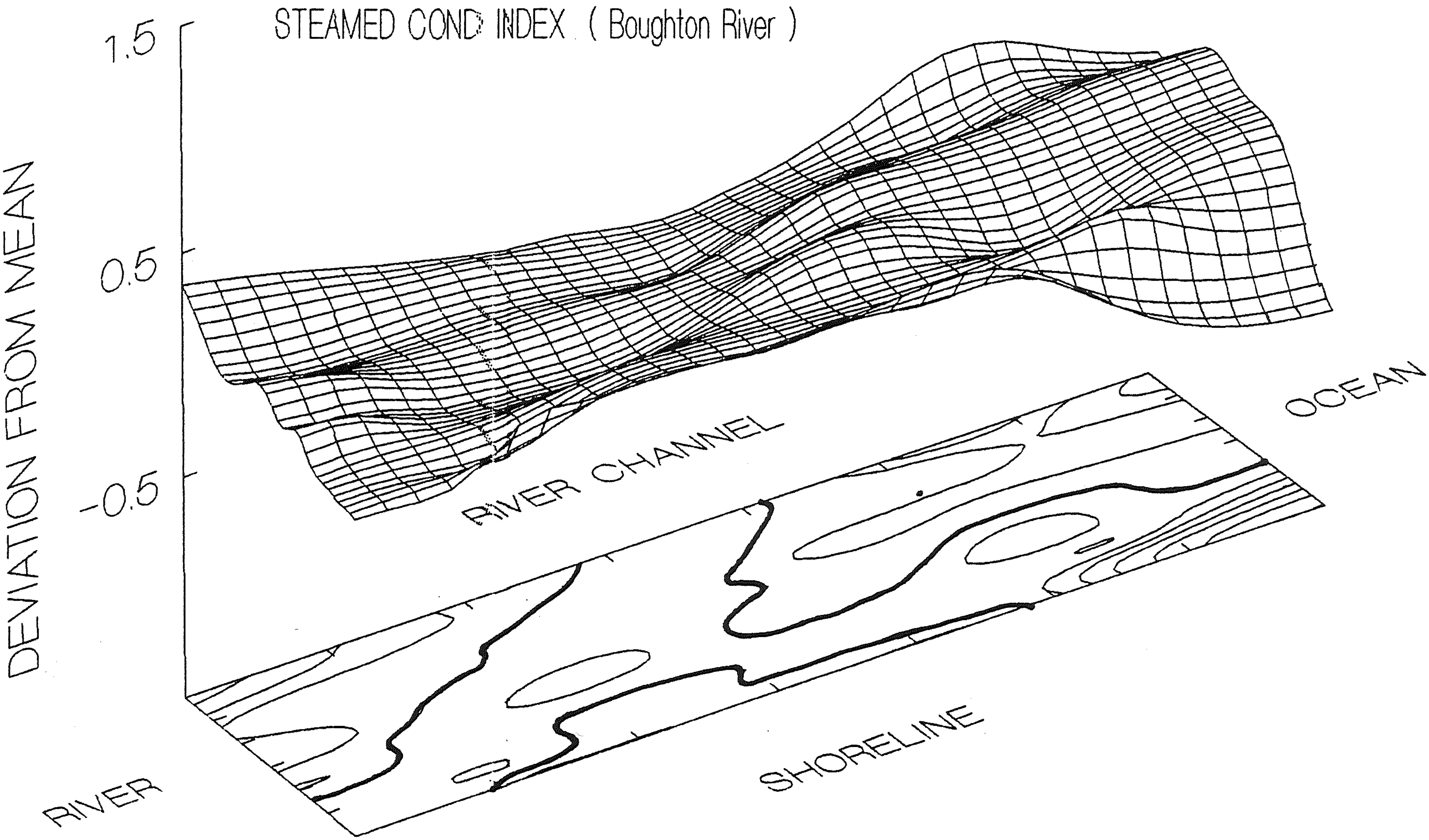



Figure E.9. Three-dimensional contour plot of steamed condition index at all blocks at the Boughton River site (heavy lines are zero isopleths).