TECHNICAL REPORT
TO THE
CALIFORNIA COASTAL COMMISSION

G. Mysids

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This report analyzes and presents the results of studies of MEC Analytical Systems, Inc. (formerly Marine Ecological Consultants), which were done on behalf of the MRC over the period 1980-1988, under the direction of Dr. Arthur M. Barnett. Their Final Report to the MRC "MEC Biological Project San Onofre Generating Station Monitoring Studies on Mysids and Soft Bottom Benthos" (30 November 1987, MEC03287056) provided the starting point for the analyses in the present report.

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SUMMARY

The study of mysid shrimps in the vicinity of SONGS addressed three basic questions: Is the abundance of mysids changed in the vicinity of the Plant? Are nearshore mysids moved offshore by the discharge waters? What is the average annual loss of mysids to intake withdrawal? The results of the study can be summarized as follows:

Abundance Changes

There is no evidence that reductions in the local populations of mysids have occurred at the Impact sampling site (2-3 km downcoast from Units 2 and 3). The once-predicted decline of 50% did not occur. In fact, there is strong evidence of an increase in the numbers of two species of mysids, *Mysidopsis intii* and *Neomysis kadiakensis*. There is also weaker evidence of an increase among mysids species in general.

While the occurrence of these changes at the Impact site in the After periods suggests that SONGS is responsible, the mechanism by which the operation of the Plant results in these changes is not known. It is possible that local mysid populations have increased in response to added food, in the form of the large amounts of organic material, remains of animals and plants withdrawn into SONGS, discharged with the cooling water.

Distributional Changes

One potential effect that was of concern was the offshore displacement of nearshore mysids. There is no evidence that such movement, which occurs as discharge water is moved offshore, is sufficient to cause a significant change in the cross-shelf distribution of the mysid species at the Impact site.

Intake Loss

We estimate that SONGS has withdrawn an average of approximately 6.5 billion mysids per year. This is equivalent to approximately 14 US tons of mysids per year. These estimates are based on the average pumping rate that has occurred during the operational period.

1.0 INTRODUCTION

Mysids are small, shrimp-like crustaceans that are characteristic inhabitants of nearshore waters in southern California. The interest in the potential effects of the San Onofre Nuclear Generating Station (SONGS) on mysids stems from the fact that they represent a group of organisms, the hypoplankton, which, while closely associated with the sea floor, regularly move up into the water column where they become an important food source for local fish (Barnett *et al.* 1987a). Near SONGS, mysids are the most abundant of the groups of small crustaceans, including amphipods, isopods, and cumaceans, which comprise this epibenthic plankton. Since mysids are distributed throughout the water column at night (Clutter 1969), it was expected that large numbers of them would be withdrawn into SONGS with the cooling water and killed and that these losses might adversely affect local populations. Marine Ecological Consultants, Inc. (MEC) was awarded the contract to conduct the MRC study of mysids, which began in 1976 and was completed in 1987.

The first phase of the study (1976-1979) was designed to gather basic information on the distribution and life-histories of local mysid species. Cross-shelf distributions and diurnal movements in the water column were described. Rates of growth and reproduction were estimated. In addition, density estimates were made at locations at various distances downcoast from the Unit 1 intake and discharge. Mysid samples were also collected from the intake riser itself and from within the plant before the water entered the condensers of the cooling system (Clutter 1977, 1978; Bernstein and Gleye 1981). This information was used to estimate intake mortality for Unit 1 and to estimate the effects of the Unit on the size and age-structure of local mysid populations. This information was then used to predict the effects of the operation of Units 2 and 3 (MEC 1979; Bernstein 1980).

Although the estimates of intake mortality at Unit 1 were substantial (9.8 metric tons per year), the sampling program did not produce compelling evidence of a depression in mysid abundance attributable to intake loss (Murdoch *et al.* 1980). However, in view of the much larger volumes of water that the new units would withdraw, the contractor predicted that there would be at least a 50% depression in nearshore mysid abundance in the area up to 10 km downstream of the plant and that an effect of such a magnitude would be detected with a reasonable sampling program (Bernstein 1980).

The subsequent monitoring program (conducted from 1979 to 1987) was designed to answer the following questions:

(1) Does the operation of Units 2 and 3 cause a detectable reduction in the abundance of mysids within several kilometers of the discharge structures?

(2) Are nearshore mysids moved offshore, into presumably unsuitable habitats, with the water entrained by the discharge from the diffusers?

(3) How many mysids are killed each year by withdrawal into the cooling system of Units 2 and 3?

1.1 Natural History of Mysids

Mysids are small crustaceans that look like shrimp. The species found along the coast of San Diego County range in size from about 5 mm to 20 mm in length as adults. The species that are the subject of this study live in areas of fine sand. Some individuals can be found on the substrate, but most are found swimming in swarms in the water above the substrate.

The distribution of mysids in the water column varies markedly from day to night. During the day, essentially all individuals remain within about 1 m of the bottom. At night, many of these epibenthic mysids move upward in the water column and become part of the plankton.

Most mysids feed on small particles which they filter from currents they produce with specialized appendages. However, they are also capable of grasping and feeding on larger food items. During the day, they filter detritus just above the bottom. From sunset until sunrise, they feed primarily on small plankton throughout the water column.

The sexes are separate in mysids and breeding occurs throughout the year. Larval development takes place in the female's marsupium or brood pouch (hence the common name, opossum shrimp). Brood-size increases with body size but averages around 10. The young are released as juveniles after 7 to 12 days. Both brood development and subsequent growth to sexual maturity are functions of temperature. During the warm summer months mysids reach sexual maturity in 26 or 27 days, whereas in winter this requires 50 to 55 days. The median age of immatures is 30 days, whereas that of adults is 60 days. For additional detail on natural history see Clutter (1977) and Bernstein and Gleye (1981), and references therein.

The description of the mysid species found in the study area is given in Section 3.1 below.

2.0 METHODS

2.1 Sampling Locations

Mysids were sampled within an Impact area 2.5 to 3.5 km downcoast from the discharge structure of Unit 1, and at a control area 17.5 to 18.5 km downcoast (Figure 1; note that the sampling locations are approximately 0.5 km closer to the Unit 3 diffuser). The location of the Impact site was chosen based on three considerations: (1) It was well within the area where effects on mysids were expected. (2) It was located in the area nearest to the diffusers where soft substrate was continuous across the depth strata sampled. Closer to the diffusers the sampling transects would have had to cross the cobble and rock substrate of the San Onofre Kelp Bed. (3) Because the prevailing direction of the longshore current is downcoast, the Impact site was located at a place that would be "downcurrent" of SONGS a majority of the time.

Separate tows, or samples, were taken within each of six depth strata along three transects in both Impact and Control areas. The actual longshore position of the transects was generally based on shore sightings, and could vary by several hundred meters from survey to survey. The three transects within an area were generally about 500 m apart. The depths of the strata sampled along each transect were: 6 - 8 m, 8 - 12 m, 12 - 15 m, 15 - 23 m, 23 - 30 m, and 30 - 37 m. The transects ran from approximately 0.4 km to approximately 4.4 km from shore.

2.2 Sampling Techniques

Mysids were sampled with an epibenthic sled during daylight hours because an estimated 99 percent of mysids are within 1 m of the bottom at this time (Barnett *et al.* 1987a). The sled had two ski-like runners and a steel frame with a 1-m^2 opening to which a net with a mesh size of 0.33 mm was attached (Figure 2). The sled was launched, towed along the bottom, and recovered while the boat was underway at a speed of about 1 m/sec. The volume of water sampled was measured by flow meters attached to the sled. The contents of the net were collected, preserved in formalin and transported to a laboratory for sorting and analysis. In the laboratory the samples were subdivided and the animals were identified to species. The sex, developmental stage and female reproductive condition were also recorded. The three developmental stages were juvenile, immature and adult. Juveniles were individuals which had not yet developed sex characteristics. Immatures were those whose sex could be determined but lacked the sex characteristics of the adult male or female.

A more extensive discussion of field and laboratory protocols and of procedures used for quality control is contained in MEC's Final Report (Barnett *et al.* 1987a, 1987b). Some pertinent details of the field methods not described elsewhere are presented below in Appendix H.

2.3 Sampling Schedule

Samples were collected on 19 surveys during the preoperational (Before) period. Sixteen of these were collected from October 1979 to August 1980. The remaining three samples were collected from June to December 1981. Sampling stopped in August 1980 because Unit 2 was expected to begin operation in the near future. However, significant operation of the two new Units did not occur until late 1982. The period during which the new units underwent testing (1981-1983) was designated an "interim period" during which samples were not expected to be representative of either Before or After conditions. By chance, however, neither unit was operating during the last half of 1981 and surveys conducted during that time were added to the collection of Before samples used in the analyses of plant effects. The operational (After) samples were collected on 17 surveys during the period December 1983 to September 1986. The dates of the surveys are listed in Appendix A.

The number of pumps operating and the percent of maximum power generated by each Unit on the day of each cruise is presented as an index of the potential impact of SONGS in the Before and After periods (Appendix A). We also present the daily averages for the 30 days prior to each cruise (Appendix B). We present the former because we expect the losses due to intake withdrawal to be instantaneous in their effect and the latter because the number of mysids, which have a generation time of one to two months and are more sedentary than other plankton, in an area at a given time is probably determined by environmental conditions in the previous months.

By either measure, there was a clear difference between the Before and After periods. Units 2 and 3 produced an average of 68% of maximum power on the day of each of the cruises during the After period and at least four, and more often seven or eight, pumps were operating (Appendix A). They produced an average of 65% of maximum power and had an average of 6.8 pumps operating during the 30 days before each of the sampling dates (Appendix B). In contrast, during the Before period no power was generated although one or two pumps were occasionally operating.

Unit 1, whose power production and circulating water volume is approximately one-fifth of Units 2 and 3 combined, was operating during both periods. The average number of Unit 1 pumps running on the sampling dates and the 30 days preceding them in the Before was 1.5 (of two) and 1.0 in the After. The average power production was approximately 50% in the Before and 30% in the After (Appendices A and B).

2.4 Analytical Methods

2.4.1 Changes in Average Density

The variate used in the analysis was the weighted, cross-shelf mean density (number/m³). Weighted mean density (d) was calculated as follows:

$$d = \frac{1}{3} \sum_{i=1}^{3} \sum_{j=1}^{n} \left(\text{Density}_j * \frac{\text{Volume}_j}{\text{Volume}_i}\right)$$

where i refers to transect and j refers to depth stratum. The weighting is necessary because the depth strata are of very different volumes. Note that the density is that in the one meter of the water immediately above the substrate, and not that found throughout the entire water column.

Although some species occur at all depths, many are restricted in their distribution (Section 3.1). If density at a given depth stratum was always less than $0.05/m^3$ at both the Impact and Control areas, the stratum was not used in the analysis. Also, if no individuals of a particular species or growth stage were sampled at both the Control or Impact site, the survey was dropped for that group.

A mean cross-shelf density was determined for the Impact and Control locations on each sampling survey. These data were then analyzed using the Before-After-Control-Impact-Pairs (BACIP) design (see Interim Technical Report 2 for a discussion of the rationale and design of the BACIP test procedure). The density at the control site was subtracted from the density at the impact site for each survey date. The average difference between sites in the preoperational period was then compared to the average difference in the operational period with a t-test.

The data were log transformed before deltas were calculated. Since there were instances of zero density, a constant was added before taking logs. The tests of assumptions and the t-test were run for a range of constants (0.01 - 100 in multiples of 10). The results presented below are those based on the transformation associated with the lowest alpha level of the test. We recognize that selecting in this manner may overestimate the occurrence of significant test results. However, by following this procedure we feel that all potentially affected species will receive further consideration.

It is also important to note that the reported estimate of percent relative change is based on the geometric means associated with the log transformation used in the BACIP test procedure, and not on the arithmetic means of the abundances observed at the various locations and periods. We therefore present the geometric means in the discussion of the results for each taxon (below). The arithmetic means are presented in Table 1.

We calculate the percent relative change in the following manner:

The difference between preoperational and operational deltas, symbolically $\Delta\Delta$, based on log transformations, is equal to

$$(\log(t^*s^*U) - \log(t^*k^*U)) - (\log(U) - \log(k^*U)).$$

U is abundance at SONGS in the Before period. k is the multiplier relating Control abundance to Impact abundance (location effect). If Impact and Control were of equal abundance in the preoperational period, k would have been 1. t is the multiplier due to changes in time, from preoperational to operational periods. t is the same for both Impact and Control. s is the multiplier due to SONGS operation and only affects Impact. For example, if there were a 50% decline s would equal 0.5. In the preceding equation, U and factors k and t cancel out.

Thus,

$$\Delta\Delta = \log(s).$$

Back-calculating s from the $\Delta\Delta$, the relative percent change is given by

$$(\text{antilog}(\Delta\Delta)-1) \times 100.$$

In many cases, the estimate of percent relative change is not precise. Because zero abundances occur at times, a small constant is added to the log transformation. Estimates of percent relative change can be sensitive to the constant chosen, particularly in those species whose survey-by-survey data have a high proportion of zeros at either Impact or Control location. Also note the asymmetry in the reported percent increases and decreases. While a doubling is a 100% increase, a halving is a 50% decrease. Increases can exceed 100%, but decreases cannot. (Percent changes are translated into "factors" or "folds" in Appendix C).

In a few instances, there were significant serial correlations in the deltas in the Before period. In these cases, the t statistic was calculated using autoregressive errors.

2.4.2 Changes in Cross-Shelf Distribution

One of the predicted effects of SONGS was to entrain nearshore waters containing mysids and push them offshore. This was predicted to have a deleterious effect on those species which only occur in the shallow, nearshore environment. If SONGS moves large numbers of animals from shallow, nearshore to deeper, offshore waters, how would this be reflected in the cross-shelf distribution of mysid populations? The answer to this question depends partly on the fate of the mysids transported offshore. If they die very quickly and are eaten or sink onto the bottom, they won't be sampled. For species which normally are restricted to shallow water, this might result in a decrease in local population density but no change in distribution. For species which occur at all depths, a decrease in abundance in shallow water might be detected as an increase in the proportion of the total population found in the offshore zones. A similar change in the relative abundance of nearshore species would occur if the individuals which were shunted offshore lived long enough to be sampled.

For purposes of analysis, the transects were divided into an inshore segment (6-15 m in depth) and an offshore segment (15-37 m in depth). The 15 m isobath is near the offshore end of the diffusers and also seems to be a natural break in the distribution of mysid species (Section 3.1). The proportion of the population (of all species and developmental stages) in the offshore segment was calculated at the Control and Impact sites for both Before and After periods.

Changes in distribution were analyzed using the procedure developed for the plankton (Interim Technical Report 4: Plankton). The abundances in the inshore and offshore segments were calculated, the data were log transformed, and the inshore abundance was subtracted from the offshore value. The number thus obtained is an expression of the offshore abundance as a proportion of the inshore population. The control values were then subtracted from the impact values to obtain the deltas that were used in a BACIP analysis. Because the various life-stages of a species may have different depth distributions, all individual life-stages, as well as the combined life-stages of a species, were tested for SONGS' effects.

2.5 Intake Loss

The number of mysids killed by being drawn through the power plant in the cooling waters was calculated by multiplying the volume of water withdrawn by the estimated concentration of mysids in the withdrawn water. The actual withdrawal loss during the operation period of the mysid study (1983-1986) was estimated. In addition, the long-term, average annual loss to intake withdrawal was estimated by averaging mysid densities over the period 1979 to 1986.

The following formula was used to calculate quarterly intake losses for each species:

LOSS = (DL x VOL) x (0.16 DEN) + ((1-DL) x VOL) x (0.64 DEN)

where: DL = Quarterly average proportion of daylight hours
VOL = Quarterly total volume pumped
DEN = Quarterly average mysid density

Daylight hours were calculated from surface irradiance. Periods with values greater than 0.05 Einsteins/m^2/day were considered daytime. Volume of circulated waters was calculated from records of the number of pumps operating. Mysid density was estimated from the samples taken in the 8 m to 12 m depth stratum. Samples from both the Impact and Control locations were used to estimate densities. Numbers were converted to weights using the average weight of an individual of each species and life-stage (Appendix D).

Losses were calculated quarterly because both intake volume and mysid densities varied seasonally. During the After period there were two quarters in which there were no samples. For these quarters, the mysid density was estimated by averaging the densities from the immediately previous and subsequent quarters.

For the calculation of the long-term, annual average intake loss, quarterly averages were calculated using samples from all years.

The concentration of mysids in the withdrawn water is an estimate based on assumptions concerning the source of the water entering the intakes, knowledge of mysid behavior, and estimates of mysid abundance near the bottom based on samples taken several kilometers downcoast from the intake structures. The assumptions are:

1. The intakes draw water from the entire water column and are not vertically selective. Reitzel (1985) concluded that the Units 2 and 3 intakes would exclude thin surface and bottom layers only on rare occasions.

2. Mysid loss is independent of current speed.

3. All the withdrawn water is taken from the area between the 8 m and 12 m depth contours. The intakes draw water from only about 250 m away even at very slow currents (2 cm/sec, Reitzel 1985). The intakes for Units 2 and 3 are about 970 m offshore. The 8 m - 12 m depth stratum extends from 550 m to 1550 m offshore.

4. The estimated concentration of mysids in the 8 m - 12 m stratum is representative of the concentration in the intake waters, with the following caveats:

a. Mysids are able to orient themselves visually during daylight hours and, by swimming against currents, maintain station. Therefore few mysids are withdrawn during the day. Samples collected from within the power plant indicate that the number of mysids in cooling waters rises from near zero at sunset to a peak around midnight and then falls again towards sunrise (Clutter 1977). Making the assumption that the peak abundances at midnight represent 100% of the mysids in the water column, Clutter calculated that, averaged over the nighttime hours, the proportion of the mysids in the water column withdrawn was 64%.

b. Clutter (1977), on the basis of an unknown number of daytime samples, concluded that the daytime density of mysids in withdrawn water was less than 5% the density at night. Bernstein (1980), based on one day's sampling, estimated that the density of mysids in the withdrawn water in daytime was 27% of that at night. We have used the average of these two estimates, 16%.

5. All mysids withdrawn in cooling waters are killed. A comparison of samples taken near the intake riser of Unit 1 with those taken from the discharged waters, indicated that 29% of mysids survive the passage through the cooling system (Bernstein 1980). Laboratory experiments suggest that more than half of those survivors will later die from the residual effects of temperature shock (Bernstein 1980). In addition, there will probably be some residual mortality from physical buffeting.

3.0 RESULTS

3.1 Mysid Abundances and Distributions

Nine species of mysids were routinely caught over soft substrates in shallow water (<37 m in depth) in the vicinity of San Onofre. The species are ranked by their mean cross-shelf densities (per m^3) at both Control and Impact locations in the Before and After periods in Table 1. The mean cross-shelf densities of the various life-stages of these species are presented in Appendix E.

Metamysidopsis elongata was the most common mysid throughout the study period, accounting for approximately 48% of all mysids sampled. Its mean cross-shelf density within one meter of the bottom varied, depending on location and period, from $11.6/m^3$ to $30.0/m^3$. Only one other species, *Acanthomysis macropsis*, had a density greater than $10/m^3$ at any location or time. At the other end of the scale, two species, *Neomysis rayii* and *Acanthomysis nephrophthalma*, never exceeded $1/m^3$ in density at any location. The five species that were intermediate in density were *Mysidopsis cathengelae, M. intii, Neomysis kadiakensis, Holmesimysis costata,* and *Acanthomysis davisii.* Six other species, *Archaeomysis maculata, Cubanomysis mysteriosa, Mysidella americana, Pseudomma americana, P. californica* and *Siriella pacifica*, occurred in fewer than 10% of the samples and are not considered in this report.

The nine common species tend to occur in distinct depth zones. *Acanthomysis davisii, Holmesimysis costata, Mysidopsis cathengelae,* and *Neomysis rayii* are nearshore species which are absent or rare in water deeper than 15 m. The cross-shelf species, *Acanthomysis macropsis, Metamysidopsis elongata* and *Mysidopsis intii*, occur at all depths sampled. Finally, two offshore species, *Acanthomysis nephrophthalma* and *Neomysis kadiakensis*, are uncommon in water shallower than 15 m. The cross-shelf distributions of the species and their life-stages are presented in Appendix F.

3.2 Changes in Relative Density

A number of mysid species changed in abundance in the study area from the Before to the After period. *Acanthomysis davisii, A. nephrophthalma, Holmesimysis costata, and Neomysis rayii* were less abundant during the After then they were in the Before (Table 1). In contrast, *Mysidopsis cathengelae, Acanthomysis macropsis,* and the adult and juvenile stages of *Metamysidopsis elongata* were more abundant in the After period than they were in the Before period (Table 1; Appendix E).

While changes in mean density occurred from Before to After, the BACIP results indicate that only a few of these changes were more pronounced near SONGS relative to the Control location. The results of the BACIP test for changes in density are presented in Table 2. This table presents the results by species (all life-stages combined) and the combined taxon, Total Mysids. Only two species, when all life-stages were combined, displayed significant ($p < 0.05$) results indicative of a SONGS effect.

3.2.1 *Mysidopsis intii*

The BACIP results indicate that the abundance of this species increased in the Impact area relative to the change observed at the Control site after the onset of plant operation. This relatively common species ranked second in abundance during the Before period and third during the After. It accounted for 16.8% (at Control) and 16.6% (at Impact) of all mysids during the Before period and 5.5% at both Control and Impact during the after period. It was found along the entire length of the cross-shelf transect. The geometric mean abundances, percent relative change and alpha level of the test on all life-stages combined were:

	Impact	Control	% change	P
Before	4.47	4.83		
After	2.10	1.05	116	0.004

The complete BACIP results and a plot of the deltas through time for this species (and the others discussed below) are presented in Appendix G.

3.2.2 *Neomysis kadiakensis*

The BACIP results indicate that the abundance of this species increased in the Impact area relative to the change observed at the Control site. This moderately common species ranked third in abundance during the Before period and fifth during the After. It accounted for 11.0% (at both Control and Impact) of all mysids during the Before period and 3.7% (at Control) and 4.8% (at Impact) during the after period. This species is found predominantly in the offshore portion of the cross-shelf transect. The geometric mean abundances, percent relative change and alpha level of the test on all life-stages combined were:

	Impact	Control	% change	P
Before	1.88	2.61		
After	1.94	1.20	120	0.010

Note that the preoperational deltas were serially correlated. A significant P value (<0.05) remained after correcting with second order autoregression.

3.2.3 Other taxa

While no other species displayed significant results, the indicated change in abundance (the sign of the percent relative change, Table 2) suggest that the six other species, *Acanthomysis davisii, A. macropsis, A. nephrophthalma, Metamysidopsis elongata, Mysidopsis cathengelae*, and *Neomysis rayii* were tending towards relative increases. Only one species, *Holmesimysis costata*, tended towards a relative decrease. The eight-to-one predominance of indicated increases (disregarding statistical significance) is itself statistically significant ($p<0.05$, binomial test).

The tendency for the mysids as a group to increase in the Impact area is also suggested by the BACIP analysis on all mysids combined (Table 2). While the P value of the test was 0.10, the indicated change in abundance was an relative increase of 50%.

BACIP analyses were also performed on individual life-stages of each mysid species and the results are summarized in Table 3. The adult ($p<0.01$), immature ($p=0.04$) and juvenile ($p=0.03$) stages of *Neomysis kadiakensis* displayed relative increases at the Impact site. Adult ($p<0.01$), juvenile ($p=0.02$) and immature ($p<0.01$) *Mysidopsis intii* all displayed relative increases. Only one other life-stage displayed a significant ($p<0.05$) change. Adult *Mysidopsis cathengelae* increased 8% ($p=0.045$). One other test result with an alpha level of $0.05<p<0.1$ occurred. Juvenile *Neomysis rayii* increased by 45% ($p=0.085$, Mann-Whitney U test).

When the directions of relative change are considered independent of significance level, 17 life-stages of the various species indicated an increase in relative abundance and six a decrease. The direction of the remaining four life-stages could not be determined.

There were no significant ($p<0.05$) trends with time in the After deltas observed among the mysid species or their individual life-stages.

3.2.4 BACIP on samples sorted by current direction

The preceding BACIP analyses test whether the abundance of mysids has changed at the Impact site relative to Control independent of the prevailing current conditions on the sampling dates. To test whether these results were biased against detecting Plant effects compared to samples taken only when the prevailing longshore current direction places the Impact site "downstream" of the diffusers, we sorted the surveys in both Before and After periods by current direction and performed BACIP tests on the two sets of surveys. The results are summarized in Appendix J.

Because sample sizes are decreased when sorted by current direction, the power of the test is reduced and the lack of significant ($p < 0.05$) test results is not surprising. However, as a test for bias, the direction of the indicated changes are telling. Under "plume" conditions (downcoast directed longshore currents), the indicated changes in relative abundance are positive for all species. Under "non-plume" conditions, there were 6 indicated relative increases and 3 relative decreases. These results argue strongly that any adverse effect of plant operation associated with current direction was not obscured by using data from all sampling dates in the preceding BACIP tests (Sections 3.2.1-3.2.3).

3.3 Changes in Cross-Shelf Distribution

Bernstein (1980) predicted that nearshore mysids would be pushed offshore by the discharge waters of the Unit 2 and 3 diffusers. There is no evidence that this has occurred. Although the proportion of individuals found offshore changed for several species during the course of the study (Table 4), the changes were generally similar at both of the study sites. In no case was the BACIP test result significant ($p < 0.05$) which would have indicated a relative change in distribution at the Impact site.

3.4 Intake Loss

The estimated average annual loss during the After period to the operation of Unit 1 was 1.05 x 10^9 mysids (weighting 2.3 metric tons) and 8.12 x 10^9 mysids (weighting 16.4 metric tons) to Units 2 and 3 combined (Table 5). Using the available pre-operational data as well, the estimated long-term annual average loss was somewhat smaller, 0.87 x 10^9 mysids (1.7 metric tons) to Unit 1 and 5.83 x 10^9 mysids (11.3 metric tons) to Units 2 and 3 (Table 6).

4.0 DISCUSSION

The observed patterns in mysid abundances and distributions as affected by the operation of SONGS Units 2 and 3 are quite different from those which were predicted in 1980 (Murdoch *et al.* 1980; Bernstein 1980). The predicted 50% reduction in mysid density within several kilometers of the of the plant was not observed. In fact, the results of the study suggest that relative increases in mysid density, not decreases, result from the operation of SONGS.

However, it is indisputable that SONGS takes in and kills large numbers of mysids. The estimated loss *per annum* to withdrawal into Units 2 and 3 is approximately 6.5 billion mysids whose total weight is 13 metric tons. These numbers are also somewhat different from those predicted in 1980. At that time, the predicted loss was approximately 23 billion mysids weighting an aggregate 46 metric tons. A number of factors account for the difference between the two estimates. The early prediction incorporated the maximum intake volume in the calculation. The estimate presented in this report is based on the average pumping rates from mid-1983 to mid-1987 (approximately 77%). At maximum pumping rates, the current estimated intake loss would be approximately 21 metric tons. The early prediction was based on mysid density estimates made in-plant at Unit 1 during 1979 only. Therefore, this estimate did not incorporate year-to-year variation in the mysid abundances, which can be pronounced. Use of inplant samples may also overestimate the intake loss. Clutter (1977) compared samples taken simultaneously close to the intakes of Unit 1 and within the plant and found that mysid densities were higher in the samples taken in the plant. He speculated that the mysids were "concentrated" by some unknown mechanism in the plant.

The prediction that intake losses would contribute to reductions in local mysid populations was, in part, based on the expected effects of the discharge waters on the receiving waters. Studies of the actions of the discharge waters have revised some of the early expectations. Any changes in local population densities due to Units 2 and 3 intake losses would come about by mixing ambient water containing mysids with the cooling waters which have been filtered of mysids. The present estimate of the magnitude of this dilution three kilometers from the diffusers is 40 parts ambient to one part cooling water (Ecosystems 1987). This would cause about a 2.5 percent reduction in local populations. The volume of receiving water entrained (displaced in the course of mixing with the discharged water) is about 10 times that discharged. If all the mysids in the entrained water were also killed (and there is no evidence of entrainment mortality) the mix at the impact site would be four parts ambient to one part plume water, resulting in a 20 percent decrease in mysid densities. The dilution volumes are based on samples taken from a discharge plume present only in upper portion of the water column. If the discharged waters were distributed throughout the water column so as to affect the bottom 1 m where mysids are sampled, then the ratio of ambient to cooling water would be much larger and the expected reduction in mysid densities much smaller. Therefore, based on these recent dilution estimates, the expected declines due to dilution alone would be small.

Another factor that would counteract the intake losses would be immigration of mysids into the Impact area. In making the early predictions, the potential effects of immigration were essentially ignored. Although we have no data concerning rates, immigration into the area, by either actively swimming into the area or passively drifting in with currents, may be sufficient to overcome the losses due to intake withdrawal. For example, a reduction in the concentration of mysids would not be expected if make-up water, water drawn into the Impact area to replace water withdrawn and discharged by the plant, contains mysids at ambient concentrations.

The relative increases observed at the Impact site in the populations of *Mysidopsis intii*, *Neomysis kadiakensis*, and the tendencies towards increases in other mysid species are unexpected in light of the predictions. However, there are plausible mechanisms that may account for these increases. One is an increase in the food supply to the mysid populations. Tons of particulate organic material, dead mysids and plankton, are discharged each month in the cooling waters. This may increase the flux of organic particles at the Impact site. Since mysids are known to feed on detrital material (Cannon and Manton 1927; Tattersall and Tattersall 1951; Pechen-Fineko and Pavlovskaya 1975; Mauchline 1980), this added food might increase both survival and reproductive success.

Barnett *et al.* (1987a) present evidence that suggests that reproductive success of mysids may be enhanced in the Impact area. They found the proportion of reproductive females in the populations of *Acanthomysis macropsis* and *Neomysis kadiadensis* increased at the Impact area relative to the Control area. The increase in the proportion of reproductive females may be related to the increase in relative abundance at the Impact site shown by the latter species.

Increases in mysids may be linked to other changes in the marine biota near SONGS. Fish prey on mysids (*e. g.* Clarke 1971; Quast 1971, Hobson and Chess 1976; Bernstein and Gleye 1981). The relative increase in mysids may, in part, account for the relative increases seen in the abundance of benthic fish at the Impact site in the After period. White croaker, queenfish, longfin sanddab and fantail sole are benthic species whose abundance increased in the After period near the plant. The aggregate biomass of the bottom fish also increased (Interim Technical Report 3: Midwater and Bottom Fish).

Furthermore, it is thought that mysids are representative of other groups of hypoplankton not sampled: amphipods, isopods, and cumaceans. If these populations have increased as the mysids have, they would also contribute to an increase in available food to local fish populations.

It was also thought in 1980 (Murdoch *et al.* 1980) that nearshore mysids might be pushed offshore with the seaward flow of discharge water. While there was no evidence that such a movement would adversely affect the individual, there was concern that if these offshore waters were unsuitable habitat or that, once displaced, the mysid could not return to its area of origin, such movement would be deleterious. However, the test for distributional shifts failed to find evidence of significant offshore movement.

The lack of the predicted distributional shifts probably results from a number of factors. One is that the extent of the offshore movement of the discharge was probably overestimated when the prediction were made. Most of the water that encounters the discharge plume is displaced an average of approximately 700 m seaward of the point at which it encounters the discharge plume (Final Technical Report L). Therefore, a relatively small proportion of water is pushed much beyond the offshore end of the Unit 2 diffuser and few individuals of those species found predominantly shoreward of the 15 m isobath (the approximate depth at the offshore end of the Unit 2 diffuser) are pushed seaward of this depth.

Another factor that may contribute to the absence of distributional shifts is the ability of the mysids to either actively resist offshore movement or move shoreward once displaced. There is evidence that cross-shelf movement by mysids does occur. Large numbers of adult female *Metamysisdopsis elongata,* brooding young, have been observed on occasion in the portion of the transect shoreward of their normal occurrence (L. Gleye, *pers. comm.*). Gleye speculates that the females may move into shallow water to release their young. However, the ability of mysids to resist passive movement by water currents remains insufficiently known to estimate the time necessary or the probability of their successful return to their point of origin.

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TABLE 1

RANKS OF MEAN DENSITIES OF MYSID SPECIES. The mean density (per m^3 of the bottom one meter of the water column) and standard error, number of surveys and the percentage of total mysids are presented for each species.

RANK	TAXON	MEAN	S.E.	N	% OF TOTAL
IMPACT LOCATION--BEFORE PERIOD					
1	*Metamysidopsis elongata*	11.62	2.26	19	35.1
2	*Mysidopsis intii*	5.48	0.78	19	16.6
3	*Acanthomysis macropsis*	3.75	0.77	19	11.3
4	*Holmesimysis costata*	3.68	1.07	19	11.1
5	*Neomysis kadiakensis*	3.62	0.99	19	11.0
6	*Acanthomysis davisii*	2.62	0.44	19	7.9
7	*Mysidopsis cathengelae*	0.89	0.31	19	2.7
8	*Neomysis rayii*	0.72	0.20	19	2.2
9	*Acanthomysis nephropthalma*	0.69	0.13	19	2.1
	Total mysids	33.07	4.79	19	100.0

RANK	TAXON	MEAN	S.E.	N	% OF TOTAL
IMPACT LOCATION--AFTER PERIOD					
1	*Metamysidopsis elongata*	30.04	10.04	17	50.3
2	*Acanthomysis macropsis*	17.80	5.67	17	29.8
3	*Mysidopsis cathengelae*	4.13	2.03	17	6.9
4	*Mysidopsis intii*	3.29	0.90	17	5.5
5	*Neomysis kadiakensis*	2.86	0.58	17	4.8
6	*Holmesimysis costata*	1.13	0.36	17	1.9
7	*Acanthomysis nephropthalma*	0.31	0.08	17	0.5
8	*Acanthomysis davisii*	0.09	0.03	17	0.2
9	*Neomysis rayii*	0.06	0.02	17	0.1
	Total mysids	59.71	17.94	17	100.0

TABLE 1 (Continued). RANKS OF MEAN DENSITIES OF MYSID SPECIES.

RANK	TAXON	MEAN	S.E.	N	% OF TOTAL
CONTROL LOCATION--BEFORE PERIOD					
1	*Metamysidopsis elongata*	17.87	4.84	19	48.0
2	*Mysidopsis intii*	6.26	0.96	19	16.8
3	*Neomysis kadiakensis*	4.09	0.94	19	11.0
4	*Acanthomysis macropsis*	3.19	0.55	19	8.6
5	*Acanthomysis davisii*	2.74	0.54	19	7.4
6	*Acanthomysis nephropthalma*	0.95	0.26	19	2.6
7	*Neomysis rayii*	0.91	0.21	19	2.4
8	*Holmesimysis costata*	0.76	0.12	19	2.0
9	*Mysidopsis cathengelae*	0.47	0.15	19	1.2
	Total mysids	37.24	4.22	19	100.0

RANK	TAXON	MEAN	S.E.	N	% OF TOTAL
CONTROL LOCATION--AFTER PERIOD					
1	*Metamysidopsis elongata*	21.65	3.91	17	57.9
2	*Acanthomysis macropsis*	9.21	1.85	17	24.6
3	*Mysidopsis cathengelae*	2.36	0.91	17	6.3
4	*Mysidopsis intii*	2.07	0.62	17	5.5
5	*Neomysis kadiakensis*	1.39	0.21	17	3.7
6	*Acanthomysis nephropthalma*	0.35	0.14	17	0.9
7	*Holmesimysis costata*	0.24	0.07	17	0.6
8	*Acanthomysis davisii*	0.08	0.05	17	0.2
9	*Neomysis rayii*	0.02	0.02	17	0.1
	Total mysids	37.37	7.20	17	100.0

TABLE 2

SUMMARY OF BACIP TEST FOR CHANGES IN ABUNDANCE. All life stages are combined within each taxon. Results presented are those associated with the transformation with the lowest type I error. The indicated direction of change, i = increase, d = decrease, is presented for those species where $P > 0.05$.

TAXA	TRANSFORMATION	P > t	% CHANGE
Mysidopsis intii	Log(X)	0.004	116%
Neomysis kadiakensis	Log(X)	0.010[1]	126%
Acanthomysis davisii	Log(X+0.01) 0.28	i	
Acanthomysis macropsis	Log(X+0.01) 0.84	i	
Acanthomysis nephrophthalma	Log(X+0.01) 0.66	i	
Holmesimysis costata	Log(X+0.1) 0.32	d	
Metamysidopsis elongata	Log(X+0.1) 0.25	i	
Mysidopsis cathengelae	Log(X+0.01) 0.36	i	
Neomysis rayii	Log(X+0.1) 0.19	i	
Total mysids	Log(X)	0.10[2]	50%

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[1] Preoperational deltas were serially correlated. Significant ($P < 0.05$) results remained after correcting with second order autoregression.

[2] Preoperational deltas were serially correlated. P value in table is value obtained after correcting with second order autoregression.

TABLE 3

SUMMARY OF BACIP TEST FOR CHANGES IN ABUNDANCE AMONG THE LIFE STAGES OF THE MYSID SPECIES. For those species whose test result had an alpha level of <0.01, the transformation associated with the lowest alpha (unless Log X passed assumption tests), the P value and the percent relative change are presented. For those taxa whose P value >0.10, the indicated direction of change (i=increase, d=decrease, ?=uncertain) is presented.

SPECIES	STAGE	TRANSFORMATION	P	CHANGE
NEARSHORE SPECIES				
Acanthomysis davisii	Adult	-	*	d
	Immature	-	*	i
	Juvenile	-	*	i
Holmesimysis costata	Adult	-	*	d
	Immature	-	*	d
	Juvenile	-	*	d
Mysidopsis cathengelae	Adult	Log (X+1)	0.045	8%
	Immature	-	*	i
	Juvenile	-	*	d
Neomysis rayii	Adult	-	*	?
	Immature	-	*	d
	Juvenile	Log (X+.1)	0.085[1]	45%

SPECIES	STAGE	TRANSFORMATION	P	CHANGE
CROSS-SHELF SPECIES				
Acanthomysis macropsis	Adult	-	*	?
	Immature	-	*	i
	Juvenile	-	*	i
Metamysidopsis elongata	Adult	-	*	i
	Immature	-	*	i
	Juvenile	-	*	i
Mysidopsis intii	Adult	Log (X)	0.004	109%
	Immature	Log (X)	0.020	93%
	Juvenile	Log (X+.1))	0.009	181%

TABLE 3. (Continued) SUMMARY OF BACIP TEST FOR CHANGES IN ABUNDANCE AMONG THE LIFE STAGES OF THE MYSID SPECIES.

SPECIES	STAGE	TRANSFORMATION	P	CHANGE
OFFSHORE SPECIES				
Acanthomysis nephrophthalma	Adult	-	*	?
	Immature	-	*	?
	Juvenile	-	*	i
Neomysis kadiakensis	Adult	Log (X+.1)	0.003	122%
	Immature	Log (X+.1)	0.038	83%
	Juvenile	Log (X+1)	0.014[2]	55%

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[1] Mann-Whitney U test

[2] Preoperational deltas were serially correlated. Significant ($p<0.05$) results remained after correcting with second order autoregressive errors.

TABLE 4

AVERAGE PERCENT OF MYSID POPULATIONS IN THE OFFSHORE AREA (> 15 M).

		SONGS				CONTROL			
		BEFORE		AFTER		BEFORE		AFTER	
SPECIES	STAGE	X	(SE)	X	(SE)	X	(SE)	X	(SE)
NEARSHORE SPECIES									
Acanthomysis davisii	Adult	4	(3)	0	(0)	6	(3)	14	(14)
	Immature	4	(3)	0	(0)	3	(2)	0	(0)
	Juvenile	3	(1)	6	(6)	2	(1)	4	(4)
Holmesimysis costata	Adult	0	(0)	0	(0)	0	(0)	0	(0)
	Immature	0	(0)	0	(0)	0	(0)	0	(0)
	Juvenile	0	(0)	0	(0)	0	(0)	0	(0)
Mysidopsis cathengelae	Adult	0	(0)	1	(0)	0	(0)	0	(0)
	Immature	0	(0)	1	(1)	0	(0)	1	(1)
	Juvenile	0	(0)	0	(0)	0	(0)	0	(0)
Neomysis rayii	Adult	0	(0)	0	(0)	0	(0)	0	(0)
	Immature	2	(2)	0	(0)	0	(0)	0	(.)
	Juvenile	8	(5)	21	(13)	3	(2)	13	(13)

		SONGS				CONTROL			
		BEFORE		AFTER		BEFORE		AFTER	
SPECIES	STAGE	X	(SE)	X	(SE)	X	(SE)	X	(SE)
CROSS-SHELF SPECIES									
Acanthomysis macropsis	Adult	48	(7)	56	(7)	61	(6)	57	(8)
	Immature	36	(7)	41	(8)	36	(6)	36	(8)
	Juvenile	8	(3)	8	(3)	11	(3)	5	(2)
Metamysidopsis elongata	Adult	38	(6)	45	(8)	33	(5)	51	(7)
	Immature	19	(4)	29	(7)	18	(4)	25	(5)
	Juvenile	3	(2)	0	(0)	0	(0)	6	(6)
Mysidopsis intii	Adult	57	(4)	58	(5)	59	(4)	58	(7)
	Immature	42	(5)	57	(6)	40	(5)	57	(7)
	Juvenile	37	(6)	60	(9)	25	(4)	52	(8)

TABLE 4. (Continued) AVERAGE PERCENT OF MYSID POPULATIONS IN THE OFFSHORE AREA (> 15 m).

		SONGS				CONTROL			
		BEFORE		AFTER		BEFORE		AFTER	
SPECIES	STAGE	X	(SE)	X	(SE)	X	(SE)	X	(SE)
OFFSHORE SPECIES									
Acanthomysis nephrophthalma	Adult	100	(0)	100	(0)	100	(0)	100	(0)
	Immature	100	(0)	100	(0)	100	(0)	100	(0)
	Juvenile	100	(0)	99	(1)	98	(2)	100	(0)
Neomysis kadiakensis	Adult	98	(1)	99	(0)	93	(3)	100	(0)
	Immature	96	(2)	99	(1)	92	(3)	100	(0)
	Juvenile	88	(4)	89	(5)	72	(6)	92	(5)

TABLE 5

ESTIMATED LOSS DUE TO SONGS OPERATIONS DURING THE OPERATIONAL PERIOD.
Biomass is in kilograms.

		UNIT 1		UNITS 2 & 3	
SPECIES	STAGE	NUMBER	BIOMASS	NUMBER	BIOMASS
NEARSHORE SPECIES					
Acanthomysis davisii	Adult	$2.76x10^{6}$	16	$2.04x10^{7}$	120
	Immature	$4.00x10^{6}$	6	$2.40x10^{7}$	37
	Juvenile	$2.89x10^{6}$	4	$1.60x10^{7}$	24
Holmesimysis costata	Adult	$4.02x10^{7}$	226	$2.60x10^{8}$	1,459
	Immature	$4.31x10^{7}$	44	$2.86x10^{8}$	292
	Juvenile	$4.48x10^{7}$	46	$2.34x10^{8}$	239
Mysidopsis cathengelae	Adult	$3.14x10^{7}$	369	$3.26x10^{8}$	3,845
	Immature	$8.47x10^{7}$	180	$8.37x10^{8}$	1,784
	Juvenile	$1.37x10^{8}$	292	$1.61x10^{9}$	3,434
Neomysis rayii	Adult	$3.09x10^{5}$	13	$2.68x10^{6}$	111
	Immature	$6.13x10^{4}$	0	$7.38x10^{5}$	5
	Juvenile	$5.08x10^{6}$	35	$2.58x10^{7}$	177

		UNIT 1		UNITS 2 & 3	
SPECIES	STAGE	NUMBER	BIOMASS	NUMBER	BIOMASS
CROSS-SHELF SPECIES					
Acanthomysis macropsis	Adult	$1.61x10^{8}$	1,392	$9.61x10^{8}$	8,302
	Immature	$2.74x10^{8}$	479	$1.66x10^{9}$	2,904
	Juvenile	$8.18x10^{8}$	1,431	$5.50x10^{9}$	9,619
Metamysidopsis elongata	Adult	$4.38x10^{8}$	1,178	$3.03x10^{9}$	8,146
	Immature	$5.80x10^{8}$	441	$3.83x10^{9}$	2,912
	Juvenile	$3.30x10^{8}$	251	$4.82x10^{9}$	3,667
Mysidopsis intii	Adult	$3.27x10^{7}$	66	$2.44x10^{8}$	495
	Immature	$1.56x10^{7}$	8	$1.24x10^{8}$	67
	Juvenile	$4.69x10^{6}$	3	$4.92x10^{7}$	27

TABLE 5. ESTIMATED LOSS DUE TO SONGS OPERATIONS DURING THE OPERATIONAL PERIOD.

		UNIT 1		UNITS 2 & 3	
SPECIES	STAGE	NUMBER	BIOMASS	NUMBER	BIOMASS
OFFSHORE SPECIES					
Acanthomysis nephrophthalma	Adult	0.00x10^{0}	0	0.00x10^{0}	0
	Immature	0.00x10^{0}	0	0.00x10^{0}	0
	Juvenile	0.00x10^{0}	0	0.00x10^{0}	0
Neomysis kadiakensis	Adult	0.00x10^{0}	0	0.00x10^{0}	0
	Immature	0.00x10^{0}	0	0.00x10^{0}	0
	Juvenile	8.40x10^{3}	0	1.35x10^{5}	1
Other Species	Adult	0.00x10^{0}	0	0.00x10^{0}	0
	Immature	2.70x10^{5}	1	1.24x10^{6}	3
	Juvenile	1.42x10^{8}	381	8.26x10^{8}	2,221
Total		3.19x10^{9}	6,863	2.47x10^{10}	49,890
Annual Average		1.06x10^{9}	2,288	8.23x10^{9}	16,630

TABLE 6

ESTIMATED LONG-TERM ANNUAL INTAKE LOSS.
Biomass is in kilograms.

		UNIT 1		UNITS 2 & 3	
SPECIES	STAGE	NUMBER	BIOMASS	NUMBER	BIOMASS
NEARSHORE SPECIES					
Acanthomysis davisii	Adult	$3.62x10^{6}$	21	$2.30x10^{7}$	135
	Immature	$1.25x10^{7}$	19	$7.70x10^{7}$	118
	Juvenile	$1.92x10^{7}$	29	$1.21x10^{8}$	184
Holmesimysis costata	Adult	$1.42x10^{7}$	80	$9.15x10^{7}$	514
	Immature	$2.24x10^{7}$	23	$1.47x10^{8}$	150
	Juvenile	$1.64x10^{7}$	17	$1.06x10^{8}$	108
Mysidopsis cathengelae	Adult	$1.04x10^{7}$	122	$6.40x10^{7}$	754
	Immature	$2.92x10^{7}$	62	$1.79x10^{8}$	382
	Juvenile	$4.98x10^{7}$	106	$3.30x10^{8}$	703
Neomysis rayii	Adult	$5.26x10^{5}$	22	$3.38x10^{6}$	139
	Immature	$2.02x10^{5}$	1	$1.30x10^{6}$	9
	Juvenile	$6.25x10^{6}$	43	$3.51x10^{7}$	241

		UNIT 1		UNITS 2 & 3	
SPECIES	STAGE	NUMBER	BIOMASS	NUMBER	BIOMASS
CROSS-SHELF SPECIES					
Acanthomysis macropsis	Adult	$1.74x10^{7}$	150	$1.17x10^{8}$	1,014
	Immature	$3.53x10^{7}$	62	$2.40x10^{8}$	420
	Juvenile	$1.22x10^{8}$	213	$8.82x10^{8}$	1,544
Metamysidopsis elongata	Adult	$1.05x10^{8}$	283	$6.75x10^{8}$	1,815
	Immature	$1.64x10^{8}$	125	$1.01x10^{9}$	765
	Juvenile	$1.39x10^{8}$	106	$1.01x10^{9}$	765
Mysidopsis intii	Adult	$1.47x10^{7}$	30	$9.81x10^{7}$	199
	Immature	$1.50x10^{7}$	8	$1.07x10^{8}$	58
	Juvenile	$1.17x10^{7}$	6	$8.71x10^{7}$	47

TABLE 6. (Continued) ESTIMATED LONG-TERM ANNUAL INTAKE LOSS.

		UNIT 1		UNITS 2 & 3	
SPECIES	STAGE	NUMBER	BIOMASS	NUMBER	BIOMASS
OFFSHORE SPECIES					
Acanthomysis nephrophthalma	Adult	0.00×10^0	0	0.00×10^0	0
	Immature	0.00×10^0	0	0.00×10^0	0
	Juvenile	1.21×10^5	0	8.80×10^5	1
Neomysis kadiakensis	Adult	1.15×10^4	0	8.62×10^4	4
	Immature	5.06×10^4	0	4.36×10^5	3
	Juvenile	4.75×10^5	3	4.05×10^6	28
Other Species	Adult	1.74×10^4	0	1.07×10^5	0
	Immature	5.56×10^4	0	3.73×10^5	1
	Juvenile	6.19×10^7	167	4.28×10^8	1,151
TOTAL		8.71×10^8	1,699	5.83×10^9	11,250

7.0 FIGURES

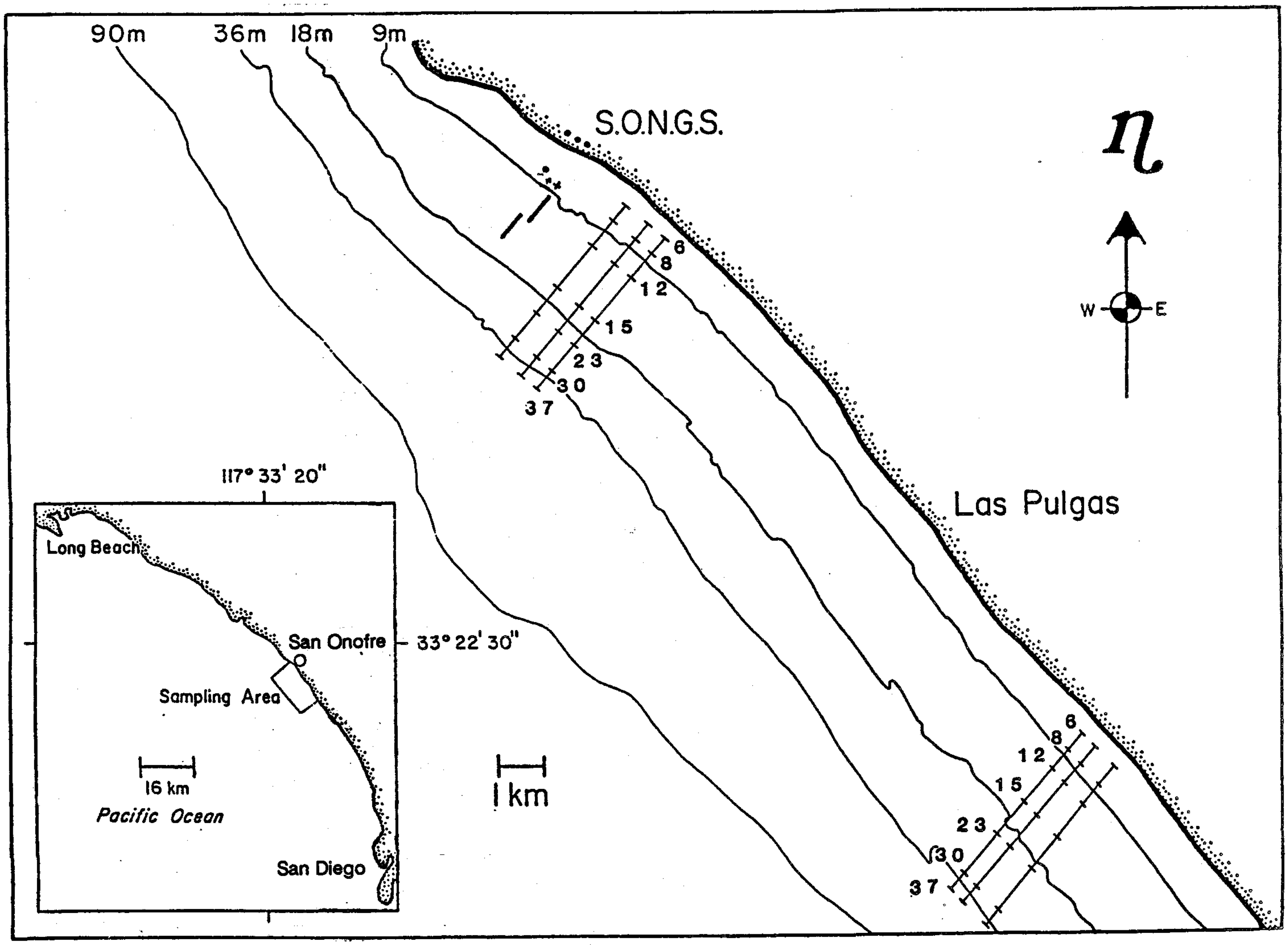

Figure 1: **Locations of monitoring transects sampled for mysids.**

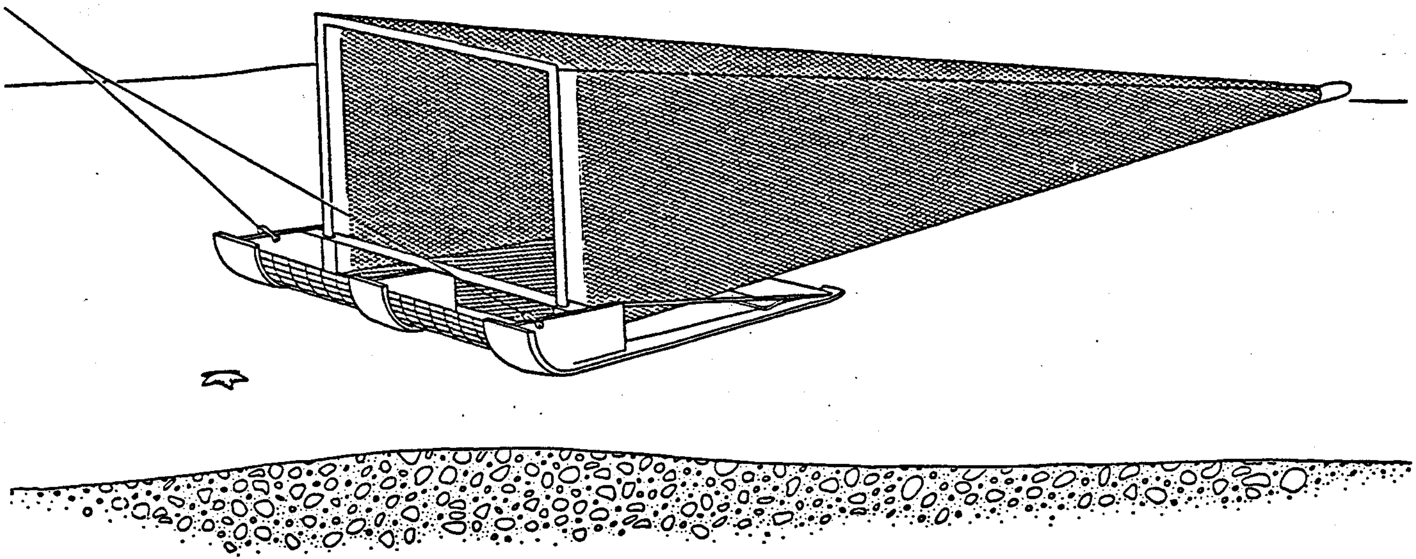

Figure 2: **Configuration of the gear used to sample mysids.**

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APPENDICES

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APPENDIX A

OPERATION OF SONGS UNITS 2 AND 3 ON MYSID SAMPLING DATES

PREOPERATIONAL			OPERATIONAL		
DATE	% POWER	PUMPS*	DATE	% POWER	PUMPS*
09OCT79	0	0.0	07DEC83	25	4.0
23OCT79	0	0.0	20MAR84	100	8.0
06NOV79	0	0.0	12JUN84	50	6.0
20NOV79	0	0.0	27AUG84	50	8.0
03DEC79	0	0.0	25SEP84	100	8.0
17DEC79	0	0.0	28DEC84	50	4.0
17JAN80	0	0.1	04APR85	37	5.0
27FEB80	0	0.1	07MAY85	100	8.0
13MAR80	0	0.0	15JUN85	93	8.0
12APR80	0	1.0	22JUL85	77	8.0
25APR80	0	0.0	02SEP85	78	8.0
08MAY80	0	1.0	05FEB86	100	8.0
22MAY80	0	0.9	13MAR86	35	6.0
17JUN80	0	0.7	05MAY86	50	4.0
03JUL80	0	1.0	05JUN86	48	7.0
07AUG80	0	0.0	10JUL86	61	7.9
11JUN81	0	1.0	08SEP86	97	8.0
22SEP81	0	0.0			
07DEC81	0	0.0			
MEAN	0	0.31		67.7	6.10

* Maximum number of pumps is 8; flow rate for each pump is 207,000 gallons per minute.

APPENDIX A. (Continued). OPERATION OF SONGS UNIT 1 ON MYSID SAMPLING DATES.

PREOPERATIONAL			OPERATIONAL		
DATE	% POWER	PUMPS*	DATE	% POWER	PUMPS*
09OCT79	97	1.9	07DEC83	0	0.0
23OCT79	97	1.7	20MAR84	0	1.0
06NOV79	99	1.9	12JUN84	0	0.4
20NOV79	96	1.9	27AUG84	0	0.0
03DEC79	92	1.9	25SEP84	0	0.0
17DEC79	88	1.0	28DEC84	93	2.0
17JAN80	70	1.8	04APR85	88	2.0
27FEB80	95	2.0	07MAY85	0	1.1
13MAR80	94	2.0	15JUN85	87	2.0
12APR80	0	1.0	22JUL85	87	2.0
25APR80	0	0.0	02SEP85	59	2.0
08MAY80	0	0.0	05FEB86	0	0.0
22MAY80	0	1.0	13MAR86	0	0.0
17JUN80	0	2.0	05MAY86	0	1.0
03JUL80	0	1.7	05JUN86	0	1.0
07AUG80	0	0.0	10JUL86	0	2.0
11JUN81	0	2.0	08SEP86	0	1.0
22SEP81	0	2.0			
07DEC81	80	2.0			
MEAN	47.7	1.45		24.4	1.03

* Maximum number of pumps is 2; flow rate for each pump is 160,000 gallons per minute.

APPENDIX B

AVERAGE OPERATION OF SONGS UNITS 2 AND 3 FOR 30 DAYS PRIOR TO MYSID SAMPLING DATES.

PREOPERATIONAL			OPERATIONAL		
DATE	% POWER	PUMPS*	DATE	% POWER	PUMPS*
09OCT79	0	0.00	07DEC83	45	5.42
23OCT79	0	0.00	20MAR84	70	7.42
06NOV79	0	0.00	12JUN84	81	7.16
20NOV79	0	0.00	27AUG84	67	7.55
03DEC79	0	0.00	25SEP84	96	8.00
17DEC79	0	0.00	28DEC84	37	3.68
17JAN80	0	0.03	04APR85	21	6.58
27FEB80	0	0.10	07MAY85	59	7.55
13MAR80	0	0.08	15JUN85	94	8.00
12APR80	0	0.72	22JUL85	78	8.00
25APR80	0	0.87	02SEP85	74	8.00
08MAY80	0	0.76	05FEB86	75	7.52
22MAY80	0	0.72	13MAR86	46	6.81
17JUN80	0	0.90	05MAY86	46	4.00
03JUL80	0	0.90	05JUN86	50	4.83
07AUG80	0	0.87	10JUL86	83	7.79
11JUN81	0	0.91	08SEP86	89	7.68
22SEP81	0	0.00			
07DEC81	0	0.00			
MEAN	0	0.36		65.4	6.82

* Maximum number of pumps is 8; flow rate for each pump is 207,000 gallons per minute.

APPENDIX B. (Continued). AVERAGE OPERATION OF SONGS UNIT 1 DURING THE 30 DAYS PRIOR TO MYSID SAMPLING DATES.

PREOPERATIONAL			OPERATIONAL		
DATE	% POWER	PUMPS*	DATE	% POWER	PUMPS*
09OCT79	67	1.86	07DEC83	0	1.61
23OCT79	93	1.87	20MAR84	0	1.66
06NOV79	97	1.87	12JUN84	0	0.23
20NOV79	81	1.88	27AUG84	0	0.00
03DEC79	80	1.87	25SEP84	0	0.00
17DEC79	91	1.81	28DEC84	80	1.08
17JAN80	88	1.87	04APR85	80	1.93
27FEB80	53	1.24	07MAY85	70	1.72
13MAR80	89	1.94	15JUN85	84	1.98
12APR80	83	1.90	22JUL85	84	1.90
25APR80	45	1.25	02SEP85	54	1.59
08MAY80	6	0.42	05FEB86	0	0.15
22MAY80	0	0.16	13MAR86	0	0.00
17JUN80	0	0.73	05MAY86	0	0.07
03JUL80	0	1.26	05JUN86	0	0.53
07AUG80	0	0.83	10JUL86	0	1.58
11JUN81	0	1.40	08SEP86	60	1.72
22SEP81	32	1.96			
07DEC81	80	1.95			
MEAN	51.8	1.48		30.4	1.04

* Maximum number of pumps is 2; flow rate for each pump is about 160,000 gallons per minute.

APPENDIX C

CONVERSION OF PERCENT RELATIVE CHANGE INTO FACTORS OF CHANGE

% DECREASE	% INCREASE	FACTOR OF CHANGE
-10%	11%	1.1
-20%	25%	1.3
-30%	43%	1.4
-40%	67%	1.7
-50%	100%	2.0
-60%	150%	2.5
-70%	233%	3.3
-80%	400%	5.0
-90%	900%	10.0

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APPENDIX D

AVERAGE WEIGHTS (IN MILLIGRAMS) OF MYSIDS USED IN INTAKE LOSS ESTIMATES

SPECIES	ADULT	JUVENILE AND IMMATURE
Mysidopsis intii	2.03	0.54
Neomysis kadiakensis	41.25	6.88
Acanthomysis davisii	5.87	1.53
Holmesimysis costata	5.62	1.02
Mysidopsis cathengelae	11.78	2.13
Neomysis rayii	41.25	6.88
Acanthomysis macropsis	8.64	1.75
Metamysidopsis elongata	2.69	0.76
Acanthomysis nephrophthalma	5.62	1.02

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APPENDIX E

MEAN DENSITIES OF THE LIFE-STAGES OF THE MYSID SPECIES

For each life-stage of each species the mean density (per m^3 of the bottom one meter of the water column) and the standard error of the mean are given for each location (Control and Impact) and each period (Preoperational and Operational). Sample sizes were 19 for the preoperational period; 17 for the operational period.

APPENDIX E. (Continued)

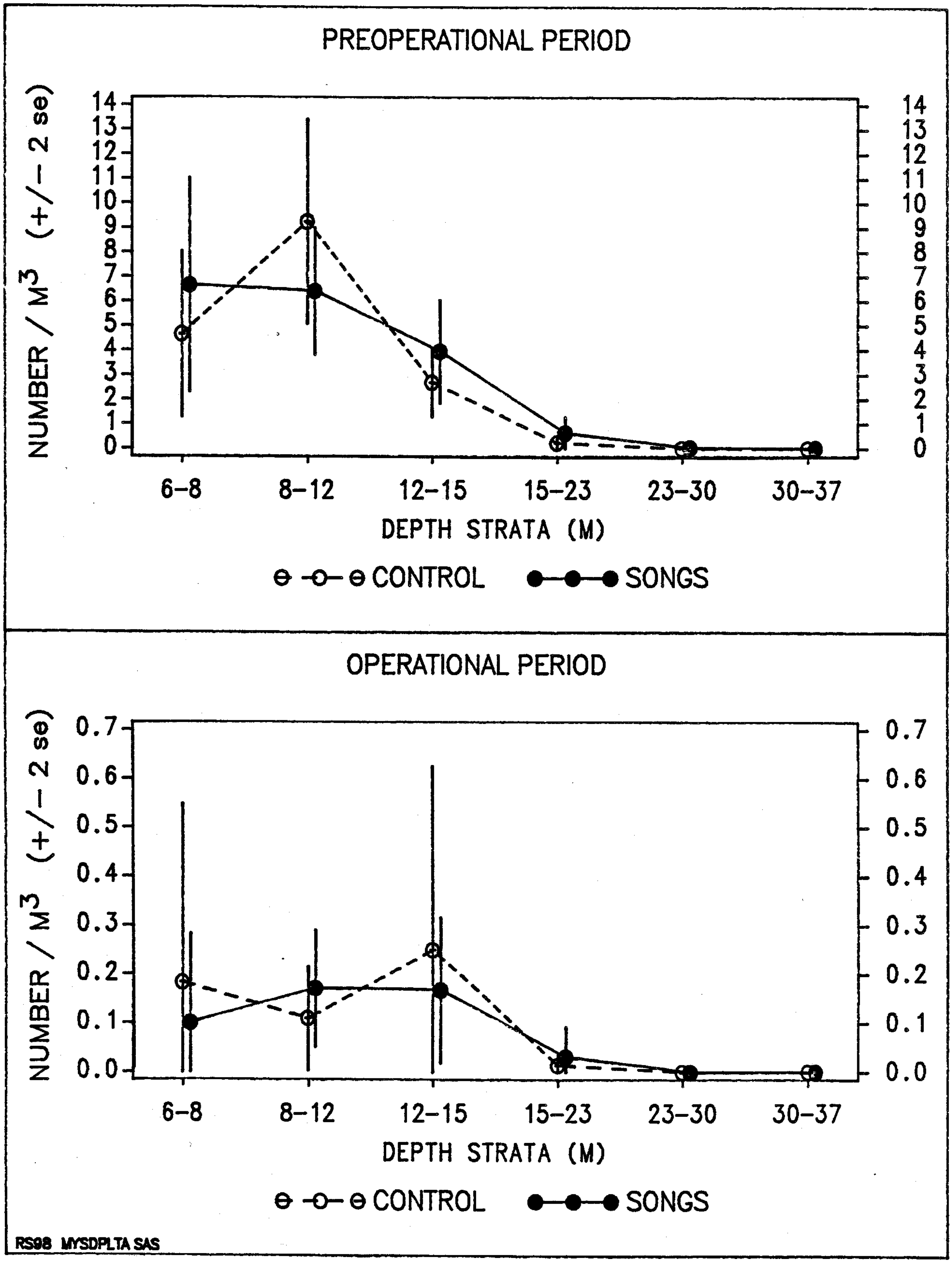
		PREOPERATIONAL				OPERATIONAL			
SPECIES	STAGE	IMPACT	ST ERR	CONTROL	ST ERR	IMPACT	ST ERR	CONTROL	ST ERR
Acanthomysis davisii	ADULT	0.2940	0.05857	0.2521	0.04237	0.0116	0.0048	0.0308	0.01729
	IMMATURE	1.0152	0.18642	0.8101	0.15964	0.0361	0.0129	0.0148	0.00591
	JUVENILE	1.3181	0.25661	1.6764	0.36549	0.0355	0.0143	0.0428	0.02654
Acanthomysis macropsis	ADULT	1.1489	0.28387	0.7830	0.14345	2.6027	0.5554	2.0653	0.50166
	IMMATURE	1.0792	0.27781	0.9496	0.18730	3.7657	0.8959	2.6278	0.59306
	JUVENILE	1.5208	0.31747	1.4615	0.32419	11.4354	4.4132	4.5152	0.99737
Acanthomysis nephrophthalma	ADULT	0.1152	0.02199	0.1372	0.03277	0.0633	0.0233	0.0683	0.02344
	IMMATURE	0.2576	0.05372	0.2947	0.06263	0.0915	0.0297	0.1097	0.02762
	JUVENILE	0.3222	0.06795	0.5169	0.18243	0.1520	0.0321	0.1710	0.08952
Holmesimysis costata	ADULT	0.5813	0.11597	0.1056	0.02572	0.4406	0.1422	0.0951	0.03770
	IMMATURE	1.3179	0.29071	0.2628	0.05862	0.4837	0.1426	0.1032	0.03230
	JUVENILE	1.7851	0.71725	0.3869	0.06914	0.2620	0.1144	0.0387	0.01130
Metamysidopsis elongata	ADULT	5.2050	0.79207	8.4970	1.44247	9.4222	1.9062	10.4615	3.03197
	IMMATURE	4.4588	0.78063	6.9328	1.41961	9.1096	2.3223	5.8493	1.08882
	JUVENILE	1.9608	1.50068	2.4442	1.04347	11.5062	7.1749	5.3409	1.78173
Mysidopsis cathengelae	ADULT	0.0868	0.02302	0.0800	0.02679	0.4144	0.1762	0.2798	0.13550
	IMMATURE	0.3098	0.12114	0.1324	0.04501	1.1405	0.5578	0.7290	0.37553
	JUVENILE	0.5372	0.19586	0.2645	0.09195	2.5774	1.3047	1.3547	0.60391
Mysidopsis intii	ADULT	1.4542	0.18539	1.7002	0.22661	0.9443	0.2035	0.6752	0.19258
	IMMATURE	2.2608	0.35298	2.4105	0.40979	1.2902	0.3399	0.7407	0.18512
	JUVENILE	1.7739	0.33012	2.1514	0.39336	1.0578	0.3924	0.6458	0.25983
Neomysis kadiakensis	ADULT	0.5322	0.11396	0.9783	0.26444	0.6746	0.1662	0.3534	0.06088
	IMMATURE	0.8487	0.21372	1.1172	0.26362	1.0726	0.2057	0.6532	0.10457
	JUVENILE	2.2427	0.70446	1.9975	0.48550	1.1106	0.2742	0.3921	0.07750
Neomysis rayii	ADULT	0.0465	0.01055	0.0198	0.00733	0.0117	0.0061	0.0011	0.00078
	IMMATURE	0.0509	0.01134	0.0156	0.00541	0.0028	0.0024	0.0008	0.00077
	JUVENILE	0.6294	0.19427	0.8798	0.21503	0.0294	0.0149	0.0213	0.01453

APPENDIX F

CROSS-SHELF DISTRIBUTIONS

Acanthomysis davisii

ALL STAGES



Acanthomysis davisii

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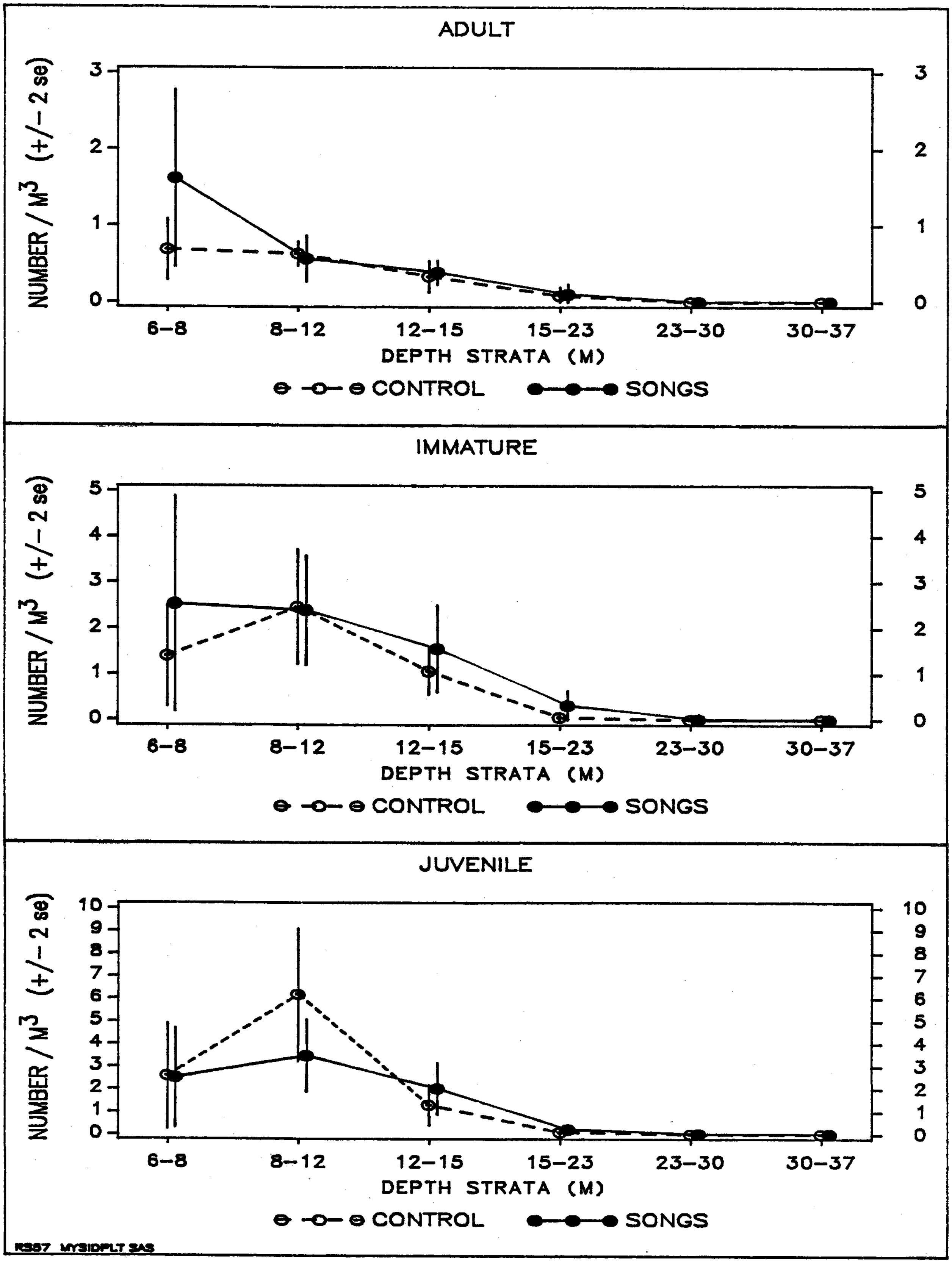

Acanthomysis davisii

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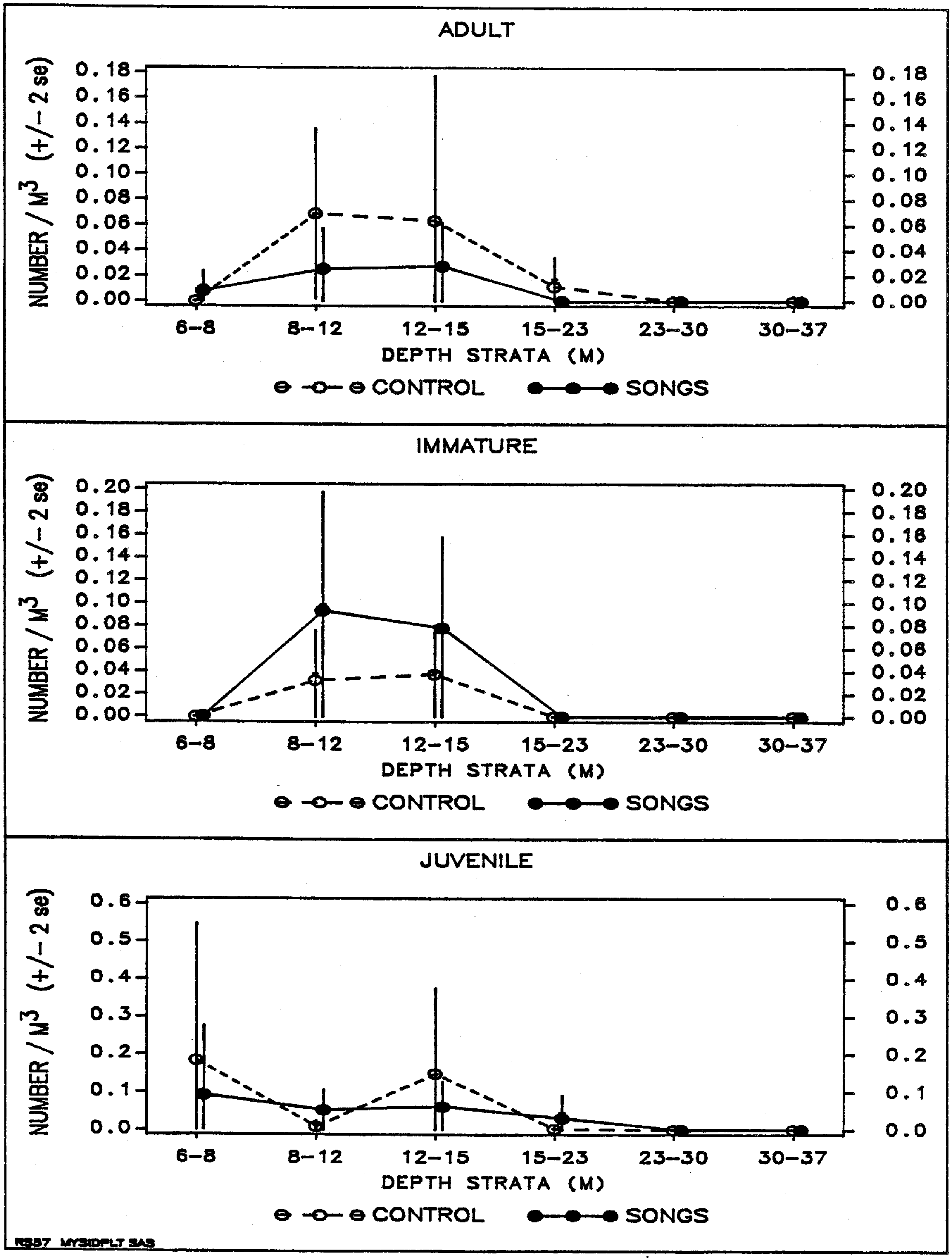

Holmesimysis costata

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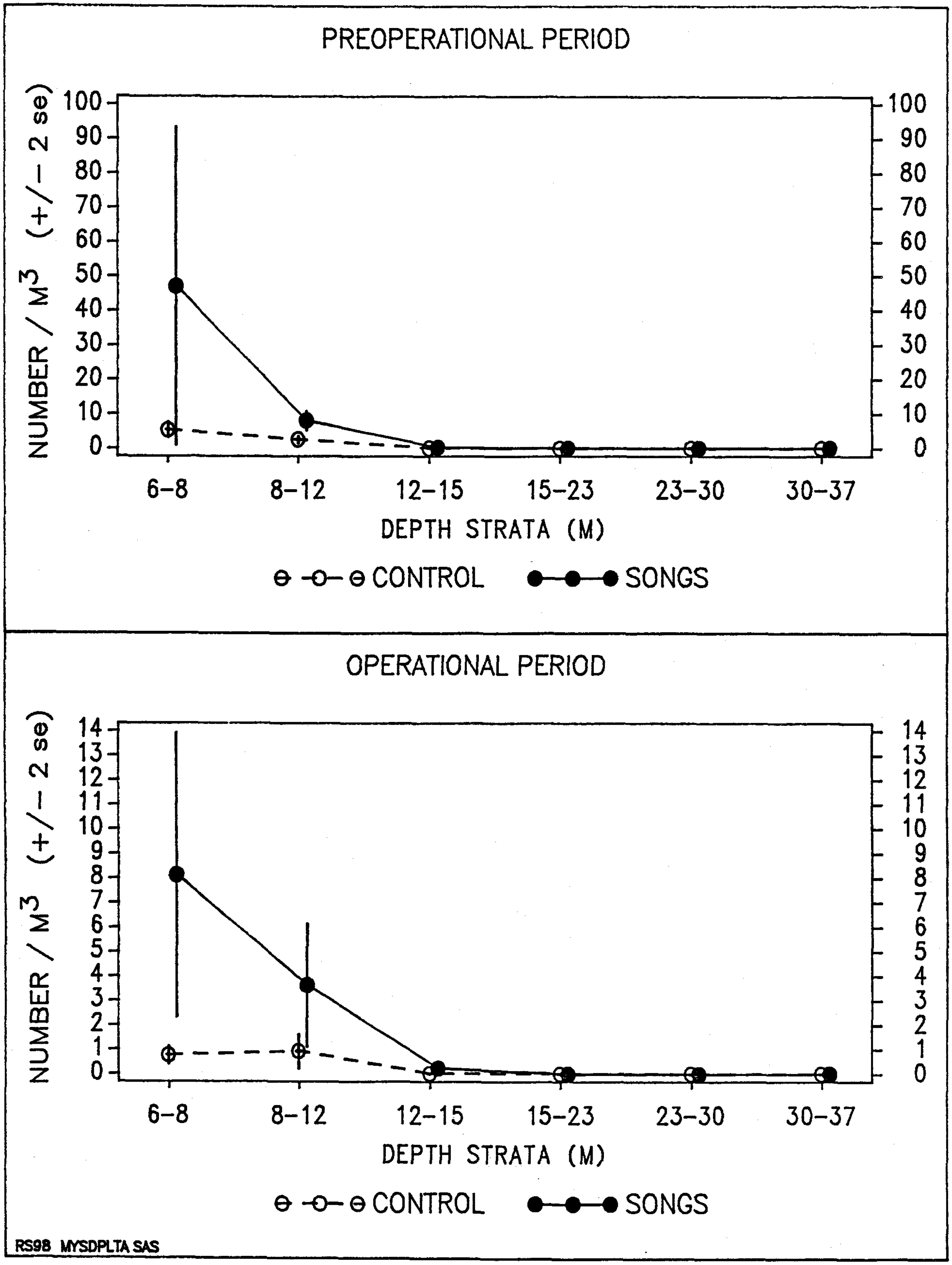

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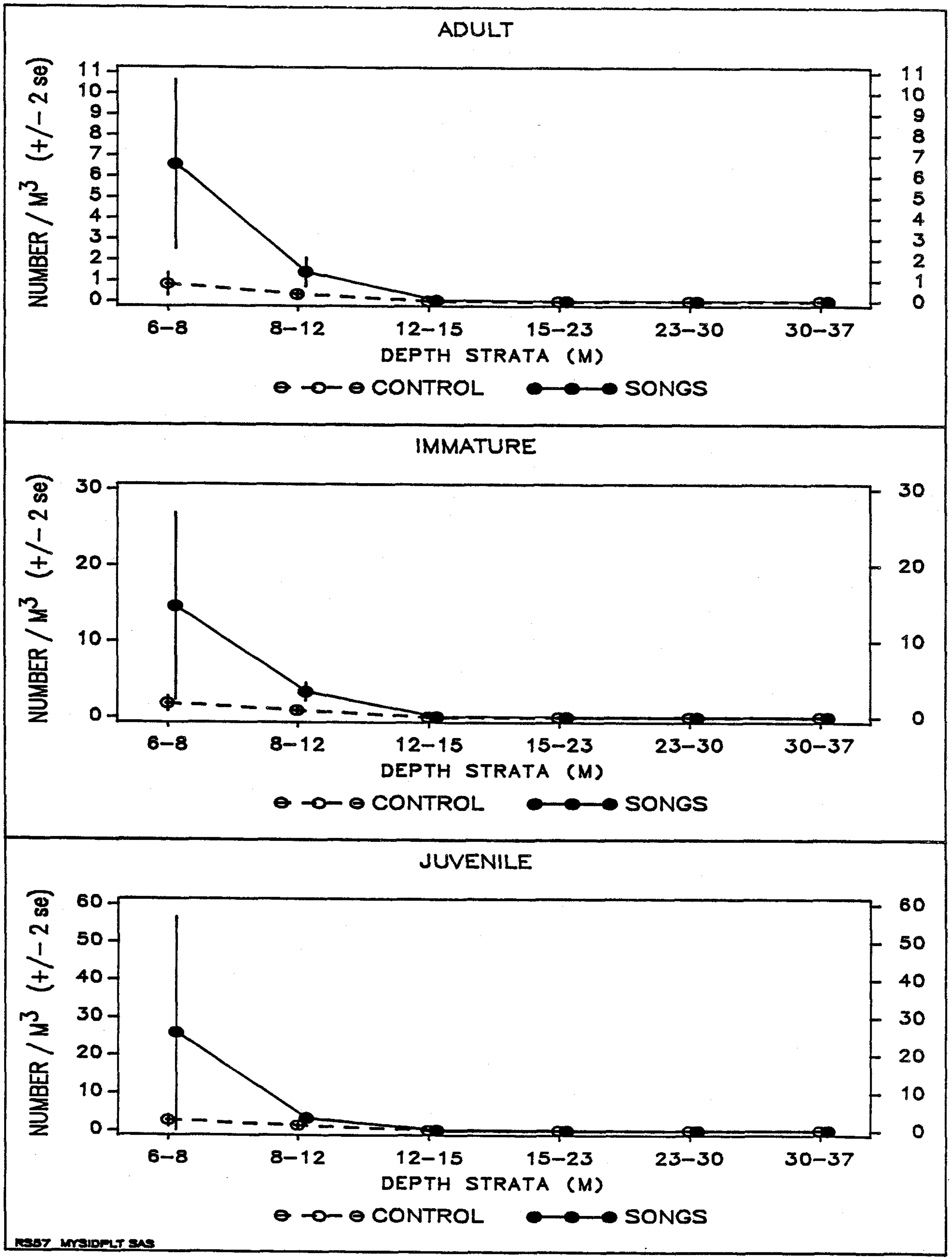
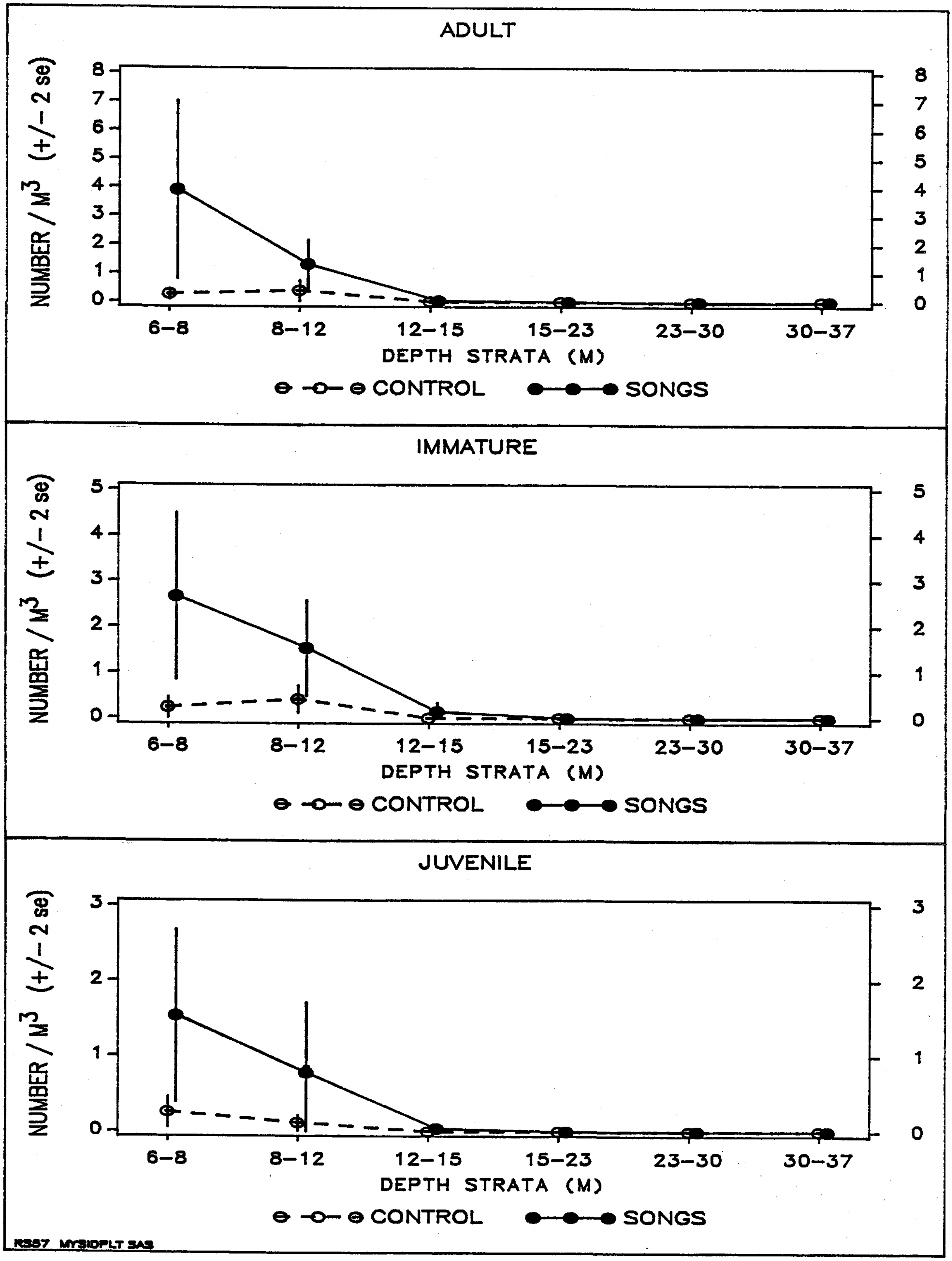


Holmesimysis costata

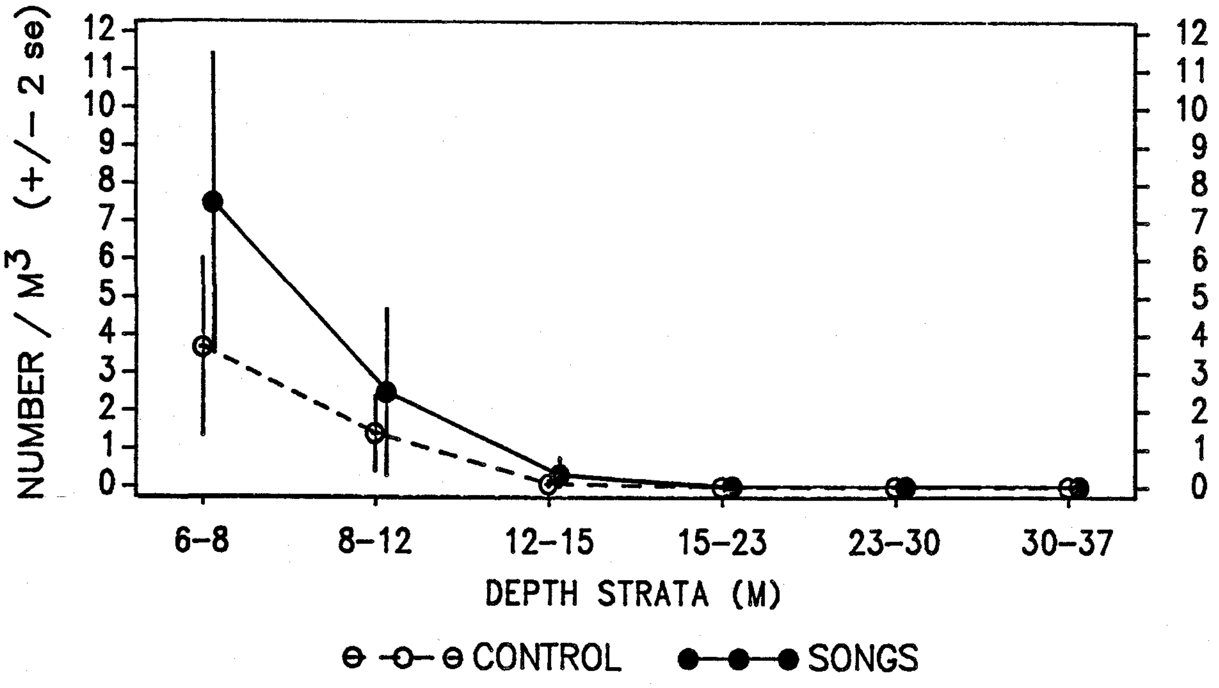
OPERATIONAL PERIOD



Mysidopsis cathengelae

ALL STAGES

PREOPERATIONAL PERIOD



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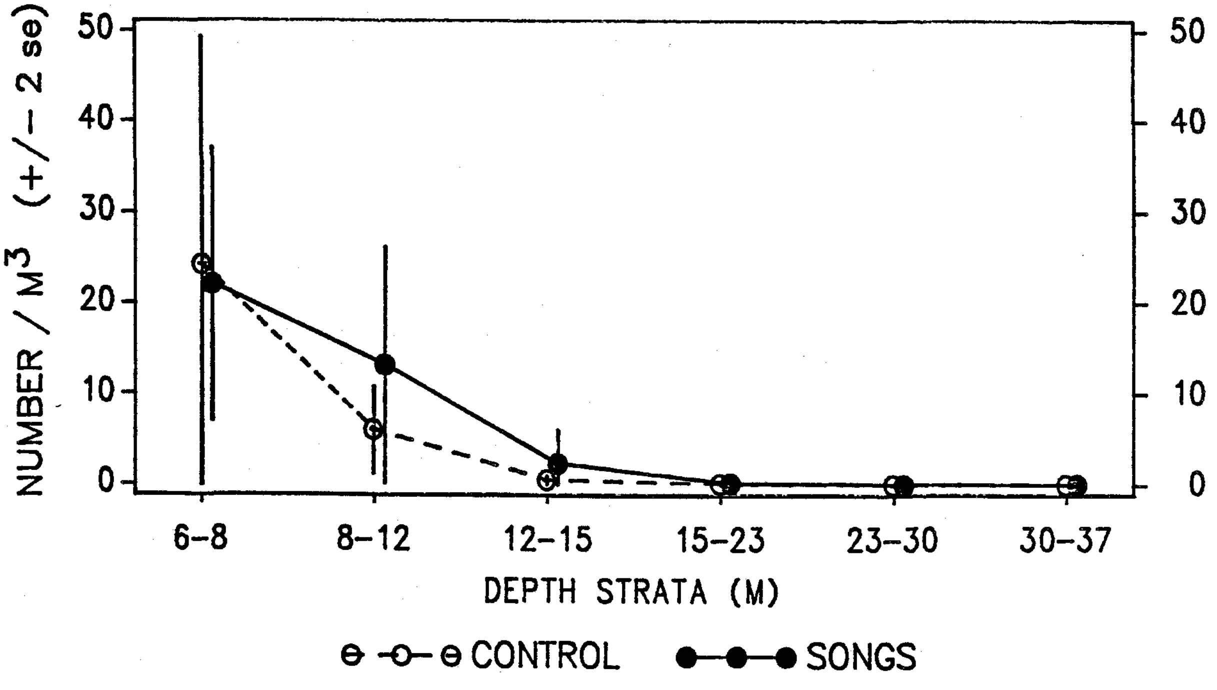

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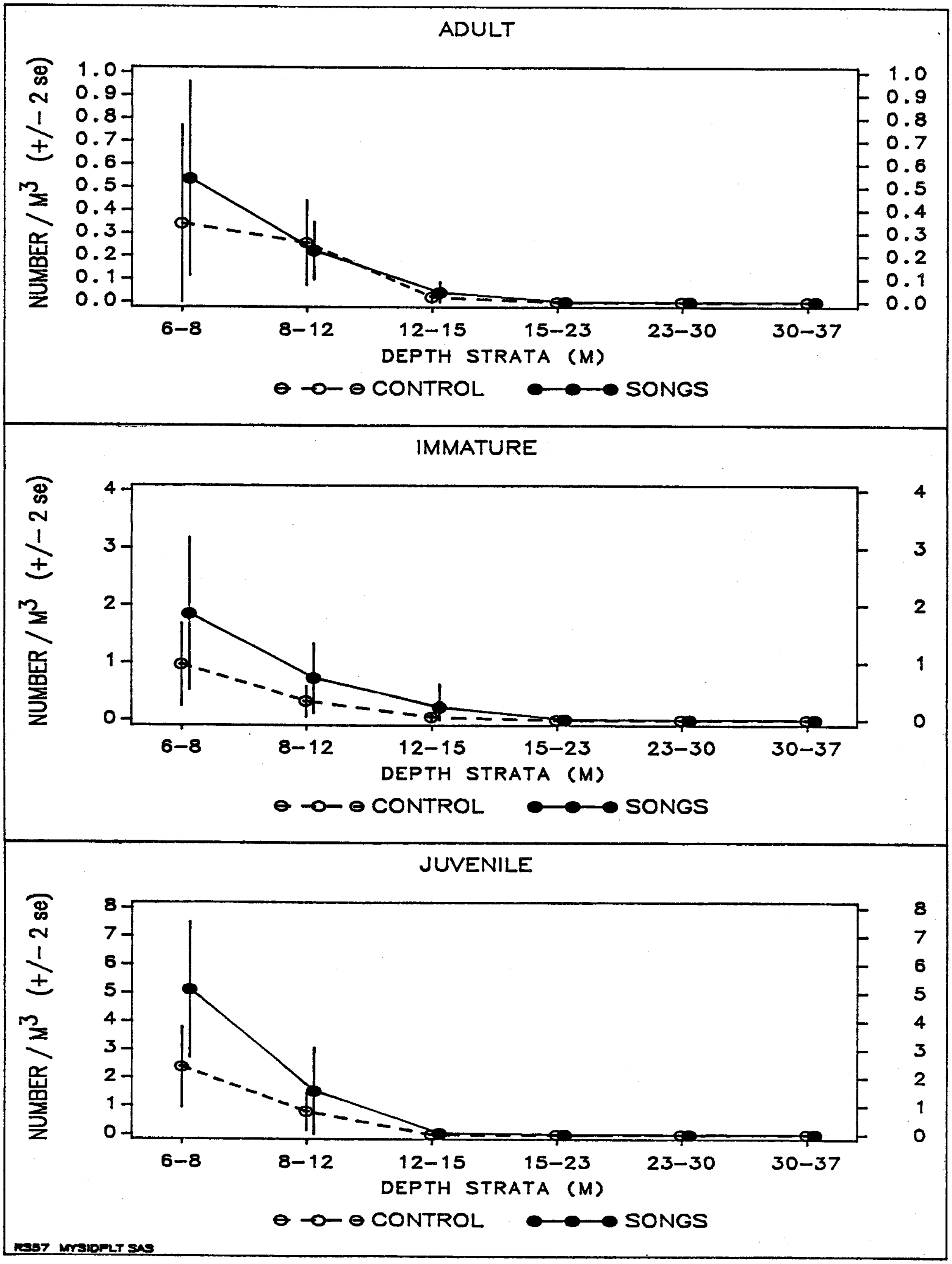
Mysidopsis cathengelae

PREOPERATIONAL PERIOD



Mysidopsis cathengelae

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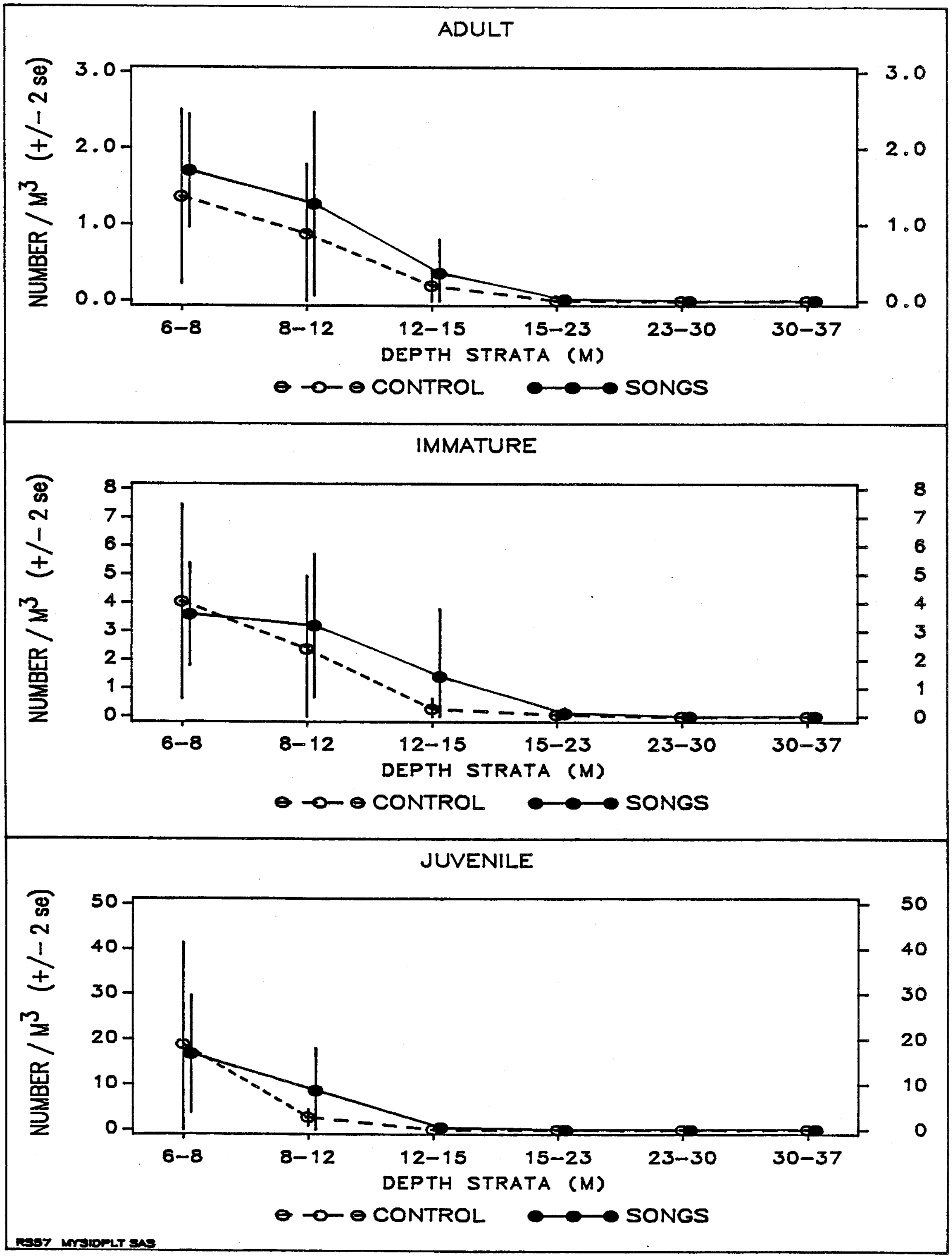

Neomysis rayii

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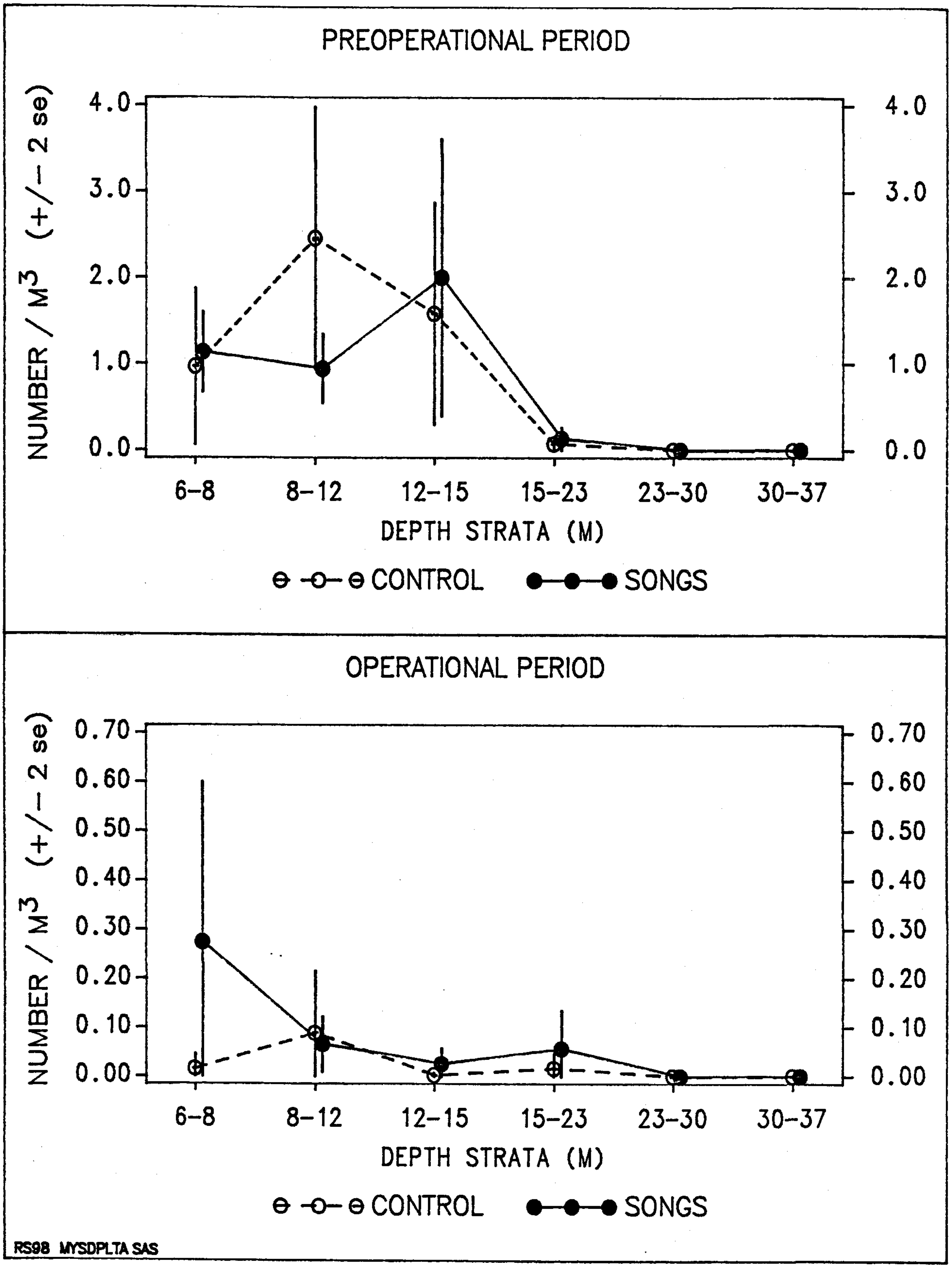

PREOPERATIONAL PERIOD

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Neomysis rayii

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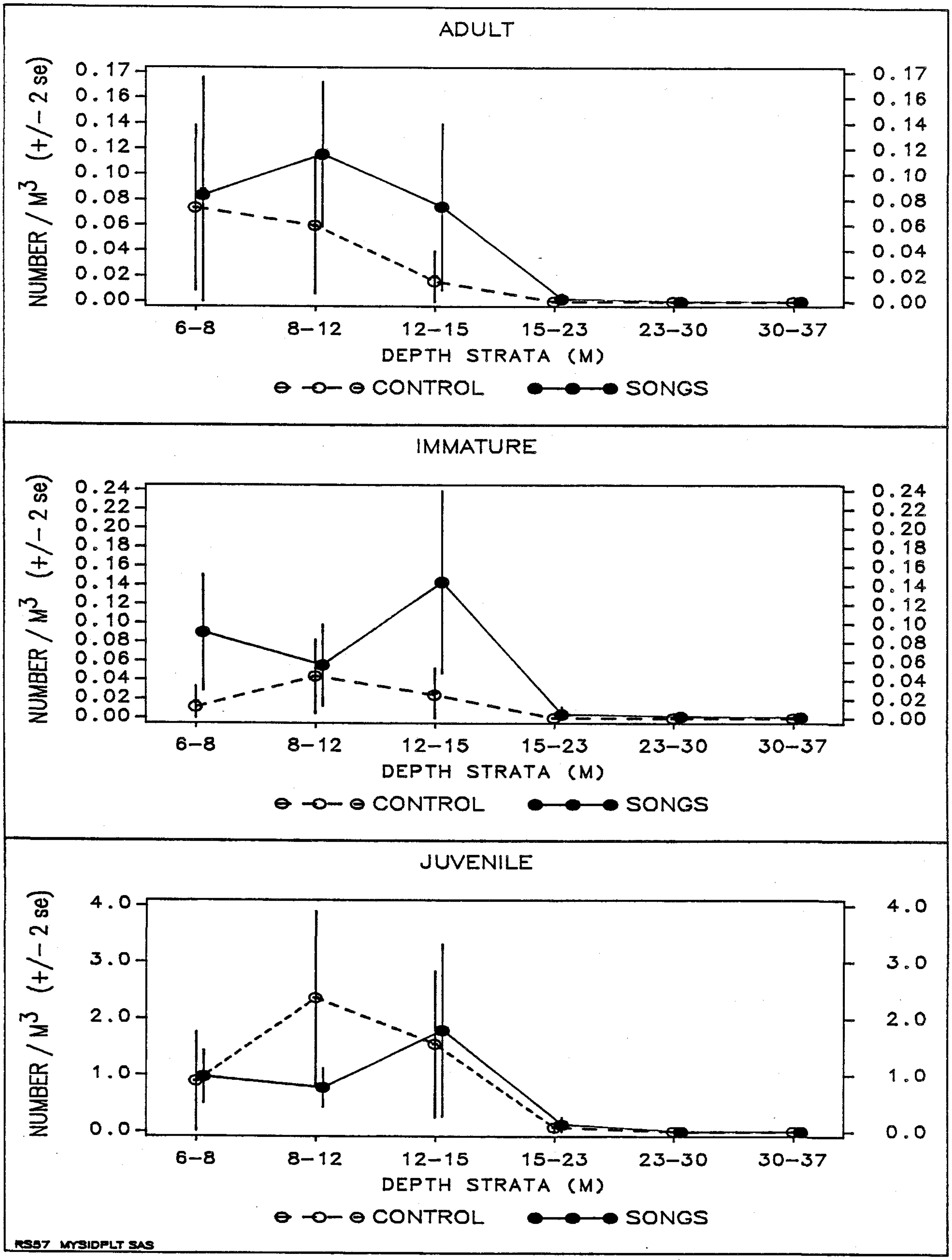

Neomysis rayii

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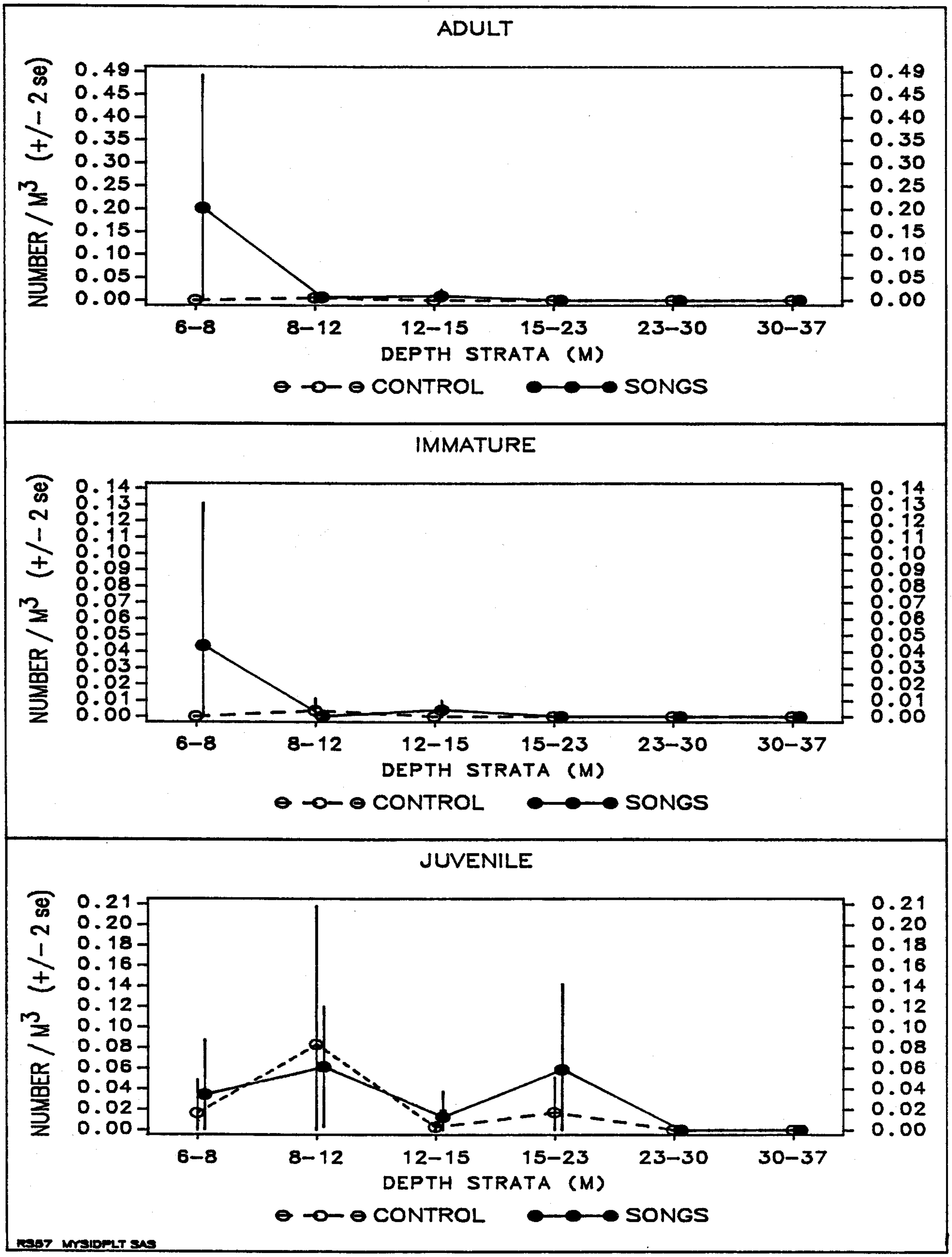

Acanthomysis macropsis

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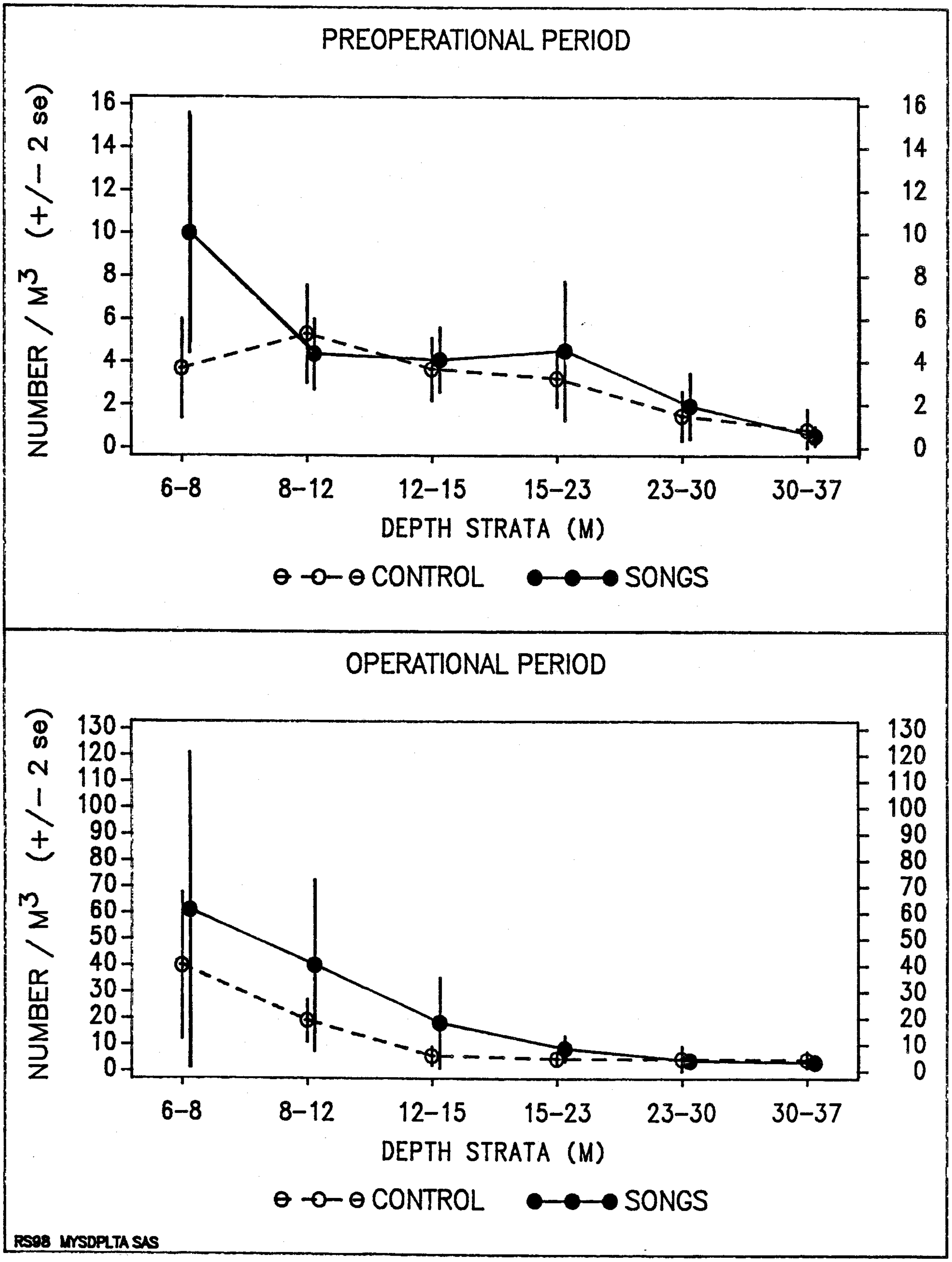

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OPERATIONAL PERIOD

Acanthomysis macropsis

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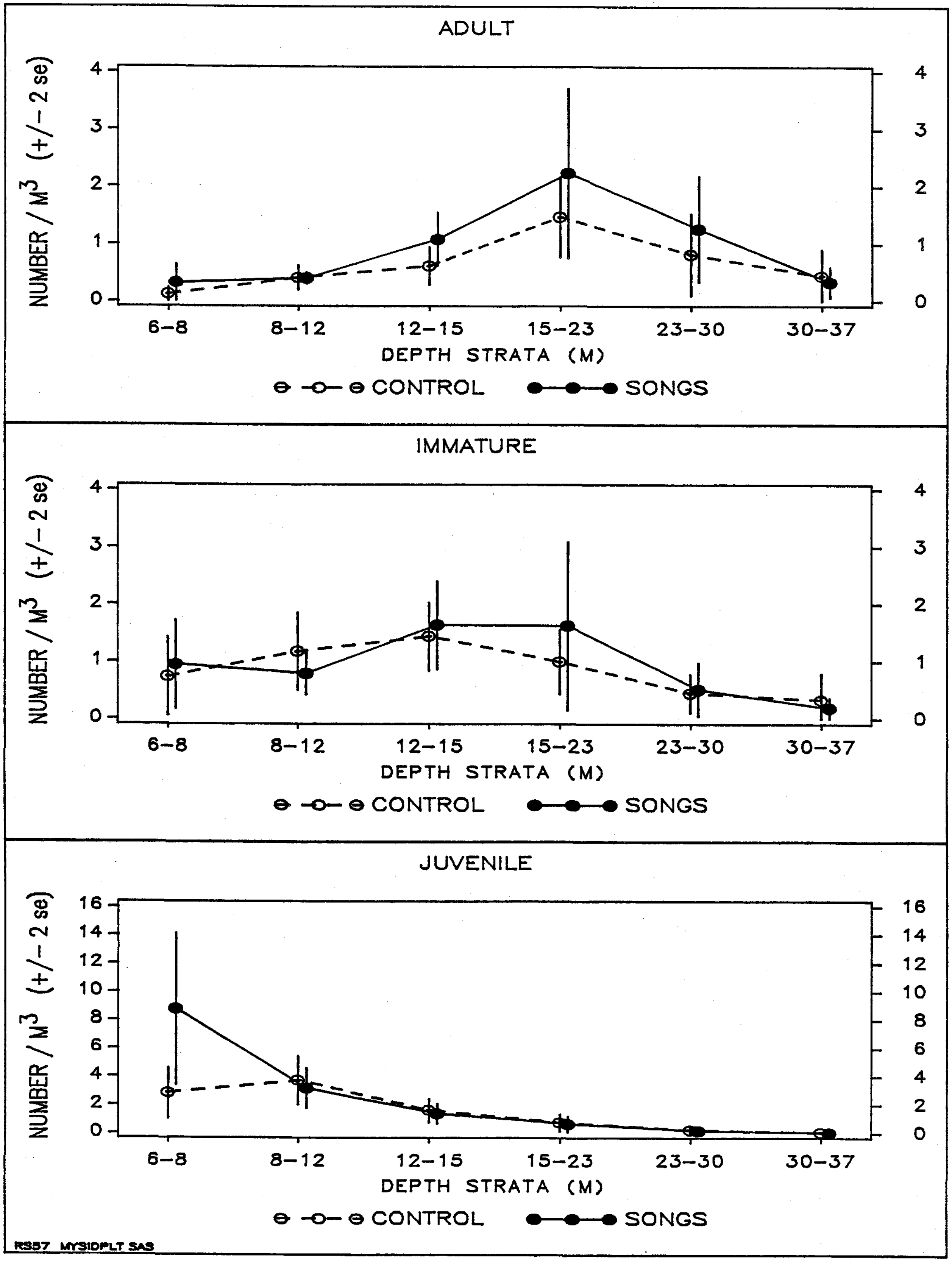

Acanthomysis macropsis

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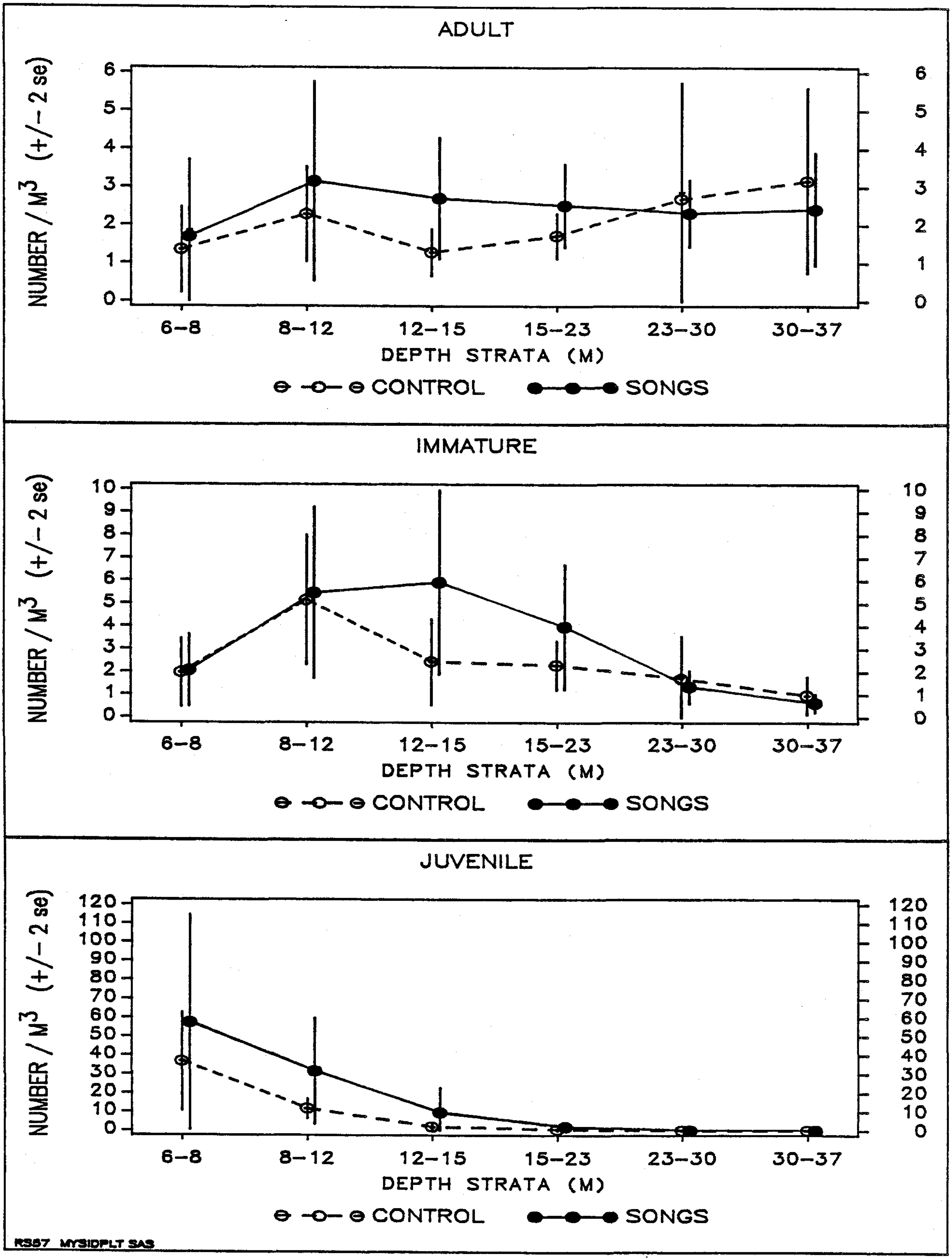

Metamysidopsis elongata

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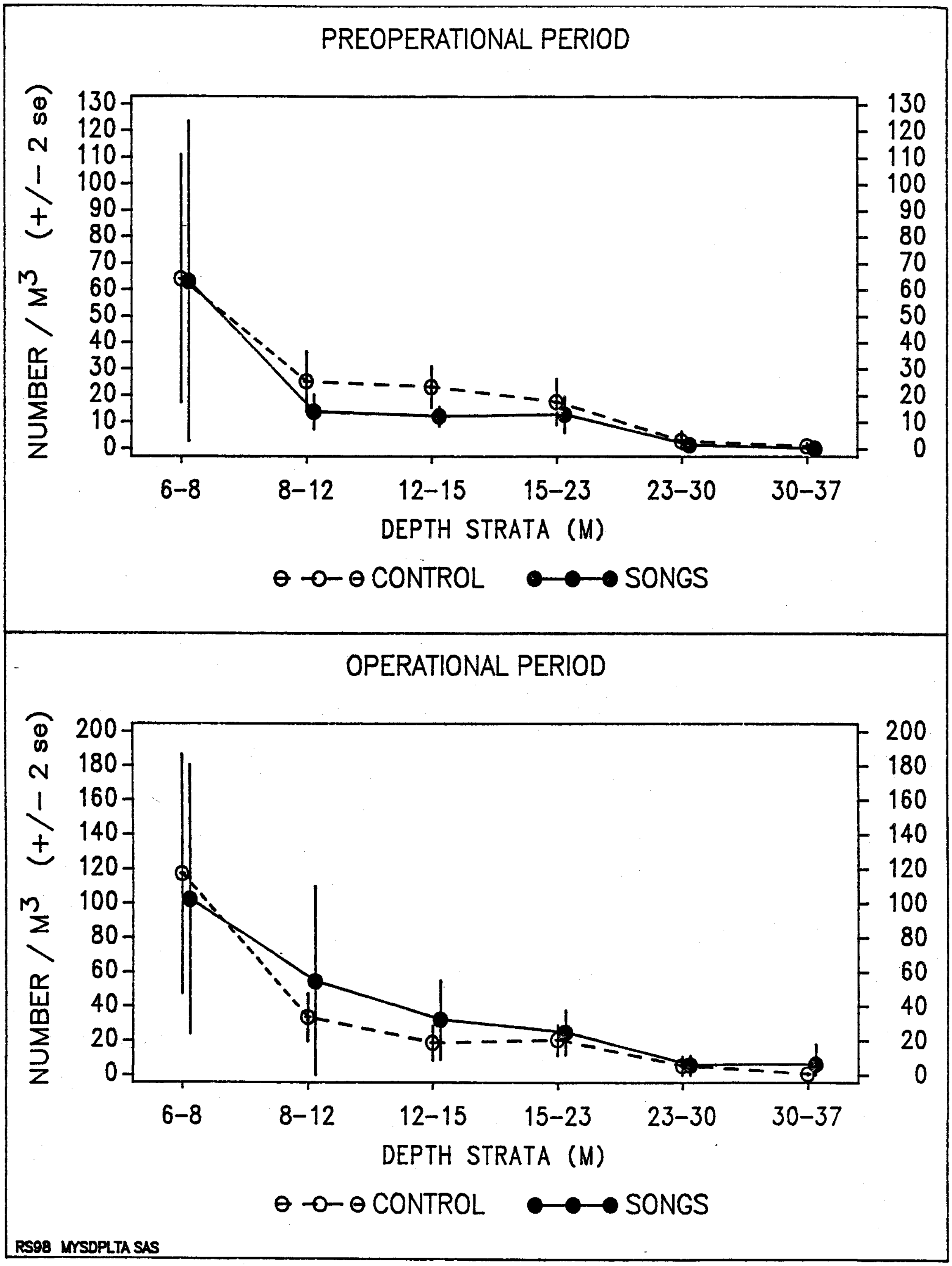
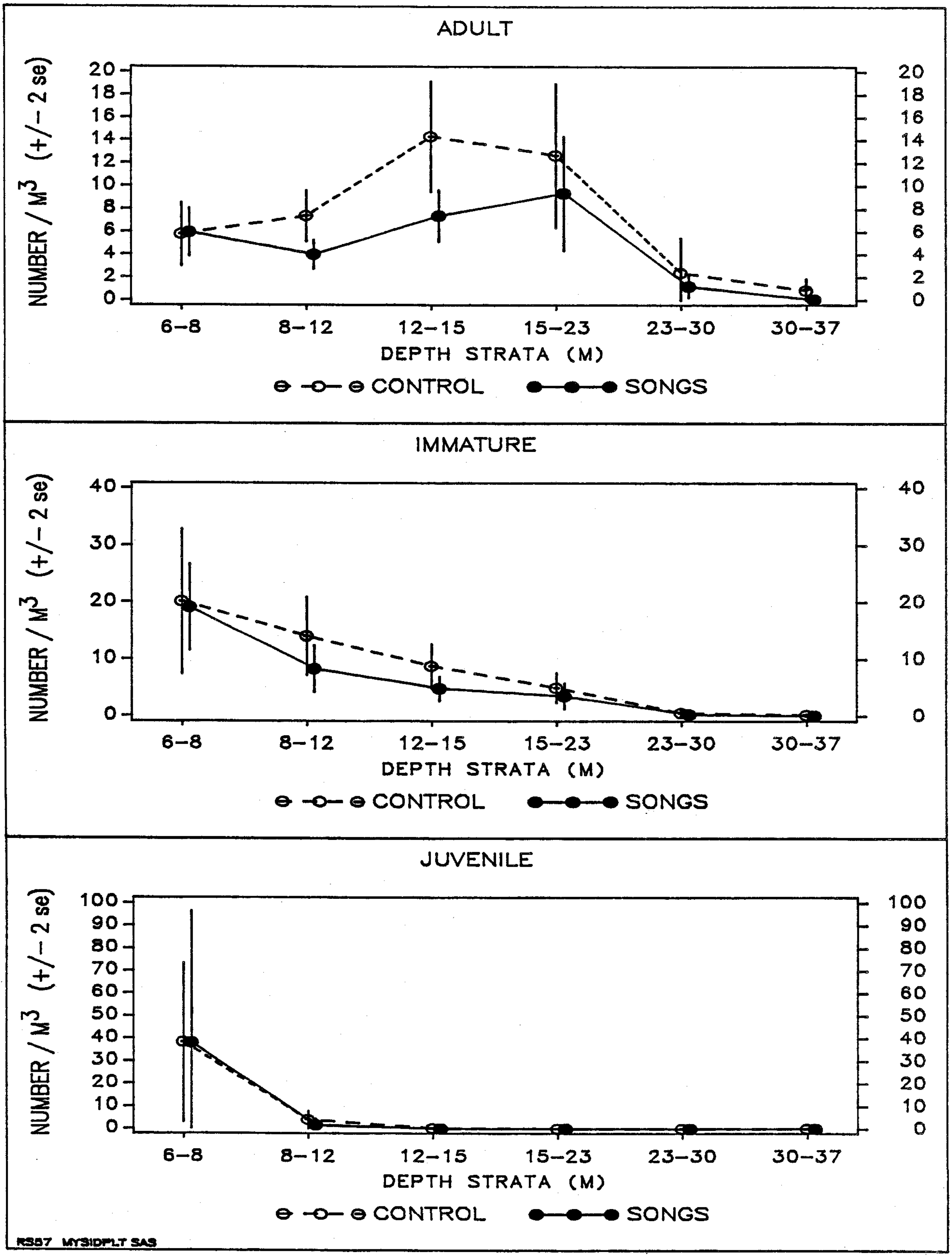


Metamysidopsis elongata

PREOPERATIONAL PERIOD



Metamysidopsis elongata

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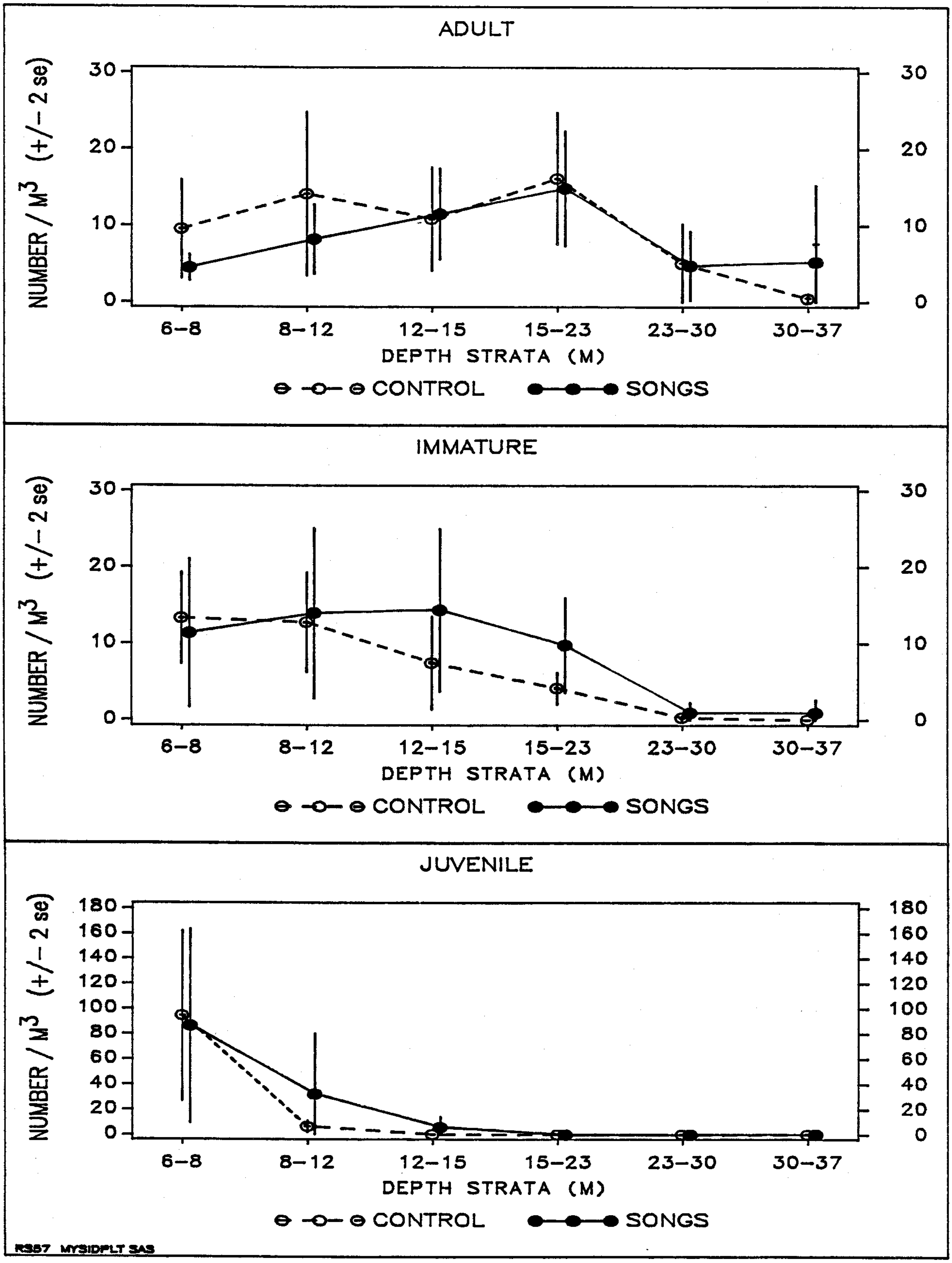

Mysidopsis intii

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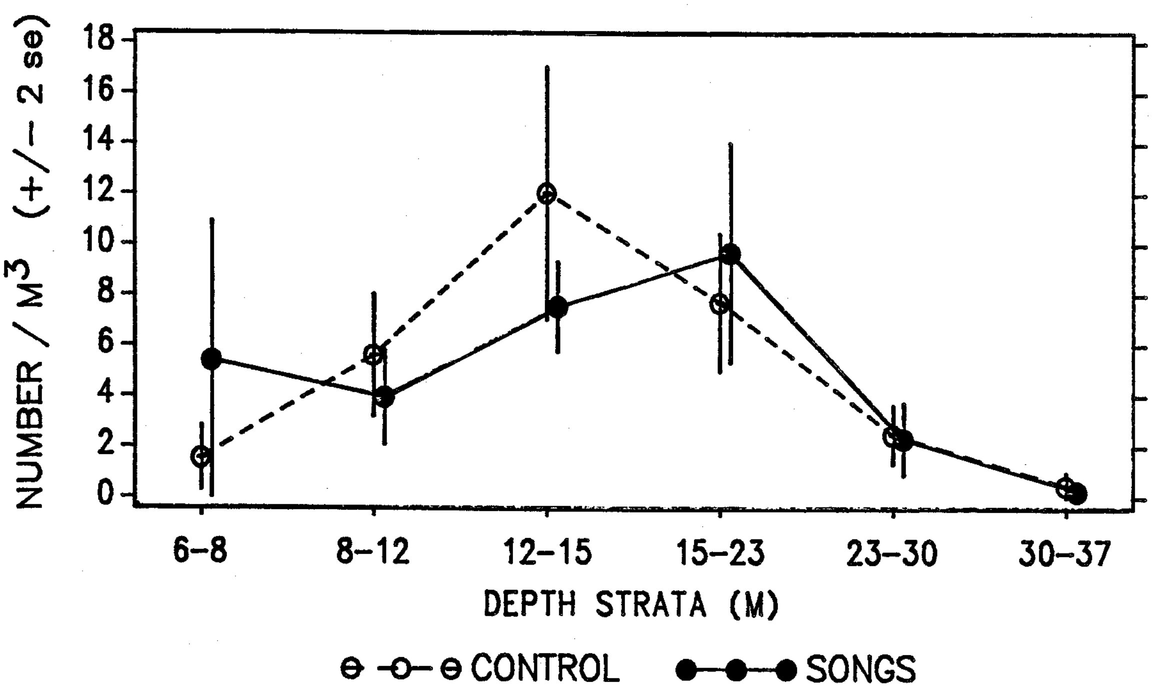

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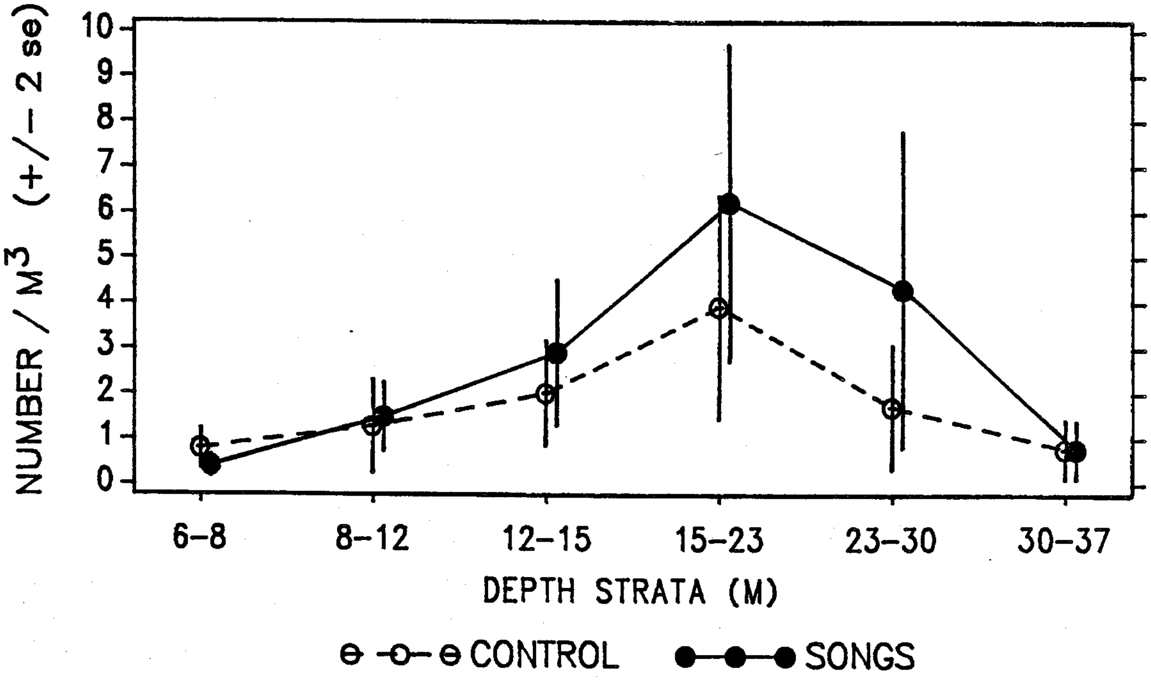

OPERATIONAL PERIOD

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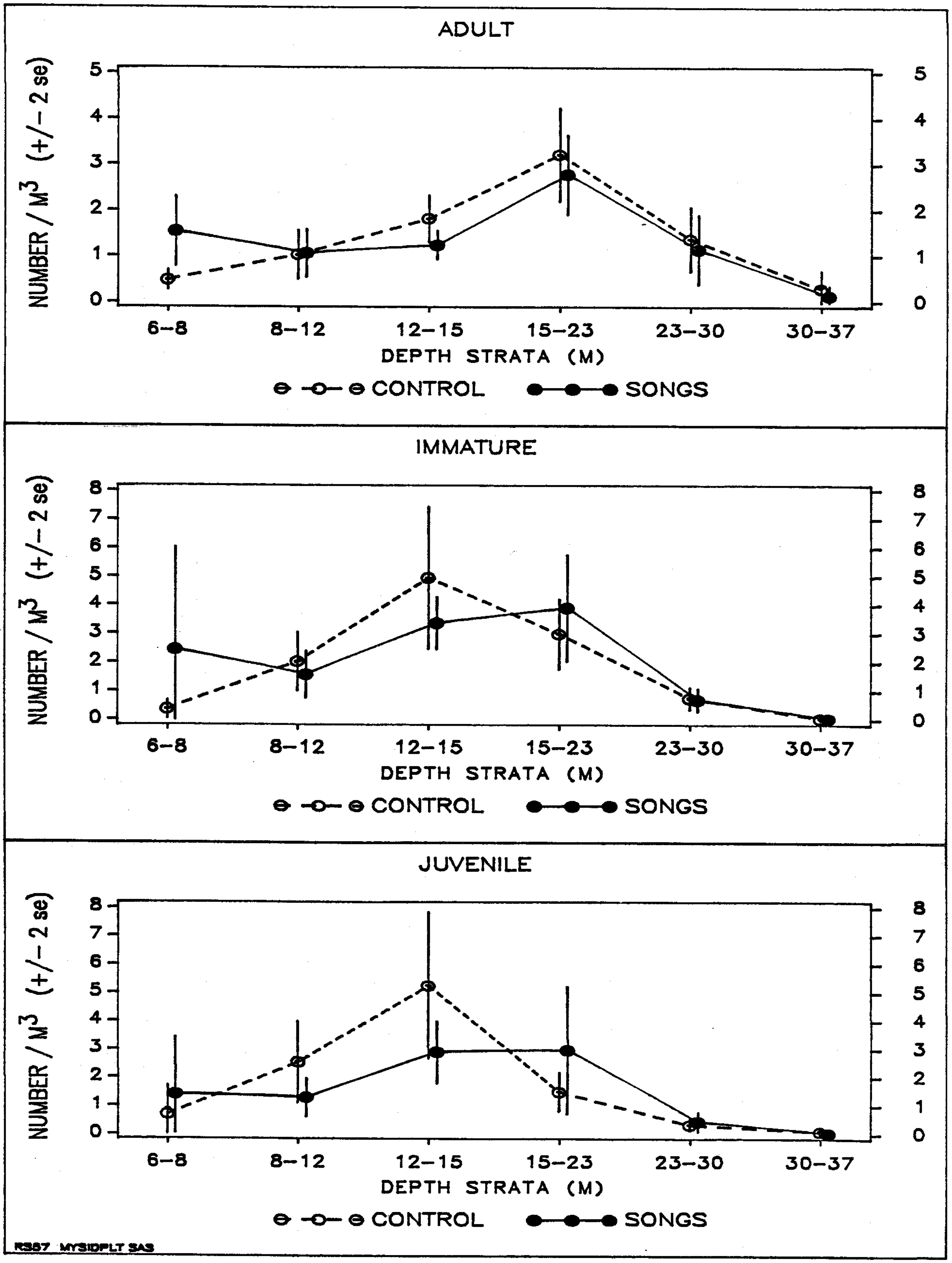
Mysidopsis intii

PREOPERATIONAL PERIOD



Mysidopsis intii

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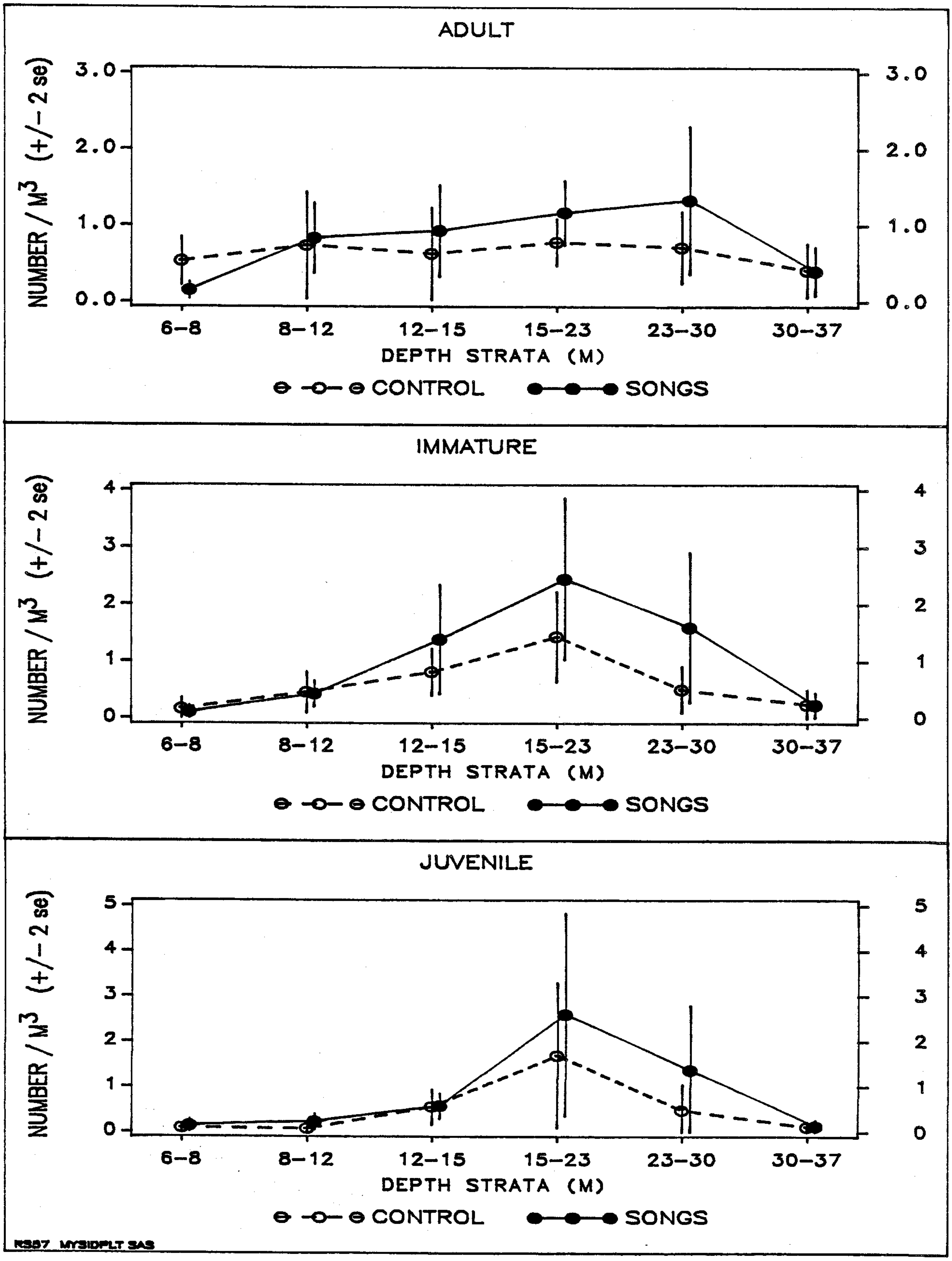

Acanthomysis nephrophthalma

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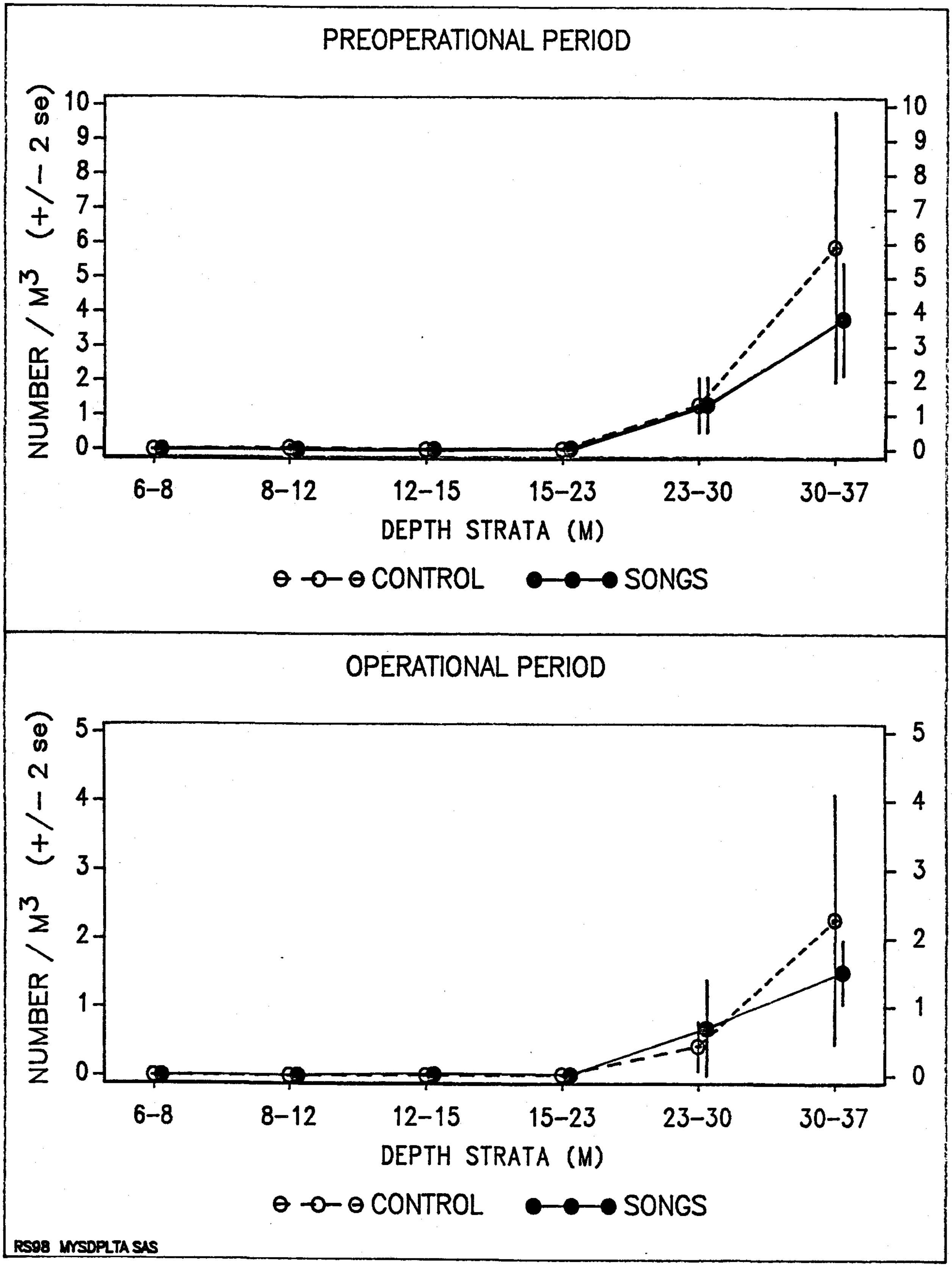

Acanthomysis nephrophthalma

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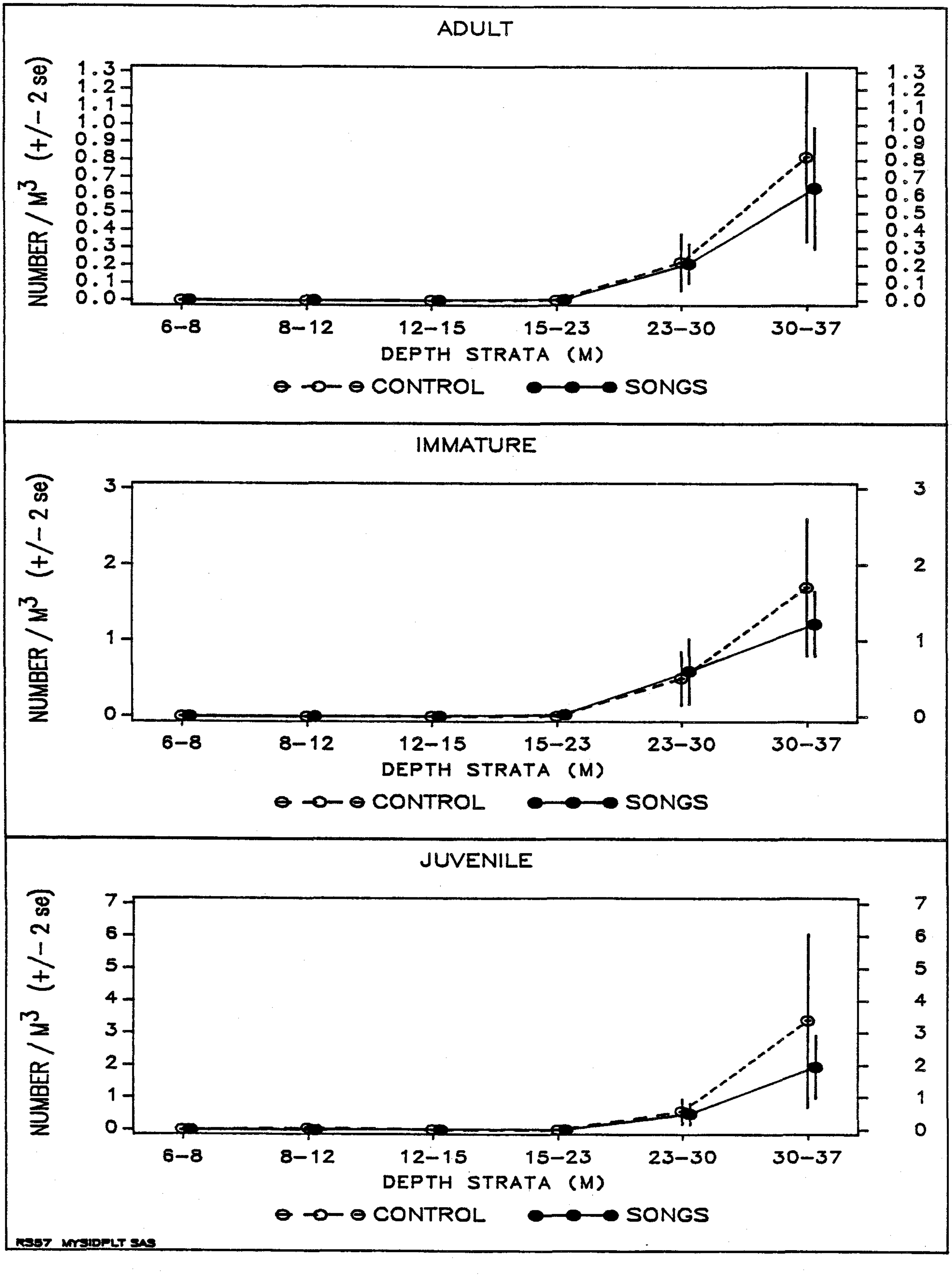

Acanthomysis nephrophthalma

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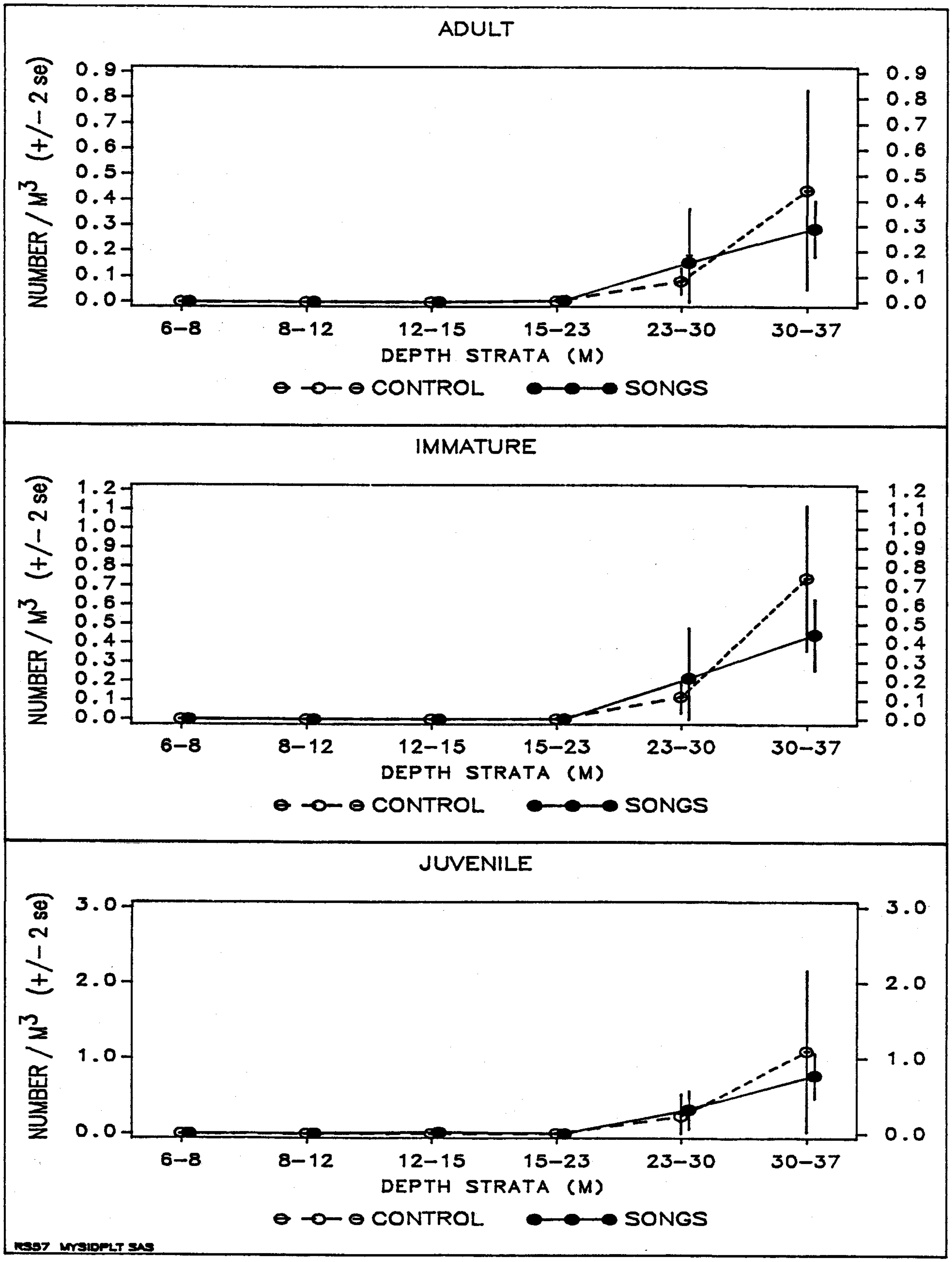

Neomysis kadiakensis

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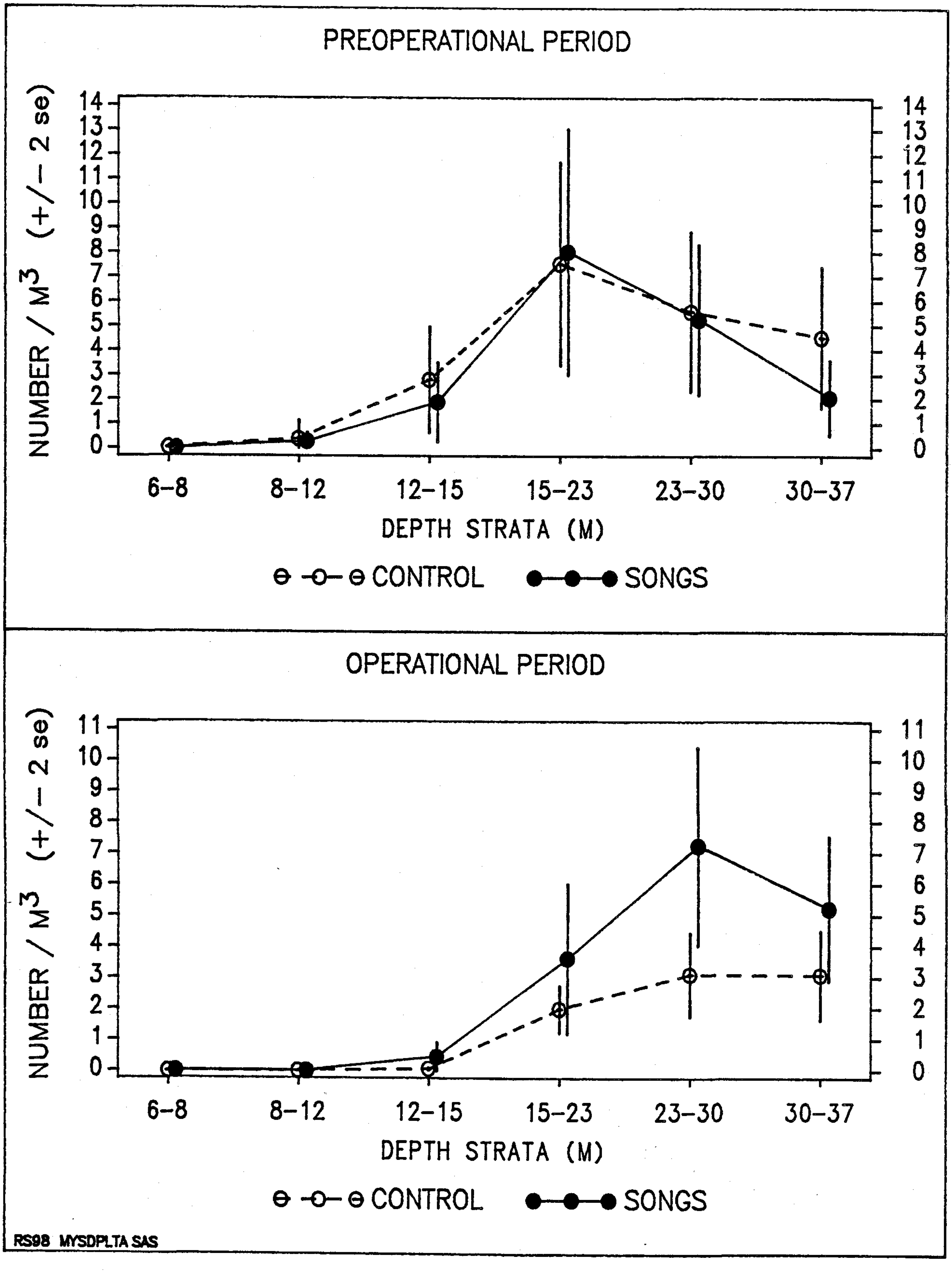
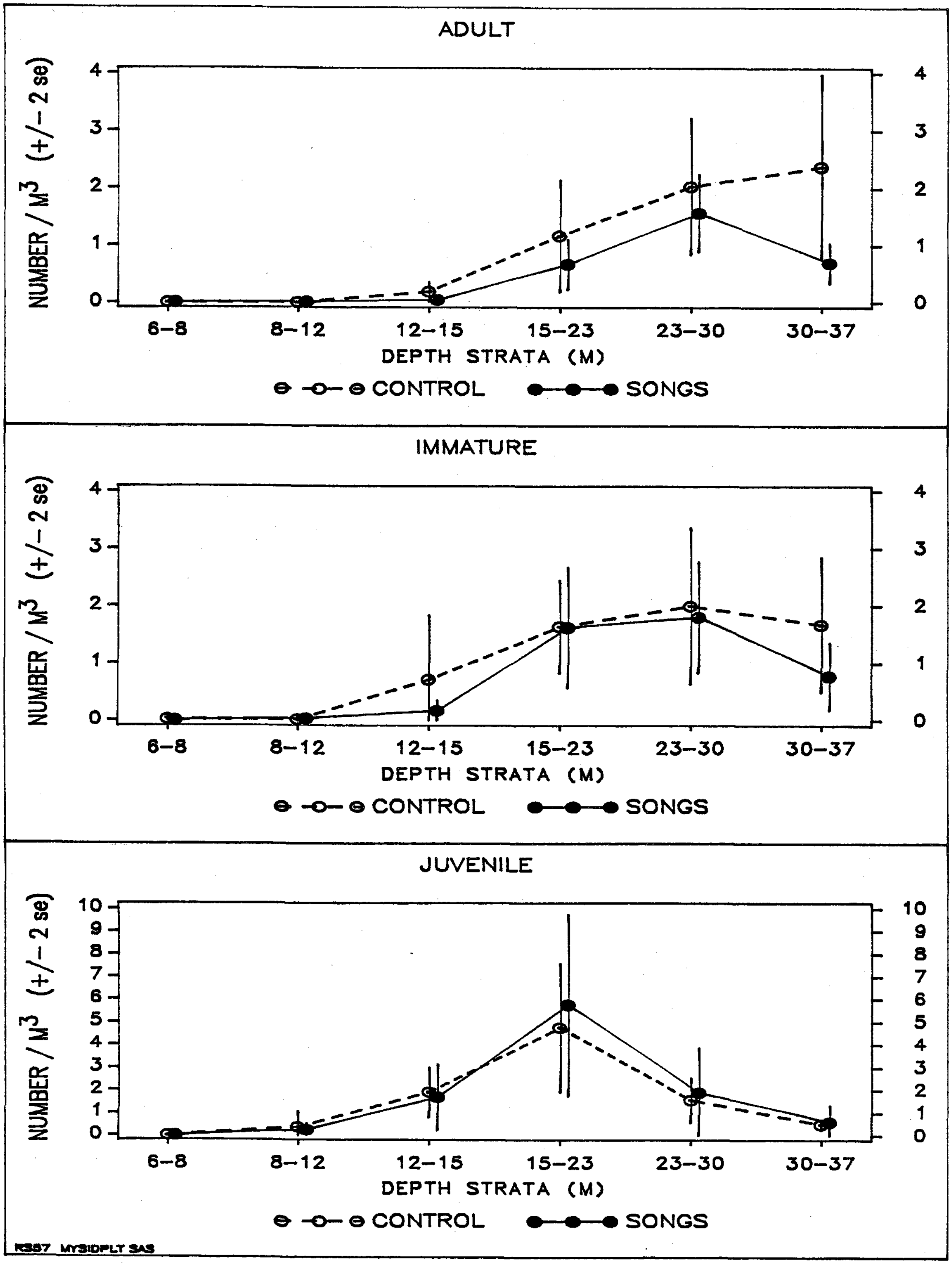


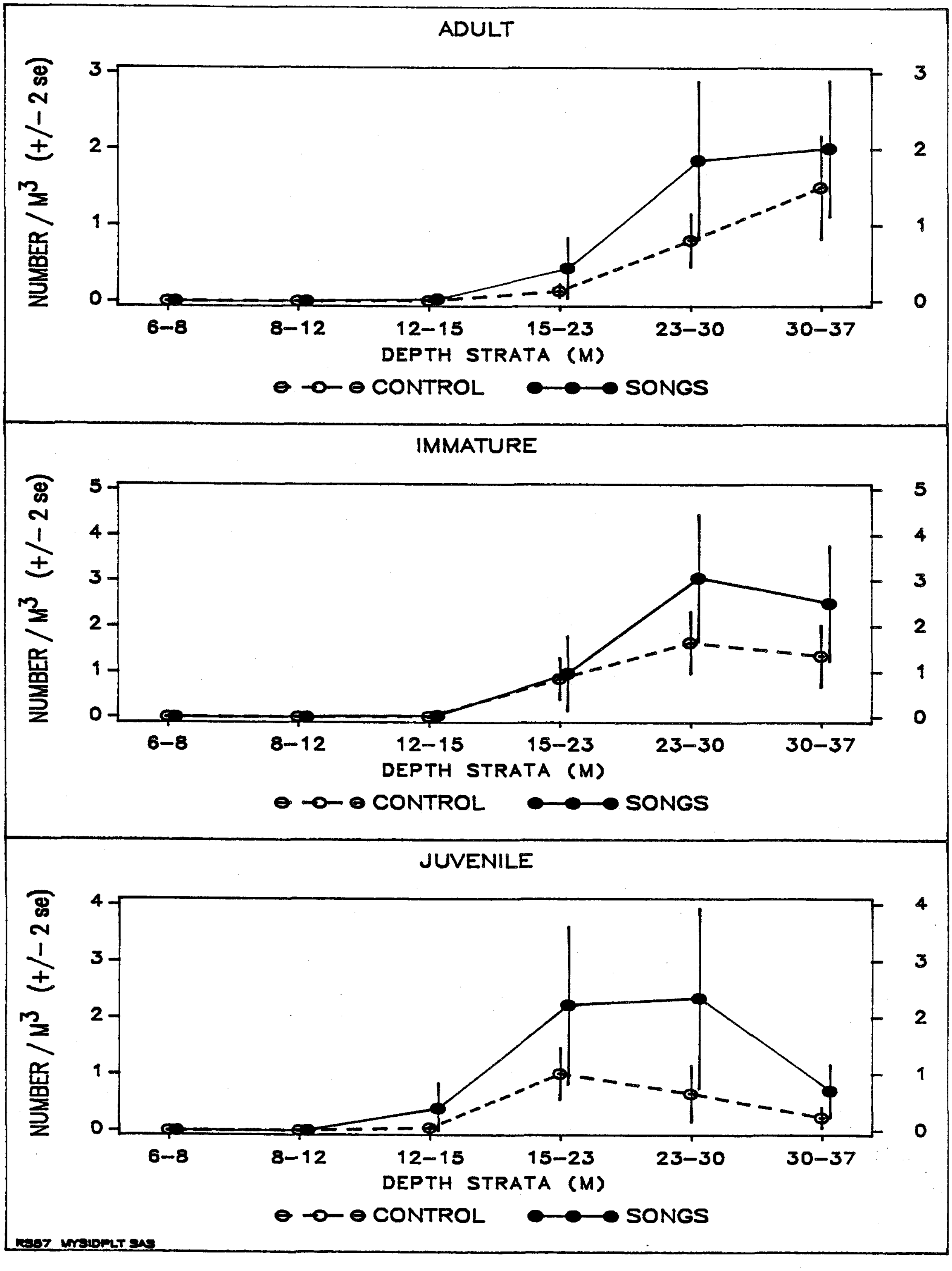
Neomysis kadiakensis

PREOPERATIONAL PERIOD



Neomysis kadiakensis

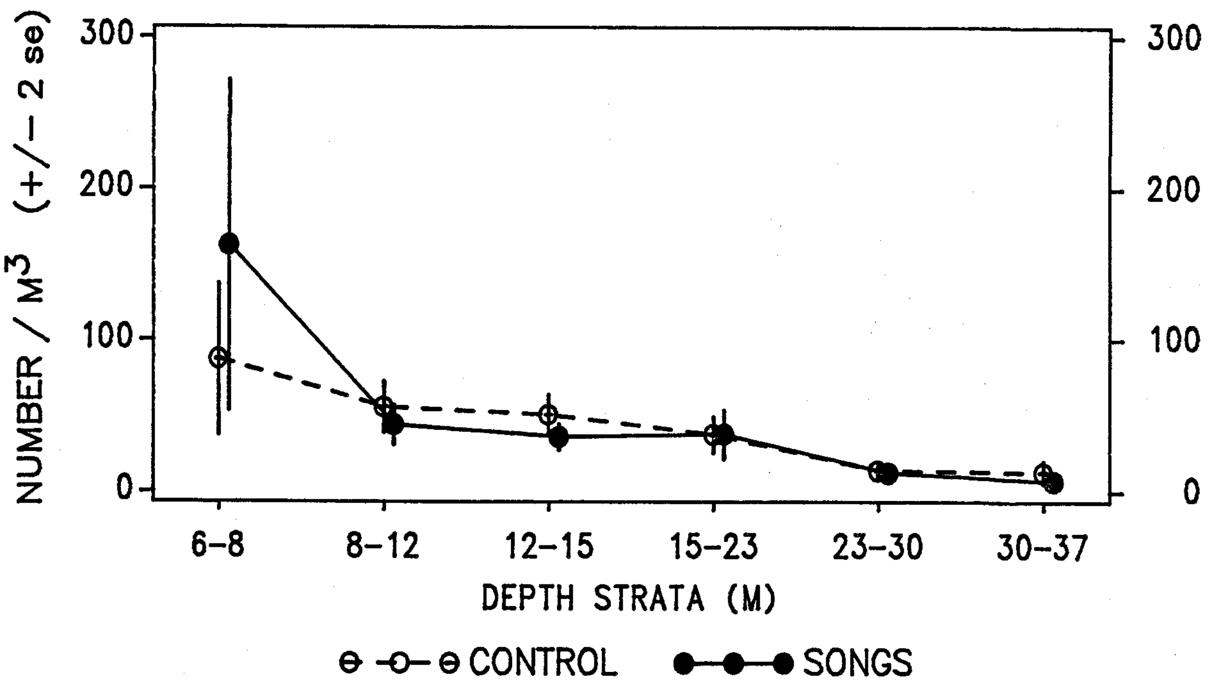
OPERATIONAL PERIOD



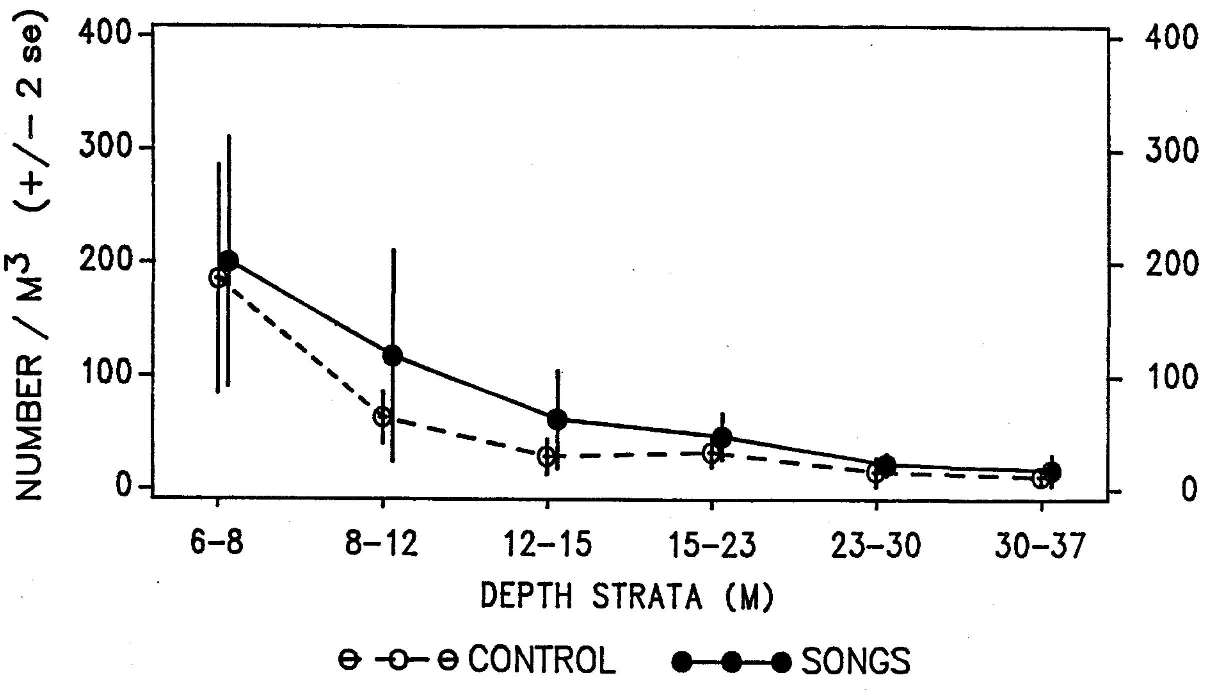
Total Mysids

ALL STAGES

PREOPERATIONAL PERIOD



OPERATIONAL PERIOD



RS98 MYSDPLTA SAS

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APPENDIX G

BACIP Results

For each of the taxa listed below (which are discussed in the text) we present the following, the detailed results of the BACIP test, a figure of the survey-by-survey deltas (with the mean delta for each period indicated by a horizontal line), and a figure of the survey-by-survey density data.

Mysidopsis intii total

- adult
- immature
- juvenile

Neomysis kadiakensis total

- adult
- immature
- juvenile

Mysidopsis cathengelae adult

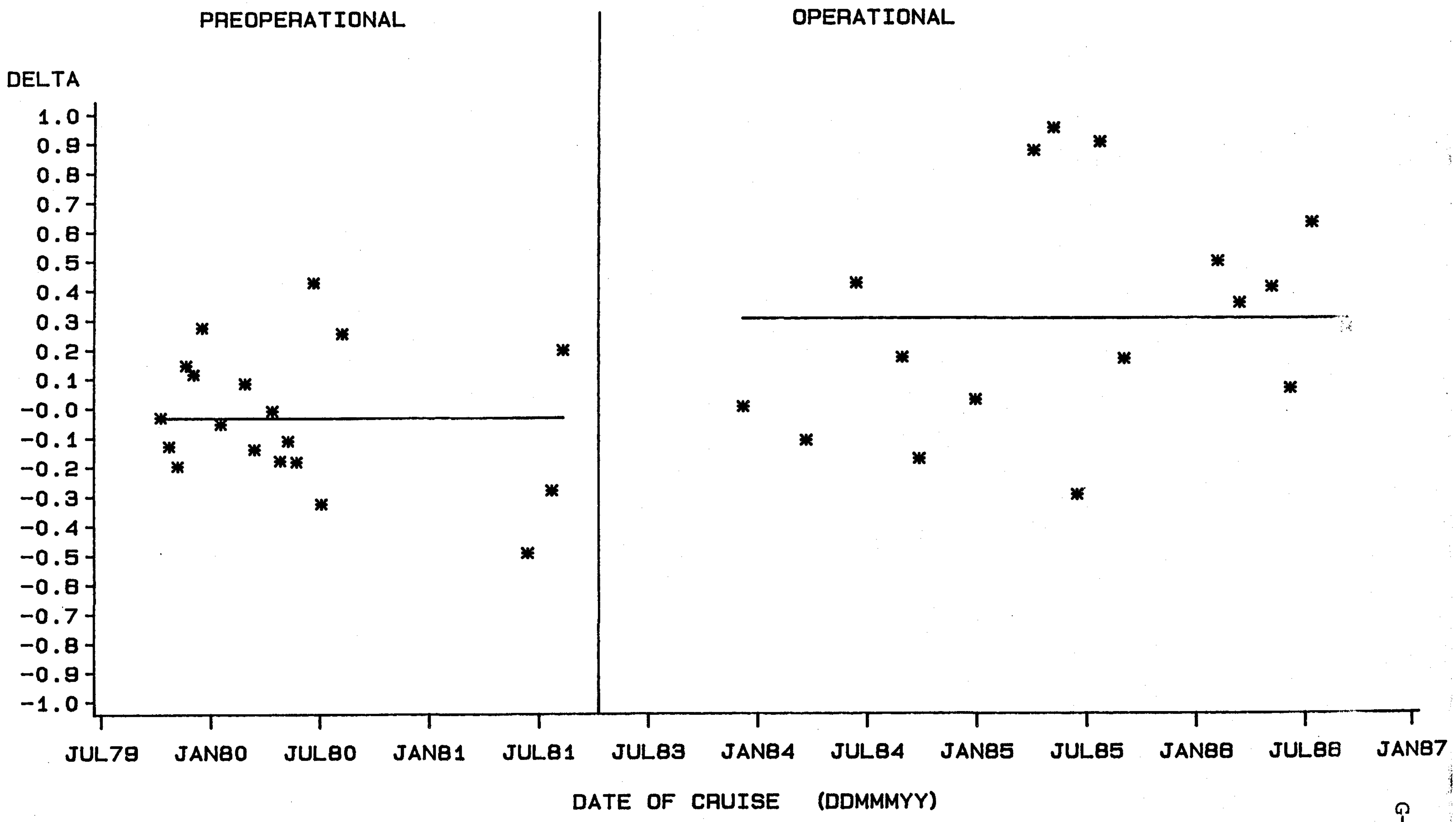
SUMMARY OF BACI TEST

Mysidopsis intii STAGE ALL

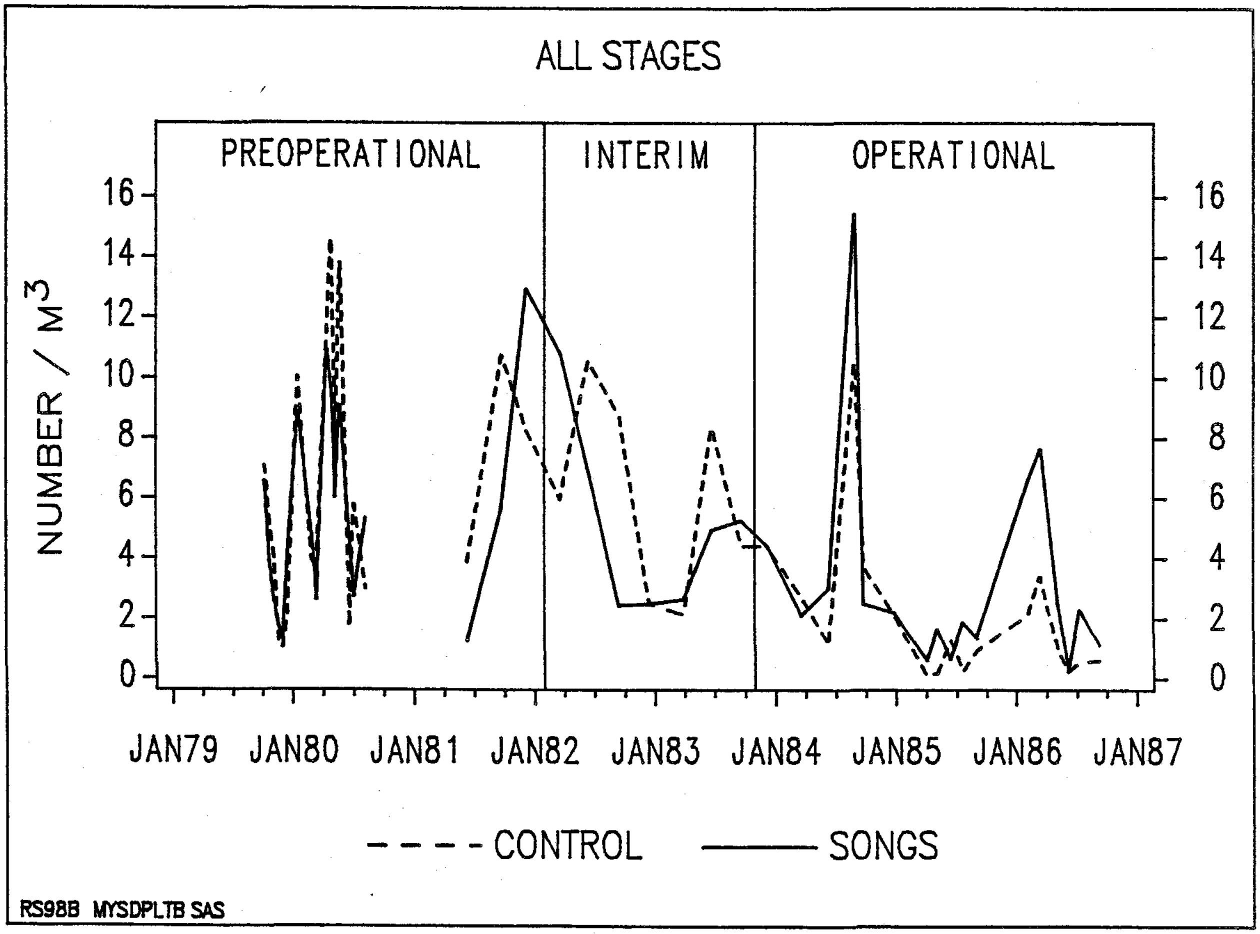
TRANSFORMATION	NUMBER OF OBSERVATIONS		TEST FOR ADDITIVITY	TEST FOR SERIAL	TRENDS TEST P-LEVEL	
	BEFORE	AFTER	P-LEVEL	CORRELATION	BEFORE	AFTER
LOG(X+0.01)	19	17	0.404	$p > 0.05$	0.409	0.217
LOG(X+0.1)	19	17	0.404	$p > 0.05$	0.420	0.169
LOG(X+0)	19	17	0.404	$p > 0.05$	0.407	0.225
LOG(X+1)	19	17	0.390	$p > 0.05$	0.508	0.100
LOG(X+10)	19	17	0.272	$p > 0.05$	0.773	0.171
LOG(X+100)	19	17	0.197	$p > 0.05$	0.947	0.321
NOTRANSFORM	19	17	0.184	$p > 0.05$	0.980	0.363

TRANSFORMATION	MEAN DENSITY BEFORE		MEAN DENSITY AFTER		PERCENT	SIGNIFICANCE TESTS	
	SONGS	CONTROL	SONGS	CONTROL	CHANGE	T	Z
LOG(X+0.01)	4.47	4.83	2.11	1.06	113.6	0.004	0.006
LOG(X+0.1)	4.49	4.87	2.15	1.14	96.2	0.003	0.006
LOG(X+0)	4.47	4.83	2.10	1.05	116.4	0.004	0.006
LOG(X+1)	4.67	5.10	2.41	1.45	50.1	0.005	0.007
LOG(X+10)	5.15	5.77	2.93	1.86	13.5	0.010	0.016
LOG(X+100)	5.44	6.18	3.23	2.03	1.9	0.013	0.016
NOTRANSFORM	5.49	6.26	3.29	2.06	155.5	0.014	0.017

Mysidopsis intii ALL
PLOT OF DELTAS (SONGS - CONTROL)
TRANSFORMATION LOG (X)



Mysidopsis intii



SUMMARY OF BACI TEST

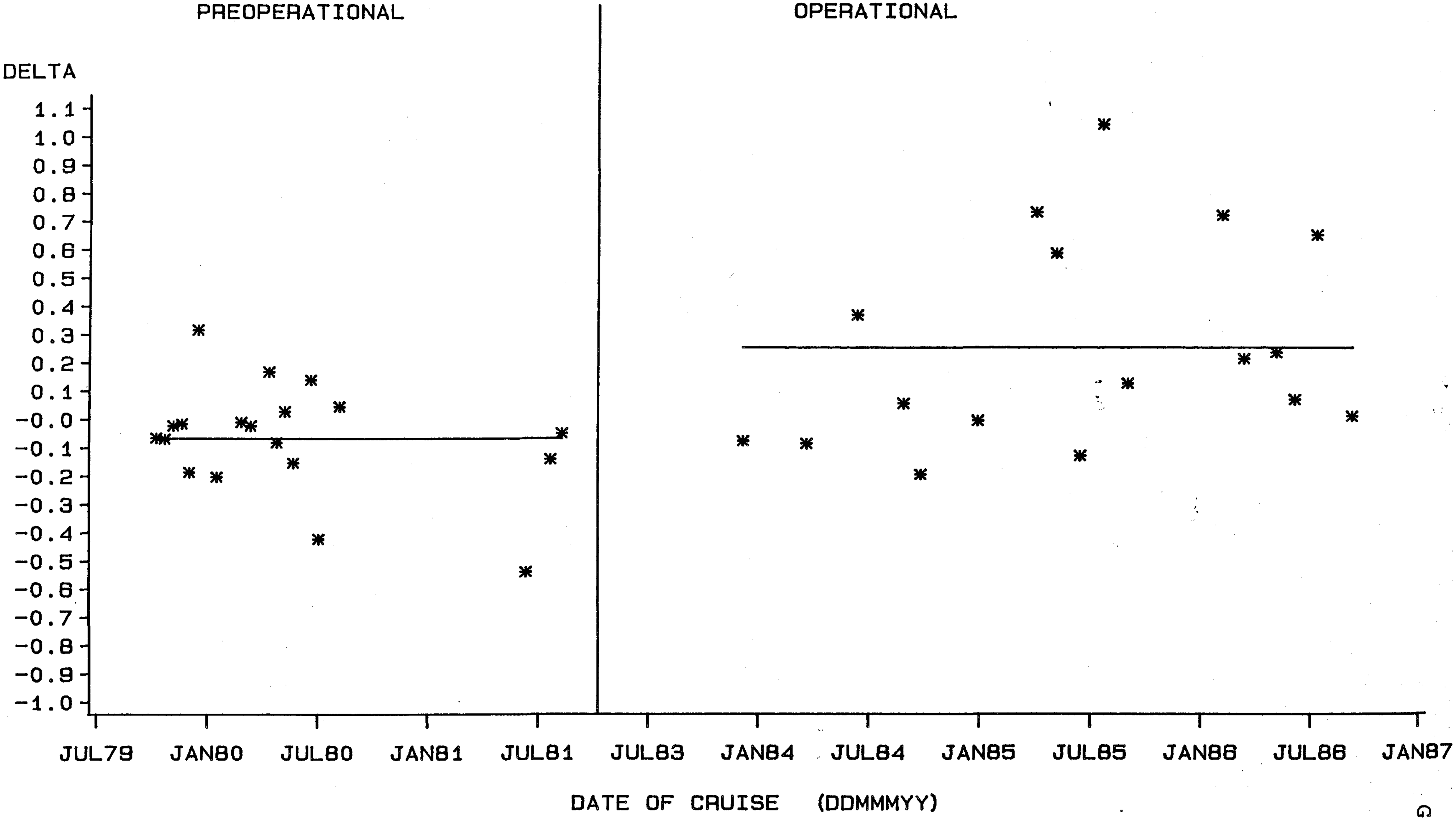
Mysidopsis intii   STAGE ADULT

TRANSFORMATION	NUMBER OF OBSERVATIONS		TEST FOR ADDITIVITY P-LEVEL	TEST FOR SERIAL CORRELATION	TRENDS TEST P-LEVEL	
	BEFORE	AFTER			BEFORE	AFTER
LOG(X+0.01)	19	17	0.932	$p > 0.05$	0.165	0.214
LOG(X+0.1)	19	17	0.989	$p > 0.05$	0.164	0.155
LOG(X+0)	19	17	0.926	$p > 0.05$	0.165	0.231
LOG(X+1)	19	17	0.642	$p > 0.05$	0.167	0.105
LOG(X+10)	19	17	0.253	$p > 0.05$	0.158	0.108
LOG(X+100)	19	17	0.184	$p > 0.05$	0.152	0.115
NOTRANSFORM	19	17	0.176	$p > 0.05$	0.151	0.116

TRANSFORMATION	MEAN DENSITY				PERCENT CHANGE	SIGNIFICANCE TESTS	
	BEFORE		AFTER				
	SONGS	CONTROL	SONGS	CONTROL		T	Z
LOG(X+0.01)	1.20	1.41	0.67	0.38	103.5	0.003	0.006
LOG(X+0.1)	1.22	1.43	0.70	0.43	76.0	0.002	0.006
LOG(X+0)	1.20	1.40	0.66	0.37	109.3	0.004	0.006
LOG(X+1)	1.32	1.53	0.82	0.55	27.7	0.005	0.006
LOG(X+10)	1.43	1.66	0.92	0.65	4.6	0.007	0.005
LOG(X+100)	1.45	1.70	0.94	0.67	0.5	0.007	0.006
NOTRANSFORM	1.45	1.70	0.94	0.68	120.0	0.007	0.006

Mysidopsis intii ADULT

PLOT OF DELTAS (SONGS - CONTROL)
TRANSFORMATION LOG (X)



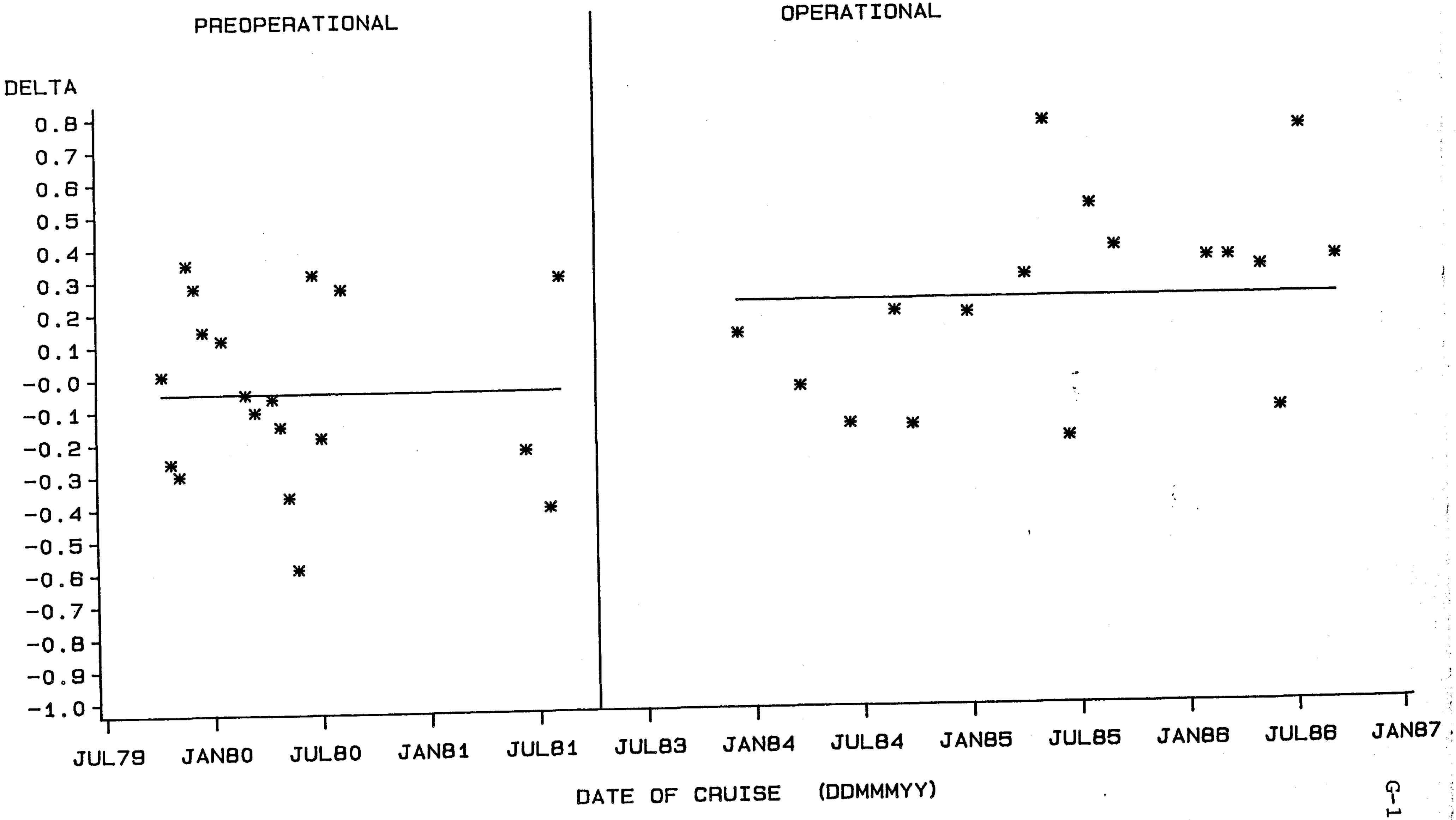
SUMMARY OF BACI TEST

Mysidopsis intii STAGE IMMATURE

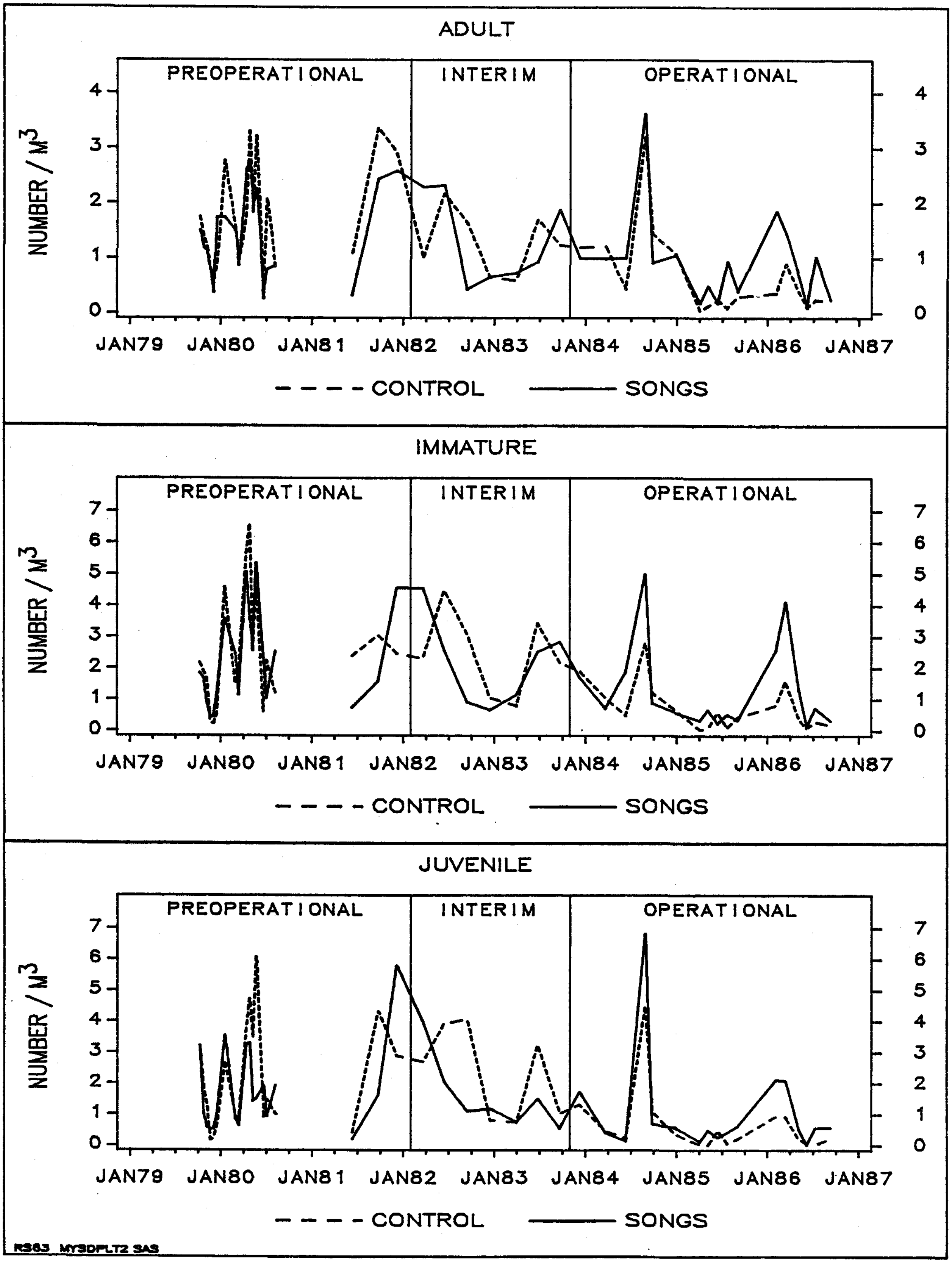
TRANSFORMATION	NUMBER OF OBSERVATIONS		TEST FOR ADDITIVITY P-LEVEL	TEST FOR SERIAL CORRELATION	TRENDS TEST P-LEVEL	
	BEFORE	AFTER			BEFORE	AFTER
LOG(X+0.01)	19	17	0.207	$p > 0.05$	0.492	0.275
LOG(X+0.1)	19	17	0.273	$p > 0.05$	0.536	0.226
LOG(X+0)	19	17	0.198	$p > 0.05$	0.487	0.289
LOG(X+1)	19	17	0.493	$p > 0.05$	0.737	0.242
LOG(X+10)	19	17	0.467	$p > 0.05$	0.956	0.389
LOG(X+100)	19	17	0.395	$p > 0.05$	0.858	0.452
NOTRANSFORM	19	17	0.384	$p > 0.05$	0.845	0.461

TRANSFORMATION	MEAN DENSITY BEFORE		MEAN DENSITY AFTER		PERCENT CHANGE	SIGNIFICANCE TESTS	
	SONGS	CONTROL	SONGS	CONTROL		T	Z
LOG(X+0.01)	1.76	1.72	0.80	0.41	88.2	0.022	0.039
LOG(X+0.1)	1.79	1.78	0.84	0.47	63.1	0.030	0.049
LOG(X+0)	1.76	1.72	0.80	0.40	93.9	0.020	0.036
LOG(X+1)	1.94	2.00	1.01	0.61	26.8	0.053	0.066
LOG(X+10)	2.17	2.30	1.22	0.72	5.7	0.063	0.071
LOG(X+100)	2.25	2.40	1.28	0.74	0.7	0.067	0.087
NOTRANSFORM	2.26	2.41	1.29	0.74	118.3	0.067	0.087

Mysidopsis intii JUVENILE
PLOT OF DELTAS (SONGS - CONTROL)
TRANSFORMATION LOG (X+0.1)



Mysidopsis intii



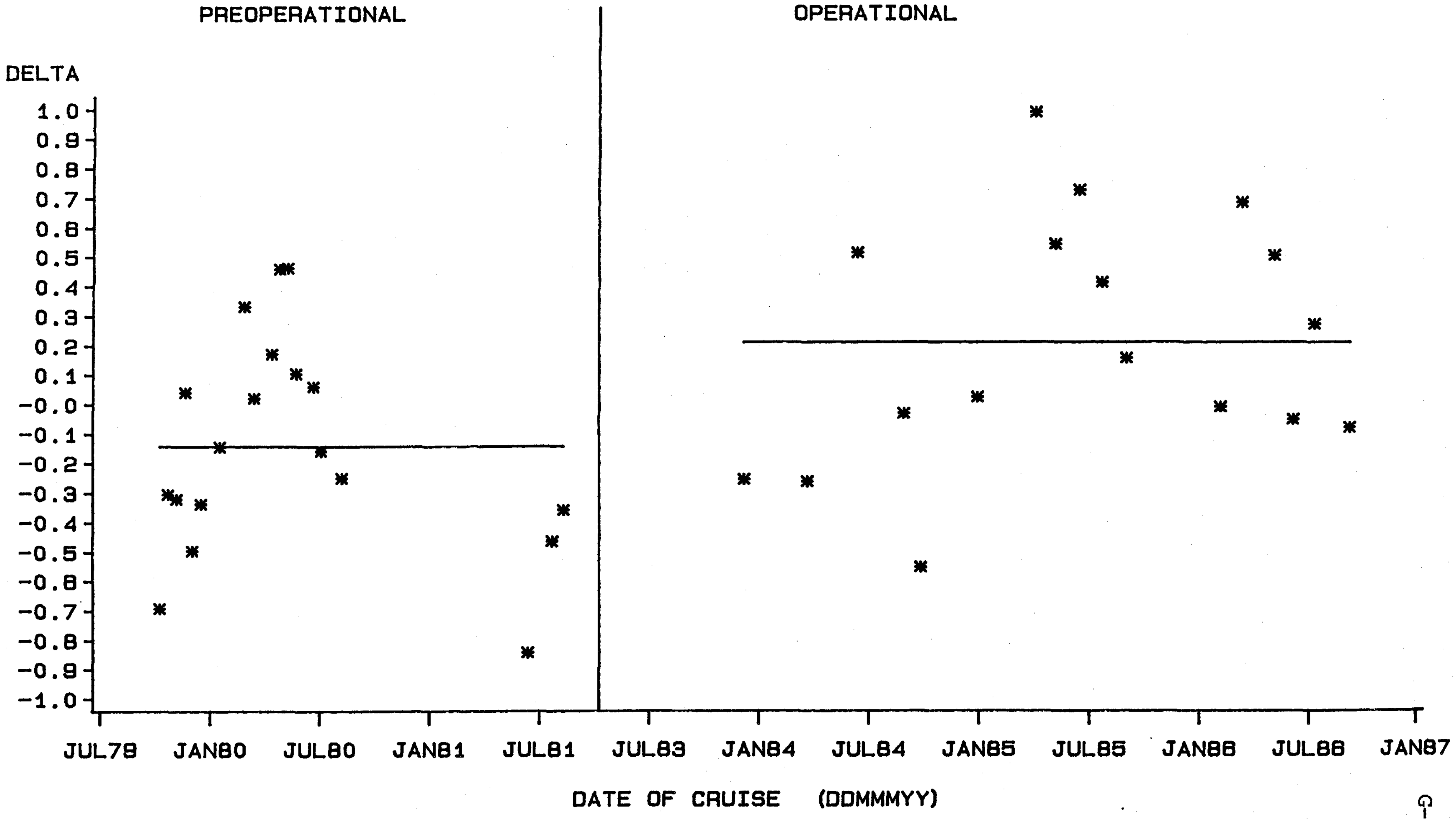
SUMMARY OF BACI TEST

Neomysis kadiakensis STAGE ALL

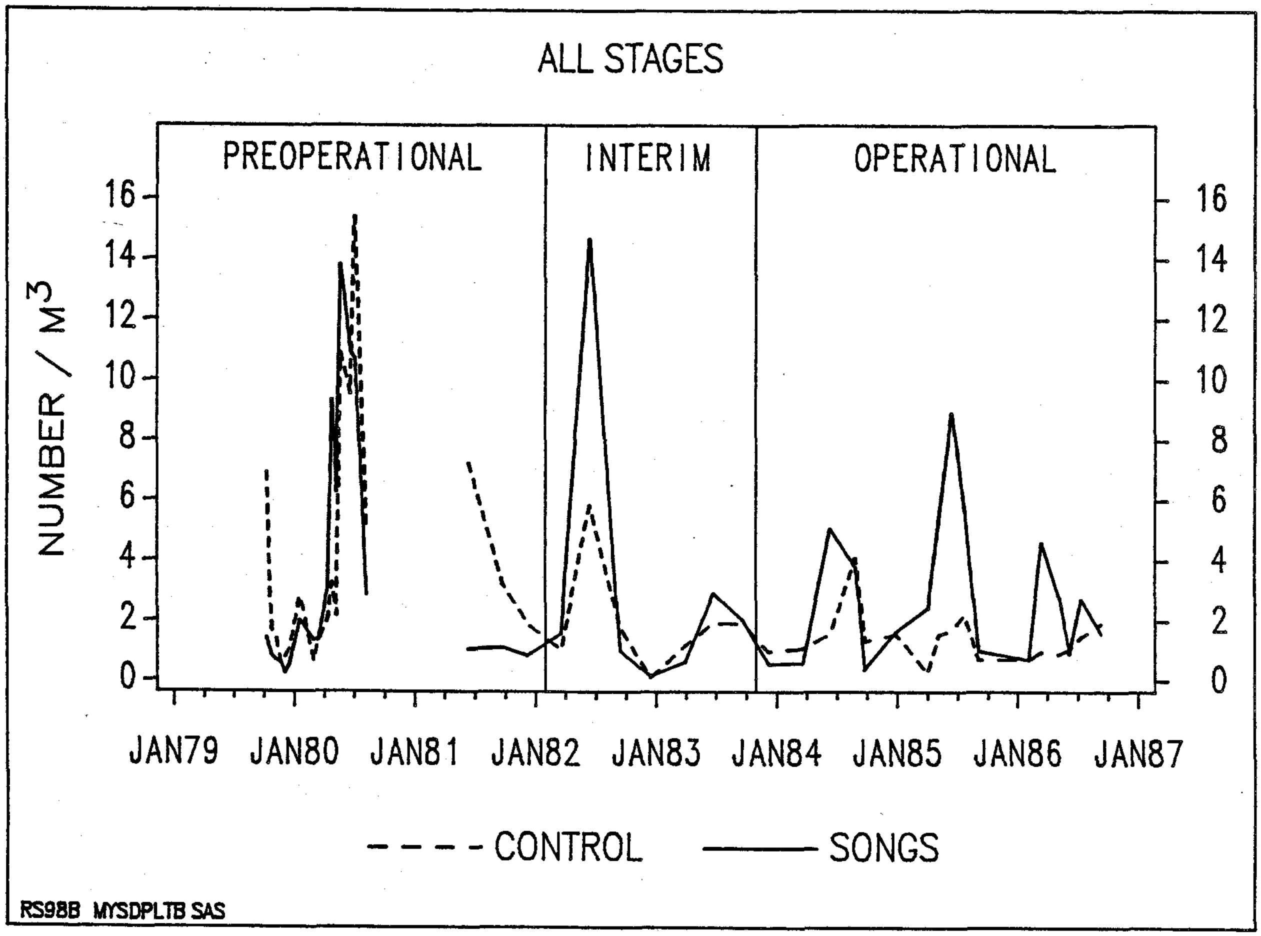
TRANSFORMATION	NUMBER OF OBSERVATIONS		TEST FOR ADDITIVITY	TEST FOR SERIAL	TRENDS TEST P-LEVEL	
	BEFORE	AFTER	P-LEVEL	CORRELATION	BEFORE	AFTER
LOG(X+0.01)	19	17	0.302	p <= 0.05	0.285	0.288
LOG(X+0.1)	19	17	0.342	p <= 0.05	0.266	0.295
LOG(X+0)	19	17	0.297	p <= 0.05	0.288	0.287
LOG(X+1)	19	17	0.490	p <= 0.05	0.237	0.377
LOG(X+10)	19	17	0.647	p <= 0.05	0.303	0.567
LOG(X+100)	19	17	0.749	p <= 0.05	0.353	0.637
NOTRANSFORM	19	17	0.776	p <= 0.05	0.363	0.647

TRANSFORMATION	MEAN DENSITY BEFORE		MEAN DENSITY AFTER		PERCENT CHANGE	SIGNIFICANCE TESTS	
	SONGS	CONTROL	SONGS	CONTROL		T	Z
LOG(X+0.01)	1.88	2.62	1.95	1.20	124.3	0.010	0.017
LOG(X+0.1)	1.94	2.66	1.99	1.22	114.6	0.009	0.015
LOG(X+0)	1.88	2.61	1.94	1.20	125.6	0.010	0.017
LOG(X+1)	2.29	2.94	2.24	1.29	69.5	0.009	0.013
LOG(X+10)	3.09	3.62	2.67	1.37	15.9	0.021	0.019
LOG(X+100)	3.54	4.02	2.83	1.40	1.9	0.035	0.024
NOTRANSFORM	3.62	4.09	2.86	1.40	207.5	0.039	0.024

Neomysis kadiakensis ALL
PLOT OF DELTAS (SONGS - CONTROL)
TRANSFORMATION LOG (X)



Neomysis kadiakensis



SUMMARY OF BACI TEST

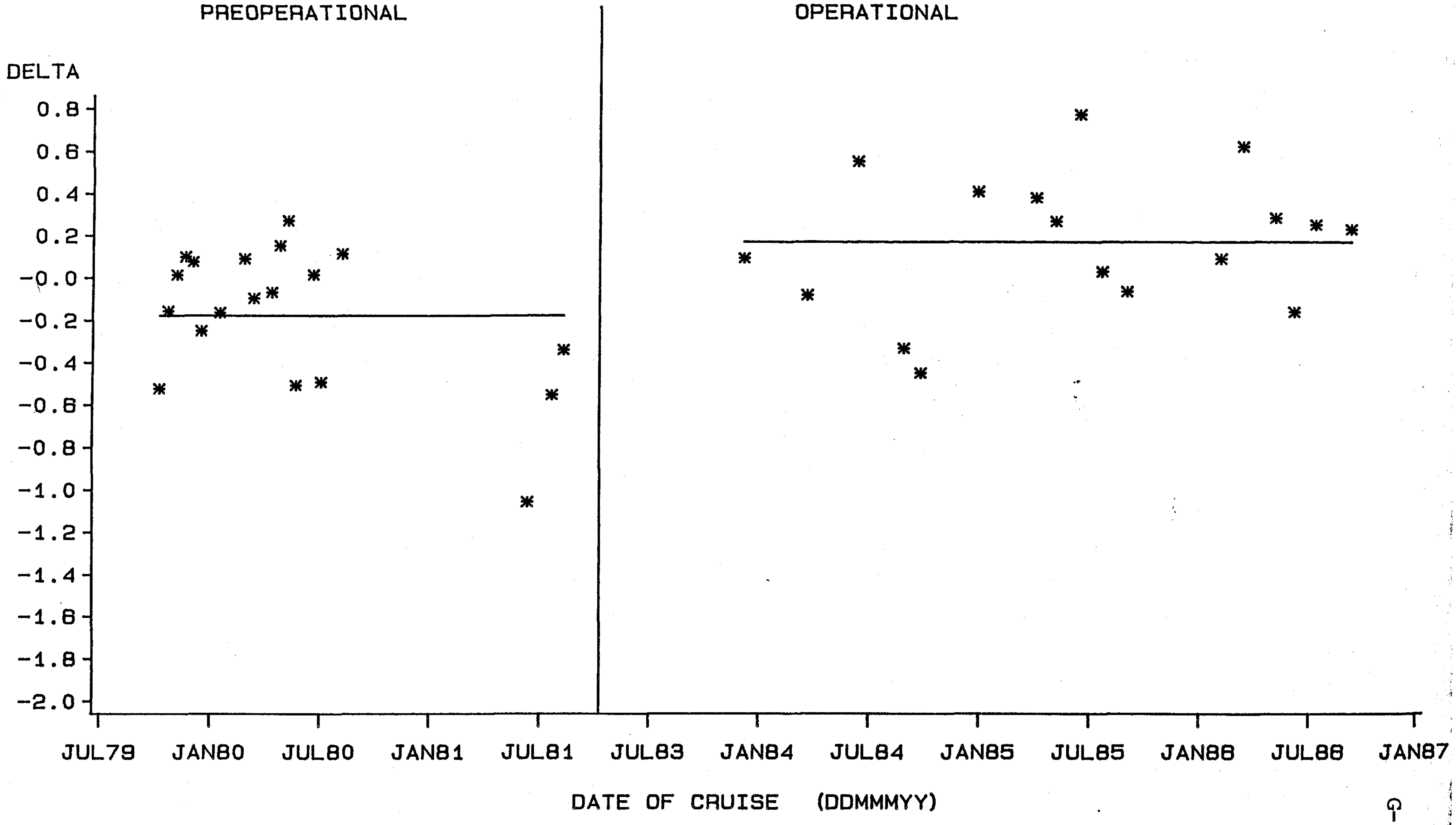
Neomysis kadiakensis STAGE ADULT

TRANSFORMATION	NUMBER OF OBSERVATIONS BEFORE	AFTER	TEST FOR ADDITIVITY P-LEVEL	TEST FOR SERIAL CORRELATION	TRENDS TEST P-LEVEL BEFORE	AFTER
LOG(X+0.01)	19	17	0.712	$p > 0.05$	0.022	0.365
LOG(X+0.1)	19	17	0.457	$p > 0.05$	0.028	0.448
LOG(X+0)	19	17	0.750	$p > 0.05$	0.021	0.353
LOG(X+1)	19	17	0.047	$p > 0.05$	0.088	0.663
LOG(X+10)	19	17	0.001	$p > 0.05$	0.205	0.788
LOG(X+100)	19	17	0.000	$p > 0.05$	0.244	0.810
NOTRANSFORM	19	17	0.000	$p > 0.05$	0.250	0.813

TRANSFORMATION	MEAN DENSITY BEFORE SONGS	CONTROL	AFTER SONGS	CONTROL	PERCENT CHANGE	SIGNIFICANCE TESTS T	Z
LOG(X+0.01)	0.34	0.57	0.45	0.28	166.7	0.004	0.007
LOG(X+0.1)	0.37	0.61	0.48	0.30	122.0	0.003	0.005
LOG(X+0)	0.33	0.56	0.45	0.28	174.9	0.004	0.007
LOG(X+1)	0.47	0.76	0.58	0.33	42.5	0.005	0.009
LOG(X+10)	0.52	0.93	0.66	0.35	6.9	0.009	0.009
LOG(X+100)	0.53	0.97	0.67	0.35	0.8	0.011	0.009
NOTRANSFORM	0.53	0.98	0.67	0.35	827.1	0.011	0.009

Neomysis kadiakensis ADULT

PLOT OF DELTAS (SONGS - CONTROL)
TRANSFORMATION LOG (X+0.1)



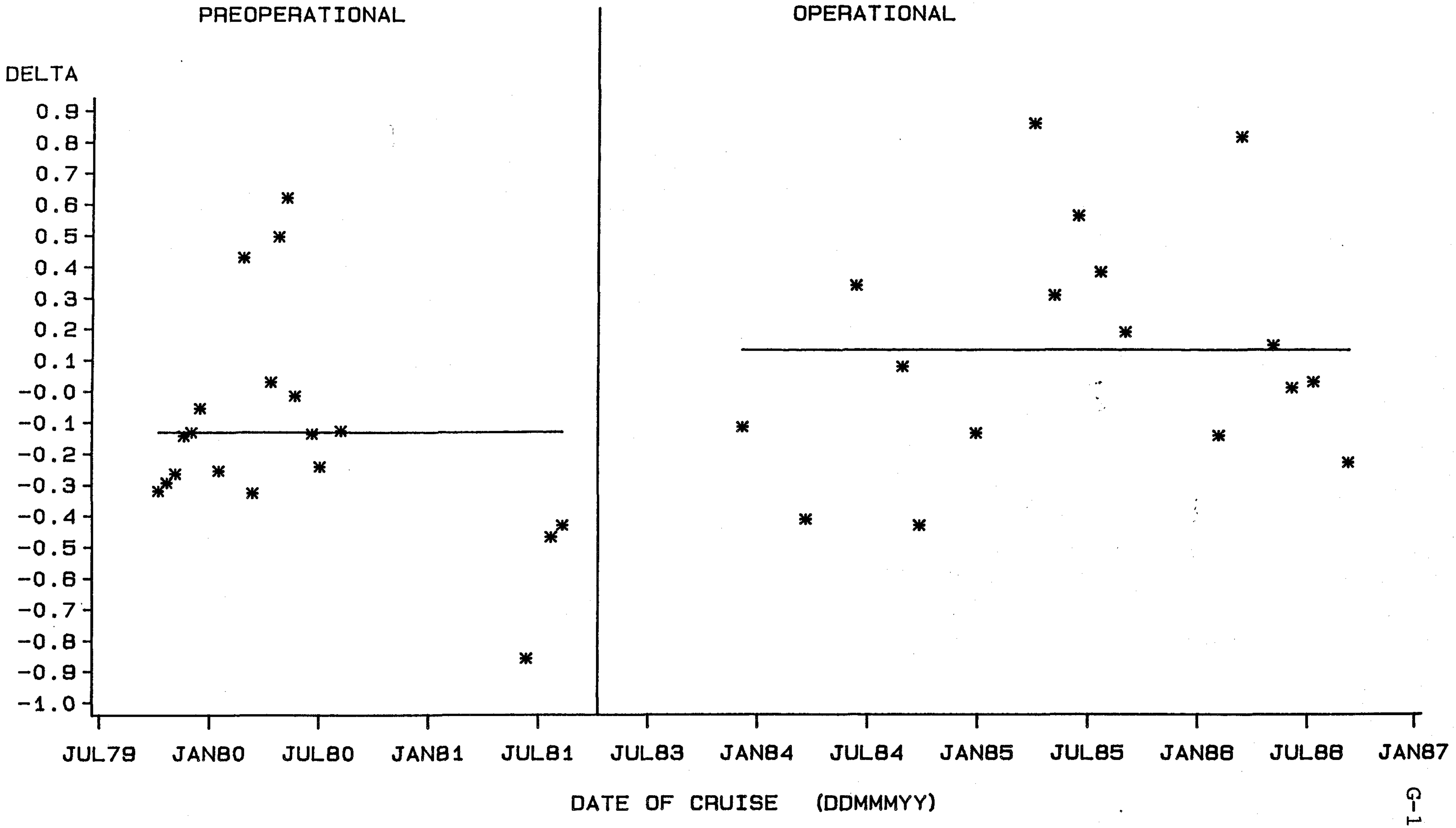
SUMMARY OF BACI TEST

Neomysis kadiakensis   STAGE IMMATURE

TRANSFORMATION	NUMBER OF OBSERVATIONS BEFORE	NUMBER OF OBSERVATIONS AFTER	TEST FOR ADDITIVITY P-LEVEL	TEST FOR SERIAL CORRELATION	TRENDS TEST P-LEVEL BEFORE	TRENDS TEST P-LEVEL AFTER
LOG(X+0.01)	19	17	0.701	p > 0.05	0.127	0.436
LOG(X+0.1)	19	17	0.790	p <= 0.05	0.093	0.477
LOG(X+0)	19	17	0.689	p > 0.05	0.134	0.432
LOG(X+1)	19	17	0.832	p <= 0.05	0.079	0.682
LOG(X+10)	19	17	0.418	p <= 0.05	0.099	0.862
LOG(X+100)	19	17	0.321	p <= 0.05	0.105	0.897
NOTRANSFORM	19	17	0.309	p <= 0.05	0.106	0.901

TRANSFORMATION	MEAN DENSITY BEFORE SONGS	MEAN DENSITY BEFORE CONTROL	MEAN DENSITY AFTER SONGS	MEAN DENSITY AFTER CONTROL	PERCENT CHANGE	SIGNIFICANCE TESTS T	SIGNIFICANCE TESTS Z
LOG(X+0.01)	0.47	0.69	0.73	0.53	100.2	0.044	0.043
LOG(X+0.1)	0.52	0.73	0.77	0.55	82.7	0.038	0.031
LOG(X+0)	0.46	0.68	0.73	0.53	102.9	0.045	0.039
LOG(X+1)	0.67	0.89	0.92	0.61	35.4	0.032	0.024
LOG(X+10)	0.81	1.07	1.04	0.65	6.2	0.030	0.023
LOG(X+100)	0.84	1.11	1.07	0.65	0.7	0.030	0.023
NOTRANSFORM	0.85	1.12	1.07	0.65	178.9	0.030	0.023

Neomysis kadiakensis IMMATURE
PLOT OF DELTAS (SONGS - CONTROL)
TRANSFORMATION LOG (X+0.1)



SUMMARY OF BACI TEST

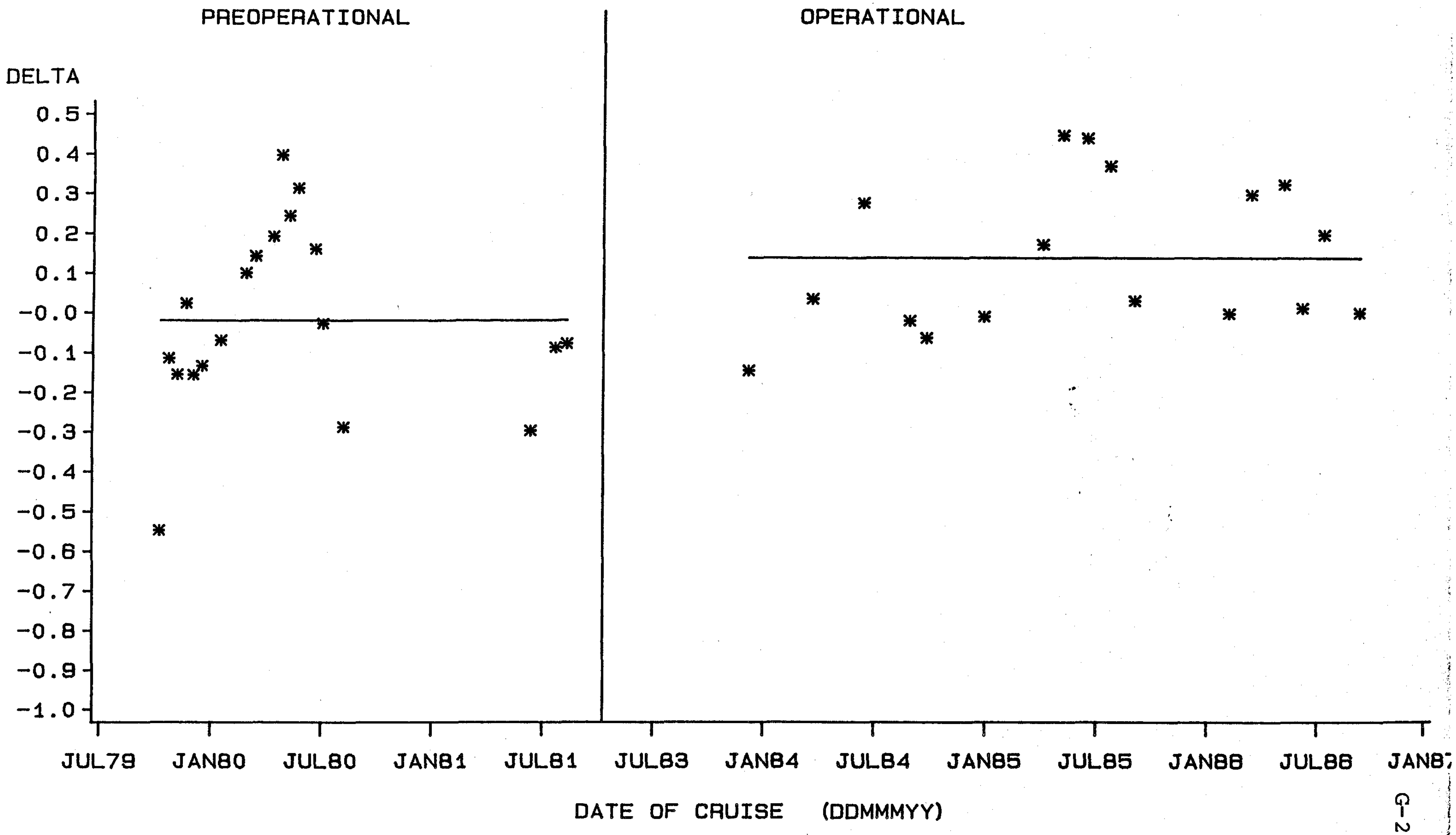
Neomysis kadiakensis STAGE JUVENILE

TRANSFORMATION	NUMBER OF OBSERVATIONS BEFORE	NUMBER OF OBSERVATIONS AFTER	TEST FOR ADDITIVITY P-LEVEL	TEST FOR SERIAL CORRELATION	TRENDS TEST P-LEVEL BEFORE	TRENDS TEST P-LEVEL AFTER
LOG(X+0.01)	19	17	0.193	$p <= 0.05$	0.944	0.102
LOG(X+0.1)	19	17	0.211	$p <= 0.05$	0.994	0.145
LOG(X+0)	19	17	0.190	$p <= 0.05$	0.934	0.097
LOG(X+1)	19	17	0.203	$p <= 0.05$	0.906	0.305
LOG(X+10)	19	17	0.078	$p <= 0.05$	0.957	0.427
LOG(X+100)	19	17	0.042	$p <= 0.05$	0.977	0.451
NOTRANSFORM	19	17	0.038	$p <= 0.05$	0.979	0.455

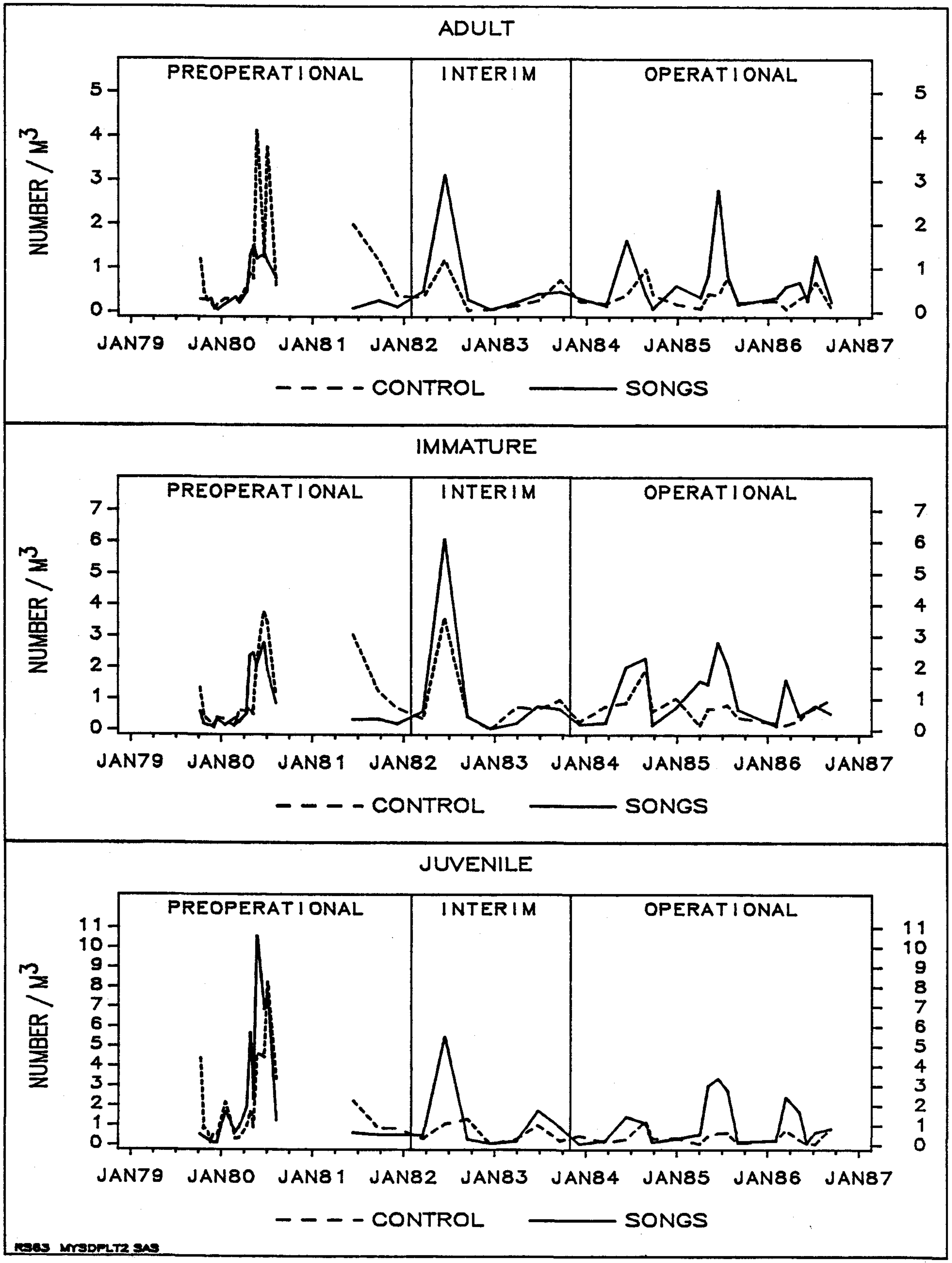
TRANSFORMATION	MEAN DENSITY BEFORE SONGS	MEAN DENSITY BEFORE CONTROL	MEAN DENSITY AFTER SONGS	MEAN DENSITY AFTER CONTROL	PERCENT CHANGE	SIGNIFICANCE TESTS T	SIGNIFICANCE TESTS Z
LOG(X+0.01)	0.94	1.19	0.57	0.26	165.8	0.013	0.017
LOG(X+0.1)	1.03	1.24	0.64	0.30	122.7	0.013	0.017
LOG(X+0)	0.93	1.18	0.56	0.26	174.8	0.014	0.017
LOG(X+1)	1.37	1.49	0.86	0.36	43.6	0.033	0.023
LOG(X+10)	1.94	1.84	1.06	0.39	5.6	0.194	0.062
LOG(X+100)	2.20	1.98	1.10	0.39	0.5	0.365	0.062
NOTRANSFORM	2.24	2.00	1.11	0.39	74.2	0.399	0.062

Neomysis kadiakensis JUVENILE

PLOT OF DELTAS (SONGS - CONTROL)
TRANSFORMATION LOG (X+1.0)



Neomysis kadiakensis



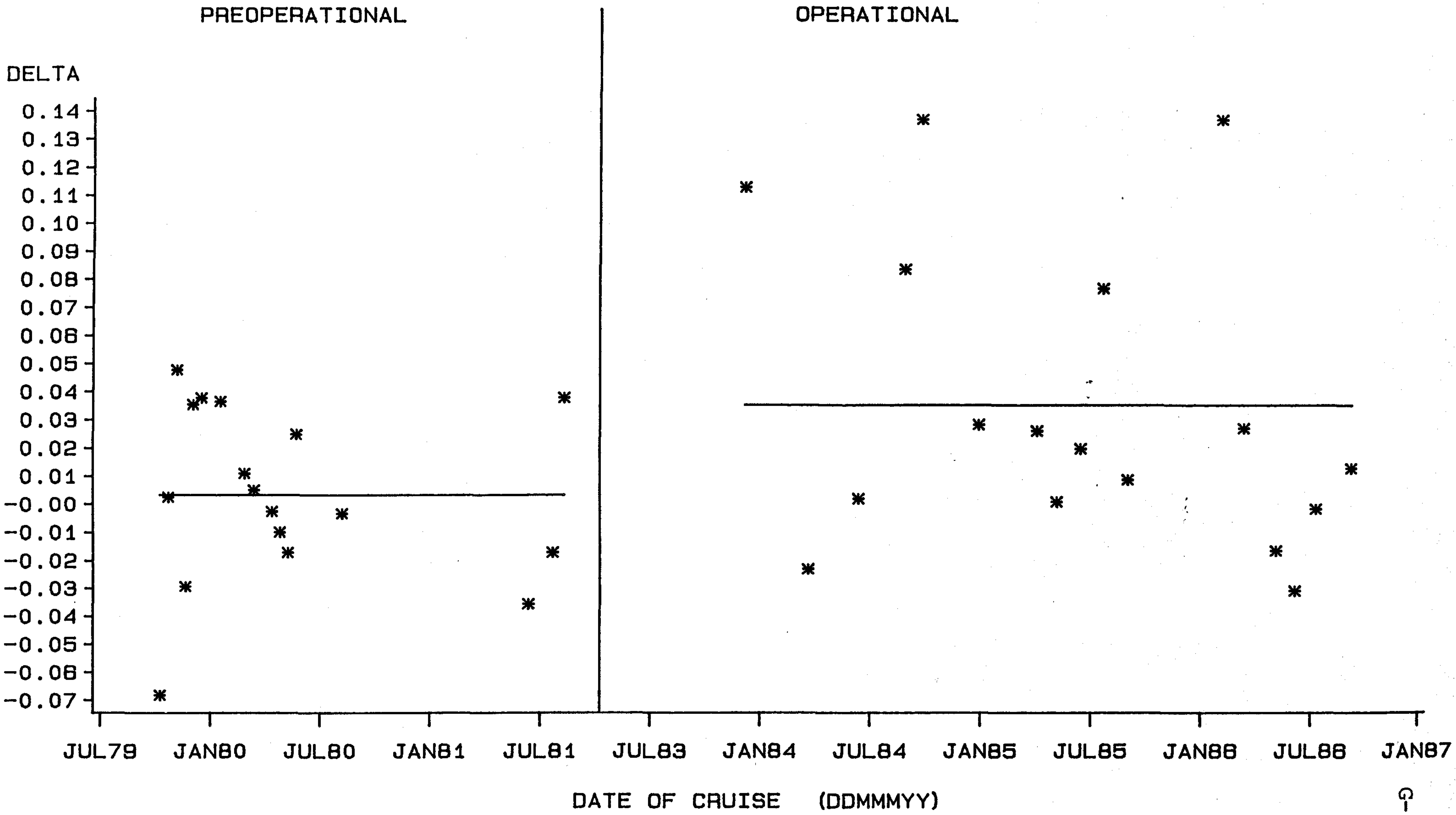
SUMMARY OF BACI TEST

Mysidopsis cathengelae STAGE ADULT

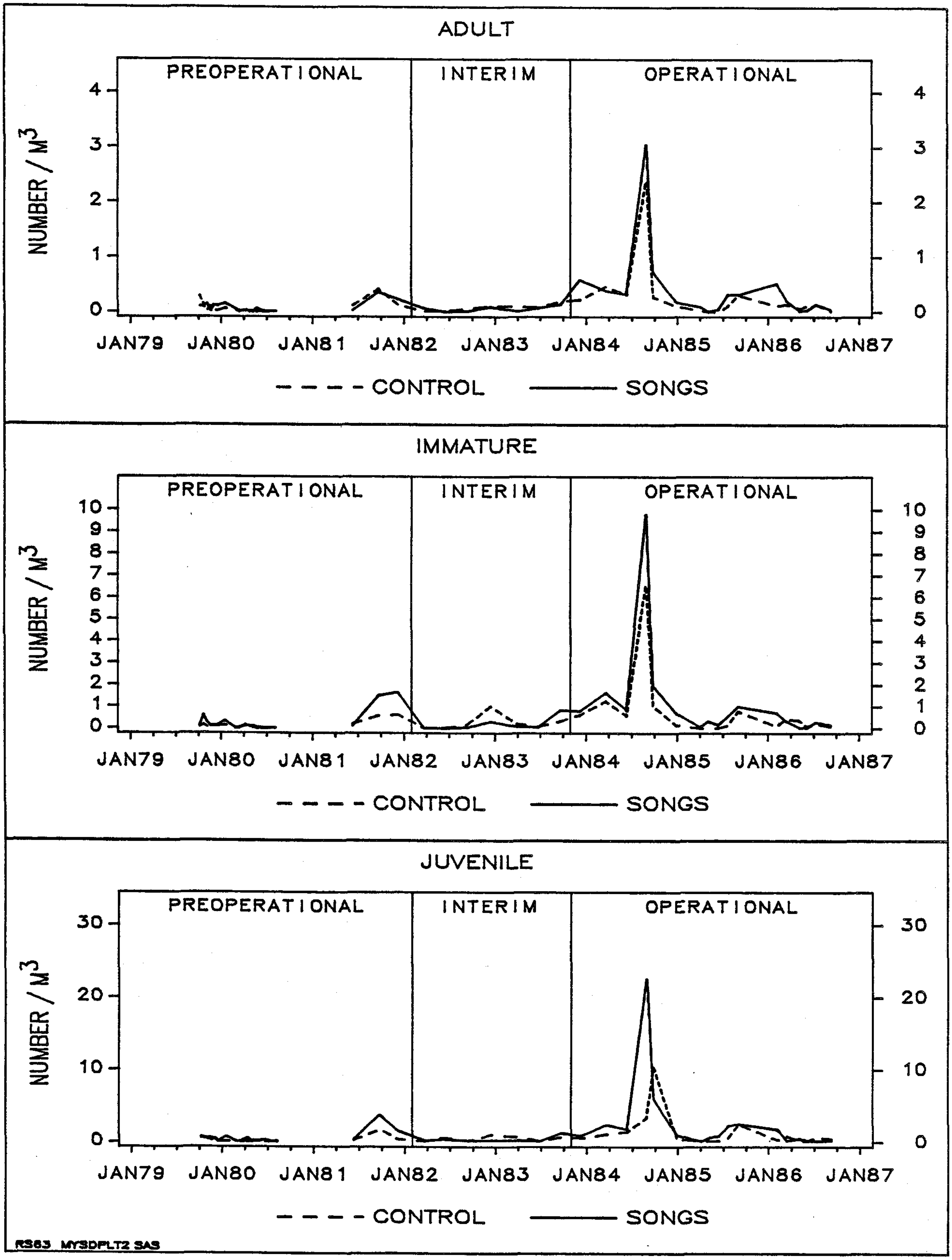
TRANSFORMATION	NUMBER OF OBSERVATIONS BEFORE	AFTER	TEST FOR ADDITIVITY P-LEVEL	TEST FOR SERIAL CORRELATION	TRENDS TEST P-LEVEL BEFORE	AFTER
LOG(X+0.01)	17	17	0.877	$p > 0.05$	0.553	0.478
LOG(X+0.1)	17	17	0.844	$p > 0.05$	0.630	0.336
LOG(X+0)	13	15	0.998	$p > 0.05$	0.476	0.516
LOG(X+1)	17	17	0.523	$p > 0.05$	0.818	0.213
LOG(X+10)	17	17	0.436	$p > 0.05$	0.849	0.149
LOG(X+100)	17	17	0.425	$p > 0.05$	0.852	0.146
NOTRANSFORM	17	17	0.424	$p > 0.05$	0.852	0.146

TRANSFORMATION	MEAN DENSITY BEFORE SONGS	CONTROL	AFTER SONGS	CONTROL	PERCENT CHANGE	SIGNIFICANCE TESTS T	Z
LOG(X+0.01)	0.05	0.04	0.17	0.11	36.1	0.360	0.352
LOG(X+0.1)	0.07	0.06	0.23	0.15	22.3	0.166	0.203
LOG(X+0)	0.07	0.06	0.21	0.14	21.5	0.629	0.549
LOG(X+1)	0.08	0.08	0.32	0.22	7.6	0.045	0.139
LOG(X+10)	0.09	0.08	0.39	0.27	1.2	0.035	0.148
LOG(X+100)	0.09	0.08	0.41	0.28	0.1	0.038	0.139
NOTRANSFORM	0.09	0.08	0.41	0.28	44.6	0.038	0.139

Mysidopsis cathengelae ADULT
PLOT OF DELTAS (SONGS - CONTROL)
TRANSFORMATION LOG (X+1.0)



Mysidopsis cathengelae



APPENDIX H

DETAILED FIELD METHODS

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Mysids were sampled at two locations - an Impact site about 3 km downcoast from the diffusers and a Control site about 18 km downcoast. At each location three, approximately 4-km transects were established perpendicular to the shore and about 500 m apart (Figure 1). The transects were not marked, but were located using shore sitings or the mini-ranger navigational device. The mini-ranger was used about half the time. On those occasions when shore sitings were used, nominal coordinates were entered in the data base (these records can be identified because the beginning and ending MRC X-coordinates are identical). During the course of the study the actual longshore location of the origin of a transect could vary by 1 to 2 km, because of practical constraints (*e.g.*, the presence of obstacles such as gill nets or anchored boats).

Each transect was divided into six depth strata: 6 - 8 m, 8 - 12 m, 12 - 15 m, 15 - 23 m, 23 - 30 m, and 30 - 37 m. Mysids were sampled within each stratum with an epibenthic sled to which a net with a 1-sq m opening was attached. The 6 - 8 m depth stratum was the most difficult to sample. Very often there was a danger of breaking waves close to shore. However, when conditions were good, samples were taken in depths less than 6 m. When there were large swells, the tow began in deeper water.

Clogging by phytoplankton was a frequent problem, particularly during the summer. Phytoplankton, and occasionally sediments, would fill the pores of the net such that water could not flow through. The net then acted as a sea anchor rather than a sampling device. The problem was addressed in several ways. In August 1980, tows 2 through 6 were started at the mid-point of the stratum and continued for 5 minutes. In June 1985, 2 to 4 short tows were made in each stratum and the data combined on the data sheets as though it had been a single tow. Tows were always repeated if the boat crew thought the net was so clogged or full of sand that the sample was bad.

The clogging problem was potentially serious because it resulted in poor estimates of the volume of water sampled. Although the meter in the net mouth underestimated the length of the tow when the net was clogged, it was probably the best estimate of the volume of water sampled and was always used when the net appeared clogged. If there was evidence that the meter was fouled with kelp, the reading from an external meter was substituted. Fortunately, since clogging occurred during both the Before and After periods and when it occurred, it did so at both the Impact and Control sites, there is no evidence that bias was introduced into the mysid density estimates.

The beginning and ending points of a tow, or transect segment, were determined by depth, not coordinates. The sled was towed straight offshore. Only a few of the tows deviated more than 30 degrees from the MRC Y-axis and most were within 20 degrees.

The sled was towed at the surface during the approach to a transect segment. When the desired depth was reached, the boat captain would give the signal to pay out cable. Speed of about 1 m/sec or 2 knots was maintained. When the captain saw the sled descend, he recorded the depth and mini-ranger coordinates. The tow then continued until the ending depth was reached. At that time, the captain would signal the deck crew to begin winching in the sled and would again record the depth and mini-ranger coordinates.

The sled weighed about 300 pounds and so dropped nearly vertically to the bottom as the cable was payed out. After the sled reached the bottom, additional cable was released until the scope was three times the expected maximum depth of the tow. When the predetermined length of cable was out, the cable drum was secured and the speed of the sled would increase to that of the boat. When the ending depth was reached, coordinates were noted and the deck crew began winching in the sled. However, the sled continued to move along the bottom until the scope was taken in. Hence, the beginning coordinates would be very close to the actual beginning of the tow, but the ending coordinates were taken before the end of the tow. The error was probably small. Depending on depth, it took between about 10 and 40 seconds to retrieve the sled to the point that the flow meters were out of the water. If the boat was traveling at 1 m/sec then the error would be less than 60 m.

Numerically, the length of bottom sampled and the volume of water sampled are equal because the net opening was 1-sq m in area. This is an important number because it is used to calculate density. The density, or concentration, of organisms is calculated as follows:

density = count * (lab vol1/lab vol2)/field vol.

where: count = number of organisms in aliquot sampled

lab vol1 = volume of diluted sample

lab vol2 = volume of aliquot

field vol = volume sampled in the field

The length of bottom sampled was estimated using flow meters. Generally, three flow meters were attached to the sled: one in the mouth of the net, one above a sled runner and one above the frame. On some cruises only the first two meters were used. The flow meters recorded the number of revolutions of a propeller. The meters recorded from the moment the sled entered the water until the sled left the water. Beginning and ending readings were recorded. In order to relate these numbers to the distance traveled, the meters were calibrated before each cruise. Each meter was attached to a stick and pulled through the water by walking briskly (c. 1.8 m/sec) along a pier for 20 meters and the number of revolutions noted.

Since the flow meters continuously record while they are moving in the water, they over-estimate the length of bottom sampled. A minimum estimate of this excess is the depth of the water at the start of the tow plus the depth of the water at the end of the tow. However, since the sled was traveling horizontally at about 1 m / sec during retrieval, that is an underestimate. To compensate for this, MEC multiplied the sum of the depths by a constant, 1.10.

The length of bottom sampled was estimated as follows:

meters sampled = (Revs/calib) - (C * (D1+D2))

where: Revs = Number of revolutions

= Final meter reading - Initial reading

Calib = calibration (revolutions/known distance)

C = 1.10

D1 = Depth at beginning of tow

D2 = Depth at end of tow

An independent estimate of the number of meters sampled is the length of the tow obtained from the mini-ranger readings. The variable "LTOW" in the data bases is obtained by applying the Pythagorean theorem to the MRC X- and Y-coordinates. This is probably quite close to the actual length of tow.

Both the estimates of the linear meters sampled based on flow meters and those based on mini-ranger coordinates seem reasonable and unbiased. Since they are independent they should provide a check on one another. One would expect them to be very similar and highly correlated. About 50 percent of the tows have actual mini-ranger readings. Using only these data, the correlation coefficient between the two estimates is 0.86 and the slope of the line formed by plotting one estimate against the other is close to unity. However, if the difference between the two estimates was large (more than 300 m) or the estimate from the current meter was less than 50% or more than 200% of either the nominal value or the estimate from the mini-ranger, the data were checked and errors corrected.

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APPENDIX I

COMMENTS ON THE MEC FINAL REPORT ON MYSIDS

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Differences between this report and the report submitted by Marine Ecological Consultants, Inc.

There are several areas in which the results reported by MEC differ from those reported herein. Although the overall answer is essentially the same, some of the BACIP results are different in detail. Also, different approaches were used both to estimate intake losses and to test the hypothesis that the operation of SONGS changed the cross-shelf distribution of mysids.

1. **BACIP Results.** Two changes were made that affect the BACIP results. First, several errors in the data were corrected (Table I-1). The errors were generally due to bad flow meter readings. If the reading on the meter from the net mouth was extreme and different from the other two meters, the reading from the meter on the net frame was substituted. Second, if a species was always absent or rare ($<0.05\ /\ m^3$) in a depth stratum, the stratum was not included in the analysis (Table I-2). These changes account for all differences in BACIP results (when using the same data transformation), and the small differences in the table of mean abundances. Most of the differences in the two reports of the BACIP results are due to selecting different data transformations. MEC was opposed to using transformed data, whereas we believe transforming the data using logarithms is more appropriate.

MEC also reported significant BACIP results (relative increases at Impact) from the combined taxa, "cross-shelf taxa" and "offshore taxa". While we were able to duplicate these results, we do not report on them because we feel they reflect the response of the most common species of each group and add little to our assessment of plant effects.

2. **Changes in cross-shelf distribution.** It was predicted that one of the effects of SONGS Units 2 and 3 would be to transport nearshore waters offshore and, as a result, to move nearshore mysids offshore to an inhospitable habitat where they would suffer high mortality. In order to evaluate this hypothesis, one needs to know if there has been a relative increase in the proportion of the population found offshore. Changes in the proportions of the populations found in each of the six depth strata are not necessarily germane. For example, a large, significant increase in stratum 1 and a decrease in strata 2 and 3, all of which are nearshore, would be of no interest in the context of the hypothesis we are interested in testing. Therefore, we divided the samples into two groups, those from less than 15 m and those from deeper tows, and looked for changes in the proportion of the population in the offshore area.

We also think that MEC's use of the MANOVA procedure is inappropriate for testing for plant effects. MEC compared mean rankings of the stratum densities found at the Impact site in the After period to those resulting from combining data from the After/Control, Before/Control and Before/Impact locations. Therefore, plant effects are confounded with both location and period effects.

3. **Estimates of intake losses.** The formula used by MEC to estimate intake losses results in the loss being indirectly proportional to water movement (MEC used a measure of excursion). As a result, MEC's estimates are much smaller than ours. Also their model is based on the assumption that the risk of being withdrawn with cooling waters is 1.0 during the night and 0.25 during the day. We think withdrawal losses are independent of longshore currents. For our calculations we used a simple model in which the loss is equal to the product of the volume of water withdrawn and the estimated concentration of mysids in the water. The latter is based on the assumption that the risk of being withdrawn with cooling water is 0.64 during the night and 0.16 during the day. These parameter values are based on early MEC studies (see Section 2.5 of the MRC Report).

TABLE I-1

DATA ENTRIES FOR WHICH FLOW METER READING WAS CORRECTED AND MYSID DENSITY RECALCULATED.

DATE	DEPTH STRATUM	TOW LINE	OLD METER READING	NEW METER READING
22MAY80	4	5	329	302
07AUG80	1	3	548	536
22SEP81	3	4	376	365
20MAR84	1	4	2879	744
29DEC84	3	1	670	142
07MAY85	1	1	440	429
07MAY85	2	4	781	760
08MAY85	5	6	161	434
17JUN85	4	5	321	437
15JUN85	2	6	275	292
05JUN86	2	3	969	958
08SEP86	3	4	2343	729
31MAR83	3	5	1084	589
08DEC83	6	1	246	235

TABLE I-2

RECORDS WHICH WERE DELETED BECAUSE TAXON WAS MISSING OR EXTREMELY RARE (< 0.05/m³).

TAXON	STAGE	TOW LINE	NUMBER/CU M BEFORE	AFTER
Acanthomysis davisii	Adult	5	0.0000	0.0000
	Adult	6	0.0000	0.0000
	Immature	5	0.0075	0.0000
	Immature	6	0.0000	0.0000
	Juvenile	5	0.0150	0.0000
	Juvenile	6	0.0021	0.0000
Acanthomysis nephrophthalma	Adult	1	0.0000	0.0000
	Adult	2	0.0000	0.0000
	Adult	3	0.0000	0.0000
	Adult	4	0.0077	0.0094
	Immature	1	0.0000	0.0000
	Immature	2	0.0000	0.0000
	Immature	3	0.0000	0.0000
	Immature	4	0.0294	0.0029
	Juvenile	1	0.0000	0.0000
	Juvenile	2	0.0464	0.0000
	Juvenile	3	0.0000	0.0179
	Juvenile	4	0.0098	0.0035
Holmesimysis costata	Adult	4	0.0023	0.0023
	Adult	5	0.0000	0.0000
	Adult	6	0.0000	0.0000
	Immature	4	0.0034	0.0046
	Immature	5	0.0000	0.0000
	Immature	6	0.0000	0.0000
	Juvenile	4	0.0000	0.0000
	Juvenile	5	0.0000	0.0000
	Juvenile	6	0.0000	0.0000
Metamysidopsis elongata	Juvenile	5	0.0000	0.0000
	Juvenile	6	0.0000	0.0000
Mysidopsis cathengelae	Adult	4	0.0000	0.0217
	Adult	5	0.0000	0.0000
	Adult	6	0.0000	0.0000
	Immature	5	0.0000	0.0000
	Immature	6	0.0000	0.0000
	Juvenile	4	0.0000	0.0262
	Juvenile	5	0.0000	0.0000
	Juvenile	6	0.0000	0.0000

TABLE I-2. (Continued)

TAXON	STAGE	TOW LINE	NUMBER/CU M BEFORE	AFTER
Neomysis kadiakensis	Adult	1	0.0000	0.0000
	Adult	2	0.0103	0.0000
	Immature	1	0.0210	0.0000
	Immature	2	0.0469	0.0000
	Juvenile	1	0.0000	0.0000
Neomysis rayii	Adult	4	0.0019	0.0000
	Adult	5	0.0000	0.0000
	Adult	6	0.0000	0.0000
	Immature	4	0.0039	0.0000
	Immature	5	0.0017	0.0000
	Immature	6	0.0009	0.0000
	Juvenile	5	0.0026	0.0000
	Juvenile	6	0.0000	0.0000

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APPENDIX J

SUMMARY OF BACIP TESTS FOR CHANGES IN ABUNDANCE ON PLUME DATES AND NON-PLUME DATES.

All life stages are combined within each taxon. The indicated direction of change, i=increase, d=decrease. ** indicates $p<0.05$; * indicates $0.05<p<0.10$

TAXA	PLUME	NON-PLUME
Mysidopsis intii	I**	I**
Neomysis kadiakensis	I*	I*
Acanthomysis davisii	I	I**
Acanthomysis macropsis	I	D
Acanthomysis nephrophthalma	I	I
Holmesimysis costata	I	D
Metamysidopsis elongata	I	I
Mysidopsis cathengelae	I	D
Neomysis rayii	I	I*
Total mysids	I	I