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STUDIES OF BENTHIC ORGANISMS IN KELP FORESTS NEAR THE SAN ONOFRE NUCLEAR GENERATING STATION 1980 - 1986

FINAL REPORT

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ABSTRACT

The BACIP study of large benthic invertebrates began in the fall of 1980. Ten preoperational and eight operational surveys were conducted. There was a general decline in the abundance of gastropod mollusks in the upcoast portion of the San Onofre kelp forest after the San Onofre Nuclear Generating Station's Units 2 and 3 began operating. This pattern is particularly striking for two species of predatory gastropods, *Conus californicus* and *Kelletia kelletii*. The most likely mechanisms underlying the observed changes are changes in habitat caused by loss of kelp and understory algae, and an increase in seston flux and sedimentation. One of the striking changes during the operational period was the accumulation of a cohesive, fine sediment at the upcoast monitoring station at San Onofre. We first saw this sediment in the fall of 1985. Its spatial distribution and the timing of its appearance suggest that it is related to the operation of SONGS Units 2 and 3.

INTRODUCTION

Our mandate from the Marine Review Committee, Inc. (MRC) was to conduct a study to determine whether the operation of Units 2 and 3 of the San Onofre Nuclear Generating Station (SONGS) affects populations of large benthic invertebrates in the San Onofre kelp forest (SOK). Like most kelp forests in southern California, San Onofre contained a diverse group of plants and animals, including hundreds of species of benthic invertebrates. Among the latter were species of sport and commercial importance (e.g., abalones, lobsters, sea urchins, and sea cucumbers), and those of functional importance in structuring the kelp bed community (e.g., sea urchins and sea stars). When considering how to evaluate the possible impact of the discharged cooling waters on such a diverse assemblage, the first problem was to select the group of species to study. We chose species that 1) are characteristic of kelp forests in southern California, 2) have been shown to influence the structure and dynamics of kelp bed communities, and 3) can be counted easily by divers in the field under conditions of relatively poor visibility. Sessile invertebrates such as bryozoans, hydroids, and sponges, which form a turf on many hard substrates, were studied by another contractor (Osman et al 1981).

Equally important was the selection of the sites at which the species were monitored. Ideally, the perturbed area and the control areas to which it would be compared would differ only in the perturbation. This, of course, is not possible in nature. In the vicinity of SONGS there are only three more or less persistent kelp forests. Besides San Onofre, there are the San Mateo kelp forest (SMK)

and the Barn kelp forest (BK) (Figure 1). Despite some differences in bottom composition and relief, we chose these areas as control sites. By using two widely spaced controls, we could estimate natural variability on the scale of several kilometers. We also established two stations in the San Onofre kelp forest. The cooling waters from Units 2 and 3 are discharged from a series of ports upcoast from the kelp bed. We placed two stations under the kelp canopy, one station as close to these diffuser ports as possible, and the second as far away as possible. We hoped to get an idea of the distance over which the cooling water discharge had an effect by comparing these two stations.

The experimental design was the Before-After/Control-Impact-Pairs (BACIP) discussed by Stewart-Oaten (1986) and Stewart-Oaten et al (1986). Samples were taken at approximately equal intervals before and after Units 2 and 3 began operating. For each species, the difference in abundance between the impact and control site was calculated for each survey. If the power plant had no effect, one would expect that the average difference between sites would be the same after Units 2 and 3 began operating as before. The test of this hypothesis is the subject of this report.

NATURAL HISTORIES OF COMMON KELP FOREST INVERTEBRATES

Perhaps the most studied denizens of kelp forests are sea urchins. Three species of sea urchins commonly occur in the kelp beds near the San Onofre Nuclear Generating Station: Red and purple sea urchins, Strongylocentrotus franciscanus and S. purpuratus, respectively, and white sea urchins, Lytechinus anamesus. The diadematid sea urchin, Centrostephanus coronatus, also occurs, but is rare. Red and purple urchins occur almost exclusively on rocky substrates. White urchins are not only common on some hard substrates, but are also abundant on sand and mud bottoms. Locally, white urchins are often most numerous in the sandy areas at the peripheries of kelp beds (Schroeter et al 1983).

Each of the three abundant urchin species is a grazer whose diet includes the giant kelp, Macrocystis pyrifera (Leighton 1960; Boolootian and Lasker 1964, cited in Lawrence 1975; Leighton et al 1966). Giant kelp is the preferred food of red and purple sea urchins. Although opinions differ on the general importance of sea urchin grazing to the distribution and abundance of kelp in southern California (for a discussion, see North 1974), there is fairly convincing evidence that strongylocentrotid urchins can limit, reduce, or eliminate kelp beds (Leighton 1968, 1971; North and Pearse 1970; North 1974; Pearse and Hines 1979; Dean et al 1984). A change in behavior precedes destructive overgrazing by red and purple urchins (Leighton 1960, 1971; Leighton et al 1966; Dean et al 1984; Harrold and Reed 1985). When drift algae is abundant, it is their primary food (Irvine 1973, cited in Lawrence 1975). Under these conditions, the urchins remain more or less stationary and capture the drifting algae

with their spines and tube feet (Lees 1970; Rosenthal et al 1974; Mattison et al 1977; Harrold and Reed 1985). However, when drift algae are scarce, red and purple urchins move over the substrate and graze on attached algae (Leighton 1960, 1971; Leighton et al 1966; Mattison et al 1977). Since rates of movement are inversely related to the availability of drift algae (Lees 1970), it seems likely that active grazing is stimulated by starvation.

Grazing aggregations or "fronts" of red sea urchins have occurred in both the San Onofre and San Mateo kelp beds. One urchin front eliminated kelp along one of the Kelp Ecology Project's (KEP) transects in the downcoast portion of the San Onofre kelp bed in 1981 (Dean et al 1983). Another removed nearly all algae from our control site in the San Mateo kelp forest. Fortunately, most of the grazing took place after the study was completed.

Before about 1983, white urchins were relatively rare on shallow rocky substrates. They were usually found on soft sediments in bays or deep water, or in areas just outside of kelp forests (Morris et al 1980; Schroeter et al 1983). The presence of the sea star, Asterina miniata (= Patiria miniata), and perhaps other asteroids in the kelp forest, appeared to restrict the distribution of white urchins to peripheral areas (Schroeter et al 1983). Although high densities and destructive grazing by L. anamesus on kelp was occasionally observed (Clarke and Neushul 1967; personal observations), white urchins were generally an unimportant source of kelp mortality (Leighton 1971).

This situation has recently changed. During the 1982-1984 El Nino, shallow water asteroid populations were drastically reduced throughout the southern California Bight by a series of epizootics

caused by a bacterium of the genus Vibrio (Schroeter et al 1988b). Concurrent with the decline in sea stars, the density of white urchins in kelp habitats increased at sites from San Diego to Santa Barbara and at the Channel Islands (Tegner and Dayton 1987; J. Patton, personal communication; unpublished data). Since L. anamesus generally have been uncommon in kelp forests, there have been few studies of their effects on giant kelp (notably, Clarke and Neushul 1967; Leighton 1971; Dean et al 1984), and the long-term significance of the recent change in their distribution is difficult to judge.

Lytechinus anamesus have always been present at SOK and SMK. Our observations and field experiments indicate that grazing by L. anamesus can affect both recruitment of juveniles and the standing stock of adult kelp. Using data collected from 1978 to 1986, we found a significant negative correlation between urchin density and that of kelp recruits (Schroeter et al 1988a). We also noted that kelp recruits were generally absent in areas of very high urchin density. In fact, white urchins appear to set the offshore boundary of the kelp forest at one of our study sites (Dean et al 1984). We have also observed significant grazing on adult kelp. In February 1985, large numbers of white urchins began grazing on the holdfasts and fronds of adult plants, which resulted in heavy mortality during a period of storm waves and associated strong surge (Dixon and Schroeter 1985). Grazing on adult kelp is still occurring at some of our study sites.

Eight species of sea stars were encountered in our benthic surveys. The four most abundant were Asterina miniata, Astrometis sertulifera, Pisaster giganteus, and Dermasterias imbricata. All are predators on sessile or motile invertebrates. Astrometis and

Dermasterias prey on adult and juvenile purple sea urchins (Leighton 1971; Rosenthal et al 1974), and probably consume juvenile red urchins as well (Leighton 1971). Other prey of Astrometis that are counted in the benthic surveys are the tunicate, Styela montereyensis, and the predatory snails, Kelletia kelletii and Conus californica (Rosenthal et al 1974). In addition to sea urchins, Dermasterias preys on at least two other species counted in our surveys: the solitary sponge, Tethya aurantia, and the sea star, Astrometis sertulifera (Rosenthal and Chess 1972). Asterina miniata is an opportunist that fills the roles of herbivore and scavenger (Gerard 1976). It also preys on some species of bryozoans (Day and Osman 1981) and on white sea urchins (personal observations). In the San Onofre kelp bed, Asterina significantly affects the distribution and abundance of white urchins (Schroeter et al 1983). Since grazing by Lytechinus appears to limit the recruitment of juvenile kelp plants (Dean et al 1984), predation by Asterina may have an important indirect effect on the local distribution and abundance of kelp.

A diverse assemblage of prosobranch gastropods is found in most kelp forests, including those near SONGS Units 2 and 3. The most abundant of these snails in the San Onofre kelp forest were the large whelk, Kelletia kelletii, the cone shell, Conus californicus, and the muricid, Pteropurpura festiva. Kelletia is a carnivorous scavenger that is often found feeding on dead or moribund individuals in company with the sea stars, Pisaster giganteus, Pisaster brevispinus, or Dermasterias imbricata (Rosenthal 1971). Kelletia forms breeding aggregations of 15 to 20 individuals in the early spring and lays egg capsules on low relief rocky substrates (Rosenthal 1970). Each capsule

contains from about 400 to 2200 eggs. The larvae leave the capsule as swimming veligers.

Conus californicus is the only member of its primarily tropical genus found in California waters. It is a generalist predator and a scavenger, and occurs on both hard and soft bottom substrates. In a two-year study conducted at the Hopkins Marine Laboratory, Shaffer (1986) found that Conus migrated into the kelp forest to breed in the late spring and early summer. Shaffer (1986) also found that cone shells selectively oviposit on the red alga, Rhodymenia pacifica. The eggs are laid in elaborate capsules that are attached to the blades of the algae.

Pteropurpura festiva occurs in intertidal as well as subtidal habitats. In the subtidal, it often occurs on rocky substrates in bays (McLean 1978). We have seen large numbers of large individuals on rocky substrates in the Agua Hedionda lagoon about 40 km south of the San Onofre kelp forest (personal observations). Our knowledge of the feeding and reproductive biology of Pteropurpura comes from studies of intertidal populations near La Jolla, California, and northern Baja California. Dietary composition varies from site to site, but consists primarily of bivalves and snails, including other muricids (Fotheringham 1971, 1974). Breeding in these intertidal populations occurred from March through July. Pteropurpura formed mixed aggregations with other muricid snails. Females laid multiple egg capsules, each containing 500 to 600 eggs. In three to four weeks, the larvae developed into swimming veligers and emerged from the capsules. Successful recruitment occurred in one out of the three years these populations were studied (Fotheringham 1971).

Two other species of muricid snails, Maxwellia gemma and Murexiella santarosana, occur in moderate abundances in the kelp beds near SONGS. As is the case with other muricids, they are probably benthic predators. We have seen large breeding aggregations of Maxwellia on cobbles and boulders at depths of about 17 meters in the Barn kelp bed.

Mitra idae, the only member of the family Mitridae along the California coast, is a specialized predator on the sipunculan, Phascolosoma agassizii (Fukuyama and Nybakken 1983). It breeds from February to July in southern California, laying 100-200 elongate egg capsules on rocks. The capsules contain from 100 to 1000 eggs. Swimming veligers emerge from the capsules after about 24 days (Morris et al 1980).

Two ubiquitous archaeogastropods, the top shells, Tegula aureotincta and Calliostoma supargranosum, are fairly common in the kelp forests near SONGS. Tegula aureotincta occur in the low intertidal and commonly in kelp forests in southern California, where they feed on micro-algae (Schmitt 1982). Little is known of their breeding behavior, but a related species, Tegula funebralis, lays small gelatinous egg masses containing several hundred eggs on rocks in the intertidal. Settlement of small snails occurs about two weeks after the eggs are laid (Morris et al 1980).

Calliostoma supragranosum and the less abundant Calliostoma gloriosum are commonly found on rocky substrates in kelp forests (McLean 1978). Calliostoma gloriosum is a scavenger, and a specialized predator on the sponge, Xestospongia diprosopia (Perron 1975).

Four of the most abundant sessile invertebrates are: the gorgonian coral, Muricea californica, the solitary tunicate, Styela montereyensis, the gorgonian coral, Muricea fruticosa, and the solitary sponge, Tethya aurantia. The two species of Muricea are characteristic of most southern California kelp beds, and in many instances contribute substantially to the vertical structure of the understory. Both species have been studied extensively in San Diego County by Grigg (1970, 1972, 1974, 1975, 1977), who used the outfall structure of SONGS Unit 1 as one of his study sites (Grigg 1977). Muricea californica is almost always the more abundant of the two species, the ratio of the maximum abundances of the two species being about 2.5:1 (Grigg 1977). The difference in abundance seems to be a result of the fact that Muricea californica recruits at a rate 2-3 times that of Muricea fruticosa and lives, on average, 2-3 times as long (Grigg 1977). In our study, M. californica was the most numerous sessile species, about 3.5 times more abundant than M. fruticosa.

The solitary tunicate, Styela montereyensis, is the second most abundant sessile species sampled in our surveys. Although little is known about its natural history, Rosenthal et al (1974) estimated that Styela had a life expectancy of 12 to 20 months in a kelp bed near Del Mar, California. Heavy recruitment usually occurred in the late summer, but it was balanced by heavy mortality in the late spring, and population numbers remained fairly constant (Rosenthal et al 1974).

The orange demosponge, Tethya aurantia, is a conspicuous inhabitant of rocky substrates in kelp forests. It reproduces both sexually and asexually (Berquist 1978). It is an oviporous species whose oocytes develop in the sea water. Within about 24 hours, a

typical parenchymella larva is formed. The larvae of most sponges swim for 3-48 hours before settlement (Berquist 1978). Tethya reproduces asexually by budding.

Several species of sport and commercial interest occur in local kelp beds. Abalones (Haliotis spp.), lobsters (Panulirus interruptus), crabs (Cancer spp), and red sea urchins (Strongylocentrotus franciscanus) are all harvested. All occur in our study areas, but with the exception of red sea urchins are normally too rare and too cryptic to be effectively sampled using our field protocol. Red sea urchins have been harvested in the San Mateo kelp bed since 1977, and in the San Onofre kelp bed since 1981.

Comparisons With Other Kelp Forests

The species we studied are characteristic of kelp beds in southern California. This assertion is based largely on personal observations and conversations with other workers, but also on a review of published papers and reports. In the context of comparing faunas, it is unfortunate that most of these papers report either the results of quantitative work done on a subset of the taxa we sampled, or of less quantitative descriptions of entire communities. An exception is the study of a kelp bed near Del Mar, California (approximately 70 kilometers south of SONGS) conducted from July 1967 to February 1973 (Rosenthal et al 1974).

These investigators sampled 14 species of conspicuous macroinvertebrates in 96 1-m^2 quadrats in August 1972. In addition, solitary tunicates, Styela montereyensis, and gorgonian corals, Muricea californica, were sampled in 12 4-m^2 quadrats approximately quarterly from 1968 to 1972.

A major difference between the invertebrate assemblage in the Del Mar bed and those in the beds near San Onofre was that the former was at times dominated by the tubiculous polychaete, Diopatra ornata. Diopatra was at first uncommon, but eventually became the most abundant invertebrate in the bed. This species influenced the physical structure and very likely the dynamics of this bed, since in one instance it covered 25-30% of a sampling area. Diopatra occurred, but were uncommon in the three beds sampled in our surveys. The abundances of white sea urchins and the predatory snail, Kelletia kelletii, also differed between Del Mar and the kelp beds near SONGS. White urchins occurred at all of the sites sampled in our surveys, and were most abundant in the San Onofre kelp bed, but were not present at Del Mar. Kelletia were equally abundant at Del Mar and in the Barn kelp bed, but were about five times more abundant at the other beds surrounding SONGS. Gorgonian populations at Del Mar were much larger than in the San Onofre kelp bed, but are only one-seventh to one-third the size of populations in the San Mateo and Barn kelp beds.

Of the differences observed in the invertebrate assemblages of the different beds, two are of clear ecological importance. The San Mateo, Barn, and Del Mar kelp beds had much larger populations of gorgonians than the San Onofre kelp bed. This probably reflects differences in the stability of substrates. The Del Mar, San Mateo, and Barn kelp beds occur on shale or boulder reefs, whereas the San Onofre bed is essentially a cobble field interspersed with sand. Therefore, at San Onofre the hard substrates are more prone to being turned and tumbled during periods of strong wave surge, and are subject to periodic, and often extensive, burial. Thus, the first three beds are probably much

more stable over time for rocky bottom organisms, which is reflected in the patterns of the distribution and abundance of the longevous gorgonian corals.

Differences in urchin populations among the beds are also important. Urchins were more abundant at the beds surrounding SONGS than they were at Del Mar, and behaved differently. The sea urchins in the Del Mar bed apparently ate drift algae, and in any case there was no evidence that sea urchin grazing limited the distribution and abundance of kelp (Rosenthal et al 1974). In contrast, our cooperative work with Tom Dean (KEP) has shown that white urchins may limit the recruitment of kelp, and that red urchins have eliminated adult kelp in portions of the San Onofre kelp bed (Dean et al 1984).

Although comparisons among the beds reveal clear and important differences, the same species generally occur in all of them. Most of the species regarded as characteristic by Rosenthal et al (1974) were also common in the kelp beds near SONGS and were included in this study.

FIELD METHODS: SURVEYS OF BENTHIC INVERTEBRATES

Station Location and Configuration

The studies reported here were done in kelp forests in northern San Diego County, California (Figure 1). Four monitoring stations were established in Fall 1980. The site nearest the Units 2 and 3 diffusers was in the upcoast, offshore portion of the San Onofre kelp bed (Figure 2, SOKU). A second station near the diffusers was located in the downcoast, offshore portion of the San Onofre kelp bed at approximately the same depth (SOKD). Distant control sites were located in the San Mateo kelp bed (Figure 3, SMK), and in the Barn kelp bed (Figure 4, BK).

The location of SOKU was chosen to be within the area predicted to be most affected by the operation of Units 2 and 3. Most of the stations were placed in about the same depth of water in what appeared to be persistent areas of kelp. BK and SMK were thought to be far enough away from SONGS so as not to be affected by the discharged cooling water. All stations were located on hard substrates at least 10 meters from the nearest sand plain.

The giant kelp population at the Barn kelp site declined throughout 1980, and had essentially disappeared by the end of the year. Giant kelp was still not present at our study site in BK at the time of our last survey. The cause of the die-off is not known, but we have speculated that it was due to increased sedimentation during 1978-1980 (Dixon et al 1988).

Each station consisted of a surface buoy anchored by a metal plate which marked the origin of four 40-m transects (oriented at 035°, 125°, 215°, and 305°). The transects were marked with 1/4-inch steel

reinforcing bar stakes. Ten permanent 1-m^2 quadrats were positioned every 4 meters along each transect (Figure 5). A description of the nearshore oceanographic conditions in northern San Diego County and of the cooling system for the power plant is presented in Dixon et al (1988).

Sampling Frequency

Surveys were conducted every 2-4 months from November 1980 to April 1983, approximately semiannually from April 1983 to November 1984, and every 2-4 months from November 1984 to December 1986. Twenty-two surveys were done (Table 1). Survey 1 was not used for the analysis because methods were still being developed and field technicians were still being trained.

Training

Training dives were made before all but one survey. Training was done at SMK, which was considered the most difficult station due to high diversity and abundance. Several quadrats were randomly chosen from the sampling array, and were sampled by each diver. The results were used immediately to standardize the surveys. After the training dive, counts were compared to those of the field leader, sampling techniques discussed, and another set of quadrats was sampled. This was repeated two or three times, in order to insure that all divers were sampling in the same manner.

Sampling

The species of animals and plants that were counted are listed in Table 2. (Note that the bat star, Asterina miniata, is referred to by its old name, Patiria, in the rest of this report.) Twelve species of snails were added to the list late in the preoperational period. These were not sampled in the early surveys because of lack of resources. Later when we were able to employ a stable group of field assistants, we increased the number of species counted. In order to avoid disturbing the sessile species, the quadrats were sampled non-destructively; i.e., only those animals on the surface of the substrate were counted. Animals which could escape out of the quadrat were counted first; those which crawled into the quadrat after the census began were not counted. Giant kelp and other algae were counted, but the methods and results are reported elsewhere (Schroeter et al 1988a).

The percent cover of selected substrates was estimated by noting the size and type of substrate under 15 uniformly distributed points within each quadrat. The categories of substrate were "silt," sand, pebble, cobble, boulder, reef, and bedrock. In addition, the percent covers of live Macrocystis holdfast, dead Macrocystis holdfast, and the colonial polychaete, Phragmatopoma californica, were estimated. Substrate categories were based on their greatest diameter. Pebbles were 1-5 cm. Cobble was recorded in three classes (6-10 cm, 11-20 cm, and 21-30 cm), as were boulders (31-40 cm, 41-50 cm, and >50 cm). The substrate categories corresponded closely to those of the Wentworth scale (Table 3).

"Silt" was not recorded until October 1985, when a fine, cohesive soft sediment was first noted at our study sites in the San Onofre kelp

forest. Obviously, a diver in the field could not distinguish accurately between very fine sand and silt. However, most sands found within the kelp beds were coarse, and the substrates normally characterized as silt in the field turned out to have a median phi near 4.0, and a dispersion of about 1 when analyzed in the laboratory. Beginning in 1985, patches of this fine material were periodically mapped in the field, and samples were collected for laboratory analysis. Grain size and Total Organic Carbon (TOC) were determined. These fine sediments were nominally characterized as "silt" in the field, and in the context of our field surveys the term is used in this report, despite the fact that some of these fine sediments would be characterized as fine sands using the standard Wentworth scale.

FIELD METHODS: KELP RECRUITMENT SURVEYS

Station Location and Configuration

Eleven to 16 stations were sampled in the San Mateo kelp forest, and 24-44 stations were sampled at San Onofre. Stations were arrayed more or less uniformly in the San Onofre and San Mateo kelp beds (Figure 6). At San Mateo a smaller array was established which only covered areas where kelp had been most persistent.

Sampling Frequency

Surveys were conducted approximately quarterly beginning in September 1981. However, the duration of the surveys and the time between them varied considerably and irregularly, depending on sea conditions. Sixteen surveys were completed between Fall 1981 and Fall 1986 (Table 4).

Sampling

Two sampling protocols were used during the course of the kelp recruitment study. From 1981 through 1983, giant kelp, sea urchins, and sea stars were counted in a single 4-m^2 quadrat along each of three transects at each station. The quadrats were randomly placed between 2 and 10 m along transects marked with a 10-m tape. The transects were laid out on random compass bearings (Figure 7). The quadrats were sampled destructively during standard surveys; i.e., boulders and cobbles were turned over and pebbles carefully searched through, in order not to overlook cryptic organisms. During the October 1981 survey, a 1-m^2 quadrat in the corner of the 4-m^2 quadrat was first

sampled nondestructively in the manner described above for the survey of benthic invertebrates.

From 1984 through 1986, five 1-m^2 quadrats were placed between 10 and 35 m along a single randomly oriented transect (Figure 7). The quadrats were placed at random points within 5-m strata and staggered, with two on one side of the transect and three on the other. Three quadrats were sampled destructively and two non-destructively. During the June 1986 survey, one 1-m^2 quadrat was sampled in the manner of the survey of benthic invertebrates, as had been done in 1981.

DATA BASE MANAGEMENT

Upon completion of a field survey, data sheets were checked, and errors, ambiguities, or confusing entries were resolved with the help of the sampler who took the data. After being checked, the field data were transcribed onto keypunch sheets. The keypunch sheets were checked, corrected, and sent to Hiro's Keypunch Service. Keypunch personnel were asked to verify all data by punching it twice and checking the second entry against the first.

A magnetic tape was received from the keypunch facility, and the data were downloaded by TITAN. A printout of the entire data set (by survey) was made, and stratified random pages were chosen to check for keypunch and transcription errors. Ten percent of the data was checked line by line. If no errors were found, checking ceased. If one or more errors were discovered (either keypunch or transcription errors), another 10% of the pages was checked. This procedure continued until no errors were discovered. All lines of small data files were checked.

After checking for keypunch and transcription errors, a Statistical Analysis System (SAS) program was run on all data sets to check for duplicate lines, and these data were eliminated if present. The SAS programs used to check for errors are included in the history section of each data base. Finally, the establishment software described in the MRC Data Standards Document checked for outlying or impossible values. If no errors were detected, the data base was established as an official MRC data base.

After data bases were established, personnel of the Marine Review Committee, Inc. randomly selected 10 percent or 300 records, whichever

was less. These were checked against the raw data. We then resolved all discrepancies and identified errors. The error rate for our data bases is less than one percent.

The SAS programs used to construct data bases which were used in this report and the programs for the analyses and construction of the Tables and Figures are shown in Appendix B. The actual code is contained in files on our project software disk and is available to all who have access to the MRC computer system.

ANALYSIS

This study was designed with the Before-After/Control-Impact-Pairs (BACIP) analysis in mind. The basic design and the development of the analytic framework are presented by Stewart-Oaten (1986) and Stewart-Oaten et al (1986). This experimental design requires that replicate surveys be conducted during roughly equal intervals before and after the environmental perturbation of interest, which in the present case is the commencement of the normal, sustained operation of SONGS Units 2 and 3. From the spring of 1980 through the spring of 1983, the pumps for one or both of the new generating units were being tested, but no power was generated until Fall 1982 (Figures 8 and 9). Since May 1983, Units 2 and 3 have been operating at the level that is expected to be normal. For the benthic survey, the period from October 1980 through April 1983 is considered "preoperational." Since the species we were monitoring tend to be long-lived and to recruit sporadically, we thought there should be a time lag between the start of normal plant operation and the beginning of our operational surveys. We have designated surveys made after October 1984 as "operational." The period from April 1983 to October 1984 was designated the "interim" period, sampling frequency was halved, and data collected during the two surveys in this period were not used in the BACIP analysis.

In order to obtain an accurate estimate of the mean at each survey, replicate spatial samples were taken at each impact and control location at about the same time. For each survey the difference, or delta, between the mean abundance estimates at the impact and control sites was calculated. For the jth survey:

$$D_j = Y_{jimpact} - Y_{jcontrol}$$

Under the null hypothesis, one would expect that the average delta in the operational period would not differ significantly from that in the preoperational period. We tested the null hypothesis with a t-test and a Wilcoxon rank sum test (Snedecor and Cochran 1967). The alternative hypothesis was simply that the "Before" and "After" deltas differed since we had no a priori expectations concerning the sign of any plant effects. Therefore, two-tailed tests were used in all the analyses.

The t-test is based on the following assumptions regarding the deltas: 1) Effects are additive; 2) The samples in the before period are 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. For equal or nearly equal sample sizes, violations of the last three assumptions have little effect on the t-test (Glass et al 1972; Stewart-Oaten 1986), and will not be discussed here. The first three assumptions, on the other hand, are very important.

The preoperational data were tested for additivity using Tukey's test and, where necessary, log transformations were used to produce additivity. In the case of density estimates, the spatial replicates were averaged at each location and then transformed, using logarithms of the form $Y = \log_{10}(x + c)$ after cases of zeros at both impact and control were deleted. Estimates of percent cover were first transformed using the angular transformation (Snedecor and Cochran 1967) in order to normalize the data, and then subjected to a log

transformation, if necessary, to produce additivity. Adequate transformations were found for most species. A constant, c, was added before taking logs if the mean density was occasionally zero at one of the stations. Two constants were used, 1 and 1/n, where n is the number of quadrats sampled.

After testing for additivity, we examined the preoperational data for temporal trends by plotting the deltas against time and by doing regression analyses. If there were no significant trends, we assumed that all the preoperational deltas were from the same statistical population.

Positive 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 size ($n < 10$), the power to detect such correlations is generally small. One solution to the problem of serial correlations is to conduct an analysis which explicitly estimates the autocorrelated errors. We elected not to do this, again because of small sample size, and instead performed the standard BACIP analysis, with a cautionary note in cases with significant results.

Several screens were written into the computer programs used in the statistical analysis. First, we selected those species which were present and counted at both the impact and control sites during at least two preoperational surveys and which had a mean abundance at one of the stations in the San Onofre kelp forest of at least 1 / 10-m^2 on at least one occasion during the six years of observations (Table 5). That is

equivalent to four animals at one of the stations on a survey. The species that passed these screens were then subjected to tests of the assumptions underlying the BACIP analysis. Only those species for which P >= 0.10 for additivity, P > 0.05 for serial correlation, and P > 0.05 for linear trends in the preoperational period were analyzed for Before-After differences in the deltas. Frequently, more than one transformation of the data passed the tests we imposed. This would not be cause for comment were it not for the fact that different transformations often produce different results of the t-test. In order to objectively select a transformation, we passed the data through one more computer screen. We selected the transformation that returned the largest P-value for additivity, unless $P_{add} > 0.50$ for more than one transformation. In that event, we chose the transformation which had $P_{add} > 0.50$ and the largest P-value for a linear trend. The unscreened results of the tests of assumptions are presented in Appendix A.

Effects of Perturbations Unrelated to SONGS

Toward the end of the study, a front of grazing red and purple sea urchins began moving across the control station at SMK. By the last survey about half the quadrats had been grazed. In order to test whether any of the species had been affected by the activities of the urchins in the front, we compared quadrats that had been grazed with those that had not. Dividing the quadrats into these two categories was a straightforward procedure, because we could easily tell where the front had been and were able to observe its movement. After dividing the data into affected and unaffected quadrats, we made temporal plots

of abundance by category to see if there were obvious differences. We also assigned surveys to a "Before" or "After" period, depending on when they were conducted relative to the appearance of the urchin front. Then with the unaffected quadrats as "Control" and the affected quadrats as "Impact," we did a BACIP analysis.

The arrival of the urchin front at the control site is obvious by the sudden increase in the density of red and purple sea urchins (Figure 10A and B). In the present context, changes caused by the urchin front are only of interest if they affect the utility of the control. The following species may have been affected (Table 6; Figures 11-13): Astraea undosa, Cypraea spadicea, Nassarius spp., Crassispira semiinflata, Patiria miniata, and Styela montereyensis. Rather than make a judgment for each species as to whether it was affected by urchins (or silt - see below), we ran the analyses twice, once using means calculated from all quadrats and once with means calculated from unaffected quadrats.

During the course of our study there occurred two other events which were also clearly unrelated to the operation of SONGS but which could cause period by location interactions in the abundance of some echinoderm species. In 1981, and especially in 1983 and 1984, a series of epizootics similar to the episode observed in Baja, California (Dungan et al 1982), virtually eliminated shallow water sea star populations in the southern California Bight (Tegner and Dayton 1987). Since initial densities were much lower at the control site in SMK, the absolute change was also lower there. A second perturbation which was unrelated to SONGS was the commercial harvesting of red sea urchins. Red urchins were initially more abundant at the control site in the San

Mateo kelp forest than in the San Onofre kelp forest. Harvesting was heaviest during the interim period. By late 1984, fishermen could no longer find sufficiently dense populations in SOK to make harvesting economically feasible. However, dense populations were still found at SMK, although the roe were of poor quality. We have not included sea stars or red urchins in our analysis because of these severe perturbations. The other species we counted were subjected to the computer screens described above and then analyzed using the BACIP approach.

Evidence of an Effect of the Power Plant

The BACIP analysis identifies significant operating period by location interactions. It is a test of whether the average difference in the abundance of organisms at the control and impact sites changed after Units 2 and 3 began operating. The BACIP analysis is not a direct test of whether SONGS affected the biota, although that may well be a reasonable inference in the case of a statistically significant result. Such an inference is greatly strengthened if there are plausible mechanisms by which SONGS could produce the observed changes, and weakened by the existence of probable extraneous causes.

During the operational period there was a marked increase in silts and fine sands at the impact site and surrounding areas. Because changes in substrate could reasonably be expected to affect the abundance of benthic animals, the origin of the sediment and the cause of its deposition in the kelp forest immediately became topics of inquiry. On the one hand, it is of interest as a possibly confounding variable. On the other hand, it is of concern because it may be a result of the operation of SONGS.

In the context of our monitoring studies, there is no thoroughly satisfactory way of dealing with the problem, because there is no way to completely isolate the effects of sediments from possible effects of SONGS which are not directly related to sediments. Our solution to the problem was to test for operating period by location interactions twice - once using all the data, and once using only data from quadrats that appeared to be unaffected by the influx of fine sediments. In addition, we directly tested for effects of the sediments at the impact site by comparing affected and unaffected quadrats. This has the advantage of controlling for unrelated SONGS effects because the quadrats are close to one another (all within an 80-m x 80-m area). On the other hand, the determination of which quadrats were affected by silt at SOKU is not clearcut, because the position of the silt changed somewhat from survey to survey. We defined affected quadrats as those which had at least 25 percent cover of silt on any survey. Twenty-five percent was chosen as the cutoff, because it was our impression that when there was less cover, the sediment was generally a thin layer and less stable. If this impression is accurate, the analysis is testing for the effects of relatively persistent silt deposits, but not necessarily for the effects of brief influxes of thin layers of silt.

Generality of the Population Estimates

In order to see how representative of the impact and control areas our monitoring stations were, we compared the estimates of density at the benthic monitoring stations with the estimates from the surrounding

kelp recruitment stations using t-tests. The number of recruitment stations in each area varied as follows:

	1981	1986
SOKU	9	6
SOKD	6	6
SMK	8	5

RESULTS

Effect of Silt Accumulation

The influx of silt at SOKU is apparent in Figure 14. The quadrats that accumulated silt must have differed from the others in depth or bottom topography, because the cover of sand was almost always 10 or 15 percent higher before the appearance of the finer sediment (Figure 14B).

None of the species we monitored showed significant increases where silt accumulated. This is not surprising, since nearly all of them are usually found associated with hard substrates. On the other hand, the density of several species declined where silt was abundant (Table 7). In the case of the predatory snails, *Kelletia kelletii* (Figure 15A), *Maxwellia gemma* (Figure 16B), and the sea star, *Patiria miniata* (Figure 16A), the decline in the affected quadrats seems to be an effect of the added silt. The snail, *Murexiella santarosana* (Figure 15B), and the sponge, *Tethya aurantia* (Figure 17A), also declined in the affected quadrats relative to controls, and the BACIP tests were significant. However, the results are somewhat less convincing because both species declined in the control quadrats. One other species appears to have been adversely affected by the accumulation of silt at SOKU. The white sea urchin, *Lytechinus anamesus*, declined sharply in density where silt was abundant (Figure 17B). BACIP tests could not be done because changes prior to the appearance of the silt were not additive.

It seems obvious that accumulations of fine sediments are deleterious to animals that prefer hard substrates, as do most of the

species we monitored. Periodic influxes of sand are normal events in kelp beds and may contribute to community stability by clearing space. However, a persistent increase in the percent cover of sand and silt would undoubtedly change community composition. In order to evaluate the significance of the changes we observed at SOKU, one needs to know if the increase in silt is a natural event or if it is a function of the operation of SONGS Units 2 and 3.

There have been several studies designed to determine the distribution and characteristics of the cohesive soft sediments that appeared at SOK. During the course of our monitoring studies of benthic invertebrates and kelp recruits, the percent cover of silt was estimated. In addition, in October 1986 and again in July-August 1987, we collected sediments for laboratory analysis at about 60 sites in a uniform grid that included the San Onofre kelp forest. Finally, in December 1986 and in September-October 1987, we estimated the percent cover of silt in 1-m^2 quadrats, and the cover of algae and sessile invertebrates on random boulders at about 25 sites located along two transects perpendicular to the diffuser lines.

In the laboratory, sediments were subjected to grain size analysis, and total organic carbon was determined. A subset of the sediment samples and samples from the lay-down pad at the SONGS construction site were analyzed for mineral content. The lay-down pad was released between late December 1984 and early January 1985, and it is possible that it was the source of some of the fine materials later observed in the kelp forest.

The results of these various studies are still being analyzed and will be reported under separate cover (Schroeter 1988). However, we will give a brief preview here:

1. A thick deposit of cohesive, fine sediments appeared at the upcoast impact site in 1985, and was still present in July 1987.
2. These sediments were generally more abundant near the diffusers than farther away (Figures 18-20), and thick deposits were observed in the upcoast part of the kelp forest.
3. This cohesive sediment was finer and higher in total organic carbon than the other soft sediments in the kelp forest.
4. The percent cover of algae on boulders was lower near the diffusers than farther downcoast, and was significantly negatively correlated with the percent cover of the cohesive sediment.

Operating Period by Location Interactions

During the course of our study of benthic invertebrates, we monitored the abundance of 47 species. Of these, 19 passed the various statistical screens, and the data for these species were subjected to the BACIP test for an operating period by location interaction.

Gastropod Mollusks

The pattern that is most apparent and convincing is a general decline in the abundance of gastropod mollusks at the impact site in the upcoast portion of the San Onofre kelp forest relative to the distant control sites (Tables 8 and 9; Figures 24-69).

Calliostoma spp.

These trochid gastropods (Figures 21-24) are omnivores that are often found on giant kelp and other algae in kelp forests. The animals included in this category are mostly Calliostoma supragranosum, but also some C. gloriosum and an occasional C. annulatum. Timothy Herrlinger (personal communication) estimated that about 75% of these snails were C. supragranosum. Calliostoma was only sampled twice during the preoperational period. Initially, it was most abundant at the impact site, but declined throughout the interim period, whereas populations at the control sites increased somewhat (Figures 21 and 23). The patterns were essentially the same whether all the data was used or only data from quadrats unaffected by silt or urchins. The changes in density resulted in significant differences in the deltas for the two operating periods (Tables 8 and 9; Figures 22 and 24).

Tegula aureotincta

The pattern for Tegula aureotincta is similar to that of Calliostoma in that initial densities were highest at the impact site and close to zero elsewhere (Figures 25 and 27). The patterns were similar for both types of quadrats. At the impact site the density declined and remained low, whereas the control populations showed modest increases. This resulted in declines in the deltas (Figures 26 and 28), but the difference in the "before" and "after" deltas was only significant for the SMK comparison (Tables 8 and 9).

Cypraea spadicea

Cypraea spadicea occurred in low numbers at all four monitoring stations throughout the preoperational period (Figures 29 and 31). In the operational period there was a marked increase in the San Mateo kelp forest, but not elsewhere. In fact, there was a decrease at Barn kelp where densities had been highest. These changes are reflected in significant changes in the deltas for comparisons between the impact station and one (Table 8; Figure 30) or both (Table 9; Figure 32) of the distant controls. There was no significant change in the deltas when the two SOK stations were compared. The lack of recruitment at SOK relative to SMK is suggestive, but one hesitates to ascribe the cause to SONGS without additional evidence, since there was a marked decline and little subsequent recruitment at BK.

Conus californicus

Conus californicus (Figures 33-36) is a predatory snail that is often associated with kelp holdfasts, perhaps because that is the home of their prey. These common snails were most abundant at the stations in the San Onofre kelp forest during the operational period, and within SOK, more abundant at SOKU (Figures 33 and 35). During the operational period, populations in SOK declined relative to those in SMK and BK. There apparently was recruitment at both distant control sites, but not at San Onofre. Within SOK, the upcoast population declined relative to the downcoast population.

Although there was a strong seasonal component to the changes in population densities, this was generally evident at all the stations. The relatively larger decline at the impact site during the operational

period resulted in smaller deltas for all comparisons (Figures 34 and 36). The differences in the average "before" and "after" deltas were significant in each case (Tables 8 and 9). The patterns were essentially the same regardless of the presence of large quantities of silt.

Crassispira semiinflata

Crassispira semiinflata, occurred at relatively low densities at all the stations, although it was most abundant in SOK. During the course of our observations the population densities have varied widely and asynchronously. The population at the impact station declined sharply during the early interim period and then fluctuated about a lower mean density. At the control sites, abundances stayed about the same or increased. These changes resulted in smaller average deltas during the operational period (Figures 38 and 40). The differences were significant for all the comparisons using data from quadrats that were unaffected by silt or urchins, and significant for the BK comparison using all the data (Tables 8 and 9).

Kelletia kelletii

Kelletia kelletii is a large predator and scavenger that is a conspicuous member of the fauna in most kelp forests. These snails were abundant at all the monitoring sites during the preoperational period, but generally were more numerous at San Onofre than elsewhere (Figures 41 and 43). Throughout the interim period, densities declined in both areas of the San Onofre kelp bed relative to the distant control sites. This resulted in smaller average deltas during the operational period

(Figures 42 and 44). The difference in the average deltas in the two operating periods was slight and not significant for the comparison of the two stations in SOK (Tables 8 and 9). The difference was statistically significant for the SMK comparisons and for the BK comparison for data from all quadrats (Tables 8 and 9). A striking pattern is the sudden and ephemeral decline in abundance estimates in late 1982. We suspect that the snails were present but cryptic. One conjecture is that they buried themselves in response to large swells.

Maxwellia gemma

In the preoperational period, *Maxwellia gemma* was counted twice. At that time it was present at low densities at the control stations but quite abundant at the impact site (Figures 45 and 47). It declined at the impact site during the interim period and remained at low densities, whereas the average abundances at the control stations increased. The pattern was essentially the same for both groups of quadrats. These shifts in density resulted in lower average deltas during the operational period (Figures 46 and 48). The operating period by location interaction was significant for all comparisons (Tables 8 and 9).

Mitra idae

Mitra idae is a relatively abundant snail that was generally more numerous in SOK than at the control sites. Within SOK its density was highest in the upcoast portion of the bed. During the operational period, the mean density of *Mitra* increased at all the monitoring stations except the impact station in upcoast SOK, where it declined

slightly (Figures 49 and 51). The changes in the relative abundance at the impact site resulted in lower average deltas during the operational period (Figures 50 and 52). The differences were not significant when data from all quadrats were used. However, there was a negative trend in the deltas during the operational period for the SMK and BK comparisons which was significant for the latter (Table 8). When data from quadrats unaffected by urchins or silts were analyzed, the BACIP results were significant for both the SOKD and BK comparisons.

Murexiella santarosana

The pattern for *Murexiella santarosana* is generally the same as for *Maxwellia gemma*. The densities at the SOK stations declined during the interim period and remained low, whereas the abundances of these snails increased at the distant control sites (Figures 53 and 55). As a result, the average deltas are smaller during the operational period (Figures 54 and 56). However, the results of the BACIP analysis are short of statistical significance for all but the SOKD comparisons for data from all quadrats (Tables 8 and 9).

Nassarius spp.

Nassarius were generally more abundant at the stations in SOK than elsewhere until the last few surveys (Figures 57 and 59). The patterns in the deltas are roughly similar to those of the other species of snails (Figures 58 and 60), but the differences in the "before" and "after" deltas are not significant for any of the comparisons (Tables 8 and 9).

Ophiodermella inermis

Like Nassarius, Ophiodermella inermis were only counted twice during the preoperational period. These snails were uncommon, and there was little difference in density in the preoperational and operational periods (Figures 61 and 63). There were no significant differences in the average deltas of the two operating periods (Tables 8 and 9; Figures 62 and 64).

Pteropurpura festiva

Pteropurpura festiva were counted twice during the preoperational period. During that time they occurred at relatively low numbers at the distant control sites but were quite abundant in the San Onofre kelp forest (Figures 65 and 67). They declined at both SOK stations during the interim period. The average density of populations at SMK and BK increased during the "after" period. The pattern was the same for data from both types of quadrats. These changes in density resulted in smaller deltas during the operational period for comparisons with both distant controls (Figures 66 and 68) which were all statistically significant (Tables 8 and 9). There was no significant change in the SOKU-SOKD deltas.

Sessile Invertebrates

The changes in the density of the other species of invertebrates that could be analyzed did not fit a single pattern. Although there are some suggestions of an effect of SONGS, the evidence is less compelling than for the snails.

Tethya aurantia

The density of Tethya was always low, particularly in the downcoast portion of SOK and at San Mateo (Figure 69 and 71). Densities at the upcoast station in the San Onofre kelp bed and in Barn kelp forest were higher, but declined during the interim period. There was no consistent pattern in the deltas (Figures 70 and 72), and none of the differences in the "before" and "after" deltas were significant (Table 10 and 11).

Muricea californica

During the preoperational period, M. californica was rare in the San Onofre kelp forest and abundant at the control sites (Figures 73 and 75). There was substantial recruitment at all the stations, but less at the impact site than at the downcoast station in SOK. On the other hand, the proportional increase was greater at the impact site than the distant controls, which resulted in significant BACIP tests (Tables 8 and 9; Figures 74 and 76). To add complexity, the proportional decrease in density during the operational period was also greater at the impact site, which resulted in significant negative trends in the deltas (Tables 8 and 9; Figures 74 and 76). In the absence of a demonstrated mechanism, we do not think the observed density changes should be interpreted as effects of SONGS.

Muricea fruticosa

Like its congener, Muricea fruticosa was rare in the San Onofre kelp forest during the preoperational period (Figures 77 and 79). There was some recruitment in 1984, but less than for M. californica. The

density of M. fruticosa was still very low in the operational period, but higher in the downcoast than upcoast portion of the San Onofre kelp forest. This resulted in a significant difference in the average deltas for the two operational periods (Table 10; Figure 78). A decline in density at SMK resulted in a significant difference in the deltas in the other direction (Table 10; Figure 78). There is no evidence of an effect of SONGS.

Strongylocentrotus purpuratus

Purple sea urchins have always been more abundant at San Mateo than elsewhere (Figures 79 and 81). This may be related to habitat availability. Like Cypraea, purple urchins are generally found in the cryptic habitats that are in greater supply at SMK than at the other sites. At San Mateo there was a general decline in S. purpuratus during the preoperational period, and a general increase during the operational period. Within SOK, purple urchins were more abundant upcoast than downcoast during the preoperational period, but were slightly less abundant at the impact site during the operational period. This resulted in a significant difference in the average deltas for the two operating periods (Tables 10 and 11; Figures 80 and 82). There was also a significant BACIP result for the SMK comparison for data from quadrats which were not affected by silt or urchin fronts (Table 11; Figure 82). However, this result reflects events at SMK, particularly a large increase during the operational period. This may indicate that recruitment was inhibited at SOK or that SOK was a poor habitat for purple urchins, since they were always uncommon there.

Lytechinus anamesus

During the preoperational period, Lytechinus anamesus was more common in the San Onofre kelp forest than at the control sites (Figures 83 and 85). Since 1983 there has been an increase in the density of white urchins at many sites in the California Bight (Tegner and Dayton 1987). In some places, as at the San Onofre and San Mateo kelp forests, this resulted in high densities of these urchins inside kelp beds. In the past they have been most common outside the kelp beds and in deeper water. We think the change may be related to the decline of predatory starfish due to disease. At our study sites the increases have been greater at San Onofre than at the control sites. Later in 1986, however, there was a rapid increase at the station at San Mateo. On average, densities increased at SOKU relative to distant controls, but increased at SOKD relative to SOKU. Although many of the changes in the deltas are statistically significant (Tables 10 and 11; Figures 84 and 86), because of the latter trend and the possible confounding effect of changes in sea star predation, we think it is unlikely that the observed changes are a result of the operation of SONGS.

Styela montereyensis

This solitary tunicate was very abundant in the downcoast portion of SOK during the preoperational period, and was common elsewhere (Figures 87-90). It declined to near zero everywhere before Units 2 and 3 went on line. During the operational period there was a proportionately greater increase in density at BK than at the impact site. This resulted in significant BACIP t-tests for this comparison (Tables 10 and 11; Figures 88 and 90). Both stations in SOK behaved

similarly, and the difference in the average deltas for the "before" and "after" periods was not significant. The results are suggestive of a negative effect of SONGS on recruitment.

DISCUSSION AND CONCLUSIONS

The results of this study demonstrate that there was a general decline in the abundance of many species of invertebrates in the San Onofre kelp forest after Units 2 and 3 of the San Onofre Nuclear Generating Station began operating. The evidence strongly suggests that the changes in the biota were caused by the operation of the new generating units and were not simply correlates. The results of the BACIP analyses were generally highly significant and, for several species, the decrease in abundance was more severe at the station in SOK that was closest to the diffusers.

Most of the species affected were gastropod mollusks and can be divided into two groups: species for which there were few samples in the preoperational period, and species for which there were many samples. Although the temporal patterns of abundance were similar for snails in both groups, the inference of a power plant effect is much stronger for the latter. In addition to the snails, the purple sea urchin, *Strongylocentrotus purpuratus*, seems to have been adversely affected by SONGS. The evidence is weaker, since it is based on much better recruitment at a control site, where abundances of this species have always been higher, than at the impact site. Similarly, the solitary tunicate, *Styela montereyensis*, recruited better at a control site than at the impact site during the operational period. The presumption of an effect of the power plant is stronger for this species, because it had been abundant in SOK during some earlier surveys.

Although we do not have the information necessary to identify the mechanism underlying the statistical evidence of a power plant effect,

a likely cause is an increase in fine sediments in the San Onofre kelp forest. Two of the species for which there was statistical evidence of an effect of SONGS, Kelletia kelletii and Maxwellia gemma, also appeared to be adversely affected by a build-up of a cohesive, fine sediment at the impact site. However, the appearance of deep deposits of this material is not a sufficient cause for the observed population declines, because the numbers of most species began to decrease before large deposits were noted. A related phenomenon that may have negative effects is the increase in the flux of fine materials at SOK caused by an interaction between the diffusers and natural sources of sediments. Inman (1987) proposed a similar interaction between the diffusers and the materials released from the lay-down pad in 1984 and 1985. It is possible that the diffusers interacted in a similar way with the large amount of fine material introduced to nearshore waters from streams during the winter storms of 1983 (Reitzel et al 1987) to increase the flux of fine material at SOK.

A frequent dusting of fine sediments on hard substrates in the San Onofre kelp forest could interfere with larval settlement and might decrease the chances of the successful attachment and development of eggs. All the gastropods we have discussed attach gelatinous egg masses or egg capsules to hard substrates or algae. After several days or weeks, the veliger larvae are released. The length of time before settlement is not known for these species. However, in general, the free veliger stage lasts from a few hours or days to two to four weeks (Hyman 1967). If the larval life is less than a day or so, a negative effect on egg laying or development could result in a decrease in local adult population densities.

Finally, one might reasonably ask, how general are the results? Are the monitoring stations representative of the surrounding area? The comparison of the density estimates made at the benthic monitoring stations with those made at the surrounding kelp recruitment stations indicates that there are few differences among sites (Tables 12-14). However, one set of comparisons demands special comment. In 1981, Conus californica was more abundant at the benthic stations than at the kelp recruitment stations at San Onofre. In 1986, the pattern was reversed. There were no differences in the San Mateo kelp bed. Since these estimates really constitute a simple, unreplicated (in time) sample in the "Before" period and one in the "After" in the BACIP context, one ought not treat them as representative. We simply may be unduly impressed with sampling error. Nonetheless, we find it difficult not to wonder at the differences, especially since they are so similar in the two parts of SOK. The only common element that we can think of is the change in the density of kelp. In 1981, both benthic survey stations were in areas of abundant kelp, whereas in 1986 there was no kelp at either station. There was still kelp at many of the kelp recruitment stations, however. It is possible that differences in the abundance of Conus may be a function of kelp density, and that this may also be one of the mechanisms underlying the BACIP results.

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LITERATURE CITED

Berquist, P.R. 1978. Sponges. Univ. of Calif. Press, Berkeley and Los Angeles. 268 pp.

Boolootian, R.A. and R. Lasker. 1964. Digestion of brown algae and the distribution of nutrients in the purple sea urchin Strongylocentrotus purpuratus. Comp. Biochem. Physiol. 11:273-289. (cited in Lawrence 1975)

Clarke, W.D. and M. Neushul. 1967. Subtidal ecology of the southern California coast. In: T.A. Olson and F.J. Burgess, eds. Pollution and Marine Ecology. John Wiley & Sons, New York. pp. 29-42.

Day, R.W. and R.W. Osman. 1981. Predation by Patiria miniata (Asteroidea) on bryozoans: prey diversity may depend on the mechanism of succession. Oecologia 51:300-309.

Dean, T.A., L. Deysher, K. Thies, S. Lagos, F. Jacobsen, and L. Bost. 1983. The effects of the San Onofre Nuclear Generating Station (SONGS) on the giant kelp, Macrocystis pyrifera: final pre-operational monitoring report for the contract period May 1981 through October 1982. Report to the Marine Review Committee, Inc. dated March 1983.

Dean, T.A., S.C. Schroeter, and J.D. Dixon. 1984. Effects of grazing by two species of sea urchins (Strongylocentrotus franciscanus and Lytechinus anamesus) on recruitment and survival of two species of kelp (Macrocystis pyrifera and Pterygophora californica). Mar. Biol. 78:301-313.

Dixon, J.D. and S.C. Schroeter. 1985. Effects of the white sea urchin, Lytechinus anamesus, on populations of giant kelp, Macrocystis pyrifera. Report to the Marine Review Committee, Inc. dated April 22, 1985.

Dixon, J.D., S.C. Schroeter, T.A. Dean, and J. Reitzel. 1988. Changes in kelp populations in the vicinity of the San Onofre Nuclear Generating Station 1981-1987. Report to the Marine Review Committee, Inc. dated January 20, 1988.

Dungan, M.L., T.E. Miller, and D.A. Thomson. 1982. Catastrophic decline of a top carnivore in the Gulf of California rocky intertidal zone. Science 216:989-991.

Fotheringham, N. 1971. Life history patterns of the littoral gastropods Shaskyus festivus (Hinds) and Ocenebra poulsoni Carpenter (Prosobranchia: Muricidae). Ecology 52:742-757.

Fotheringham, N. 1974. Trophic complexity in a littoral boulder-field. Limnol. and Oceanogr. 19(1):84-91.

Fukuyama, A. and J. Nybakken. 1983. Specialized feeding in mitrid gastropods: Evidence from a temperate species, Mitra idae. Melvill. Veliger 26(2):96-100.

Gerard, V.A. 1976. Some aspects of material dynamics and energy flow in a kelp forest in Monterey Bay, California. Ph.D. diss. Univ. of Calif., Santa Cruz. 173 pp.

Glass, G.V., P.D. Peckham, and J.R. Sanders. 1972. Consequences of failure to meet assumptions underlying the fixed effects analyses of variance and covariance. Rev. Educ. Res. 42:237-288.

Grigg, R.W. 1970. Ecology and population dynamics of the gorgonians, Muricea californica and Muricea fruticosa. Ph.D. diss. Univ. of Calif., San Diego. 261 pp.

Grigg, R.W. 1972. Orientation and growth form of sea fans. Limnol. and Oceanogr. 17:185-192.

Grigg, R.W. 1974. Growth rings: annual periodicity in two gorgonian corals. Ecology 55:876-881.

Grigg, R.W. 1975. Age structure of a longevous coral: a relative index of habitat suitability and stability. Am. Natur. 109:647-657.

Grigg, R.W. 1977. Population dynamics of two gorgonian corals. Ecology 58:278-290.

Harrold, C. and D.C. Reed. 1985. Food availability, sea urchin grazing, and kelp forest community structure. Ecology 66: 1160-1169.

Hyman, C.H. 1967. The Invertebrates. Vol. VI. Mollusca I. McGraw-Hill, New York. 792 pp.

Inman, D. 1987. A working hypothesis for the deposition of cohesive sediments offshore of the San Onofre Nuclear Generating Station (SONGS). Report submitted to the Marine Review Committee, Inc.

Irvine, G.V. 1973. The effect of selective feeding by two species of sea urchins. Amer. Zool. 13:1315. (cited in Lawrence 1975)

Lees, D.C. 1970. The relationship between movement and available food in the sea urchins Strongylocentrotus franciscanus and Strongylocentrotus purpuratus. M.S. thesis, Univ. of Calif., San Diego. 117 pp.

Leighton, D.L. 1960. Study of kelp-grazing organisms. In: Kelp investigations quarterly progress report. Univ. of Calif. Inst. Marine Resources, IMR Ref. 60-6, pp. 12-15.

Leighton, D.L. 1968. A comparative study of food selection and nutrition in the abalone Haliotis rufescens Swanson, and the sea urchin Strongylocentrotus purpuratus (Stimpson). Ph.D. diss. Univ. of Calif., San Diego. 197 pp.

Leighton, D.L. 1971. Grazing activities of benthic invertebrates in southern California kelp beds. In: W.J. North, ed. The biology of giant kelp beds (Macrocystis) in California. Nova Hedwigia 32:421-453.

Leighton, D.L., L.G. Jones, and W.J. North. 1966. Ecological relationships between giant kelp and sea urchins in southern California. In: E.G. Young and J.M. McLaughlin, eds. Proc. of the Fifth Int. Seaweed Symp. Pergammon Press, Oxford. pp. 141-153.

Mattison, J.E., J.D. Trent, A.L. Shanks, T.B. Akin, and J.S. Pearse. 1977. Movement and feeding activity of red sea urchins (Strongylocentrotus franciscanus) adjacent to a kelp forest. Mar. Biol. 39:25-30.

McLean, J.H. 1978. Marine shells of Southern California. Natural History Museum of Los Angeles County. Science Series 24, Revised Edition. 104 pp.

Morris, R.H., D.P. Abbott, and E.C. Haderlie. 1980. Intertidal invertebrates of California. Stanford Univ. Press, Stanford. 690 pp.

North, W.J. 1974. A review of the studies supporting sea urchin control as a means of restoring kelp beds. In: Kelp Habitat Improvement Proj. Ann. Rep. 1973-1974.

North, W.J. and J.S. Pearse. 1970. Sea urchin population explosion in southern California coastal waters. Science 167:209.

Osman, R.W., R.W. Day, J.A. Haugsness, J. Deacon, and C. Mann. 1981. The effects of the San Onofre Nuclear Generating Station on sessile invertebrate communities inhabiting hard substrata (including experimental panels). Final report of the Hard Benthos Project, Marine Science Institute, Univ. of Calif., Santa Barbara. Report submitted to the Marine Review Committee, Inc. dated May 1981.

Pearse, J.S. and A.H. Hines. 1979. Expansion of a central California kelp forest following the mass mortality of sea urchins. Mar. Biol. 51:83-91.

Perron, F. 1975. Carnivorous Calliostoma (Prosobranchia:Trochidae) from the northeastern Pacific. Veliger 18:52-54.

Reitzel, J., H. Elwany, M.R. Erdman, and K. Zabloudil. 1987. SONGS physical and chemical oceanography. Final report, Volume 11-2. Report submitted to the Marine Review Committee, Inc.

Rosenthal, R.J. 1970. Observations on the reproductive biology of the Kellet's whelk, Kelletia kelletii (Gastropoda : Neptuneidae). Veliger 12(3):319-324.

Rosenthal, R.J. 1971. Trophic interaction between the sea star Pisaster giganteus and the gastropod Kelletia kelletii. Fish. Bull. 69:669-679.

Rosenthal, R.J. and J.R. Chess. 1972. A predator-prey relationship between the leather star, Dermasterias imbricata, and the purple urchin, Strongylocentrotus purpuratus. Fish. Bull. 72:670-684.

Rosenthal, R.J., W.D. Clarke, and P.K. Dayton. 1974. Ecology and natural history of a stand of giant kelp, Macrocystis pyrifera, off Del Mar, California. Fish. Bull. 72:670-684.

Schmitt, R.J. 1982. Consequences of dissimilar defenses against predation in a subtidal marine community. Ecology 63:1599-1601.

Schroeter, S.C. 1988. Origin and biological effects of a cohesive, fine sediment in the San Onofre kelp forest. Report to the Marine Review Committee, Inc. In preparation.

Schroeter, S.C., J.D. Dixon, and J. Kastendiek. 1983. Effects of the starfish Patiria miniata on the distribution of the sea urchin Lytechinus anamesus in a southern California kelp forest. Oecologia 56:141-147.

Schroeter, S.C., J. D. Dixon, T.A. Dean, R.O. Smith, T.J. Herrlinger, L.E. Deysher, and F.R. Jacobsen. 1988a. Effects of the operation of SONGS Units 2 and 3 on patterns of kelp recruitment in the San Onofre kelp forest. Final report to the Marine Review Committee, Inc. dated February 16, 1988.

Schroeter, S.C., J.D. Dixon, J.E. Hose, and R.O. Smith. 1988b. Mass mortalities of sea stars in southern California caused by a new marine Vibrio. Unpublished manuscript.

Shaffer, J.A. 1986. The adult reproductive behavior and larval biology of Conus californicus. M.S. thesis, San Francisco State Univ., San Francisco.

Snedecor, G.W. and W.G. Cochran. 1967. Statistical methods. 7th ed. Iowa State Univ. Press, Ames. 507 pp.

Stewart-Oaten, A. 1986. The Before-After/Control-Impact-Pairs design for environmental impact assessment. Report to the Marine Review Committee, Inc. dated June 20, 1986.

Stewart-Oaten, A., W.W. Murdoch, and K.R. Parker. 1986. Environmental impact assessment: "pseudoreplication" in time? Ecology 67:929-940.

Tegner, M.J. and P.K. Dayton. 1987. El Nino effects on southern California kelp forest communities. Adv. Ecol. Res. 17:243-279.

TABLES

Table 1. Date and duration of benthic surveys.

SURVEY	BEGINNING DATE	ENDING DATE	MID DATE	SURVEY LENGTH (DAYS)	DAYS BETWEEN SURVEYS	DAYS BETWEEN STARTS
2	13NOV80	17NOV80	15NOV80	5	.	.
3	14JAN81	27JAN81	21JAN81	14	58	62
4	25MAR81	06APR81	31MAR81	13	57	70
5	08JUN81	17JUN81	13JUN81	10	63	75
6	21OCT81	05NOV81	29OCT81	16	126	135
7	26JAN82	02FEB82	30JAN82	8	82	97
8	22APR82	13MAY82	03MAY82	22	79	86
9	29JUL82	30AUG82	14AUG82	33	77	98
10	18NOV82	29NOV82	24NOV82	12	80	112
11	31MAR83	26APR83	13APR83	27	122	133
12[1]	19OCT83	11NOV83	31OCT83	24	176	202
13	24MAY84	05JUN84	30MAY84	13	183	218
14	06NOV84	27NOV84	17NOV84	22	154	166
15	05MAR85	22MAR85	14MAR85	18	98	119
16	24MAY85	04JUN85	30MAY85	12	63	80
17	02OCT85	18OCT85	10OCT85	17	120	131
18[2]	10FEB86	14FEB86	12FEB86	5	115	131
19[3]	03MAR86	07MAR86	05MAR86	5	136	152
20	27MAY86	13JUN86	05JUN86	18	81	85
21	05SEP86	11SEP86	08SEP86	7	84	101
22	01DEC86	05DEC86	03DEC86	5	81	87

Notes:

[1]No sample at SOKD; poor sea conditions.

[2]Aborted due to storms.

[3]Duration calculated from Survey 17.

Table 2. Sample size by period for the various species and substrates for which abundances were estimated as part of the study of the effects of SONGS on large benthic organisms.

SPECIES	PREOPERATIONAL PERIOD	INTERIM PERIOD	OPERATIONAL PERIOD
Porifera:			
Tethya aurantia	10	2	8
Cnidaria:			
Muricea californica	10	2	8
Muricea fruticosa	10	2	8
Mollusca:			
Astraea gibberosa	10	2	8
Astraea undosa	10	2	8
Bursa californica	2	2	8
Calliostoma spp.	2	2	8
Conus californicus	6	2	8
Crassispira semiinflata	5	2	8
Cypraea spadicea	10	2	8
Haliotis corrugata	10	2	8
Haliotis rufescens	10	2	8
Haliotis spp.	10	2	8
Hinnites giganteus	10	2	8
Kelletia kelletii	10	2	8
Maxwellia gemma	2	2	8
Megathura crenulata	10	2	8
Mitra idae	6	2	8
Murexiella santarosana	2	2	8
Nassarius spp.	2	1	8
Norrisia norrisi	10	2	8
Ocenebra spp.	2	2	8
Octopus spp.	2	2	8
Ophiodermella inermis	2	2	8
Pteropurpura festiva	2	2	8
Pteropurpura macroptera	2	2	8

Table 2 (cont.)

SPECIES	PREOPERATIONAL PERIOD	INTERIM PERIOD	OPERATIONAL PERIOD
Phaeophyta (cont):			
Pterygophora californica	10	2	8
Substrata:			
Bedrock	10	2	8
Reef	10	2	8
Boulder	10	2	8
Cobble + Pebble	10	2	8
Sand	10	2	8
Boulder >50 cm	8	2	8
Boulder 41-50 cm	8	2	8
Boulder 31-40 cm	8	2	8
Cobble 21-30 cm	8	2	8
Cobble 11-20 cm	8	2	8
Cobble 6-10 cm	8	2	8
Pebble 1-5 cm	8	2	8

Table 3. Substrate classification. (Wentworth scale taken from from Shepard, F. P. 1973. Submarine Geology, 3rd ed. N.Y.:Harper & Row.)

U.S.C. DESIGNATION	DIAMETER (MM)	PHI ($-LOG_2$(MM)	WENTWORTH SCALE
BOULDER			BOULDER
----------	300	-8.2	
	256	-8	----------
COBBLE	128	-7	COBBLE
	64	-6	----------
----------	50	-5.6	
	32	-5	
	16	-4	PEBBLE
PEBBLE	8	-3	
	4	-2	----------
	2	-1	GRANULE
----------	1	0	
	1/2	+1	
SAND	1/4	+2	SAND
	1/8	+3	
----------	1/16	+4	----------
	1/32	+5	
SILT	1/64	+6	SILT
	1/128	+7	
----------	1/256	+8	----------

Table 4. Date and duration of kelp recruitment surveys.

SURVEY	BEGINNING DATE	ENDING DATE	MID DATE	SURVEY LENGTH (DAYS)	DAYS BETWEEN SURVEYS	DAYS BETWEEN STARTS
1	21SEP81	20OCT81	06OCT81	30	.	.
2	15DEC81	18JAN82	01JAN82	35	56	85
3	24JUN82	27JUL82	11JUL82	34	157	191
4	06OCT82	28OCT82	17OCT82	23	71	104
5	09MAY83	27JUN83	03JUN83	50	193	215
6	25JUL83	19AUG83	07AUG83	26	28	77
7	28NOV83	30DEC83	14DEC83	33	101	126
8	17MAY84	05JUN84	27MAY84	20	139	171
9	02OCT84	30OCT84	16OCT84	29	119	138
10	28DEC84	14FEB85	21JAN85	49	59	87
11	01MAY85	15MAY85	08MAY85	15	76	124
12	09JUL85	02AUG85	21JUL85	25	55	69
13	29OCT85	17DEC85	23NOV85	50	88	112
14	21MAR86	04APR86	28MAR86	15	94	143
15	18JUN86	16JUL86	02JUL86	29	75	89
16	06NOV86	19NOV86	13NOV86	14	113	141

Table 5. Average density (number / m^2) of species selected for BACIP analysis. Species which were counted during two or more preoperational surveys and which had an average density in the San Onofre kelp forest of at least 1 / 10 m^2 on one or more surveys were selected for further analysis. Station means over all surveys during the preoperational and operational periods are tabulated.

	PREOPERATIONAL				OPERATIONAL			
	BK	SMK	SOKD	SOKU	BK	SMK	SOKD	SOKU
Astraea undosa	0.00	0.02	0.02	0.01	0.03	0.39	0.08	0.01
Calliostoma spp.	0.00	0.00	0.06	0.12	0.02	0.02	0.12	0.03
Conus californicus	0.60	0.66	2.91	4.41	1.65	1.75	1.67	1.11
Crassispira semiinflata	0.11	0.01	0.10	0.14	0.17	0.04	0.07	0.03
Cypraea spadicea	0.16	0.07	0.03	0.07	0.02	0.18	0.02	0.05
Kelletia kelletii	0.88	2.50	2.90	2.87	0.79	2.27	1.44	1.00
Lytechinus anamesus	3.89	0.44	7.89	8.35	1.58	13.06	34.90	15.61
Maxwellia gemma	0.06	0.22	0.20	0.75	0.23	0.40	0.11	0.10
Mitra idae	0.20	0.05	0.32	0.74	0.72	0.18	0.78	0.75
Murexiella santarosana	0.31	0.40	0.17	0.40	0.57	0.39	0.04	0.08
Muricea californica	4.76	5.04	0.21	0.17	8.65	7.01	5.27	1.51
Muricea fruticosa	1.93	0.85	0.01	0.02	2.79	1.36	0.27	0.12
Nassarius spp.	0.09	0.20	0.72	0.34	0.07	0.19	0.43	0.21
Ocenebra spp.	0.01	0.05	0.05	0.00	0.02	0.02	0.00	0.01
Patiria miniata	0.06	0.06	0.50	1.12	0.03	0.08	0.26	0.08
Phragmatopoma californica	0.00	0.03	0.02	0.03	0.04	1.00	0.85	0.12
Pisaster giganteus	0.03	0.14	0.00	0.03	0.01	0.04	0.01	0.01
Pteropurpura festiva	0.16	0.47	4.26	2.95	0.70	1.03	1.29	0.80

Table 5 (cont.)

	PREOPERATIONAL				OPERATIONAL			
	BK	SMK	SOKD	SOKU	BK	SMK	SOKD	SOKU
Strongylocentrotus franciscanus	0.12	1.05	0.19	0.04	0.04	1.20	0.00	0.05
S. purpuratus	0.17	1.37	0.05	0.14	0.03	1.60	0.06	0.08
Styela montereyensis	0.47	0.30	2.13	0.42	0.11	0.10	0.01	0.00
Tegula aureotincta	0.01	0.00	0.00	0.16	0.00	0.05	0.02	0.01
Tethya aurantia	0.20	0.04	0.02	0.12	0.13	0.01	0.03	0.07

Table 6. Effect of an urchin front at SMK on benthic invertebrates. A moving aggregation of red urchins was first noted grazing on the study transects in September 1986. Surveys conducted prior to that time are defined as "Before"; all others are "After". "Impact" quadrats are those that were affected by the urchin front; the unaffected quadrats are considered the "Control". Cases where P > 0.05 for the test of additivity and where P < 0.20 for the t-test are tabulated. N1 = number of surveys in the "Before" period; N2 = number of surveys in the "After" period.

TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION	AVERAGE DENSITY (NUMBER/SQ M) IMPACT BEFORE	IMPACT AFTER	CONTROL BEFORE	CONTROL AFTER	P>T
SPECIES = Astraea undosa										
LOG(X+.025)	12	2	.87	.38	NS	0.10	0.48	0.06	0.99	.14
SPECIES = Crassispira semiinflata										
LOG(X+.025)	3	2	.64	.51	UN	0.09	0.05	0.06	0.07	.14
SPECIES = Cypraea spadicea										
NONE	15	2	.47	.20	NS	0.09	0.15	0.12	0.35	.08
SPECIES = Murexiella santarosana										
LOG(X+.025)	8	1	.87	.72	NS	0.33	0.00	0.43	0.05	.
SPECIES = Nassarius spp.										
LOG(X+.025)	7	2	.67	.44	NS	0.19	0.10	0.16	0.00	.00
SPECIES = Pteropurpura festiva										
LOG(X+0)	7	2	.55	.90	NS	0.60	0.25	0.84	0.20	.17
SPECIES = Styela montereyensis										
LOG(X+.025)	16	2	.49	.59	NS	0.16	0.03	0.15	0.17	.07

Table 7. Effect of silt accumulation at SOKU on benthic invertebrates. Large deposits of silt were first noted in October 1985. Surveys prior to that time are defined as "Before"; all others are "After". "Impact" quadrats are those that had at least 25% cover of silt on one or more surveys; all others are "Control" quadrats. Cases where P > 0.05 for the test of additivity and where P < 0.20 for the t-test are tabulated. N1 = number of surveys in the "Before" period; N2 = number of surveys in the "After" period.

TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION	AVERAGE DENSITY (NUMBER/SQ M) IMPACT BEFORE	IMPACT AFTER	CONTROL BEFORE	CONTROL AFTER	P>T
			SPECIES = Conus californicus							
NONE	9	5	.19	.87	NS	3.40	0.41	4.08	0.39	.16
			SPECIES = Kelletia kelletii							
LOG(X+.025)	13	5	.16	.92	NS	1.87	0.39	2.24	1.13	.00
			SPECIES = Maxwellia gemma							
LOG(X+.025)	5	5	.59	.84	NS	0.28	0.01	0.31	0.07	.04
			SPECIES = Murexiella santarosana							
LOG(X+.025)	5	2	.57	.31	NS	0.25	0.03	0.14	0.13	.03
			SPECIES = Patiria miniata							
LOG(X+0)	12	2	.35	.14	NS	0.60	0.06	0.66	0.19	.00
			SPECIES = Tethya aurantia							
LOG(X+0)	12	4	.50	.90	NS	0.09	0.05	0.13	0.16	.00

Table 8. Results of the BACIP analysis on various species of snails. The average deltas in the preoperational and operational periods were compared with a t-test (P > T). The deltas are the differences in the mean densities of organisms at the impact and control stations on each survey. All quadrats were used in the analysis. N1, N2 = Sample sizes for "Before" and "After" periods, respectively. TREND = P-value for a test for a linear trend during the operational period. # = Test for serial correlation in preoperational data was significant.

SPECIES	CONTROL	TRANS-FORMATION	TREND	AVERAGE DENSITY (NUMBER/SQ M) IMPACT BEFORE	IMPACT AFTER	CONTROL BEFORE	CONTROL AFTER	P>T
Archeogastropoda								
Calliostoma spp.	SOKD	NONE	.26	0.13	0.04	0.06	0.14	.07
	SMK	NONE	.33	0.13	0.05	0.00	0.03	.13
	BK	NONE	.03	0.13	0.04	0.00	0.02	.03
Tegula aureotincta	SOKD	NONE	.77	0.16	0.02	0.00	0.04	.27
	SMK	NONE	.75	0.16	0.01	0.00	0.06	.24
	BK	NONE	.	0.16	0.03	0.01	0.00	.43
Mesogastropoda								
Cypraea spadicea	SOKD	LOG(X+0)	.34	0.09	0.04	0.04	0.05	.27
	SMK	LOG(X+0)	.39	0.07	0.04	0.06	0.15	.00
	BK	LOG(X+0)	.30	0.05	0.04	0.20	0.03	.02
Neogastropods								
Conus californica	SOKD	LOG(X+.025)	.40	4.23	0.64	2.72	0.86	.04
	SMK	LOG(X+.025)	.22	4.23	0.64	0.56	1.01	.00
	BK	NONE #	.46	4.41	1.11	0.60	1.65	.00
Crassispira semiinflata	SOKD	LOG(X+1)	.52	0.14	0.04	0.10	0.08	.11
	BK	NONE	.19	0.14	0.03	0.11	0.18	.05
Kelletia kelletii	SOKD	LOG(X+1)	.94	2.63	0.96	2.64	1.34	.07
	SMK	LOG(X+1)	.18	2.63	0.96	2.21	2.23	.00
	BK	LOG(X+1)	.08	2.51	0.96	0.82	0.75	.01
Maxwellia gemma	SOKD	NONE	.70	0.75	0.10	0.20	0.11	.00
	SMK	NONE	.16	0.75	0.10	0.23	0.39	.01
	BK	NONE	.60	0.75	0.10	0.06	0.23	.00
Mitra idae	SOKD	LOG(X+0)	.96	0.56	0.43	0.29	0.52	.08
	SMK	LOG(X+.025)	.07	0.57	0.46	0.04	0.14	.16
	BK	LOG(X+.025)	.03	0.57	0.46	0.13	0.55	.08

Table 8. (cont.)

SPECIES	CONTROL	TRANS-FORMATION	TREND	AVERAGE DENSITY (NUMBER/SQ M) IMPACT BEFORE	IMPACT AFTER	CONTROL BEFORE	CONTROL AFTER	P>T
Murexiella santarosana	SOKD	NONE	.08	0.40	0.09	0.18	0.05	.04
	SMK	NONE	.25	0.40	0.09	0.40	0.45	.06
	BK	NONE	.61	0.40	0.08	0.31	0.57	.08
Nassarius spp.	SOKD	NONE	.19	0.34	0.24	0.73	0.50	.72
	SMK	NONE	.56	0.34	0.21	0.20	0.19	.56
	BK	NONE	.28	0.34	0.21	0.09	0.08	.53
Ophiodermella inermis	SOKD	NONE	.32	0.06	0.06	0.08	0.02	.07
	SMK	NONE	.30	0.06	0.06	0.00	0.01	.72
	BK	NONE	.23	0.06	0.04	0.01	0.02	.24
Pteropurpura festiva	SOKD	NONE	.24	2.95	0.80	4.26	1.29	.85
	SMK	NONE	.31	2.95	0.80	0.48	1.03	.01
	BK	NONE	.78	2.95	0.80	0.16	0.70	.00

Table 9. Results of the BACIP analysis on various species of snails. The average deltas in the preoperational and operational periods were compared with a t-test (P > T). The deltas are the differences in the mean densities of organisms at the impact and control stations on each survey. Only quadrats not impacted by urchin fronts or heavy (>= 25% cover) deposits of silt were used in the analysis. N1, N2 = sample sizes for "Before" and "After" periods, respectively. TREND = P-value for a test for a linear trend during the operational period.

SPECIES	CONTROL	TRANS-FORMATION	TREND	AVERAGE DENSITY (NUMBER/SQ M) IMPACT BEFORE	IMPACT AFTER	CONTROL BEFORE	CONTROL AFTER	P>T
Archeogastropoda								
Calliostoma spp	SOKD	NONE	.32	0.17	0.03	0.07	0.15	.05
	SMK	NONE	.67	0.17	0.06	0.00	0.04	.07
	BK	NONE	.02	0.17	0.04	0.00	0.03	.02
Tegula aureotincta	SOKD	NONE	.12	0.28	0.01	0.00	0.05	.21
	SMK	NONE	.75	0.28	0.02	0.00	0.10	.04
Mesogastropoda								
Cypraea spadicea	SOKD	LOG(X+.025)	.19	0.11	0.07	0.03	0.02	.80
	SMK	LOG(X+1)	.63	0.13	0.09	0.10	0.19	.03
	BK	LOG(X+.025)	.52	0.08	0.09	0.09	0.02	.16
Neogastropoda								
Conus californica	SOKD	LOG(X+1)	.49	4.53	0.95	2.67	1.32	.00
	SMK	LOG(X+.025)	.34	4.48	0.60	0.58	0.86	.00
	BK	LOG(X+1)	.13	4.53	0.95	0.38	1.31	.00
Crassispira semiinflata	SOKD	LOG(X+1)	.86	0.14	0.02	0.10	0.08	.04
	SMK	LOG(X+1)	.99	0.14	0.03	0.01	0.07	.01
	BK	NONE	.45	0.14	0.01	0.11	0.18	.03
Kelletia kelletii	SOKD	LOG(X+1)	.31	2.83	1.27	2.71	1.43	.34
	SMK	LOG(X+0)	.26	2.53	1.24	2.07	2.03	.00
	BK	LOG(X+0)	.14	2.35	1.24	0.77	0.63	.31
Maxwellia gemma	SOKD	NONE	.76	0.78	0.13	0.19	0.12	.00
	SMK	NONE	.67	0.78	0.13	0.18	0.28	.01
	BK	NONE	.60	0.78	0.13	0.06	0.23	.00

Table 9. (cont.)

SPECIES	CONTROL	TRANS-FORMATION	TREND	AVERAGE DENSITY (NUMBER/SQ M) IMPACT BEFORE	IMPACT AFTER	CONTROL BEFORE	CONTROL AFTER	P>T
Mitra idae	SOKD	LOG(X+.025)	.85	0.67	0.33	0.29	0.56	.04
	BK	LOG(X+.025)	.11	0.67	0.33	0.13	0.55	.05
Murexiella santarosana	SOKD	NONE	.48	0.39	0.08	0.16	0.05	.08
	SMK	NONE	.14	0.39	0.08	0.40	0.51	.06
	BK	NONE	.73	0.39	0.07	0.32	0.58	.10
Nassarius spp.	SOKD	NONE	.13	0.36	0.15	0.70	0.51	.96
	SMK	NONE	.15	0.36	0.18	0.13	0.24	.08
	BK	NONE	.87	0.36	0.13	0.06	0.07	.50
Ophiodermella inermis	SOKD	NONE	.08	0.03	0.08	0.08	0.02	.10
Pteropurpura festiva	SOKD	NONE	.14	4.03	0.91	4.53	1.33	.99
	SMK	NONE	.26	4.03	0.91	0.40	1.15	.00
	BK	NONE	.41	4.03	0.91	0.17	0.71	.00

Table 10. Results of the BACIP analysis on various invertebrates other than snails. The average deltas in the preoperational and operational periods were compared with a t-test (P > T). The deltas are the differences in the mean densities of organisms at the impact and control stations on each survey. All quadrats were used in the analysis. N1, N2 = Sample sizes for "Before" and "After" periods, respectively. TREND = P-value for a test for a linear trend during the operational period. # = Test for serial correlation in preoperational data was significant.

SPECIES	CONTROL	TRANS-FORMATION	TREND	AVERAGE DENSITY (NUMBER/SQ M) IMPACT BEFORE	IMPACT AFTER	CONTROL BEFORE	CONTROL AFTER	P>T
Sponges								
Tethya aurantia	SOKD	LOG(X+0)	.75	0.10	0.06	0.04	0.03	.46
	SMK	LOG(X+1)	.68	0.12	0.07	0.04	0.01	.78
	BK	NONE	.80	0.13	0.08	0.20	0.13	.46
Gorgonians								
Muricea californica	SMK	LOG(X+.025)	.00	0.17	1.10	4.99	6.86	.00
Muricea fruticosa	SOKD	NONE	.27	0.03	0.13	0.03	0.27	.04
	BK	LOG(X+0)	.31	0.03	0.18	1.83	2.83	.00
Sea Urchins								
Strongylocentrotus purpuratus	SOKD	NONE	.73	0.14	0.08	0.05	0.06	.05
	SMK	LOG(X+.025)	.00	0.13	0.06	1.29	1.12	.36
Lytechinus anamesus	SOKD	NONE #	.10	8.35	15.61	7.89	34.90	.00
	SMK	LOG(X+1)#	.00	7.68	15.37	0.35	10.41	.00
	BK	NONE	.02	8.64	15.61	3.89	1.58	.00
Tunicates								
Styela montereyensis	SOKD	LOG(X+.025)	.	0.30	0.01	1.37	0.02	.39
	BK	LOG(X+.025)	.19	0.29	0.00	0.41	0.12	.01

Table 11. Results of the BACIP analysis on various invertebrates other than snails. The average deltas in the preoperational and operational periods were compared with a t-test (P > T). The deltas are the differences in the mean densities of organisms at the impact and control stations on each survey. Only quadrats not impacted by urchin fronts or heavy (>= 25% cover) deposits of silt were used in the analysis. N1, N2 = sample sizes for "Before" and "After" periods, respectively. TREND = P-value for a test for a linear trend during the operational period.

SPECIES	CONTROL	TRANS-FORMATION	TREND	AVERAGE DENSITY (NUMBER/SQ M) IMPACT BEFORE	IMPACT AFTER	CONTROL BEFORE	CONTROL AFTER	P>T
Tethya aurantia	SOKD	LOG(X+0)	.52	0.13	0.12	0.05	0.03	.62
	SMK	LOG(X+1)	.22	0.14	0.13	0.06	0.01	.21
	BK	NONE	.94	0.15	0.12	0.20	0.13	.31
Muricea californica	SMK	LOG(X+0)	.00	0.32	1.73	5.53	6.86	.00
	BK	LOG(X+1)	.00	0.32	1.90	4.87	8.51	.07
Strongylocentrotus purpuratus	SOKD	LOG(X+1)	.04	0.20	0.02	0.05	0.07	.00
	SMK	LOG(X+.025)	.26	0.18	0.01	0.67	0.78	.00
	BK	LOG(X+1)	.41	0.21	0.03	0.16	0.04	.35
Lytechinus anamesus	SOKD	NONE	-.24	9.21	21.49	8.51	37.00	.00
	SMK	LOG(X+0)	.02	9.18	21.38	0.18	10.76	.00
	BK	NONE	.30	9.65	21.49	3.99	1.59	.00
Styela montereyensis	BK	LOG(X+.025)	.11	0.44	0.00	0.40	0.12	.00

Table 12. Comparison of density estimates at the benthic survey station (SOKU) and at the kelp recruitment stations in the upcoast, offshore portion of the San Onofre kelp forest.

SPECIES	DATE	KELP SURVEY	BENTHIC SURVEY	T	P > T
Calliostoma spp.	1981	.	.	.	.
	1986	0.17	0.00	0.37	0.187
Conus californicus	1981	0.44	3.93	0.83	0.000
	1986	2.18	0.07	0.51	0.023
Crassispira semiinflata	1981	.	.	.	.
	1986	0.05	0.00	0.00	0.331
Cypraea spadicea	1981	0.22	0.03	0.96	0.059
	1986	0.06	0.02	0.50	0.620
Kelletia kelletii	1981	2.44	2.78	0.60	0.551
	1986	0.56	0.77	0.82	0.414
Lytechinus anamesus	1981	12.07	3.03	0.47	0.154
	1986	14.94	13.07	0.31	0.758
Maxwellia gemma	1981	.	.	.	.
	1986	0.11	0.02	0.07	0.295
Mitra idae	1981	0.07	0.15	0.99	0.326
	1986	0.22	0.17	0.35	0.730
Murexiella santarosana	1981	.	.	.	.
	1986	0.00	0.00	.	.
Muricea californica	1981	0.30	0.23	0.40	0.687
	1986	3.11	0.45	0.48	0.023
Muricea fruticosa	1981	0.11	0.03	0.01	0.320
	1986	0.22	0.00	0.20	0.041
Nassarius spp.	1981	.	.	.	.
	1986	0.11	0.12	0.10	0.917
Patiria miniata	1981	0.93	0.75	0.55	0.582
	1986	0.17	0.07	0.92	0.367
Pteropurpura festiva	1981	.	.	.	.
	1986	1.39	0.80	0.35	0.188
Strongylocentrotus purpuratus	1981	0.04	0.13	0.98	0.330
	1986	0.06	0.05	0.07	0.941
Tegula aureotincta	1981	.	.	.	.
	1986	0.00	0.00	.	.
Tethya aurantia	1981	0.04	0.10	0.04	0.303
	1986	0.06	0.10	0.55	0.585

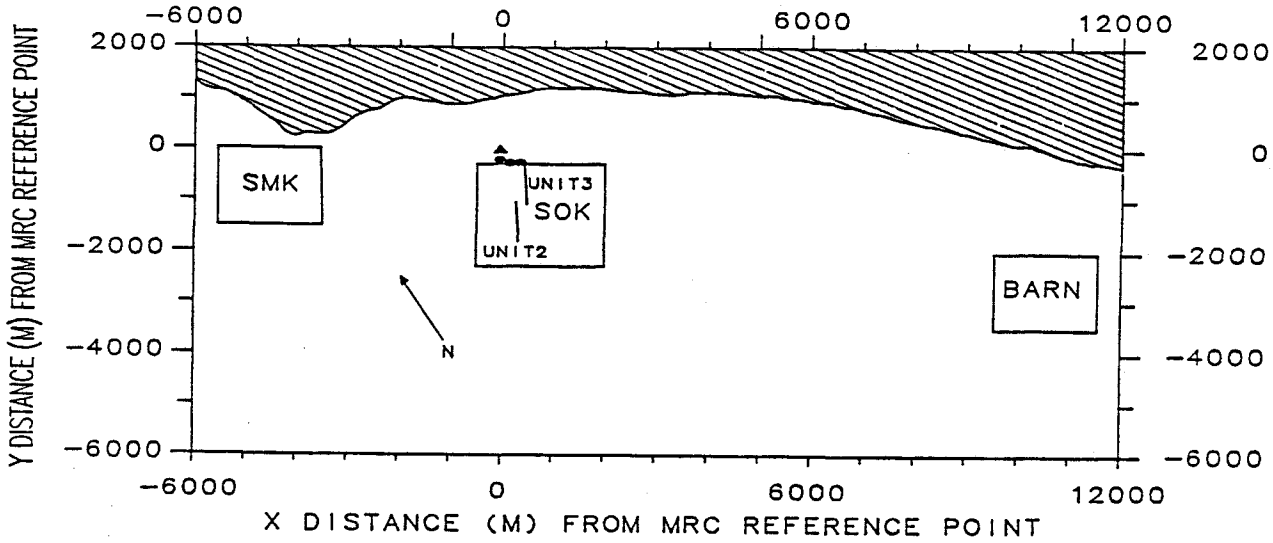
Table 13. Comparison of density estimates at the benthic survey station (SOKD) and at the kelp recruitment stations in the downcoast, offshore portion of the San Onofre kelp forest.

SPECIES	DATE	KELP SURVEY	BENTHIC SURVEY	T	P > T
Calliostoma spp.	1981	.	.	.	.
	1986	0.00	0.00	.	.
Conus californicus	1981	0.50	1.66	0.38	0.001
	1986	1.67	0.35	0.21	0.038
Crassispira semiinflata	1981	.	.	.	.
	1986	0.00	0.05	0.43	0.160
Cypraea spadicea	1981	0.00	0.00	.	.
	1986	0.05	0.05	0.08	0.931
Kelletia kelletii	1981	1.22	2.16	0.79	0.079
	1986	1.22	1.15	0.16	0.877
Lytechinus anamesus	1981	19.00	10.61	0.29	0.203
	1986	19.55	35.87	0.27	0.026
Maxwellia gemma	1981	.	.	.	.
	1986	0.05	0.00	0.00	0.331
Mitra idae	1981	0.17	0.26	0.55	0.580
	1986	0.28	0.15	0.69	0.500
Murexiella santarosana	1981	.	.	.	.
	1986	0.00	0.00	.	.
Muricea californica	1981	0.00	0.18	0.89	0.006
	1986	1.67	2.85	0.67	0.101
Muricea fruticosa	1981	0.00	0.00	.	.
	1986	0.00	0.17	0.48	0.018
Nassarius spp.	1981	.	.	.	.
	1986	0.05	0.02	0.50	0.620
Patiria miniata	1981	0.22	0.39	0.91	0.367
	1986	0.11	0.27	0.29	0.201
Pteropurpura festiva	1981	.	.	.	.
	1986	1.11	1.47	0.52	0.605
Strongylocentrotus purpuratus	1981	0.00	0.00	.	.
	1986	0.00	0.00	.	.
Tegula aureotincta	1981	.	.	.	.
	1986	0.00	0.00	.	.
Tethya aurantia	1981	0.00	0.03	0.00	0.324
	1986	0.00	0.00	.	.

Table 14. Comparison of density estimates at the benthic survey station (SMK) and at the kelp recruitment stations in the San Mateo kelp forest. The two kelp recruitment stations which were located in a white urchin barrens were not included in the analysis.

SPECIES	DATE	KELP SURVEY	BENTHIC SURVEY	T	P > T
Conus californicus	1981	0.46	0.30	0.87	0.391
	1986	0.40	0.15	0.13	0.275
Crassispira semiinflata	1981	.	.	.	.
	1986	0.13	0.00	0.00	0.334
Cypraea spadicea	1981	0.17	0.08	0.72	0.478
	1986	0.20	0.15	0.33	0.740
Kelletia kelletii	1981	0.17	2.32	0.29	0.025
	1986	0.60	1.87	0.75	0.000
Lytechinus anamesus	1981	5.75	0.40	0.95	0.063
	1986	24.53	8.30	0.70	0.016
Maxwellia gemma	1981	.	.	.	.
	1986	0.20	0.17	0.19	0.847
Mitra idae	1981	0.00	0.02	0.00	0.323
	1986	0.13	0.07	0.49	0.624
Murexiella santarosana	1981	.	.	.	.
	1986	0.13	0.20	0.44	0.665
Muricea californica	1981	2.42	4.47	0.45	0.016
	1986	3.60	5.65	0.95	0.057
Muricea fruticosa	1981	0.58	0.82	0.88	0.380
	1986	0.80	1.15	0.93	0.355
Nassarius spp.	1981	.	.	.	.
	1986	0.00	0.05	0.43	0.160
Patiria miniata	1981	0.37	0.07	0.53	0.138
	1986	0.47	0.17	0.18	0.254
Pteropurpura festiva	1981	.	.	.	.
	1986	0.47	0.05	0.10	0.052
Strongylocentrotus purpuratus	1981	0.92	0.90	0.02	0.980
	1986	5.20	1.50	0.67	0.115
Tegula aureotincta	1981	.	.	.	.
	1986	0.00	0.00	.	.
Tethya aurantia	1981	0.13	0.05	0.97	0.338
	1986	0.00	0.03	0.00	0.324

FIGURES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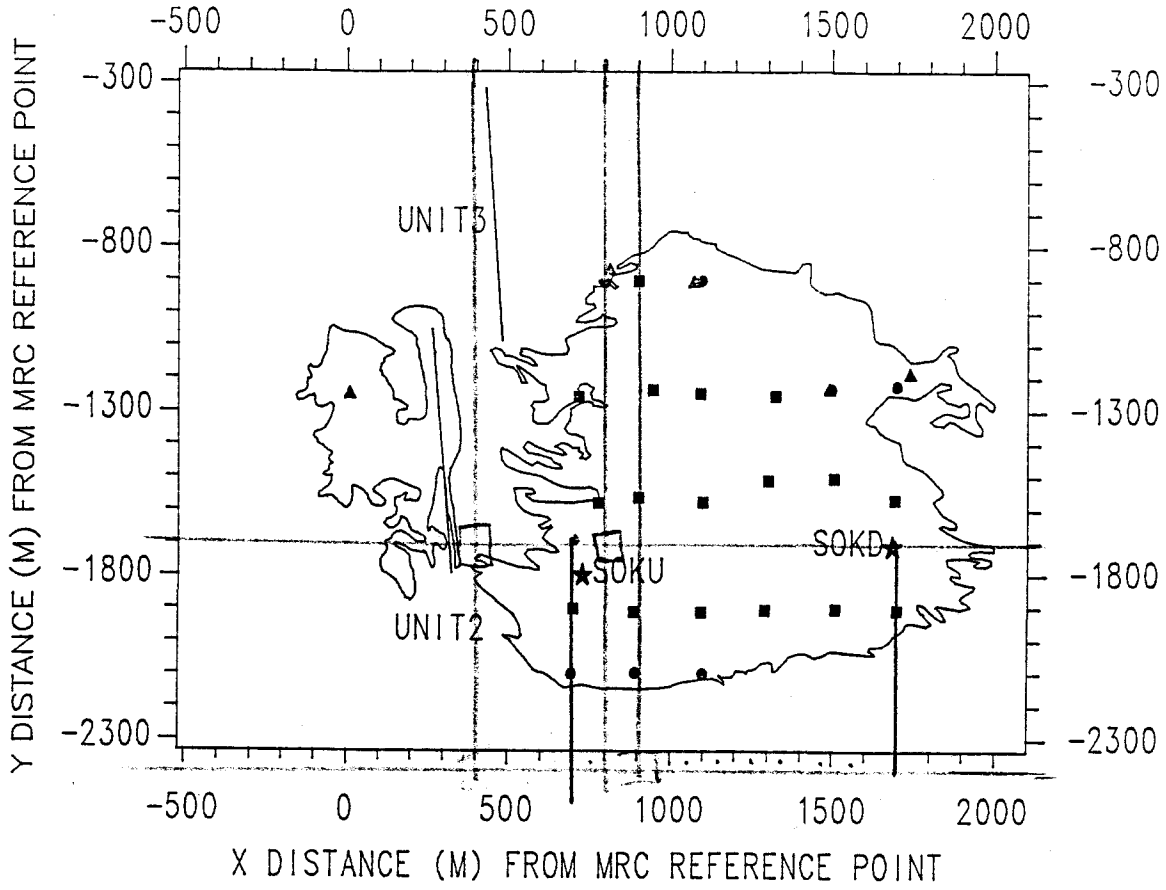
UNIT3
SOK
UNIT2
BARN
N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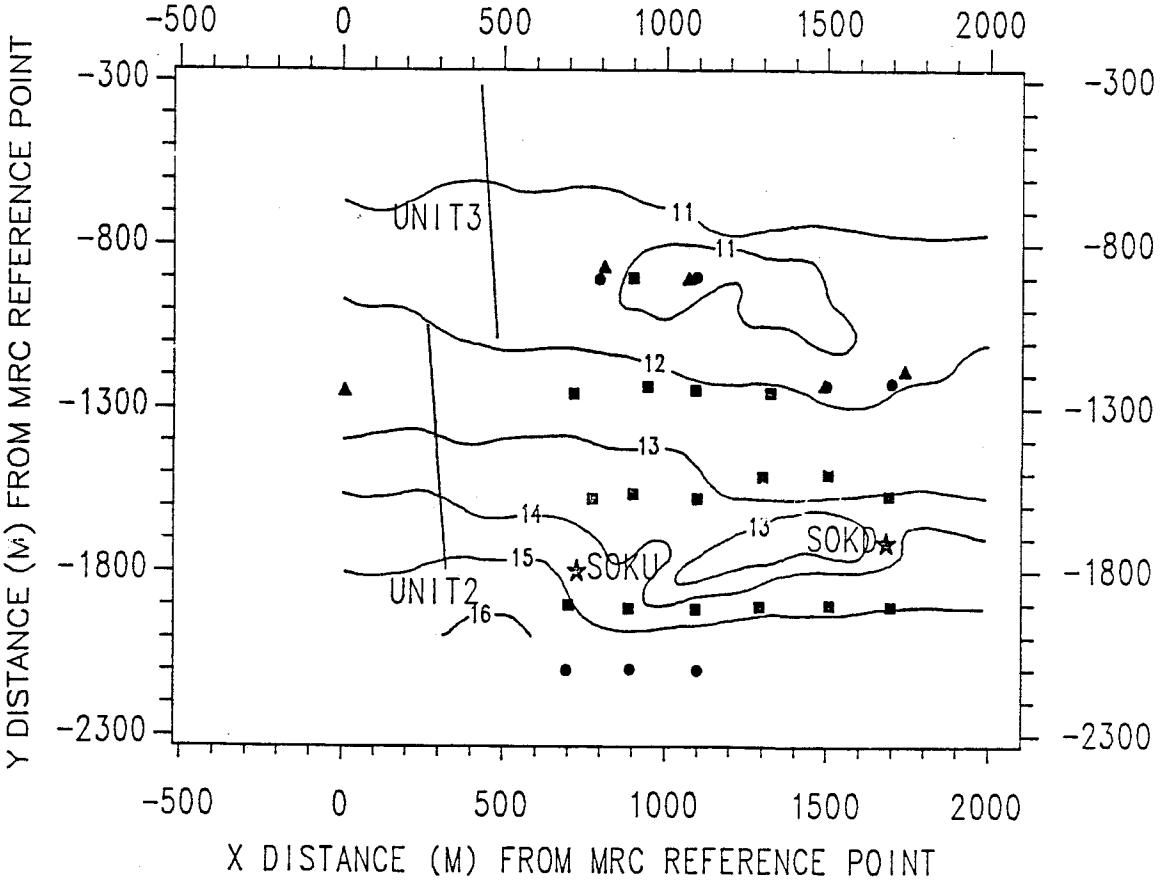
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UNIT3
UNIT2
SOKU
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12
13
13
14
15
16
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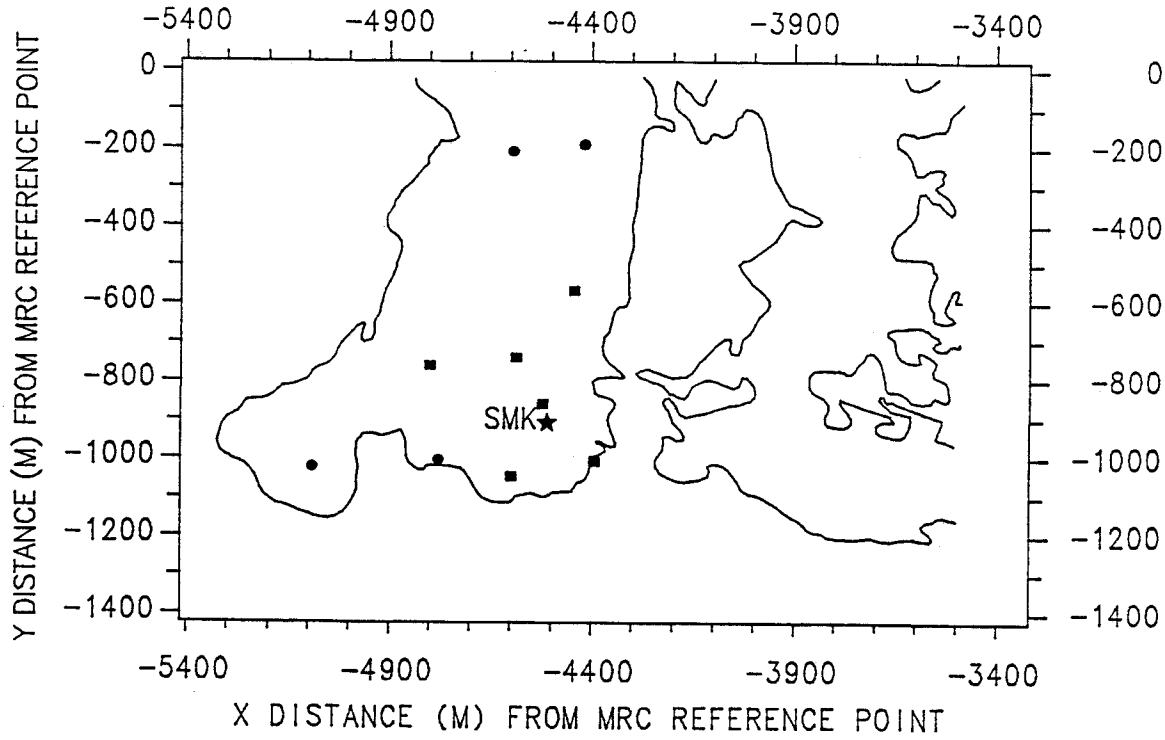
X DISTANCE (M) FROM MRC REFERENCE POINT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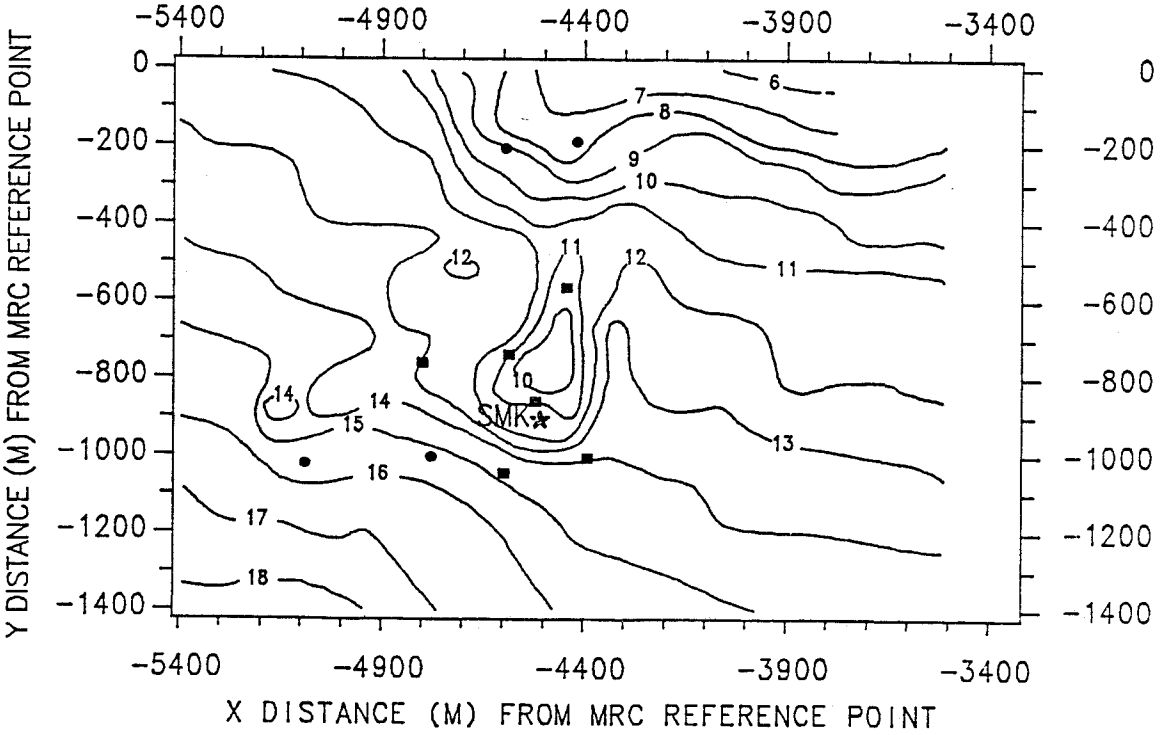
X DISTANCE (M) FROM MRC REFERENCE POINT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8
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SMK
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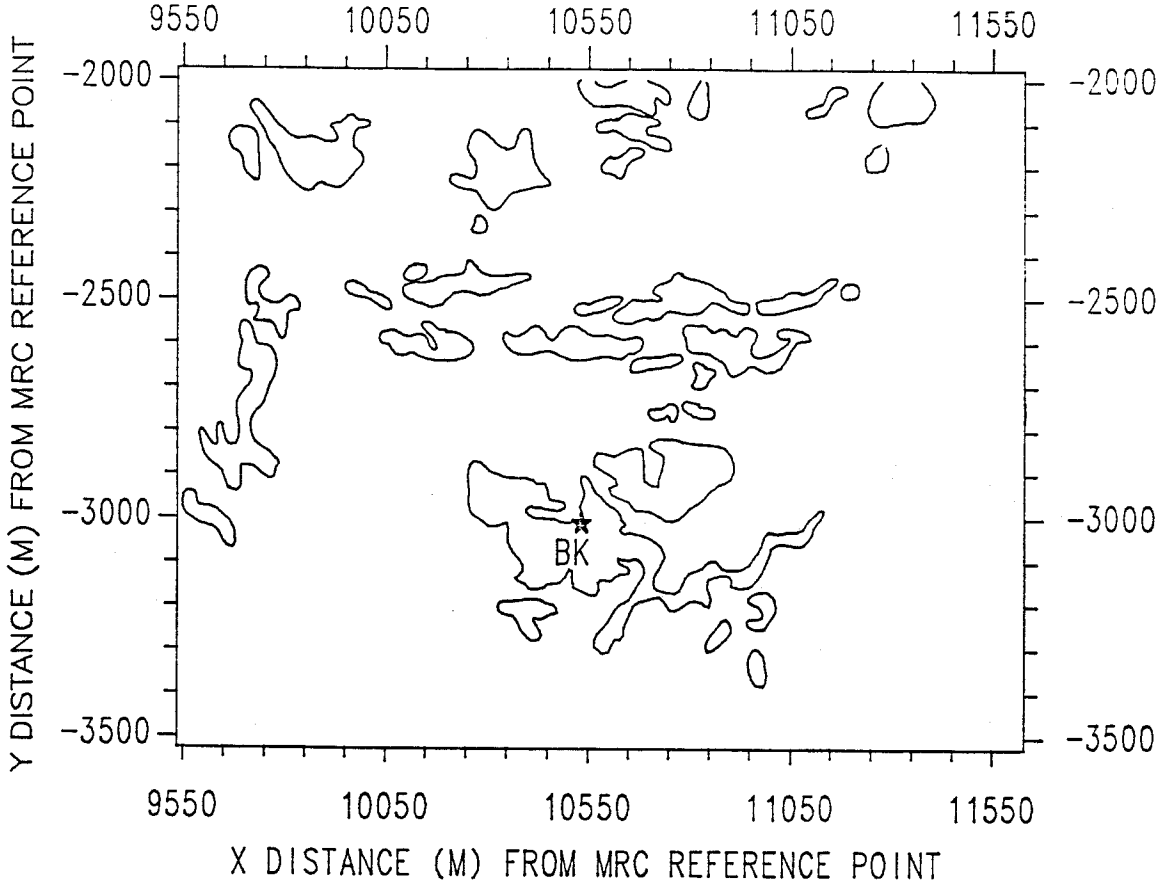
X DISTANCE (M) FROM MRC REFERENCE POINT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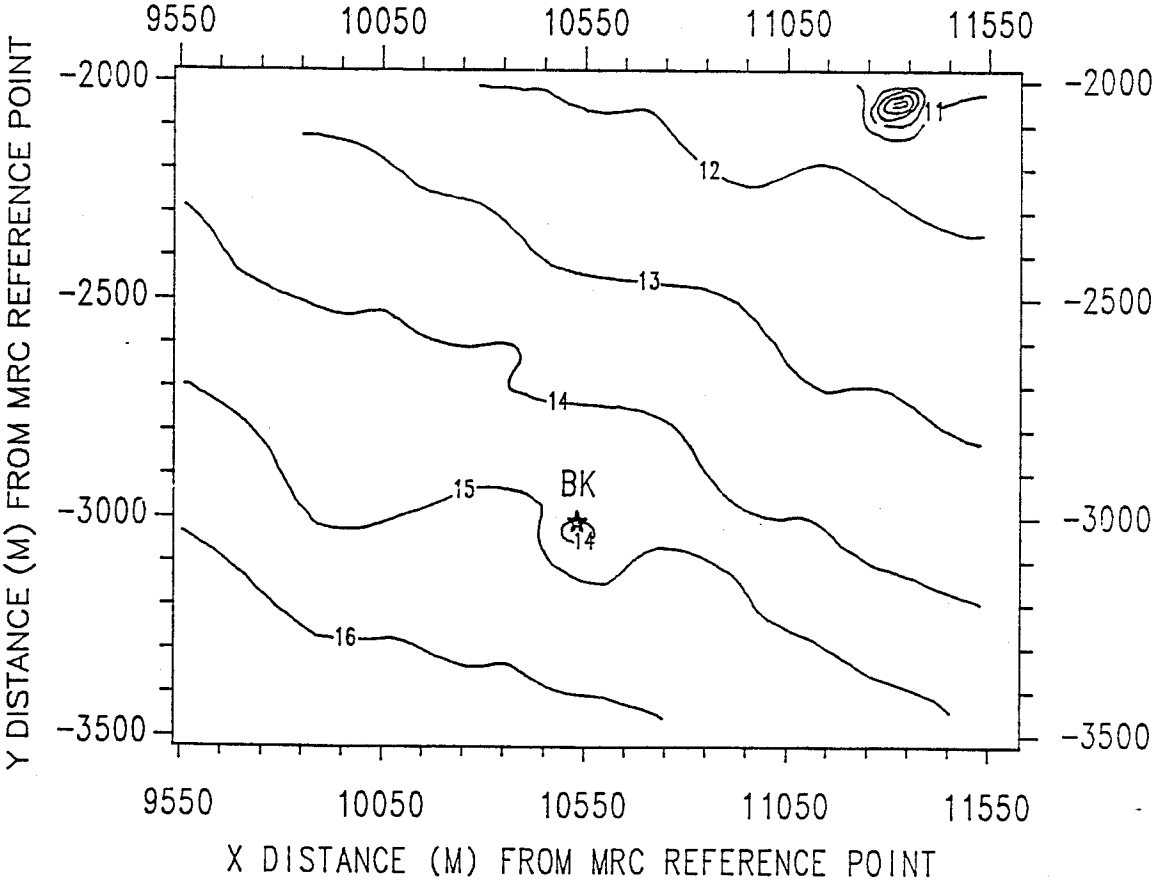
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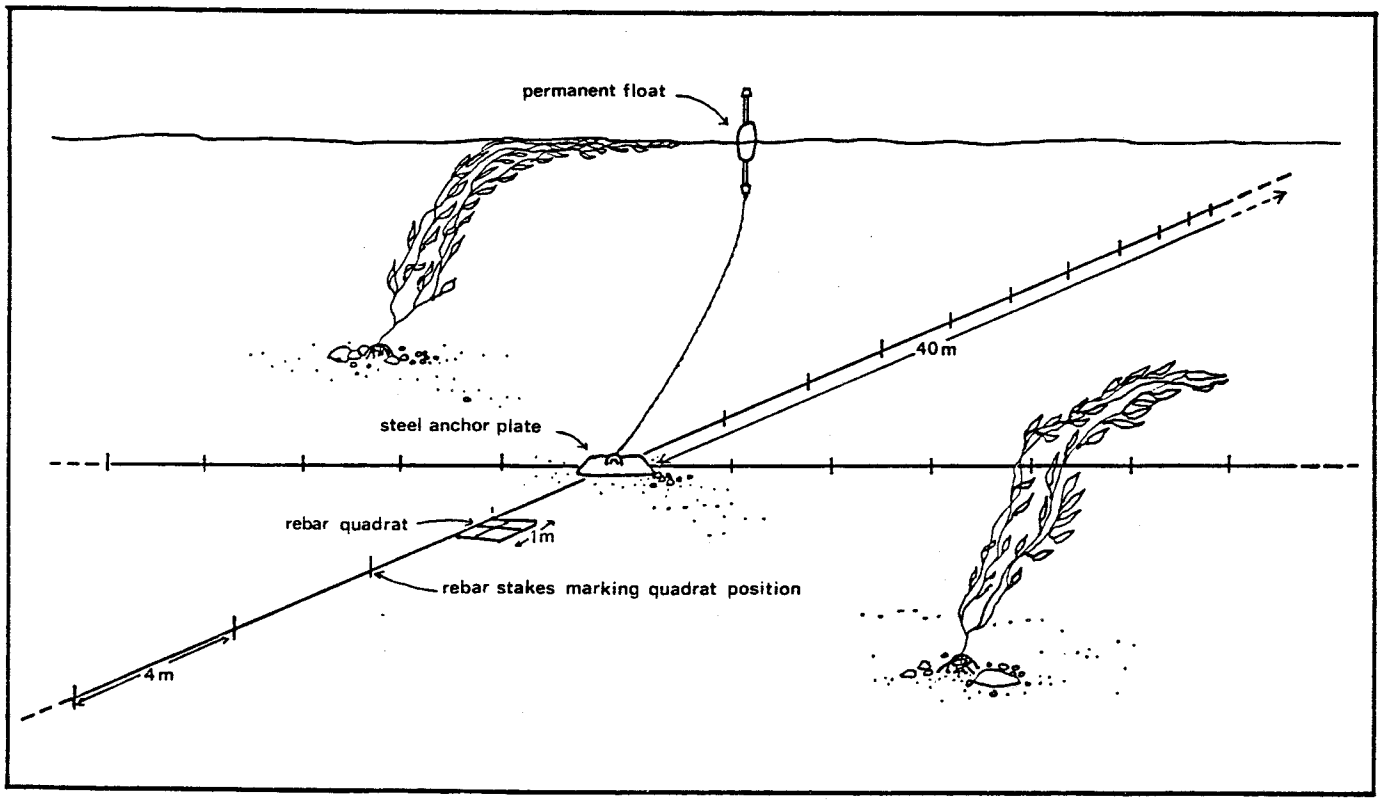
X DISTANCE (M) FROM MRC REFERENCE POINT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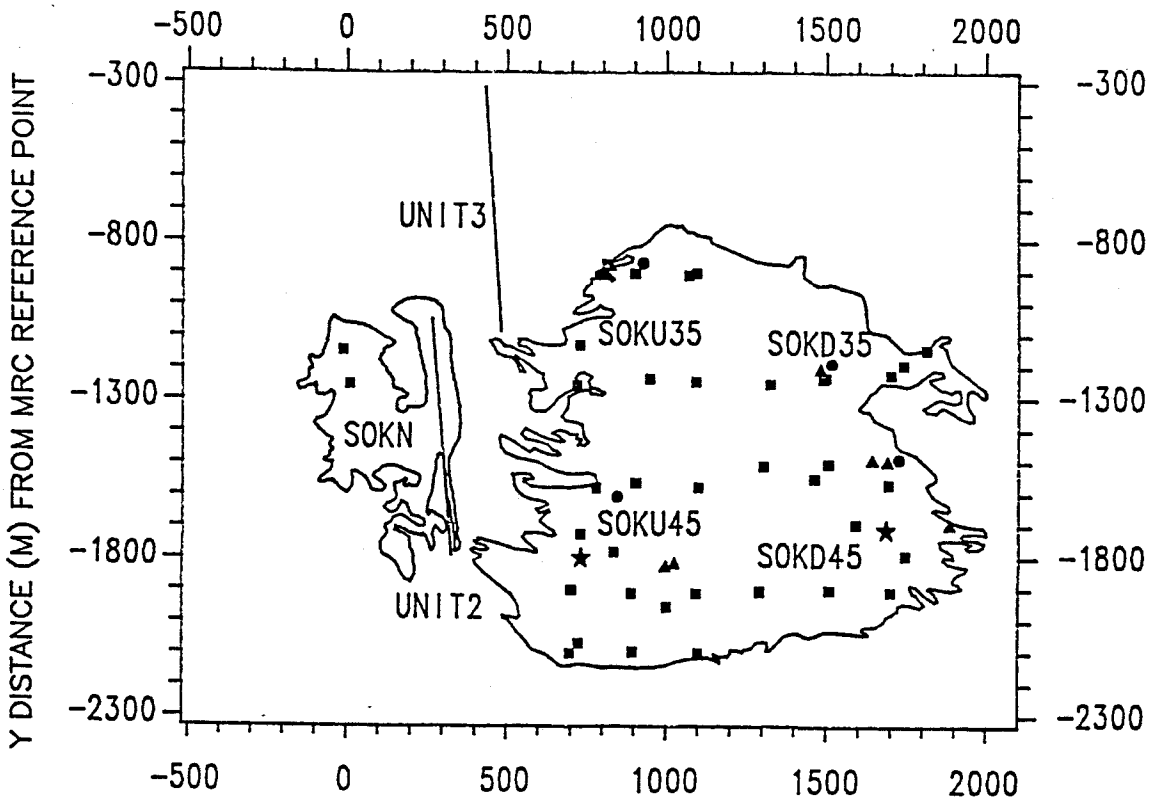
40m
steel anchor plate
rebar quadrat
1m
rebar stakes marking quadrat position
4m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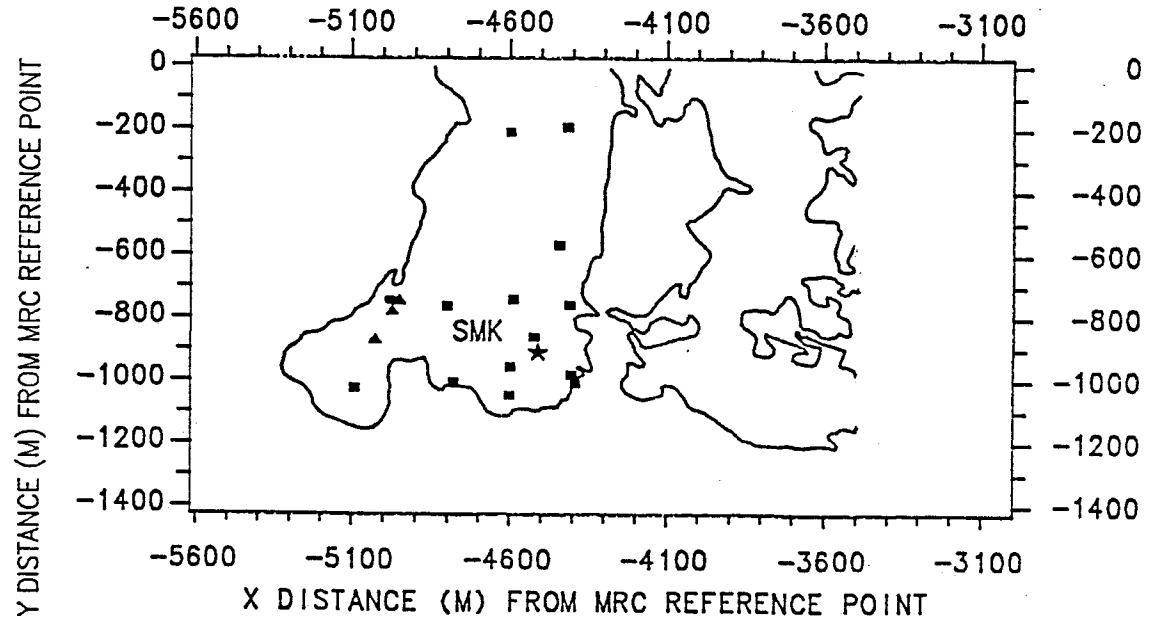
SOKU35
SOKD35
SOKN
SOKU45
SOKD45
UNIT2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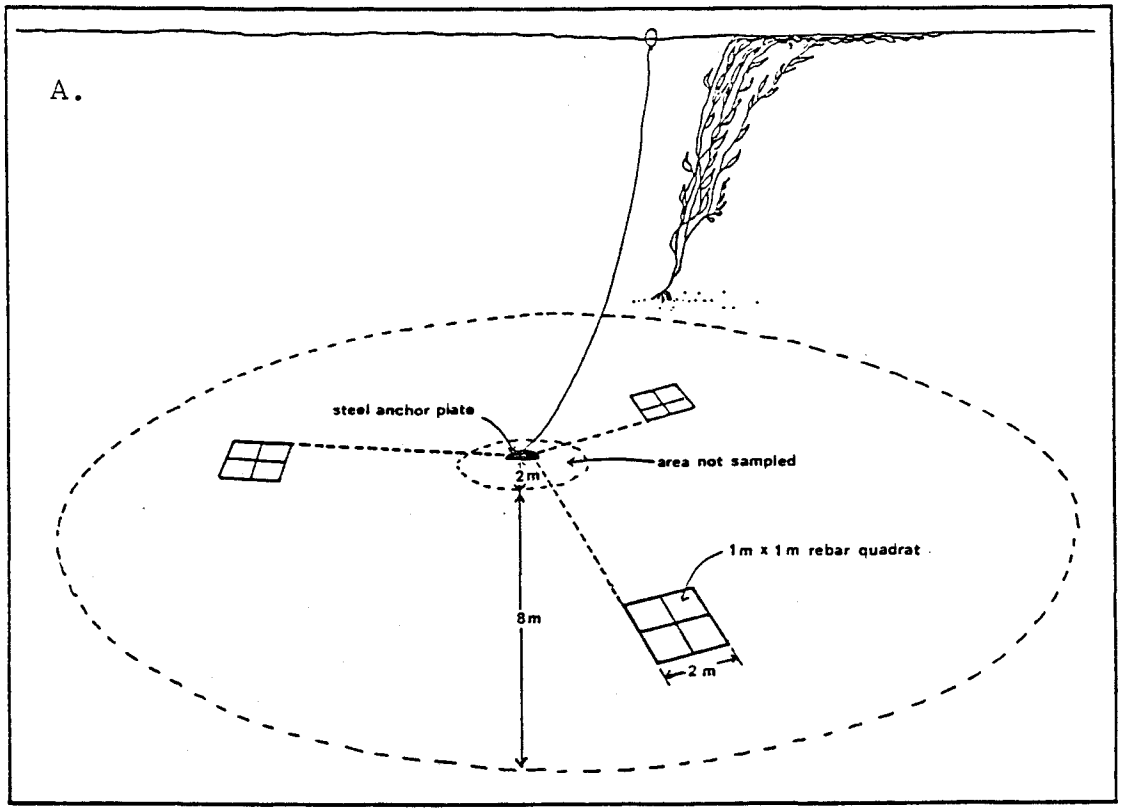
Y DISTANCE (M) FROM MRC REFERENCE POINT
SMK
X DISTANCE (M) FROM MRC REFERENCE POINT
PHYSICAL/CHEM.
BENTHIC SURVEY
KELP RECRUITMENT
CLEARING EXP.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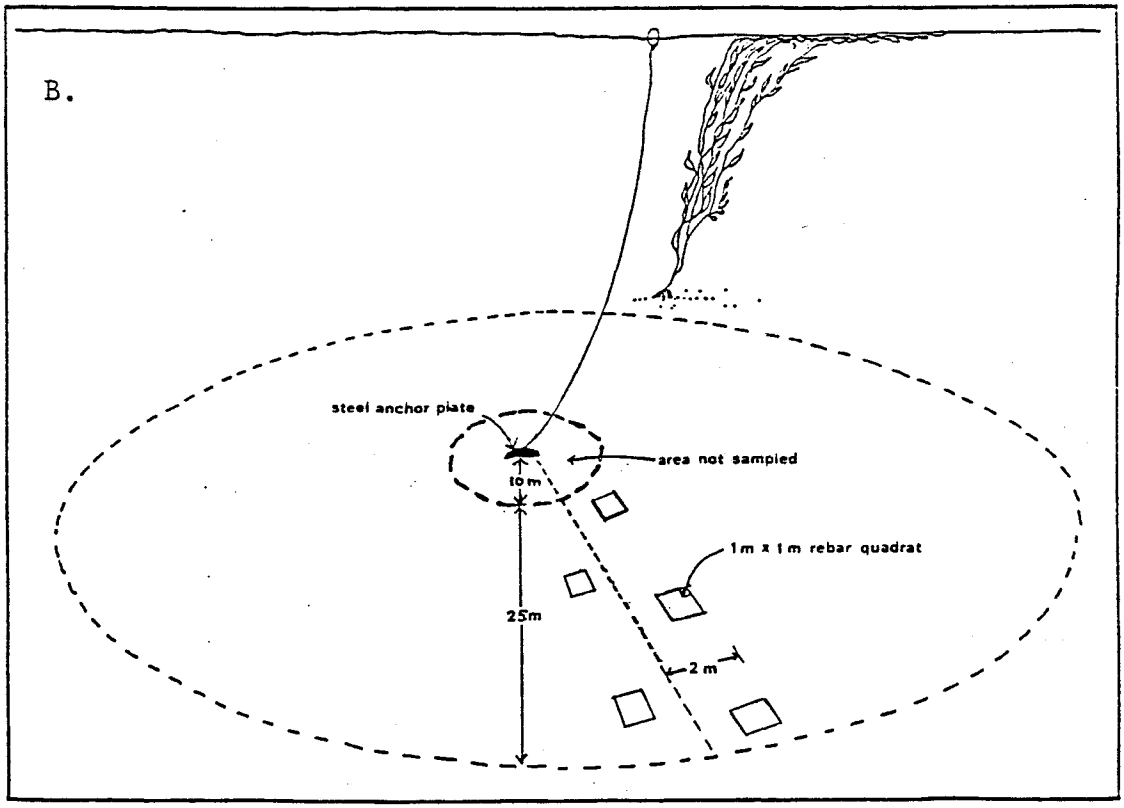
1m x 1m rebar quadrat
8m
2 m


B.
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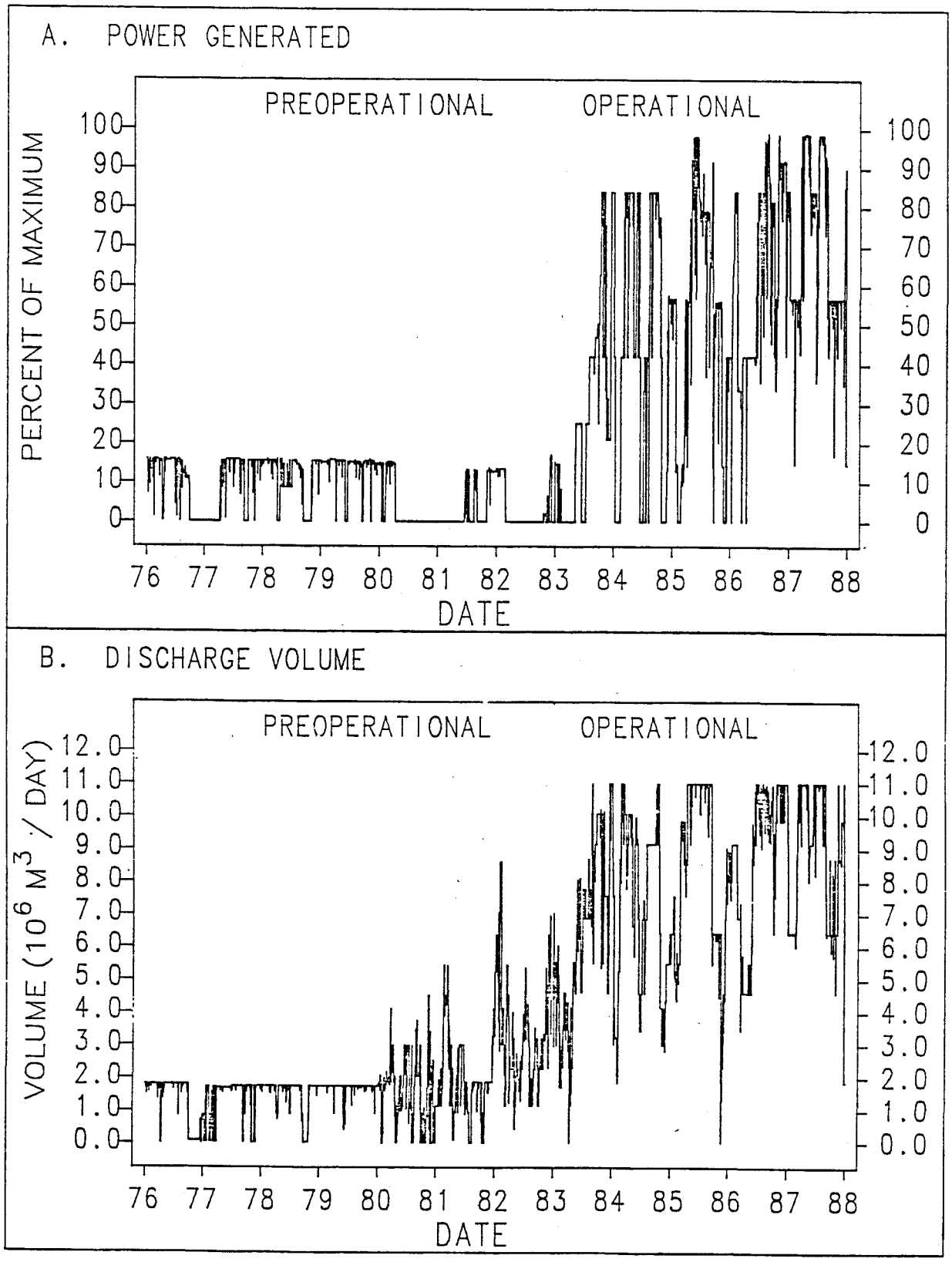
area not sampled
10m
1m x 1m rebar quadrat
25m
2 m

OPERATING HISTORY: UNITS 1+2+3



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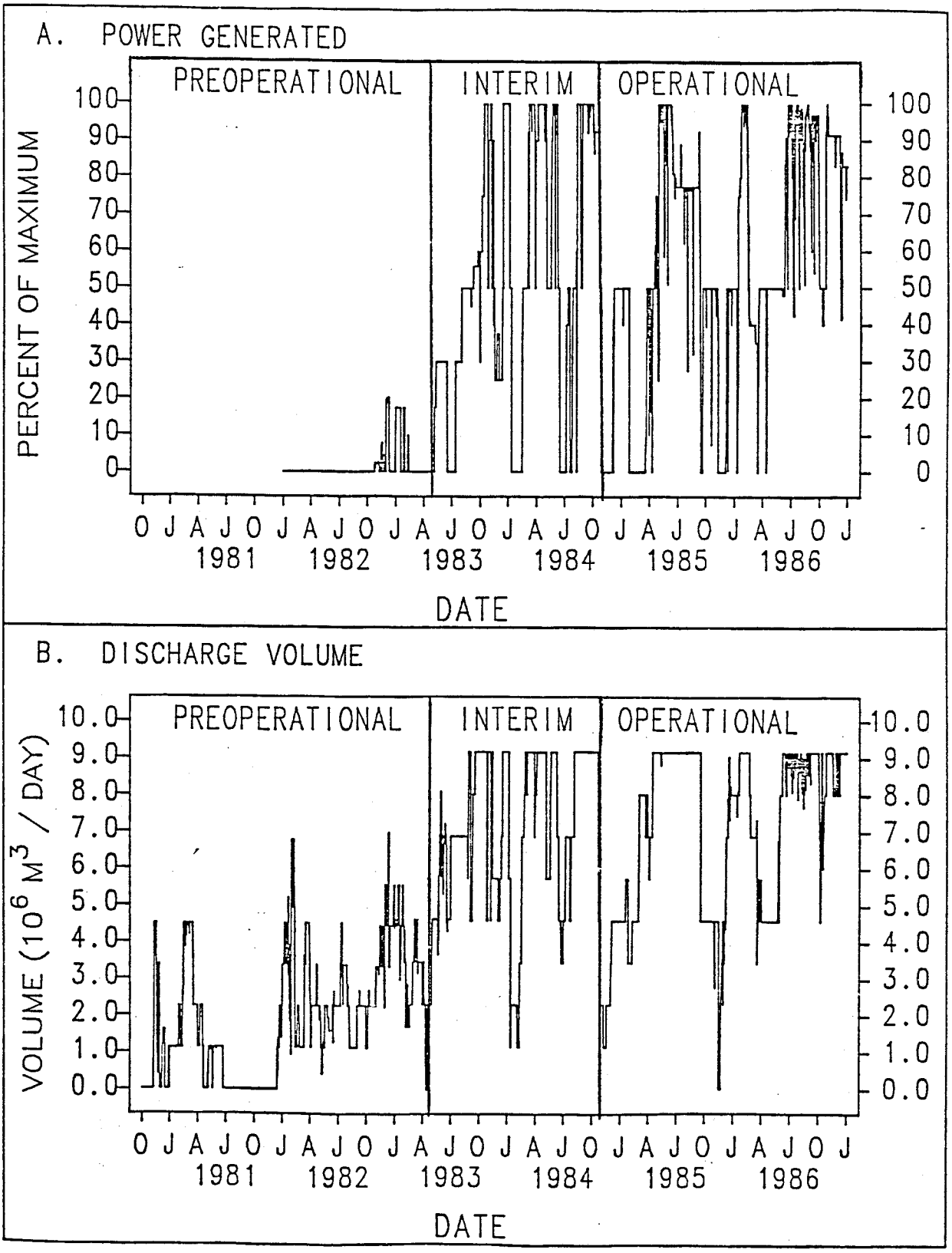

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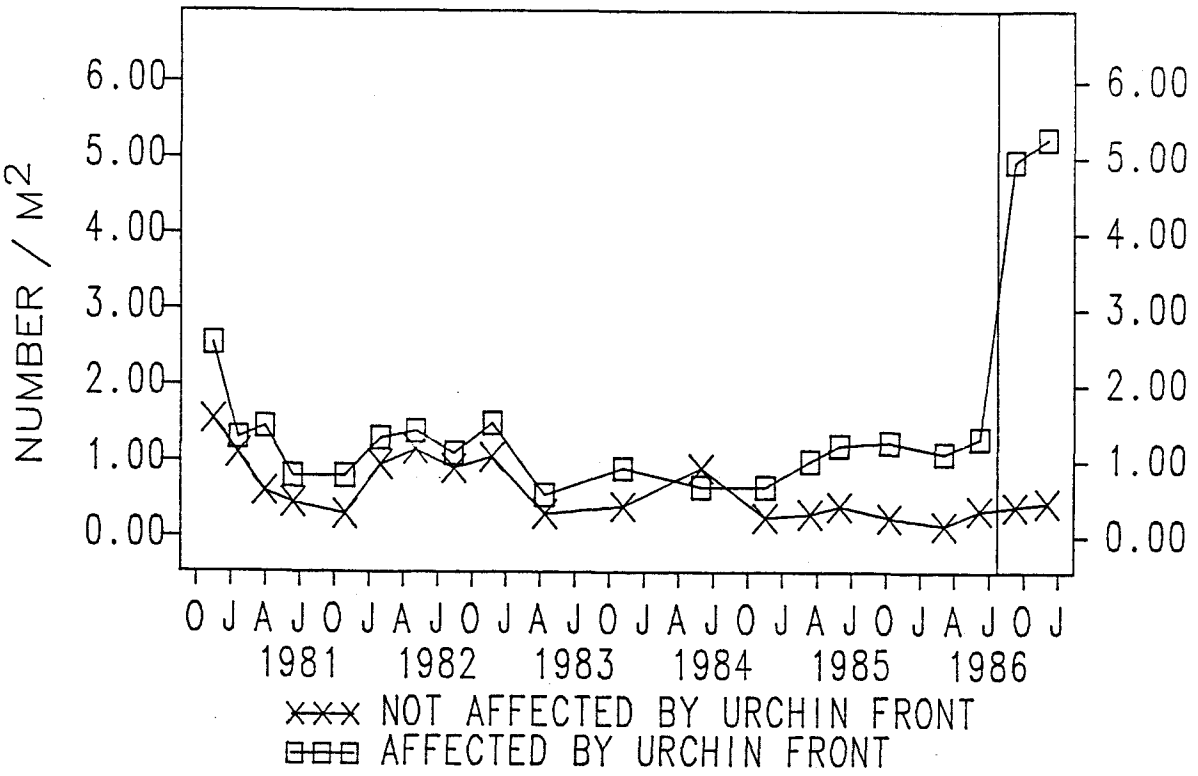
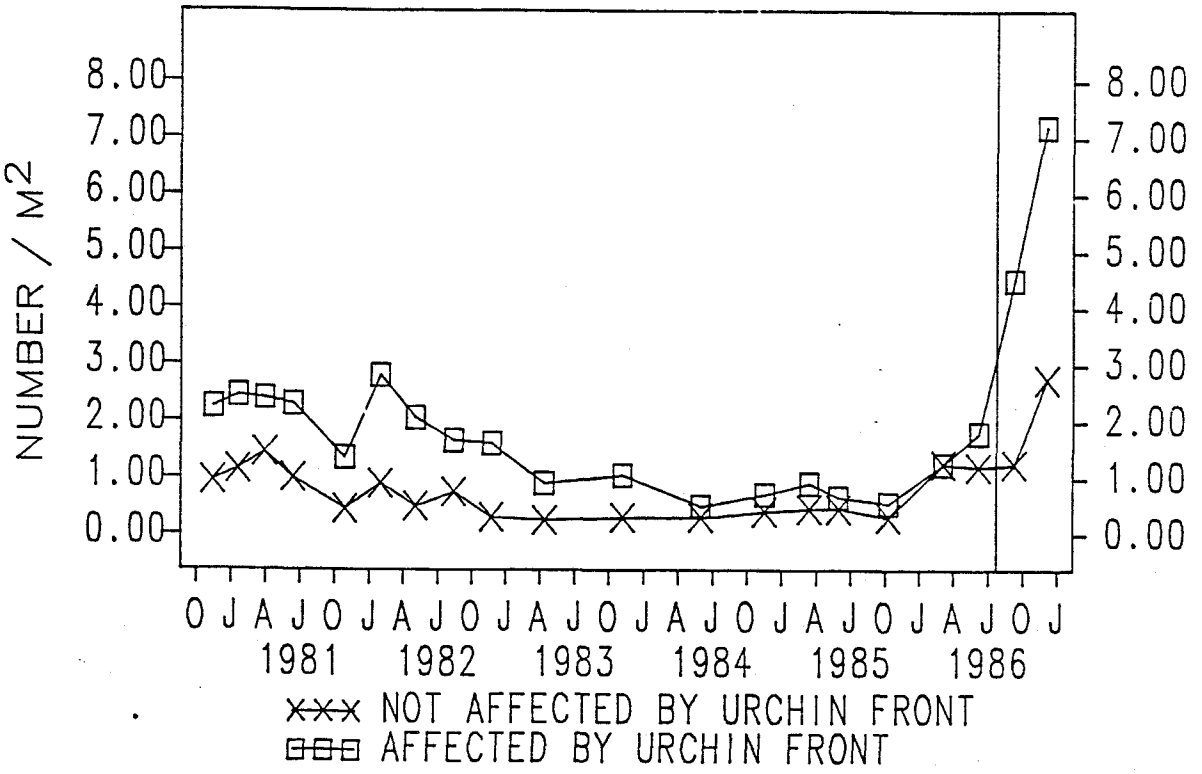
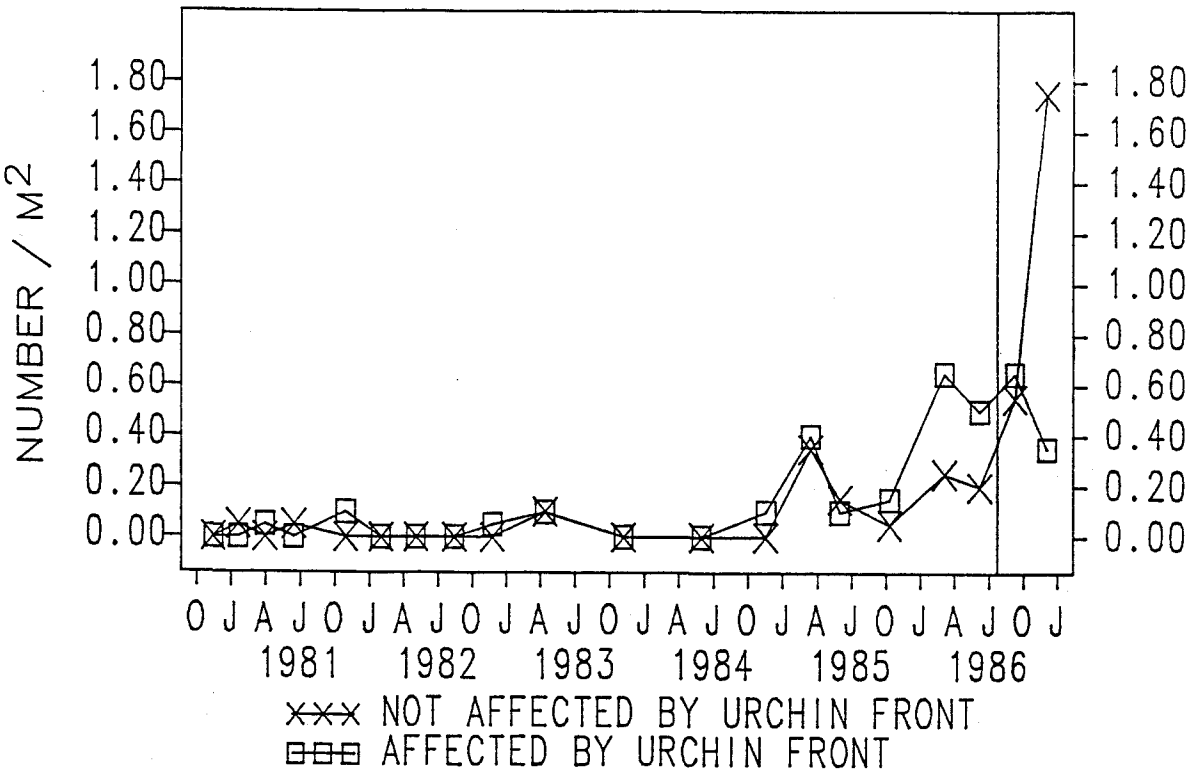


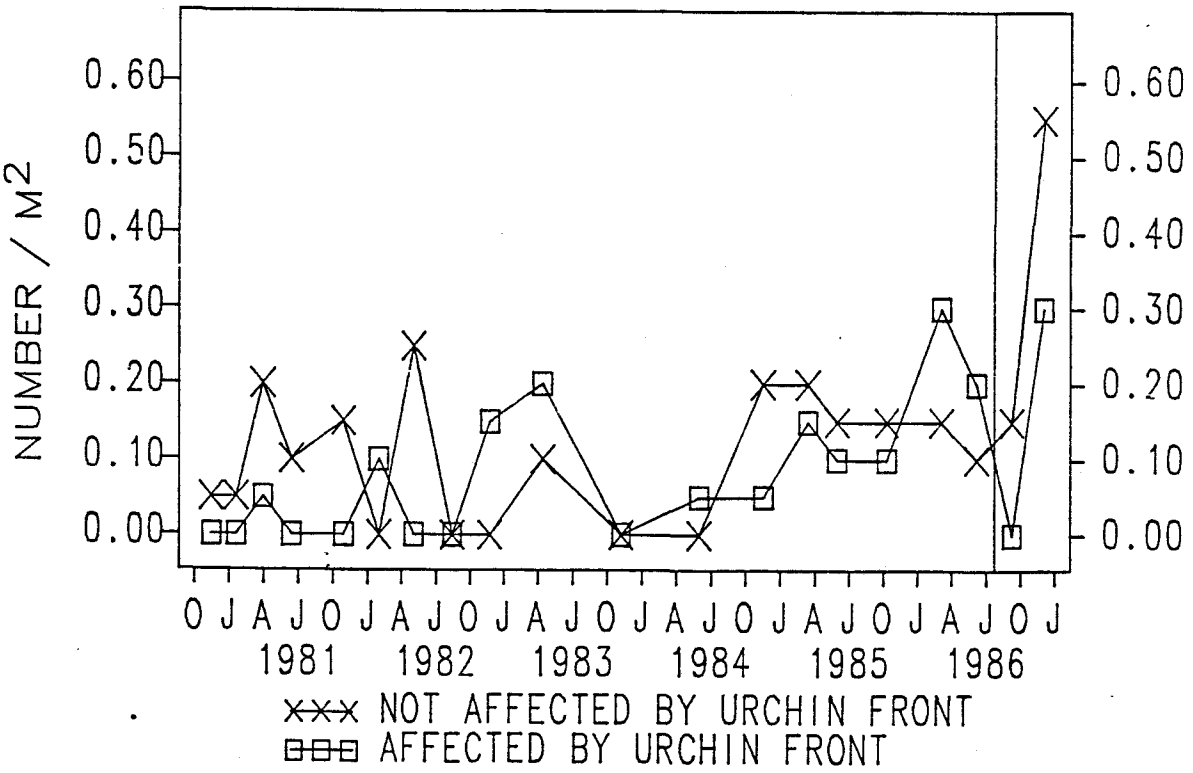
B. *STRONGYLOCENTROTUS PURPURATUS*



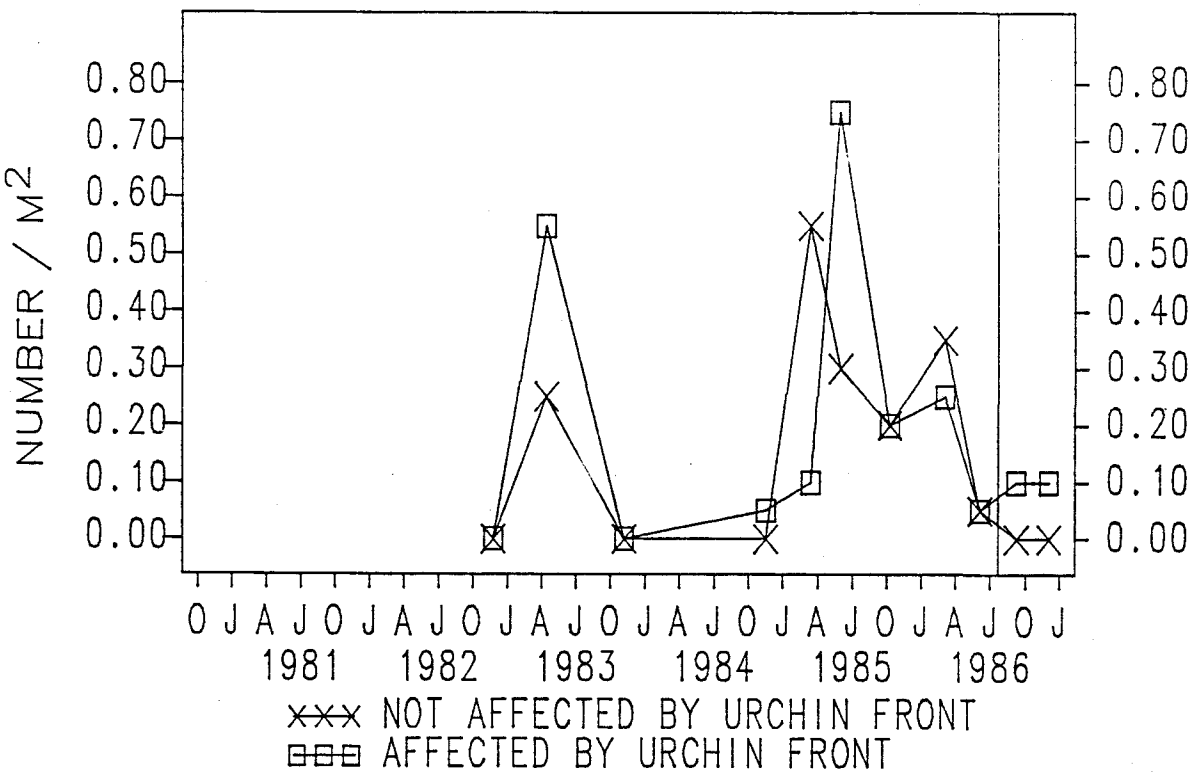
A. *ASTRAEA UNDOSA*



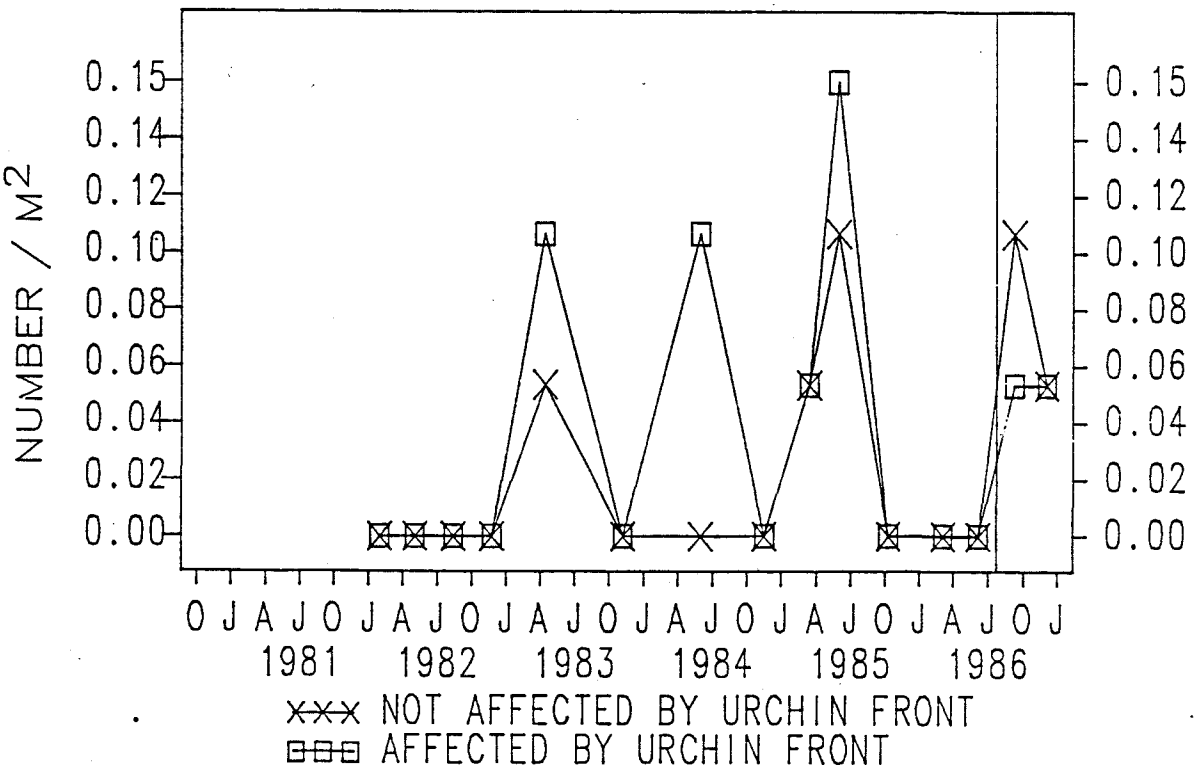
B. *CYPRAEA SPADICEA*



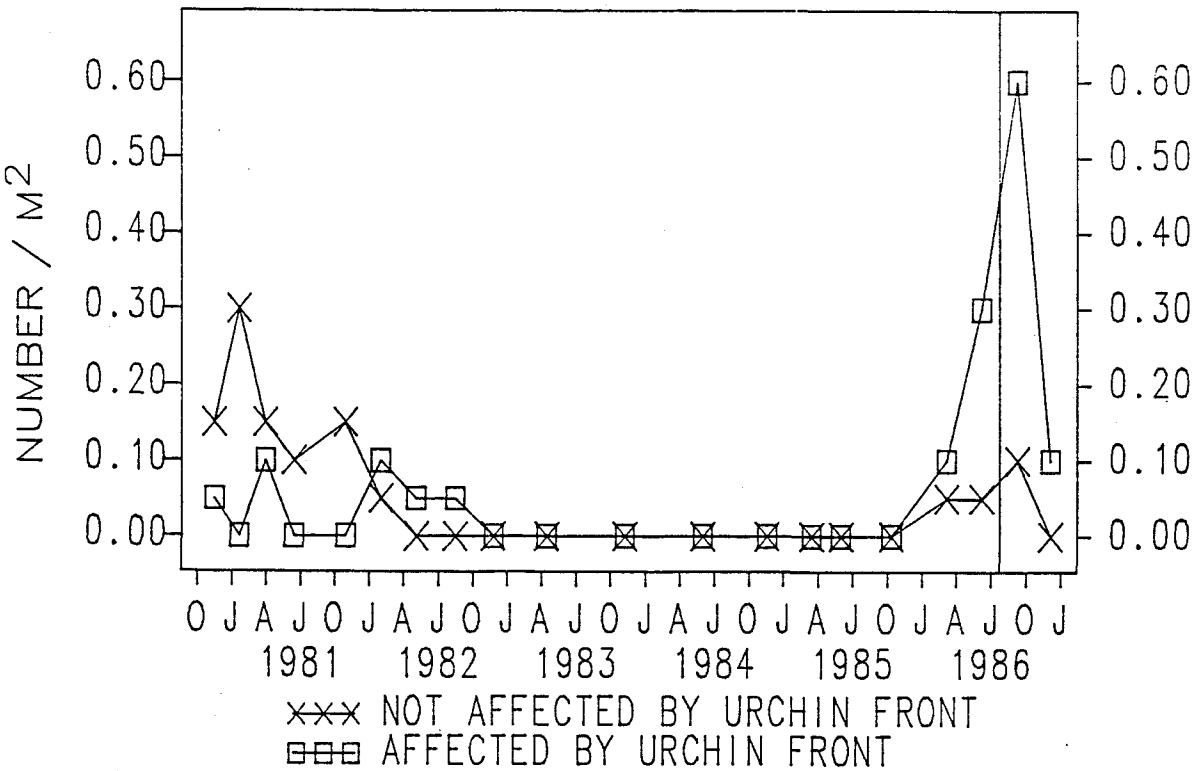
A. *NASSARIUS SPP.*



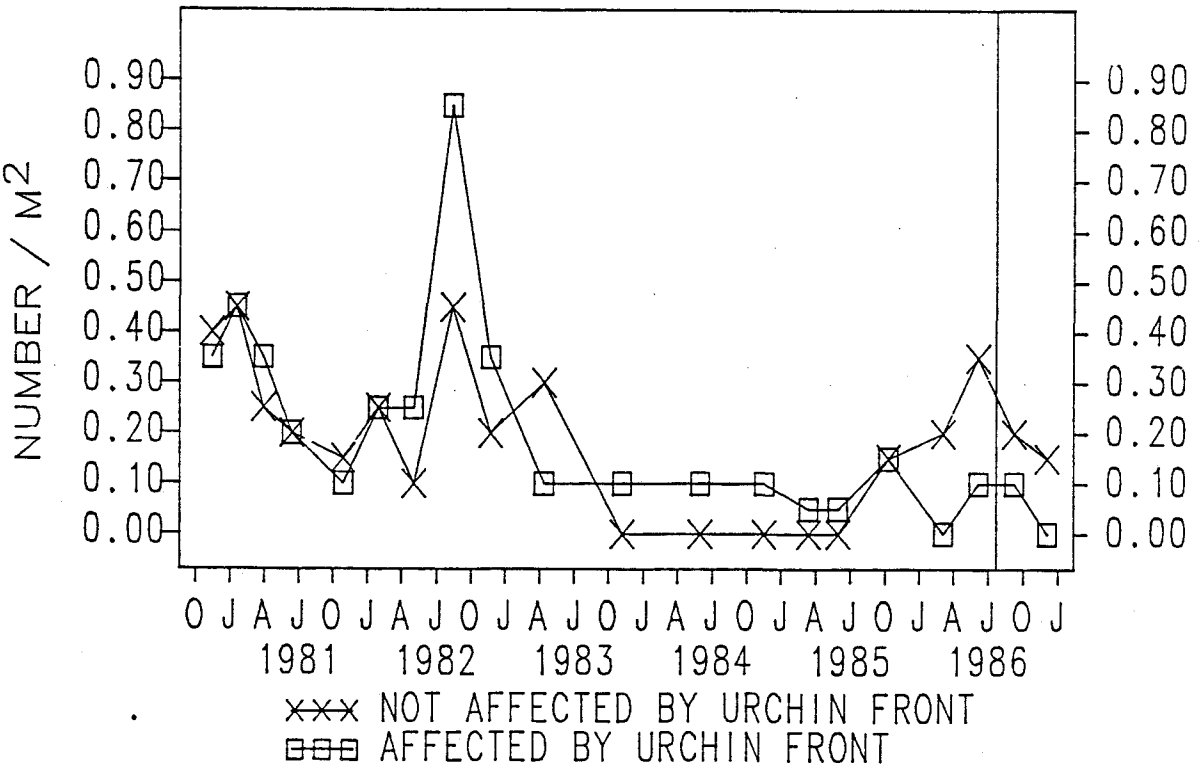
B. *CRASSISPIRA SEMIINFLATA*

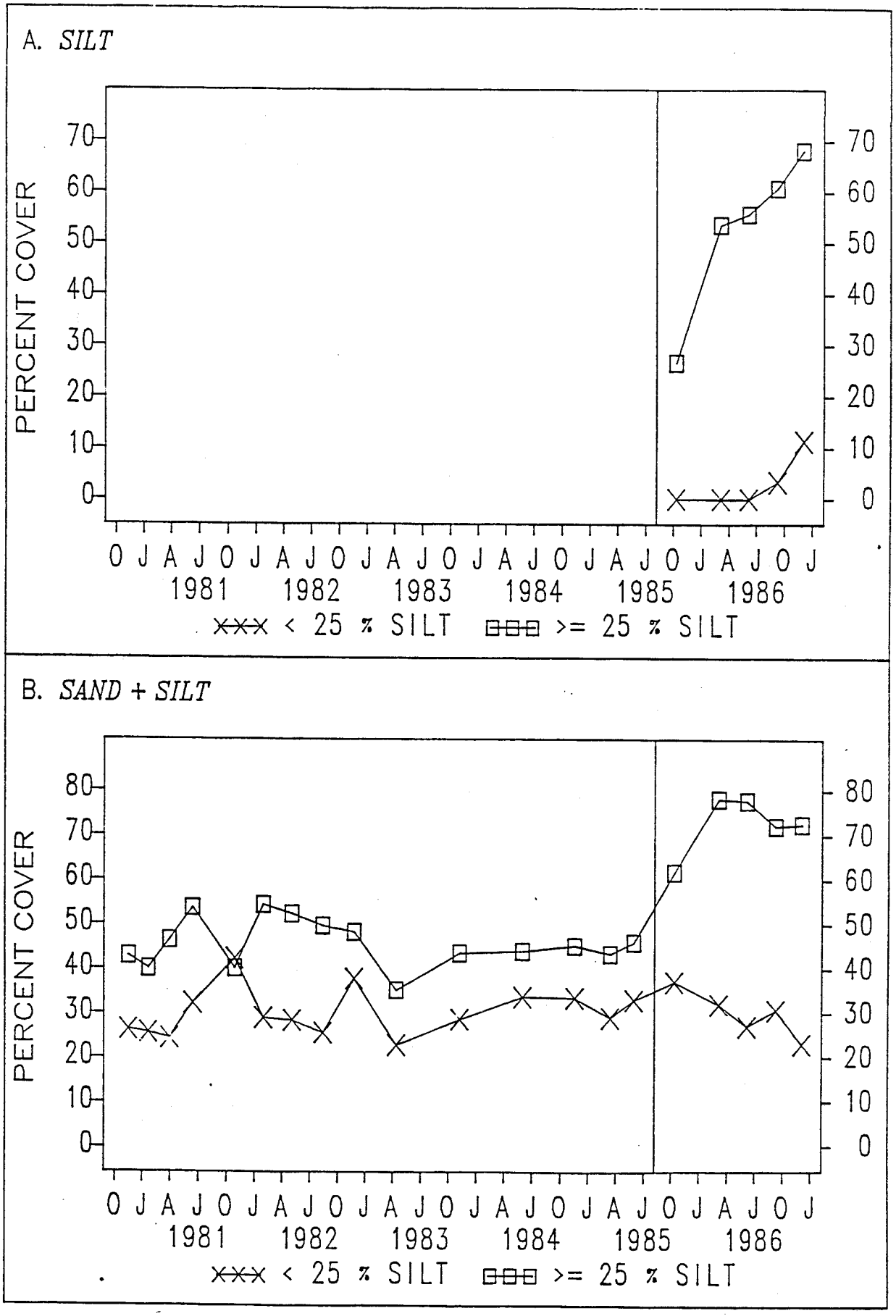


A. *PATIRIA MINIATA*

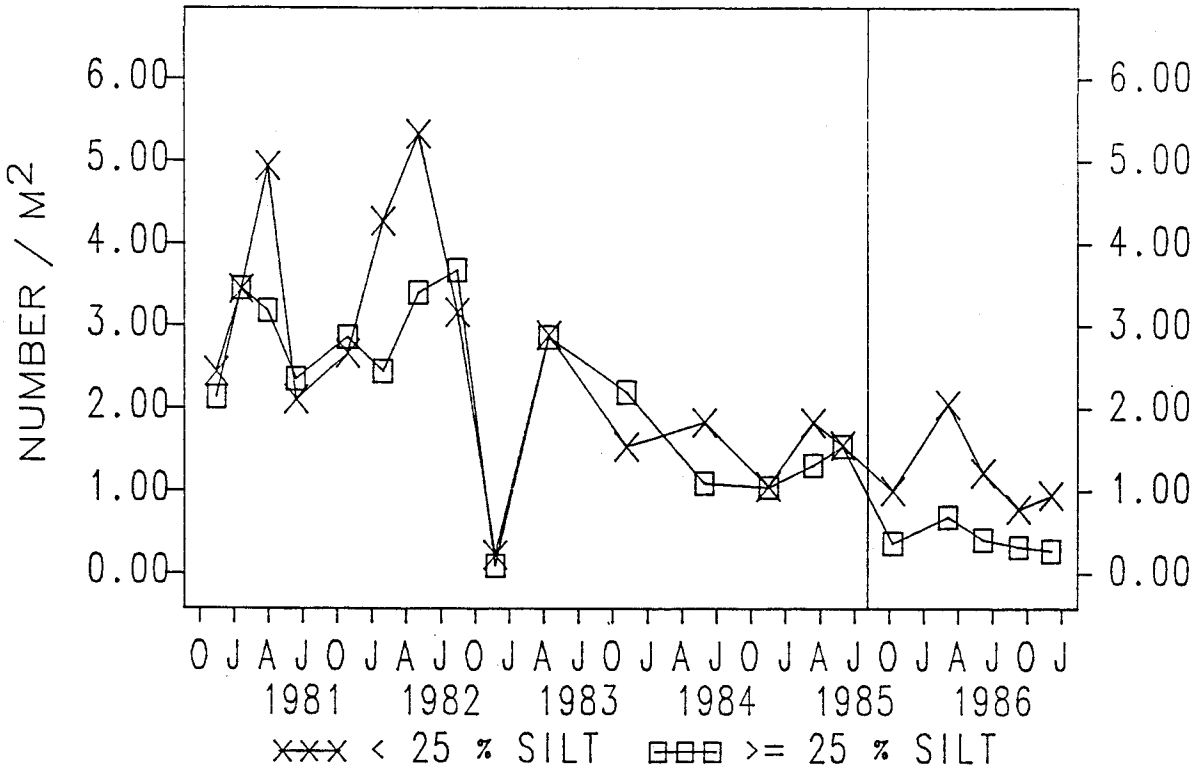


B. *STYELA MONTEREYENSIS*

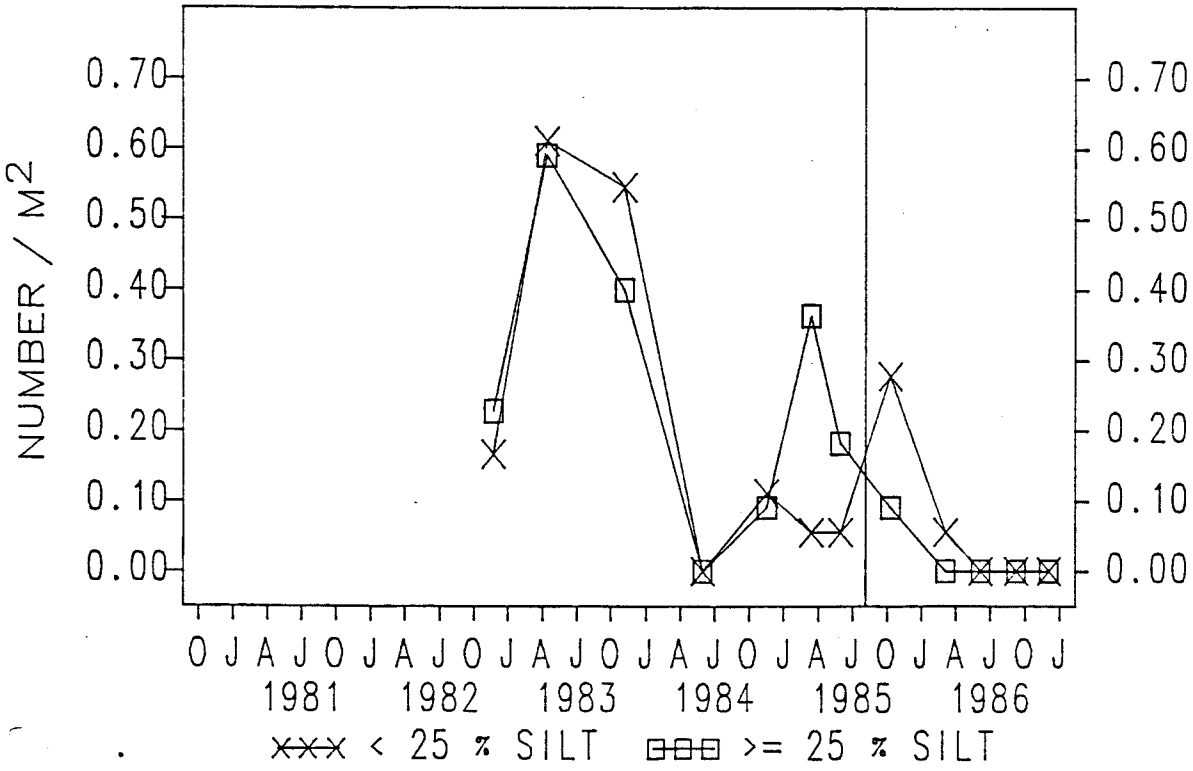



A. SILT
PERCENT COVER
0
10
20
30
40
50
60
70
O J A J O J A J O J A J O J A J O J A J O J A J O J
1981
1982
1983
1984
1985
1986
< 25 % SILT
>= 25 % SILT
B. SAND + SILT
PERCENT COVER
0
10
20
30
40
50
60
70
80
O J A J O J A J O J A J O J A J O J A J O J A J O J
1981
1982
1983
1984
1985
1986
< 25 % SILT
>= 25 % SILT

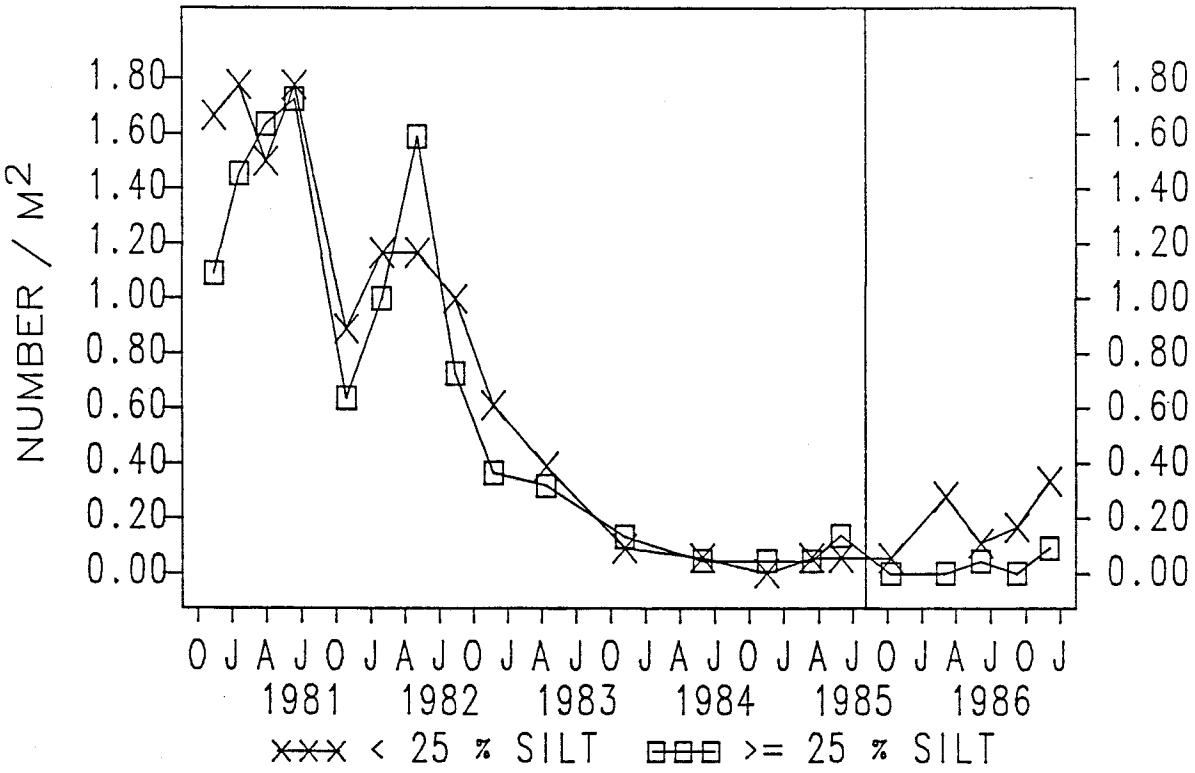
A. *KELLETIA KELLETII*



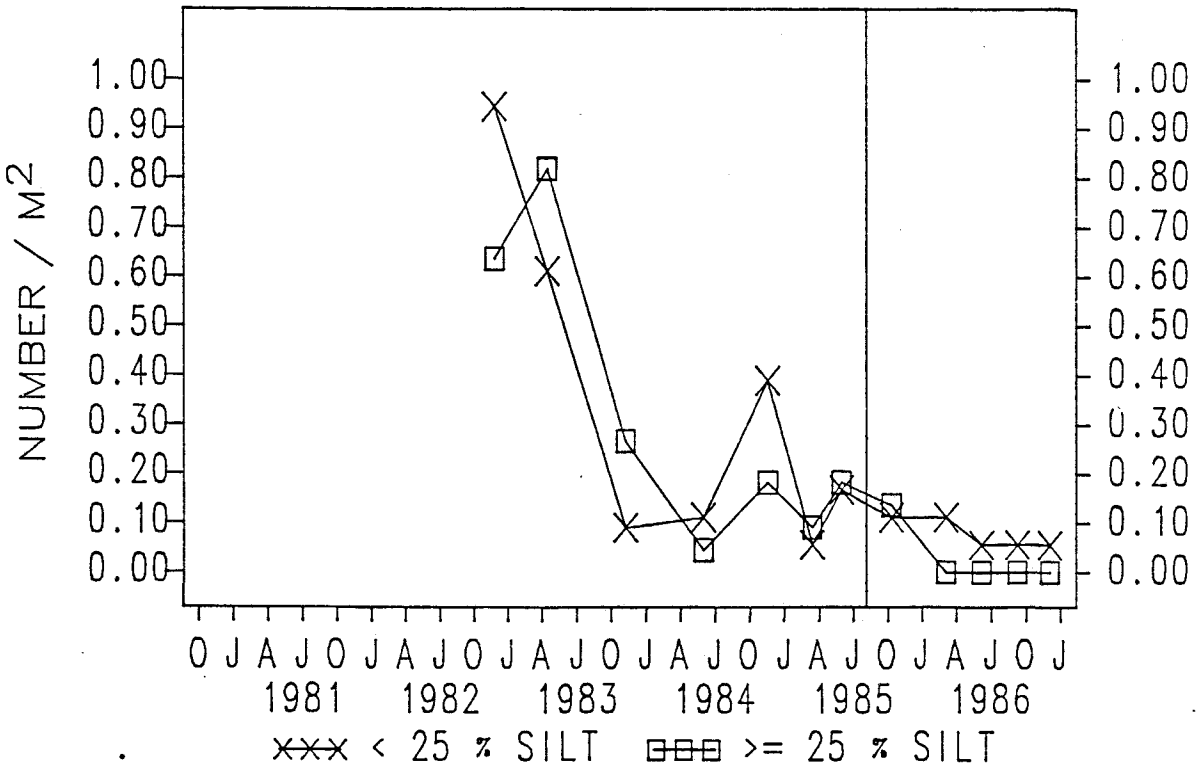
B. *MUREXIELLA SANTAROSANA*



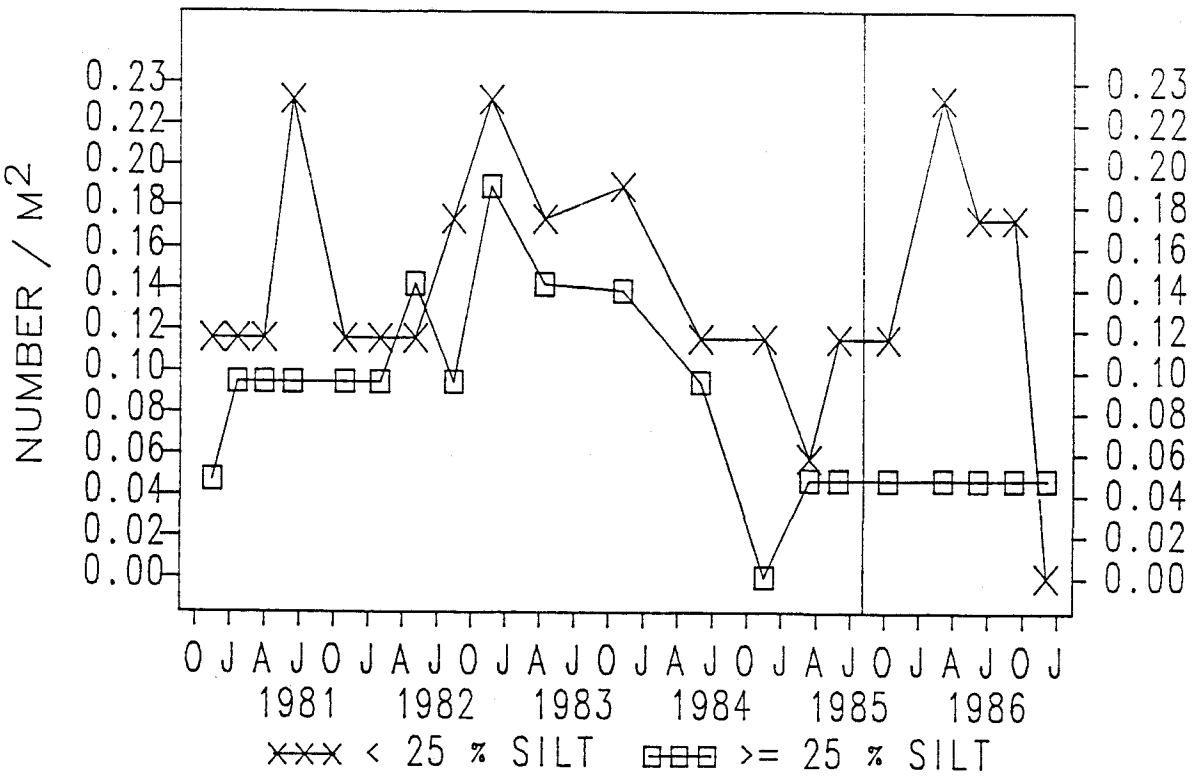
A. *PATIRIA MINIATA*



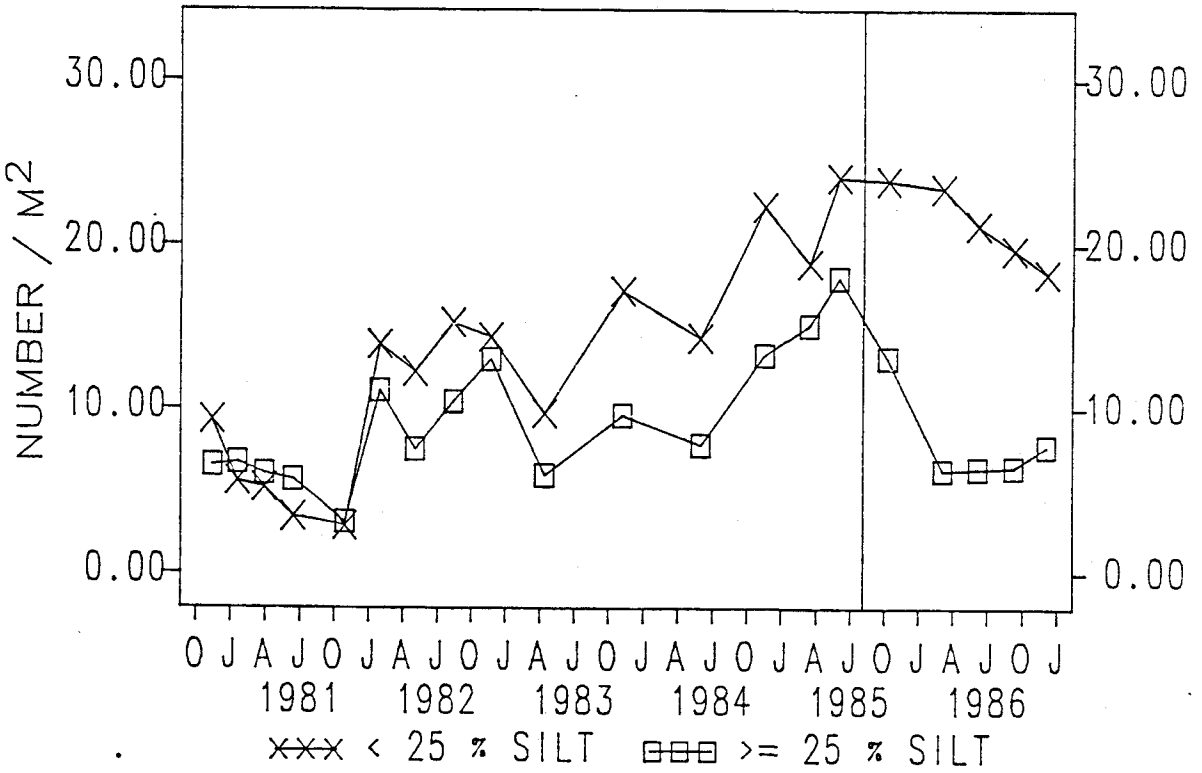
B. *MAXWELLIA GEMMA*

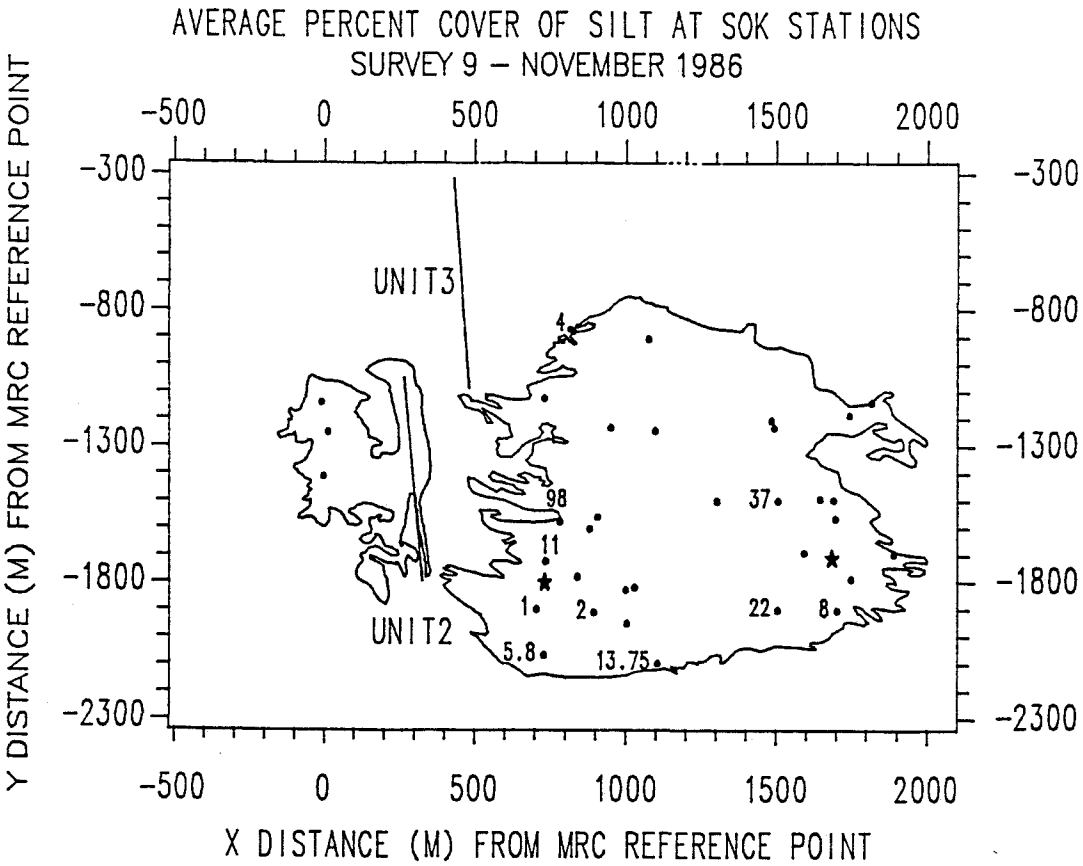


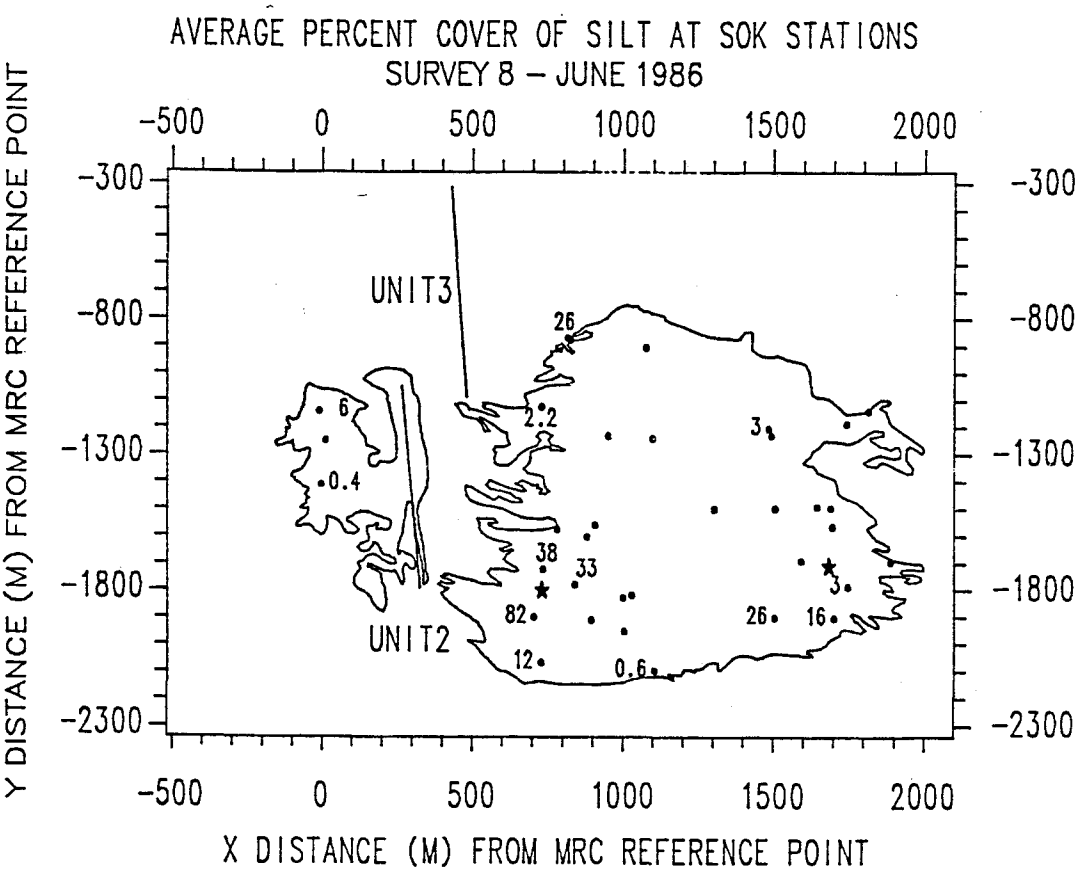
A. *TETHYA AURANTIA*

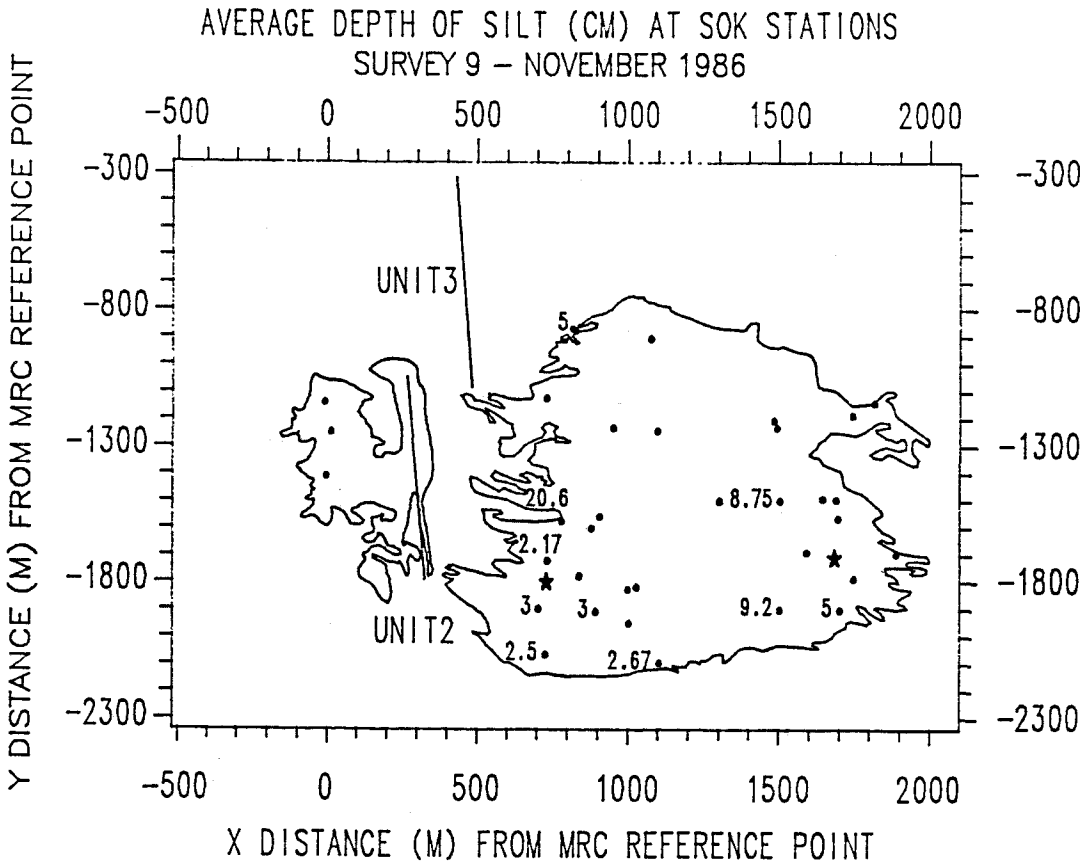


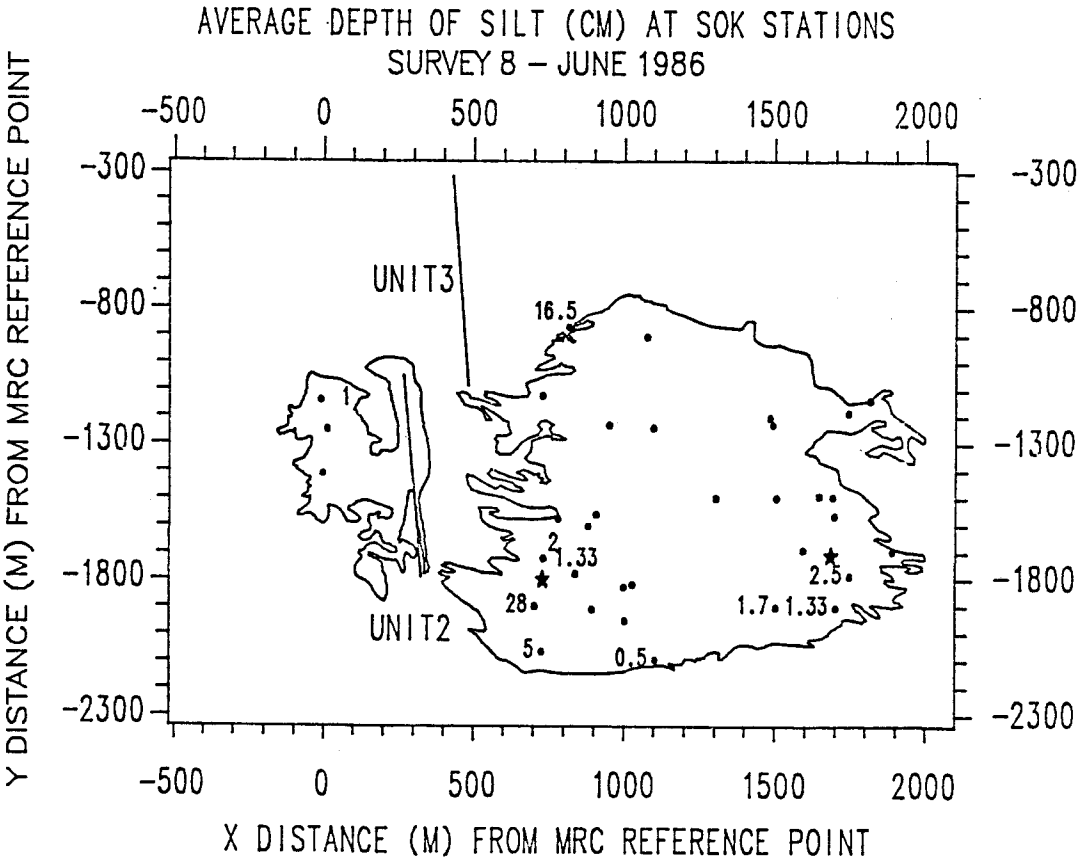
B. *LYTECHINUS ANAMESUS*



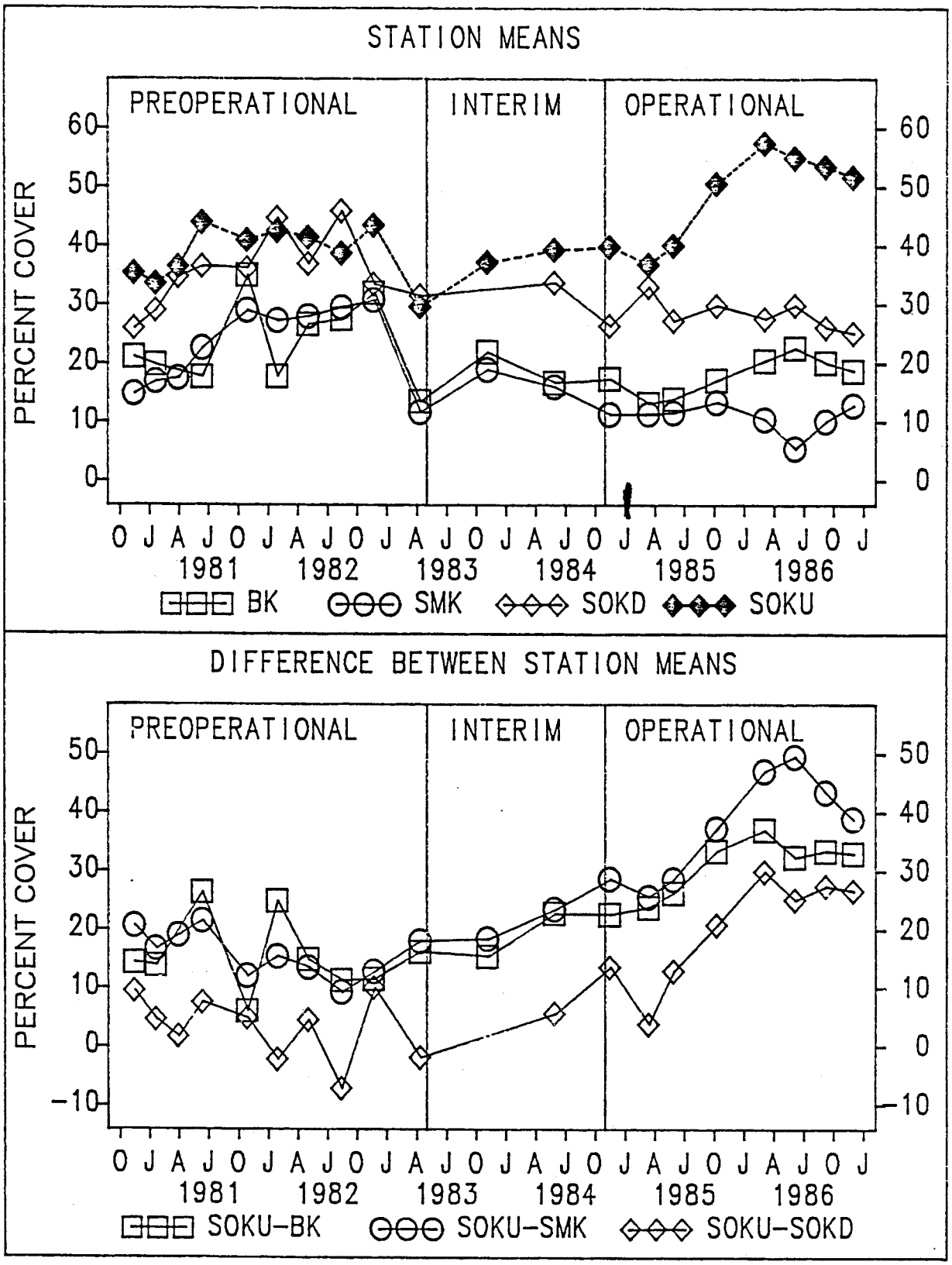

AVERAGE PERCENT COVER OF SILT AT SOK STATIONS
SURVEY 9 – NOVEMBER 1986
UNIT3
UNIT2
4
98
11
1
2
5.8
13.75
37
22
8
Y DISTANCE (M) FROM MRC REFERENCE POINT
X DISTANCE (M) FROM MRC REFERENCE POINT
-500
0
500
1000
1500
2000
-300
-800
-1300
-1800
-2300


AVERAGE PERCENT COVER OF SILT AT SOK STATIONS
SURVEY 8 – JUNE 1986
UNIT3
UNIT2
26
6
0.4
2.2
3
38
33
82
12
0.6
26
16
3
Y DISTANCE (M) FROM MRC REFERENCE POINT
X DISTANCE (M) FROM MRC REFERENCE POINT
-500
0
500
1000
1500
2000
-300
-800
-1300
-1800
-2300

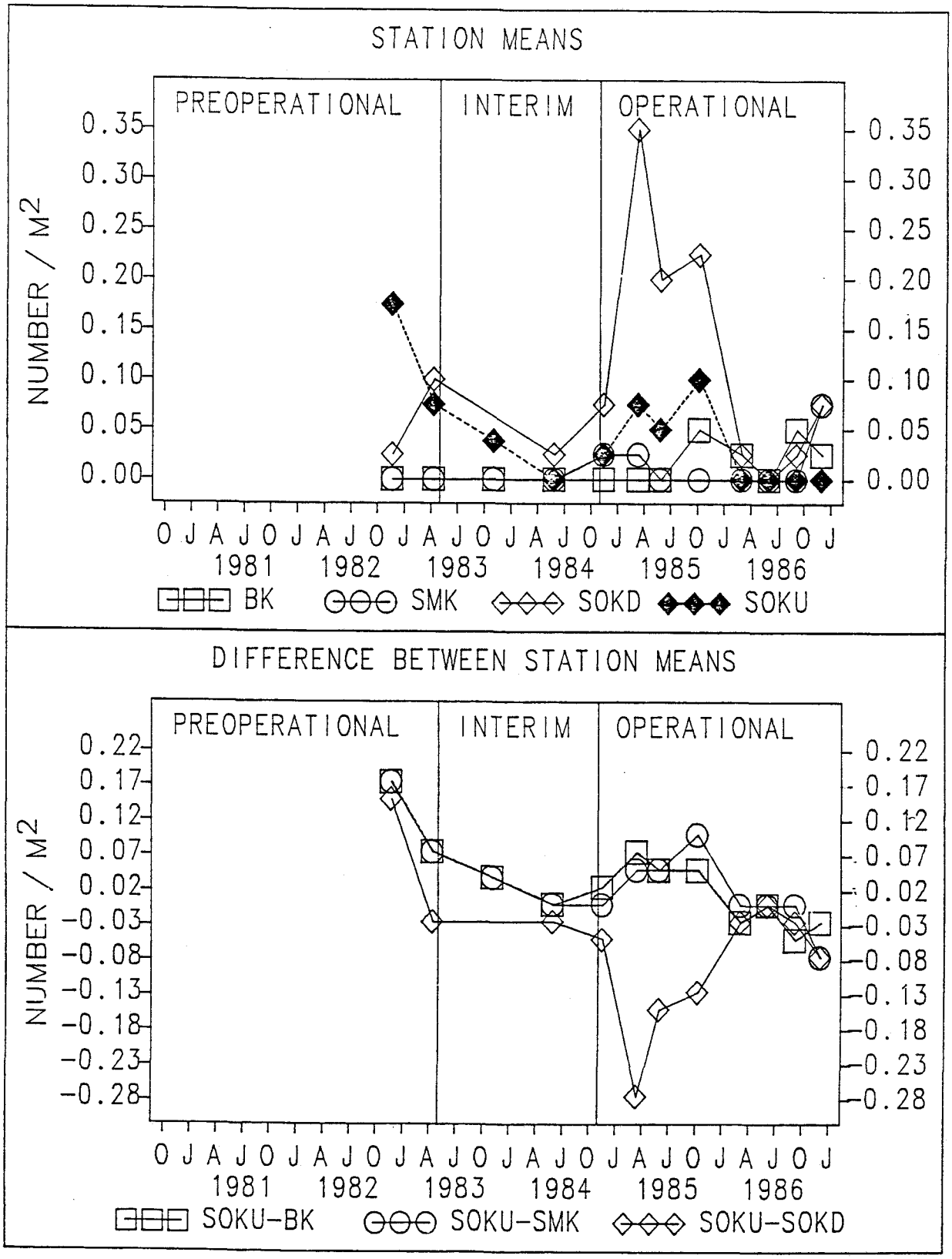

AVERAGE DEPTH OF SILT (CM) AT SOK STATIONS
SURVEY 9 – NOVEMBER 1986
UNIT3
UNIT2
5
20.6
2.17
3
3
2.5
2.67
8.75
9.2
5
Y DISTANCE (M) FROM MRC REFERENCE POINT
X DISTANCE (M) FROM MRC REFERENCE POINT
-500
0
500
1000
1500
2000
-300
-800
-1300
-1800
-2300


AVERAGE DEPTH OF SILT (CM) AT SOK STATIONS
SURVEY 8 – JUNE 1986
UNIT3
UNIT2
16.5
1
2
1.33
28
5
0.5
2.5
1.7
1.33
Y DISTANCE (M) FROM MRC REFERENCE POINT
X DISTANCE (M) FROM MRC REFERENCE POINT
-500
0
500
1000
1500
2000
-300
-800
-1300
-1800
-2300

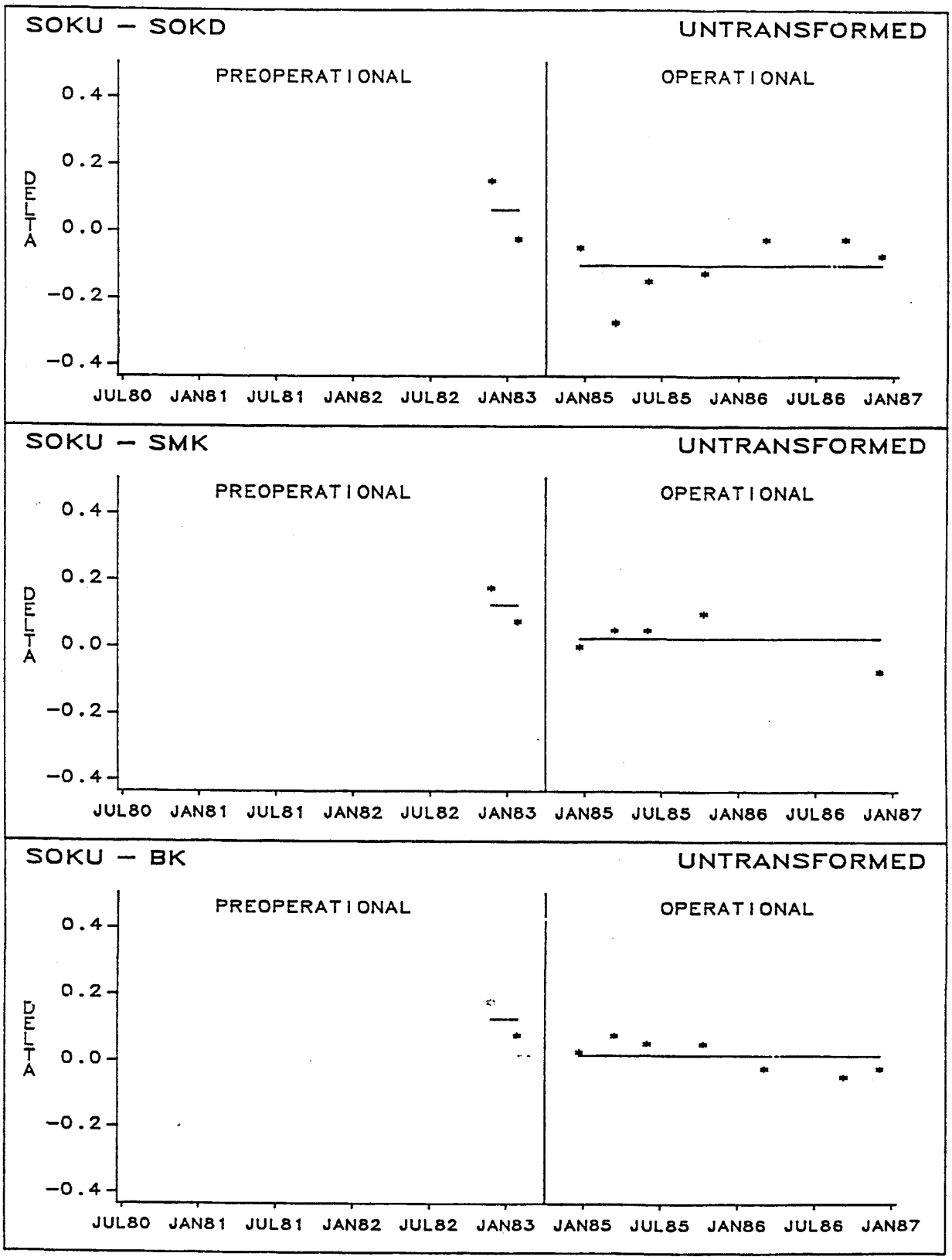
SAND + SILT


STATION MEANS
PREOPERATIONAL
INTERIM
OPERATIONAL
PERCENT COVER
60
50
40
30
20
10
0
O J A J O J A J O J A J O J A J O J A J O J A J O J
1981
1982
1983
1984
1985
1986
BK
SMK
SOKD
SOKU
DIFFERENCE BETWEEN STATION MEANS
PREOPERATIONAL
INTERIM
OPERATIONAL
PERCENT COVER
50
40
30
20
10
0
-10
O J A J O J A J O J A J O J A J O J A J O J A J O J
1981
1982
1983
1984
1985
1986
SOKU-BK
SOKU-SMK
SOKU-SOKD

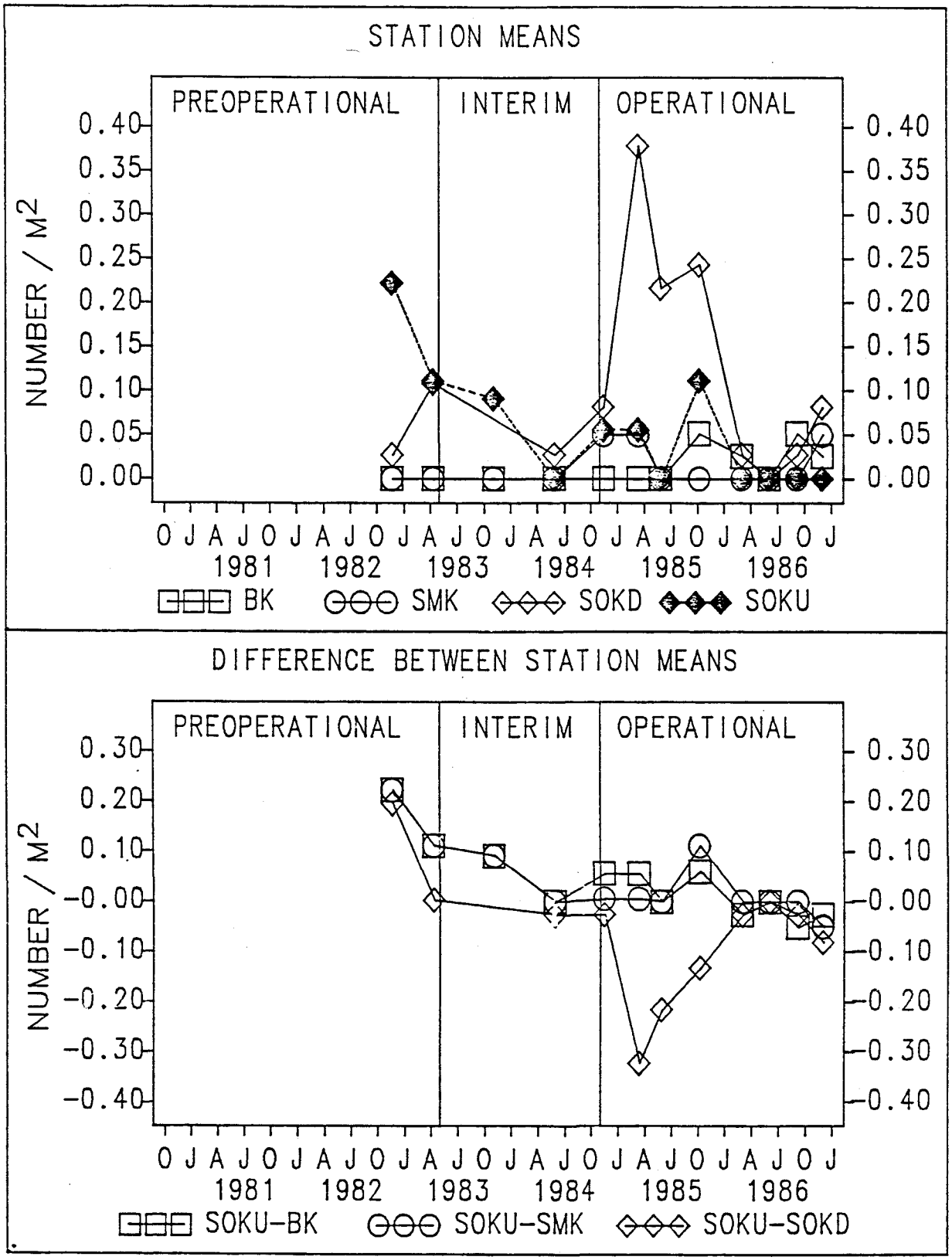
CALLIOSTOMA SPP.



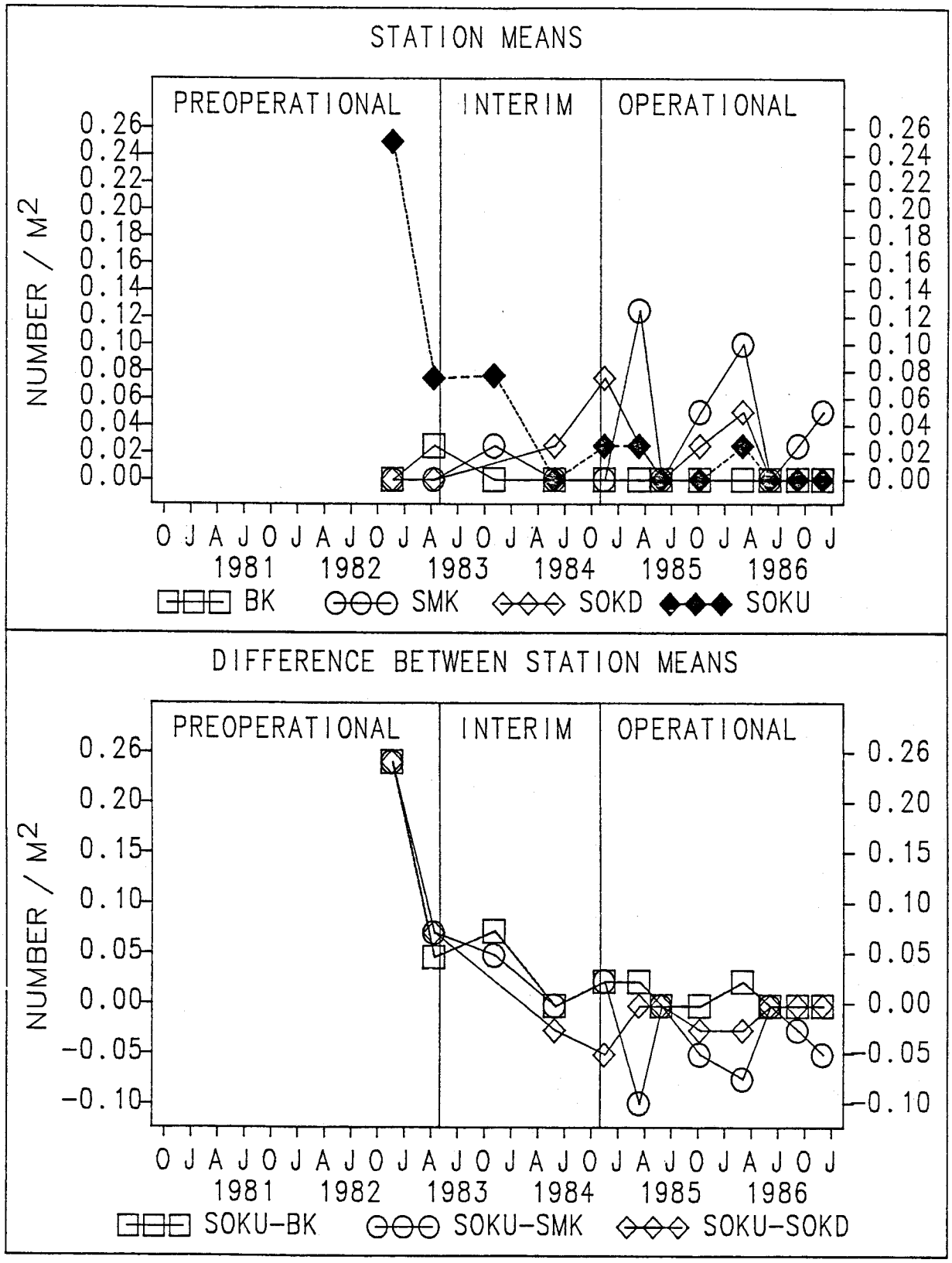
CALLIOSTOMA SPP.



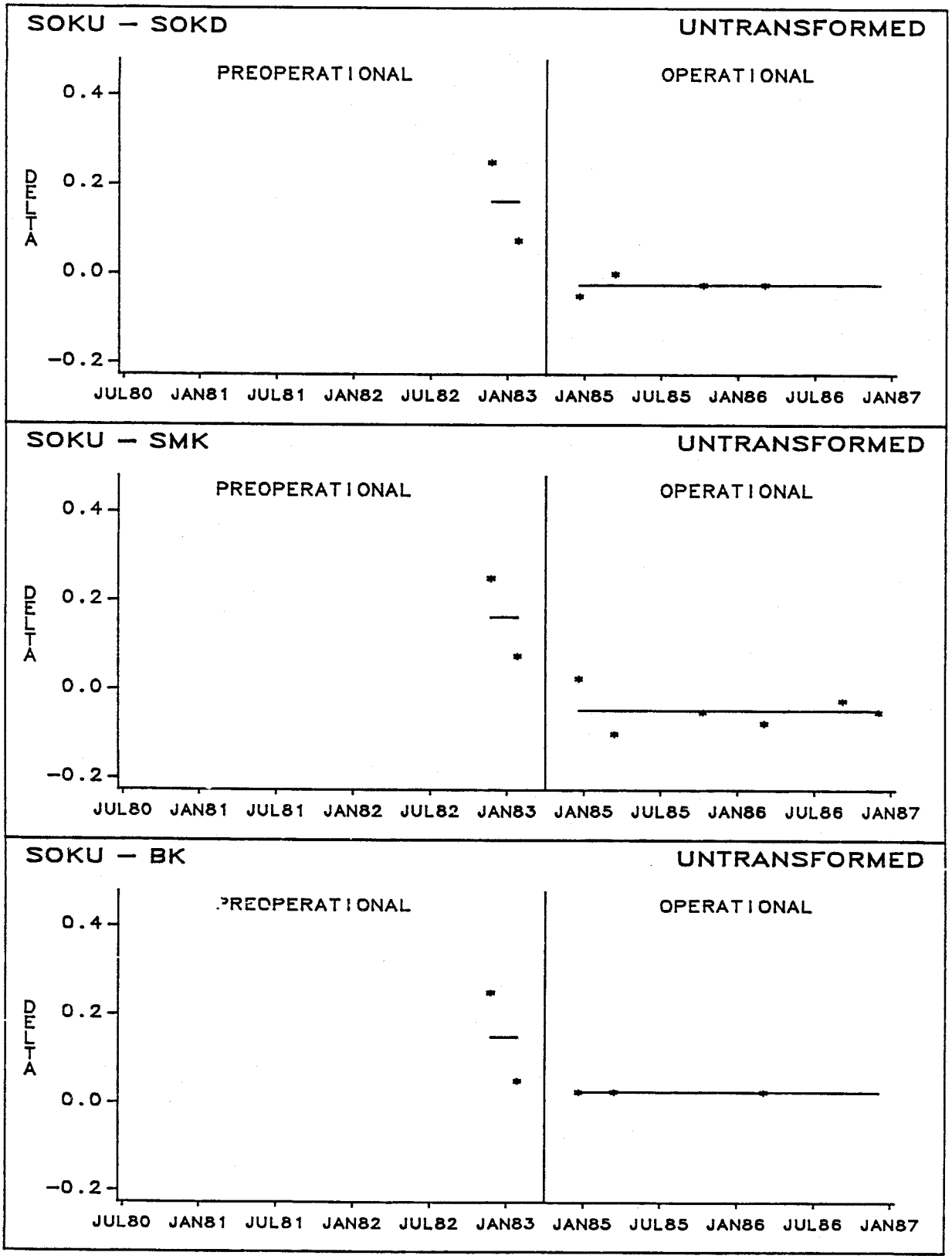
CALLIOSTOMA SPP.



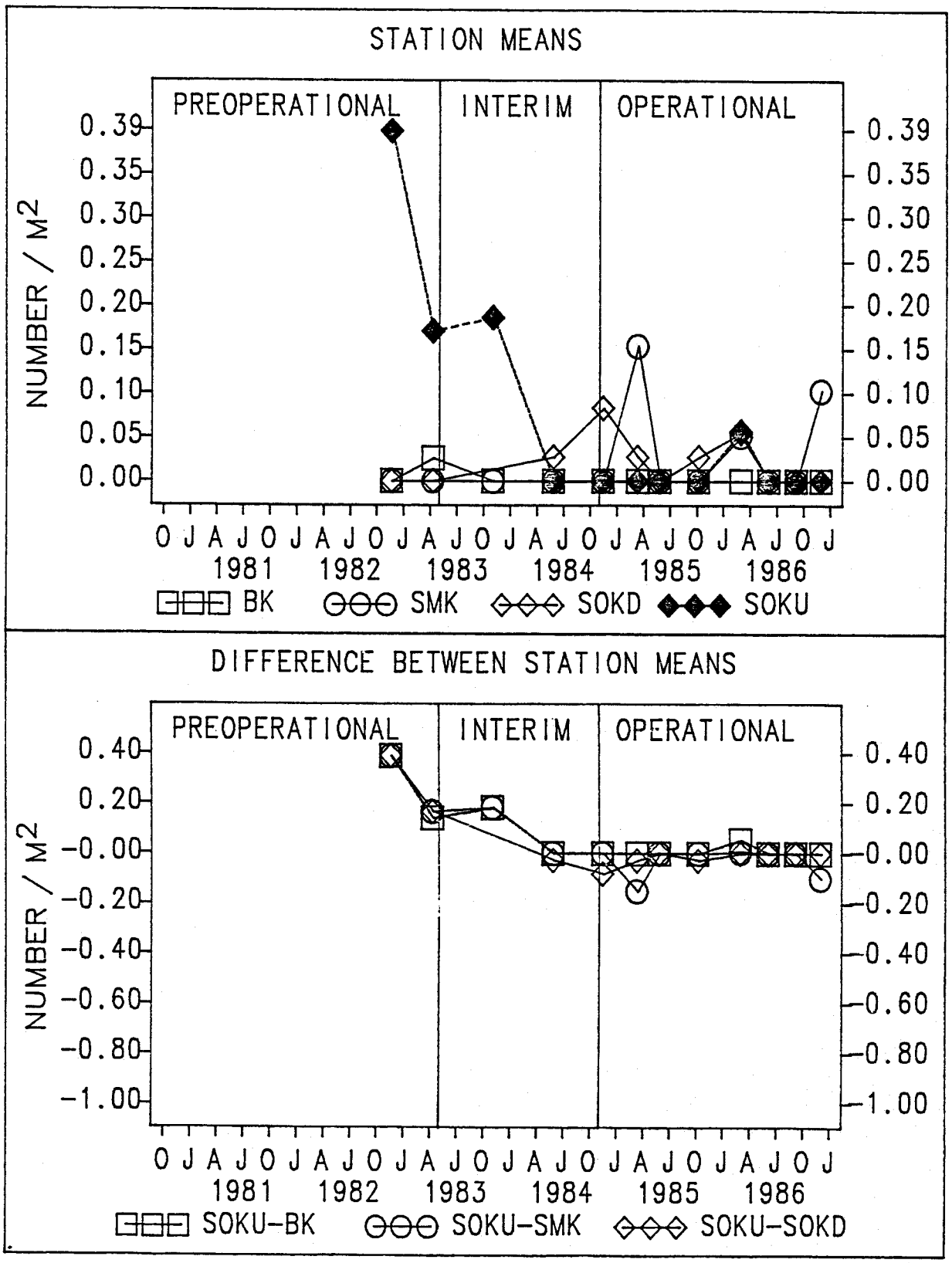
TEGULA AUREOTINCTA



TEGULA AUREOTINCTA



TEGULA AUREOTINCTA



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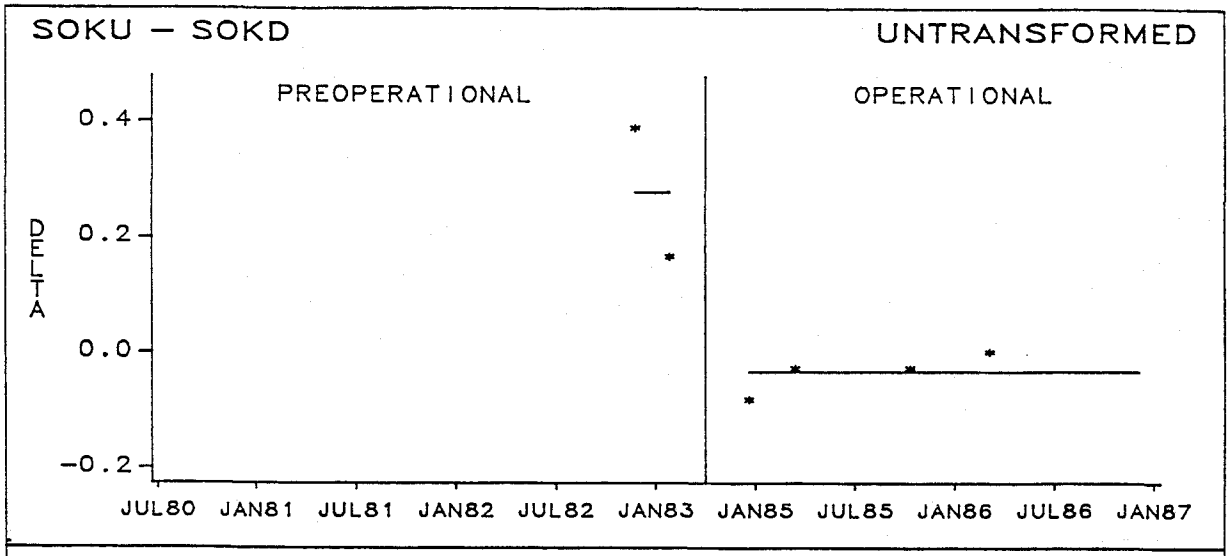
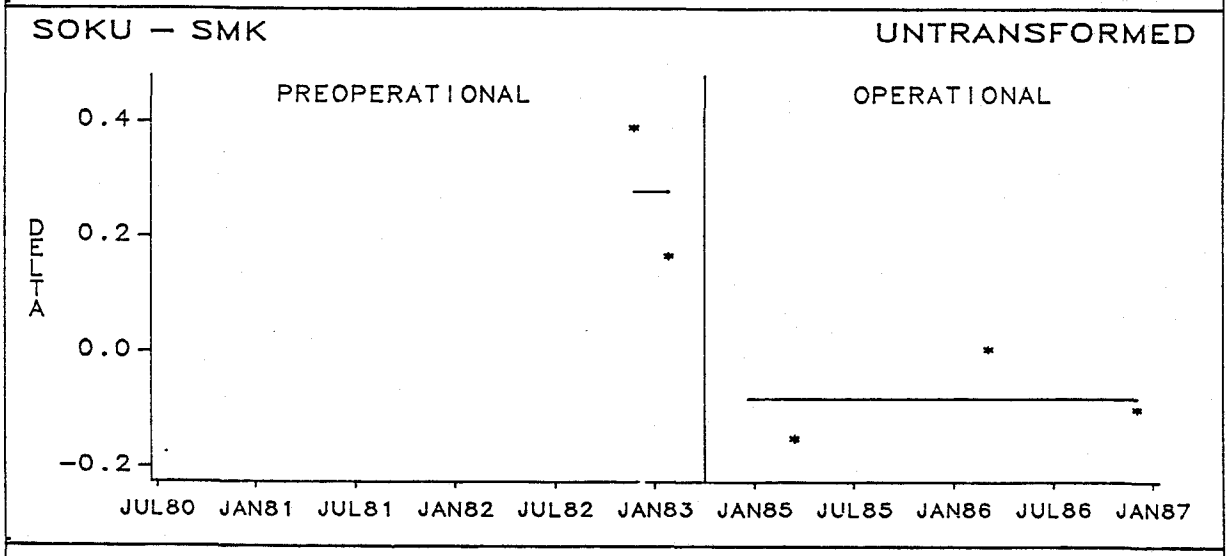


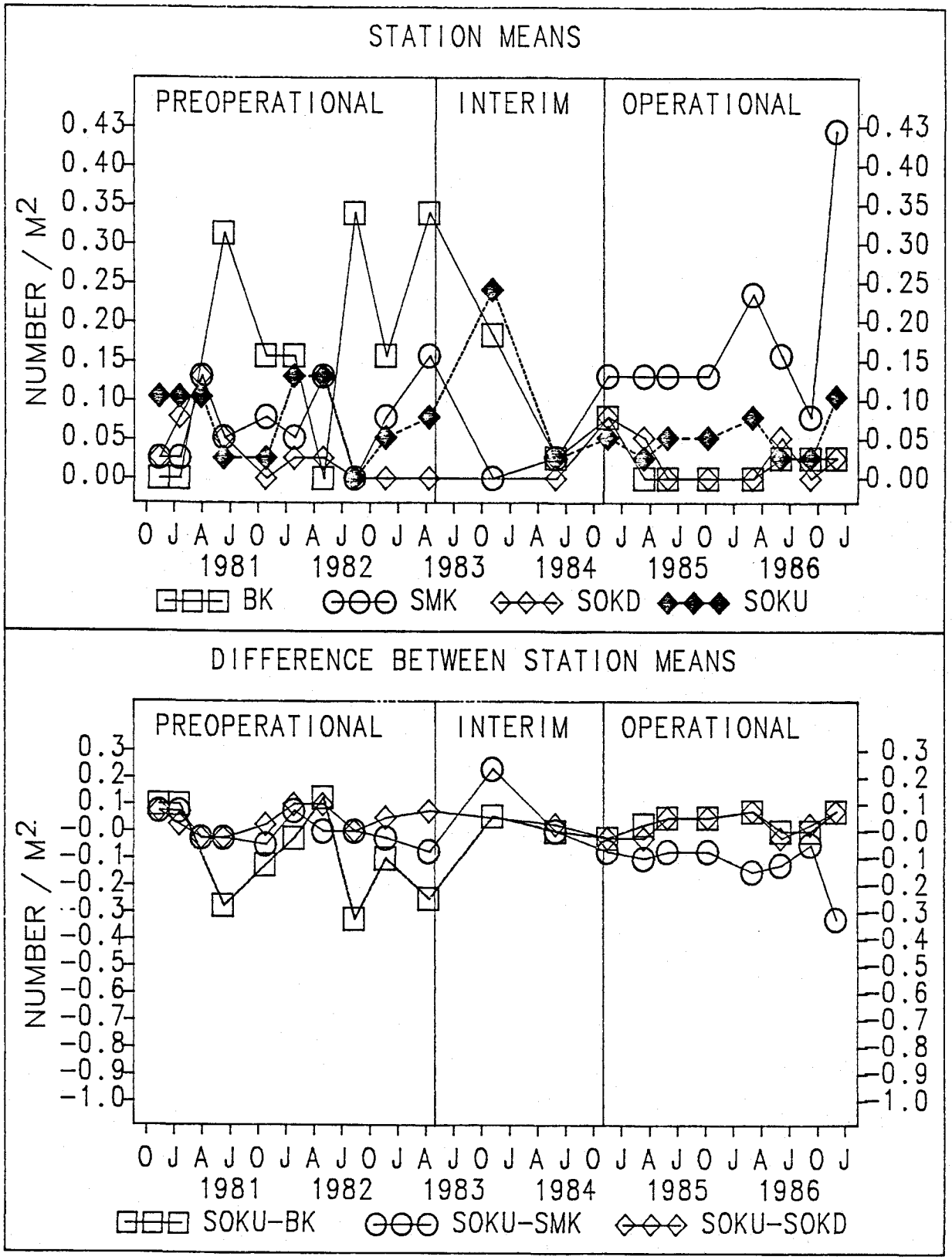


SOKU – BK

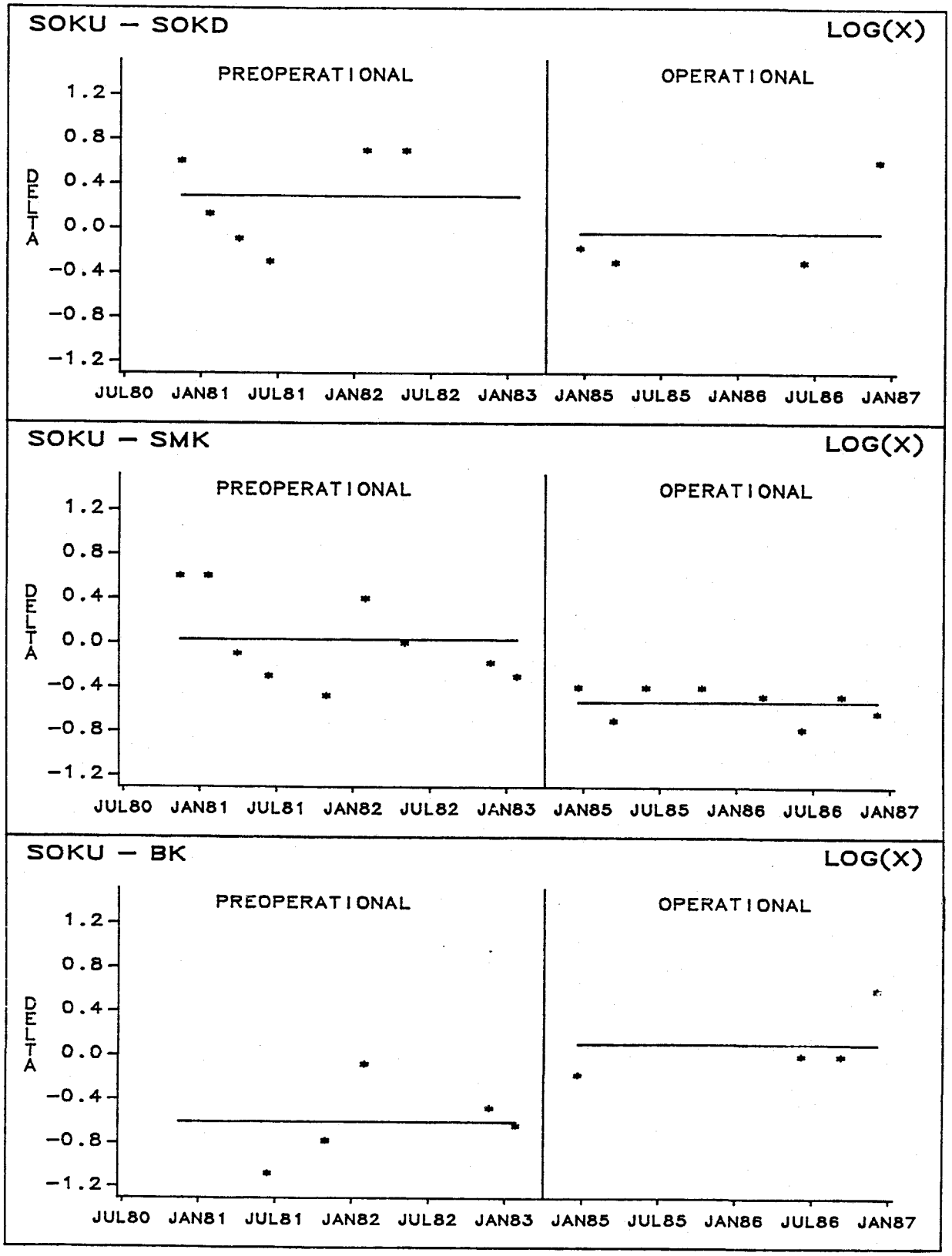
NO TEST

ASSUMPTIONS NOT MET

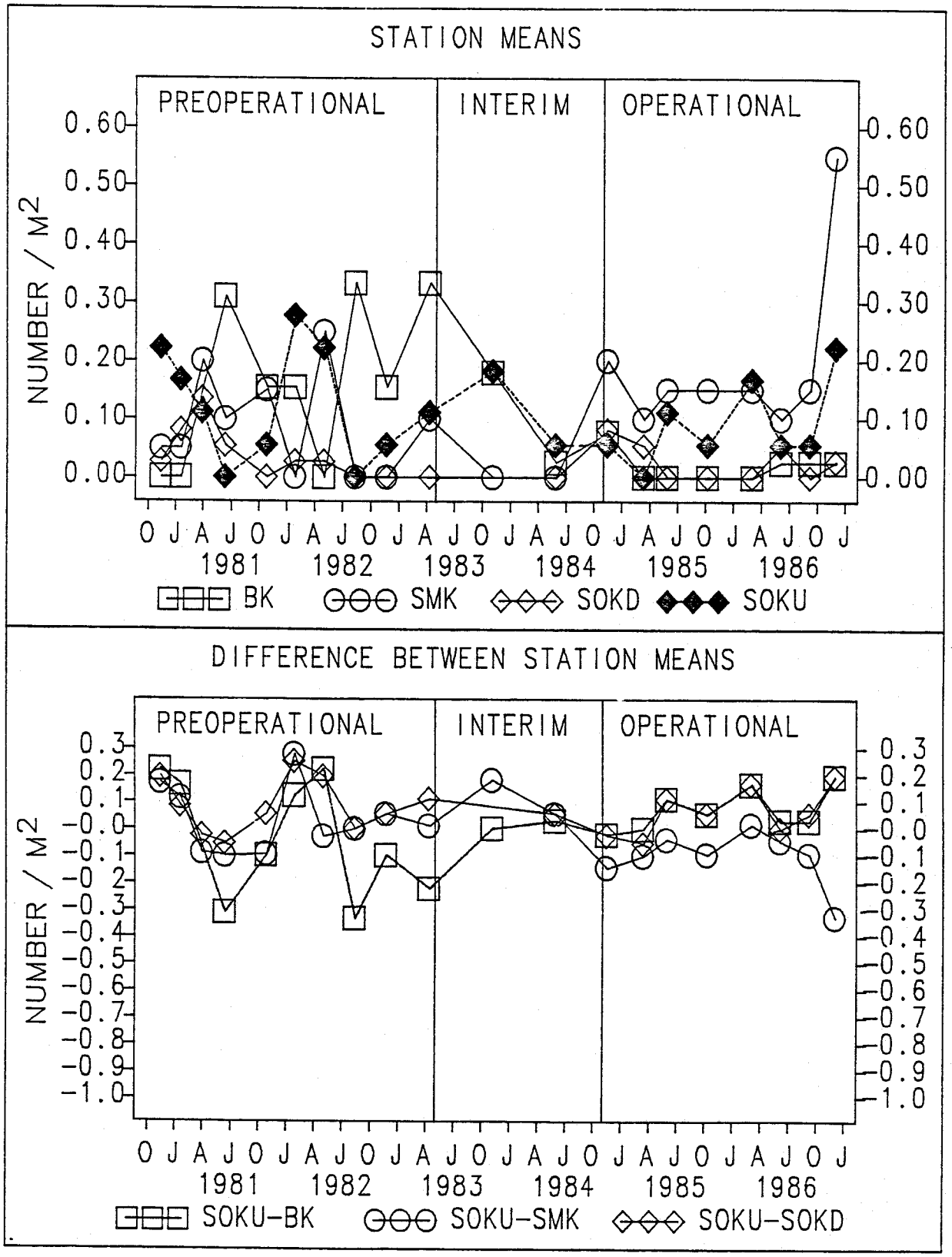
CYPRAEA SPADICEA



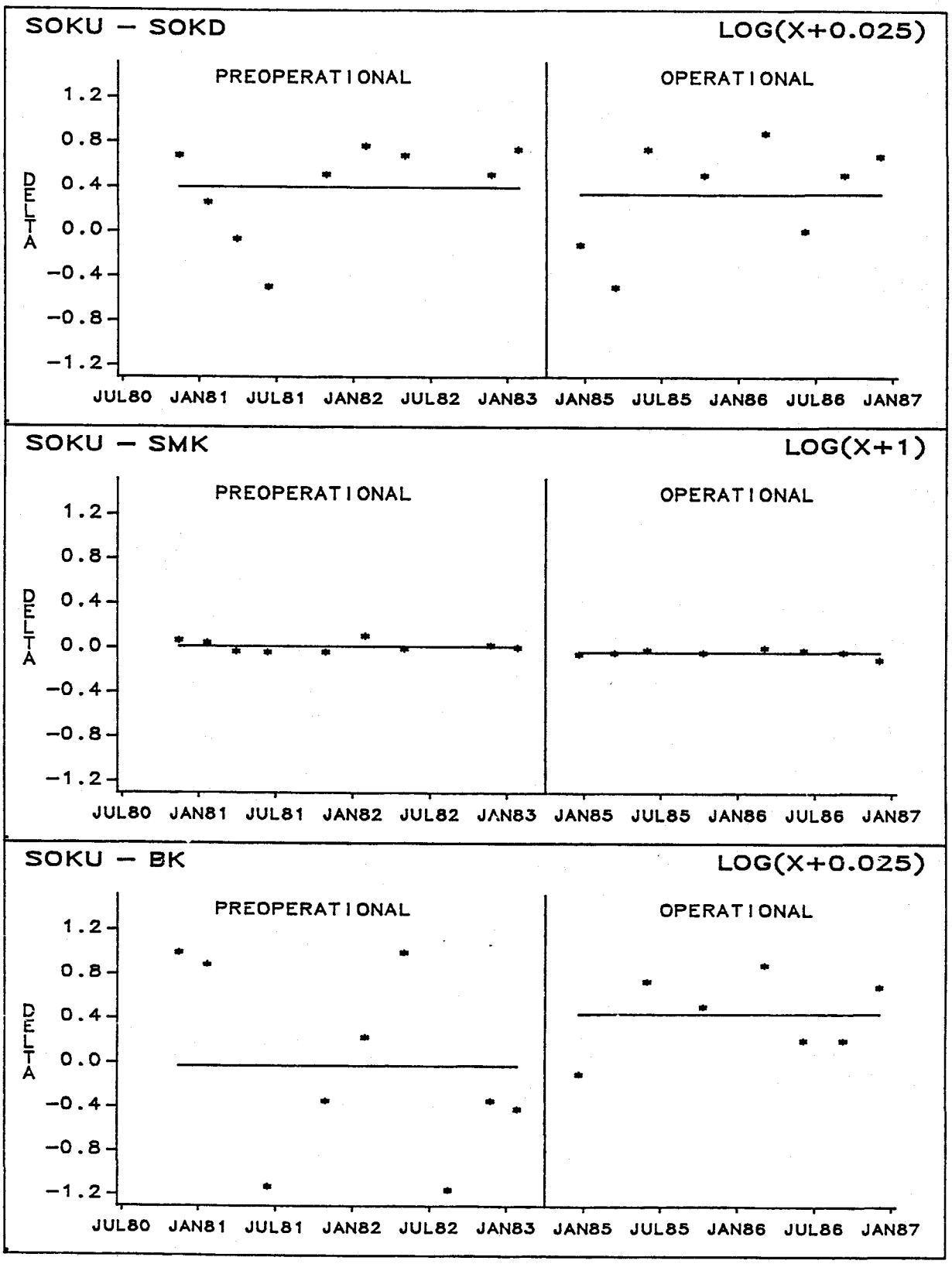
CYPRAEA SPADICEA



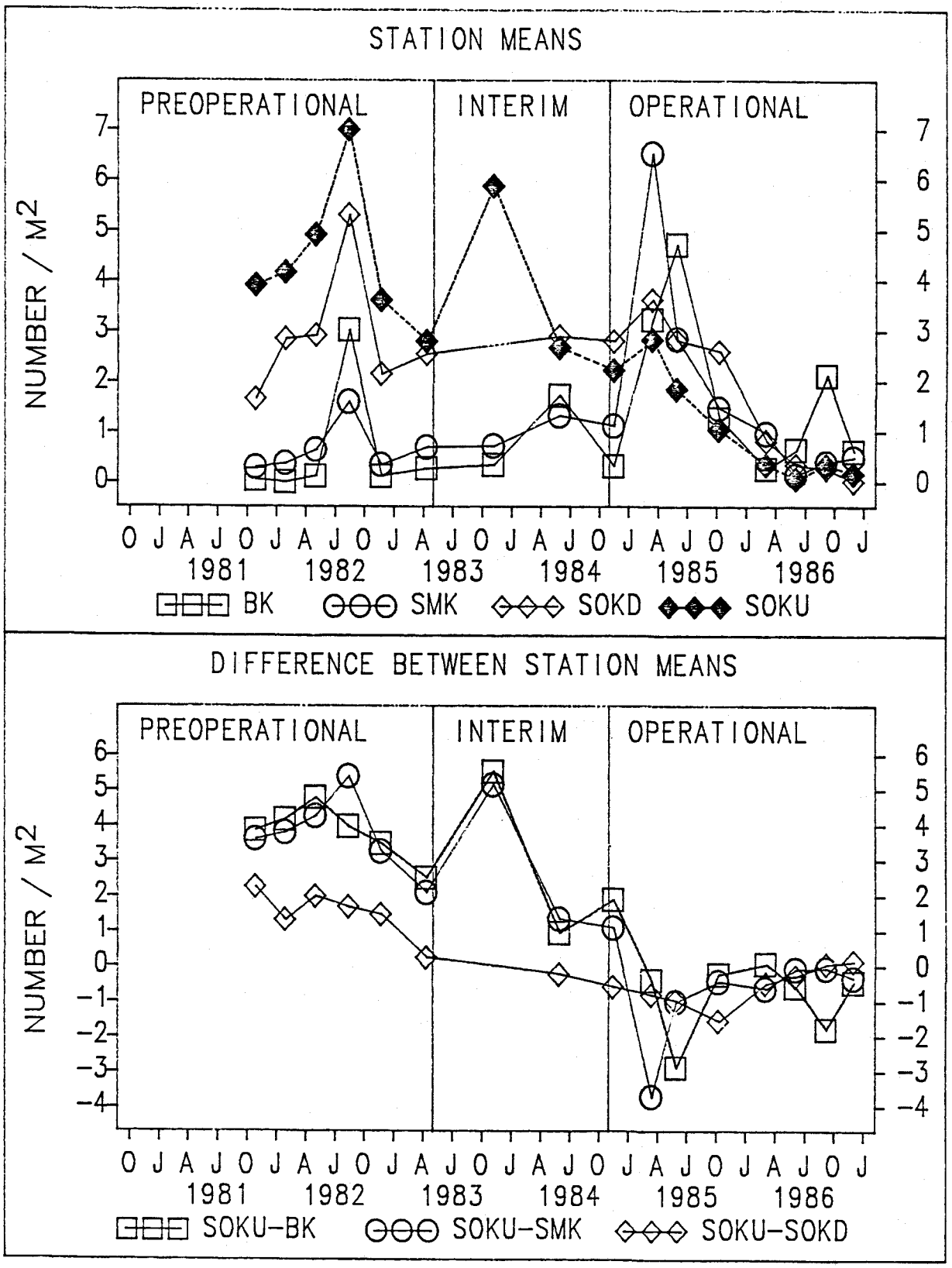
CYPRAEA SPADICEA



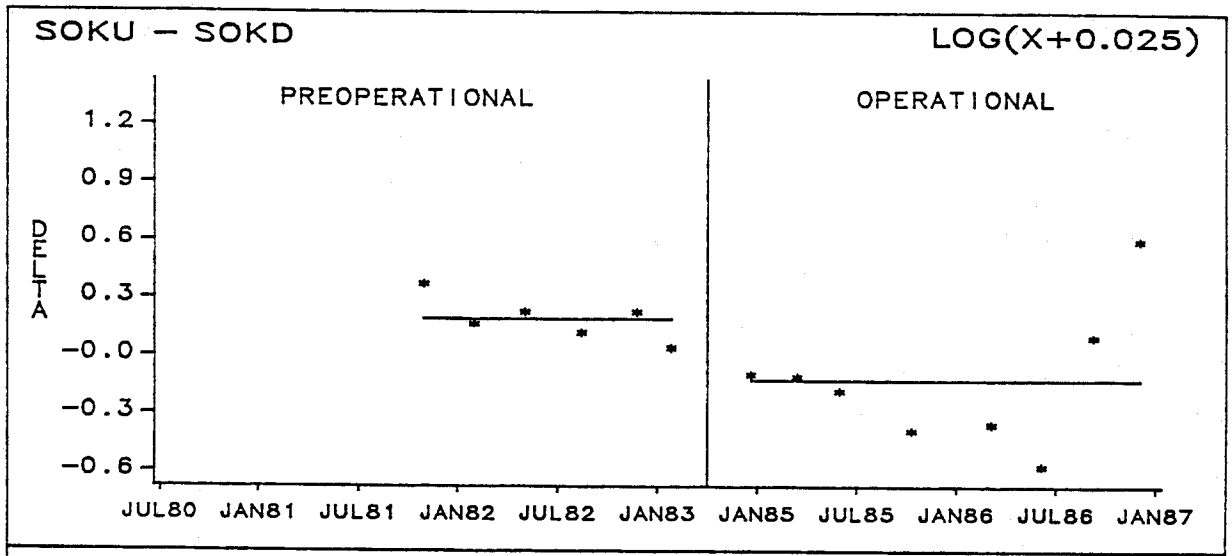
CYPRAEA SPADICEA

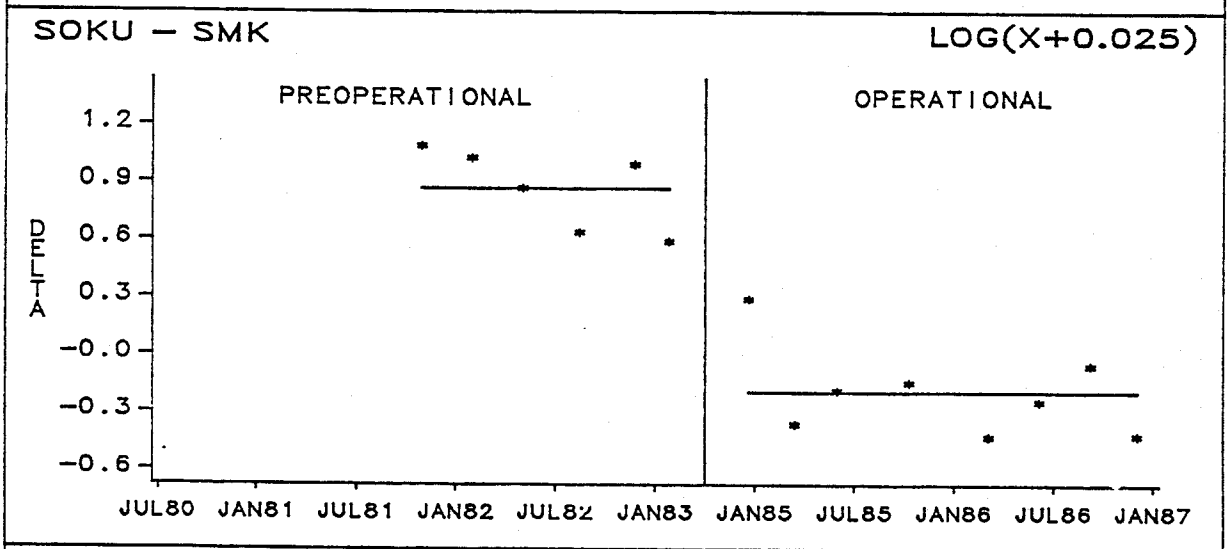


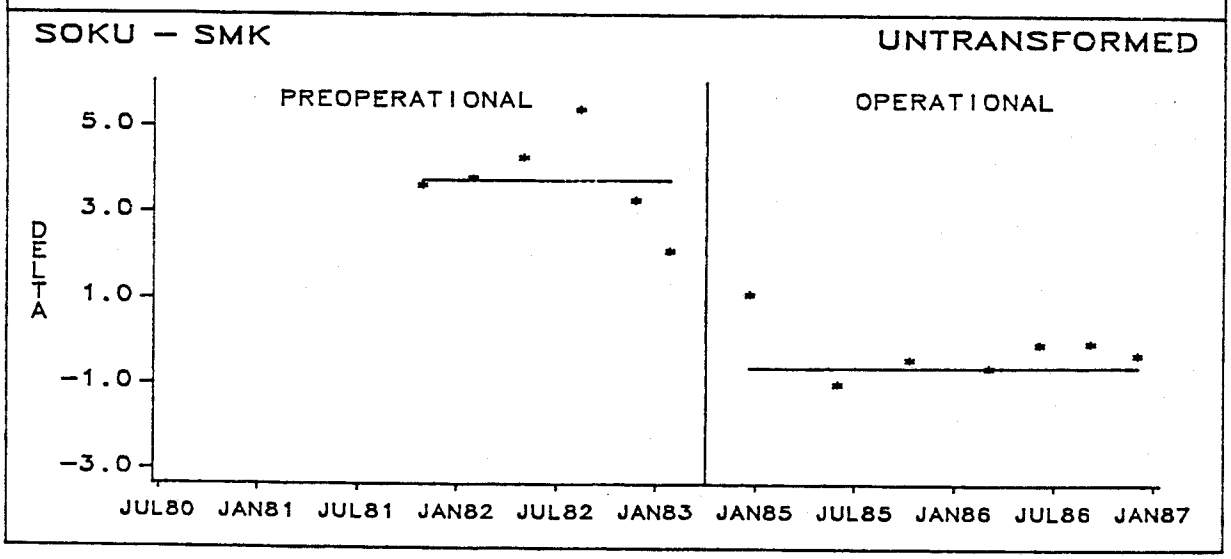
CONUS CALIFORNICUS



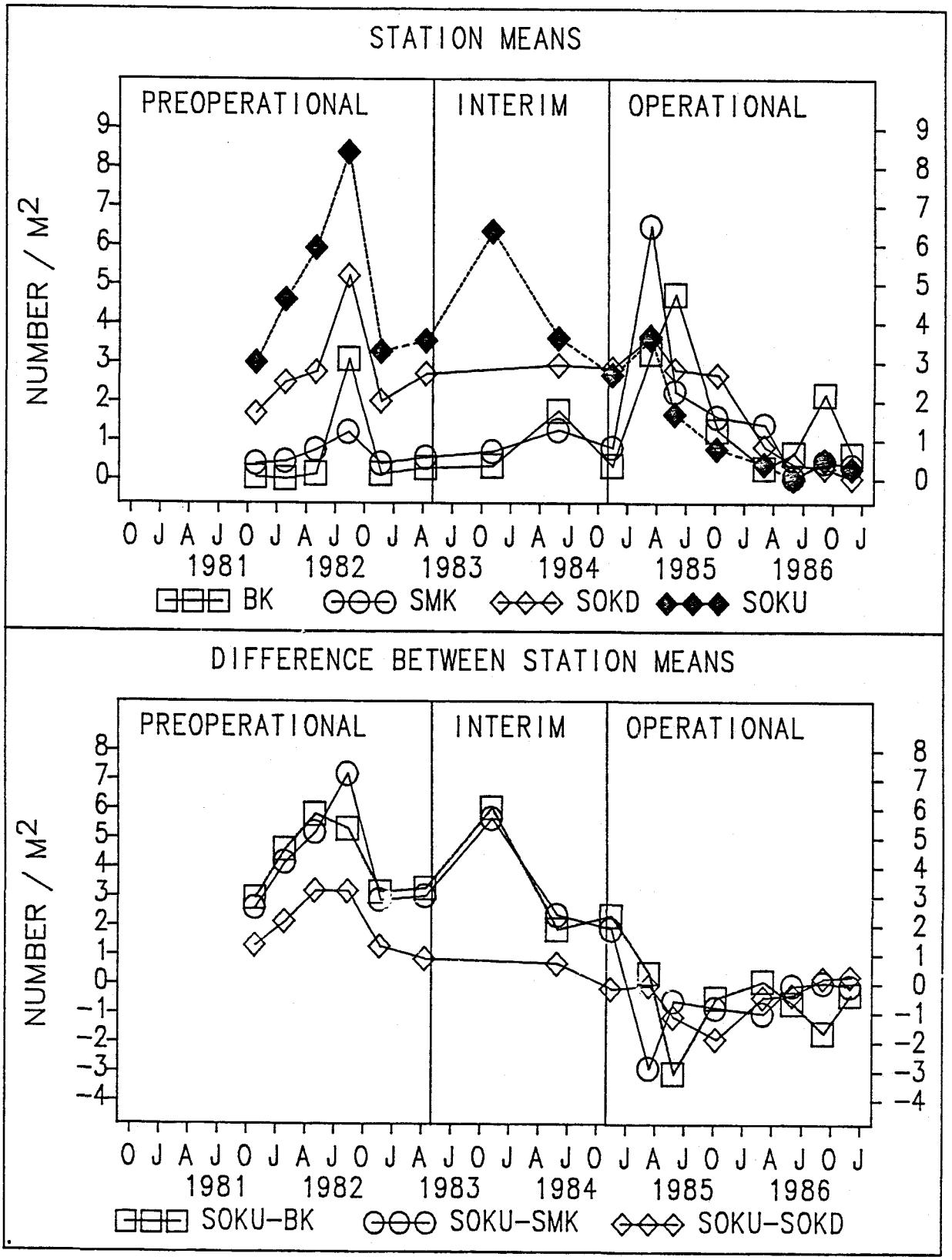
CONUS CALIFORNICUS



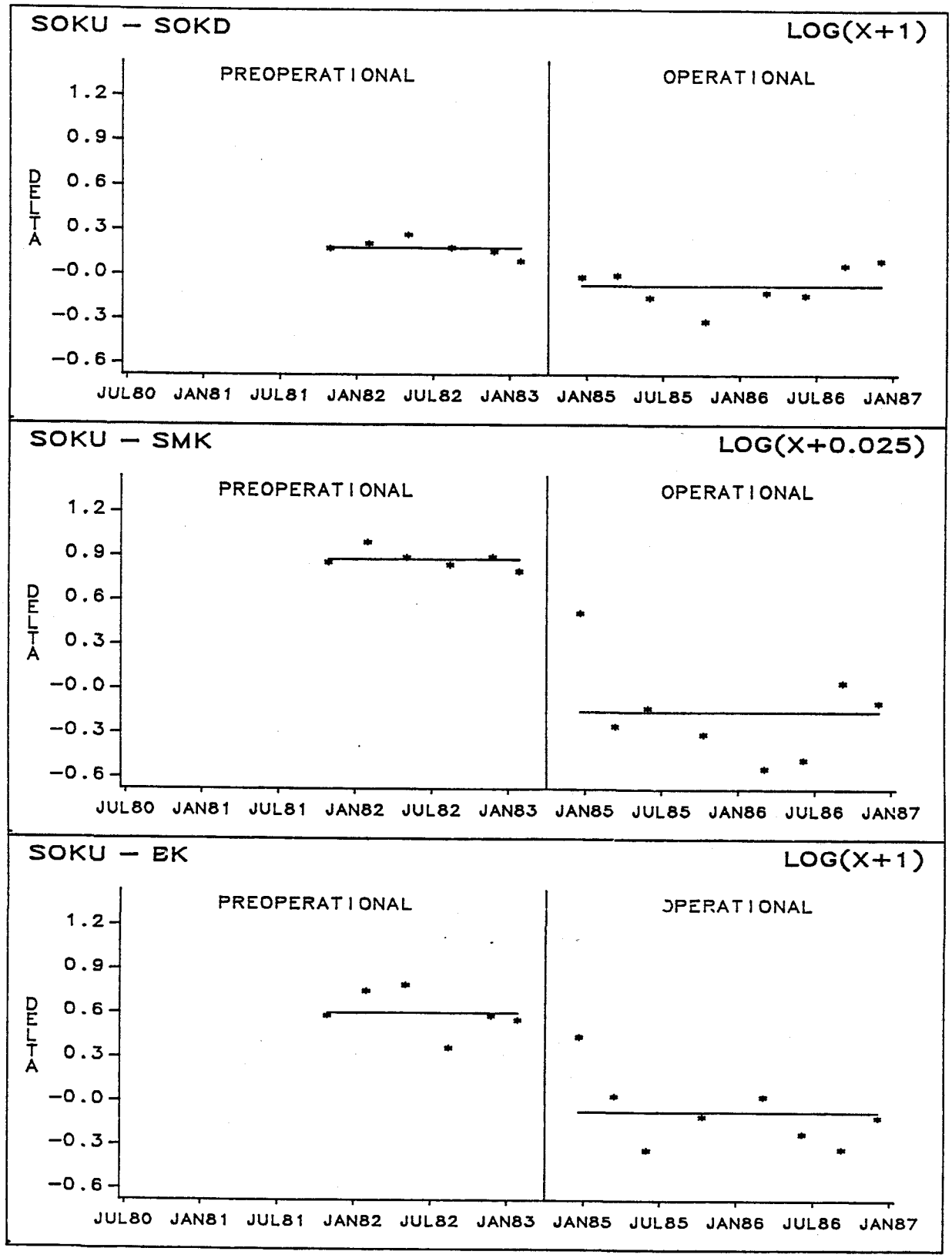




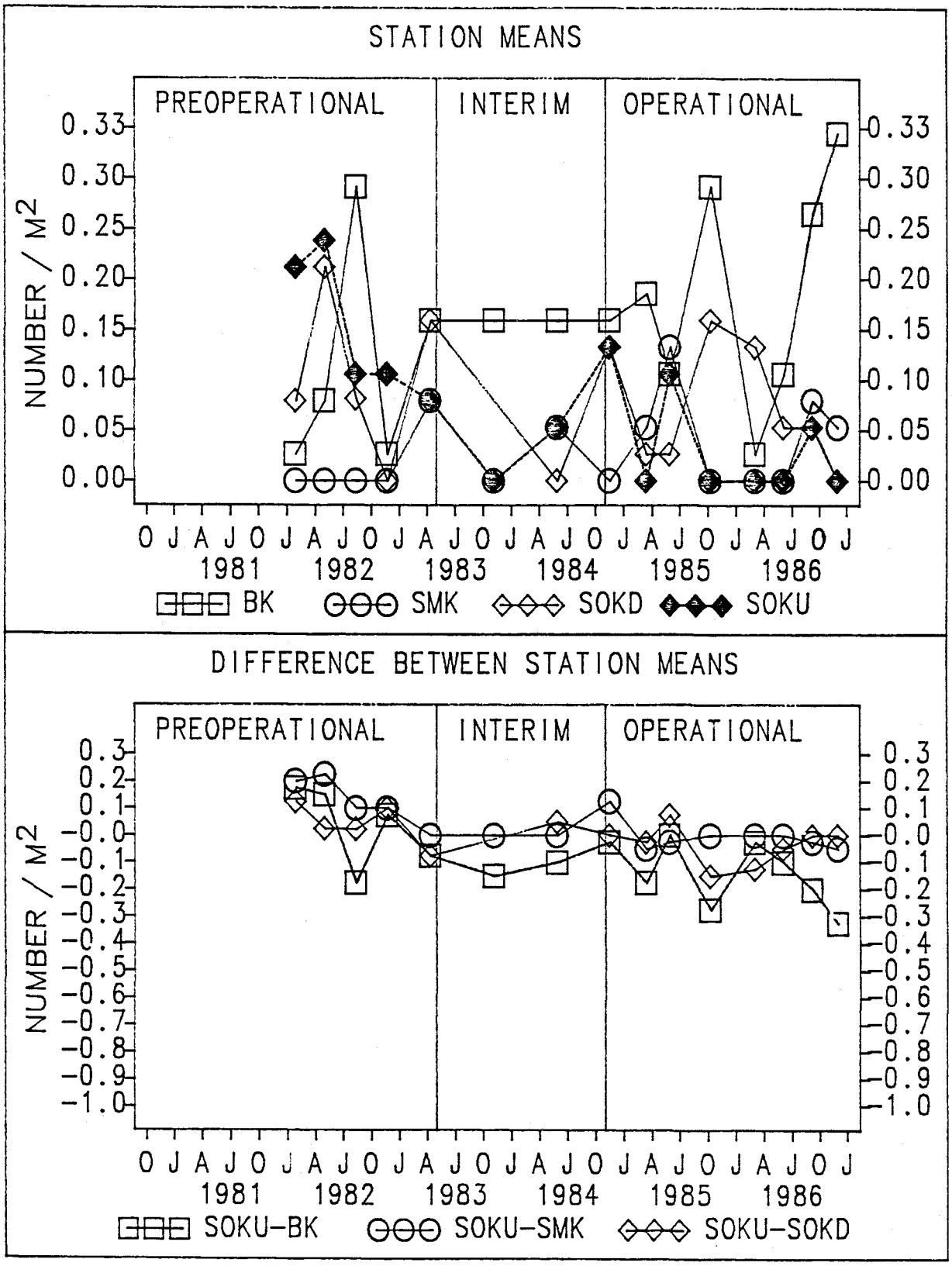
CONUS CALIFORNICUS



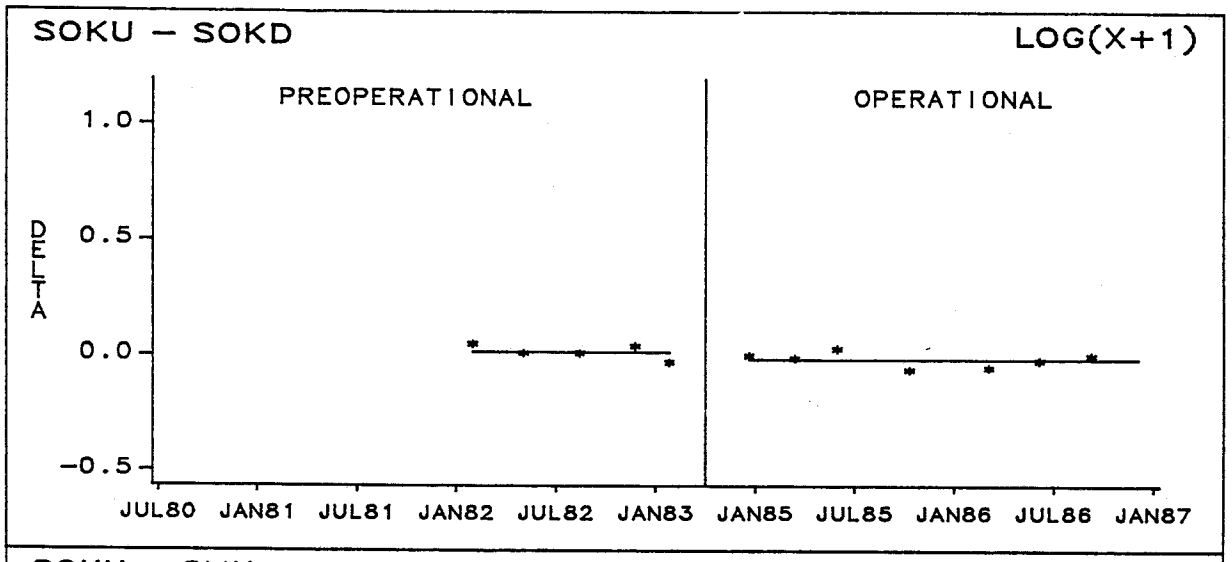
CONUS CALIFORNICUS



CRASSISPIRA SEMIINFLATA



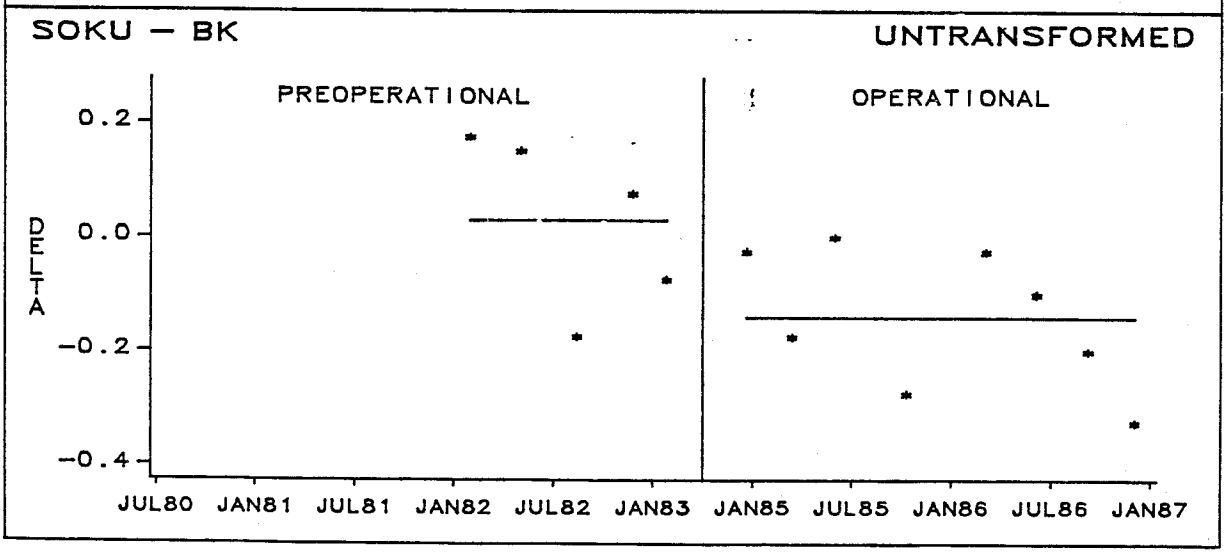
CRASSISPIRA SEMIINFLATA



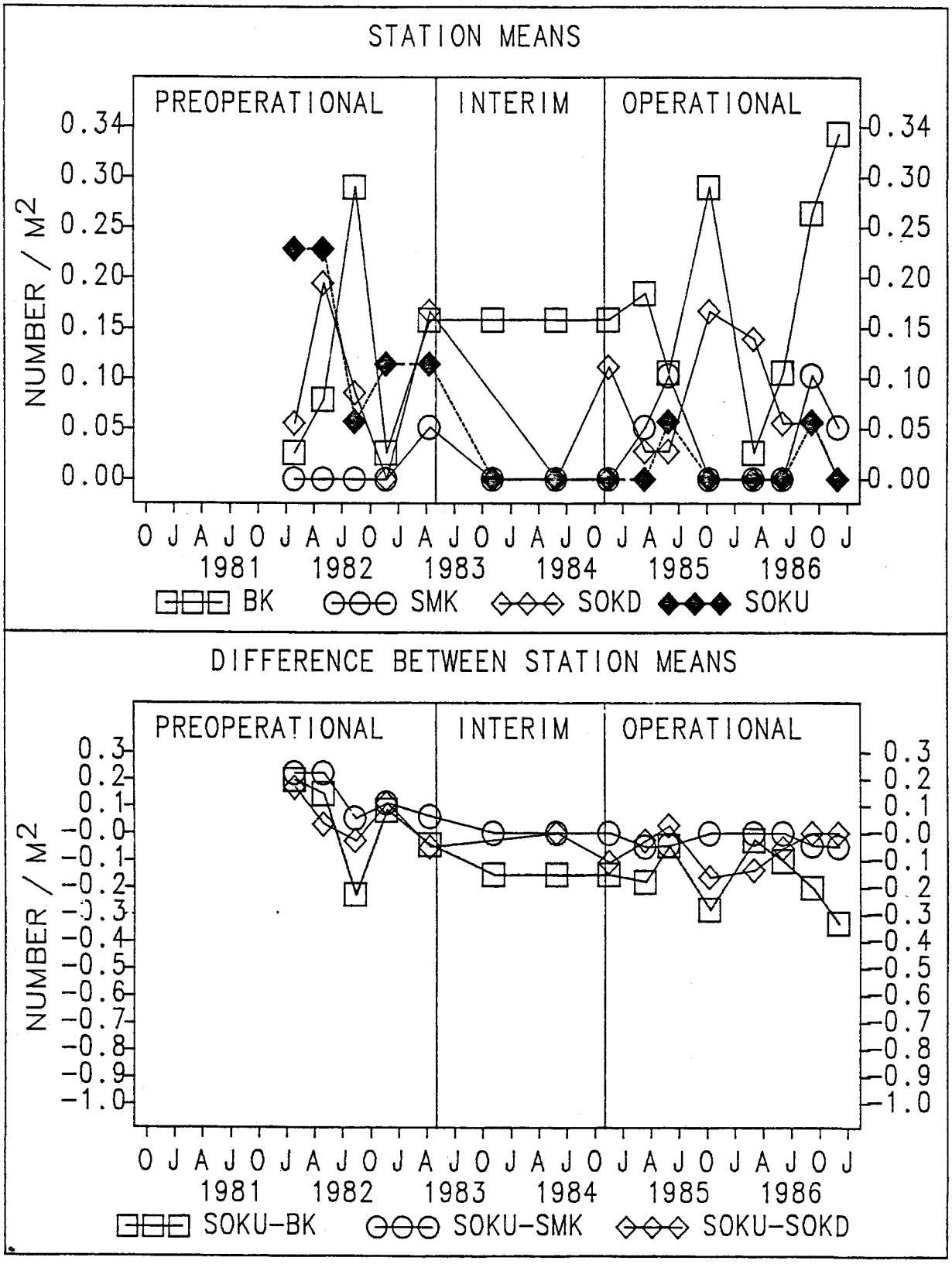
SOKU – SMK

NO TEST

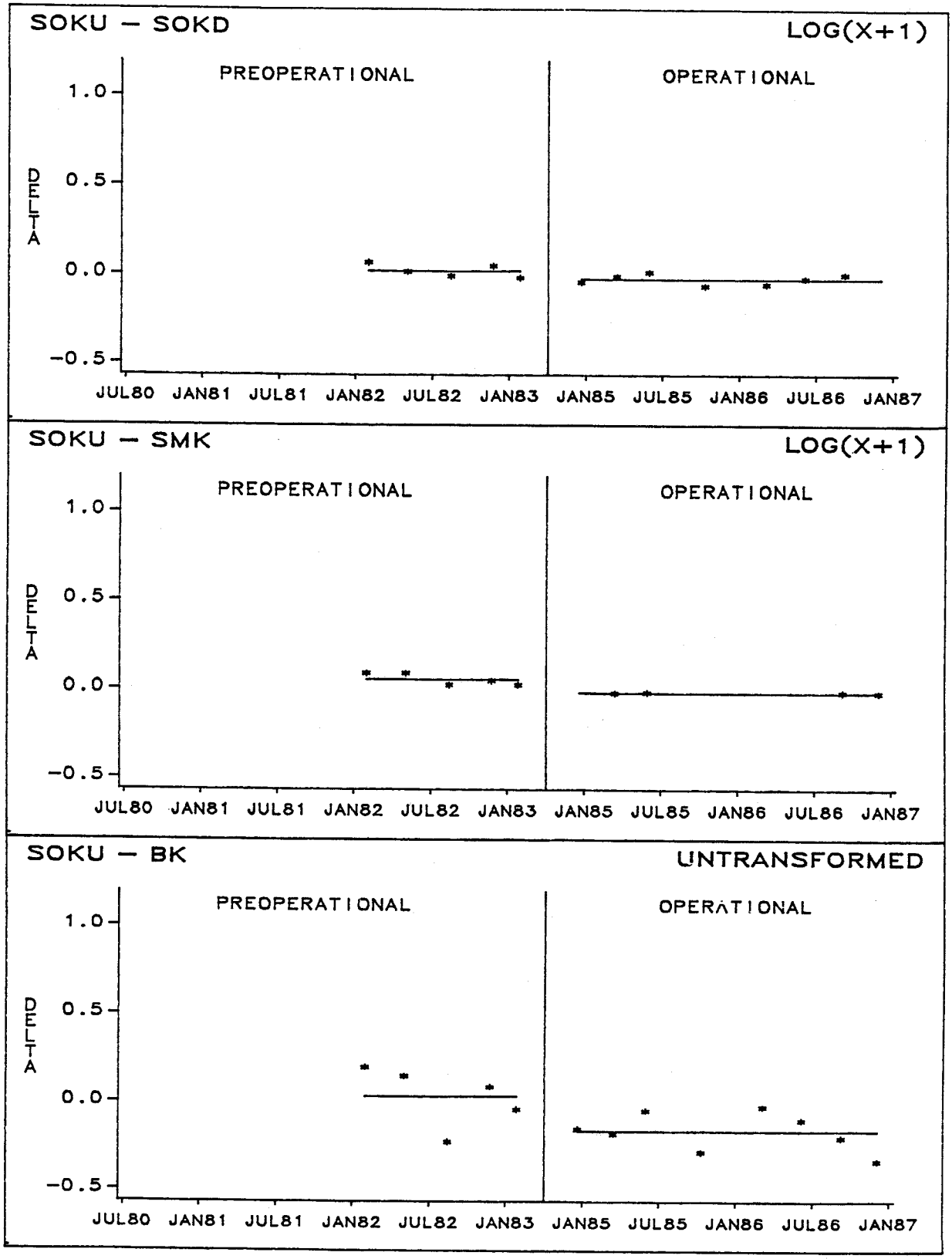
ASSUMPTIONS NOT MET



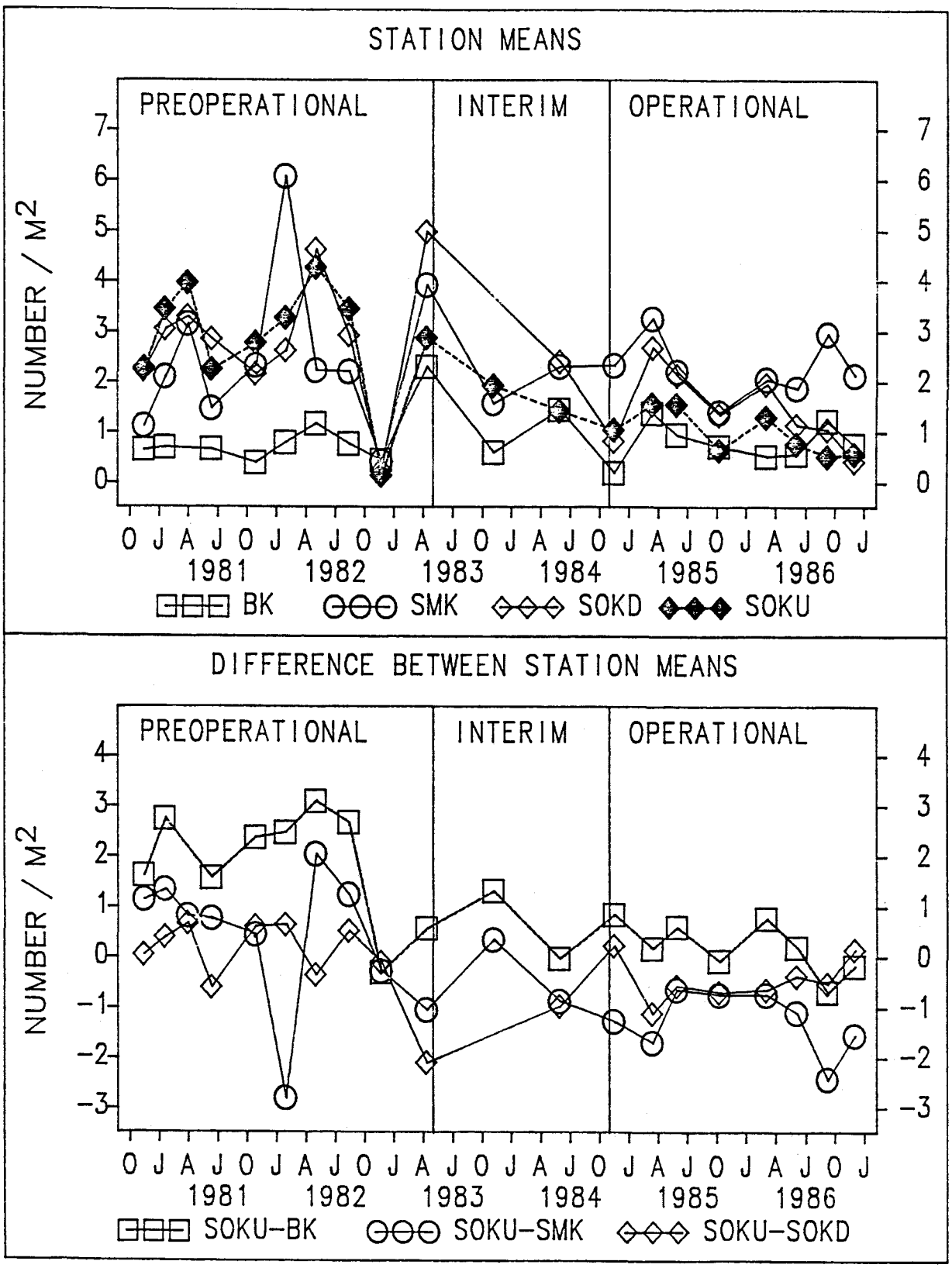
CRASSISPIRA SEMIINFLATA



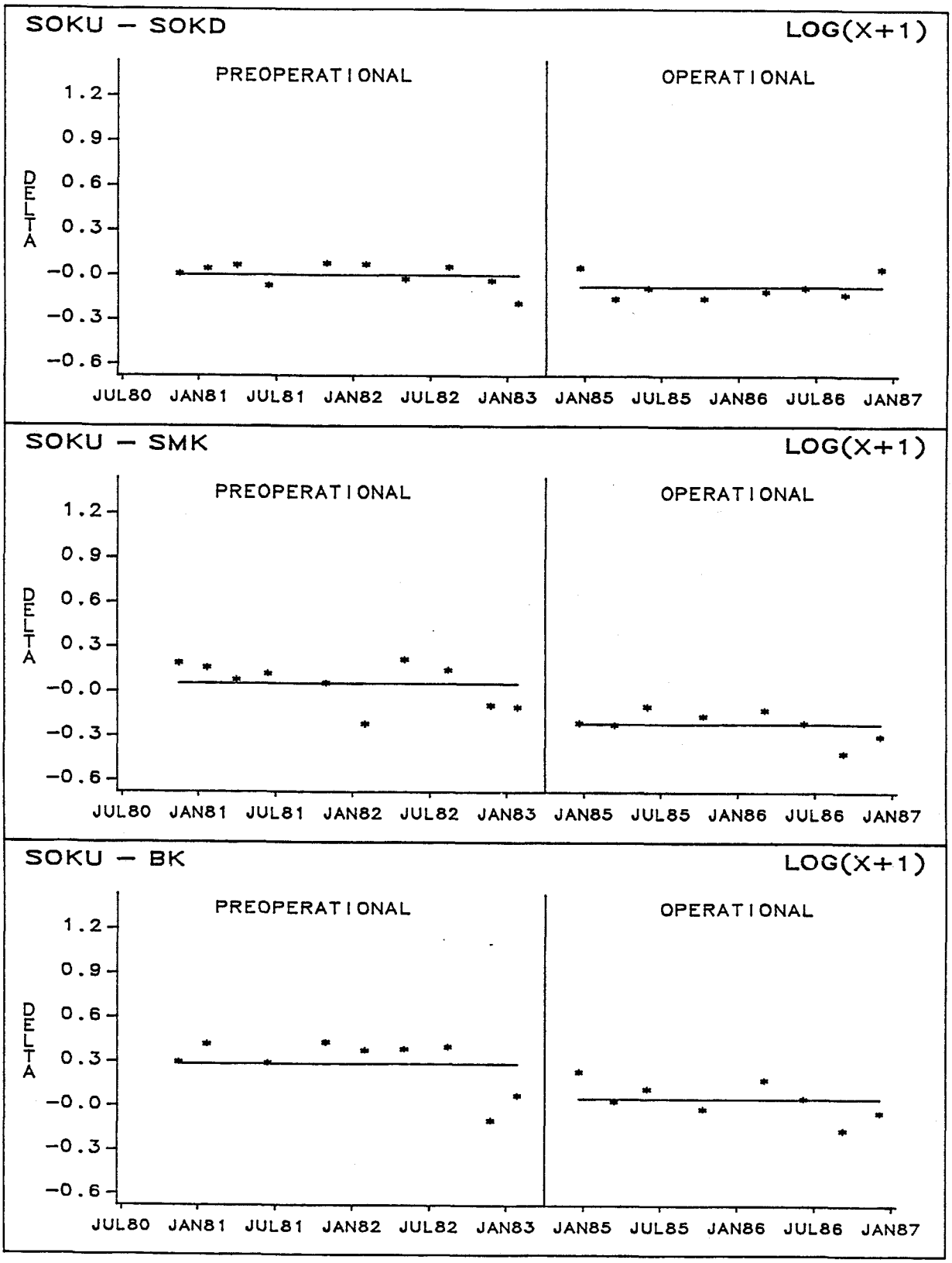
CRASSISPIRA SEMIINFLATA



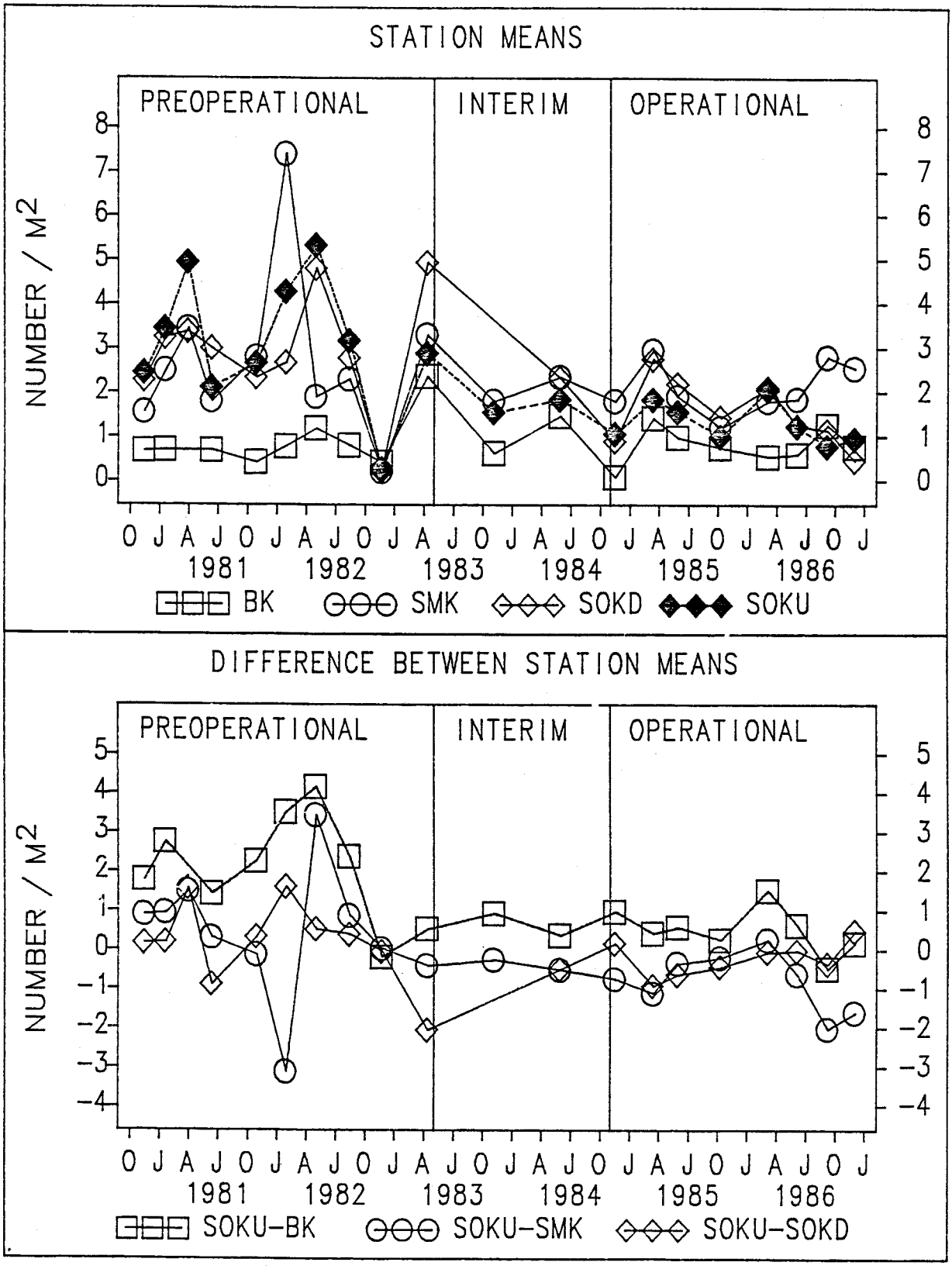
KELLETIA KELLETII



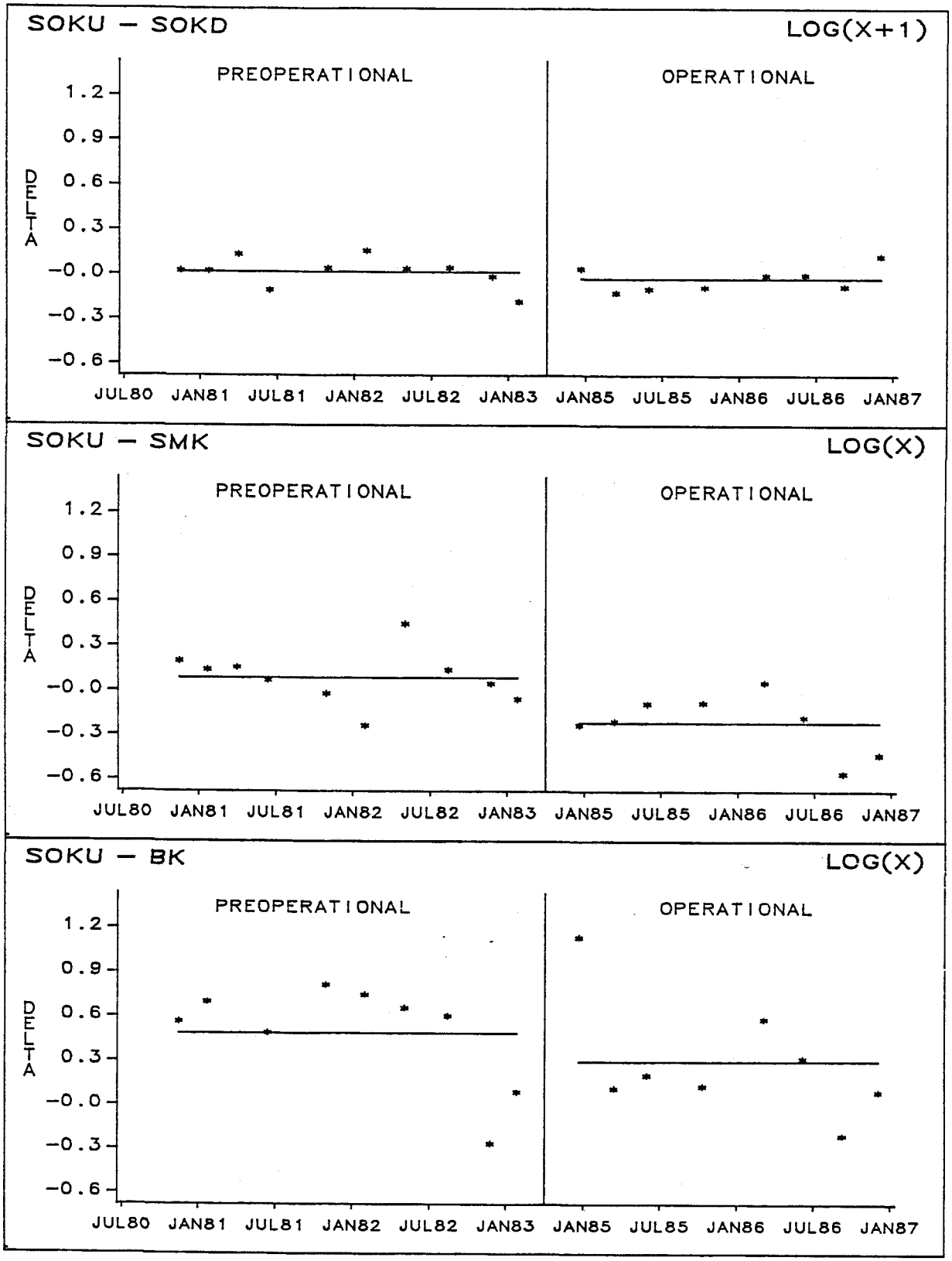
KELLETIA KELLETII



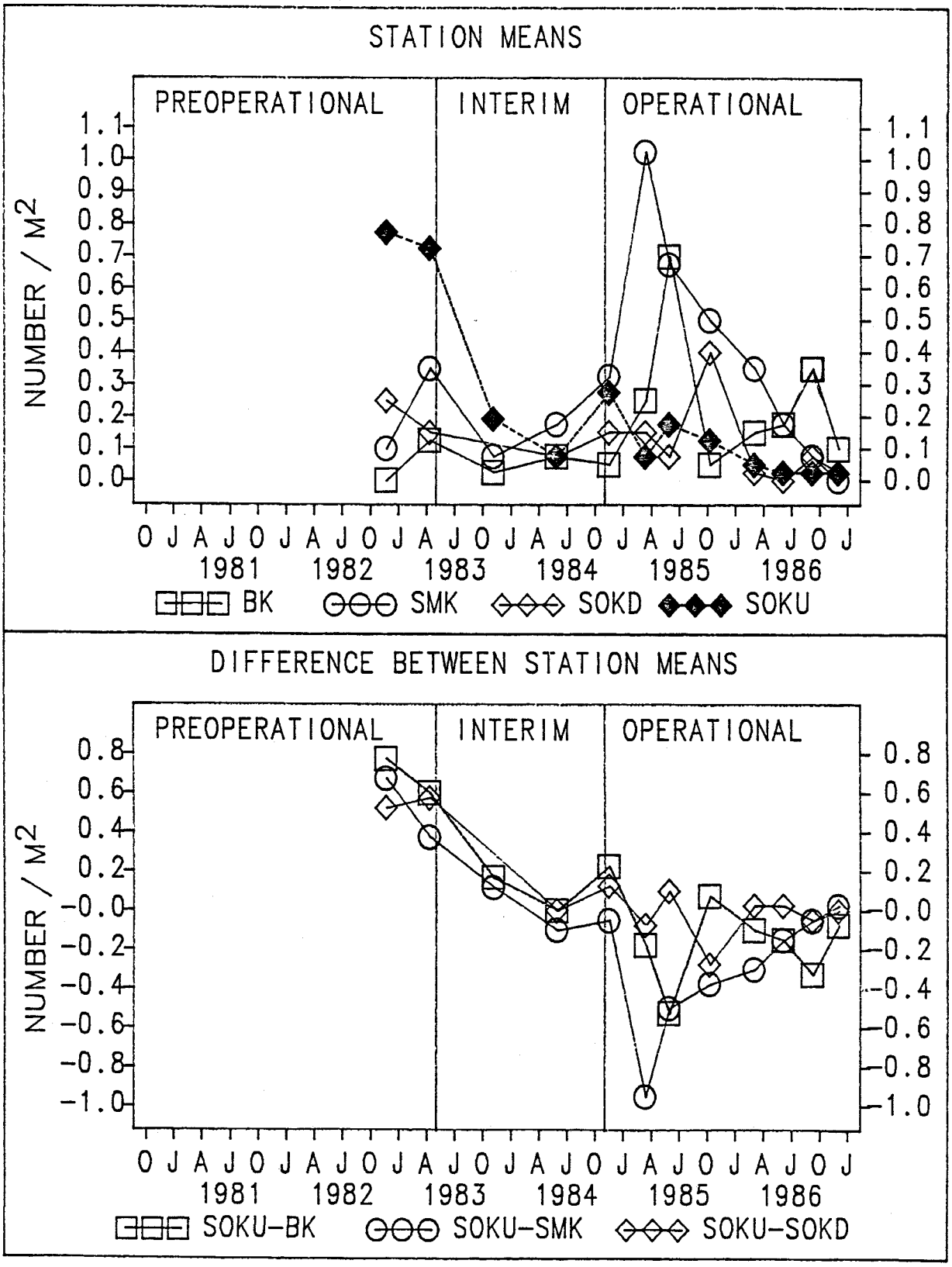
KELLETIA KELLETII



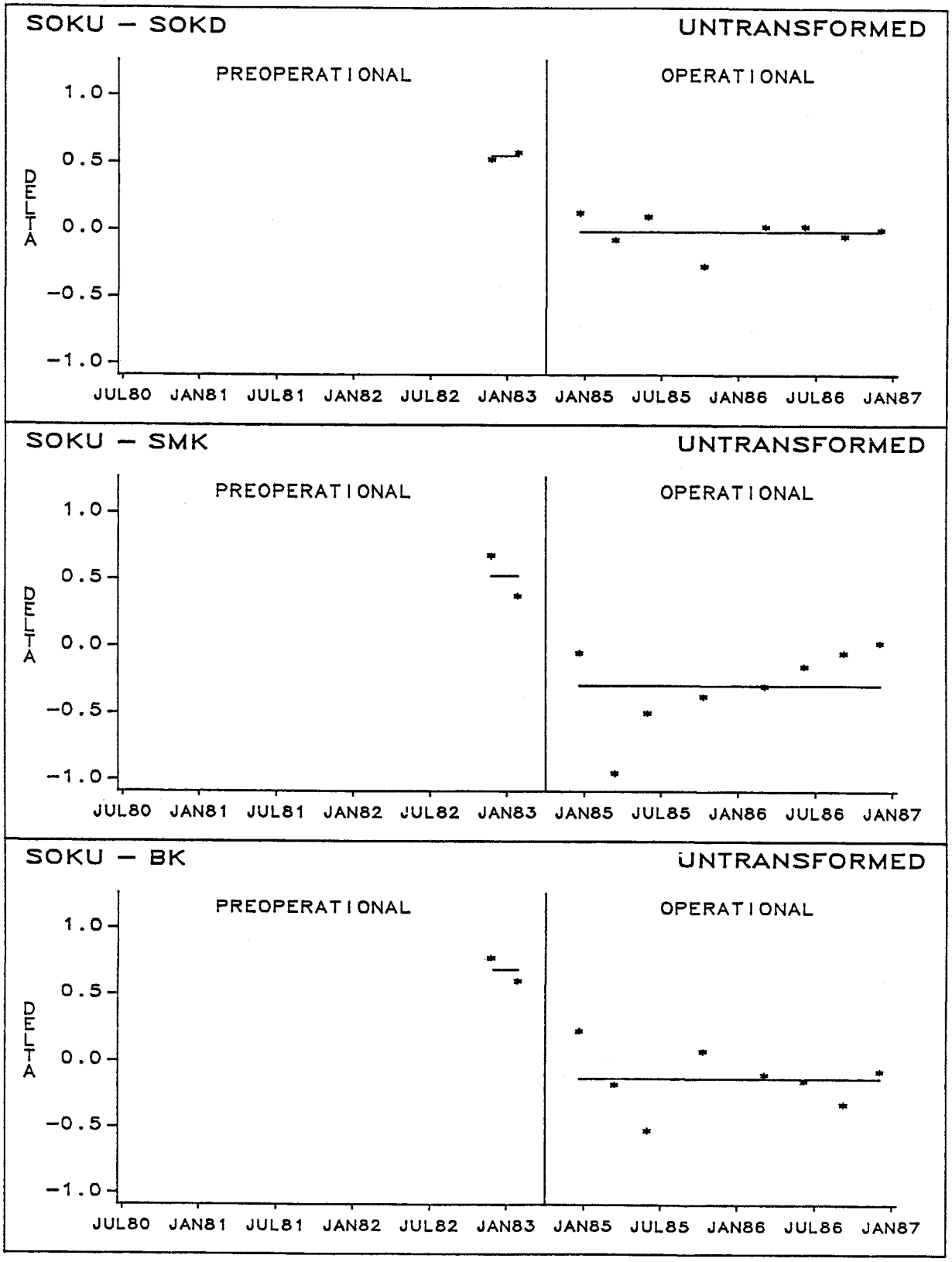
KELLETIA KELLETII



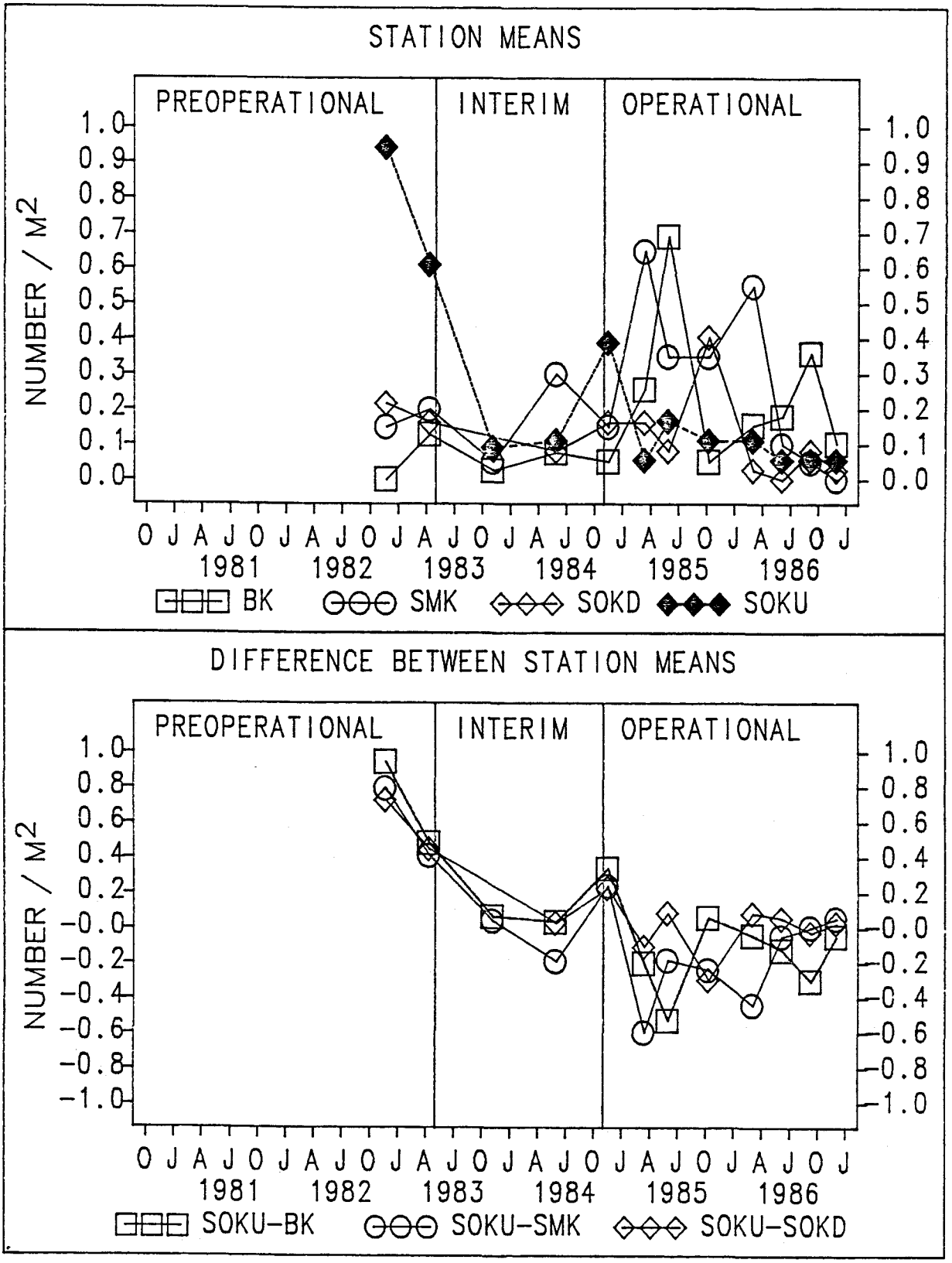
MAXWELLA GEMMA



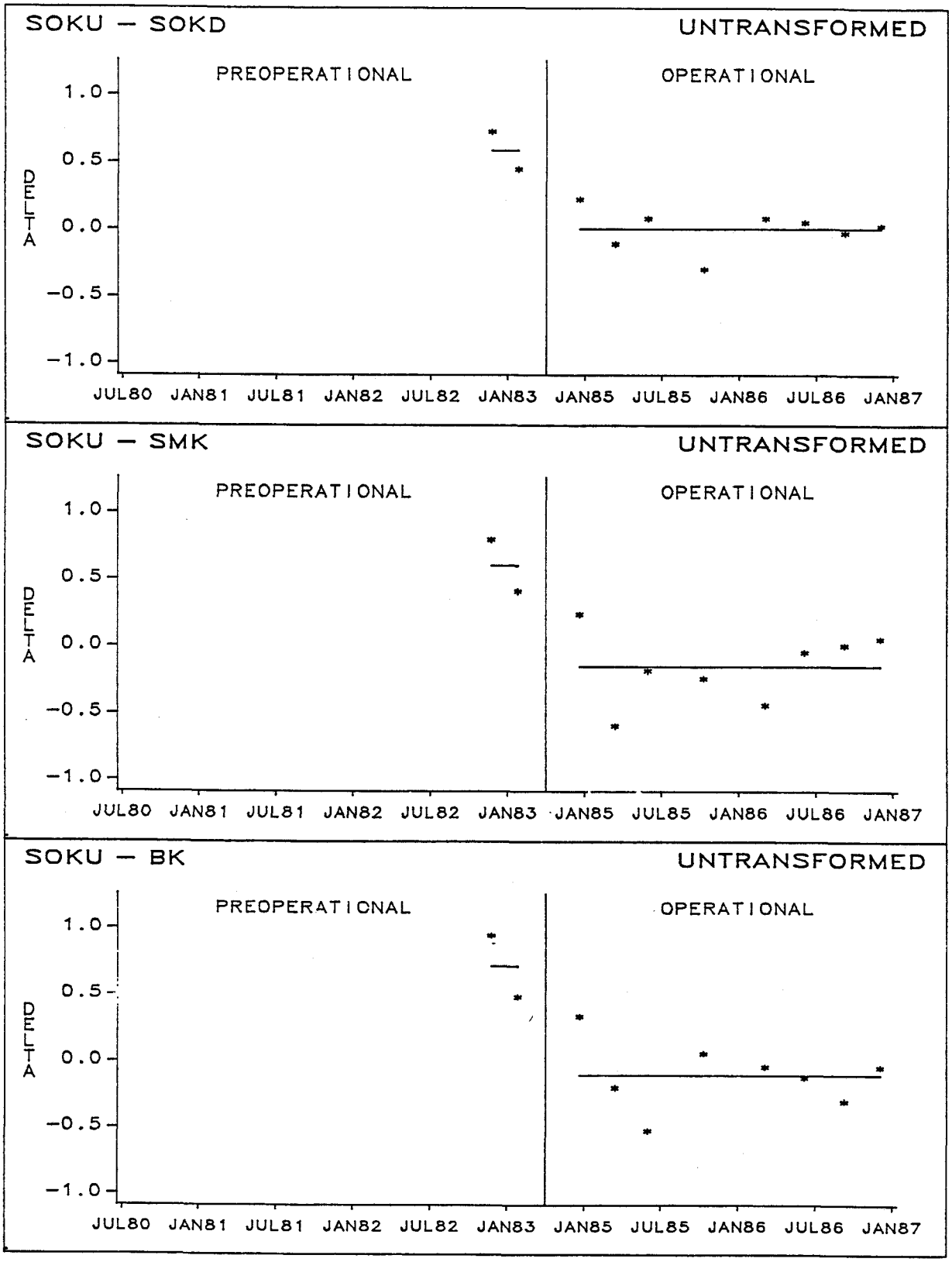
MAXWELLIA GEMMA



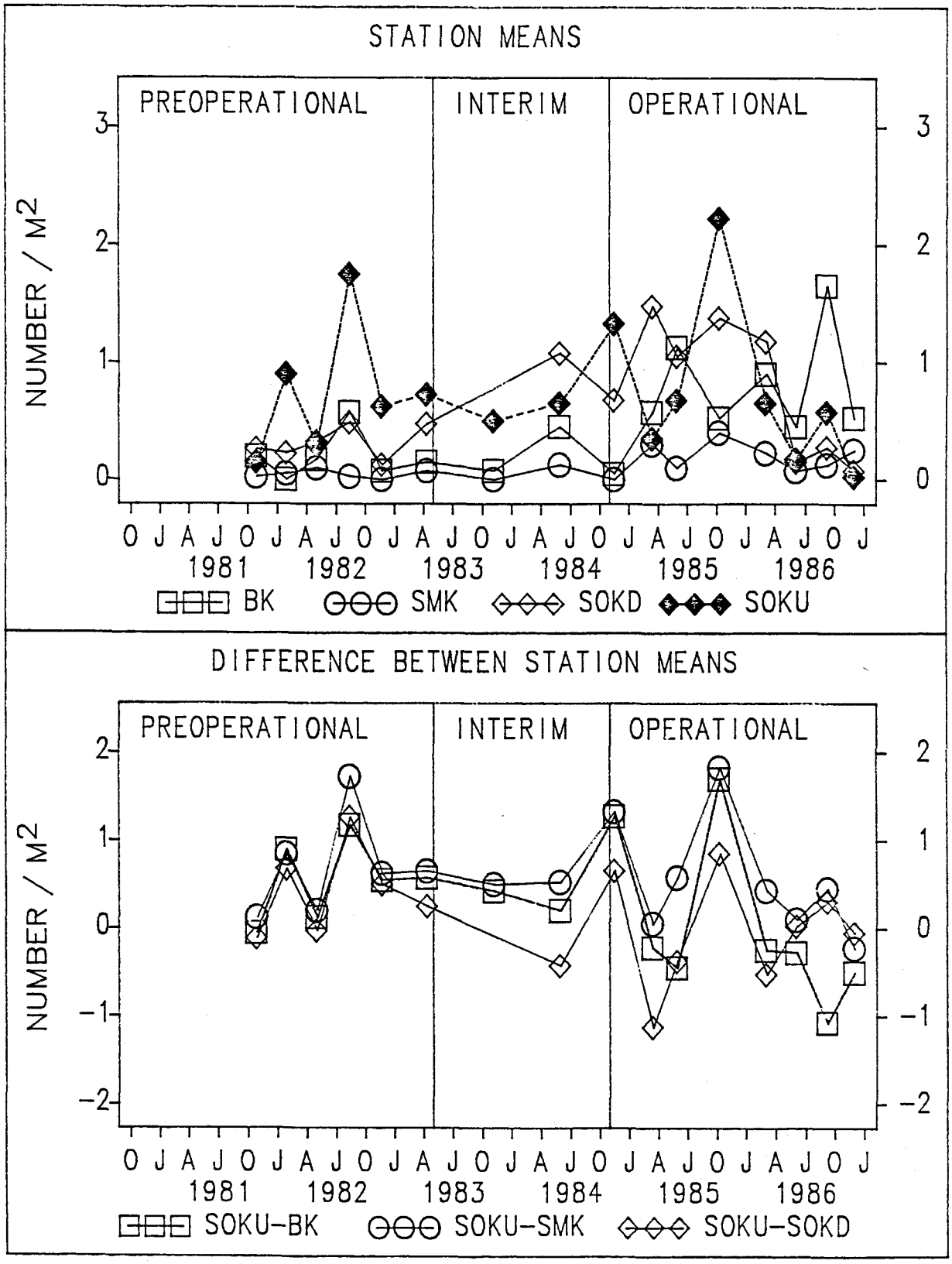
MAXWELLIA GEMMA



MAXWELLIA GEMMA



MITRA IDAE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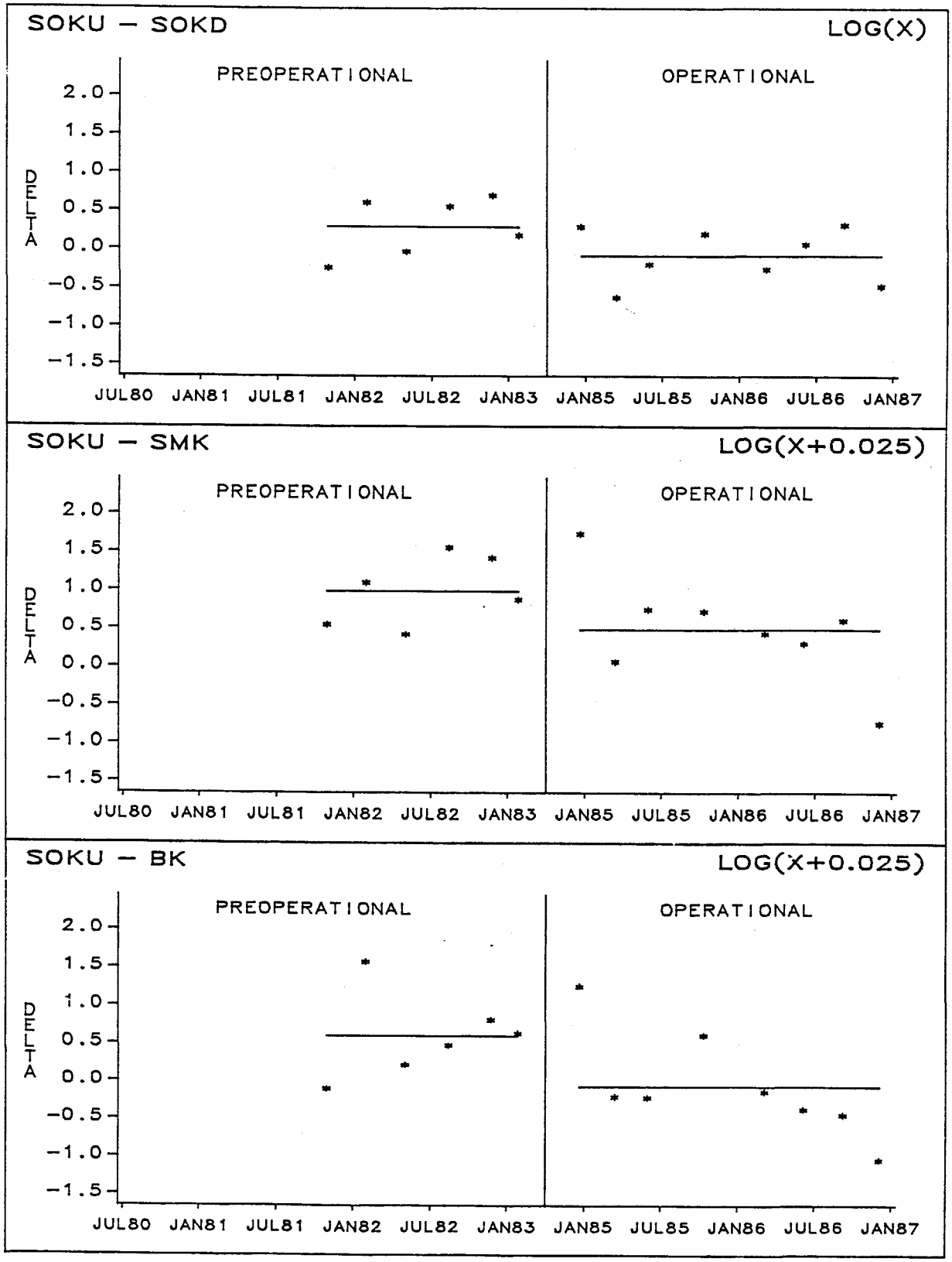
PREOPERATIONAL
INTERIM
OPERATIONAL
NUMBER / M2
0
1
2
3
O J A J O J A J O J A J O J A J O J A J O J A J O J
1981
1982
1983
1984
1985
1986
BK
SMK
SOKD
SOKU
DIFFERENCE BETWEEN STATION MEANS
PREOPERATIONAL
INTERIM
OPERATIONAL
NUMBER / M2
-2
-1
0
1
2
O J A J O J A J O J A J O J A J O J A J O J A J O J
1981
1982
1983
1984
1985
1986
SOKU-BK
SOKU-SMK
SOKU-SOKD

MITRA IDAE


SOKU – SOKD
LOG(X)
PREOPERATIONAL
OPERATIONAL
DELTA
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
JUL80 JAN81 JUL81 JAN82 JUL82 JAN83 JAN85 JUL85 JAN86 JUL86 JAN87
SOKU – SMK
LOG(X+0.025)
PREOPERATIONAL
OPERATIONAL
DELTA
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
JUL80 JAN81 JUL81 JAN82 JUL82 JAN83 JAN85 JUL85 JAN86 JUL86 JAN87
SOKU – BK
LOG(X+0.025)
PREOPERATIONAL
OPERATIONAL
DELTA
2.0
1.5
1.0
0.5
0.0
-0.5
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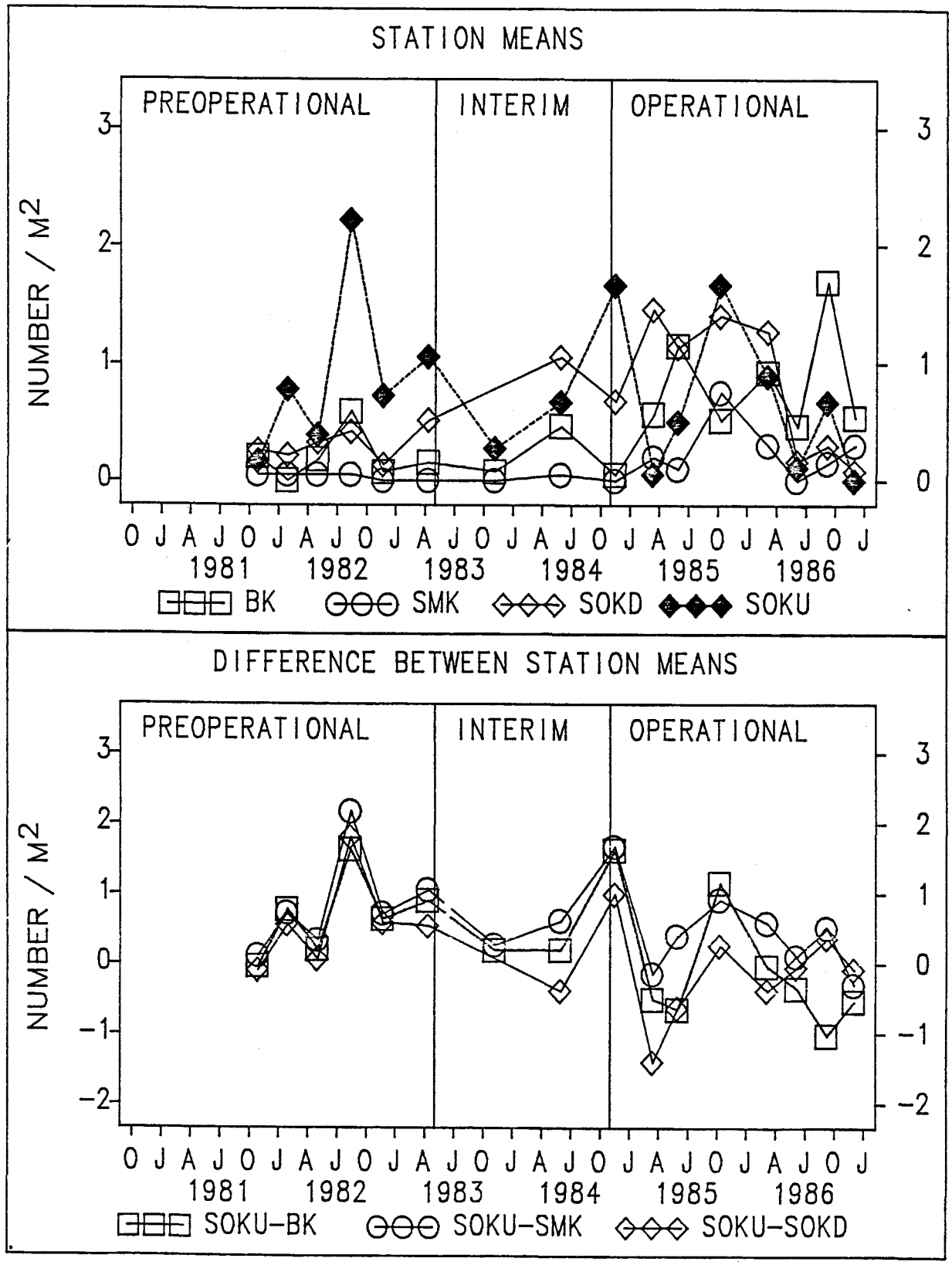
-1.5
JUL80 JAN81 JUL81 JAN82 JUL82 JAN83 JAN85 JUL85 JAN86 JUL86 JAN87

MITRA IDAE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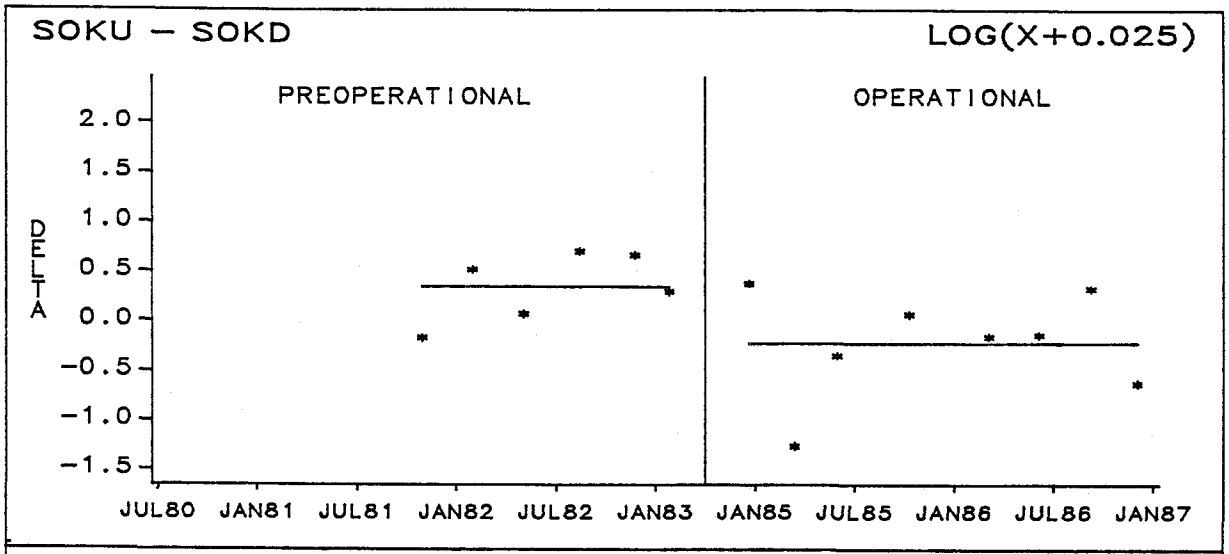
INTERIM
OPERATIONAL
NUMBER / M2
0
1
2
3
O J A J O J A J O J A J O J A J O J A J O J A J O J
1981
1982
1983
1984
1985
1986
BK
SMK
SOKD
SOKU
DIFFERENCE BETWEEN STATION MEANS
PREOPERATIONAL
INTERIM
OPERATIONAL
NUMBER / M2
-2
-1
0
1
2
3
O J A J O J A J O J A J O J A J O J A J O J A J O J
1981
1982
1983
1984
1985
1986
SOKU-BK
SOKU-SMK
SOKU-SOKD

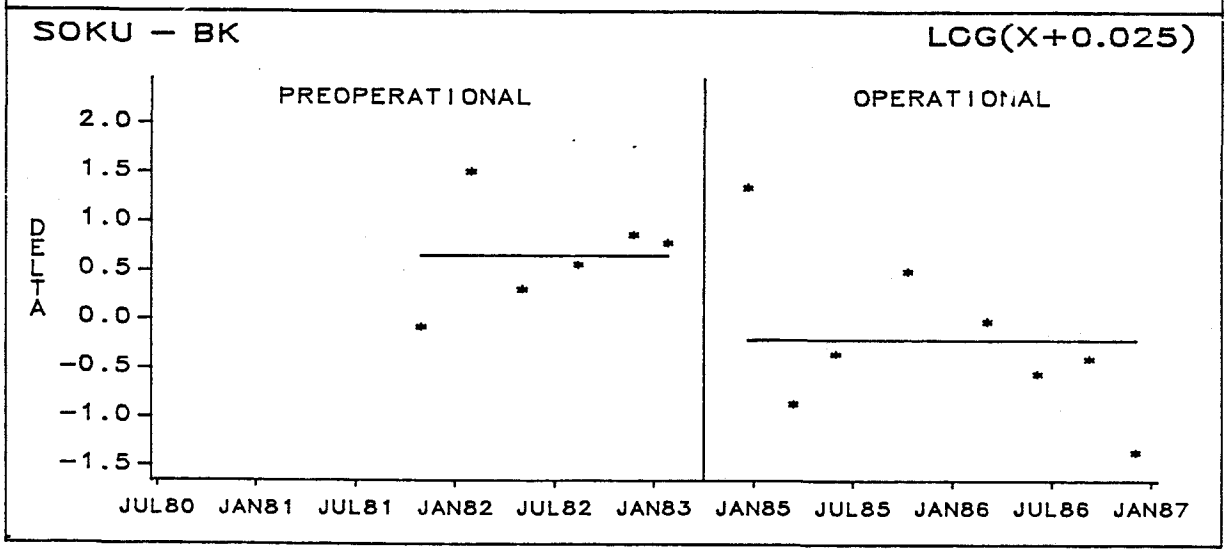
MITRA IDAE



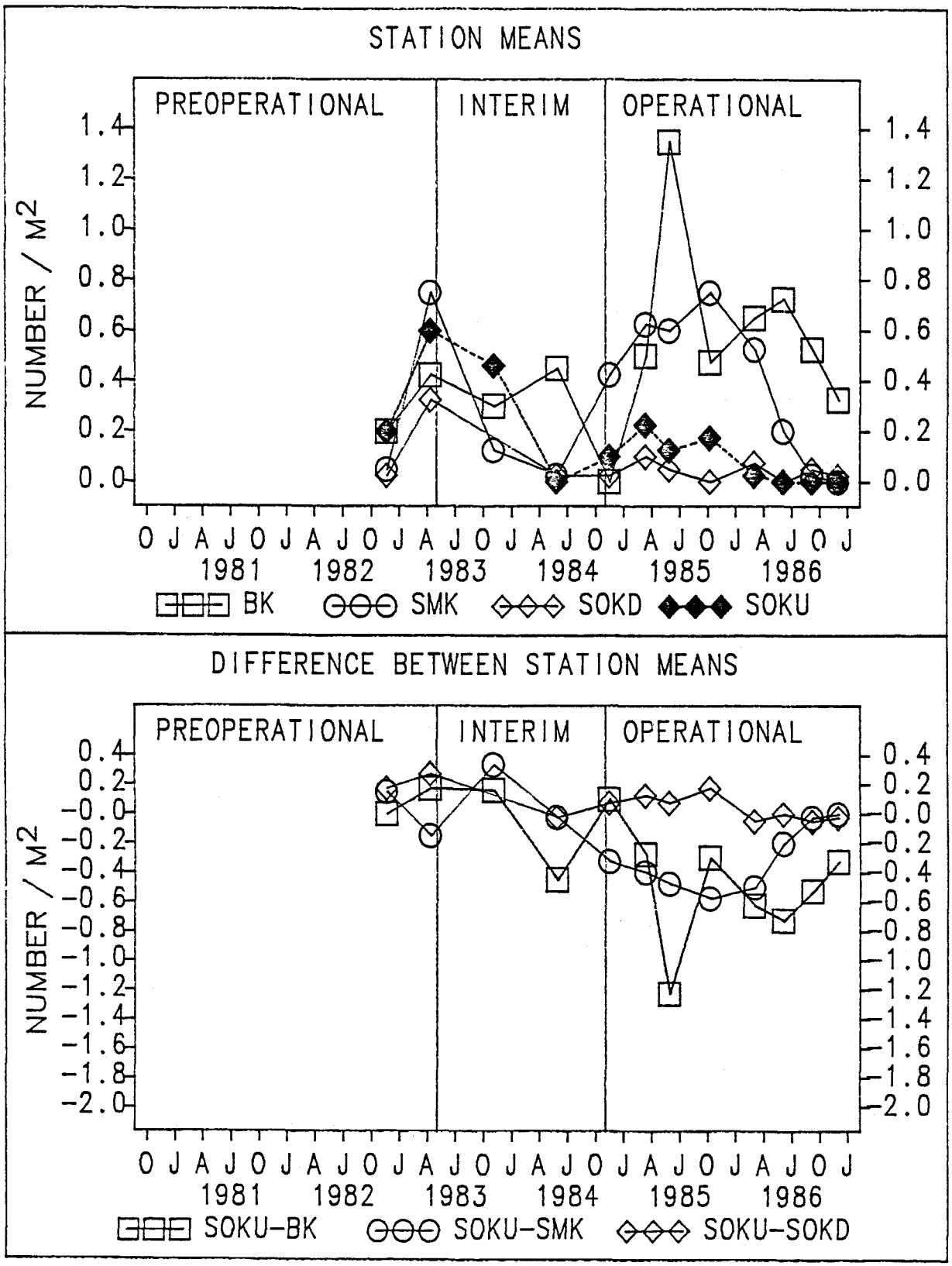
SOKU — SMK

NO TEST

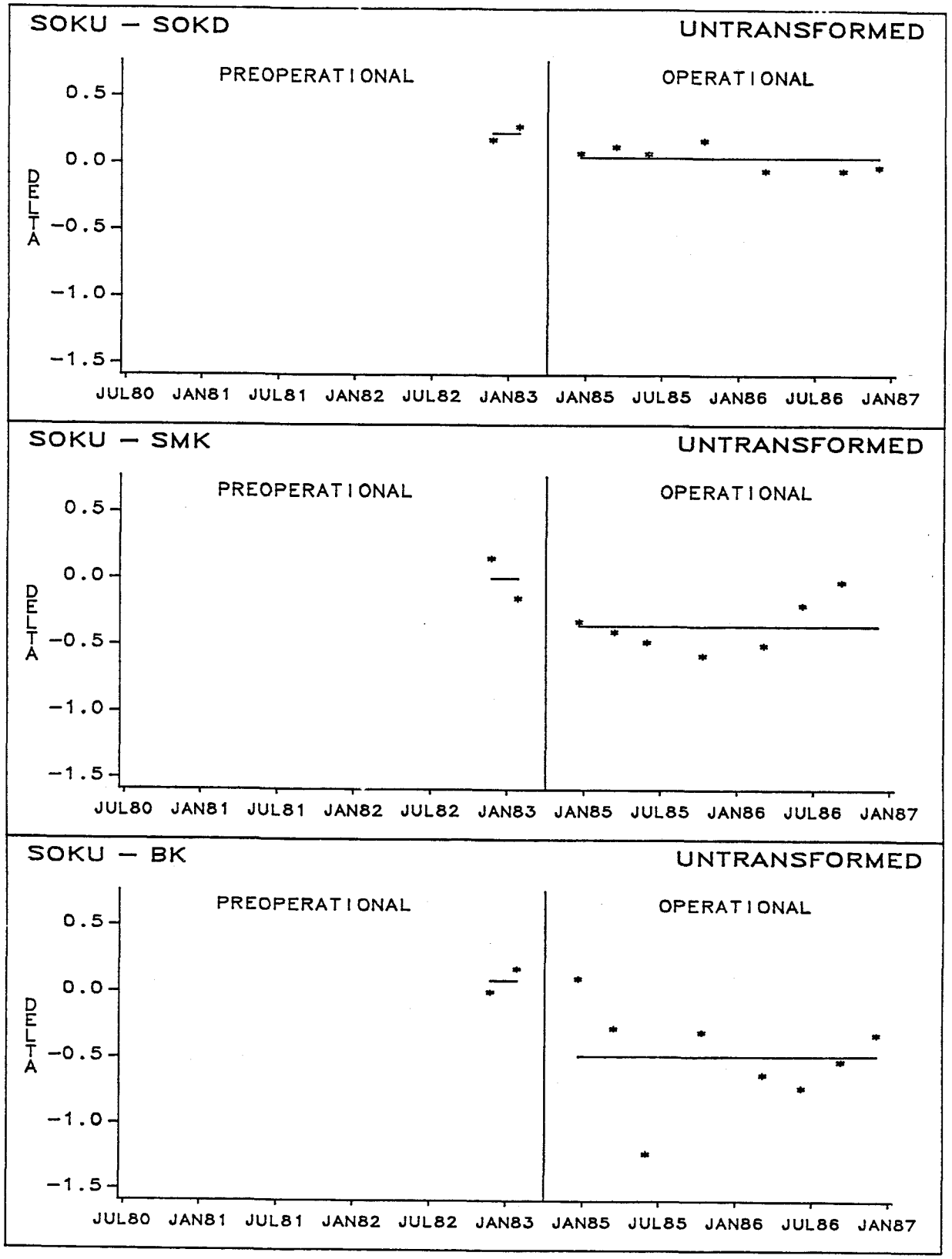
ASSUMPTIONS NOT MET



MUREXIELLA SANTAROSANA



MUREXIELLA SANTAROSANA



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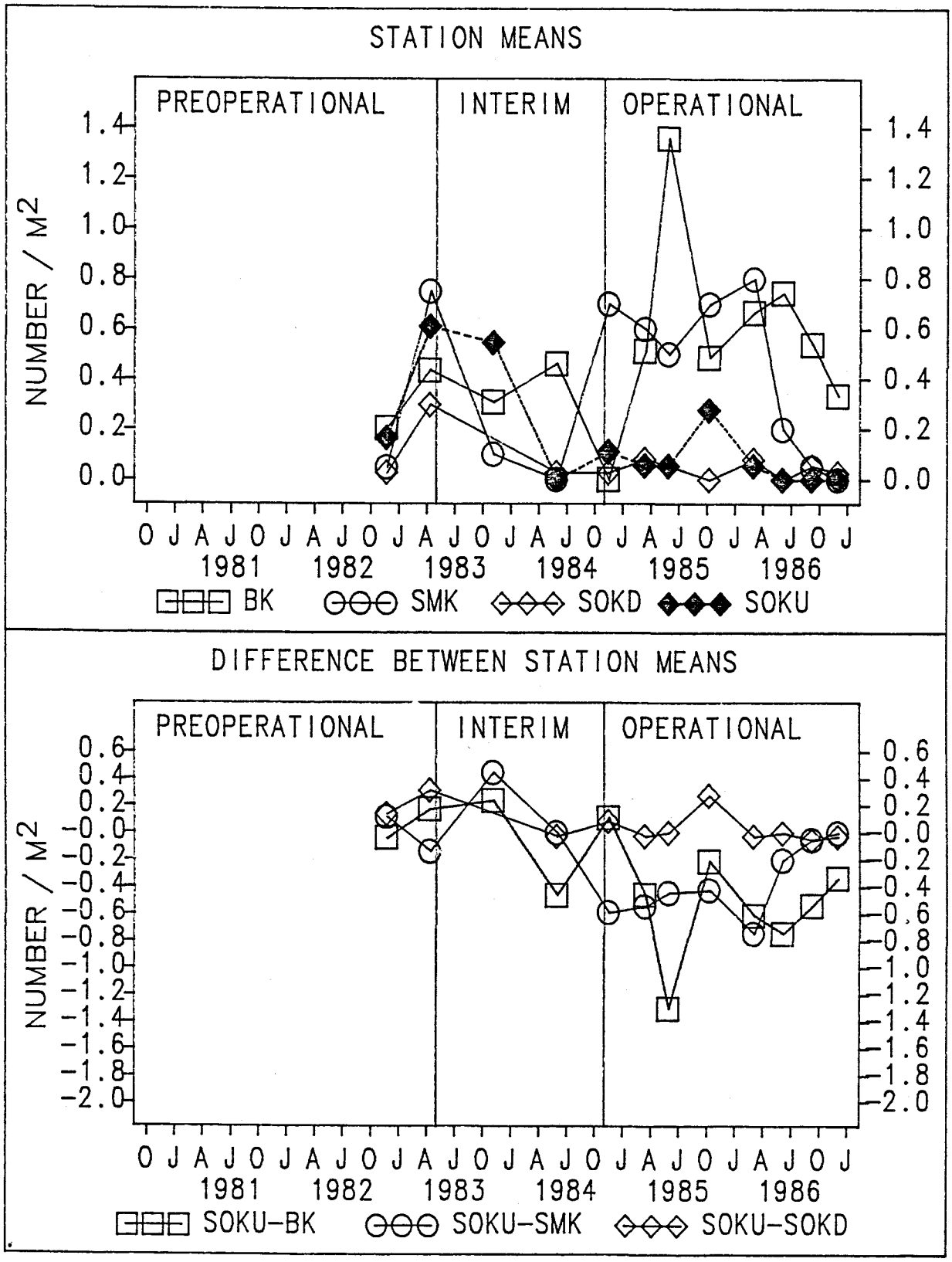

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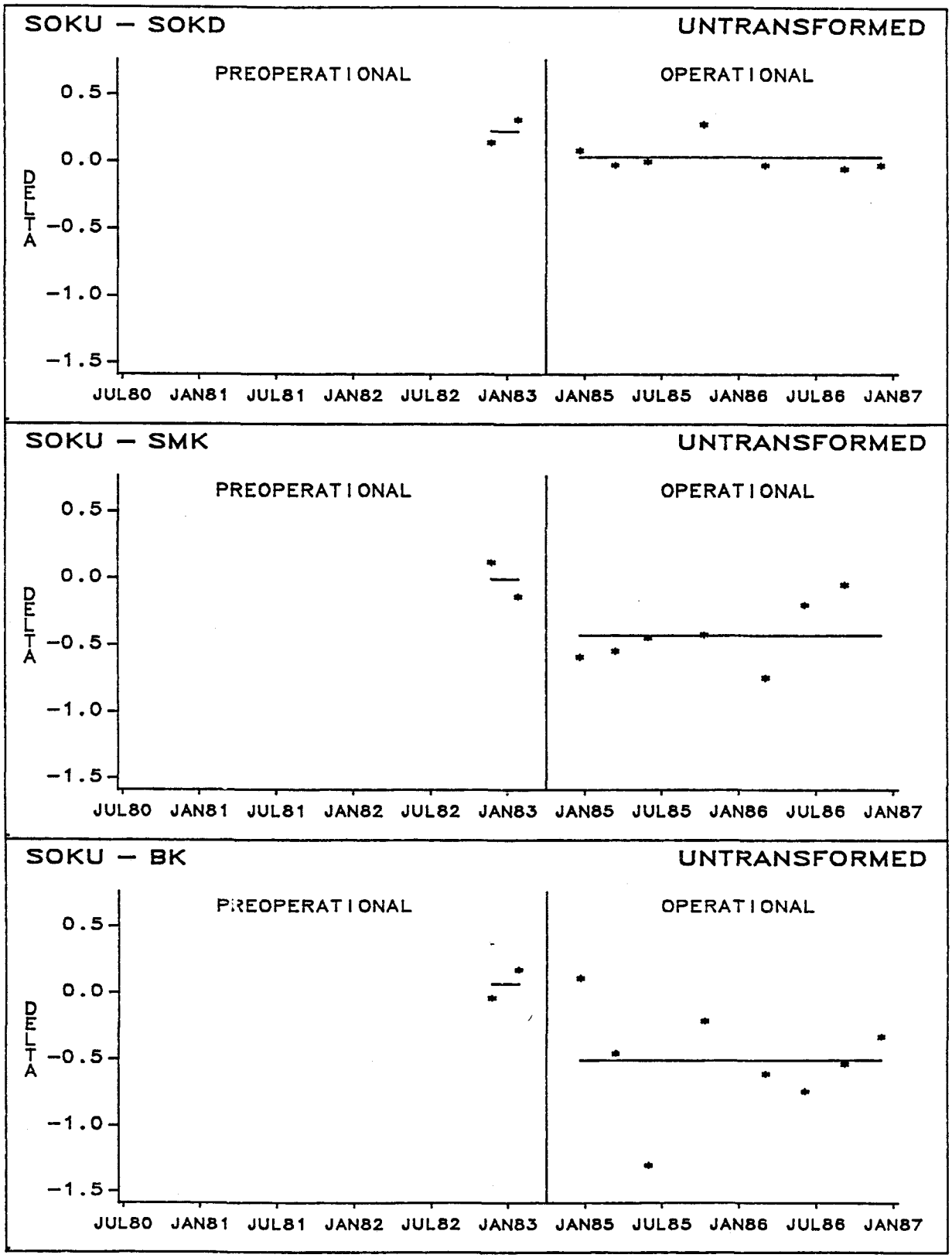

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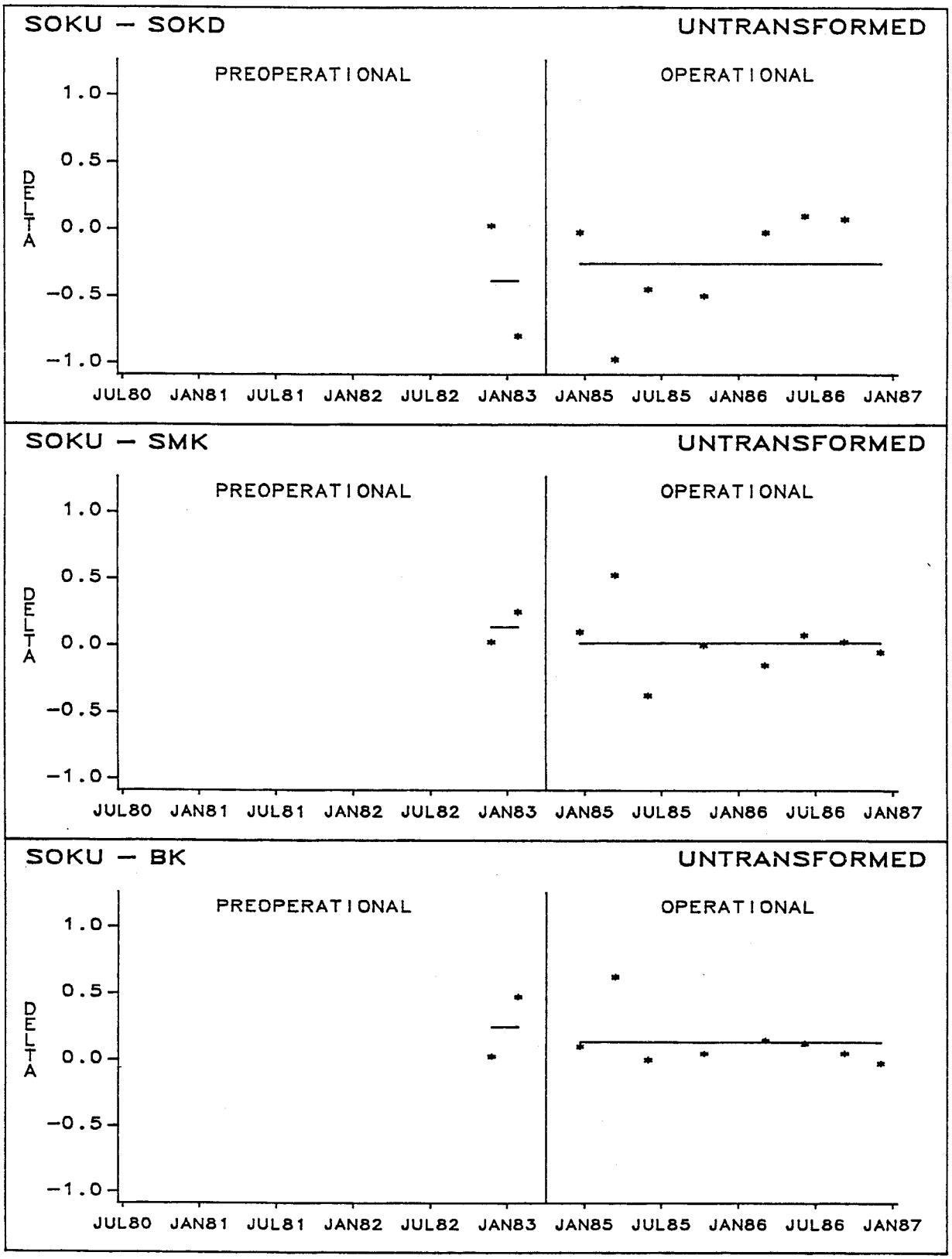
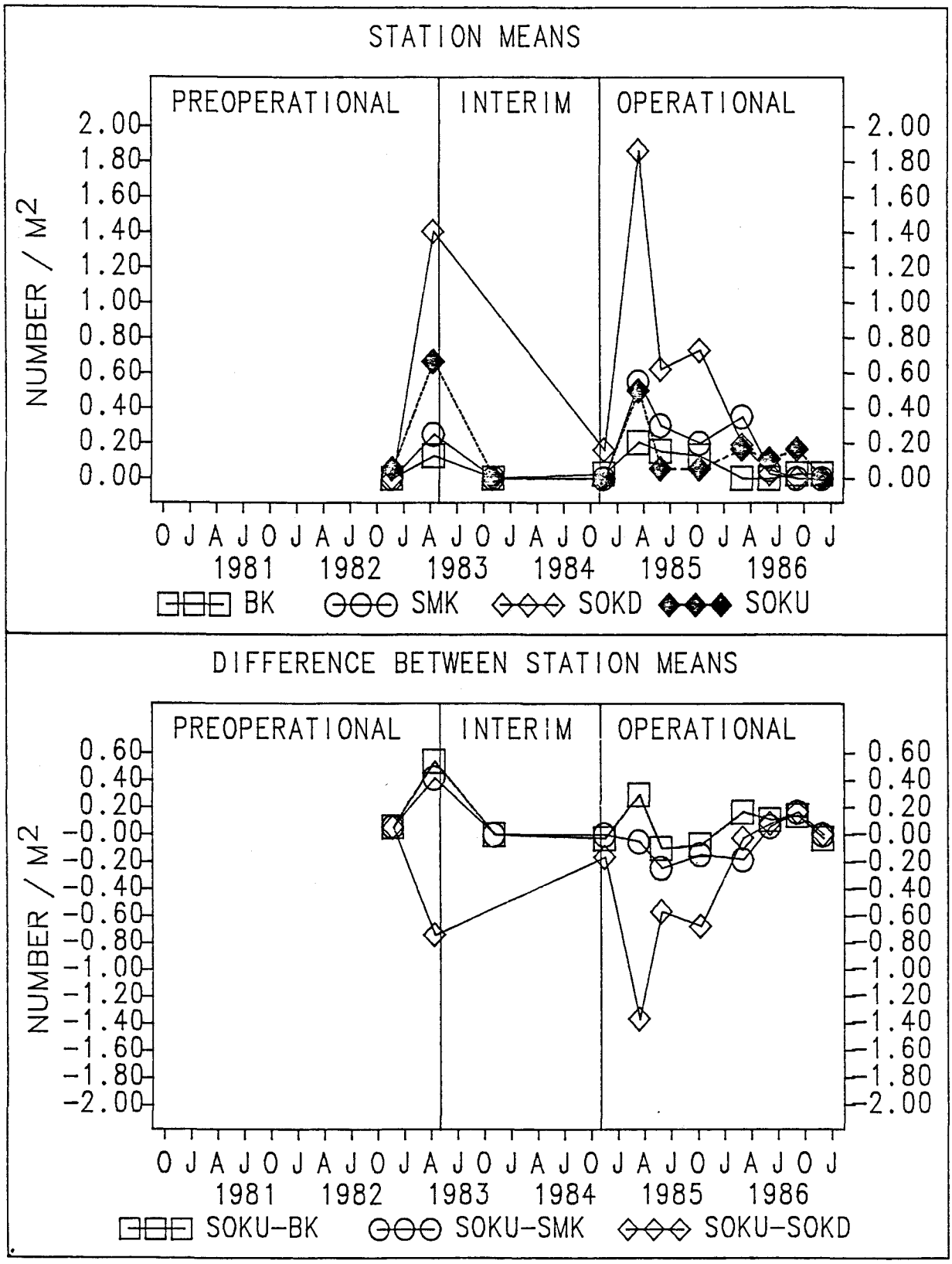
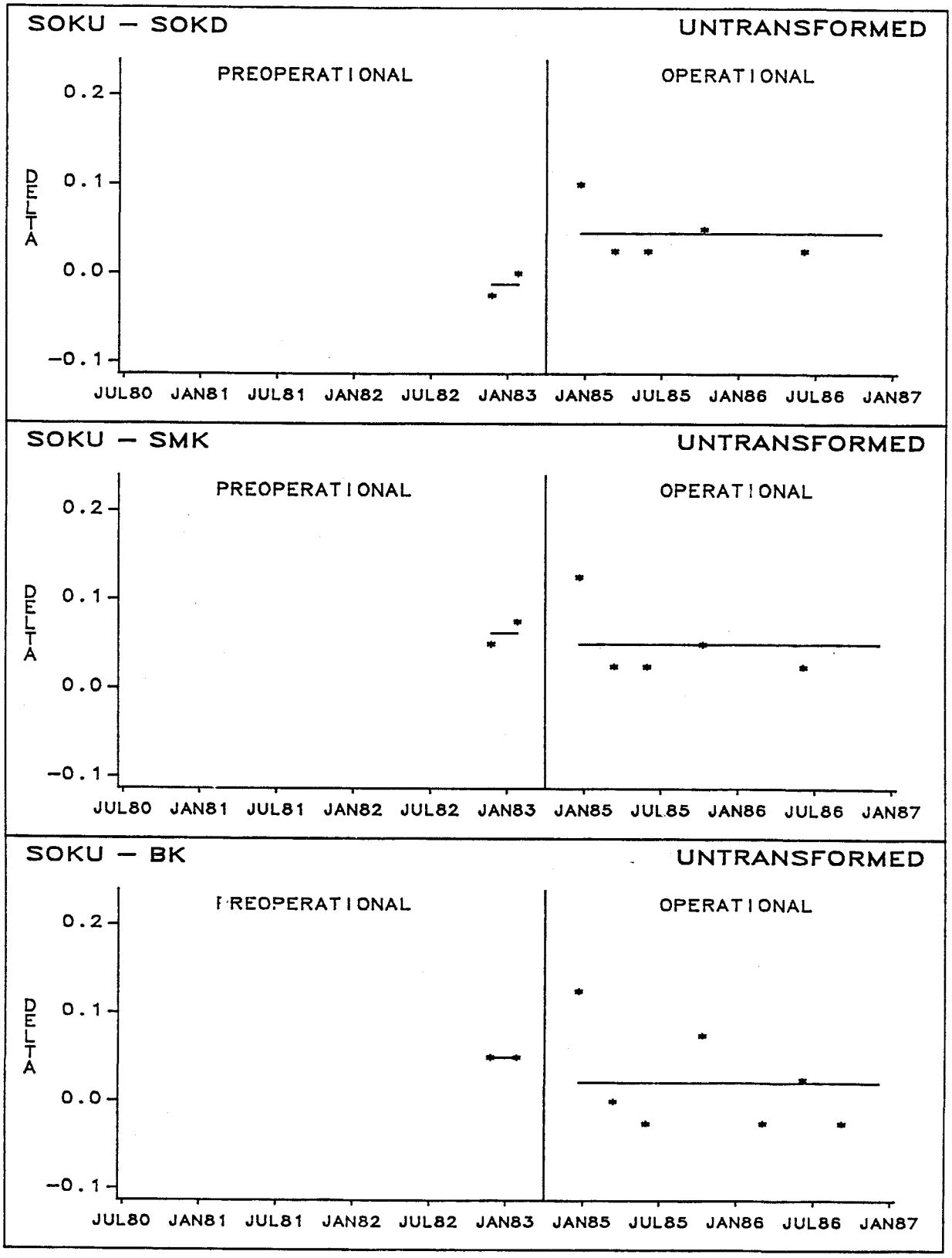


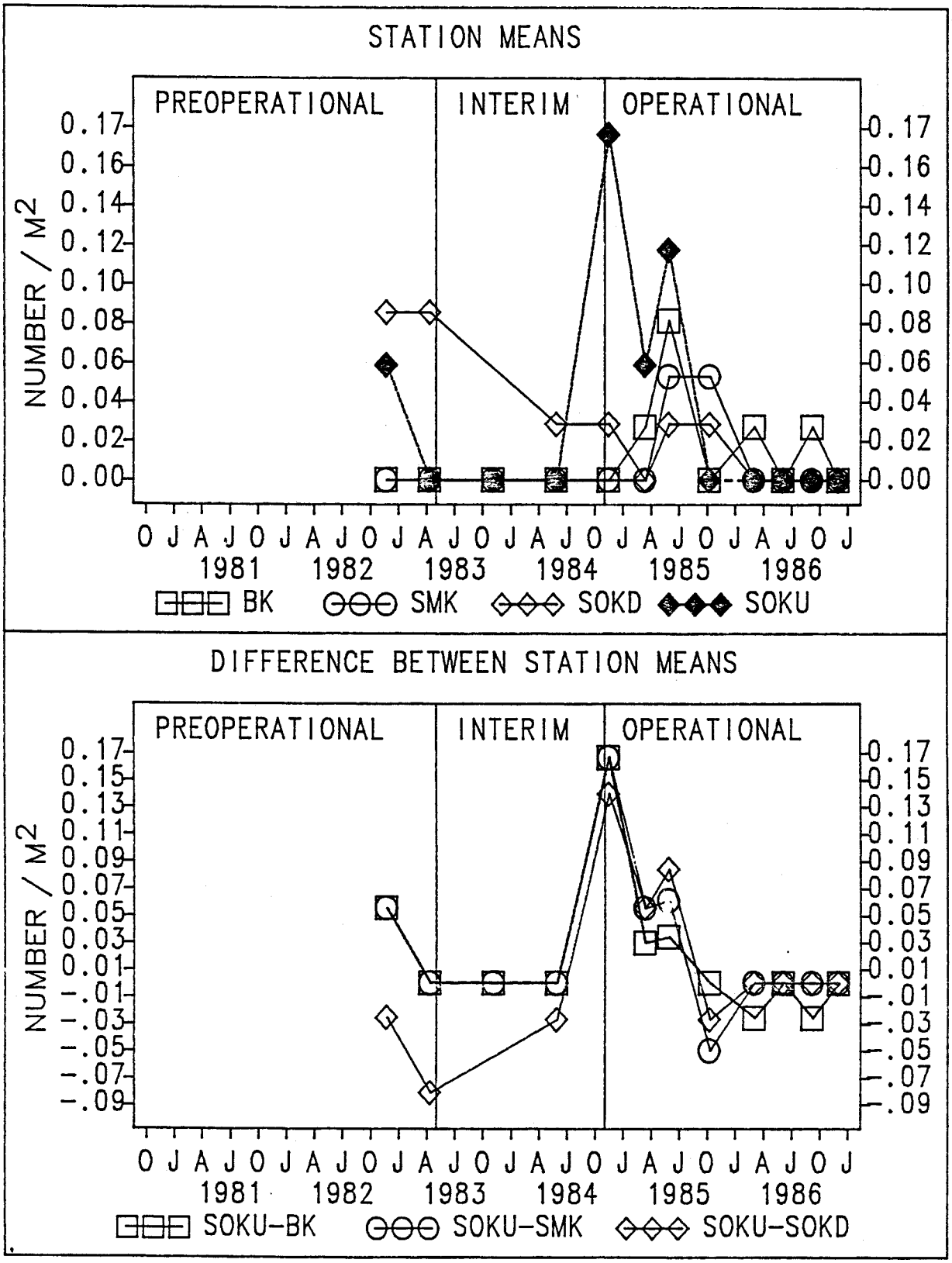
NASSARIUS SPP.



OPHIODERMELLA INERMIS



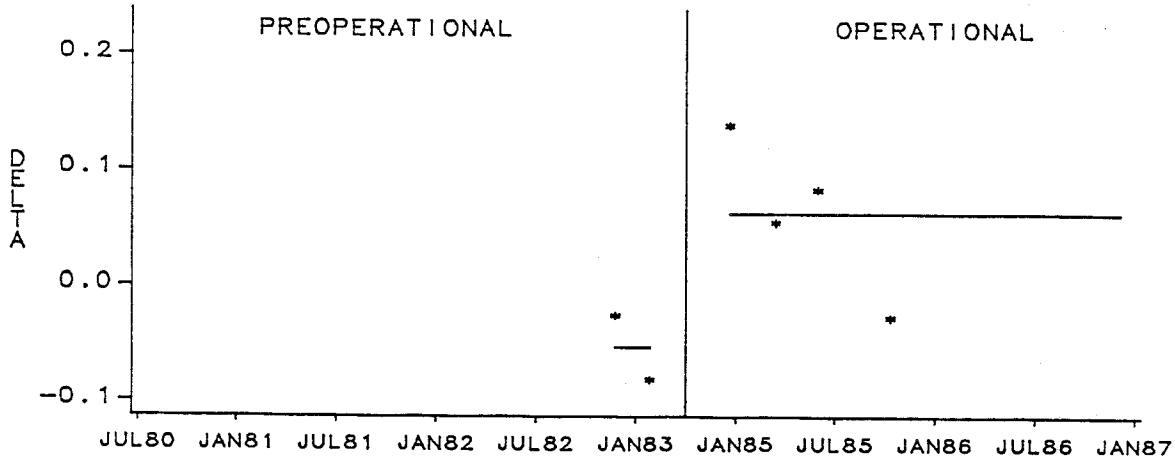
OPHIODERMELLA INERMIS



OPHIODERMELLA INERMIS

SOKU – SOKD

UNTRANSFORMED



SOKU – SMK

NO TEST

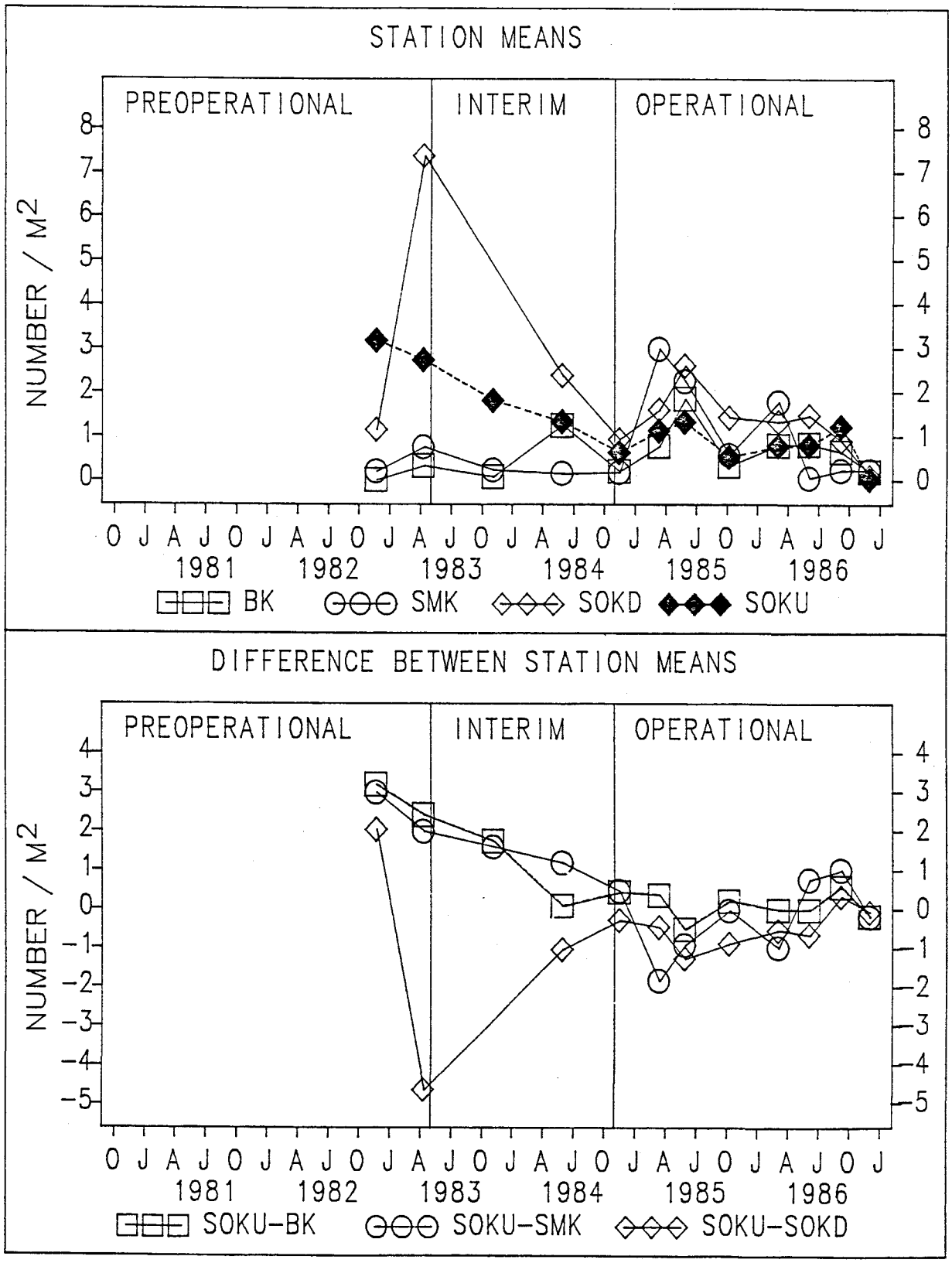
ASSUMPTIONS NOT MET

SOKU – BK

NO TEST

ASSUMPTIONS NOT MET

PTEROPURPURA FESTIVA



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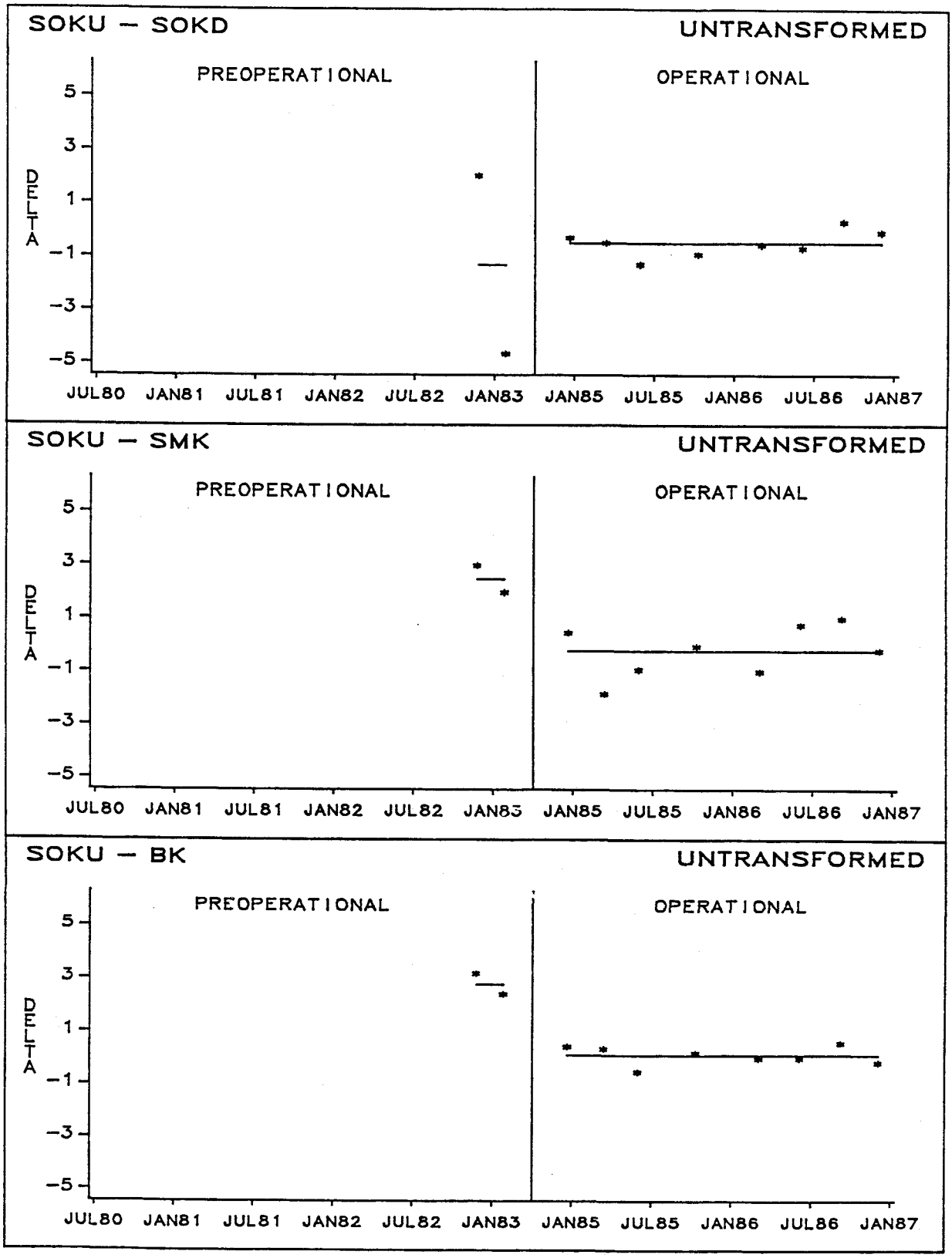

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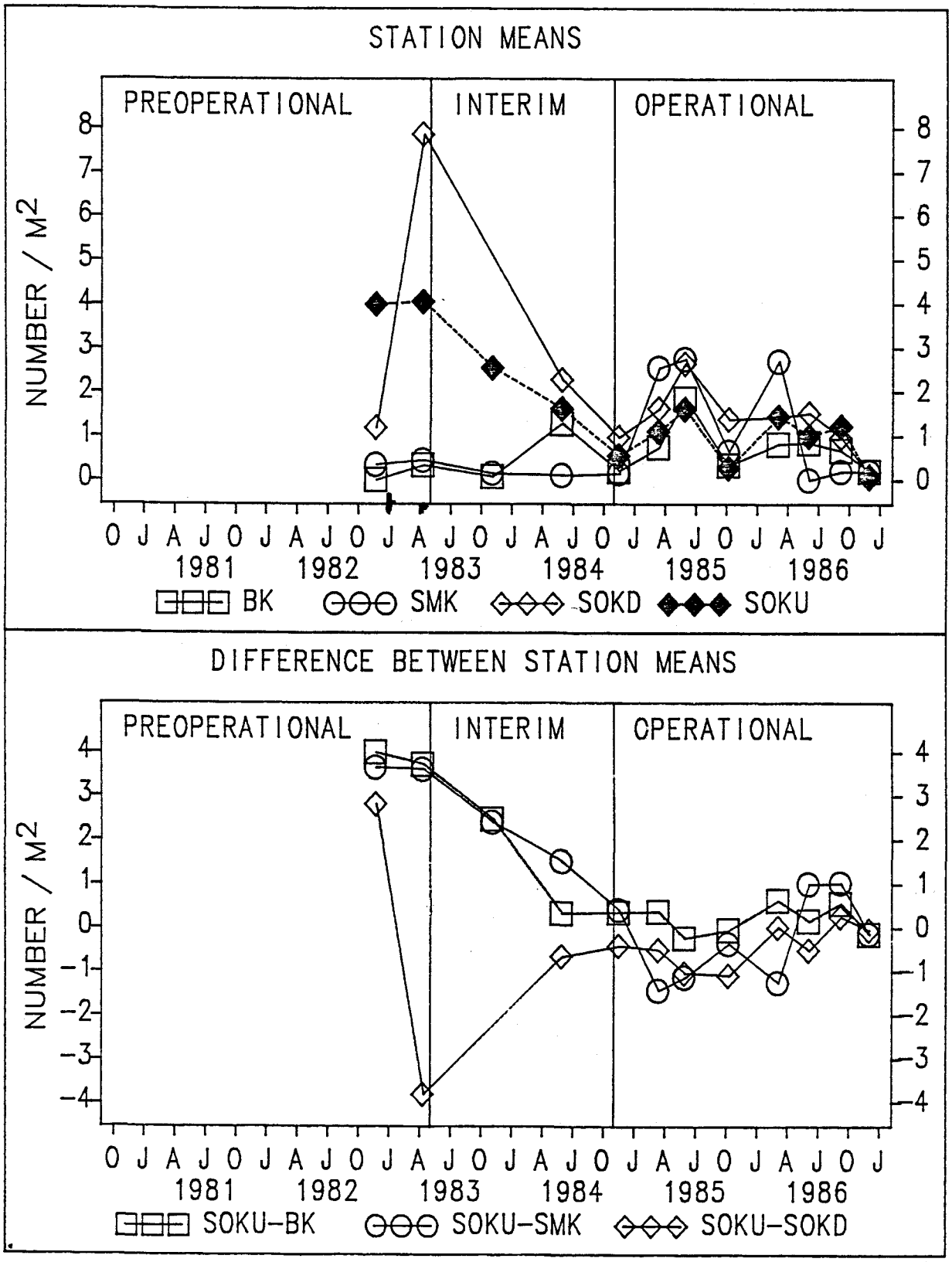

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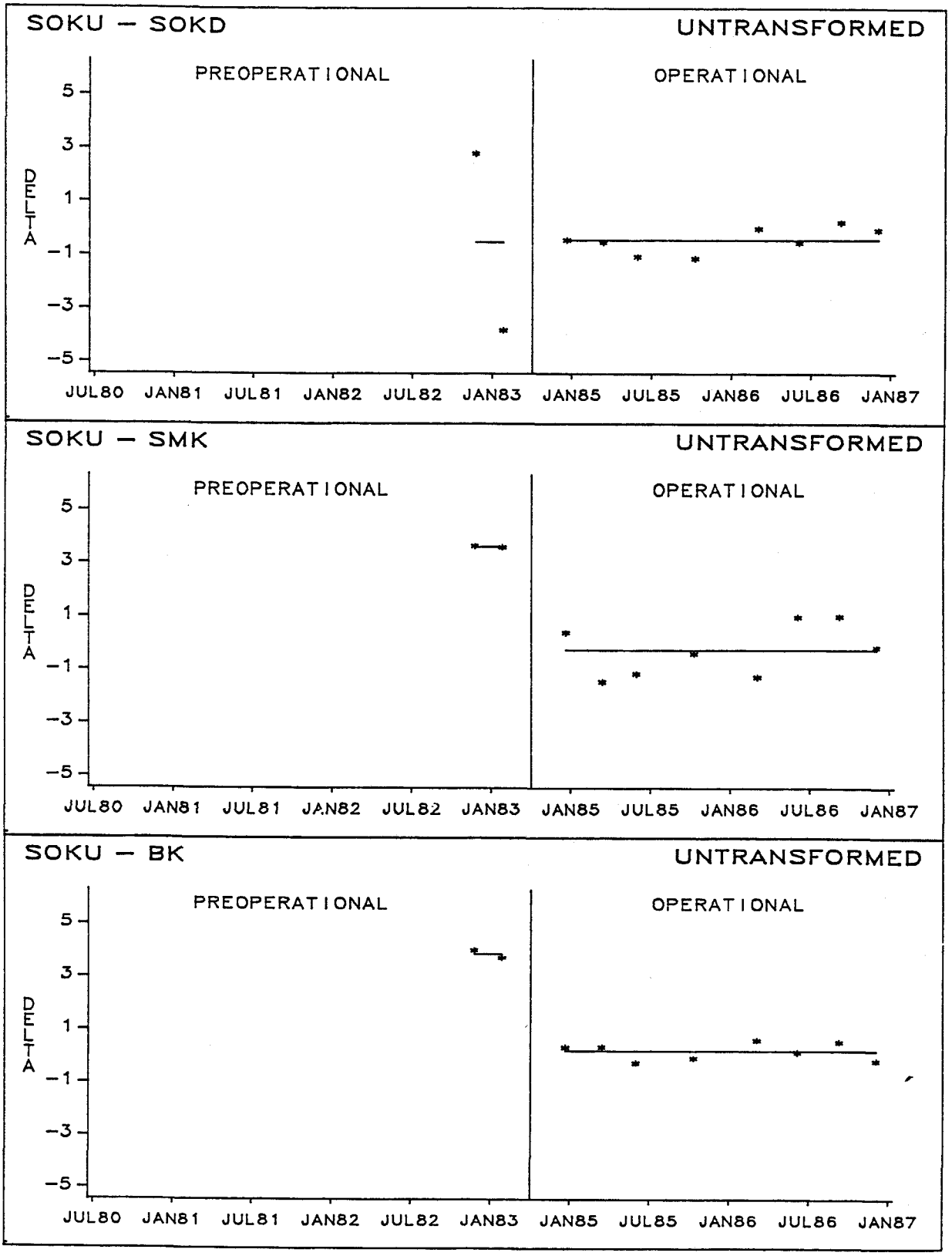
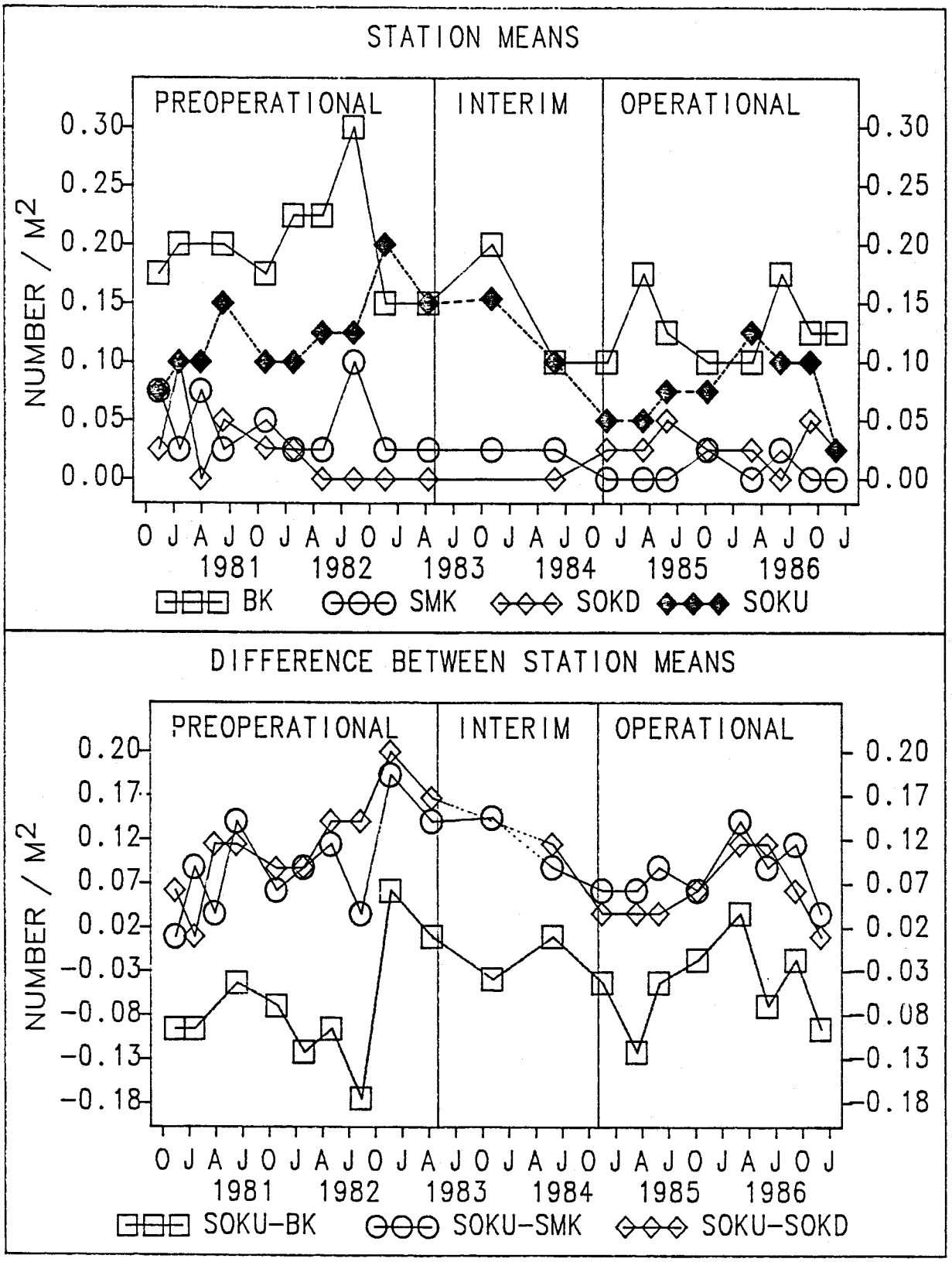


TETHYA AURANTIA



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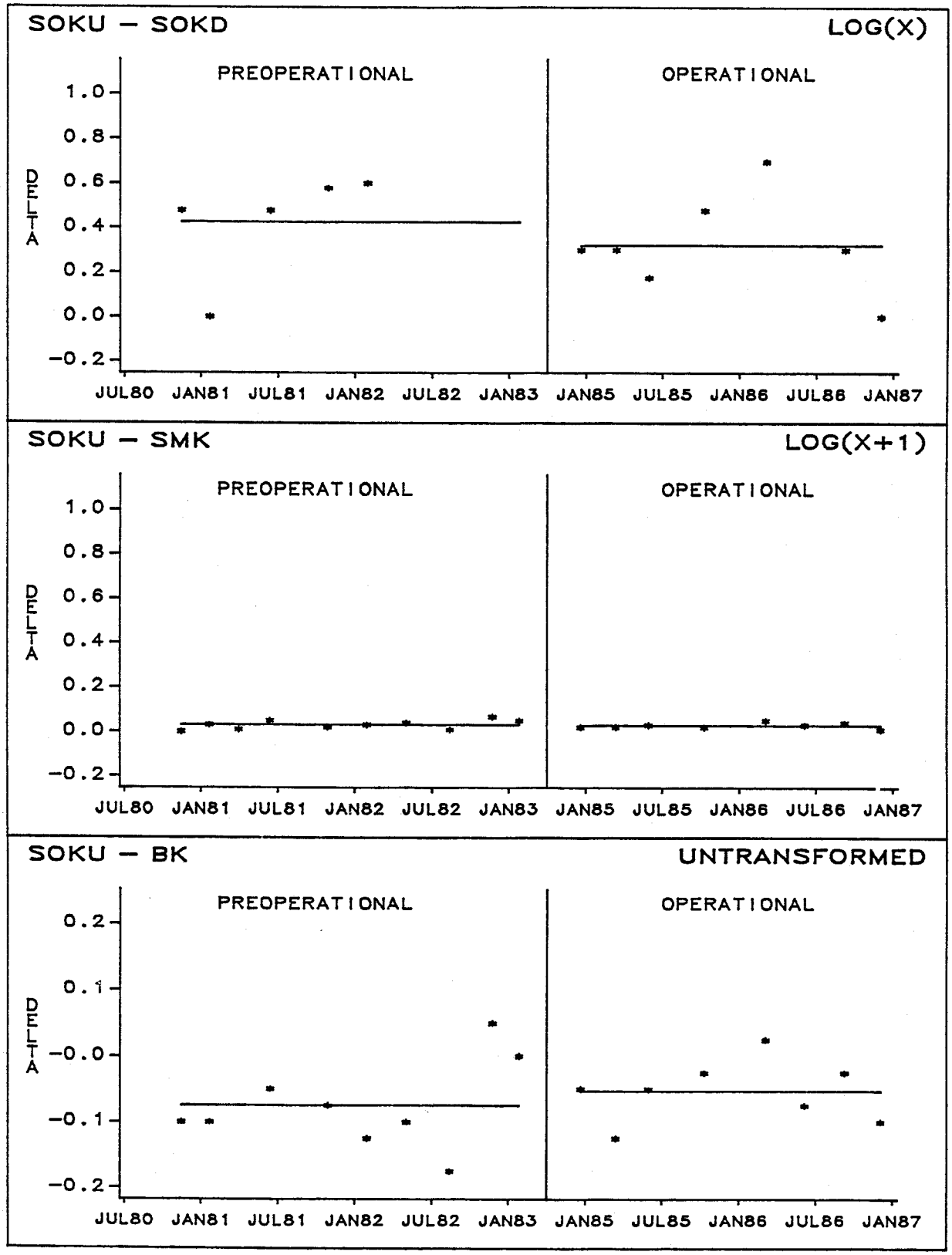

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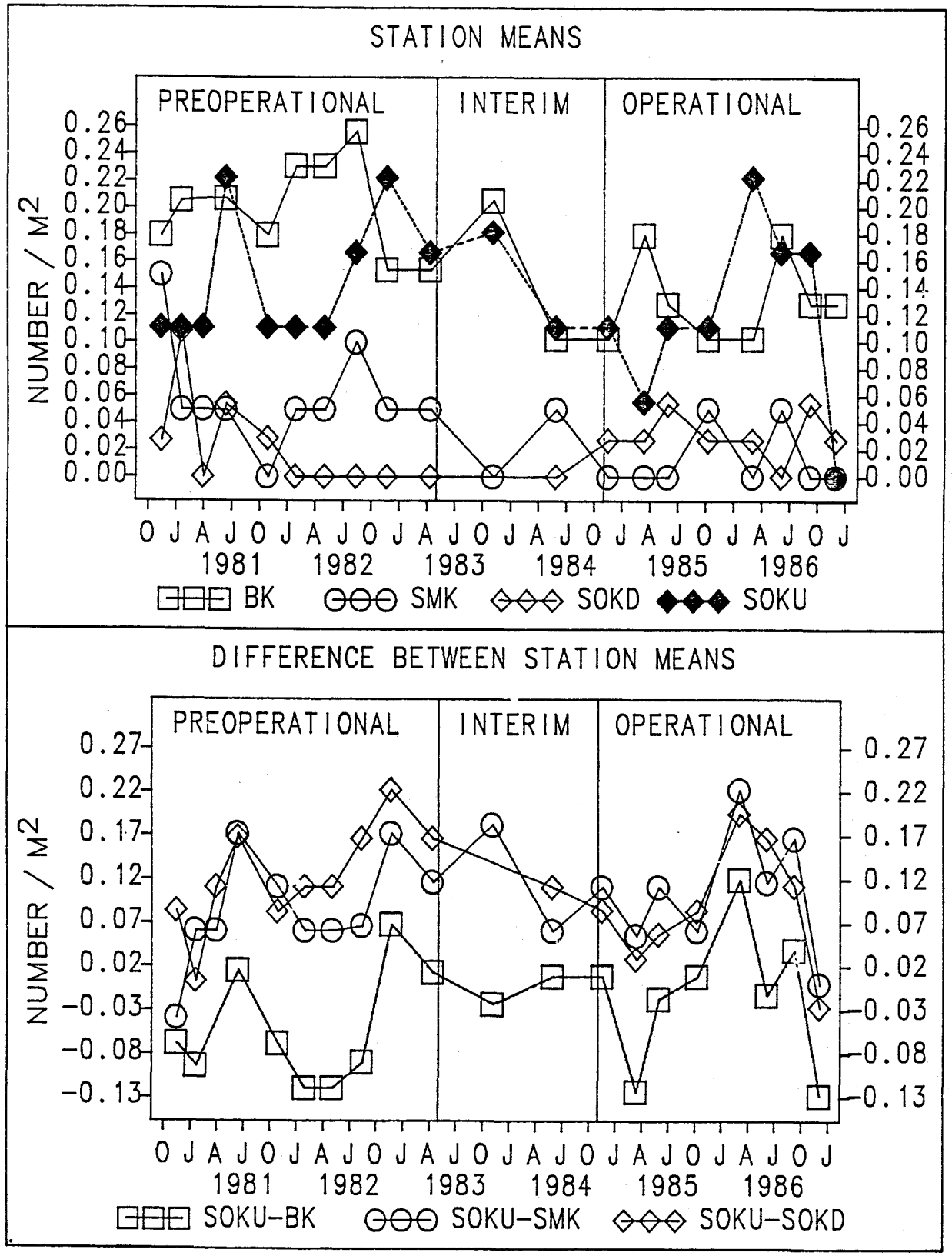

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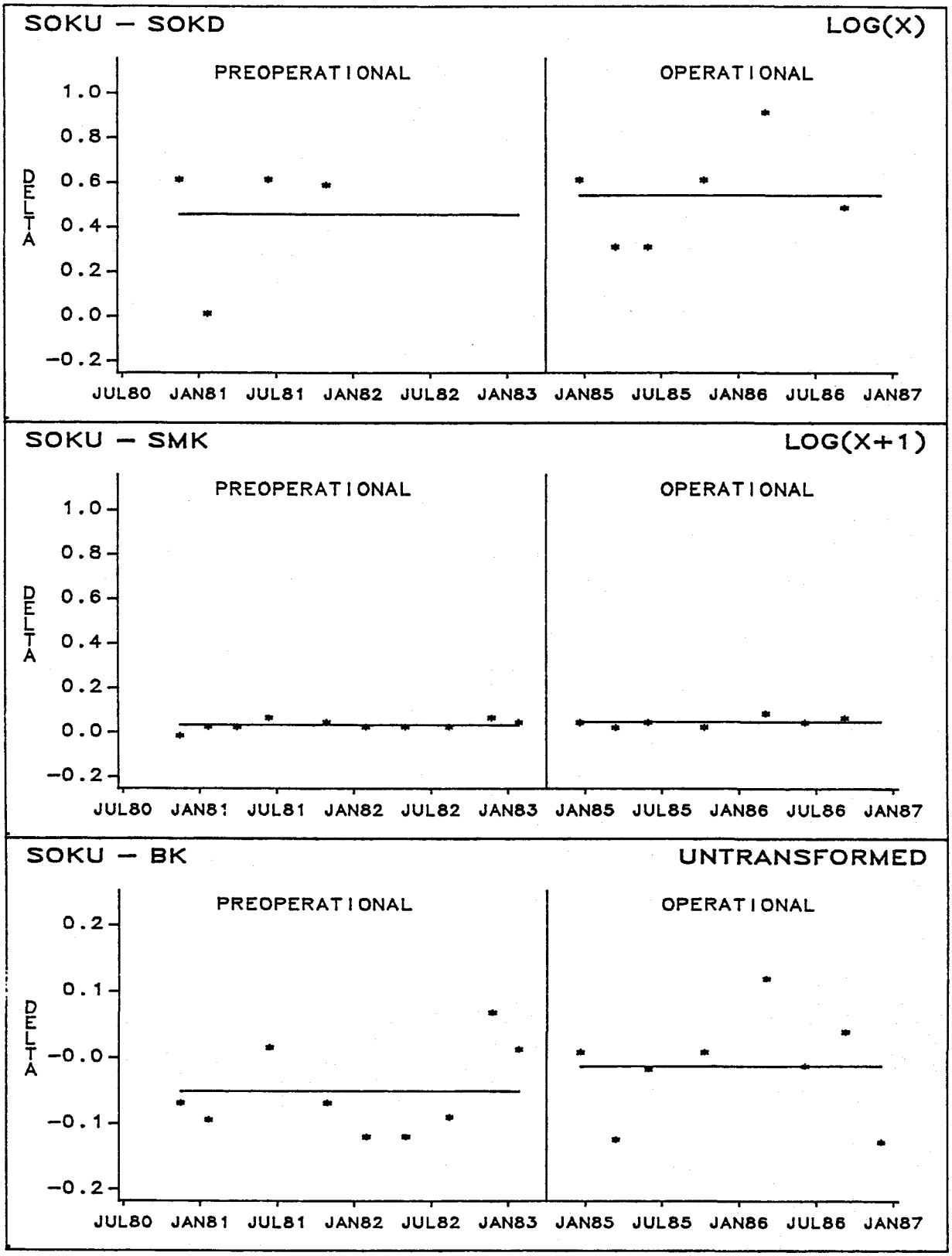
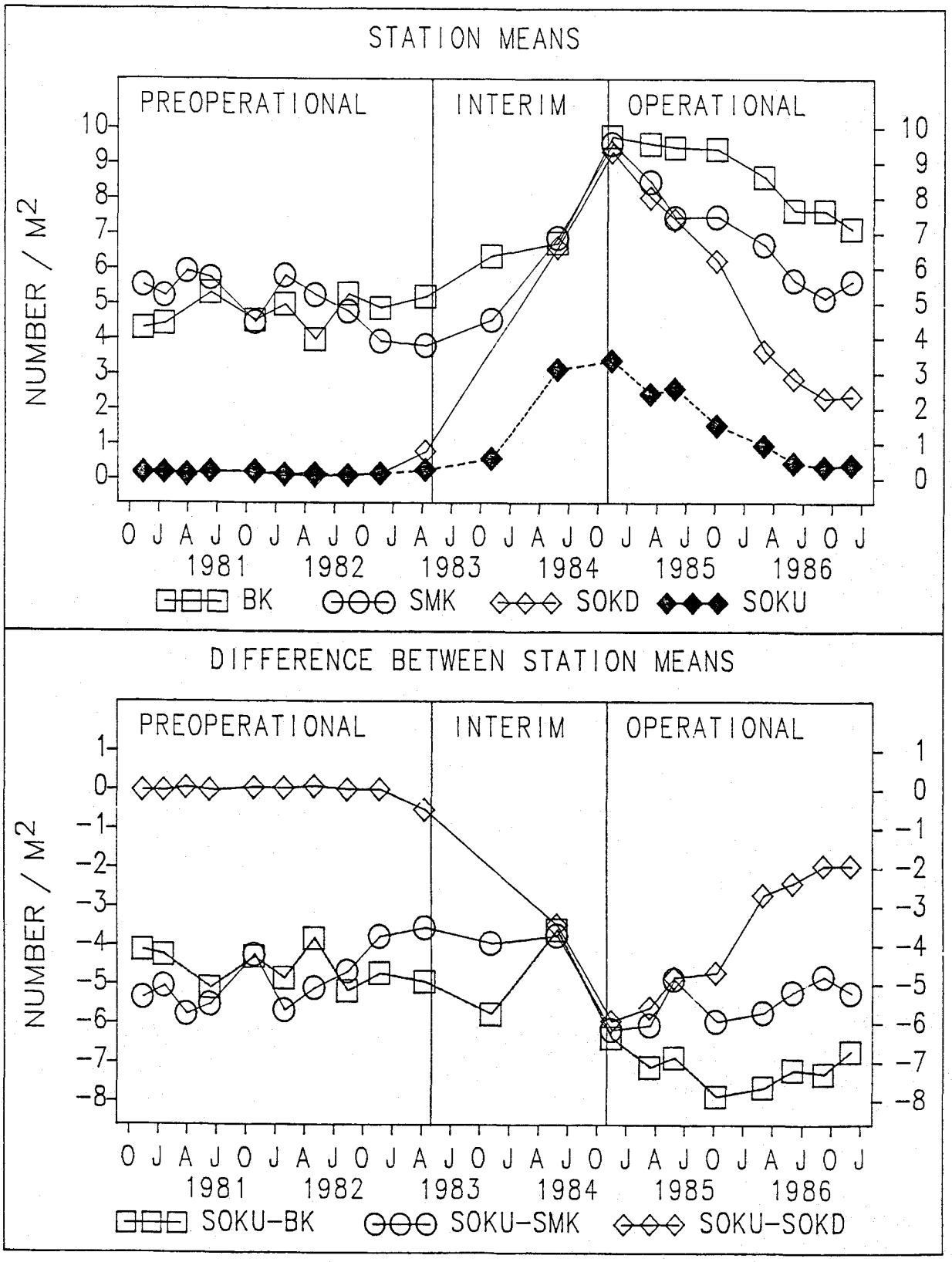


MURICEA CALIFORNICA



MURICEA CALIFORNICA

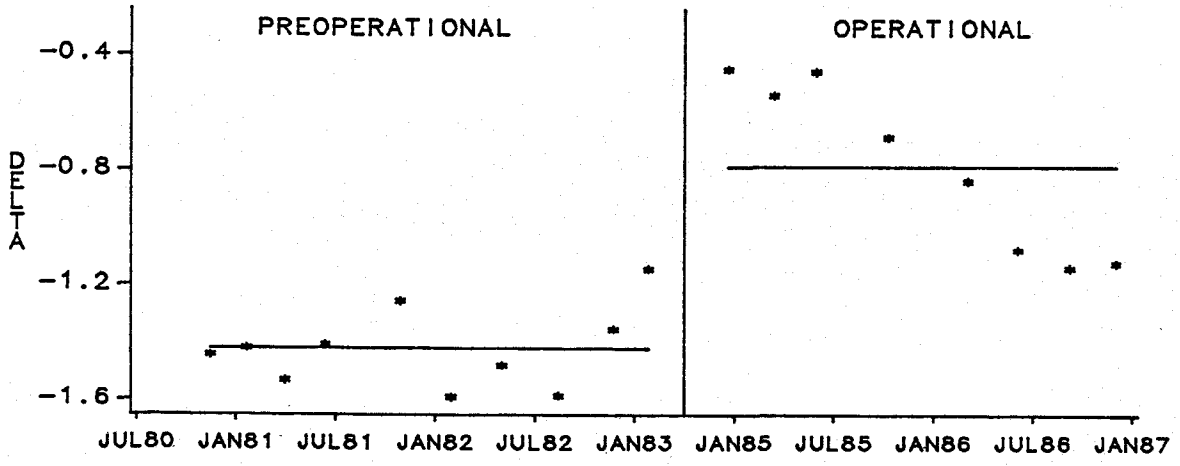
SOKU – SOKD

NO TEST

ASSUMPTIONS NOT MET

SOKU – SMK

LOG(X+0.025)

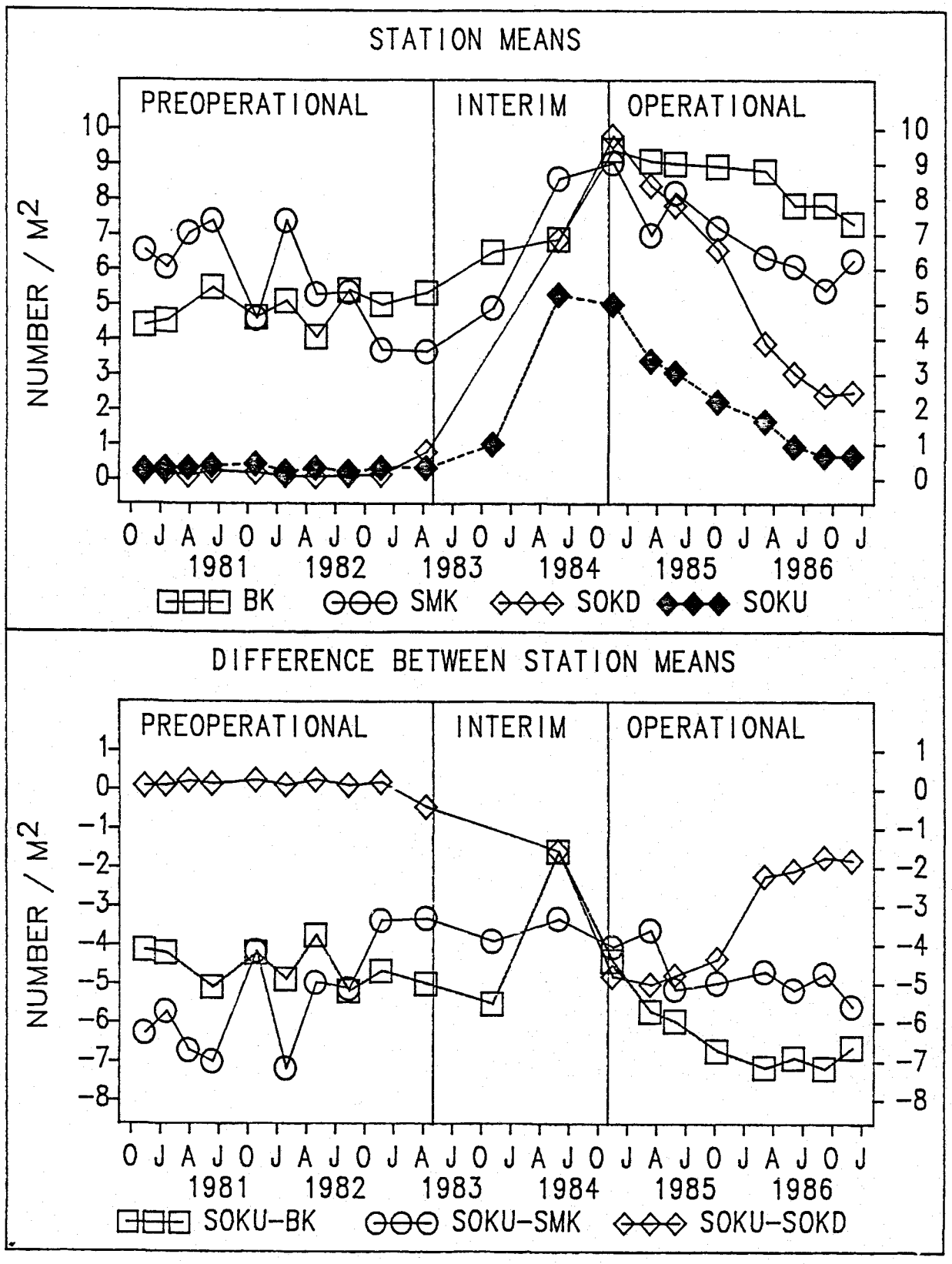


SOKU – BK

NO TEST

ASSUMPTIONS NOT MET

MURICEA CALIFORNICA



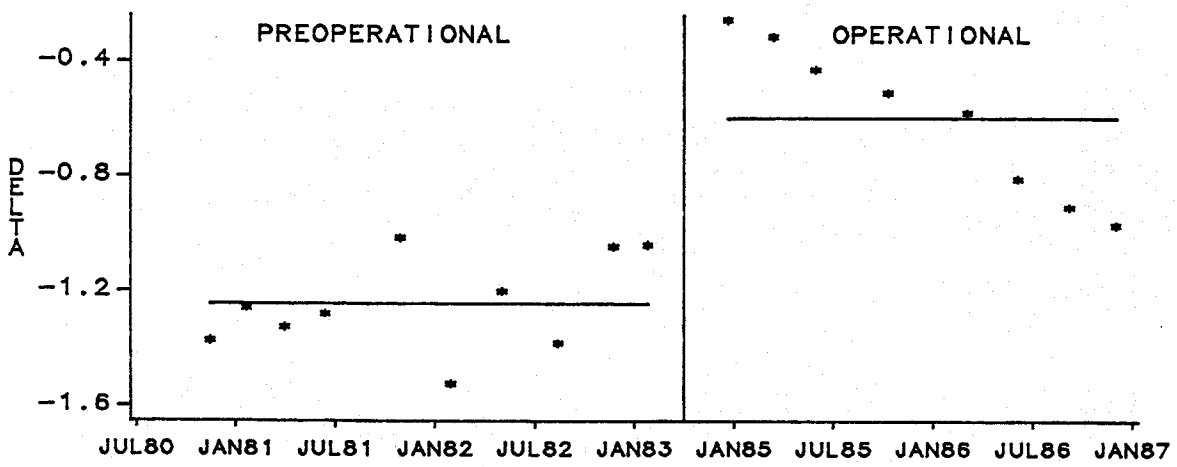
MURICEA CALIFORNICA

SOKU – SOKD

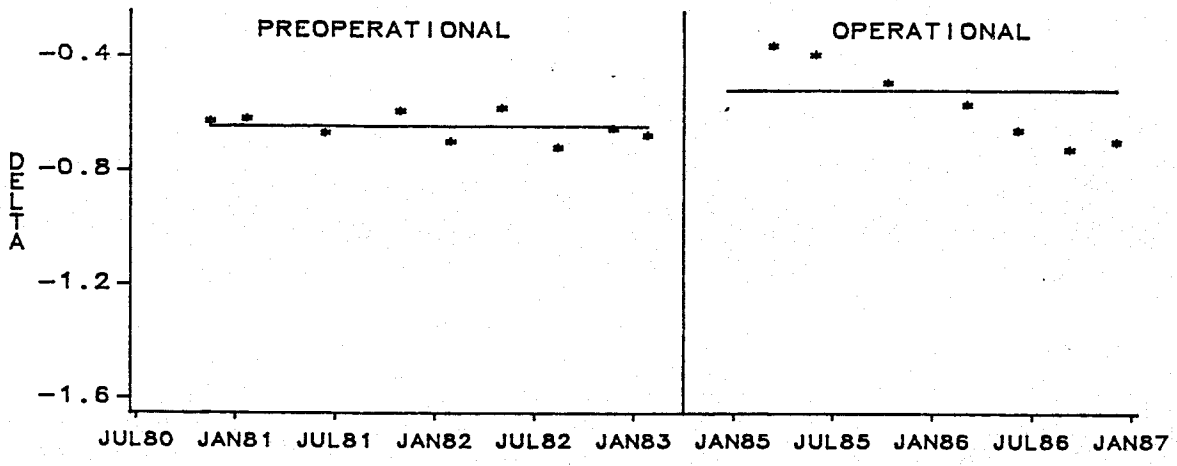
NO TEST

ASSUMPTIONS NOT MET

SOKU – SMK LOG(X)



SOKU – BK LOG(X+1)



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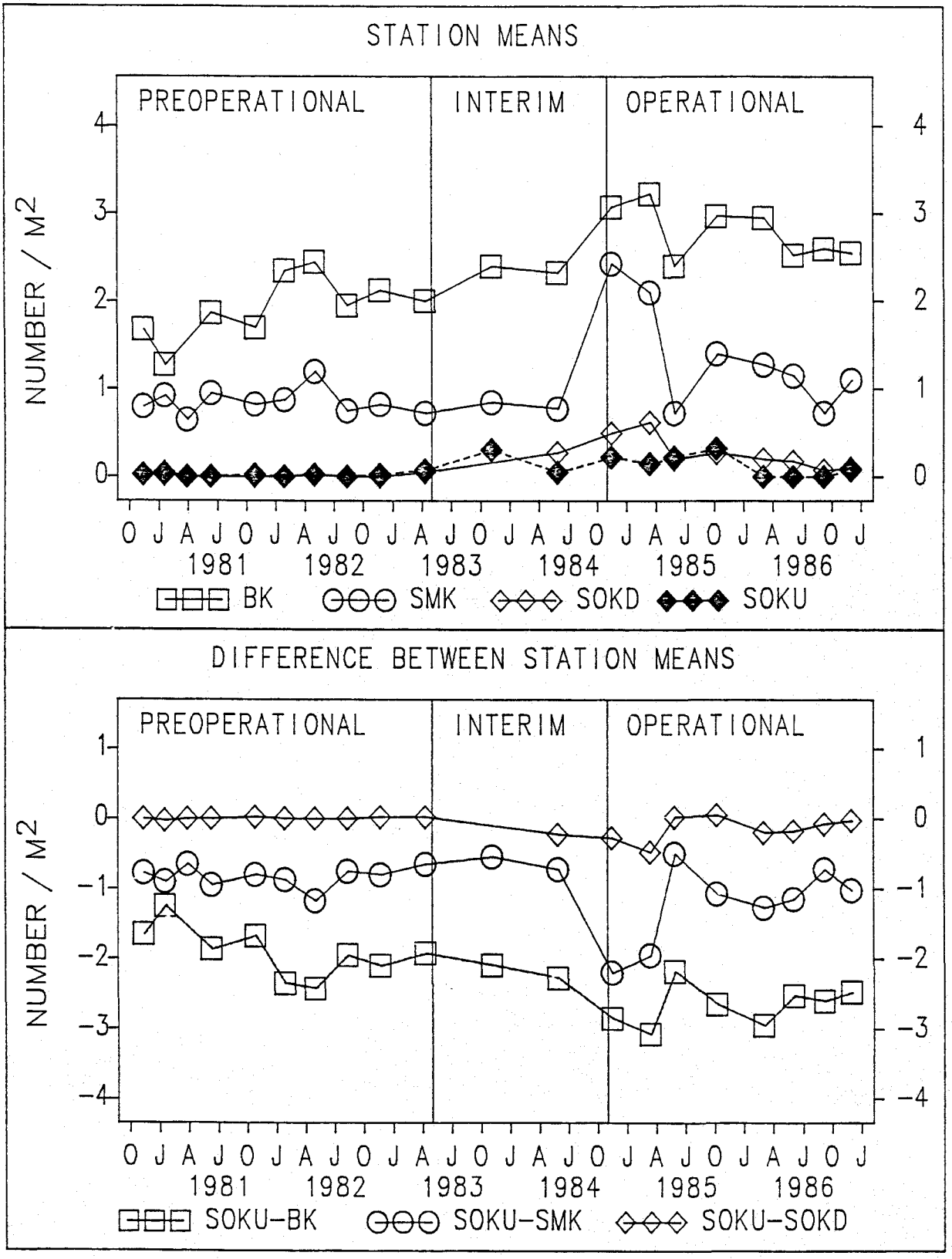
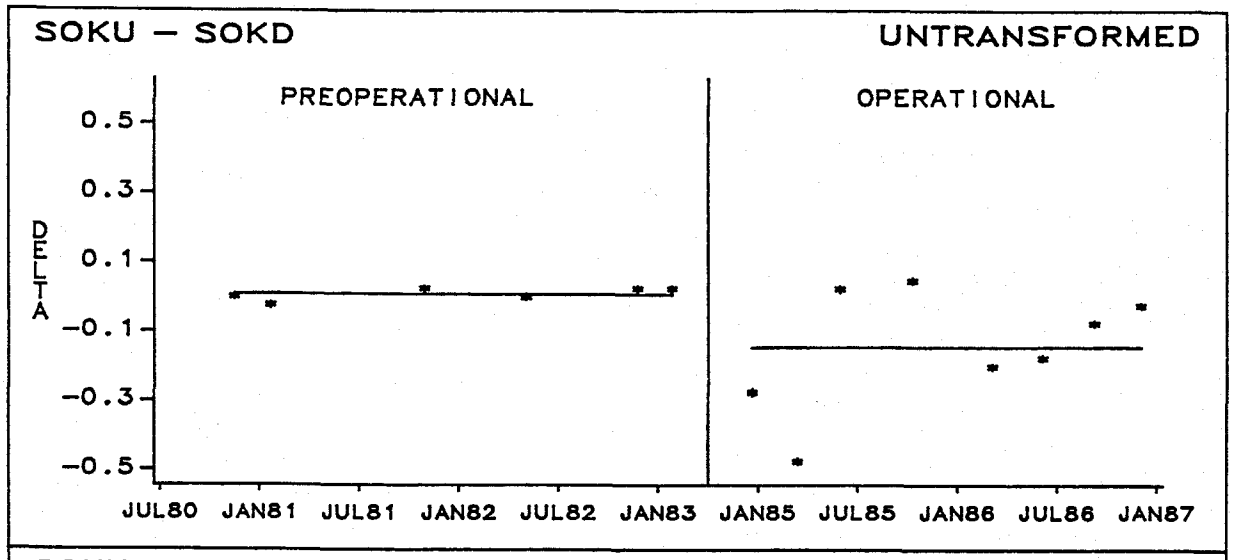
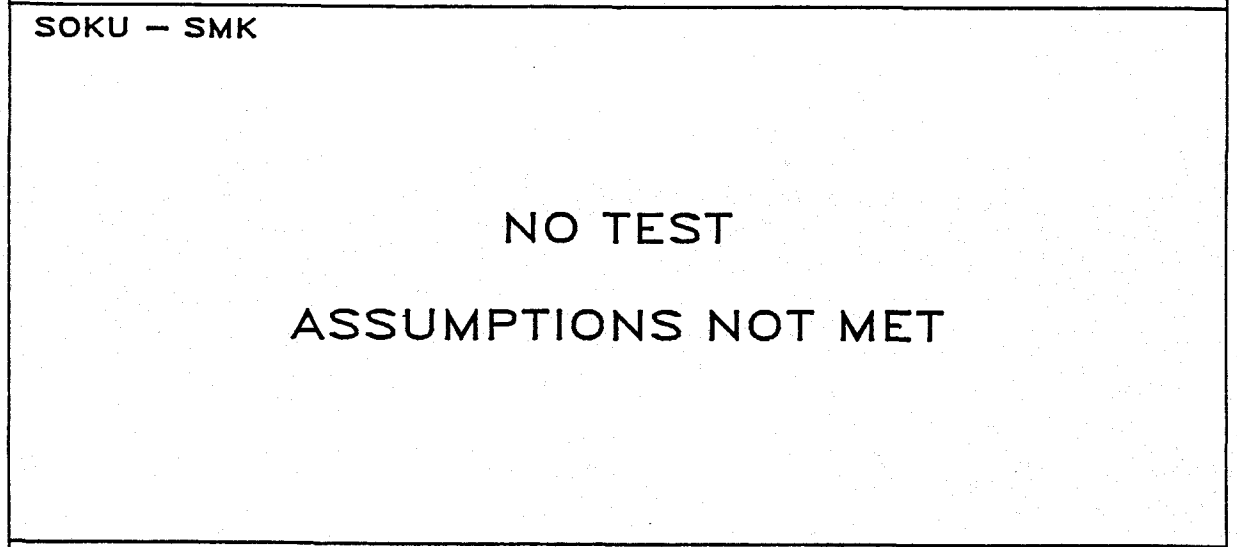
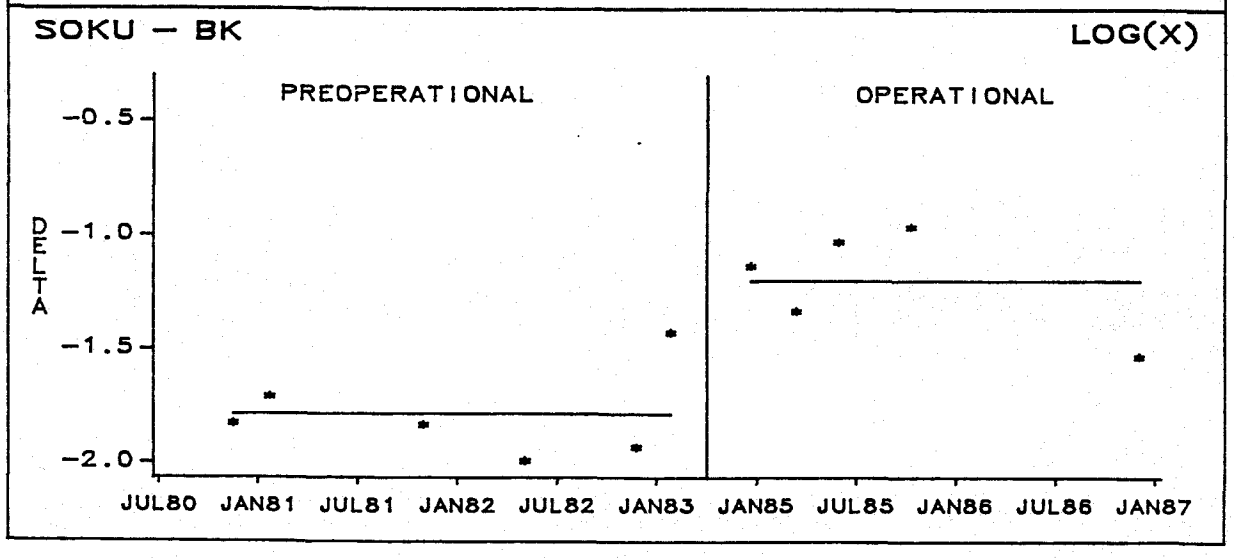


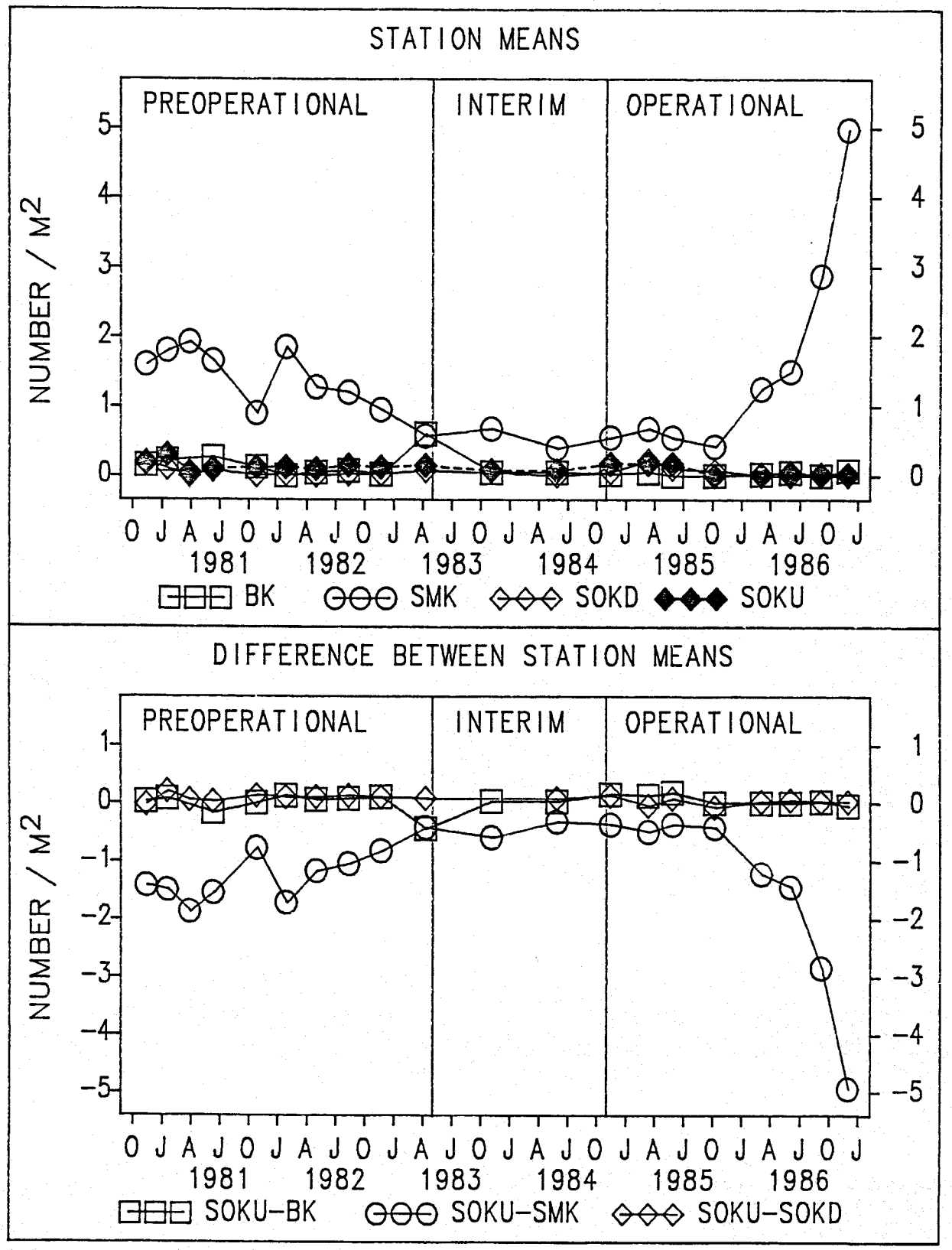
MURICEA FRUTICOSA







STRONGYLOCENTROTUS PURPURATUS



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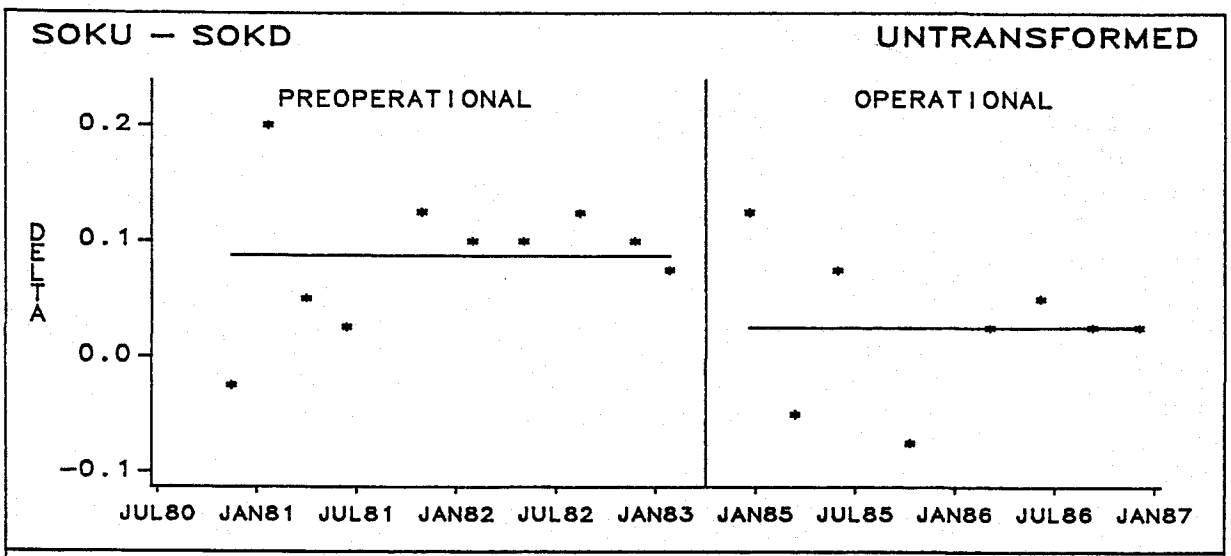
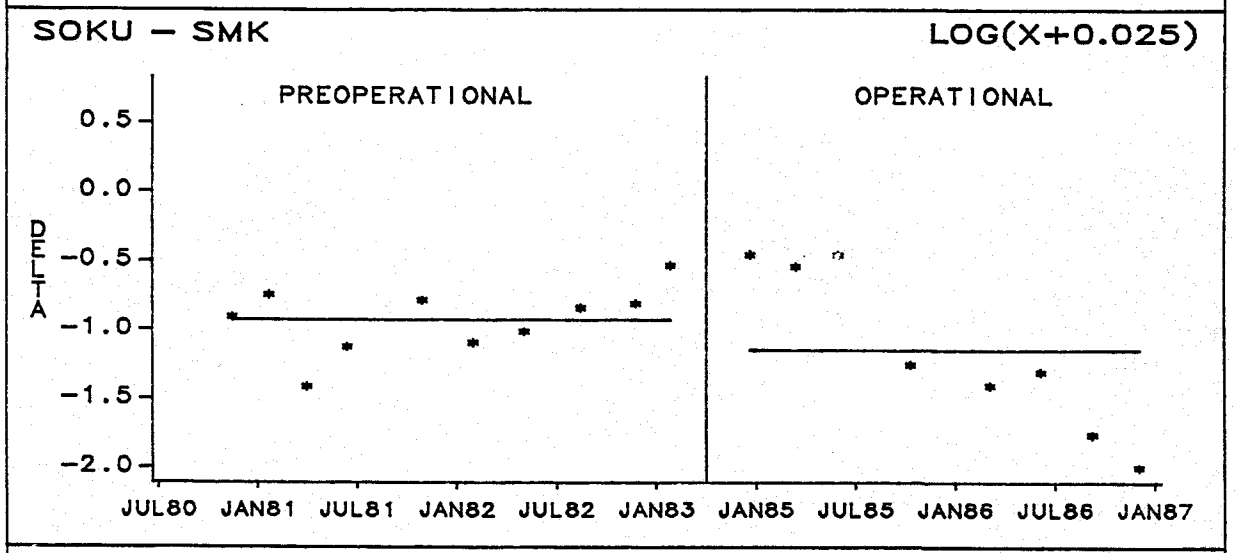


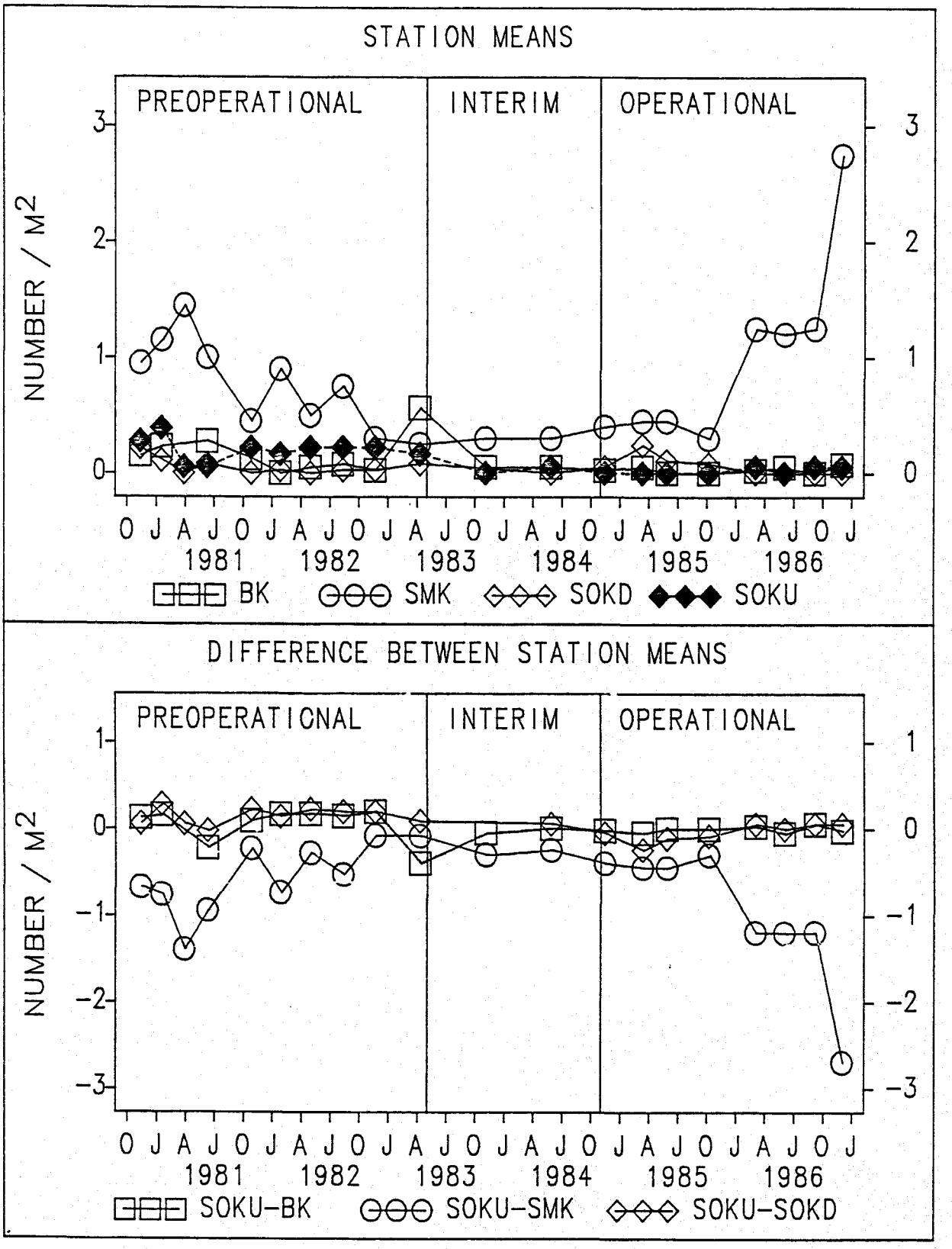


SOKU – BK

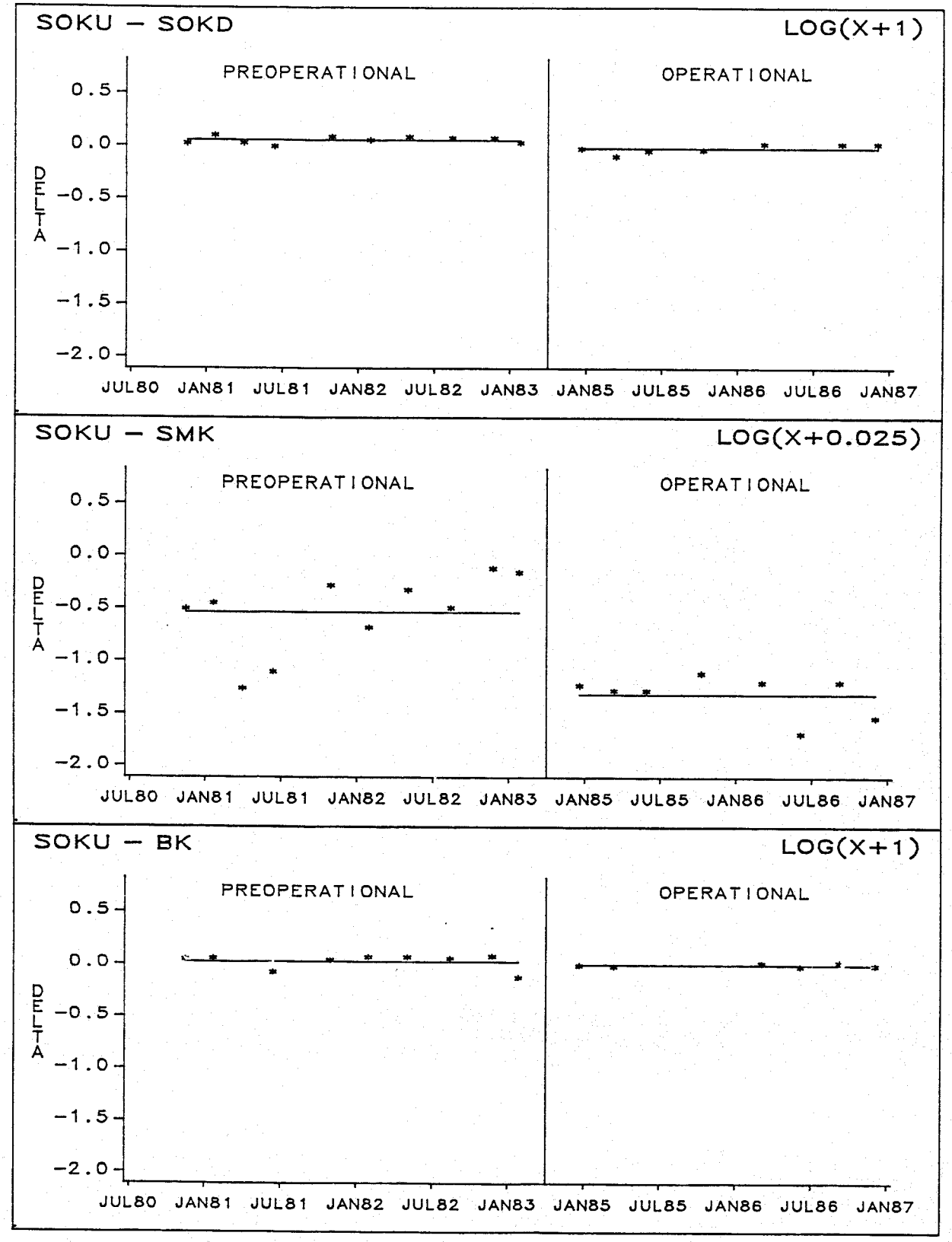
NO TEST

ASSUMPTIONS NOT MET

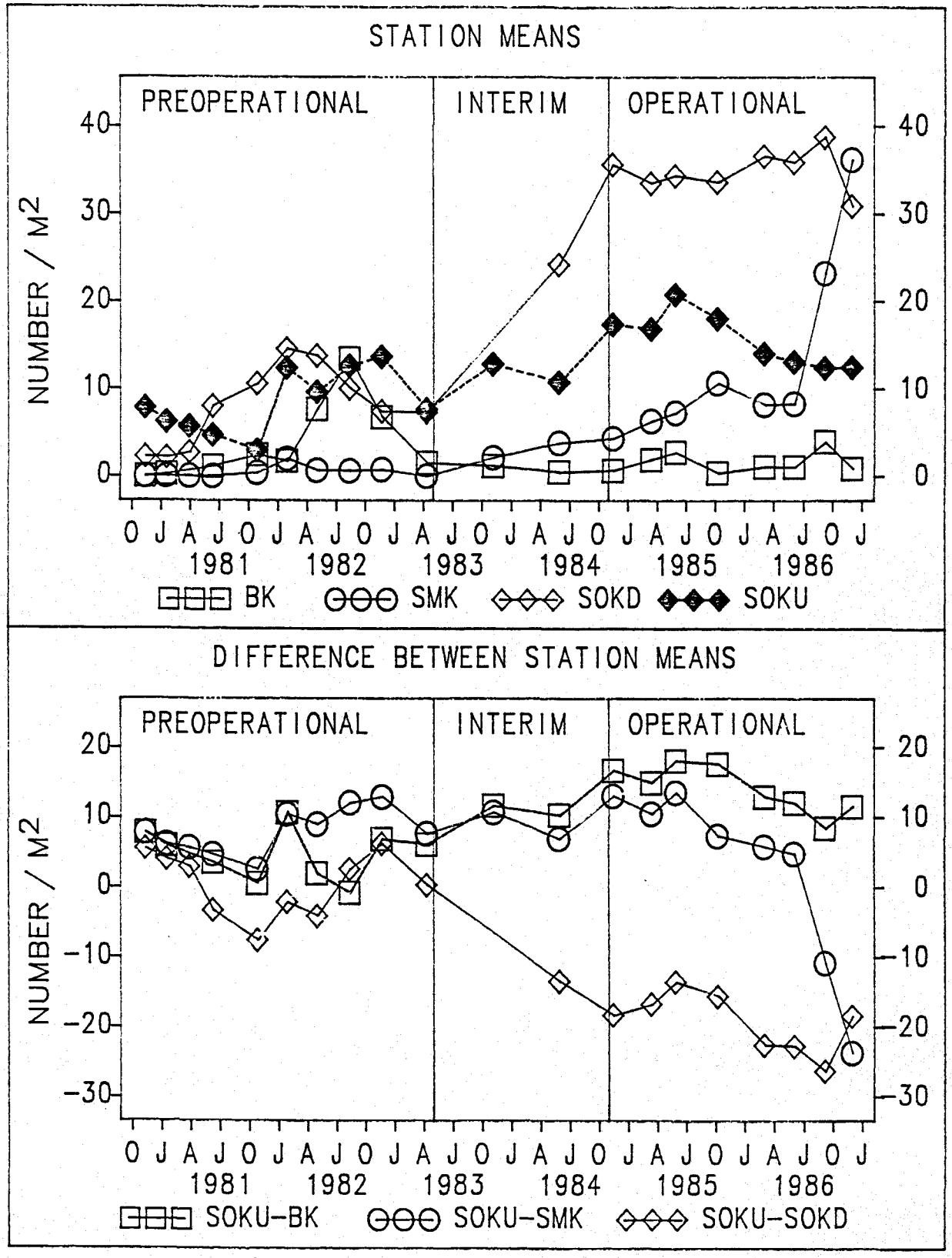
STRONGYLOCENTROTUS PURPURATUS



STRONGYLOCENTROTUS PURPURATUS



LYTECHINUS ANAMESUS



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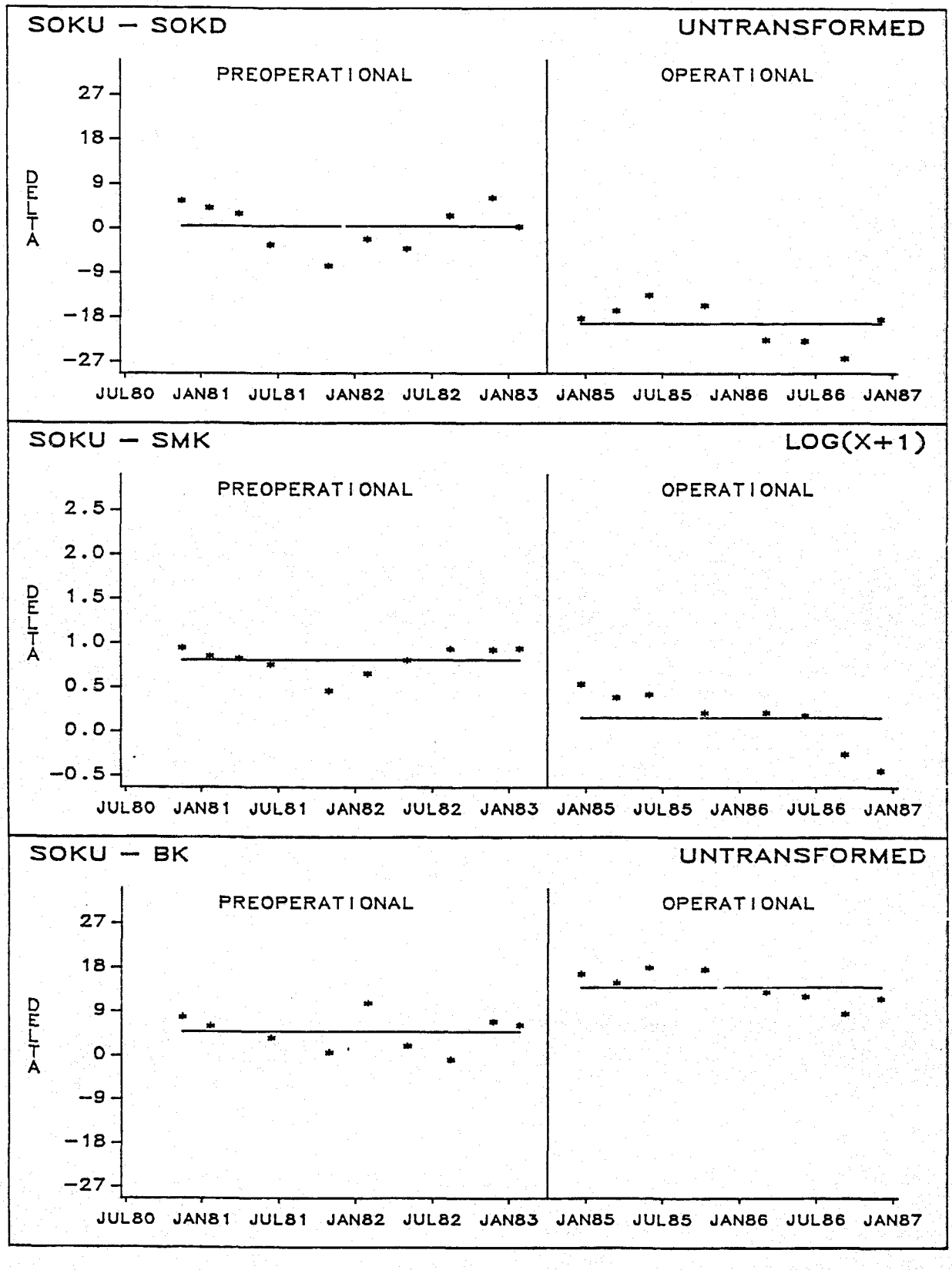

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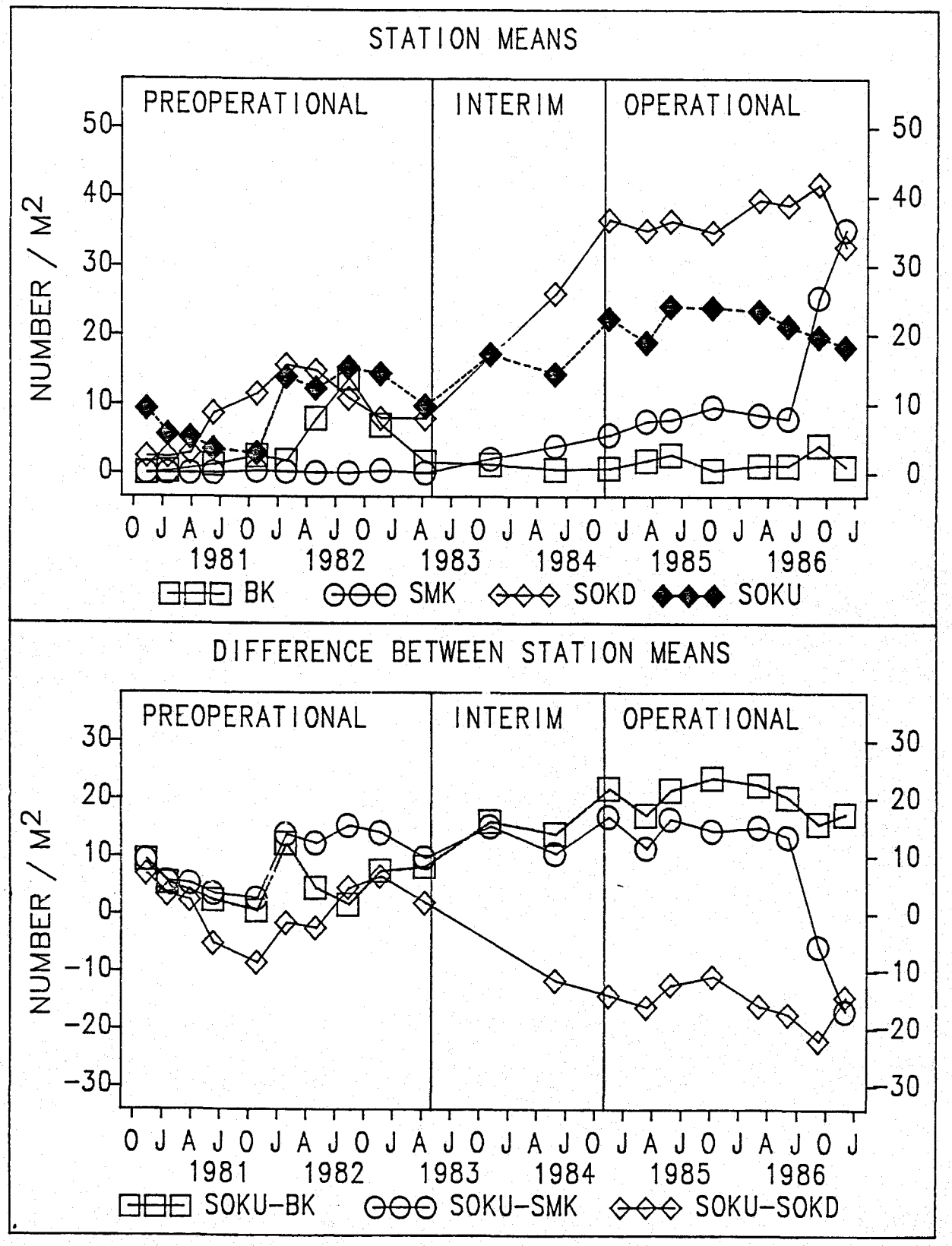

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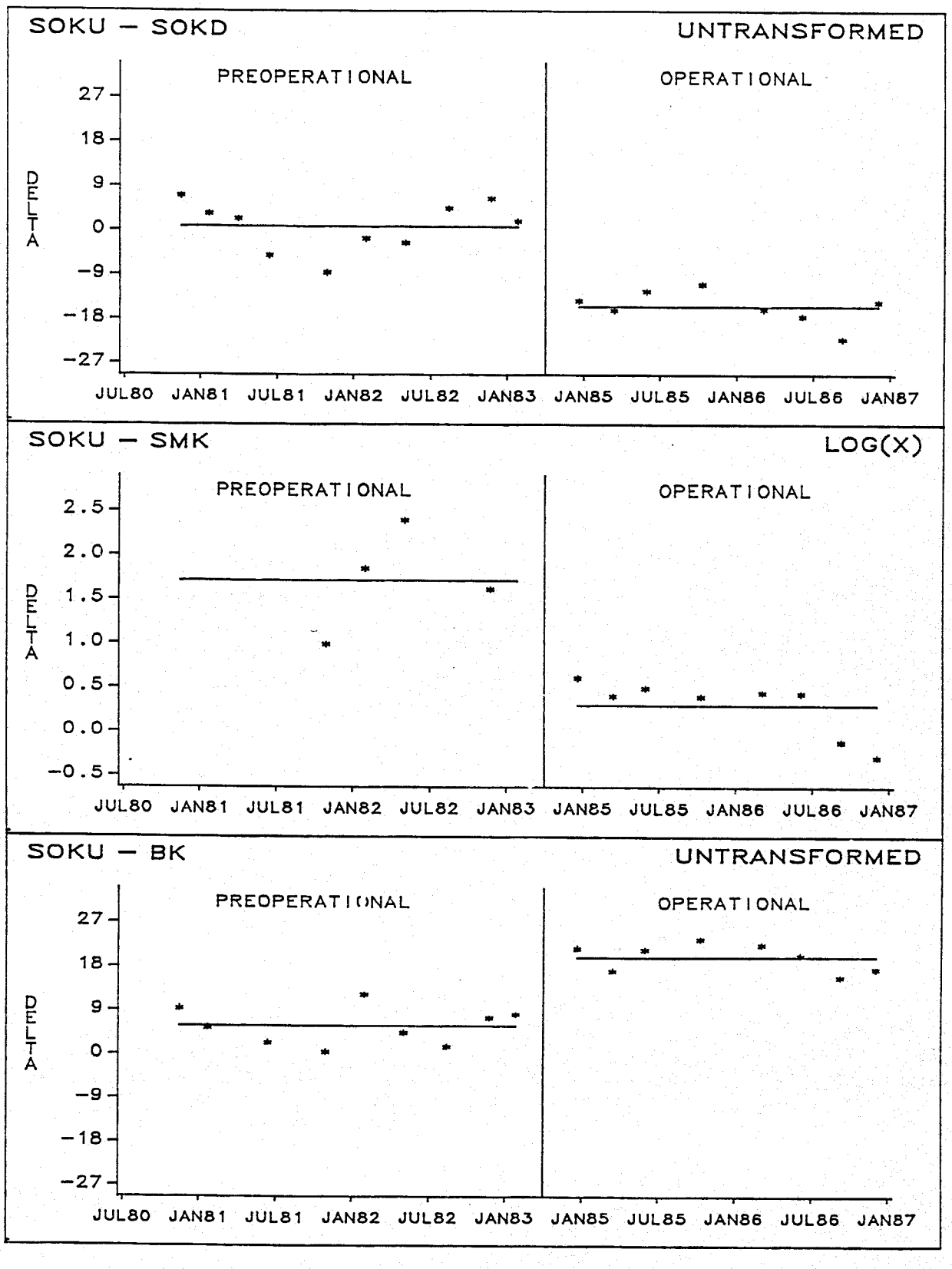
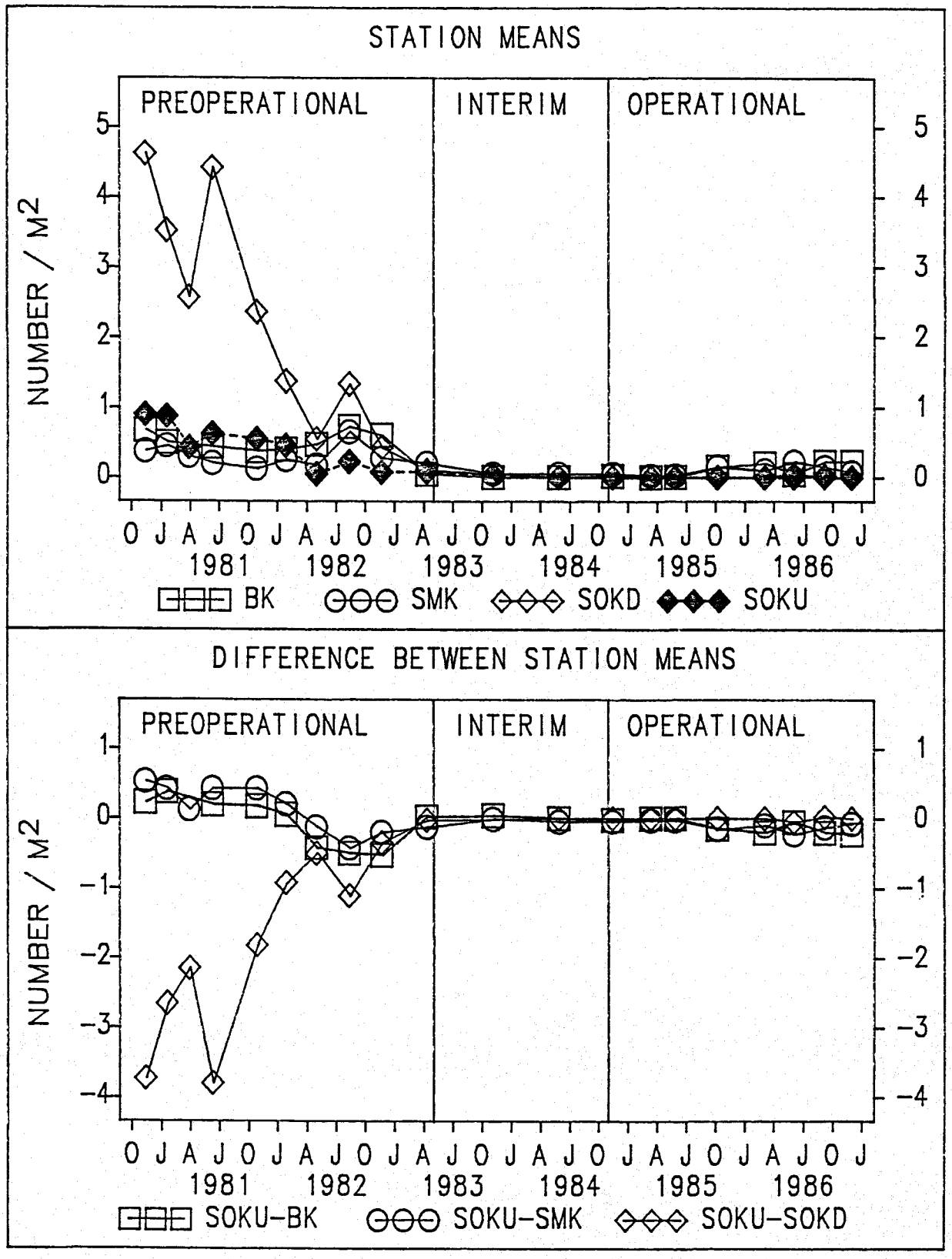
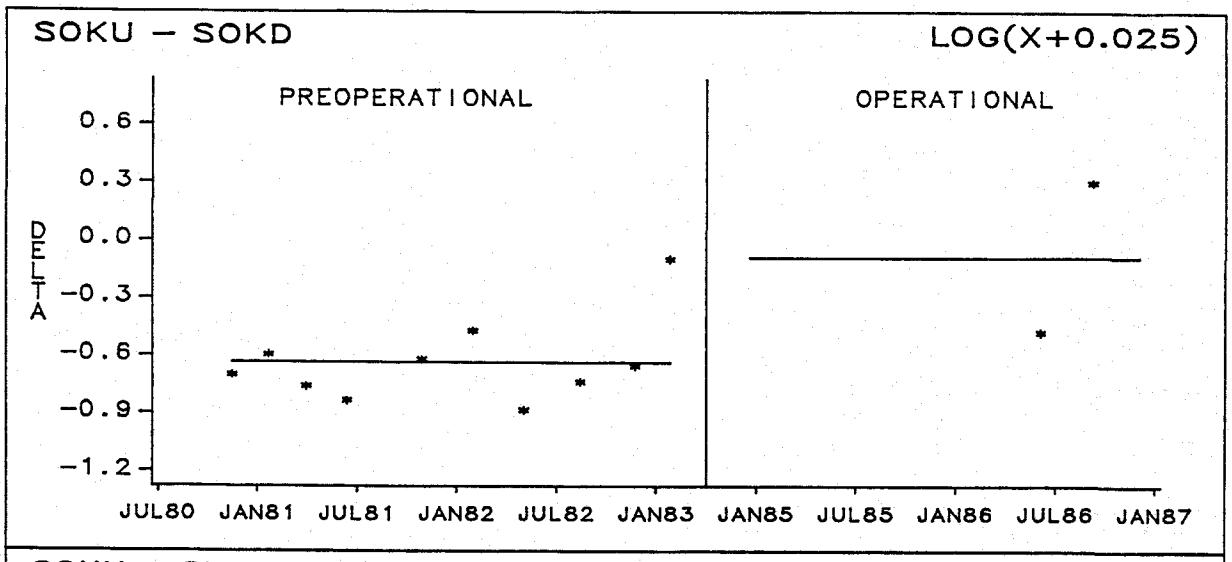


STYELA MONTEREYENSIS



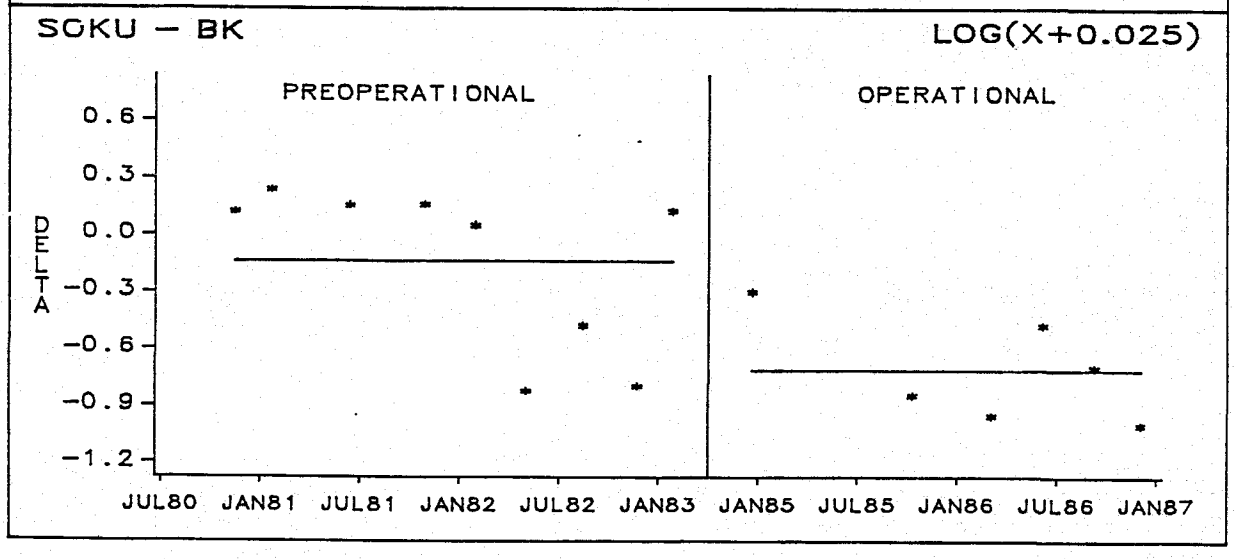
STYELA MONTEREYENSIS



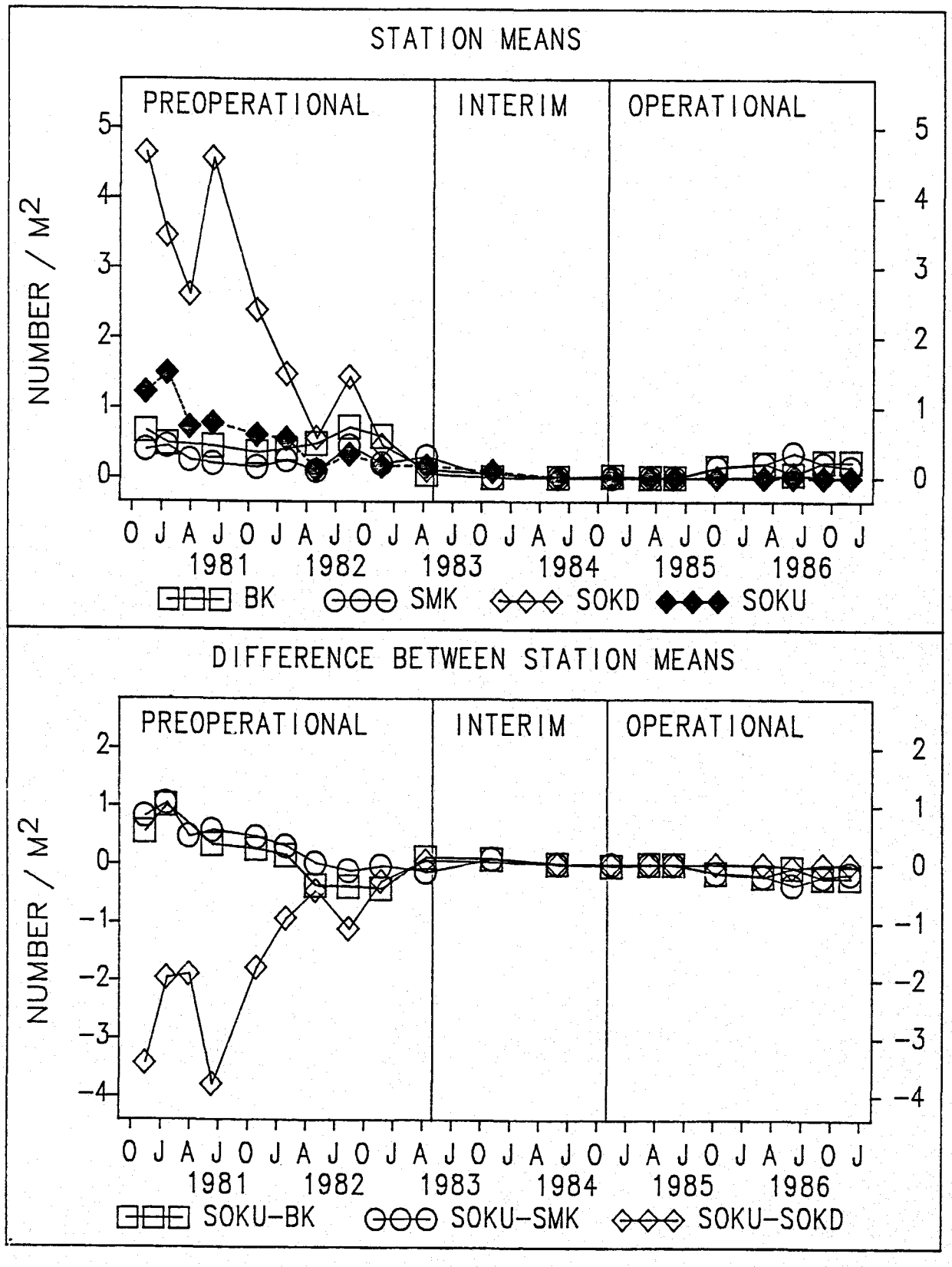
SOKU – SMK

NO TEST

ASSUMPTIONS NOT MET



STYELA MONTEREYENSIS



STYELA MONTEREYENSIS

SOKU – SOKD

NO TEST

ASSUMPTIONS NOT MET

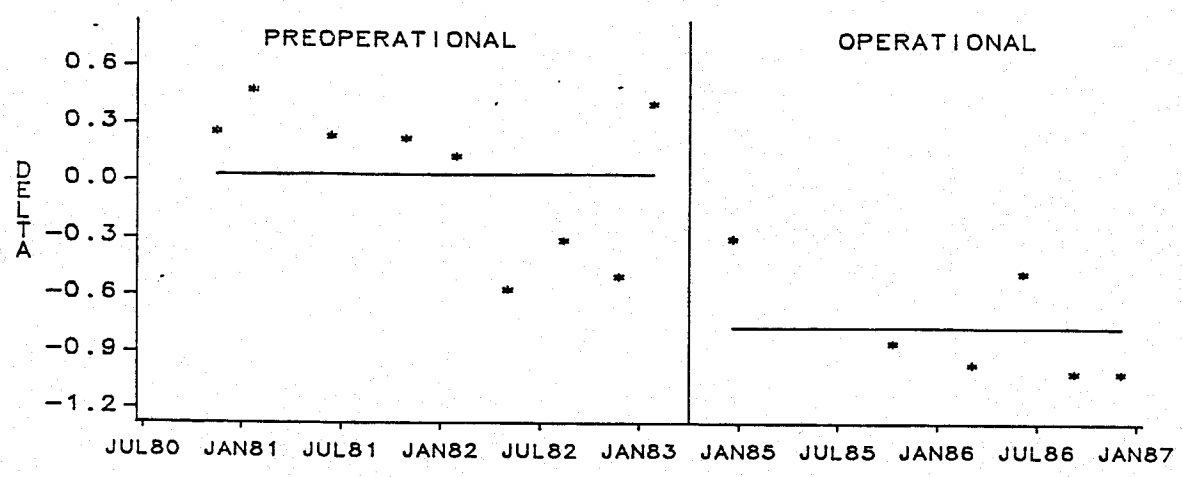
SOKU – SMK

NO TEST

ASSUMPTIONS NOT MET

SOKU – BK

LOG(X+0.025)



APPENDIX A

Appendix A-1. Results of tests of the assumptions underlying the t-test used in the BACIP analysis. All quadrats were used in the analysis. N1, N2 = sample sizes for "Before" and "After" periods, respectively. TREND = linear trend in the "Before" period.

SPECIES	CONTROL	TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION
Astraea undosa	SOKD	LOG(X+.025)	8	8	.43	.00	SIG
Astraea undosa	SOKD	LOG(X+0)	2	2	.	.	UNK
Astraea undosa	SOKD	LOG(X+1)	8	8	.40	.00	SIG
Astraea undosa	SOKD	NONE	8	8	.40	.00	SIG
Astraea undosa	SMK	LOG(X+.025)	7	8	.91	.02	SIG
Astraea undosa	SMK	LOG(X+0)	3	3	.00	.99	UNK
Astraea undosa	SMK	LOG(X+1)	7	8	.37	.02	SIG
Astraea undosa	SMK	NONE	7	8	.34	.02	SIG
Astraea undosa	BK	LOG(X+.025)	3	6	.	.46	UNK
Astraea undosa	BK	LOG(X+0)	0	1	.	.	
Astraea undosa	BK	LOG(X+1)	3	6	.00	.46	UNK
Astraea undosa	BK	NONE	3	6	.	.46	UNK
Calliostoma spp.	SOKD	LOG(X+.025)	2	7	.	.	UNK
Calliostoma spp.	SOKD	LOG(X+0)	2	4	.	.	UNK
Calliostoma spp.	SOKD	LOG(X+1)	2	7	.	.	UNK
Calliostoma spp.	SOKD	NONE	2	7	.	.	UNK
Calliostoma spp.	SMK	LOG(X+.025)	2	5	.	.	UNK
Calliostoma spp.	SMK	LOG(X+0)	0	2	.	.	
Calliostoma spp.	SMK	LOG(X+1)	2	5	.	.	UNK
Calliostoma spp.	SMK	NONE	2	5	.	.	UNK
Calliostoma spp.	BK	LOG(X+.025)	2	7	.	.	UNK
Calliostoma spp.	BK	LOG(X+0)	0	1	.	.	
Calliostoma spp.	BK	LOG(X+1)	2	7	.	.	UNK
Calliostoma spp.	BK	NONE	2	7	.	.	UNK
Conus californicus	SOKD	LOG(X+.025)	6	8	.53	.08	NS
Conus californicus	SOKD	LOG(X+0)	6	8	.52	.08	NS
Conus californicus	SOKD	LOG(X+1)	6	8	.66	.07	NS
Conus californicus	SOKD	NONE	6	8	.61	.06	NS
Conus californicus	SMK	LOG(X+.025)	6	8	.14	.10	NS
Conus californicus	SMK	LOG(X+0)	6	8	.13	.11	NS
Conus californicus	SMK	LOG(X+1)	6	8	.94	.03	NS
Conus californicus	SMK	NONE	6	8	.01	.38	NS
Conus californicus	BK	LOG(X+.025)	6	8	.00	.20	NS
Conus californicus	BK	LOG(X+0)	5	8	.02	.35	NS
Conus californicus	BK	LOG(X+1)	6	8	.07	.26	NS
Conus californicus	BK	NONE	6	8	.50	.11	SIG

Appendix A-1 (cont.)

SPECIES	CONTROL	TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION
Crassispira semiinflata	SOKD	LOG(X+.025)	5	7	.23	.64	NS
Crassispira semiinflata	SOKD	LOG(X+0)	4	3	.92	.07	NS
Crassispira semiinflata	SOKD	LOG(X+1)	5	7	.76	.23	NS
Crassispira semiinflata	SOKD	NONE	5	7	.82	.20	NS
Crassispira semiinflata	SMK	LOG(X+.025)	5	5	.41	.03	NS
Crassispira semiinflata	SMK	LOG(X+0)	1	2	.	.	UNK
Crassispira semiinflata	SMK	LOG(X+1)	5	5	.28	.02	SIG
Crassispira semiinflata	SMK	NONE	5	5	.22	.02	SIG
Crassispira semiinflata	BK	LOG(X+.025)	5	8	.26	.25	NS
Crassispira semiinflata	BK	LOG(X+0)	5	3	.19	.27	NS
Crassispira semiinflata	BK	LOG(X+1)	5	8	.42	.28	NS
Crassispira semiinflata	BK	NONE	5	8	.43	.29	NS
Cypraea spadicea	SOKD	LOG(X+.025)	9	8	.30	.05	SIG
Cypraea spadicea	SOKD	LOG(X+0)	6	4	.83	.36	NS
Cypraea spadicea	SOKD	LOG(X+1)	9	8	.83	.20	SIG
Cypraea spadicea	SOKD	NONE	9	8	.86	.22	SIG
Cypraea spadicea	SMK	LOG(X+.025)	9	8	.87	.13	NS
Cypraea spadicea	SMK	LOG(X+0)	9	8	.92	.15	NS
Cypraea spadicea	SMK	LOG(X+1)	9	8	.70	.10	NS
Cypraea spadicea	SMK	NONE	9	8	.68	.10	NS
Cypraea spadicea	BK	LOG(X+.025)	9	8	.04	.18	NS
Cypraea spadicea	BK	LOG(X+0)	5	4	.38	.54	NS
Cypraea spadicea	BK	LOG(X+1)	9	8	.00	.17	NS
Cypraea spadicea	BK	NONE	9	8	.00	.17	NS
Kelletia kelletii	SOKD	LOG(X+.025)	10	8	.20	.08	NS
Kelletia kelletii	SOKD	LOG(X+0)	10	8	.15	.08	NS
Kelletia kelletii	SOKD	LOG(X+1)	10	8	.94	.14	NS
Kelletia kelletii	SOKD	NONE	10	8	.60	.13	NS
Kelletia kelletii	SMK	LOG(X+.025)	10	8	.23	.07	NS
Kelletia kelletii	SMK	LOG(X+0)	10	8	.18	.07	NS
Kelletia kelletii	SMK	LOG(X+1)	10	8	.93	.12	NS
Kelletia kelletii	SMK	NONE	10	8	.32	.28	NS
Kelletia kelletii	BK	LOG(X+.025)	9	8	.08	.09	NS
Kelletia kelletii	BK	LOG(X+0)	9	8	.07	.10	NS
Kelletia kelletii	BK	LOG(X+1)	9	8	.14	.11	NS
Kelletia kelletii	BK	NONE	9	8	.07	.26	NS

Appendix A-1 (cont.)

SPECIES	CONTROL	TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION
Lytechinus anamesus	SOKD	LOG(X+.025)	10	8	.25	.38	SIG
Lytechinus anamesus	SOKD	LOG(X+0)	10	8	.25	.38	SIG
Lytechinus anamesus	SOKD	LOG(X+1)	10	8	.30	.43	SIG
Lytechinus anamesus	SOKD	NONE	10	8	.52	.81	SIG
Lytechinus anamesus	SMK	LOG(X+.025)	10	8	.00	.31	SIG
Lytechinus anamesus	SMK	LOG(X+0)	6	8	.07	.23	NS
Lytechinus anamesus	SMK	LOG(X+1)	10	8	.65	.61	SIG
Lytechinus anamesus	SMK	NONE	10	8	.00	.10	NS
Lytechinus anamesus	BK	LOG(X+.025)	9	8	.00	.05	SIG
Lytechinus anamesus	BK	LOG(X+0)	8	8	.04	.24	NS
Lytechinus anamesus	BK	LOG(X+1)	9	8	.05	.14	NS
Lytechinus anamesus	BK	NONE	9	8	.54	.72	NS
Maxwellia gemma	SOKD	LOG(X+.025)	2	8	.	.	UNK
Maxwellia gemma	SOKD	LOG(X+0)	2	7	.	.	UNK
Maxwellia gemma	SOKD	LOG(X+1)	2	8	.	.	UNK
Maxwellia gemma	SOKD	NONE	2	8	.	.	UNK
Maxwellia gemma	SMK	LOG(X+.025)	2	8	.	.	UNK
Maxwellia gemma	SMK	LOG(X+0)	2	7	.	.	UNK
Maxwellia gemma	SMK	LOG(X+1)	2	8	.	.	UNK
Maxwellia gemma	SMK	NONE	2	8	.	.	UNK
Maxwellia gemma	BK	LOG(X+.025)	2	8	.	.	UNK
Maxwellia gemma	BK	LOG(X+0)	1	8	.	.	UNK
Maxwellia gemma	BK	LOG(X+1)	2	8	.	.	UNK
Maxwellia gemma	BK	NONE	2	8	.	.	UNK
Mitra idae	SOKD	LOG(X+.025)	6	8	.28	.47	NS
Mitra idae	SOKD	LOG(X+0)	6	8	.32	.46	NS
Mitra idae	SOKD	LOG(X+1)	6	8	.05	.58	NS
Mitra idae	SOKD	NONE	6	8	.01	.65	NS
Mitra idae	SMK	LOG(X+.025)	6	8	.52	.42	NS
Mitra idae	SMK	LOG(X+0)	5	7	.50	.74	NS
Mitra idae	SMK	LOG(X+1)	6	8	.00	.48	NS
Mitra idae	SMK	NONE	6	8	.00	.57	NS
Mitra idae	BK	LOG(X+.025)	6	8	.63	.78	NS
Mitra idae	BK	LOG(X+0)	5	8	.68	.04	SIG
Mitra idae	BK	LOG(X+1)	6	8	.17	.45	NS
Mitra idae	BK	NONE	6	8	.03	.51	NS

Appendix A-1 (cont.)

SPECIES	CONTROL	TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION
Murexiella santarosana	SOKD	LOG(X+.025)	2	7	.	.	UNK
Murexiella santarosana	SOKD	LOG(X+0)	2	4	.	.	UNK
Murexiella santarosana	SOKD	LOG(X+1)	2	7	.	.	UNK
Murexiella santarosana	SOKD	NONE	2	7	.	.	UNK
Murexiella santarosana	SMK	LOG(X+.025)	2	7	.	.	UNK
Murexiella santarosana	SMK	LOG(X+0)	2	5	.	.	UNK
Murexiella santarosana	SMK	LOG(X+1)	2	7	.	.	UNK
Murexiella santarosana	SMK	NONE	2	7	.	.	UNK
Murexiella santarosana	BK	LOG(X+.025)	2	8	.	.	UNK
Murexiella santarosana	BK	LOG(X+0)	2	4	.	.	UNK
Murexiella santarosana	BK	LOG(X+1)	2	8	.	.	UNK
Murexiella santarosana	BK	NONE	2	8	.	.	UNK
Muricea californica	SOKD	LOG(X+.025)	10	8	.00	.29	NS
Muricea californica	SOKD	LOG(X+0)	10	8	.00	.33	NS
Muricea californica	SOKD	LOG(X+1)	10	8	.00	.16	NS
Muricea californica	SOKD	NONE	10	8	.00	.14	NS
Muricea californica	SMK	LOG(X+.025)	10	8	.27	.34	NS
Muricea californica	SMK	LOG(X+0)	10	8	.14	.41	NS
Muricea californica	SMK	LOG(X+1)	10	8	.00	.03	NS
Muricea californica	SMK	NONE	10	8	.00	.01	SIG
Muricea californica	BK	LOG(X+.025)	9	8	.03	.53	NS
Muricea californica	BK	LOG(X+0)	9	8	.01	.55	NS
Muricea californica	BK	LOG(X+1)	9	8	.07	.30	NS
Muricea californica	BK	NONE	9	8	.00	.26	NS
Muricea fruticosa	SOKD	LOG(X+.025)	6	8	.24	.24	NS
Muricea fruticosa	SOKD	LOG(X+0)	4	5	.63	.27	NS
Muricea fruticosa	SOKD	LOG(X+1)	6	8	.80	.11	NS
Muricea fruticosa	SOKD	NONE	6	8	.84	.11	NS
Muricea fruticosa	SMK	LOG(X+.025)	10	8	.01	.30	NS
Muricea fruticosa	SMK	LOG(X+0)	6	5	.06	.26	NS
Muricea fruticosa	SMK	LOG(X+1)	10	8	.00	.66	NS
Muricea fruticosa	SMK	NONE	10	8	.00	.78	NS
Muricea fruticosa	BK	LOG(X+.025)	9	8	.04	.98	NS
Muricea fruticosa	BK	LOG(X+0)	6	5	.21	.64	NS
Muricea fruticosa	BK	LOG(X+1)	9	8	.00	.13	NS
Muricea fruticosa	BK	NONE	9	8	.00	.10	NS

Appendix A-1 (cont.)

SPECIES	CONTROL	TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION
Nassarius spp.	SOKD	LOG(X+.025)	2	7	.	.	UNK
Nassarius spp.	SOKD	LOG(X+0)	1	6	.	.	UNK
Nassarius spp.	SOKD	LOG(X+1)	2	7	.	.	UNK
Nassarius spp.	SOKD	NONE	2	7	.	.	UNK
Nassarius spp.	SMK	LOG(X+.025)	2	8	.	.	UNK
Nassarius spp.	SMK	LOG(X+0)	1	7	.	.	UNK
Nassarius spp.	SMK	LOG(X+1)	2	8	.	.	UNK
Nassarius spp.	SMK	NONE	2	8	.	.	UNK
Nassarius spp.	BK	LOG(X+.025)	2	8	.	.	UNK
Nassarius spp.	BK	LOG(X+0)	1	5	.	.	UNK
Nassarius spp.	BK	LOG(X+1)	2	8	.	.	UNK
Nassarius spp.	BK	NONE	2	8	.	.	UNK
Ophiodermella inermis	SOKD	LOG(X+.025)	2	5	.	.	UNK
Ophiodermella inermis	SOKD	LOG(X+0)	2	3	.	.	UNK
Ophiodermella inermis	SOKD	LOG(X+1)	2	5	.	.	UNK
Ophiodermella inermis	SOKD	NONE	2	5	.	.	UNK
Ophiodermella inermis	SMK	LOG(X+.025)	2	5	.	.	UNK
Ophiodermella inermis	SMK	LOG(X+0)	0	2	.	.	
Ophiodermella inermis	SMK	LOG(X+1)	2	5	.	.	UNK
Ophiodermella inermis	SMK	NONE	2	5	.	.	UNK
Ophiodermella inermis	BK	LOG(X+.025)	2	7	.	.	UNK
Ophiodermella inermis	BK	LOG(X+0)	1	2	.	.	UNK
Ophiodermella inermis	BK	LOG(X+1)	2	7	.	.	UNK
Ophiodermella inermis	BK	NONE	2	7	.	.	UNK
Parastichopus parvimensi	SOKD	LOG(X+.025)	2	5	.	.	UNK
Parastichopus parvimensi	SOKD	LOG(X+0)	1	2	.	.	UNK
Parastichopus parvimensi	SOKD	LOG(X+1)	2	5	.	.	UNK
Parastichopus parvimensi	SOKD	NONE	2	5	.	.	UNK
Parastichopus parvimensi	SMK	LOG(X+.025)	10	8	.27	.80	NS
Parastichopus parvimensi	SMK	LOG(X+0)	2	3	.	.	UNK
Parastichopus parvimensi	SMK	LOG(X+1)	10	8	.00	.68	NS
Parastichopus parvimensi	SMK	NONE	10	8	.00	.66	NS
Parastichopus parvimensi	BK	LOG(X+.025)	9	8	.01	.25	NS
Parastichopus parvimensi	BK	LOG(X+0)	1	3	.	.	UNK
Parastichopus parvimensi	BK	LOG(X+1)	9	8	.00	.49	NS
Parastichopus parvimensi	BK	NONE	9	8	.00	.58	NS

Appendix A-1 (cont.)

SPECIES	CONTROL	TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION
Pteropurpura festiva	SOKD	LOG(X+.025)	2	8	.	.	UNK
Pteropurpura festiva	SOKD	LOG(X+0)	2	8	.	.	UNK
Pteropurpura festiva	SOKD	LOG(X+1)	2	8	.	.	UNK
Pteropurpura festiva	SOKD	NONE	2	8	.	.	UNK
Pteropurpura festiva	SMK	LOG(X+.025)	2	8	.	.	UNK
Pteropurpura festiva	SMK	LOG(X+0)	2	8	.	.	UNK
Pteropurpura festiva	SMK	LOG(X+1)	2	8	.	.	UNK
Pteropurpura festiva	SMK	NONE	2	8	.	.	UNK
Pteropurpura festiva	BK	LOG(X+.025)	2	8	.	.	UNK
Pteropurpura festiva	BK	LOG(X+0)	1	8	.	.	UNK
Pteropurpura festiva	BK	LOG(X+1)	2	8	.	.	UNK
Pteropurpura festiva	BK	NONE	2	8	.	.	UNK
S. purpuratus	SOKD	LOG(X+.025)	10	8	.02	.37	NS
S. purpuratus	SOKD	LOG(X+0)	7	3	.06	.20	NS
S. purpuratus	SOKD	LOG(X+1)	10	8	.92	.46	NS
S. purpuratus	SOKD	NONE	10	8	.88	.54	NS
S. purpuratus	SMK	LOG(X+.025)	10	8	.95	.15	NS
S. purpuratus	SMK	LOG(X+0)	10	7	.68	.19	NS
S. purpuratus	SMK	LOG(X+1)	10	8	.00	.02	NS
S. purpuratus	SMK	NONE	10	8	.00	.01	NS
S. purpuratus	BK	LOG(X+.025)	9	7	.00	.99	NS
S. purpuratus	BK	LOG(X+0)	8	5	.02	.88	NS
S. purpuratus	BK	LOG(X+1)	9	7	.01	.45	NS
S. purpuratus	BK	NONE	9	7	.01	.37	NS
Styela montereyensis	SOKD	LOG(X+.025)	10	2	.22	.17	NS
Styela montereyensis	SOKD	LOG(X+0)	10	0	.49	.34	NS
Styela montereyensis	SOKD	LOG(X+1)	10	2	.00	.00	SIG
Styela montereyensis	SOKD	NONE	10	2	.00	.00	SIG
Styela montereyensis	SMK	LOG(X+.025)	10	8	.04	.01	SIG
Styela montereyensis	SMK	LOG(X+0)	10	1	.03	.01	SIG
Styela montereyensis	SMK	LOG(X+1)	10	8	.07	.00	SIG
Styela montereyensis	SMK	NONE	10	8	.06	.00	SIG
Styela montereyensis	BK	LOG(X+.025)	9	6	.31	.14	NS
Styela montereyensis	BK	LOG(X+0)	9	1	.35	.17	NS
Styela montereyensis	BK	LOG(X+1)	9	6	.20	.05	SIG
Styela montereyensis	BK	NONE	9	6	.17	.03	SIG

Appendix A-1 (cont.)

SPECIES	CONTROL	TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION
Tegula aureotincta	SOKD	LOG(X+.025)	2	4	.	.	UNK
Tegula aureotincta	SOKD	LOG(X+0)	0	3	.	.	
Tegula aureotincta	SOKD	LOG(X+1)	2	4	.	.	UNK
Tegula aureotincta	SOKD	NONE	2	4	.	.	UNK
Tegula aureotincta	SMK	LOG(X+.025)	2	6	.	.	UNK
Tegula aureotincta	SMK	LOG(X+0)	0	2	.	.	
Tegula aureotincta	SMK	LOG(X+1)	2	6	.	.	UNK
Tegula aureotincta	SMK	NONE	2	6	.	.	UNK
Tegula aureotincta	BK	LOG(X+.025)	2	3	.	.	UNK
Tegula aureotincta	BK	LOG(X+0)	1	0	.	.	UNK
Tegula aureotincta	BK	LOG(X+1)	2	3	.	.	UNK
Tegula aureotincta	BK	NONE	2	3	.	.	UNK
Tethya aurantia	SOKD	LOG(X+.025)	10	8	.01	.01	NS
Tethya aurantia	SOKD	LOG(X+0)	5	7	.15	.27	NS
Tethya aurantia	SOKD	LOG(X+1)	10	8	.92	.00	SIG
Tethya aurantia	SOKD	NONE	10	8	.73	.00	SIG
Tethya aurantia	SMK	LOG(X+.025)	10	8	.17	.13	NS
Tethya aurantia	SMK	LOG(X+0)	10	2	.04	.15	NS
Tethya aurantia	SMK	LOG(X+1)	10	8	.61	.08	NS
Tethya aurantia	SMK	NONE	10	8	.46	.08	NS
Tethya aurantia	BK	LOG(X+.025)	9	8	.58	.13	NS
Tethya aurantia	BK	LOG(X+0)	9	8	.46	.11	NS
Tethya aurantia	BK	LOG(X+1)	9	8	.69	.27	NS
Tethya aurantia	BK	NONE	9	8	.56	.30	NS

Appendix A-2. Results of tests of the assumptions underlying the t-test used in the BACIP analysis. Only quadrats not impacted by urchin fronts or heavy (>= 25% cover) deposits of silt were used in the analysis. N1, N2 = sample sizes for "Before" and "After" periods, respectively. TREND = linear trend in the "Before" period.

SPECIES	CONTROL	TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION
Astraea undosa	SOKD	LOG(X+.025)	8	8	.20	.00	SIG
Astraea undosa	SOKD	LOG(X+0)	2	2	.	.	UNK
Astraea undosa	SOKD	LOG(X+1)	8	8	.14	.00	SIG
Astraea undosa	SOKD	NONE	8	8	.14	.00	SIG
Astraea undosa	SMK	LOG(X+.025)	5	8	.50	.04	NS
Astraea undosa	SMK	LOG(X+0)	2	2	.	.	UNK
Astraea undosa	SMK	LOG(X+1)	5	8	.23	.02	NS
Astraea undosa	SMK	NONE	5	8	.21	.02	NS
Astraea undosa	BK	LOG(X+.025)	3	6	.	.	UNK
Astraea undosa	BK	LOG(X+0)	0	1	.	.	
Astraea undosa	BK	LOG(X+1)	3	6	.	.	UNK
Astraea undosa	BK	NONE	3	6	.	.	UNK
Calliostoma spp.	SOKD	LOG(X+.025)	2	7	.	.	UNK
Calliostoma spp.	SOKD	LOG(X+0)	2	3	.	.	UNK
Calliostoma spp.	SOKD	LOG(X+1)	2	7	.	.	UNK
Calliostoma spp.	SOKD	NONE	2	7	.	.	UNK
Calliostoma spp.	SMK	LOG(X+.025)	2	4	.	.	UNK
Calliostoma spp.	SMK	LOG(X+0)	0	2	.	.	
Calliostoma spp.	SMK	LOG(X+1)	2	4	.	.	UNK
Calliostoma spp.	SMK	NONE	2	4	.	.	UNK
Calliostoma spp.	BK	LOG(X+.025)	2	6	.	.	UNK
Calliostoma spp.	BK	LOG(X+0)	0	1	.	.	
Calliostoma spp.	BK	LOG(X+1)	2	6	.	.	UNK
Calliostoma spp.	BK	NONE	2	6	.	.	UNK
Conus californicus	SOKD	LOG(X+.025)	6	8	.90	.09	NS
Conus californicus	SOKD	LOG(X+0)	6	7	.91	.09	NS
Conus californicus	SOKD	LOG(X+1)	6	8	.57	.16	NS
Conus californicus	SOKD	NONE	6	8	.05	.55	NS
Conus californicus	SMK	LOG(X+.025)	6	8	.78	.27	NS
Conus californicus	SMK	LOG(X+0)	6	7	.66	.27	NS
Conus californicus	SMK	LOG(X+1)	6	8	.02	.71	NS
Conus californicus	SMK	NONE	6	8	.00	.95	NS
Conus californicus	BK	LOG(X+.025)	6	8	.01	.24	NS
Conus californicus	BK	LOG(X+0)	5	7	.02	.40	NS
Conus californicus	BK	LOG(X+1)	6	8	.19	.46	NS
Conus californicus	BK	NONE	6	8	.11	.73	NS

Appendix A-2 (cont.)

SPECIES	CONTROL	TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION
Crassispira semiinflata	SOKD	LOG(X+.025)	5	7	.35	.67	NS
Crassispira semiinflata	SOKD	LOG(X+0)	4	2	.87	.22	NS
Crassispira semiinflata	SOKD	LOG(X+1)	5	7	.89	.29	NS
Crassispira semiinflata	SOKD	NONE	5	7	.94	.26	NS
Crassispira semiinflata	SMK	LOG(X+.025)	5	4	.95	.05	NS
Crassispira semiinflata	SMK	LOG(X+0)	1	2	.	.	UNK
Crassispira semiinflata	SMK	LOG(X+1)	5	4	.10	.09	NS
Crassispira semiinflata	SMK	NONE	5	4	.07	.09	NS
Crassispira semiinflata	BK	LOG(X+.025)	5	8	.29	.41	NS
Crassispira semiinflata	BK	LOG(X+0)	5	2	.23	.43	NS
Crassispira semiinflata	BK	LOG(X+1)	5	8	.41	.40	NS
Crassispira semiinflata	BK	NONE	5	8	.41	.41	NS
Cypraea spadicea	SOKD	LOG(X+.025)	9	8	.69	.22	NS
Cypraea spadicea	SOKD	LOG(X+0)	5	3	.02	.41	NS
Cypraea spadicea	SOKD	LOG(X+1)	9	8	.11	.64	NS
Cypraea spadicea	SOKD	NONE	9	8	.08	.68	NS
Cypraea spadicea	SMK	LOG(X+.025)	9	8	.78	.80	NS
Cypraea spadicea	SMK	LOG(X+0)	6	7	.61	.42	SIG
Cypraea spadicea	SMK	LOG(X+1)	9	8	.90	.89	NS
Cypraea spadicea	SMK	NONE	9	8	.86	.88	NS
Cypraea spadicea	BK	LOG(X+.025)	9	7	.45	.24	NS
Cypraea spadicea	BK	LOG(X+0)	4	4	.41	.54	NS
Cypraea spadicea	BK	LOG(X+1)	9	7	.31	.20	NS
Cypraea spadicea	BK	NONE	9	7	.28	.20	NS
Kelletia kelletii	SOKD	LOG(X+.025)	10	8	.46	.23	NS
Kelletia kelletii	SOKD	LOG(X+0)	10	8	.43	.23	NS
Kelletia kelletii	SOKD	LOG(X+1)	10	8	.66	.27	NS
Kelletia kelletii	SOKD	NONE	10	8	.66	.24	NS
Kelletia kelletii	SMK	LOG(X+.025)	10	8	.87	.54	NS
Kelletia kelletii	SMK	LOG(X+0)	10	8	.87	.54	NS
Kelletia kelletii	SMK	LOG(X+1)	10	8	.80	.54	NS
Kelletia kelletii	SMK	NONE	10	8	.43	.63	NS
Kelletia kelletii	BK	LOG(X+.025)	9	8	.12	.09	NS
Kelletia kelletii	BK	LOG(X+0)	9	8	.12	.09	NS
Kelletia kelletii	BK	LOG(X+1)	9	8	.13	.14	SIG
Kelletia kelletii	BK	NONE	9	8	.03	.38	NS

Appendix A-2 (cont.)

SPECIES	CONTROL	TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION
Lytechinus anamesus	SOKD	LOG(X+.025)	10	8	.62	.64	SIG
Lytechinus anamesus	SOKD	LOG(X+0)	10	8	.62	.64	SIG
Lytechinus anamesus	SOKD	LOG(X+1)	10	8	.68	.70	SIG
Lytechinus anamesus	SOKD	NONE	10	8	.92	.89	SIG
Lytechinus anamesus	SMK	LOG(X+.025)	10	8	.08	.92	NS
Lytechinus anamesus	SMK	LOG(X+0)	4	8	.86	.65	NS
Lytechinus anamesus	SMK	LOG(X+1)	10	8	.00	.15	SIG
Lytechinus anamesus	SMK	NONE	10	8	.00	.06	SIG
Lytechinus anamesus	BK	LOG(X+.025)	9	8	.01	.08	SIG
Lytechinus anamesus	BK	LOG(X+0)	8	8	.10	.40	NS
Lytechinus anamesus	BK	LOG(X+1)	9	8	.15	.25	NS
Lytechinus anamesus	BK	NONE	9	8	.92	.90	NS
Maxwellia gemma	SOKD	LOG(X+.025)	2	8	.	.	UNK
Maxwellia gemma	SOKD	LOG(X+0)	2	7	.	.	UNK
Maxwellia gemma	SOKD	LOG(X+1)	2	8	.	.	UNK
Maxwellia gemma	SOKD	NONE	2	8	.	.	UNK
Maxwellia gemma	SMK	LOG(X+.025)	2	8	.	.	UNK
Maxwellia gemma	SMK	LOG(X+0)	2	7	.	.	UNK
Maxwellia gemma	SMK	LOG(X+1)	2	8	.	.	UNK
Maxwellia gemma	SMK	NONE	2	8	.	.	UNK
Maxwellia gemma	BK	LOG(X+.025)	2	8	.	.	UNK
Maxwellia gemma	BK	LOG(X+0)	1	8	.	.	UNK
Maxwellia gemma	BK	LOG(X+1)	2	8	.	.	UNK
Maxwellia gemma	BK	NONE	2	8	.	.	UNK
Mitra idae	SOKD	LOG(X+.025)	6	8	.21	.33	NS
Mitra idae	SOKD	LOG(X+0)	6	7	.24	.33	NS
Mitra idae	SOKD	LOG(X+1)	6	8	.03	.38	NS
Mitra idae	SOKD	NONE	6	8	.00	.47	NS
Mitra idae	SMK	LOG(X+.025)	6	8	.45	.02	SIG
Mitra idae	SMK	LOG(X+0)	4	5	.	.16	NS
Mitra idae	SMK	LOG(X+1)	6	8	.00	.23	NS
Mitra idae	SMK	NONE	6	8	.00	.36	NS
Mitra idae	BK	LOG(X+.025)	6	8	.65	.63	NS
Mitra idae	BK	LOG(X+0)	5	7	.62	.02	SIG
Mitra idae	BK	LOG(X+1)	6	8	.09	.21	NS
Mitra idae	BK	NONE	6	8	.01	.31	NS

Appendix A-2 (cont.)

SPECIES	CONTROL	TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION
Murexiella santarosana	SOKD	LOG(X+.025)	2	7	.	.	UNK
Murexiella santarosana	SOKD	LOG(X+0)	2	4	.	.	UNK
Murexiella santarosana	SOKD	LOG(X+1)	2	7	.	.	UNK
Murexiella santarosana	SOKD	NONE	2	7	.	.	UNK
Murexiella santarosana	SMK	LOG(X+.025)	2	7	.	.	UNK
Murexiella santarosana	SMK	LOG(X+0)	2	5	.	.	UNK
Murexiella santarosana	SMK	LOG(X+1)	2	7	.	.	UNK
Murexiella santarosana	SMK	NONE	2	7	.	.	UNK
Murexiella santarosana	BK	LOG(X+.025)	2	8	.	.	UNK
Murexiella santarosana	BK	LOG(X+0)	2	4	.	.	UNK
Murexiella santarosana	BK	LOG(X+1)	2	8	.	.	UNK
Murexiella santarosana	BK	NONE	2	8	.	.	UNK
Muricea californica	SOKD	LOG(X+.025)	10	8	.01	.41	NS
Muricea californica	SOKD	LOG(X+0)	10	8	.00	.45	NS
Muricea californica	SOKD	LOG(X+1)	10	8	.01	.20	NS
Muricea californica	SOKD	NONE	10	8	.00	.17	NS
Muricea californica	SMK	LOG(X+.025)	10	8	.46	.18	NS
Muricea californica	SMK	LOG(X+0)	10	8	.60	.20	NS
Muricea californica	SMK	LOG(X+1)	10	8	.00	.03	NS
Muricea californica	SMK	NONE	10	8	.00	.02	NS
Muricea californica	BK	LOG(X+.025)	9	8	.06	.50	NS
Muricea californica	BK	LOG(X+0)	9	8	.04	.51	NS
Muricea californica	BK	LOG(X+1)	9	8	.26	.32	NS
Muricea californica	BK	NONE	9	8	.00	.27	NS
Muricea fruticosa	SOKD	LOG(X+.025)	4	8	.	.71	NS
Muricea fruticosa	SOKD	LOG(X+0)	0	5	.	.	
Muricea fruticosa	SOKD	LOG(X+1)	4	8	.	.71	NS
Muricea fruticosa	SOKD	NONE	4	8	.	.71	NS
Muricea fruticosa	SMK	LOG(X+.025)	10	8	.00	.48	NS
Muricea fruticosa	SMK	LOG(X+0)	0	5	.	.	
Muricea fruticosa	SMK	LOG(X+1)	10	8	.	.49	NS
Muricea fruticosa	SMK	NONE	10	8	.	.50	NS
Muricea fruticosa	BK	LOG(X+.025)	9	8	.	.07	NS
Muricea fruticosa	BK	LOG(X+0)	0	5	.	.	
Muricea fruticosa	BK	LOG(X+1)	9	8	.00	.07	NS
Muricea fruticosa	BK	NONE	9	8	.	.08	NS

Appendix A-2 (cont.)

SPECIES	CONTROL	TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION
Nassarius spp.	SOKD	LOG(X+.025)	2	7	.	.	UNK
Nassarius spp.	SOKD	LOG(X+0)	1	5	.	.	UNK
Nassarius spp.	SOKD	LOG(X+1)	2	7	.	.	UNK
Nassarius spp.	SOKD	NONE	2	7	.	.	UNK
Nassarius spp.	SMK	LOG(X+.025)	2	6	.	.	UNK
Nassarius spp.	SMK	LOG(X+0)	1	5	.	.	UNK
Nassarius spp.	SMK	LOG(X+1)	2	6	.	.	UNK
Nassarius spp.	SMK	NONE	2	6	.	.	UNK
Nassarius spp.	BK	LOG(X+.025)	2	8	.	.	UNK
Nassarius spp.	BK	LOG(X+0)	1	4	.	.	UNK
Nassarius spp.	BK	LOG(X+1)	2	8	.	.	UNK
Nassarius spp.	BK	NONE	2	8	.	.	UNK
Ophiodermella inermis	SOKD	LOG(X+.025)	2	4	.	.	UNK
Ophiodermella inermis	SOKD	LOG(X+0)	1	2	.	.	UNK
Ophiodermella inermis	SOKD	LOG(X+1)	2	4	.	.	UNK
Ophiodermella inermis	SOKD	NONE	2	4	.	.	UNK
Ophiodermella inermis	SMK	LOG(X+.025)	1	4	.	.	UNK
Ophiodermella inermis	SMK	LOG(X+0)	0	1	.	.	
Ophiodermella inermis	SMK	LOG(X+1)	1	4	.	.	UNK
Ophiodermella inermis	SMK	NONE	1	4	.	.	UNK
Ophiodermella inermis	BK	LOG(X+.025)	1	5	.	.	UNK
Ophiodermella inermis	BK	LOG(X+0)	0	2	.	.	
Ophiodermella inermis	BK	LOG(X+1)	1	5	.	.	UNK
Ophiodermella inermis	BK	NONE	1	5	.	.	UNK
Parastichopus parvimensi	SOKD	LOG(X+.025)	2	4	.	.	UNK
Parastichopus parvimensi	SOKD	LOG(X+0)	0	2	.	.	
Parastichopus parvimensi	SOKD	LOG(X+1)	2	4	.	.	UNK
Parastichopus parvimensi	SOKD	NONE	2	4	.	.	UNK
Parastichopus parvimensi	SMK	LOG(X+.025)	10	8	.04	.61	NS
Parastichopus parvimensi	SMK	LOG(X+0)	1	2	.	.	UNK
Parastichopus parvimensi	SMK	LOG(X+1)	10	8	.08	.48	NS
Parastichopus parvimensi	SMK	NONE	10	8	.02	.38	NS
Parastichopus parvimensi	BK	LOG(X+.025)	9	8	.00	.19	NS
Parastichopus parvimensi	BK	LOG(X+0)	0	2	.	.	
Parastichopus parvimensi	BK	LOG(X+1)	9	8	.00	.41	NS
Parastichopus parvimensi	BK	NONE	9	8	.00	.49	NS

Appendix A-2 (cont.)

SPECIES	CONTROL	TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION
Pteropurpura festiva	SOKD	LOG(X+.025)	2	8	.	.	UNK
Pteropurpura festiva	SOKD	LOG(X+0)	2	8	.	.	UNK
Pteropurpura festiva	SOKD	LOG(X+1)	2	8	.	.	UNK
Pteropurpura festiva	SOKD	NONE	2	8	.	.	UNK
Pteropurpura festiva	SMK	LOG(X+.025)	2	8	.	.	UNK
Pteropurpura festiva	SMK	LOG(X+0)	2	7	.	.	UNK
Pteropurpura festiva	SMK	LOG(X+1)	2	8	.	.	UNK
Pteropurpura festiva	SMK	NONE	2	8	.	.	UNK
Pteropurpura festiva	BK	LOG(X+.025)	2	8	.	.	UNK
Pteropurpura festiva	BK	LOG(X+0)	1	8	.	.	UNK
Pteropurpura festiva	BK	LOG(X+1)	2	8	.	.	UNK
Pteropurpura festiva	BK	NONE	2	8	.	.	UNK
S. purpuratus	SOKD	LOG(X+.025)	10	7	.27	.37	NS
S. purpuratus	SOKD	LOG(X+0)	7	0	.53	.26	NS
S. purpuratus	SOKD	LOG(X+1)	10	7	.41	.49	NS
S. purpuratus	SOKD	NONE	10	7	.28	.59	NS
S. purpuratus	SMK	LOG(X+.025)	10	8	.86	.07	NS
S. purpuratus	SMK	LOG(X+0)	10	3	.81	.09	NS
S. purpuratus	SMK	LOG(X+1)	10	8	.01	.02	NS
S. purpuratus	SMK	NONE	10	8	.00	.02	NS
S. purpuratus	BK	LOG(X+.025)	9	6	.06	.87	NS
S. purpuratus	BK	LOG(X+0)	8	2	.19	.76	NS
S. purpuratus	BK	LOG(X+1)	9	6	.11	.58	NS
S. purpuratus	BK	NONE	9	6	.10	.48	NS
Styela montereyensis	SOKD	LOG(X+.025)	10	1	.09	.12	SIG
Styela montereyensis	SOKD	LOG(X+0)	10	0	.13	.16	NS
Styela montereyensis	SOKD	LOG(X+1)	10	1	.00	.00	SIG
Styela montereyensis	SOKD	NONE	10	1	.00	.00	SIG
Styela montereyensis	SMK	LOG(X+.025)	10	5	.05	.00	SIG
Styela montereyensis	SMK	LOG(X+0)	10	0	.07	.00	SIG
Styela montereyensis	SMK	LOG(X+1)	10	5	.00	.00	SIG
Styela montereyensis	SMK	NONE	10	5	.00	.00	SIG
Styela montereyensis	BK	LOG(X+.025)	9	6	.53	.20	NS
Styela montereyensis	BK	LOG(X+0)	9	0	.68	.26	NS
Styela montereyensis	BK	LOG(X+1)	9	6	.08	.03	SIG
Styela montereyensis	BK	NONE	9	6	.02	.01	SIG

Appendix A-2 (cont.)

SPECIES	CONTROL	TRANS-FORMATION	N1	N2	ADDITI-VITY	TREND	SERIAL CORRE-LATION
Tegula aureotincta	SOKD	LOG(X+.025)	2	4	.	.	UNK
Tegula aureotincta	SOKD	LOG(X+0)	0	1	.	.	
Tegula aureotincta	SOKD	LOG(X+1)	2	4	.	.	UNK
Tegula aureotincta	SOKD	NONE	2	4	.	.	UNK
Tegula aureotincta	SMK	LOG(X+.025)	2	3	.	.	UNK
Tegula aureotincta	SMK	LOG(X+0)	0	1	.	.	
Tegula aureotincta	SMK	LOG(X+1)	2	3	.	.	UNK
Tegula aureotincta	SMK	NONE	2	3	.	.	UNK
Tegula aureotincta	BK	LOG(X+.025)	2	1	.	.	UNK
Tegula aureotincta	BK	LOG(X+0)	1	0	.	.	UNK
Tegula aureotincta	BK	LOG(X+1)	2	1	.	.	UNK
Tegula aureotincta	BK	NONE	2	1	.	.	UNK
Tethya aurantia	SOKD	LOG(X+.025)	10	8	.02	.01	NS
Tethya aurantia	SOKD	LOG(X+0)	4	6	.44	.64	NS
Tethya aurantia	SOKD	LOG(X+1)	10	8	.64	.02	NS
Tethya aurantia	SOKD	NONE	10	8	.45	.02	NS
Tethya aurantia	SMK	LOG(X+.025)	10	7	.08	.32	NS
Tethya aurantia	SMK	LOG(X+0)	9	2	.47	.19	NS
Tethya aurantia	SMK	LOG(X+1)	10	7	.79	.15	NS
Tethya aurantia	SMK	NONE	10	7	.64	.15	NS
Tethya aurantia	BK	LOG(X+.025)	9	8	.20	.24	NS
Tethya aurantia	BK	LOG(X+0)	9	7	.17	.23	NS
Tethya aurantia	BK	LOG(X+1)	9	8	.39	.31	NS
Tethya aurantia	BK	NONE	9	8	.44	.33	NS

APPENDIX B: FLOW CHARTS OF COMPUTER PROGRAMS USED TO PRODUCE THE TABLES AND FIGURES

Intermediate data bases. Flow chart for intermediate data bases used in flow charts listed on the following pages.

<Species master>

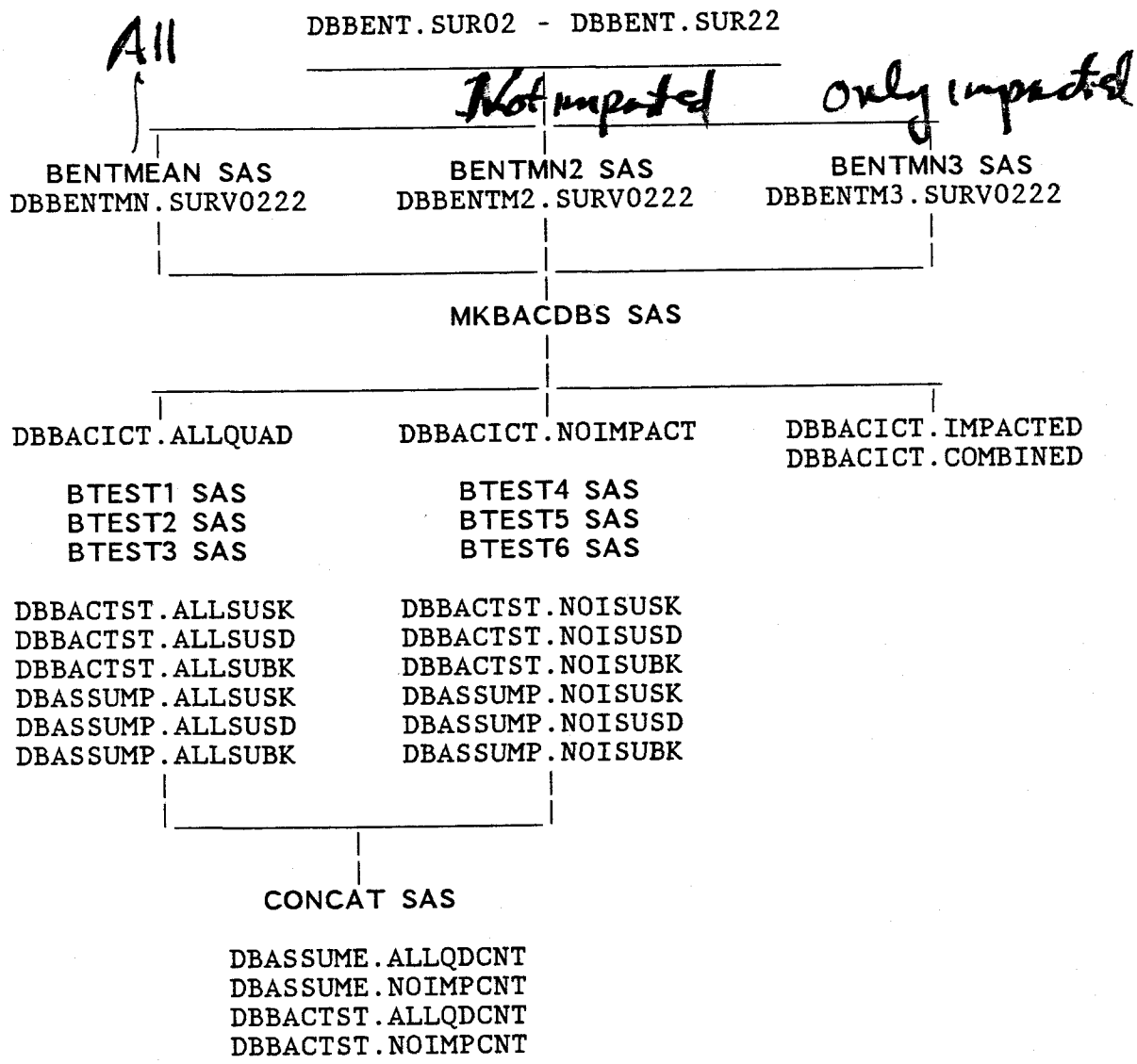


Table 1. Date and duration of benthic surveys.

Constructed by hand from data notebooks.

Table 2. Sample size by period for the various species and substrates for which abundances were estimated as part of the study of the effects of SONGS on large benthic organisms.

DBBENT.SUR02 - DBBENT.SUR22

BENTMEAN SAS

DBBENTMN.SURV0222

CNT_TABL SAS

Table 2.

Table 3. Substrate classification. (Wentworth scale taken from from Shepard, F. P. 1973. Submarine Geology, 3rd ed. N.Y.:Harper & Row.)

Constructed by hand.

Table 4. Date and duration of kelp recruitment surveys.

Constructed by hand from data notebooks.

Table 5. Average density (number / m^2) of species selected for BACIP analysis. Species which were counted during two or more preoperational surveys and which had an average density in the San Onofre kelp forest of at least 1 / 10 m2 on on one or more surveys were selected for further analysis. Station means over all surveys during the preoperational and operational periods are tabulated.

DBBENT.SUR02 - DBBENT.SUR22

BENTMEAN SAS

DBBENTMN.SURV0222

SPMEAN SAS

Table 5.

Table 6. Effect of an urchin front at SMK on benthic invertebrates. A moving aggregation of red urchins was first noted grazing on the study transects in September 1986. Surveys conducted prior to that time are defined as "Before"; all others are "After". "Impact" quadrats are those that were affected by the urchin front; the unaffected quadrats are considered the "Control". Cases where P > 0.05 for the test of additivity and where P < 0.20 for the t-test are tabulated.
N1 = number of surveys in the "Before" period;
N2 = number of surveys in the "After" period.

DBBACICT.COMBINED (See intermediate data base flow diagram)

URSILTDB SAS

DBIMPACT.URFRONT

BACITEST EXEC (URCHBACI MACROCAL)

DBASSUM.URFRONT
DBBTEST.URFRONT

MKDBURSL SAS

DBURFRNT.FORTABL

URFTTABL SAS

Table 6.

Table 7. Effect of an urchin front at SOKU on benthic invertebrates. A moving aggregation of red urchins was first noted grazing on the study transects in September 1986. Surveys conducted prior to that time are defined as "Before"; all others are "After". "Impact" quadrats are those that were affected by the urchin front; the unaffected quadrats are considered the "Control". Cases where $P > 0.05$ for the test of additivity and where $P < 0.20$ for the t-test are tabulated.
N1 = number of surveys in the "Before" period;
N2 = number of surveys in the "After" period.

DBBACICT.COMBINED (see intermediate data base flow diagram)

URSILTDB SAS

DBIMPACT.SILT

BACITEST EXEC (SILTBACI MACROCAL)

DBASSUM.SILT
DBBTEST.SILT

MKDBURSL SAS

DBSILT.FORTABL

SILTTABL SAS

Table 7.

Tables 8-11. Results of BACIP anayses on various species of snails (Tables 8 and 9) and species other than snails (Tables 10 and 11). The average deltas in the preoperational and operational periods were compared with a t-test (P > T). The deltas are the differences in the mean densities of organisms at the impact and control stations on each survey. All quadrats were used in the analyses for Tables 8 and 10. Only quadrats not impacted by urchin fronts or heavy (>= 25% cover) deposits of silt were used in analyses for Tables 9 and 11. N1, N2 = sample sizes for "Before" and "After" periods, respectively. TREND = P-value for a test for a linear trend during the operational period. # = test for serial correlation in operational data was significant.

DBASSUM.ALLQDCNT (See intermediate data base flow chart for these data bases.)
DBASSUM.NOIMPACT
DBBACTST.ALLQDCNT
DBBACTST.NOIMPACT

DBBTTABL SAS

DBALLDAT.BACTABL
DBNOIDAT.BACTABL

SELECT SAS

DBSELECT.ALLQUADS
DBSELECT.NOIMPACT

TESTTABL SAS

Tables 8, 9, 10, and 11.

Tables 12-14. Comparisons of density estimates between the SOKU benthic survey station and the kelp recruitment stations in the upcoast, offshore portion of the San Onofre kelp forest (Table 12); between the SOKD benthic survey station and the kelp recruitment stations in the downcoast, offshore portion of the San Onofre kelp forest (Table 13); and between the SMK benthic survey station and the kelp recruitment stations in the San Mateo kelp forest (Table 14). The two SMK kelp recruitment stations which were located in a white urchin barrens were not included in the SMK analysis.

1. MINIMB01 DATA
   MINIMB02 DATA
   MINIMBS SAS
   DBMINIMB.SUR01
   DBMINIMB.SUR02
   MINIMBS2 SAS
   DBMINI.MAC0102

2. DBBENT.SUR06
   DBBENT.SUR20
   MKMINMBS SAS
   DBMINI.MBS0102

3. DBMINI.MAC0102
   DBMINI.MBS0102

   MINITEST SAS

   TTEST LISTING

   BENSUM DATA (values entered by hand)

   TTSTTABL SAS

   Tables 12, 13, and 14.

Appendix A. Flow chart for Appendix A.

DBALLDAT.BACTABL
DBNOIDAT.BACTABL

ASSUMPTN SAS

APPENDIX A

Figure 1. Study areas in the vicinity of the San Onofre Nuclear Generating Station. The rectangles are the boundaries of the detailed maps of the San Mateo kelp forest (SMK, Figure 2), the San Onofre kelp forest (SOK, Figure 3), and the Barn kelp forest (BARN, Figure 4). The Units 1, 2, and 3 intakes (circles), the Unit 1 outfall (triangle), and the Units 2 and 3 diffusers (labeled lines) are shown.

U.S. Geological Survey Map

Digitized using Summagraphics tablet and Sigmascan software by Jandel Scientific on an IBM PC compatible

Data transferred to IBM 4341 using CXI card

COASTLN2 DATA

ANNOMAP SAS

DBANNO.SHADEMAP

MAPPLOT SAS

Figure 1.

Figure 2. San Onofre kelp forest. The area of hard substrate is outlined in the upper figure, and the depth contours (m) are shown in the lower figure. The positions of various sampling stations are also shown.

PLOT 1: SOK map with substrate profile

SOKSUB DATA
SOKNSUB DATA

SOKPLOT SAS

Figure 2a.

PLOT 2: SOK map with depth profiles

Ecosystems depth profile maps

Digitized using Summagraphics tablet and Sigmascan software by Jandel Scientific on an IBM PC compatible

Data transferred to IBM 4341 using CXI card

SOK11A DATA SOK11B DATA SOK12 DATA
SOK13A DATA SOK13B DATA
SOK14 DATA to SOK16 DATA

ANNODEP SAS

DBANNO.SOKDEPTH

SOKZPLT SAS

Figure 2b.

Figure 3. San Mateo kelp forest. The area of hard substrate is outlined in the upper figure, and the depth contours (m) are shown in the lower figure. The positions of various sampling stations are also shown.

PLOT 1: SMK map with substrate profile

SMK1SUB DATA
SMK2SUB DATA

SMKPLOT SAS

Figure 3a.

PLOT 2: SMK map with depth profiles

SMK6 DATA to SMK9 DATA
SMK10A DATA to SMK14A DATA
SMK10B DATA TO SMK14B DATA
SMK15 DATA to SMK18 DATA

ANNODEP2 SAS

DBANNO.SMKDEPTH

SMKZPLT SAS

Figure 3b.

Figure 4. Barn kelp forest. The area of hard substrate is outlined in the upper figure, and the depth contours (m) are shown in the lower figure. The positions of various sampling stations are also shown.

PLOT 1: Barn kelp bed map with substrate profile showing KIP station

Ecosystems substrate profile maps

Digitized using Summagraphics tablet and Sigmascan software by Jandel Scientific on an IBM PC compatible

Data transferred to IBM 4341 using CXI card

01BKSUB DATA to 02BKSUB DATA
03BKSUB DATA to 18BKSUB DATA
19ABKSUB DATA
19BBKSUB DATA
20BKSUB DATA to 35BKSUB DATA

ANNOSUBB SAS

DBANNO.BKSUB

BKPLOT SAS

Figure 4a.

PLOT 2: Barn kelp bed map with depth profiles

Ecosystems depth profile maps

Digitized using Summagraphics tablet and Sigmascan software by Jandel Scientific on an IBM PC compatible

Data transferred to IBM 4341 using CXI card

BK7L DATA to BK13L DATA
BK14AL DATA
BK14BL DATA
BK15L DATA
BK16L DATA

ANNODEPB SAS

DBANNO.BKDEPTH

BKZPLT SAS

Figure 4b.

Figure 5. Sampling station for study of benthic organisms.

Figure drawn by Leilani Bost.

Figure 6. San Onofre and San Mateo kelp forests. Benthic survey stations, kelp recruitment survey stations, and physical/chemical survey stations are shown.

PLOT 1: SOK map

Ecosystems substrate profile maps

Digitized using Summagraphics tablet and Sigmascan software by Jandel Scientific on an IBM PC compatible

Data transferred to IBM 4341 using CXI card

SOKSUB DATA
SOKNSUB DATA

ANNOSUB SAS

DBANNO.SOKSUB
DBANNO.SOKNSUB

SOKPLT2 SAS

Figure 6a.

PLOT 2: SMK map

Ecosystems substrate profile maps

Digitized using Summagraphics tablet and Sigmascan software by Jandel Scientific on an IBM PC compatible

Data transferred to IBM 4341 using CXI card

SMKSUB DATA
SMKNSUB DATA

ANNOSUB SAS

DBANNO.SMKSUB
DBANNO.SMKDSUB

SMKPLT2 SAS

Figure 6b.

Figure 7. Schematic drawing of stations used to sample kelp and sea urchin recruitment. A. September 1981 to December 1983. B. May 1984 to November 1986.

Figures drawn by Leilani Bost.

Figure 8. Operating characteristics of the San Onofre Nuclear Generating Station's Units 1, 2, and 3 combined.

DBSONGS.YR76 to DBSONGS.YR87

SONGSPLT SAS

Figure 8.

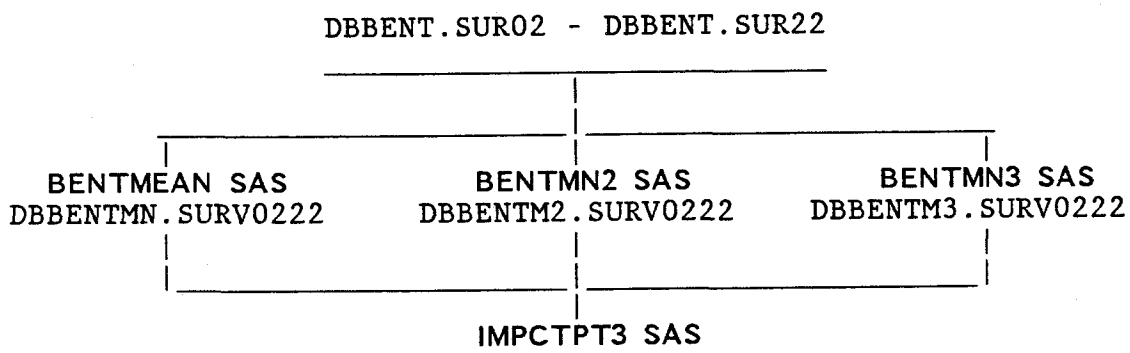
Figure 9. Operating characteristics of the San Onofre Nuclear Generating Station's Units 2 and 3 combined.

DBSONGS.YR80 to DBSONGS.YR87

SONGSPLT SAS

Figure 9.

Figures 10-13. Changes in density (number / m^2) in two classes of fixed 1-m2 quadrats at SMK in the San Mateo kelp forest for several species of invertebrates. Quadrats were divided into those through which an urchin "front" moved and those beyond the leading edge of the "front" which were unaffected. The moving aggregation of red urchins, Strongylocentrotus franciscanus, was first observed on the study transects in September 1986. The vertical line divides the data into "Before" and "After" periods.



Figures 10-13.

Figure 14. Changes in substrate composition in two classes of fixed 1-m2 quadrats at SOKU in the upcoast portion of the San Onofre kelp forest. Quadrats were divided into those which had at least 25% cover of silt on one or more surveys and those which always had less. A heavy deposit of silt was first noted in October 1985. The vertical line divides the data into "Before" and "After" periods.

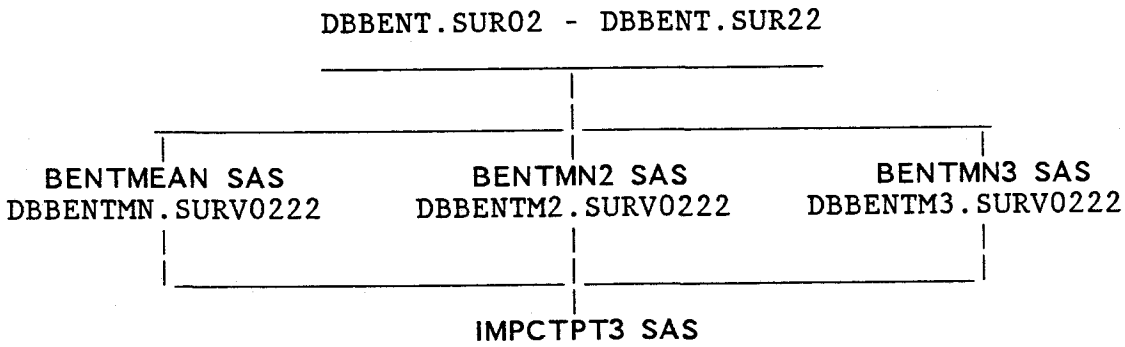
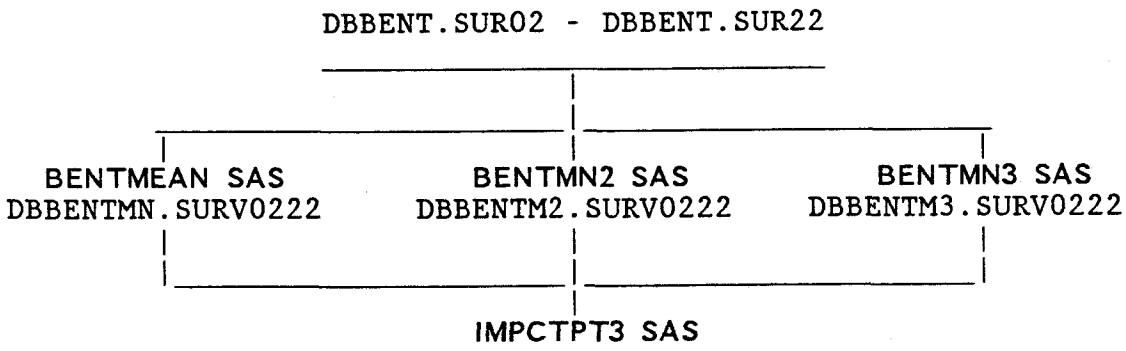


Table 14.

Figures 15-17. Changes in density (number / m^2) in two classes of fixed 1-m2 quadrats at SOKU in the upcoast portion of the San Onofre kelp forest for several species of invertebrates. Quadrats were divided into those which had at least 25% cover on one or more surveys and those which always had less. A heavy deposit of silt was first noted in October 1985. The vertical line divides the data into "Before" and "After" periods.



Tables 15-17.

Figures 18-19. Average percent cover (Fig. 18) or depth (Fig. 19) of silt in five randomly placed 1-m2 quadrats at stations used for the study of kelp recruitment. Stations are indicated by closed circles. Percent cover or depth of silt was zero unless otherwise indicated.

1. EcoSystems substrate profile maps

   Digitized using Summagraphics tablet and Sigmascan software by Jandel Scientific on an IBM PC compatible

   Data transferred to IBM 4341 using CXI interface

   SOKSUB DATA
   SOKNSUB DATA

   ANNOSUB SAS

   DBANNO.SOKSUB
   DBANNO.SOKNSUB

2. DBANNO.SOKSUB
   DBANNO.SOKNSUB
   DBMACCNT.SUR08
   DBMACCNT.SUR09
   DBCOORD.STATION

   OOZPLTS SAS

   Tables 18 and 19.

Figure 20. Mean percent cover of sand + silt at stations in the San Onofre, San Mateo, and Barn kelp forests. During the operational period, large quantities of silt covered many quadrats at the San Onofre stations, and a dense aggregation of grazing red urchins moved through many of the quadrats at the San Mateo station. Data from affected and unaffected quadrats were combined to calculate the station means.

DBBENT.SUR02 - DBBENT.SUR22

BENTMEAN SAS

DBBENTMN.SURV0222

BENTMNPLT SAS

Figure 20.

Figures 21, 25, 29, 33, 37, 41, 45, 49, 53, 57, 61, 65, 69, 73, 77, 79, 83, and 87. Mean density of selected species at stations in the San Onofre, San Mateo, and Barn kelp forests. During the operational period, large quantities of silt covered many quadrats at the San Onofre stations, and a dense aggregation of grazing red urchins moved through many of the quadrats at the San Mateo station. Data from affected and unaffected quadrats were combined to calculate the station means.

DBBENT.SUR02 - DBBENT.SUR22

BENTMEAN SAS

DBBENTMN.SURV0222

BENTMNPLT SAS

Figures 22, 26, 30, 34, 38, 42, 46, 50, 54, 58, 62, 66, 70, 74, 78, 80, 84, and 88. Average deltas during the preoperational and operational periods for selected species. Deltas are the difference between the average density at the impact and control sites. The horizontal lines are mean deltas for the before and after periods. The transformation used in the analysis is printed in the upper right-hand corner of each graph. During the operational period, large quantities of silt covered many quadrats at the San Onofre stations, and a dense aggregation of grazing red urchins moved through many of the quadrats at the San Mateo station. Data from affected and unaffected quadrats were combined to calculate the deltas.

DBBENT.SUR02 - DBBENT.SUR22

BENTMEAN SAS

DBBENTMN.SURV0222

BDLTPLT SAS

Figures 23, 27, 31, 35, 39, 43, 47, 51, 55, 59, 63, 67, 71, 75, 81, 85, and 89. Mean density of selected species at stations in the San Onofre, San Mateo, and Barn kelp forests. During the operational period, large quantities of silt covered many quadrats at the San Onofre stations, and a dense aggregation of grazing red urchins moved through many of the quadrats at the San Mateo station. Data from quadrats which had 25% or more silt on any survey, or which were affected by the urchin front, were not used to calculate station means for any survey.

DBBENT.SUR02 - DBBENT.SUR22

BENTMN2 SAS

DBBENTM2.SURV0222

BENTM2PLT SAS

Figures 24, 28, 32, 36, 40, 44, 48, 52, 56, 60, 64, 68, 72, 76, 82, 86, and 90. Average deltas during the preoperational and operational periods for selected species. Deltas are the difference between the average density at the impact and control sites. The horizontal lines are mean deltas for the before and after periods. The transformation used in the analysis is printed in the upper right-hand corner of each graph. During the operational period, large quantities of silt covered many quadrats at the San Onofre stations, and a dense aggregation of grazing red urchins moved through many of the quadrats at the San Mateo station. Data from quadrats which had 25% or more silt on any survey, or which were affected by the urchin front, were not used to calculate deltas for any survey.

DBBENT.SUR02 - DBBENT.SUR22

BENTMN2 SAS

DBBENTM2.SURV0222

BDLTPLT2 SAS