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THE EFFECTS OF THE OPERATION OF THE SAN ONOFRE NUCLEAR GENERATING STATION ON EXPERIMENTAL POPULATIONS OF KELP

FINAL REPORT

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SUMMARY

The growth and survival of experimental populations of gametophytes and small sporophytes of <u>Macrocystis</u> were examined in order to assess the possible effects of the San Onofre Nuclear Generating Station (SONGS) on these life stages which are critical to adult sporophyte recruitment. Experimental populations grown on artificial substrates, were placed at stations in the San Onofre Kelp forest (SOK), near discharges of cooling waters from SONGS' Units 2 and 3, and at a control station in the San Mateo Kelp forest (SMK). Observations on these experimental populations were used to supplement observations of the effects of SONGS on natural recruitment events that occur only once every several years. (Effects of SONGS on natural recruitment are presented in a separate report.)

The operation of SONGS' discharges created a turbid plume that caused a reduction in light and an increase in suspended sediments in SOK. The presence of the plume was correlated with a reduction in the growth and survival of small sporophytes, indicating an adverse effect of SONGS. The growth rates of both microscopic and juvenile sporophytes were lower, and the mortality rates of microscopic sporophytes were higher when turbid plumes from the discharge were over the experimental stations in SOK. However, there were no statistically significant overall reductions in the production, growth, or survival of sporophytes at SOK after Units 2 and 3 began operation, in part because of temporal and spatial variability in the plume.

The reduction in growth rate that was associated with the plume was likely caused by a reduction in light that was attributable to SONGS. This is suggested by evidence that SONGS reduced light levels, that growth rates of small sporophytes were largely determined by light levels, and that the quantitative relationships

between light levels and growth rates (based on pre-operational studies) were relatively good predictors of growth rates observed at SOK in the period after SONGS Units 2 and 3 began operation.

Increases in mortality rates were possibly caused by an increase in suspended sediments although the evidence for this is somewhat circumstantial. SONGS increased suspended sediments (as infered form an increase in extinction), and abrasion and burial by sediments can kill small sporophytes. However, the measured rates of seston flux explained only a small fraction of the variability in mortality.

The observed adverse effects of SONGS on experimental populations of small sporophytes generally corroborates evidence provided from studies of natural recruitment. In both experimental and natural populations, recruitment of <u>Macrocystis</u> appears to be inhibited by an increase in seston flux and a reduction in light that are attributable to the discharge plume from SONGS Units 2 and 3.

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1.0 INTRODUCTION

Earlier we predicted that the San Onofre Nuclear Generating Station (SONGS) might inhibit recruitment of kelp by reducing irradiance and increasing seston flux (Dean, 1980). We evaluated these potential effects of SONGS, in part, by examining temporal and spatial patterns of juvenile sporophytes following recruitment events (Schroeter <u>et al.</u>, 1987). However, we knew from our previous work that recruitment events were rare, and that it would be difficult to evaluate SONGS' effects on recruitment by examining the relatively few natural events that were likely to occur over the length of our study. Therefore, we supplemented observations of natural recruitment events with studies of experimental populations of <u>Macrocystis</u> in its early life stages.

Gametophytes and microscopic sporophytes were cultured on artificial substrates in the laboratory and outplanted to impact and control sites at regular intervals in the pre-operational and operational periods. Also, juvenile sporophytes (about 40 cm in height) were transplanted to these same sites. These replicated outplants or transplants, conducted under more controlled conditions than natural recruitment events, were then used in a Before-After, Control-Impact (BACIP) assessment design in order to evaluate the potential effects of SONGS (see below for a further explanation of the BACIP design).

The use of experimental populations also allowed for examination of the potential mechanisms of impact. Previously described studies of experimental populations in the pre-operational period (Dean <u>et al.</u>, 1987) led to quantitative models of the influence of various physicochemical factors (irradiance, temperature, seston flux, and nutrient concentrations) on recruitment processes. By



coupling these models with studies of changes in physicochemical factors resulting from the operation of SONGS, and with changes in experimental populations observed in the operational period, we hoped to establish a link between physicochemical and biological impacts.

While experimental studies offer the advantages of replication and control of factors such as location, substrate, and initial density of recruits, they also have several disadvantages that should be recognized. First, a measure of control is only obtained through an introduction of artificiality; experimental populations are not identical to natural ones. The experimental populations were attached to artificial substrates (either rope or PVC) that were, initially at least, free of competitors or grazers. Also, substrates were sometimes held off of the bottom (see Mehtods below) out of the reach of benthic grazers, away from the influence of shifting sediments on the bottom, and away from local sources of nutrients regenerated from bottom sediments. As a result, there may be impacts to the natural populations that are not observed in the experimental ones and vice versa. Second, the studies on experimental populations are short (on the order of 3 to 6 weeks of field exposure for each outplanting or transplanting) relative to natural recruitment processes. Natural recruitment events require several months from the time of spore settlement until recognizable sporophytes are produced and almost a year for the production of new adults. The experimental studies evaluate relatively acute effects on specific life stages, but do not evaluate possible longer-term, cumulative effects. Therefore, it is important to evaluate results from experimental studies in close conjunction with samplings of natural recruitment events.



2.0 METHODS

2.1 Outplant and Transplant Techniques

2.1.1 Gametophyte Outplants

The effect of SONGS on the production of sporophytes from gametophytes was examined by outplanting known densities of gametophytes on nylon lines and sampling these lines 6 weeks later to determine the number of sporophytes produced. Procedures for culturing gametophytes on lines in the laboratory, outplanting, and counting the numbers of sporophytes produced, were described in detail in Dean <u>et al</u>., 1987, Section 5.0, and are briefly summarized below.

Sporophylls were collected from adult sporophytes in the San Onofre kelp forest and were returned to the laboratory. There, spores were released from the sporophylls and an inoculation solution, which consisted of a known density of spores in filtered seawater, was made. Plastic plates with nylon line substrates were placed in the inoculation solution overnight. On the next day, one line was removed from each plate and the densities of gametophytes on the lines were counted. The plates with remaining lines were then outplanted onto PVC racks at field sites in SOK and SMK. After 6 weeks in the field, the plates were collected and returned to the laboratory where the number of sporophytes per line were counted. A 6-week exposure period was used because previous studies had indicated that peaks in sporophyte density generally occurred within this time interval. Prior to 6 weeks, sporophyte densities had begun decline as the result of sporophyte mortality (Dean et al., 1987, Section 5.0).

The number of substrate plates and lines per plate varied as the experimental design evolved. Generally, 2 plates with 7 lines per plate were outplanted to the seafloor and to 2 m above the seafloor at each station. (Appendix G, Dean <u>et al.</u>, 1987).

Uninoculated substrates were outplanted along with inoculated lines during each experiment in order to assess possible recruitment from naturally settling spores. Densities of sporophytes on uninoculated lines were generally less than 4% of densities on inoculated substrates (Dean <u>et al.</u>, 1987, Section 5), and were therefore not included in the analyses presented herein.

A number of stations in SOK, SMK, and BK were used in this study (see Appendix G, Dean <u>et al.</u>, 1987, for a complete list of stations). In the operational period, one station in SMK (SMK45) and 4 in SOK (SOKU45, SOKD45, SOKU35, and SOKD35) were used (Fig. 1). All but the SOKU35 site, which was established in November 1985, were sampled in the pre-operational period. Substrates were outplanted to racks located both on the seafloor and at 2 m above the seafloor at all stations.

The number of outplantings made to each station varied as the experimental design evolved. In the pre-operational period, there was a maximum of 10 paired observations (i.e., outplanting at both SOK and SMK) that could be used in the BACIP analysis. The preoperational outplantings were made between August 1981 and August 1982. In the operational period, 17 outplantings were made to each site between June 1984 and July 1986. A complete listing of outplant dates is given in Dean <u>et al.</u>, 1987, Appendix G.

2.1.2 Microscopic Sporophyte Outplants

The effect of SONGS on the growth and survival of microscopic sporophytes was examined by outplanting known densities of newly recruited sporophytes on nylon lines and examining these lines 3 weeks hence to determine the size of sporophytes and the number of survivors. Substrate lines were inoculated with gametophytes, as outlined in Section 2.1.1, kept in laboratory culture for 2 weeks until sporophytes were produced, and then outplanted to field sites. Laboratory culture conditions used for sporophytes are given in detail in Dean <u>et al.</u>, 1987, Section 6.0.

In the pre-operational period, from September 1979 to October 1982, we sampled 2 to 3 lines on each of 2 substrate plates that were outplanted to each station in each experiment. In the operational period, 2 plates with 3 lines per plate were sampled at each station. A summary listing of the number of plates and number of lines per plate is given in Dean <u>et al.</u>, 1987, Appendix J.

Outplantings were made to 4 stations in SOK (SOKU45, SOKD45, SOKU35, and SOKD35) and one station in SMK (SMK45) in the operational period (Fig. 1). All but the SOKU35 station were used in the pre-operational period. Substrates were placed on racks similar to those described in gametophyte outplant studies (Dean <u>et al</u>., 1987, Section 6.0). Outplants were placed on the seafloor and 2 m above the seafloor from 1979 to 1981. Thereafter, substrate plates were placed only on the seafloor.

The number of outplantings varied with a maximum of 15 placed at SOKD45 in the pre-operational period. During 7 pre-operational experiments, conducted from September 1981 to September 1982, outplantings were made to stations located in both SOK and SMK. Eleven outplantings were made to each station in the operational period, between July 1984 and July 1986. A complete listing of outplant dates is given in Dean et al., 1987, Appendix J.

2.1.3 Transplant Studies with Juvenile Sporophytes

Juvenile sporophytes, generally about 40 cm in height, were transplanted to stations located in SOK and SMK. Each plant was measured after transplanting, and after 6 weeks, we counted and measured the remaining plants. Details of transplant methods are given in Dean <u>et al</u>., 1987, Section 9.0. Briefly, either plants were taken from naturally recruited stocks growing in SOK, SMK, or the other nearby kelp forests, or were taken from laboratory-reared stocks grown out to juvenile size at either SOKD45 (prior to 1984) or SMK45 (after 1984). The plants were collected by divers and transplanted onto sawhorse-like racks at various stations in SOK and SMK. The racks held plants about 1 m above the seafloor so that they were inaccessible to benthic grazers. Growth rates were expressed as the change in the natural log of length over the elapsed time in days and mortality rates were given as the change in the natural log of the number of survivors over the time in days.

Juveniles were transplanted to one station in SMK (SMK45) and two in SOK (SOKU45 and SOKD45) in the operational period. These stations and others were used in the pre-operational experiments. The number of pre-operational transplants at each station varied between 6 and 8. Preoperational experiments were conducted from August 1979 to September 1982 and both impact and control sites were sampled from July 1981 to September 1982. Eight transplants were made to each of the 3 stations in the operational period, between July 1984 and August 1986. In addition, two transplants were conducted at inshore stations at SOK (SOKD35 and SOKU35) and SMK (SMK35) during June and August 1986 to assess growth at these sites following a recruitment event in spring, 1986. The results from these inshore studies are presented in Schroeter et al., 1987, and will not be discussed here.

2.2 BACIP Analyses

Possible effects of SONGS on the production of sporophytes from gametophytes, the growth and survival of microscopic sporophytes, and the growth and survival of transplanted juveniles were examined using a Before-After, Control-Impact pairs design. A thorough discussion of the rationale for this analysis is provided by Stewart-Oaten, 1986, and Stewart-Oaten <u>et al.</u>, 1986. Briefly, the differences (called deltas) between mean abundances at control and impact sites were calculated for each replicate survey in the pre-operational and operational periods. A t-test and its non-parametric equivalent, the Wilcoxon rank sum test (Snedecor and Cochran, 1967), were then done to compare the deltas from the pre-operational and operational periods. Both tests were one-tailed, since we expected SONGS to affect kelp recruitment adversely.

The t-test is based on the following assumptions: (1) effects are additive, (2) the samples in the before period are all drawn from the same population and have a common mean, (3) observations are independent, (4) observations are drawn from the same distribution, (5) observations are normally distributed, and (6) variances in the two treatments are equal. Violations of the last three assumptions have little effect on the outcome of the t-test (Glass <u>et al.</u>, 1972; Stewart-Oaten, 1986), and will not be discussed here. The first three assumptions, on the other hand, are very important.

Pre-operational data were tested for additivity using Tukey's test (Snedecor and Cochran, 1967). After testing for additivity, we examined the pre-operational data for temporal trends by plotting the deltas against time and performing regression analyses. If there were no significant trends, we assumed that all the pre-operational samples were drawn from the same statistical population. (Results of this and other tests of assumptions are given in Appendix A).

Serial correlations in the data result in underestimates of the true error variance of the deltas, and hence wrongly increase the chance of finding a statistically significant BACIP result. We tested for serial correlations with the Von Neuman test, and in most cases, found no significant serial correlations. However, it must be noted that, because of small sample sizes (n < 10), the power to detect such correlations is generally low. One solution to the problem of serial correlations is to conduct an analysis which explicitly estimates the auto-correlated errors. We elected not to do this, because of small sample size, and instead performed the standard BACIP analysis with a cautionary note attached to cases with significant serial correlations.

The variables used in the BACIP design were as follows: (1) For sporophyte production, the proportion of female gametophytes producing sporophytes. (2) For growth, the change in the natural log of length of sporophytes over the elapsed time in days, and (3) for mortality, the change in the natural log of the number of survivors over the elapsed time in days. In the case of microscopic sporophytes, growth rates were calculated using mean lengths. For juvenile transplant studies, in which the same individual plants were measured at the beginning and end of the transplant period, the mean of the growth rates for individual plants was used.

For the production of sporophytes from gametophytes, mortality rates of microscopic sporophytes, and growth rate of juvenile sporophytes, both untransformed values and log-transformed values were used in the analyses in order to meet the assumption of additivity. For the log-transformation, constants of 0.00001 and 0.01 were added to sporophyte production and sporophyte survival rates, respectively, to avoid taking the logs of zero values. These were equivalent to the smallest observed values for each variable following the suggestion of Stewart-Oaten

(1986). Times when both impact and control stations had zero values were excluded from the analyses becuase these values provide no information with regard to potential impacts (Stewart-Oaten, 1986).

For all BACIP analyses, we defined the pre-operational period as prior to January 1983, when Units 2 and 3 collectively were operating at less than 50% capacity based on power output (Fig. 2). The first operational samples were collected in May 1984 as there were no samples taken between January 1983 and May 1984.

The BACIP analyses rely on the deltas between impact stations at SOK (SOKU45, SOKD45, and SOKD35) and the control station in SMK (SMK45). Plots of SOKU35 vs SMK45 are also given, but no analyses are available because of the lack of before data at SOKU35.

2.3 Correlations with Plume Attributes

The BACIP analyses outlined above treat all operational samples equally. However, because of the changing operational status of the power plant and changing oceanographic conditions (in terms of currents and ambient turbidity conditions), the influence of the discharge plume on a particular station varied among experiments. One way to assess the influence of the plume would be to divide the operational data set into two groups, based on plume presence or absence, and conduct the BACIP analyses using only those operational samples that were taken when a plume was evident. Unfortunately, there is no obvious dichotomy of plume presence or absence. Instead, the plume is usually evident to varying degrees. Therefore, we examined possible relationships between the discharge plume and differences in biological variates using regression analyses. Differences in sporophyte

production, growth, and mortality, at impact and control sites in the operational period were correlated with plume attributes. Plume attributes included the proportion of the time the discharge plume was located over a particular station in a given experiment, and the percentage of reduction in irradiance attributable to the plume. These plume attributes were determined using models based on both the current regimes and on differences in irradiance at stations located in the plume compared with paired stations located outside the influence of the plume (Reitzel <u>et al.</u>, 1987). The percentage reduction in irradiance provides a relative measure of how turbid a particular plume was, on average, and implies the degree of increase in seston flux. Deleted from the analyses were instances when there was no sporophyte production at both of the paired stations. In these instances, further reductions in irradiance would obviously have no measurable impact.

Analyzing the data in this way has several advantages over the normal BACIP approach. First, as mentioned previously, it accounts for variability in the plume both with regard to its location and its "intensity" or turbidness. Second, it compares more closely coupled periods in time (i.e., all from the operational period) than the normal "before" and "after" BACIP analysis. This eliminates the potential problems associated with changing conditions at the control site, from the before period to the after period. This is especially helpful in the case of the experimental studies analyzed here, which rely on a single control station. These studies may be particularly prone to natural time-by-location interactions due to increases in grazing by sea urchins, changes in substrate distribution, etc.

The plume model does not provide an accurate estimate of absolute change in irradiance due to SONGS. The possible effect of the plume in increasing irradiance at the upstream station (estimated to be small relative to reductions on the

downstream side of the plume (Reitzel <u>et</u>. <u>al</u>, 1987)) is not accounted for. Also, the model does not consider the larger temporal and spatial scale influences of SONGS, such as the effects of accumulation of sediments or and offshore transport of nearshore turbidity. However, the model does provide estimates of relative rankings of plume conditions, both among experiments and among stations. The model estimates for each station and experiment are given in Appendix B.

These anayses suffer from a possible bias relating to the effects of current direction on the levels of irradiance at the control site (SMK). Analyses by ECOsystems Management Associates (Appendix C) suggest that irradiance levels at SMK were lower when currents were in the upcoast direction, and that the effect was unrelated to the operation of SONGS. As a result, significant correlations between plume attributes and differences in growth or mortality at SOK vs SMK might result from decreased growth (or increased mortality) at SMK when currents were directed upcoast (i.e., when SOK was not in the plume) as opposed to reduced growth (or increased mortality) at SOK when currents were SOK.

To examine this possibility, we conducted plume correlation analyses for the preoperational period. If significant correlations in the "after" period were the result of effects unrelated to SONGS, then significant correlations should also exist in the "before" period. The portion of the plume model based on current data was run using "before" data, while assuming that both SONGS Units 2 and 3 were fully operational. This yielded values for the proportion of the time a hypothetical plume would have been over the stations in SOK, based on current speed and direction. We then regressed the differences in sporophyte production, growth and survival vs the proportion of time this hypothetical plume was over the impact sites.

2.4 Sporophyte Production, Growth, and Survival in Relation to Physicochemical Factors

In order to explain possible effects of SONGS, or the lack thereof, on experimental populations, we examined the relationships between sporophyte production, growth, and survival and the physicochemical conditions which existed at impact and control sites in the operational period. These relationships were viewed with respect to previously established models based on data obtained during the pre-operational period and also on data obtained at the control site (SMK45) during the operational period. The models examined sporophyte production, growth, and survival in relation to temperature, irradiance, and seston flux.

Values of irradiance, temperature, and seston flux observed at impact stations in SOK during each operational-period experiments, were substituted into these regression models, and predicted values of sporophyte production, growth, and survival were thereby generated. These predicted values were plotted against the observed values: If the predicted and observed values were the same (i.e., if the regression of predicted vs observed was significant and the slope did not differ significantly from 1) then observed values could be explained based on physicochemical factors alone, and any impact of SONGS on biological factors could be interpreted as a result of changes to the physicochemical factors in question. Any deviation from previously established models could be caused by either a change in the environmental conditions other than those used in the model, a failure of the model to accurately relate the biological measure to environmental conditions, or to stochastic error.

The regression analyses of biological factors vs physicochemical factors for the pre-operational period are presented in Dean et al., 1987, Section 5 (for
sporophyte production), Section 6 (for microscopic growth and survival) and Section 9 (for juvenile growth). The resulting models are summarized in Table 1. Methods for measuring physicochemical factors are reviewed in Dean <u>et al.</u>, 1987, and Schroeter <u>et al.</u>, 1987.

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3.0 RESULTS

3.1 Production of Sporophytes from Gametophytes

There is little evidence that SONGS impacted sporophyte production. Results of BACIP analyses indicated that there were no significant decreases in sporophyte production at stations in SOK, relative to the control in SMK, during the period of SONGS operations (Tables 2 and 3, and Figs. 3a to 3d, and Figs. 4a to 4d). Also, deltas of sporophyte production in the operational period were not significantly correlated with either the percent of time an impact station was influenced by the plume, or the percentage reduction in irradiance attributable to SONGS (Figs. 5a and 5b).

Levels of sporophyte production generally decreased at both impact and control stations during the operational period. The proportion of gametophytes producing sporophytes differed significantly among the before and after periods on the seafloor at SMK45, and at 2 m above bottom at SMK45, SOKU45, and SOKD45 (Table 4). Moreover, the relationship between sporophyte production and physical factors differed in the pre-operational and operational periods. Levels of sporophyte production were generally lower than predicted in the operational period, at both impact and control stations, based on the previously established relationships between sporophyte production, irradiance, and temperature (Fig. 6). The largest and most persistent deviations from predicted values were observed on the seafloor at SOKU45, SOKD45, and SMK45 (Figs. 7 and 8). In most instances, large deviations were the result of no sporophyte production that appeared to be independent of the physical factors. At SOKU45 and SOKD45 on the seafloor, there was a significant linear increase in deviation with time (r = 0.58, P < 0.05, and r = 0.62, P < 0.01, respectively), suggesting a worsening of conditions with time, at these sites, that was independent of irradiance and temperature.



We do not know why these deviations from predicted values occurred. One hypothesis is that it may have resulted from grazing by sea urchins. Urchins obviously have easier access to substrates on the seafloor, where the highest deviations were observed. Also, urchin densities were higher at offshore sites (SOKD45, SOKU45, and SMK45) than at inshore sites (SOKD35 and SOKU35) (Dixon et al., 1987a). Furthermore, the decline in sporophyte production in 1985 coincided with a general increase in Lytechinus densities at all sites (Schroeter et al., 1987). This hypothesis is supported by the observation that most deviations from the model were the result of instances when there was little or no sporophyte production, suggesting possible death due to grazers. A second hypothesis is that deviations from expected values were due to a chronic effect of SONGS, perhaps through a buildup of fine sediments that occurred in offshore portions of SOK, and especially at SOKU45 (Dixon et al., 1987). This is supported by the observed increase in deviation with time at SOKU45 and SOKD45.

3.2 Growth and Mortality of Microscopic Sporophytes

There were no significant changes in growth rates of microscopic sporophytes at the impact sites relative to the control site in the pre-operational and operational periods (Table 5 and Figs. 9a to 9d). However, differences in growth rates at impact and control sites in the operational period were significantly correlated with the presence of the plume (Fig. 10, TOP), suggesting a possible adverse effect of SONGS. The correlation between deltas and percent change in irradiance was not significant (Fig. 10, BOTTOM), but the sample size for this analysis was small (N = 12, Appendix B).

The relationship between growth rate of microscopic sporophytes and physical factors (irradiance and seston flux; see Table 1 for the regression equation) was

similar in the before and after periods. There was a significant correlation between observed and predicted values, and the slope of the regression of observed vs predicted did not differ significantly from 1 (Fig. 11). This suggests that reductions in growth at SOK, when the plume was present, were due to decreases in irradiance and increases in seston flux associated with the plume.

Relative decreases in mortality rates were observed at SOKU45 and SOKD35 in the operational period, and nearly significant decreases were observed at SOKD45 (Table 6 and Fig. 12a to 12d). However, we do not think that the decreases in mortality rate at SOK relative to SMK, as indicated in the BACIP analysis, were the result of the operation of SONGS. The significant differences in deltas from the before to the after period, resulted from a large increase in mortality rate at SMK45 rather than a decrease in mortality rate at SOK. We do not know why mortality at SMK45 increased in the operational period, but suspect it may have been due to increased grazing, probably by sea urchins (see below).

In contrast to the BACIP results, correlations of deltas, in the operational period, with plume characteristics indicated that the plume from SONGS Units 2 and 3 had a negative impact on survival (Fig. 13). Mortality rates were higher at the impact sites relative to the control when influenced by the plume, and mortality rates increased at SOK, relative to SMK, as reductions in irradiance increased.

The correlation between observed mortality rates and predicted values, based on a previously established regression of mortality rate with seston flux (see Table 1), was not significant (Fig. 14). This is not surprising given that, in previously established regression models, seston flux could only account for 12% of the variability in the survival of the microsporophytes. There was substantial



variability in the observed values even though the range in predicted values was small. The largest deviations from predicted values occurred in summer and fall 1985, and especially at SMK45 (Fig. 15). We suspect that the higher than predicted values for mortality resulted from grazing, probably by white sea urchins. Lines collected from SMK45 in summer and fall, 1985, were almost entirely cleaned of microscopic sporophytes as well as other algae and encrusting invertebrates, suggesting intense grazing. During this same time Lytechinus densities increased sharply at SMK45 (Schroeter et al., 1987).

3.3 Growth and Mortality of Juvenile Sporophytes

Growth rates of juvenile sporophytes at SOKU45 and SOKD45 did not change significantly, relative to the control at SMK45, in the operational period (Table 7 and Figs. 16a and 16d). However, growth rates were lower at SOK in the after period when a turbid plume was present, suggesting an adverse effect of SONGS (Fig. 17). There was a significant correlation between the deltas in growth rate and the percent change in irradiance attributable to the plume. The correlation between deltas in growth rate and plume presence was nearly significant.

The growth rates observed during operational periods tended to be lower on average than predicted values of growth that were based on a previous regression (see Table 1) with irradiance and temperature (Fig. 18). The largest deviations occurred in 1984, during the latter stages of an El Nino event (Fig. 19). Similar deviations from predicted values were observed at SOK and SMK, suggesting that they were unrelated to SONGS. The growth of juveniles was severely limited by nitrogen during this time and growth generally showed less of a dependence on irradiance than it did in other experiments (Dean and Jacobsen, 1985). When times of severe nitrogen limitation were eliminated from consideration, observed values tended to



track predicted values more closely. This suggests that, except during an El Nino event, growth rates in the before and after period were similarly determined by irradiance and temperature. Moreover, possible impacts of SONGS on growth were probably caused by a reduction in irradiance.

We noted no significant increase in juvenile mortality at SOK in the operational period (Table 8 and Fig. 20a and 20b). Also, there were no significant correlations between mortality rates and various plume attributes, although the correlation between deltas in mortality rates and the percent change in irradiance was nearly significant (Fig. 21). We did not attempt to predict mortality rates based on prior regression results since these regressions failed to demonstrate a significant relationship between juvenile mortality and any of the measured physicochemical factors. It should be noted that our transplant experiments were designed to eliminate sources of natural mortality. Plants were securely fastened to raised racks, thereby reducing possible effects of wave surge and benthic grazers.

3.4 Possible Biases in Plume Analyses

The significant correlations between plume attributes and differences in growth and mortality appeared to be largely related to the effects of SONGS, and relatively little affected by the influences of current direction on irradiance at SMK. While correlations between the proportion of the time the plume from SONGS was over the SOK stations and the deltas in the growth or mortality of small sporophytes were significant (or nearly so) in the operational phase, there were no significant correlations in the preoperational period. The later used a hypothetical "plume" from SONGS and the same current model used in the analyses for the operational period (Table 9). There appeared to be a possible bias for microsporophyte growth

and mortality. The r values for both the before and after periods were somewhat similar (0.34 vs 0.48 for mortality and -0.27 vs -0.47 for growth), and although the correlations in the before period were not significant, the sample sizes for these analyses were small. However, while <u>some</u> of the variability in deltas for growth and mortality may be attributable to an effect of current direction on irradiance at SMK, much of the variability appears related to SONGS.

4.0 DISCUSSION

Results of BACIP analyses of data from experimental populations indicated that there were no significant adverse effects of SONGS on the production, growth, or survival of sporophytes. These results contradicted the evidence that there was a significant adverse effect of the plume on microsporophyte growth, microsporophyte survival, and juvenile sporophyte growth based on correlations of deltas from the operational period with plume attributes.

We feel that the contradiction stems from 3 major sources. First, the BACIP models are subject to error based on natural time by location interactions that may be unrelated to the operation of SONGS. For example, the lack of significant BACIP effects appeared to stem from a general worsening of conditions for sporophyte recruitment and survival at the control site (SMK45) operational period. The worsening of conditions at SMK was probably related to an increase in white sea urchin densities, relative to SOK, in the after period. Additional changes may also have occurred at SMK as a result of the extremely heavy recruitment of kelp at SMK in 1983. Densities of adult <u>Macrocystis</u> in the after period in SMK were exceedingly high and probably altered current and wave regimes (Jackson and Winant, 1983).

Second, oceanographic conditions changed as a result of El Nino which extended through 1984, into the early period of our operational phase sampling. During this time, light levels and temperatures were much higher than normal and nutrient concentrations were lower than normal (Dixon <u>et al</u>., 1987a). Many processes that were normally light-limited, such as the growth of juveniles became nutrient-limited during the El Nino (Dean and Jacobsen, 1985). As a result, effects of SONGS that



could be caused by a reduction in irradiance, were at this time overshadowed by nutrient-limitation. For example, the growth rates of juveniles were low at all stations during the El Nino as the result of nutrient-limitation and were probably little affected by any reduction in irradiance due to SONGS.

Third, there was a lot of variability in both the position and "turbidness" of the plume from SONGS Units 2 and 3. As a result, there was considerable variability in the biological effects that were measured between experiments. This variability weakened the BACIP analysis, especially in the case of our relatively short-term (3to 6-week) experiments.

These possible sources of error in the BACIP design are especially problematic in the analyses presented herein that rely on a single control site, where rather site specific changes can alter the outcome of statistical tests. These problems are not as likely to occur in other BACIP analyses, such as the analysis of possible effects of SONGS on natural recruitment events (Schroeter <u>et al</u>., 1987), which rely on multiple control sites.

Our BACIP results do not rule out a possible effect of SONGS on kelp. Unlike the relatively short-term experiments conducted in BACIP analyses, natural populations of kelp must endure several months of continuous, yet variable, exposure to the plume. One short period of especially adverse conditions may be sufficient to severely restrict recruitment in natural populations of kelp. In the BACIP analyses, such a period of adverse impacts may have been just one of many observation periods. Many other experiments may have been conducted during times when SONGS effects were negligible, thereby leading to insignificant BACIP results.



In our view, the more convincing evidence indicates that SONGS did have adverse impacts on the growth and survival of microscopic sporophytes, and on the growth of juveniles. This conclusion is based largely on the correlation between the deltas in growth and survival and the percent reduction in irradiance attributable to the plume. This suggests that the plume from SONGS Units 2 and 3, when present, reduced the growth rate and increased the mortality rate of small sporophytes. It also indicates that the magnitude of the changes in growth and survival were dependent on how often the plume was present, and how turbid it was.

For growth rate data, the argument for an effect of SONGS is further supported by the use of mechanistic models which indicated a direct dependence of growth rate on irradiance in both the before and after periods. Growth rates at the impact site could largely be accounted for by the observed irradiance levels. Observed changes in growth rates can be directly linked to changes in irradiance caused by the operation of SONGS since it was demonstrated that the operation of SONGS reduced irradiance levels (Reitzel et. al, 1987).

The mechanistic argument for an effect of SONGS on mortality rates is somewhat less convincing. We demonstrated that, in the pre-operational period, the mortality rates of microscopic sporophytes were correlated with seston flux. Based on plume model data, we know that SONGS increased extinction and we can infer from this that SONGS' operations increased the amount of seston within the water column. However, BACIP analyses of seston flux data (the amount of sediment collected in tubes) have failed to demonstrate a statistically significant effect of SONGS. Furthermore, seston flux explained only a small fraction of the variability in mortality rate in our mechanistic model, and not surprisingly, the relationship between seston flux and mortality rates that was observed in the before period, proved to be a poor predictor of mortality rates at impact sites in the after period.

Data for the production of sporophytes from gametophytes do not provide strong evidence for an adverse effect of SONGS. The only suggestion of a possible impact was that conditions for sporophyte production (other than irradiance and temperature) appeared to be deteriorating over time. However, it is difficult to link this observation with the operation of SONGS.

There were times when ambient levels of irradiance are near minimum levels necessary for sporophyte production, and that reductions in irradiance caused by the operation of SONGS probably resulted in a concomitant reduction in sporophyte recruitment (Schroeter <u>et al</u>., 1987). However, we found little evidence for such an effect in our analyses of outplanted gametophytes. This was either because ambient irradiance levels were high enough that reductions due to SONGS had little effect on sporophyte production, or because factors other than irradiance (e.g., nutrients, grazers) limited sporophyte production.

The lack of an effect of SONGS on sporophyte production may have been overstated somewhat by our analyses. Irradiance levels during after periods were higher than normal (Dixon <u>et al.</u>, 1987b) and irradiance limitation was less likely than would be expected on average. Also, our experiments were carried out throughout the year, but natural recruitment tends to take place only during upwelling events in the spring (Dean <u>et al.</u>, 1987, Section 5), when ambient light levels are generally lower than the yearly average.

Observations of adverse impact on experimental populations are in accordance with data from natural populations. Both the experimental data and observations made during natural recruitment (Schroeter <u>et al</u>., 1987) indicate that the operation of SONGS reduced levels of recruitment in SOK, possibly by inhibiting sporophyte

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production, and almost certainly by causing an increase in the mortality rate of microscopic sporophytes. Furthermore, both data sets indicate that the adverse effects were probably related to either decreases in irradiance or increases in seston flux associated with the plume.

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Table 1. Equations from regression analyses of sporophyte production growth and survival vs physicochemical factors. The analyses used all pre-operational data, plus data from the control site (SMK45) in the operational period. Table 1.

(1) SPOROPHYTE PRODUCTION FROM CAMETOPHYTES

0 m (Seafloor)

SP = 36.74 - 18.46 × In(TEMP) + 2.7 (IDUM)

2 m above seafloor)

SP = 39.40 - 17.79 × In(TEMP) <u>where</u>

SP = In |(final density) + (1 × 10**-6)| initial density/2

TEMP = mean daily temperature IDUM = 1 if irradiance > 0.4 E/m**2/d and IDUM = 0 if irradiance < 0.4 E/m**2/d MICROSCOPIC SPOROPHYTE GROWTH

(2)

growth rate = 0.0965 + [0.02845 × In(IRR)] - [0.02991 × In(SED)] where

growth rate = <u>ln(mean final length) - ln(mean initial length</u>) duration

IRR = Mean daily irradiance SED = Mean daily seston flux

rate

MICROSCOPIC SPOROPHYTE MORTALITY

(3)

mortality rate = 0.058 + |0.031 × |n(SED)| <u>where</u>

mortality rate = <u>|ln(mean initial density)| - |in(mean final density + 0.01</u> duration

SED = Mean daily seston flux

(7)

mean growth rate = 0.184 + (0.012 × In(IRR)) - (0.064 × In(TEMP) <u>where</u> 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 20000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000 + 2000

JUVENILE GROWTH

growth rate = <u>in(final length) - in(initial length</u>) duration

IRR = Mean daily irradiance TEMP = Mean daily temperature

Table 2. Results of BACIP tests of differences in mean percent sporophyte production in the operational and pre-operational periods at 0 m (bottom).

	Operating Period							
	Pre- Oper	ation	Oper	ration		Probability Levels for BACI Test		
<u>Station Pair</u>	<u>N</u>	Mean	<u>N</u>	Mean	Transformation	PR>T	<u>PR>Z</u>	Power
SOKU45	10	0.043	13	0.002	Nega	 0.06	0.06	8.9
SMK45	10	0.199	13	0.009	None			
SOKD45	 10	0.076	13	0.010		 0.11	0.11	11.7
SMK45	10	0.199	13	0.009	None 			
SOKD35	10	0.119	15	0.029	Nees		0.24*	62.8
SMK45	10	0.186	15	0.008	None:	0.27*		
	 						.,	
SOKU35		_	7	0.033] }			
SMK45	0	-	² 7	0.006				
	 		·					

* Delta values in the operational period were serially correlated. Probabilities for T and Z statistics were not corrected for serial correlation and are underestimated.

Table 3. Results of BACIP tests of differences in mean percent sporophyte production in the operational and pre-operational periods at 2 m above bottom.

	Operating Period			riod	•	D		
	Pre- Oper	ation	Ope	ration	•	Probability Levels for BACI Test		ty r <u>t</u>
<u>Station Pair</u>	<u>N</u>	Mean	<u>N</u>	Mean	Transformation	<u>PR>T</u>	<u>PR>Z</u>	Power
SOKU45 SMK45	11	0.177 0.226	13 13	0.006 0.047	 None 	0.44	0.19	54.0
SOKD45 SMK45	11	0.223	16 16	0.025 0.038	 None 	0.47	0.14	30.0
SOKD35 SMK45	11	0.305	16 16	0.051 0.038			*	
SOKU35 SMK35	0	-	8 8	0.079		*		

* Neither log-transformed nor untransformed data were additive.



Table 4. Student's t-test of differences in mean sporophyte production in preoperational vs operational periods at each station and depth. In all cases, Fstatistics indicated unequal variances in the two periods and t-statistics were adjusted accordingly.

Operating Status	Mean	<u>N</u>	t	$\underline{PR > t}$				
SOKU45 - 0 m (seafloor)								
Pre-operational	0.018	24	1 01	0 00				
Operational	0.001	18	-1.01	0.32				
<u>SOKD45 - 0 m (seafloor)</u>								
Pre-operational	0.037	0.037 27		0.10				
Operational	0.007	18	-1.33	0.19				
SOKD35	- 0 m (s	eafl	oor)					
Pre-operational	0.169	11	1 70					
Operational	0.024	18	-1./2	0.12				
<u>SMK45</u> -	0 m (se	<u>aflo</u>	or)					
Pre-operational	0.166	12						
Operational	0.007	17	-2.52	0.03				
<u>SOKU45 - 2</u>	<u>m (abov</u>	e se	afloor)					
Pre-operational	0.103	26	0.00	0.01				
Operational	0.004	20	-2.69	0.01				
SOKD45 - 2 m (above seafloor)								
Pre-operational	0.207	27	2 44	-0.01				
Operational	0.020	20	-3.44	<0.01				
SOKD35 - 2 m (above seafloor)								
Pre-operational	0.305	11	1 00	0 10				
Operational	0.041	20	-1.80	0.10				
<u>SMK45 - 2</u>	m (above	sea	floor)					
Pre-operational	0.207	12	0.07	0.04				
Operational	0.032	19	-2.3/	0.04				


Table 5. Results of BACIP tests of differences in mean growth rate of microscopic sporophytes in the operational and pre-operational periods at 0 m (seafloor) only.

	C)peratir	· _						
	Pre- Operation			ration		Probability Levels for BACI Test			
<u>Station Pair</u>	<u>N</u>	Mean	<u>N</u>	Mean	Transformation	<u>PR>T</u>	<u>PR>Z</u>	Power	
SOKU45	 7	0.020	8	0.058				0	
SMK45	7	0.071	8	0.112		U.40 	0.34	У	
SOKD45	6	0.048	8	0.110	 	 		17	
SMK45	6	0.082	8	0.112	None 	0.20	0.23		
SOKD35	7	0.073	8	0.123	 			28	
SMK45	7	0,071	8	0.112	None 	0.40	0.39		
		*	<u> </u>						
SOKU35	0	-	2	0.100					
SMK45	0	-	2	0.109			<u>.</u>		
			·			l	<u> </u>		



Table 6. Results of BACIP tests of differences in mean mortality rate of microscopic sporophytes in the operational and pre-operational periods at 0 m (seafloor) only.

)peratin	ig Pe	riod					
	Pre- Oper	Pre- Dperation Operation			Probability Levels for BACI Test				
<u>Station Pair</u>	<u>N_</u>	Mean	<u>N</u>	Mean	Transformation	<u>PR>T</u>	<u>PR>Z</u>	Power	
SOKU45	7	0.166	11	0.134			<0.01	60	
SMK45	7	0.041	11	0.156	X + U.UI 	~U.UI 		62	
						I			
SOKD45	6	0.074	11	0.149	 *		*		
SMK45	6	0.035	11	0.156		 			
						İ			
SOKD35	7	0.087	11	0.095			0.00	25	
SMK45	7	0.041	11	0.156	x + 0.01 	0.02	0.03	35	
SOKU35	0	-	3	0.083					
SMK45	0	-	3	0.174	 	 			
		·		·		 			

* Neither log-transformed nor untransformed data met the assumptions. There was significant asymmetry in variances in the Before data.

Table 7. Results of BACIP tests of differences in mean growth rate of juvenile sporophytes in the operational and pre-operational periods.

	Operating Period								
	Pre- Operation		Operation			Probability Levels for BACI Test			
Station Pair	N	Mean	<u>N</u>	Mean	Transformation	<u>PR>T</u>	<u>PR>Z</u>	Power	
SOKU45	4	0.0127	8	0.0138		0.00*	0.00*	ماد ماد	
SMK45	4	0.0176	8	0.0146	None	0.08*	0.08*	**	
SOKD45	4	0.0169	8	0.0146					
SMK45	4	0.0176	8	0.0146	***		***		

* Delta values in the operational period were serially correlated. Probabilities for 1 and 2 statistics were not corrected for serial correlation and are, therefore, underestimated.

** Power was less than tabled values in Cohen, 1977.

*** Neither log-transformed nor untransformed data met the assumptions. There was significant asymmetry in variances in the "Before" data.

Table 8. Results of BACIP tests of differences in mean mortality rate of juvenile sporophytes in the operational and pre-operational periods.

		Operatin	g Pe						
	Pre- Operation Operation			eration		Pro Lev BA	Probability Levels for BACI Test		
Station Pair	<u>N</u>	Mean	<u>N</u>	Mean	Transformation	<u>PR>T</u>	<u>PR>Z</u>	Power	
SOKU45	4	0.0028	8	0.0068		0.93	0.87	9.4	
SMK45	4	0.0034	8	0.0072	None 				
			<u> </u>						
SOKD45	4	0.0018	8	0.0065			0.45	8.6	
SMK45	4	0.0034	8	0.0072	None	0.65			
	 				l				

Table 9. Correlations between the proportion of the time the plume from SONGS was over stations in SOK vs deltas in various biological variables. Separate regressions were done for preoperational and operational periods. Prepoperational analyses used a hypothetical plume from SONGS.

	P	Preoperation			Operational			
Variable Sporophyte production (O m)	<u>N</u> 21	r -0.02	<u>Р</u> 0.94	<u>1</u>	N 18	<u>r</u> 0.02	P 0.91	
Sporophyte production (2 m)	22	-0.32	0.15	Ę	53	-0.18	0.18	
Microscopic growth	13	- 0.27	0.37	2	26	-0.47	0.02	
Microscopic growth	13	0.34	0.25		36	0.48	<0.01	
Juvenile growth	8	-0.08	0.85]	16	-0.47	0.06	
Juvenile mortality	8	0.51	0.20		16	0.36	0.17	

Figure 1. Maps of the San Onofre (SOK) and San Mateo (SMK) Kelp forests showing the location of sampling stations used for studies of production, growth, and survival of sporophytes in the operational sampling phase. Figure 1



Figure 2. Operating history for the San Onofre Nuclear Generating Station Units 2 and 3.

Figure 2



Figures 3a through 3d. Mean sporophyte production at pairs of impact and control stations (TOP), and deltas in sporophyte production (BOTTOM), on artificial substrates placed on the seafloor.

Figure 3a









Figure 3c



Figure 3d



Figures 4a through 4d. Mean sporophyte production at pairs of impact and control stations (TOP), and deltas in sporophyte production (BOTTOM), on artificial substrates placed 2 m above the seafloor.

<u>,</u>5-

Figure 4a



Figure 4b





Figure 4c



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Figure 4d



Figures 5a and 5b.

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nd 5b. Deltas (control-impact) of sporophyte production during each experiment vs the percent of time that the impact station was in the plume during the experiment (TOP), or the percent change in irradiance at the impact site that was attributable to the plume (BOTTOM). Separate plots are given for substrates on the seafloor (5a) and those 2 m above the seafloor (5b). (See Appendix B for a listing of the data).









Figure 6. Observed values of sporophyte production vs predicted values. Predicted values are based on previous regressions of the log sporophyte production vs physicochemical factors. The regression coefficient and probability level for the observed vs predicted values are given. Also given is the probability that the slope of the regression line not equal 1 (the line shown) based on an F test. Values from SMK45 were not used in the statistical analyses but are plotted for comparison. Separate plots are given for substrates placed on the seafloor (TOP) and 2 m above the seafloor (BOTTOM). Negative values for log sporophyte production result from taking the logs of values less than 1.





Figure 7. Differences in predicted and observed values of sporophyte production over time for substrates placed on the seafloor.


Figure 8. Differences in predicted and observed values of sporophyte production over time for substrates placed 2m above the seafloor.



Figures 9a to 9d. Mean growth rate of microscopic sporophytes at pairs of impact and control stations (TOP), and deltas in growth rate (BOTTOM), on artificial substrates placed on the seafloor.

Figure 9a



Figure 9b





Figure 9c



-

Figure 9d



Figure 10. Deltas (control-impact) of growth rate of microscopic sporophytes during each experiment vs the percent of time that the impact station was in the plume during the experiment (TOP), or the percent change in irradiance at the impact site that was attributable to the plume (BOTTOM). All experiments were placed on the seafloor (0 m).



Figure 11. Observed values of growth rate of microscopic sporophytes vs predicted values. Predicted values are based on previous regressions of sporophyte growth vs physicochemical factors. The regression coefficient and probability level for the regression are given. Also given is the probability that the slope of the regression line not equal 1 (the line shown) based on an F test. Values from SMK45 were not used in the statistical analyses but are plotted for comparison.

Figure 11



Figures 12a to 12d. Mean mortality rates of microscopic sporophytes at pairs of impact and control stations (TOP), and deltas in mortality rates (BOTTOM), on artificial substrates placed on the seafloor.

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Figure 12a



Figure 12b



Figure 12c





Figure 13. Deltas (control-impact) of mortality rate of microscopic sporophytes during each experiment vs the percent of time that the impact station was in the plume during the experiment (TOP) or the percent change in irradiance at the impact site that was attributable to the plume (BOTTOM), for substrates on the seafloor (0 m).





Figure 14. Observed values of mortality rate of microscopic sporophytes vs predicted values. Predicted values are based on previous regressions of sporophyte mortality vs physicochemical factors. The regression coefficient and probability level are given. Also given is the probability that the slope of the regression line not equal 1 (the line shown) based on an F test. Values from SMK45 were not used in the statistical analyses but are plotted for comparison.

Figure 14



Figure 15. Differences in predicted and observed values of mortality rate of microscopic sporophytes over time for substrates placed on the seafloor.



Figures 16a and 16b. Mean growth rate of juvenile sporophytes at at pairs of impact and control stations (TOP), and deltas in growth rate (BOTTOM), on artificial substrates placed approximately 1 m above the seafloor.

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Figure 16a



Figure 16b



Figure 17. Deltas (Control-Impact) of growth rate of juvenile sporophytes during each experiment vs percent of time that the impact station was in the plume during the experiment (TOP), or the percent change in irradiance at the impact site that was attributable to the plume (BOTTOM). Figure 17



Figure 18. Observed values of growth rate of juvenile sporophytes vs predicted values. Predicted values are based on previous regressions of growth rate vs physicochemical factors. The regression coefficient and probability level for the observed vs predicted values are given. Also given is the probability that the slope of the regression line not equal 1 (the line shown), based on an F test. Values from SMK45 were not used in the statistical analyses but are plotted for comparison.

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Figure 19. Differences in predicted and observed values of growth rate of juvenile sporophytes over time.



Figure 20. Mortality rate of juvenile sporophytes at pairs of impact and control stations (TOP), and deltas in growth rate (BOTTOM), on artificial substrates placed on the seafloor.

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Figure 20a





Figure 20b



Figure 21. Deltas (Control-Impact) of mortality rate of juvenile sporophytes during each experiment vs the percent of time that the impact station was in the plume during the experiment (TOP), or the percent change in irradiance at the impact site that was attributable to the plume (BOTTOM).







		d	RODUC	TION OF SP	OROPHYTES	FROM CAMETOPH	IYTES		
				0	M (Seafloc	rr)			
	Stations	Transformation	₹ Z	dd i t i v i ty	Symmetry	Serial correlation	Trends	Variance larger half of observ.	Variance smaller half of observ.
	SMK45 - SOKD3	5 None 10g (x + 0.00001)	00	0.287 0.867	0.604 0.854	sig Sig	0.073	0.04	0.12 0.97
	SMK45 - SOKD4	5 None 100001)	10	0.537 0.341	0.854 0.701	NS Sig	0.769 0.079	0.17 4.11	0.01 4.02
	SMK45 - SOKU4	5 None 10g (x + 0.00001)	00	0.125 0.479	0.854	Sig	0.982 0.181	0.12	0.01 3.16
				2 W	Above Sea	floor			
	Stations	Transformation	∢ z	dditivity	Symmetry	Serial correlation	Trends	Variance larger half of observ.	Variance smaller half of observ.
	SMK45 - SOKD3	5 None log(x + 0.00001)		0.003 0.033	0.157 0.883	SN SN SN SN	0.373 0.377	0.19	0.00 1.86
	SMK45 - SOKD4	5 None None 109(× + 0.00001)		0.293 0.828	0.464	NS NS	0.629 0.547	0.37 1.22	0.02
• • •	SMK45 - SOKU4	5 None log(x + 0.00001)		0.981 0.235	0.739	NS NS	0.555 0.861	0.05	0.00
			GRO	WTH RATE OI	F MICROSCO	PIC SPOROPHYT	ES		
	Stations	[ransformation	Z	dditivity	Symmetry	Serial correlation	Trends	Variance larger half of observ.	Variance smaller half of observ.
	SMK45 - SOKD3	5 None	- L	0.786	0.275	NS	0.032	0.001	0.006
	SMK45 - SOKD4	5 None	6	0.815	0.500	NS	0.125	0.001	0.002
	SMK45 - SOKU4	5 None	8	0.784	0.918	SN	0.176	0.002	0.008



		Ξ	ORTALITY RAT	TE OF MICRC	SCOPIC SPOROF	•HYTES		
Stations	Transformation	z	Additivity	Symmetry	Serial correlation	Trends	Variance larger half of observ.	Variance smaller half of observ.
SMK45 - SOKD35	None log(x + 0.01)	~~	0.132 0.918	0.014	N N N N	0.327 0.123	0.005 0.106	0.001 0.072
SMK45 - SOKD45	None None (X + 0.01)	99	0.041 0.470	0.013 0.013	NS Sig.	0.040	0.004	0.001 0.074
SMK45 - SOKU45	None log(x + 0.01)	7	0.002 0.391	0.036 0.918	NS	0.956 0.326	0.002 0.002	0.002 0.170
		Ŭ	SROWTH RATE	OF JUVENIL	E SPOROPHYTES			
Stations	Transformation	z	Additivity	Symmetry	Serial correlation	Trends	Variance larger half of observ.	Variance smaller half of observ.
SMK45 - SOKD45	None Log x	##	0.375 0.143	0.002 0.829	SN	0.171 0.036	0.000	0.000
SMK445 - SOKU445	None Log x	44	0.083 0.016	0.171 0.829	Sig. NS	$0.010 \\ 0.239$	0.000	0.000
			MORTALITY R	ATE OF JUV	ENILE SPOROPH	YTES		
Stations	Transformation	z	Additivity	Symmetry	Serial correlation	Trends	Variance larger half of observ.	Variance smaller half of observ.
SMK45 - SOKD45	None	t	0.124	0.829	NS	0.134	0.000	0.000
SMK45 - SOKU45	None	4	0.888	0.171	NS	0.925	0.000	0,000

Appendix A, continued

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Appendix B. Deltas (SOK - Control at SMK) for sporophyte production, growth, and survival with estimates of plume attributes. A dot indicates that no estimates were available because of an insufficient number of samples.

		SPOROPHY	YTE PRODU	ICTION	
Outplant				Pct. Change	Pct. time
date	Height	<u>Station</u>	Delta	irradiance	in plume
	_	·			
24MAY84	0	SOKD35	0.000	•	9
15MAR85	0	SOKD35	0.059	-7	32
23MAY85	0	SOKD35	0.142	-5	39
20JUN85	0	SOKD35	0.043	-1	11
18JUL85	0	SOKD35	0.000	-1	11
030CT85	0	SOKD35	0.000	3	6
21NOV85	0	SOKD35	0.002	-2	21
12DEC85	. 0	SOKD35	0.042	-5	37
06MAR86	0	SOKD35	-0.001	-4	34
29MAR86	0	SOKD35	0.031	-5	23
17APR86	0	SOKD35	0.002	-11	30
08MAY86	0	SOKD35	0.006	-15	39
30MAY86	0	SOKD35	0.001	-15	45
19JUN86	0	SOKD35	-0.004	-14	50
10JUL86	0	SOKD35	-0.002	-8	42
24MAY84	0	SOKD45	0.000	•	8
15MAR85	0	SOKD45	0.020	-4	26
23MAY85	0	SOKD45	0.006	-10	36
20JUN85	0	SOKD45	0.014	-1	9
18JUL85	0	SOKD45	0.000	-2	11
12DEC85	0	SOKD45	-0.002	-6	26
06MAR86	0	SOKD45	-0.002	-5	28
29MAR86	0	SOKD45	-0.017	-4	19
17APR86	0	SOKD45	-0.001	-4	26
08MAY86	0	SOKD45	-0.004	-8	33
30MAY86	0	SOKD45	0.000	-12	40
19JUN86	0	SOKD45	-0.004	-13	46
10JUL86	0	SOKD45	-0.002	-7	36
12DEC85	0	SOKU35	0.186	-11	44
06MAR86	0	SOKU35	-0.002	-5	42
29MAR86	0	SOKU35	0.004	-5	37
17APR86	0	SOKU35	0.007	-10	47
08MAY86	0	SOKU35	-0.004	-12	53
30MAY86	0	SOKU35	0.000	-16	51
19JUN86	. 0	SOKU35	-0.003	-20	55
24MAY84	0	SOKU45	0.000	•	34
15JUN84	0	SOKU45	0.000	22	44
15MAR85	0	SOKU45	-0.063	3	51
23MAY85	0	SOKU45	0 001	-4	52

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20JUN85	0	SOKU45	-0.003	-9	29
18JUL85	0	SOKU45	0.000	-8	33
12DEC85	0	SOKU45	-0.002	-10	55
06MAR86	0	SOKU45	-0.002	-5	30
29MAR86	0	SOKU45	-0.013	-1	13
17APR86	0	SOKU45	-0.003	0	11
08MAY86	0	SOKU45	-0.004	-6	29
19JUN86	0	SOKU45	-0.004	-11	53
10JUL86	0	SOKU45	-0.002	-8	46
24MAY84	2	SOKD35	0.000	•	9
05JUL84	2	SOKD35	0.000	•	33
15MAR85	2	SOKD35	0.090	-6	32
23MAY85	2	SOKD35	-0.014	-5	39
20JUN85	2	SOKD35	0.112	-1	11
18JUL85	2	SOKD35	0.008	-2	11
13SEP85	2	SOKD35	0.001	-3	6
030CT85	2	SOKD35	0.000	-1	6
21NOV85	2	SOKD35	0.002	2	21
12DEC85	2	SOKD35	-0.030	-8	37
06MAR86	2	SOKD35	-0.026	-6	34
29MAR86	2	SOKD35	0.036	-4	23
08MAY86	2	SOKD35	0.033	-11	39
30MAY86	2	SOKD35	0.002	-11	45
19JUN86	2	SOKD35		-19	50
10JUL86	2	SOKD35	-0.003	-9	42
24MAY84	2				2
15MAR85	2		-0 211	-6	26
23MAY85	2		0.211	-6	20
20.1UN85	2		0.002	-1	
18.111.85	2		0.123	-1	11
135EP85	2		0.007	-3	5
0300785	2		0.000	-1	5
21NOV85	2		0.000	-1	15
12DEC85	2		-0 129	-8	26
D6MAR86	2		-0.029	-11	28
29MAR86	2		0.025	-2	10
17APR86	2		0.010	-5	26
08MAY86	2		-0 001	-7	. 22
30MAY86	2		0.001	-3	10
19.1UN86	2		-0 028	-17	40
10.101 86	2		-0 007	-7	36
12DFC85	2	SOKU35	0.007	-5	10
06MAR86	2	SOKU35	0.151	-11	44
29MAR86	2	SOKUSS	0.015	-6	42
17APR86	2	SUKIISE	0.140	-7	37 17
N8MAY86	2	SUKI132	0.005	-15	F2
30MAY86	2	20K032	0.112	-15	55 E1
19,111026	2	20K022	-0.000	-10	51
10.111.86	2	SUKI13E	-0.020	-23 -15	
24MAY84	2	SUKUSS	0.000	-15	49
05.1111.84	2	SUKINE	0.000	• • • •	54
JUULUT	۵.	201043	0.002	۷ ک	02

15MAR85	2	SOKU45	-0.309	-13	51
23MAY85	2	SOKU45	-0.058	-13	52
20JUN85	2	SOKU45	-0.003	-10	29
18JUL85	2	SOKU45	0.000	-7	33
13SEP85	2	SOKU45	0.007	-14	31
12DEC85	2	SOKU45	-0.139	-11	55
06MAR86	2	SOKU45	-0.020	-12	30
29MAR86	2	SOKU45	0.020	-1	13
08MAY86	2	SOKU45	0.000	-6	30
19JUN86	2	SOKU45	- 0.025	-16	53
10JUL86	2	SOKU45	-0.008	-7	46

MICROSCOPIC SPOROPHYTE GROWTH

Outplant			Pct. Change	Pct. time
date	<u>Station</u>	Delta	irradiance	in plume
27JUL84	SOKD35	-0.040		38
16AUG84	SOKD35	0.005		12
06SEP84	SOKD35	-0.035	•	10
06JUN85	SOKD35	-0.033	0	57
04JUL85	SOKD35	0.174	0	2
01AUG85	SOKD35	0.022	•	14
30MAY86	SOKD35	0.034	-19	42
03JUL86	SOKD35	-0.036	-19	65
27JUL84	SOKD45	-0.034	•	33
16AUG84	SOKD45	-0.100		11
06SEP84	SOKD45	0.003	0	8
06JUN85	SOKD45	-0.067	•	53
04JUL85	SOKD45	0.159		1
01AUG85	SOKD45	0.020		14
30MAY86	SOKD45	0.033	-14	35
03JUL86	SOKD45	-0.034	-19	61
30MAY86	SOKU35	0.010	-13	49
03JUL86	SOKU35	-0.028	-30	70
27JUL84	SOKU45	-0.024	•	81
16AUG84	SOKU45	-0.138	•	50
06SEP84	SOKU45	-0.015	0	44
06JUN85	SOKU45	-0.096		73
04JUL85	SOKU45	-0.003	•	18
01AUG85	SOKU45	-0.153	•	37
30MAY86	SOKU45	0.003	9	46
03JUL86	SOKU45	-0.007	-18	65

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2⁸ 2

Appendix B, continued

	MICROS	SCOPIC S	POROPHYTE SURV	IVAL
Outplant			Pct. Change	Pct. time
date	<u>Station</u>	Delta	<u>irradiance</u>	<u>in plume</u>
07 100 0 4	0000			
2/JUL84	SOKD35	0.091	•	38
16AUG84	SOKD35	-0.032	•	12
06SEP84	SOKD35	0.102	•	10
06JUN85	SOKD35	0.032	0	57
04JUL85	SOKD35	-0.196	0	2
01AUG85	SOKD35	0.019	•	14
26SEP85	SOKD35	-0.339	2	4
170CT85	SOKD35	-0.163	0	6
14NOV85	SOKD35	- 0.255	0	8
30MAY86	SOKD35	-0.023	-19	42
03JUL86	SOKD35	0.095	-19	65
27JUL84	SOKD45	0.058	•	33
16AUG84	SOKD45	0.156	•	11
06SEP84	SOKD45	0.055	0	8
06JUN85	SOKD45	0.004	•	53
04JUL85	SOKD45	-0.016	•	1
01AUG85	SOKD45	0.018	•	14
26SEP85	SOKD45	-0.313	•	4
170CT85	SOKD45	-0.056	•	5
14NOV85	SOKD45	-0.010	•	8
30MAY86	SOKD45	-0.023	-14	35
03JUL86	SOKD45	0.060	-19	61
14NOV85	SOKU35	-0.327	0	0
30MAY86	SOKU35	-0.023	-13	49
03JUL86	SOKU35	0.076	-30	70
27JUL84	SOKU45	0.008	•	81
16AUG84	SOKU45	0.048	•	50
06SEP84	SOKU45	0.026	0	44
06JUN85	SOKU45	-0.010		73
04JUL85	SOKU45	-0.099	• 1	18
01AUG85	SOKU45	0.038	•	37
26SEP85	SOKU45	-0.170	•	32
170CT85	SOKU45	-0.098	•	27
14NOV85	SOKU45	0.003		16
30MAY86	SOKU45	-0.023	-9	46
03JUL86	SOKU45	0.043	-18	65

Appendix B, continued

	JUVENIL	E SPOROP	HYTE GROWTH	
Transplant	;		Pct. Change	Pct. time
date	Station	Delta	irradiance	in plume
			·····	
24JUL84	SOKD45	-0.001	-13	22
13SEP84	SOKD45	0.001	2	15
09JUL85	SOKD45	0.001	-1	11
05SEP85	SOKD45	0.003	0	11
220CT85	SOKD45	0.003		7
18DEC85	SOKD45	0.006	-4	22
24JUN86	SOKD45	-0.013		40
07AUG86	SOKD45	0.001	-9	34
24JUL84	SOKU45	-0.003	-31	67
13SFP84	SOKU45	0 001	-4	50
09.001 85	SOKU45	0.000	-7	35
05SEP85	SOKU45	-0 002	-10	39
220CT85	SOKU45	0.002	10	22
18DFC85		-0 001	-16	49
24JUN86	SOKU45	-0 007	10	49
07AUG86	SOKU45	0.007	-7	41
		0.002	,	T ⊥
	JUVENILE	SPOROPHY	TE SURVIVAL	
Transplant			Pct. Change	Pct. time
date	Station	Delta	irradiance	in plume
24JUL84	SOKD45	0.000	-13	22
13SEP84	SOKD45	0.000	2	15
09JUL85	SOKD45	-0.003	-1	11
05SEP85	SOKD45	0.004	0	11
220CT85	SOKD45	-0.006	•	7
18DEC85	SOKD45	0.001	-4	22
24JUN86	SOKD45	-0.004	•	40
07AUG86	SOKD45	0.003	-9	34
24JUL84	SOKU45	0.005	-31	67
13SEP84	SOKU45	-0.004	-4	50
09JUL85	SOKU45	0.002	-7	35
05SEP85	SOKU45	0.000	-10	39
220CT85	SOKU45	-0.009	•	22
18DEC85	CONTRACT	0 000	10	
	SUKU45	0.006	-16	49
24JUN86	SUKU45 SOKU45	0.006 -0.001	-16	49

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The following memo from EcoSystems Management indicates that irradiance levels at San Mateo Kelp are influenced by current direction, and that irradiance levels are lower when currents are upcoast.



ECOSYSTEMS MANAGEMENT,

531 Encinitas Blvd., Suite 119 Encinitas, Calif. 92024 (619) 436-2594

MEMORANDUM

TO: Tom Dean

FROM: Hany Elwany and Jan Callahan

SUBJECT: Current Reversal at SMK

DATE: December 23, 1987

Inspection of simultaneous time plots of hourly irradiance and longshore currents at SMK45 show clearly that measured irradiance values depend on current direction. There are sudden changes in irradiance values associated with current direction reversals. Light levels at SMK45 are higher when currents are downcoast.

To quantify the above reduction in the light level at SMK45, the following model has adapted:

 $I(t) = B_0 + B_1 C(t) + e(t)$

where

I(t) = measured irradiance at SMK45,e(t) = A₁ e(t-1) + A₂ e(t-2) + A₃ e(t-3) + (t).

In this expression, B's and A's are constants, and C(t) is an indicator variable that takes value 1 during periods of upcoast current and 0 during periods of downcoast current. The coefficient B_0 , determined by the SAS procedure Proc Autoreg, estimates the mean irradiance level when the current is downcoast. The coefficient B_1 estimates the change in this mean due to a current reversal (the current effect), and the maximum likelihood test for the significance of its departure from zero (p-level). The terms in the model with coefficients A_1 , A_2 , and A_3 are auto-regressive errors, used to model serial correlation.

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In applying the above model, several assumptions have to be made:

 no serial correlation in residuals from the model between observations;

2) irradiance measurements are stationary over time.

Clearly, hourly irradiance values do not satisfy the above assumptions. To overcome these difficulties, we used daily total irradiance instead of hourly values.

All results were checked for serial correlation of the residuals by the Durbin-Watson test. We also looked at values of A_1 , A_2 and A_3 for indications of non-stationarity. All models reported were first order auto-regressive.

Table 1 shows the following for Before and After periods: the mean irradiance when the current is downcoast (B_0) , the maximum liklihood estimate of the current effect on irradiance $(B_1) +$ one standard error of the current effect, the error degrees of freedom (DFE), and the p-level for the test that the current effect is zero.

Table 2 contains the same results based on the natural logarithm of total daily irradiance. Note that no values are given in Table 2 for the Before period at 2 m height. This is because in this case we were unable to find a model which accounted for all the serial correlation.

We assigned C(t) = 1 for day t if, during the period from 8:00 a.m. to 4:00 p.m., at least 5 hours have positive (upcoast) averaged hourly current. Similarly C(t) = 0 for day t if, during the period from 8:00 a.m. to 4:00 p.m., at least 5 hours have negative (downcoast) averaged hourly current. Otherwise, C(t) is missing. This means only observations for days with currents predominantly in one direction are used.

The Before period is defined here as all days before January 1, 1983; all days after December 31, 1982 are defined as the After period.

The results in Tables 1 and 2 indicate that irradiance at SMK are affected by current direction.

TABLE 1

RESULTS FOR IRRADIANCE

Period	Height (m)	Mean Irradiance (E/m ² - Day)	Current Effect <u>+</u> 1 standard error (E/m ² - Day)	DFE	P-level
BEFORE	0	1.3	43 <u>+</u> .13	263	.001
BEFORE	2	3.2	-1.20 <u>+</u> .36	111	.001
AFTER	0	1.63	35 <u>+</u> .09	620	.0002
AFTER	2	2.67	91 <u>+</u> .36	547	.0001

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TABLE 2

RESULTS FOR LOGARITHM IRRADIANCE

Period	Height (m) d	Mean of Ln (irradiance) owncoast current	Ln (current effect) <u>+</u> l standard error	DFE	P-level
BEFORE	0	36	48 <u>+</u> .16	251	.004
BEFORE	2	1.00	·	109	
AFTER	0	.14	32 <u>+</u> .07	597	.0001
AFTER	2	.62	31 <u>+</u> .07	542	.0001

APPENDIX D

The following flow diagrams indicate databases and SAS jobs used to produce tables and figures in this report. Physical/chemical databases were not part of the DICS (disk inventory control system) at the time of our analyses. As a result, some jobs that utilize data from EcoSystems Management Assoc. may have to be altered in order to access the proper disk that is currently used to store these databases. Also, these physical chemical databases may have been edited after our analyses were completed. These changes to the databases (if any) were minor modifications and should alter neither the outcome of our statistical tests nor the conclusions drawn from the results.
Table 1

No analysis

Table 2

DBGI.EXPxx DBGD.EXPxx DBILOG.YRxx DBIINT.YRxx DBTINT.YRxx DBTRYAN.YRxx DBPROFILE.YRxx DBWATER.YRxx DBSED.YRxx DB

> m104game exec m104game data m104game sasm m104date data

DBGOMRG.YRxx

tposegom sas

BACIDATA.GOMOD

bacitest exec

Table 2

Table 3

DBGI.EXPxx DBGD.EXPxx DBILOG.YRxx DBIINT.YRxx DBTINT.YRxx DBTRYAN.YRxx DBPROFILE.YRxx DBWATER.YRxx DBSED.YRxx DB

> m104game exec m104game data m104game sasm m104date data

DBGOMRG.YRxx

tposegom sas

BACIDATA.GOMOD

bacitest exec

Table 3

Table 4

DBGI.EXPxx DBGD.EXPxx DBILOG.YRxx DBIINT.YRxx DBTINT.YRxx DBTRYAN.YRxx DBPROFILE.YRxx DBWATER.YRxx DBSED.YRxx DB

> m104game exec m104game data m104game sasm m104date data

DBGOMRG.YRxx

tposego sas

BACIDATA.GO goprepst sas Table 4

Table 5

DBSL.EXPxx DBILOG.YRxx DBIINT.YRxx DBTINT.YRxx DBTRYAN.YRxx DBPROFILE.YRxx DBWATER.YRxx DBSED.YRxx DB

> m129spor exec m129spor data m129spor sasm m129date data

DBSOMRG.YRxx

tposeso sas

BACIDATA.SO

bacitest exec

Table 5

Table 6

DBSD.EXPxx DBILOG.YRxx DBIINT.YRxx DBTINT.YRxx DBTRYAN.YRxx DBPROFILE.YRxx DBWATER.YRxx DBSED.YRxx DB

> m129spor exec m129spor data m129spor sasm m129date data

DBSOMRG.YRxx

tposesom sas

BACIDATA.SOM

bacitest exec

Table 6

Table 7

DBJT.EXPxx

DBJTP.EXPxx DBILOG.YRxx DBIINT.YRxx DBTINT.YRxx DBTRYAN.YRxx DBPROFILE.YRxx DBWATER.YRxx DBSED.YRxx DB

> ml26tran exec ml26tran data ml26tran sasm

ml26tran data

DBTOMRG.YRxx

tposeto sas

BACIDATA.TO

bacitest exec

Table 7

Table 8

DBJT.EXPxx

jtdm exec

DBJTP.EXPxx DBILOG.YRxx DBIINT.YRxx DBTINT.YRxx DBTRYAN.YRxx DBPROFILE.YRxx DBWATER.YRxx DBSED.YRxx DB

> ml26tran exec ml26tran data ml26tran sasm ml26tran data

DBTOMRG.YRxx

tposetom sas

BACIDATM.TO

bacitest exec

Table 8

Figure 1 No analysis

Figure 2

DBSONGS.YRxx

↓ sngsplt2 sas Figure 2

Figure 3

DBGI.EXPxx DBGD.EXPxx DBILOG.YRxx DBIINT.YRxx DBTINT.YRxx DBTRYAN.YRxx DBPROFILE.YRxx DBWATER.YRxx DBSED.YRxx DB

> m104game exec m104game data m104game sasm m104date data

DBGOMRG.YRxx

•

tposego sas



Figure 4

↓ tposego sas ↓ BACIDATA.GO

> plmego sas pldelgo sas

Figure 4

Figure 5

BACIDATA.GO

PCTIRRED.GSJDATE1 PCTIRRED.GSJDATE2

baciird2 sas

BACIIRRD.GO

plucorgo sas plcorgo0 sas plcorgo2 sas

Figure 5

notes: See Fig. 4 for derivation of bacidata.go. Pctirred databases were obtained form EcoSystems Management as Summary.data files and renamed.

Figure 6

DBGOMRG.YRxx

plavspg0 sas plavspg2 sas avspg0 sas avspg2 sas

Figure 6

note: See Fig. 4 for derivation of Dbgomrg.yrxx.



Figures 7-8

DBGOMRG.YRxx

plpogo sas

Figures 7-8

note: See Fig. 4 for derivation of Dbgomrg.yrxx.

Figure 9

DBSL.EXPxx DBILOG.YRxx DBIINT.YRxx DBTINT.YRxx DBTRYAN.YRxx DBPROFILE.YRxx DBWATER.YRxx DBSED.YRxx DB

> ml29spor exec ml29spor data ml29spor sasm ml29date data

DBSOMRG.YRxx

tposeso sas

BACIDATA.SO

plmeso sas pldelso sas

Figure 9

Figure 10

BACIDATA.SO

PCTIRRED.GSJDATE1 PCTIRRED.GSJDATE2

baciird3 sas

BACIIRRD.GO

plucorso sas plcorsog sas

Figure 10

notes: See Fig. 9 for derivation of bacidata.so. Pctirred databases were obtained form EcoSystems Management as Summary.data files and renamed.

Figure 11

DBSOMRG.YRxx

plavspsg sas avspsg sas



Figure 11

note: See Fig. 9 for derivation of Dbsomrg.yrxx.

Figure 12

DBSD.EXPxx DBILOG.YRxx DBIINT.YRxx DBTINT.YRxx DBTRYAN.YRxx DBPROFILE.YRxx DBWATER.YRxx DBSED.YRxx DB

> ml29spor exec ml29spor data ml29spor sasm ml29date data

DBSOMRG.YRxx

tposesom sas

BACIDATA.SOM

plmesom sas pldelsom sas

Figure 12

Figure 13

BACIDATA.SOM

PCTIRRED.GSJDATE1 PCT

PCTIRRED.GSJDATE2

baciird5 sas

BACIIRRD.SO

plucorsm sas plcorsom sas

Figure 13

notes: See Fig. 12 for derivation of bacidata.som. Pctirred databases were obtained form EcoSystems Management as Summary.data files and were renamed.

Figure 14

DBSOMRG.YRxx

plavspsm sas avspsm sas

Figure 14

note: See Fig. 9 for derivation of Dbsomrg.yrxx.

Figure 15

DBSOMRG.YRxx

plposo sas

Figure 15

note: See Fig. 12 for derivation of Dbsomrg.yrxx.

Figure 16

DBJT.EXPxx

jtdm exec

DBJTP.EXPxx DBILOG.YRxx DBIINT.YRxx DBTINT.YRxx DBTRYAN.YRxx DBPROFILE.YRxx DBWATER.YRxx DBSED.YRxx DB

> ml26tran exec ml26tran data ml26tran sasm ml26tran data

DBTOMRG.YRxx

, tposeto sas

BACIDATA.TO

plme87sm sas / pldelt87 sas

Figure 16

Figure 17

BACIDATA.TO

PCTIRRED.GSJDATE1 PCTIRRED.GSJDATE2

baciirrd sas

BACIIRRD.JTP

plucorjt sas plcorjtg sas

Figure 17

notes: See Fig. 16 for derivation of bacidata.to. Pctirred databases were obtained form EcoSystems Management as Summary.data files and renamed. ,

Figure 18

DBTOMRG.YRxx

plavspjg sas avspjtg sas

Figure 18

note: See Fig. 16 for derivation of Dbtomrg.yrxx.

Figure 19

DBTOMRG.YRxx

plpoto sas

Figure 19

note: See Fig. 16 for derivation of Dbtomrg.yrxx.

Figure 20

DBJT.EXPxx

jtdm exec

DBJTP.EXPxx DBILOG.YRxx DBIINT.YRxx DBTINT.YRxx DBTRYAN.YRxx DBPROFILE.YRxx DBWATER.YRxx DBSED.YRxx DB

> m126tran exec m126tran data m126tran sasm m126tran data

DBTOMRG.YRxx

, tposetom sas

BACIDATM. TO

plme87sm sas pldelt87 sas

Figure 20

Figure 21

BACIDATM.TO

PCTIRRED.GSJDATE1 PCTIRRED.GSJDATE2

baciird6 sas

BACIIRRD.JTPM

plucorjm sas plcorjtm sas

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notes: See Fig. 20 for derivation of bacidatm.to. Pctirred databases were obtained form EcoSystems Management as Summary.data files and renamed. • -