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Analysis of benthic, planktonic, & pelagic fauna & flora in Cedar Bayou, the discharge canal, cooling pond, & Trinity Bay in relation to discharges of heated water by Houston Lighting & Power

by J. G. Mackin

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I. Objectives of the study.

It was aimed in this study to determine what changes, if any, have resulted from the discharge of heated water from the cooling units. This heated water is subjected to a cooling process in the cooling lake before reaching Trinity Bay. The determination of effect therefore involves a measurement of the effectiveness of the cooling pond in reduction of temperature of cooling waters. Secondarily, it involves also a determination of whether or not toxic or biological pollutants are introduced into Trinity Bay in quantities sufficient to change the fauna and flora.

II. Methods.

A critical study of voluminous biological data from several sources was necessary. First, many of the data resulting from the four year faunal study by Wildlife and Fisheries Science Department of Texas A&M University, Project 1774 of the Agricultural Experiment Station directed by Dr. Kirk Strawn, were analyzed. These data were contained in annual reports covering the period from late 1969 to 1973. Southwest Research Institute initiated similar studies in 1973 and their data were made available up to the spring of 1974. Dr. Bill Wilson of the Texas A&M University Marine Laboratory at Galveston contributed plankton studies in the cooling pond and Dr. Frank G. Schlicht and the author made plankton studies at the HL&P Robinson and Cedar Bayou generating plants, in the critical summer of 1972.

Methods of analysis of these data will be demonstrated in the body of the report. Basically these methods consist of comparisons of productivity and diversity of the biotic communities at critical stations with various control stations.

III. Results.

1. The benthos.

It is generally agreed that the benthic communities are most useful in measurement of effect of environmental stress factors, irrespective of whether these factors are chemical, physical (including temperature), or biological. The reason for this is that with few exceptions benthic organisms may not leave a location, once they are established in that location. Also larvae of benthic organisms have little choice in the matter of where they are deposited by tidal and wind driven currents. It is therefore possible to measure colonization rates, on a seasonal basis, and to determine by comparison with control areas and stations whether or not a benthic colony, once established, is normally productive and is normally diverse.

Benthic study A

A study of the changes in productivity over the period from January 1970 to May 1973, using the Wildlife Science "frame" samples was made. Five stations were involved. These were close inshore in Trinity Bay, and the stations were numbered 6, 9, 19, 21, and 24. Station 19 was situated at the discharge site to Trinity Bay in shallow water just to the north of the drop structure from the discharge canal. Stations 6 and 9 were close inshore to the south by 2 and 1 statute miles respectively, and stations 24 and 21 were similarly situated to the north (see map Fig. 1). It was assumed that if an adverse effect resulted from the discharge waters, Station 19 would be inferior to the flanking stations to the north and south.

Fig. 1a covering the year 1970 shows that in the first 8 months of the year, prior to discharge of any heated water, Station 19 was intermediate in productivity between the flanking stations. The stations to the north appeared to be generally better than those to the south. Winter months show a definite improvement over the summer months, with a definite advantage of Station 19 over the flanking stations taken together, but no real difference between it and the two stations to the north (21, 24). Because of low volume of hot water, it is believed that 1970 data show no effect of the discharge, and may be considered to be of value as control data. Fig. 1b for 1971 shows that the high winter productivity was continued. In the summer months of July, August, and September, Station 19 was superior to the flanking controls. However, the data were inconclusive, as there was no heated water discharge from early July to mid-September. Failure to show increasing productivity in the fall months is not explained, but may be due to low salinity. Fig. 1c for 1972 shows a definite effect of heated discharge in the summer, beginning in May. This probably was enhanced by low salinity. At about the end of April the cooling pond was put in use. Beginning in July Station 19 showed a superiority to the flanking stations, a superiority which became more obvious in the fall and winter. It is highly significant that the discharge station showed improvement within two months after the cooling pond was put in use, and a massive numerical superiority of that station over controls was maintained until May of 1973 (Fig. 1d), the data period for the A&M study.

Benthic study B

Samples taken by Wildlife Science using an Ekman dredge in deeper water offshore show approximately the same pattern as shown by the "frame" samples discussed above, but without the definite superiority of the discharge stations. Actually there is no "discharge" station, because the stations 16-17 (Fig. 2 and map, Fig. 1) closest to the discharge site average about a half mile off shore from the discharge site. However, the Ekman stations in Trinity Bay are arranged in pairs in Fig. 2, each pair being farther out in Trinity Bay from the discharge. The time of measurement was from 11-4-72 to 5-31-73, and both species number (pooled) and individual numbers/ M^2 (mean of the two paired stations over the period) are shown in the graph. Stations 16 and 17 nearest to the discharge site are directly offshore, had the best record for number of species and the second best for number of individuals. Controls (stations 27 and 28), about 3 statute miles offshore, showed the poorest record for species number and the next poorest for number of individuals.

However, it is probable that none of the differences between these stations is significant.

Benthic study C

The extensive A&M data in graphs 1a to 1d showing the effects of the hot water discharge at station 19 ended in the April 1973 collection. It seemed to be desirable to summarize the station 19 data as far as possible, so the Southwest Research Institute data for stations DS-C1 were spliced onto the frame data. The result is shown in summary in Fig. 3. The left hand column for each year shows the mean number of species for the 12 months, and the right column shows the mean number of individuals/ M^2. It is evident that the discharge site continued the large gains of 1973 into 1974. However, the data are biased in that the 1974 data cover only the January to April period, which is characteristically the highest producing 4 months of the year. It probably is true that 1974 is about the equal of the 1973 period, but even this is not certain.

Benthic study D

There were certain changes in the balance of species in the different major taxa. Fig. 4 and Table 1 summarize these changes. In the period from 1970 to 1974 the crustacean species at Station 19, and the successor stations at the discharge site to Trinity bay,DS-C1,very greatly increased, nearly 9-fold increase. Partly this was a result of bottom changes caused by scouring action of the discharge water, but it was partly due to increased food availability and perhaps other changes. The Molluscan species decreased in the same period, probably because of the lower salinities of the last several years. The changes may also have resulted from the changes in gear for sampling. Prior to 1973 a 1/4 meter square frame sampler was used; after that time corers of small diameter were used. The Polychaeta changed only slightly over the 4 years, but the indicated drop in 1974 may be real.

Irrespective of the reasons for the changes in number of Crustacean species and Molluscan species, the fact that the Crustacean species increased is of significance. The group as a whole is pollution sensitive, which indicates that toxic chemicals are not present in significant amounts in the discharge water.

Benthic study E

Using only the data taken by Southwest Research Institute, graph, Fig. 5 was prepared. Stations CP3, and all those in Trinity Bay, including the discharge site stations DS-C1, were used in this study. The stations were grouped as indicated in the explanation of Fig. 5, and numbered 1 to 10, according to distance from the discharge site. The columns show the value of the mean of all samples for all stations of a group for the period from May 1973 to April 1974. Left column of two shows number of species and the right column shows number of individuals/ M^2.

Station CP3 obviously out produced all other groups, including both sets of controls. It had greater number of species except the G series of controls. The discharge site exceeded productivity of six of the Trinity Bay groups, and was inferior to one of the two sets of controls and was superior to the other set of controls. More exact data including monthly values are contained in Table 2.

Benthic study F

Up to this point little attention has been given to seasonal variation in number of species and numbers of individuals. Graph, Fig. 1a to 1d showed seasonal variation to some extent, enough to show that rather radical differences between winter and summer occur. Fig. 6, and Table 2 were prepared to show in greater detail productivity differences between summer (July, August, and September) and winter (December, January and February). In Fig. 6 stations CC in the discharge canal, CP3, and DS and D1 in the cooling pond and at the discharge site to Trinity Bay, and a group of six stations in Trinity Bay are contrasted. Station CC has very high summer temperatures, between 38 and 40 C. At that station the bottom fauna nearly disappears in summer. But in the cooling pond and discharge sites productivity averages around 15,000 individuals/ M^2 in summer, a respectable number in any environment. Winter productivity at station CC surprisingly was comparable to the Bay controls, and winter productivity in the cooling pond was about twice that of the controls. Variation within the control groups is indicated in table 2. The high summer productivity of the control group was confined to station G5; the others were small producers compared with CP3, DS and C1.

Table 3 contains more detailed data from May, 1973 to April, 1974. It includes selected stations from Cedar Bayou to the Trinity Bay controls. It differs from Table 2 in that stations are not grouped.

A comparison of winter and summer productivity at station 19 (frame samples) is shown in Table 4 for the years 1970 to 1973. The contrast between 1972 and 1973 summer productivity is informative. Species number did not vary significantly, except for the high point in the winter of 1973.

Although there is some doubt of the validity of using a diversity index constructed to measure effects of biological pollutions for testing effects of high temperature water discharge, the Weaver-Shannon index for $\bar{H}$ was applied to five stations (CC, DS, C1, F5 and G5). The Weaver-Shannon formula is as follows:

$$\bar{H} = -\Sigma\ (n/N)\ \mathrm{Ln}\ (n/N)$$

where N = total individuals in the sample, and

n = number of individuals of the ith species.

The data are presented in Table 5. They indicate that only station CC was affected by the high temperatures, and at that station only in the summer months. This fact has already been shown with much greater precision by variations in productivity and species number. It may be that the formula is of value as a corroborative measure.

2. The plankton.

Plankton study A

<u>The Robinson Plant Samples.</u>

Methods:

Samples were taken with a number 20 conical plankton net. The net was held for 5 minutes in the swift stream of the intake and discharge areas. These samples are not considered to be quantitative because of obvious variation in rate of water movement at the different stations. The purpose of the study was to determine whether or not there was a significant alteration of community structure on passage through the cooling units. The Robinson plant, having been in operation for a comparatively long period, would be expected to show alterations more clearly than would the shorter term experience of the Cedar Bayou Plant.

Results:

Although the samples were not quantitative, it was obvious that the volume of mixed plankton in the discharge canal was greater than that taken outside the "plume" area in Galveston Bay. There appeared to be little difference between the intake canal fauna and flora and that found in the discharge canal.

The basic data on total species number, number of zooplankters, blue green algae, diatoms, and other phytoplankton species, are shown in Table 7. Zooplankton species outnumbered all other plankton species combined. Of particular interest is the near absence of Cyanophyte species (blue-green algae). Not only was the number of species low, the number of cells (or colony of cells) was very small. Mostly a few strands of Oscillatoria or Lyngbya was all that were found. These had become dislodged from small growths attached to pilings. No blue greens were found in the bottom of the discharge canal, which was packed clay cleared of silt by fast water movement.

Diatom species were numerous throughout the discharge canal and these were probably the numerical dominants of the collections. Species of Calanoid copepoda were also very numerous. Probably dominant in the zooplankton were the Rotifera, which were present at all stations in large numbers.

Although there were no significant changes in the communities as a whole, certain effects of passage through the heating units were observed. These effects were shown on comparison of the second sample at the intake platform and the sample taken very close to the discharge from the plant. It was noted that there were large numbers of Polychaete larvae on the intake side but few at the discharge. Conversely, there were few calanoid copepods in the intake side but very large numbers on the discharge side.

Both of these effects may be based on the random choice of sites both above and below the plant.

The effect of the bypass canal, which allows the shunting of water from the intake side around the plant could not be determined with any certainty. It was designed as a cooling device, and probably was effective. Note the considerable increase in species at the first catwalk below the bypass over the number at the station at the plant discharge (not affected by the bypass). This increase is effective throughout all stations in the discharge canal, but not in the control area in Galveston bay.

Plankton study B

The Cedar Bayou Plant Samples.

Samples were from 50 gallons of water pumped through a #20 plankton net. Stations are shown on the map, Fig. 8. These samples were quantitative, but the data here presented are qualitative.

Data from this study are presented in Table 8, which duplicates the form of Table 7 for comparative purposes. The number of Cyanophytes at the intake structure of the Cedar Bayou plant was significantly higher than at stations in the discharge canal, probably an effect of eutrophication caused by the sewerage outfall a short distance up Cedar Bayou. This effect was not carried into the discharge canal, all stations (2 to 5) showing less than one half the number of blue-green species. Diatom species were also reduced in passage through the heating units. On the intake side Polychaete larvae, bivalve mollusc larvae, crab larvae, copepod nauplii and fish eggs were recorded. Only two of these (oyster larvae and nauplii) were found in the discharge cubicle on the discharge side of the Cedar Bayou Plant, and total species number was reduced from 36 to 22, possibly a significant reduction. The discharge cubicle, however, had a number of species not present on the intake side: very numerous Vorticella cells and colonies, a stalked rotiferan species, a suctorian (Paracineta sp.), and an entoproct bryozoan (Pedicellina?). These are all sessile forms and were undoubtedly attached to the discharge tunnel walls and the concrete walls of the discharge cubicle, and are especially resistant to high temperatures. Turbulence in the discharge cubicle and tunnels account for taking them in the plankton.

At station 3, (fish platform in the discharge canal) the oyster larvae had become very numerous, the Polychaete larvae and nauplii were present in large numbers, and the plankton contained numerous fish eggs. Recovery from the losses, if they were real, in the cooling units was accomplished in the discharge canal itself.

Station 4 (drop structure to cooling lake) again produced large numbers of sessile species, which attached to the walls of the concrete structure in masses. These were essentially the same species as cover the walls of the discharge cubicle at the end of the tunnels from the cooling units.

The discharge area to Trinity Bay was approximately normal. Numerical dominants were Calanoid copepoda and diatoms, with a considerable number of larval invertebrates. These evidently were coming mostly from the cooling pond.

Some relations with the Cedar Bayou Plant should be mentioned. First, the approximate maximum production of heated water from the cooling units had been achieved when these samples were collected. Second, the time was in the approximate maximum heat of summer. This would be calculated to produce the maximum effect possible on the fauna and flora in the discharge canal, and beyond, if it had any effect beyond the discharge to Trinity Bay. The cooling pond was put in use in the latter part of April; there had been, therefore, only two months to effect any faunal and floral changes which might develop from the use of the pond, which probably would not be sufficient time in the heat of the summer. Other studies have indicated (see benthic and nekton studies) that the summer of 1972 was the period of lowest productivity in the discharge canal. It is believed therefore, that the studies just presented show a highly satisfactory performance for this period. Certainly plankton samples with number of species ranging from 16 to 36 cannot be considered to be significantly below normal.

Plankton study C

Dr. Bill Wilson took samples of Phytoplankton in Trinity Bay and the cooling pond on December 19, 1972. Because these samples represent winter conditions about 8 months after the cooling pond was put into operation, they are of interest in comparison with the samples from the preceding summer period discussed above. The data are contained in table 9. The complete absence of planktonic blue-green algae is remarkable. However, Dr. Wilson reported Oscillatoria from benthic samples in the cooling pond, but apparently no floating blue greens were taken. Dr. Wilson noted that a large bloom of diatoms was found at the stations in Trinity Bay, but the dominant form was a Chysophyte in the cooling pond, with several species of Dinoflagellates collectively next in abundance. Skeletonema and Nitzschia were the dominant diatoms. At the discharge area to Trinity Bay Chlorophyll A fluorometric readings were significantly higher than at any of the other stations.

Plankton study D

Zooplankton samples collected by Southwest Research Institute in Cedar Bayou, discharge canal, cooling pond and Trinity Bay will now be considered. These samples were taken, beginning in May, 1973 and data are available to February, 1974. The data include the critical summer months. Comparisons made are (1) between stations, from IS (intake in Cedar Bayou), CC (discharge canal) three cooling pond stations, combined stations DS and CI (drop structure to Trinity Bay and next station between the groins) and three sets of two combined stations in Trinity Bay successively farther from the discharge site (D3-B3, A3-E3, and F5-G5); and (2) comparison of seasonal variations of these stations and sets of stations. Basic data are contained in Table 10 and graphs Fig. 9, Fig. 10, Fig. 11 and Fig. 12.

Table 10 and graph Fig. 9 show that during the 10 months of available data the three cooling pond stations were significantly superior to the station in Cedar Bayou (IS), the discharge canal (CC) and the Trinity Bay stations, so far as productivity was concerned. The cooling pond stations combined out-produced the others by 2.67 to 1. The intake station (IS) was poorest of all. The discharge canal was superior to the combined Trinity Bay stations by 1.5 to 1. Cooling pond stations were slightly poorer than the Trinity Bay stations in number of species (by a ratio of 1 to 1.2) but this is probably not a significant difference, considering the variation in number of species at other stations. The ratio at all stations varied from 1.6 to 2.8, over the 10 months of the study. This is not, however, a completely valid comparison because the range at any one station covered the entire temperature range from midsummer to midwinter.

Table 10 and Fig. 10 show the variation of productivity and species number (all stations) between warm and cool months. Remarkably, the discharge canal station (CC, Table 10) produced more in the heat of the summer than in the winter, showing that some zooplankters are unaffected by high temperature up to 38°C, which was about the average temperature for July, August, and September, 1973, at station CC. It was assumed that the zooplankton fauna was made up of some heat resistant species. A study of the basic data on the zooplankton community at station CC showed that Brachionid rotifers were dominant in the early July period and that the intake station (IS) and cooling pond stations (CP1, CP2, and CP3) also had large concentrations of the rotifers. However, by the end of July the rotifer bloom was over, and in the months of August and September, the rotifers were in very small numbers or (in some collections) they were absent. During all of this period from early July through September the number of crustacean species was high.

Focusing attention more specifically on the cooling pond effects, zooplankton productivity is shown for stations CC, station CP3 (cooling pond), and the two most distant controls in Trinity Bay, F5-G5. The data are contained in graph Fig. 11 for the period May 1973 to February 1974. These data show that cooling pond (CP3) station exceeded the controls in productivity every month in the year but were exceeded by station CC in August, September and October. However, species number was highest at the control stations in 8 of the ten months, and equaled either the discharge site or the cooling pond in the other two months. Differences in some months seemed to be significant. The summer months failed to reduce productivity at station

CP3 significantly, (Fig. 12), but did produce reduction at the control stations from July through the following January. This could have been an effect of low salinity in Trinity Bay.

Certain factors make the records for the discharge canal station CC appear to be better than they really were during high temperature months. First, because of diurnal sinking and rising of *Acartia tonsa*, a Calanoid copepod, surface samples at the intake station IS showed the copepods to be relatively low in number. But concentrations in deep water were high and Acartia showed up (after passing through the cooling units) at Station CC in higher numbers than appeared at the intake.

On the dates when samples were taken at Station CC no data were taken to determine whether or not some of the reported zooplankters may have been dead after going through the cooling units. Subsequently such studies were made by Southwest Research Institute. These studies showed that certain zooplankters, notably *Acartia tonsa*, were sensitive to the heat, and a high percentage died in the summer months. The effect extended to Station CPI but did not affect CP3. Cyclopoid copepodids and barnacle larvae were affected to much lesser extent in the discharge canal. It is assumed that most plankters, excepting only the heat resistant types mentioned above, were affected to some extent.

Plankton study E

Southwest Research Institute collected Phytoplankton at all stations at the surface and near the bottom. Usually there were 2 samplings per month but sometimes there were three. Three samplings were taken at the surface and three near the bottom. This usually will produce 12 samples per month but occasionally it is 6 or 18. Data for this summary were reduced to mean number of cells per station per month. For purposes of comparison, diatom species and blue-green species were counted separately. Species other than the diatoms and blue-greens were abundant but were not used in this analysis, which aimed particularly at a comparison of productivity of the two groups named.

In Table 12 is a summary of the numbers of diatom cells/ml and the pooled number of diatom species/month at 8 key stations. The table compares the different stations and shows the seasonal changes from May, 1973 to April, 1974. Where a species "blooms", the identity of the species producing the bloom is indicated by footnotes. Of interest is the fact that station CC averaged nearly twice the number of diatom cells/liter (about 4 million) than did control stations F5 and G5 (2.6 million and 2.0 million respectively). Furthermore stations CP3 and C1 (cooling pond and discharge to Trinity Bay) both attained a mean of about 8 million cells/liter, about twice the productivity of CC, and nearly 4 times the productivity of stations F5 and G5.

These relations are shown graphically in Fig. 13. Diatom genera contributing to blooms include Coscinodiscus, Cyclotella, Chaetoceros, Nitzschia, Navicula, and Thallassiosira. Cyclotella and Nitzschia produced moderate blooms in the hot months in the cooling pond. Station CC failed to produce bloom in the months of July, August, and September, but did produce a heavy bloom of Thallassiosira in October. Stations F5 and G5 produced blooms of Cyclotella and Thallassiosira only in the months from December to April.

In Table 13 the number of blue-green species (pooled) per month and the average number of cells/ml are presented. Where diatoms were generally counted in the thousands/ml, the blue green cells were counted in hundreds. Overall the diatom cells outnumbered the blue-greens a little more than 6 to 1. Only one bloom, by diatom standards, appeared in the counts; this was a Coccochluorus outbreak in January which affected stations CC in the discharge canal, all cooling pond stations, and station C1 at the discharge site to Trinity Bay. A lesser bloom of Anabaena occurred at F5 and G5 in August and September. Fig. 14 is a graphic presentation of the production of blue-greens at the stations of particular interest. Station CC was the most efficient producer of blue-greens, followed by Station C1. The decrease from CC to CP3 is an interesting feature.

Figures 15 and 16 need to be studied together. They show the seasonal changes in number of diatoms/ml (Fig. 15) and number of blue-green cells/ml (Fig. 16) at stations CC, CP3, and F5. In each case the left column of each group of three shows productivity of station CC, the middle column is CP3, the right column is F5. It should be kept in mind that the scale for Fig. 15 (diatoms) is for hundreds of cells/ml. Proper adjustments should be made. In August and September blue-green cells exceeded the diatoms by a small margin at both CC and CP3. This happened also in January at station CC; otherwise production of diatoms exceeded that of blue-greens by a lopsided margin at all three stations. See also Tables 12 and 13 for more extensive data at other stations.

3. The nekton.

The nekton generally provides rather poor and unreliable data for measuring effects of pollution. But in the case under consideration just the opposite is true. This is because of a semi-isolation of three populations of fishes and shrimps, one in the Tabbs Bay - Cedar Bayou complex, one in the discharge canal-cooling pond combination, and a third in Trinity Bay. This isolation is far from complete, however, because larval and juvenile forms of fishes and shrimp are small enough to pass through the cooling units from the intake from Cedar Bayou to the discharge canal and over the dropstructure to the cooling pond, and both adult fishes and larvae may pass from the cooling pond over the dropstructure to Trinity Bay. But it should be noted that neither adult nekton species nor juveniles can negotiate the migration in the reverse direction.

It is instructive to examine sufficient early data, taken in the period December 1971 to October 1972 at seine stations close inshore in the Trinity Bay discharge area, and including station 19 at the discharge site. It was expected to determine whether or not the discharges in the summer months, prior to and just following the beginning of use of the cooling pond,would cause an avoidance reaction in the nekton. Peneid shrimp distribution at the seine stations was studied, as it is believed that these crustaceans would be most likely to show sensitivity to high temperatures.

The data are condensed in Fig. 17. It is obvious that station 19 was affected, and it appears that stations 9 and 13 to the south of the discharge station were also less desirable areas than stations 18, 21, and 24 north of the discharge site and station 6 about 2 miles to the south. Penaeus setiferus appears to be more sensitive than is P. aztecus but the difference may be a reflection of differing migration seasons. It appears to be evident that there may be an avoidance reaction prior to the introduction of the cooling pond.

Data on trawl samples taken by Southwest Research Foundation in the period from April 1973 to March 1974 are contained in Table 14. Stations of significance are contained in the table beginning with GB (Tabbs Bay at junction with Galveston Bay) through Cedar Bayou, the discharge canal, cooling pond and Trinity Bay. Data presented are on a monthly basis and represent pooled number of species from (usually) four samples and mean number of individuals per month. Mean number of species and mean number of individuals at these stations are graphically presented for the entire period from April to the following March (Fig. 18). There appears to be little significant difference between any of the stations, except that the combined DS (drop structure) - C1 station easily is superior to all others both in number of species and in productivity. This means that fishes and ambulatory crustacea (shrimp, crabs) are attracted to the discharge area. This attraction of the highly motile fishes and other nektonic forms must be based on greater availability of food, and better physico-chemical conditions at the discharge to Trinity Bay.

Seasonal variation in number of individuals taken in the trawl samples is shown in the graph, Fig. 19. The stations CC (in discharge canal), CP3 (in the cooling pond), DS-Cl (at the discharge to Trinity Bay, and F5-G5 (controls in Trinity Bay) are compared in this graph. Fishes and crustacea disappear from the discharge canal in July and August, and are very low in number from June to November. In December, January, February and March, extremely large numbers of fishes were found. These were healthy and growing fast, but none reached large size compared with fishes taken in Trinity Bay. Cooling pond station CP3 was generally better than controls, (F5-G5) except in the summer. In August, September, and October this station was nearly as low as was station CC. Stations DS-Cl at the discharge to Trinity Bay was superior to the controls summer and winter. From October through the following March the concentrations increased. Peculiarly stations CC and DS-Cl differed little in number of fishes from December, 1974 to March, 1974.

A comparison of stations CC and DS-Cl with all other stations shown in Table 14 is presented in Fig. 20. This graph shows clearly the extreme depression of station CC in the discharge canal in the summer months of July, August, and September. Normal summer depression is shown by the combination of 13 stations in Tabbs Bay, Cedar Bayou, cooling pond and Trinity Bay. The discharge site was superior to the controls from June through the following November. Winter months showed a vigorous recovery of station CC (December through March), nearly equaling the discharge site (DS-Cl). Both the CC and DS-Cl stations were distinctly superior in winter to the combination of 13 other stations.

4. Community structure at station DS.

Diversity and the balance of ecological groups making up the total community studied at station DS was investigated. The aggregation of species is remarkable, and the development of large populations of the different elements of the community is still more remarkable. Using the least productive summer months (July, August, and September) a tabulation was made of the species present combining the primary producers (phytoplankton), animal plankters, benthic species, and nektonic species. The result is shown in Table 15, which is a list of the pooled species for the three months, arranged beginning with the fishes and ending with the phytoplankton. A summary of the data shows:

(1) Total species number came to 133, of which 82 belong in the animal kingdom, and 56 to the plant kingdom.

(2) There were 17 major taxa represented (classes or higher).

(3) The class Crustacea accounted for 41 of the 133 total species, nearly one third.

(4) Those groups unable to achieve significant movement in adult stages were poorly represented, for example the Phylum Mollusca was represented by only one species.

(5) Excessively low salinities accounted in part for the low number of Molluscs and the high number of Crustacea. The latter group included a number of freshwater species (Ostracoda, Cladocera, and Copepoda) washed into the area by flood water from the freshwater marshes above the discharge site.

5. Effects of plant operation on Cedar Bayou.

Early studies of the Tabbs Bay area and Cedar Bayou by the A&M group in 1970 and 1971 showed that both were severely depressed biologically. Chemical and physical conditions were poor. However, data collected by Southwest Research Institute in 1973 and 1974 show that Cedar Bayou has very greatly improved biologically (see Table 14) and now compares favorably with Trinity Bay controls.

Summary.

At this point certain statements can be made:

(a) There is no evidence that indicates that the biotic community in Trinity Bay has been adversely affected after the cooling pond was put to use.

(b) The movement of cooling water through Cedar Bayou has greatly improved that water body.

(c) Conditions in the cooling pond and at the discharge site to Trinity Bay are now far above the level of Trinity Bay, specifically in the diversity of the biotic communities and in productivity.

(d) Toxic substances cannot be present in significant quantity anywhere in the cooling system.

(e) The improvement of the biotic communities results from the rapidity of water movement and the consequent increase in available food supply.

Recommendations for continuing studies.

The great mass of biological data accumulated since 1969 and which is aimed at determining what are the effects of thermal stress on the biotic communities in Tabbs Bay, Cedar Bayou, the discharge canal, cooling pond, and Trinity Bay, is an achievement of considerable magnitude. Its diversity of approach is commendable, and Houston Lighting and Power and the contributing organizations, Wildlife Science of Texas A&M University, and Southwest Research Institute may well be proud of the achievement.

But there comes a time when review of methodology becomes desirable and necessary. That time has arrived.

There is always an argument for a large number of stations. One can assure a reasonably accurate reflection of numbers of species and numbers of individuals of a community if there are sufficient stations that the coverage of several of them is used in calculation. But there are still better ways to achieve the same result. One may (a) take larger samples at one station, or (b) take several subsamples at one station and fuse the samples into one. There seems to be no real reason why one must have a large number of stations, certainly not more than can reasonably be studied with efficiency.

It is pointed out that the data furnished by Southwest Research has been most satisfactory because the data are basic. They consist of lists of species and number of individuals; exactly the form which can most easily be used for determining whether or not the warm water discharge is effectively cooled. But some modifications in the matter of the number of stations could be effected without loss of any advantage. Station numbers in the group from Tabbs Bay through Cedar Bayou, discharge canal, cooling pond, and discharge site are about at rock bottom. Station CP1 of this group probably could be discarded, but no others. However, there are 34 stations in Trinity Bay not counting the discharge site C1 station. We could accomplish any analysis by using data from less than half of these stations. It was originally assumed that one would want to be able to define the limits of effect of the high temperature water (the "plume") if such effect progressed beyong the discharge site. Indeed, any able minded analyst would delight in so defining the limits of a "plume". But I cannot think of any practical advantage in it. If the effect ever passes beyong the discharge site into Trinity Bay, modifications of the cooling pond (baffles?) or a bypass around the plant would necessarily be constructed, or some other engineering palliative invented. So we really need only a few close-up stations around the discharge site in Trinity Bay, plus a half dozen more distant control stations. I think that 12 to 15 stations would be sufficient for the Trinity Bay area. This might not have been possible before some experience had been gained. But we now have that experience, and repetition would be redundant.

The problem of whether or not it is necessary to take samples of the benthos, nekton, zooplankton and phytoplankton is a more difficult problem to solve. This is because there are Phytoplankton advocates, Nekton advocates, etc., each believing that his own field affords the best chance of getting answers to all of the problems. It is pointed out that if we had depended on the benthos alone we would have accurately assessed the effects of the hot water discharge. This is not true of the phytoplankton. It did not detect clearly the effect of the hot water discharge at station CC in the discharge canal. But there is always the problem of whether or not a damaged benthos would result in a chain reaction affecting, let us say, the nekton. And one can point to some contribution of any of the divisions of the biotic community. So it may not be advantageous to drop any of the four major approaches.

However, in the study of the data just concluded, it became evident that this specialized type of study could easily do without extensive collections for one half of the months of the the year. Using the summer period (July, August, and September) contrasting against the winter period of December, January, and February provides a satisfactory result. Months of the fall and spring are all transitory, between the summer and winter periods, either a decrease in the fauna and flora or the reverse. So the taking of samples in these latter periods could certainly be reduced to a minimum without any loss of efficiency. Furthermore, the bimonthly samples of the phytoplankton could be reduced to a single set of samples per month.

I have a strong feeling that predation is, in some key areas, greatly reducing the fauna below what would be there if predation was curtailed or eliminated. My conviction is based on experience. When in some areas the benthos appeared to be limited, we used trays of oysters (for an attachment substrate) which were contained in a wire mesh container to prevent access of the larger predators. These artificial substrates were productive of many species and showed rapid development of productivity not shared by the exposed stations. It might be instructive to use such protected substrates at strategic points, such as station CC, CP3 and DS. We now have only a very limited knowledge of the sessile fauna of the cooling pond. It is suggested that the method be tried out in the areas named to determine whether or not we can measure quantitatively the development of the sessile flora and fauna and their associated biota.

FIG. 1

Stations used by Wildlife and Fishery Department, Texas Agricultural Experiment Station Project 1774.

A. Stations 6, 9, 19, 21, 24 benthic collections were taken with the "frame" apparatus close inshore in Trinity Bay; station 19 at the discharge site.

B. The Ekman dredge was used at all other station for benthic samples.

C. Nekton samples using seine drags were the same as those using the frame apparatus.

D. Nekton samples taken with the trawl came from all stations other than the frame stations.

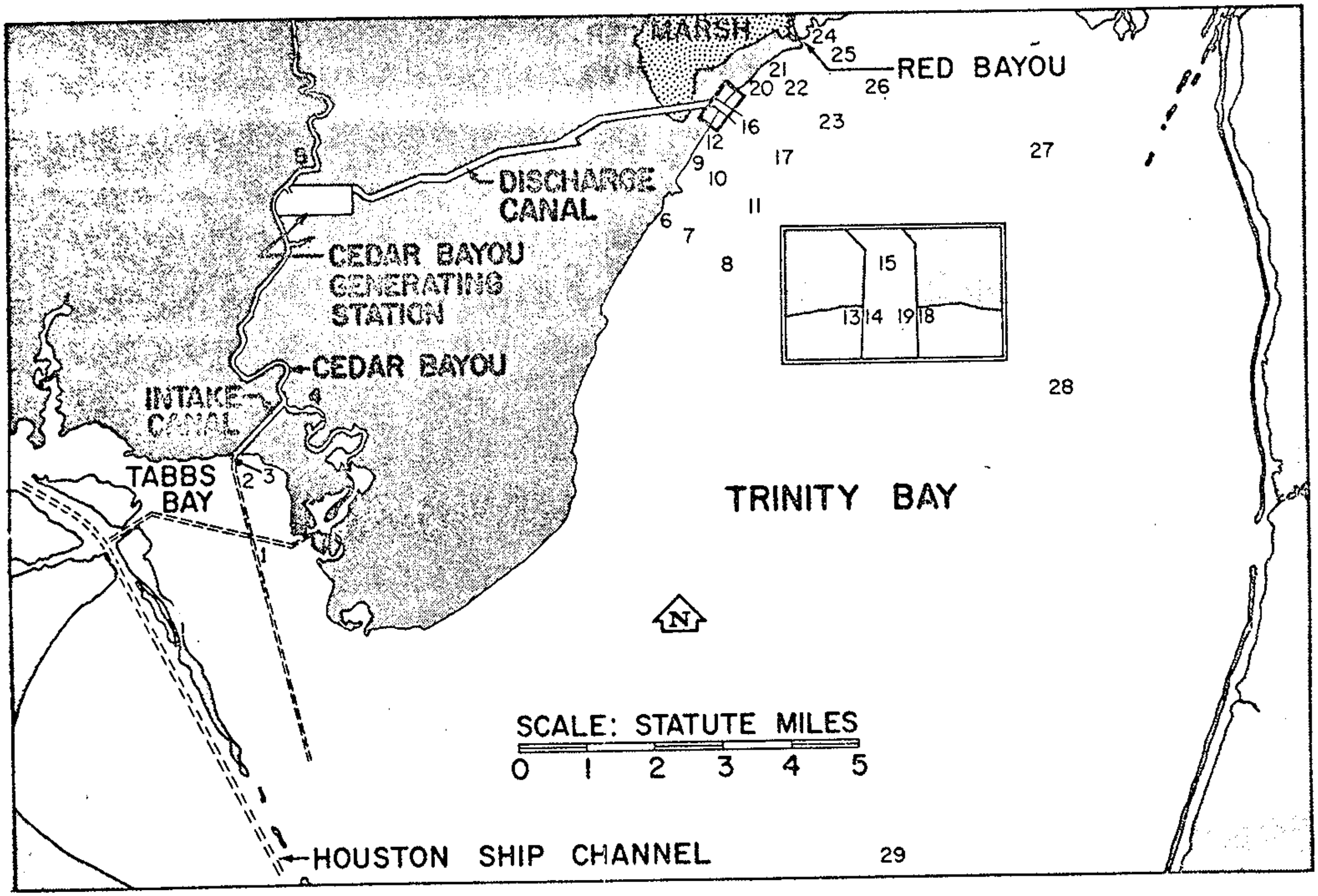


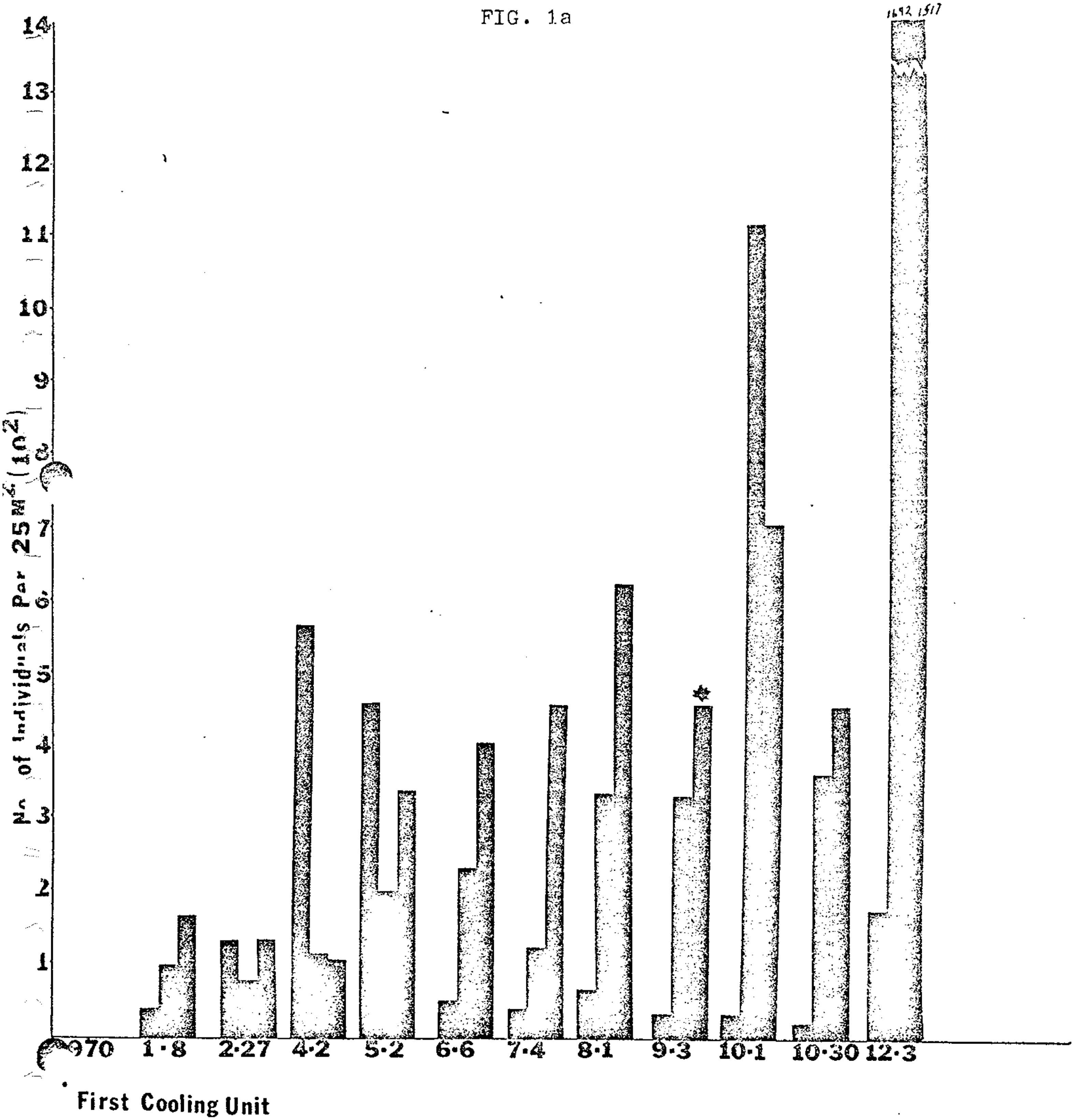
Figure 1. Map of portions of upper Galveston and Trinity Bays, with collecting stations indicated.

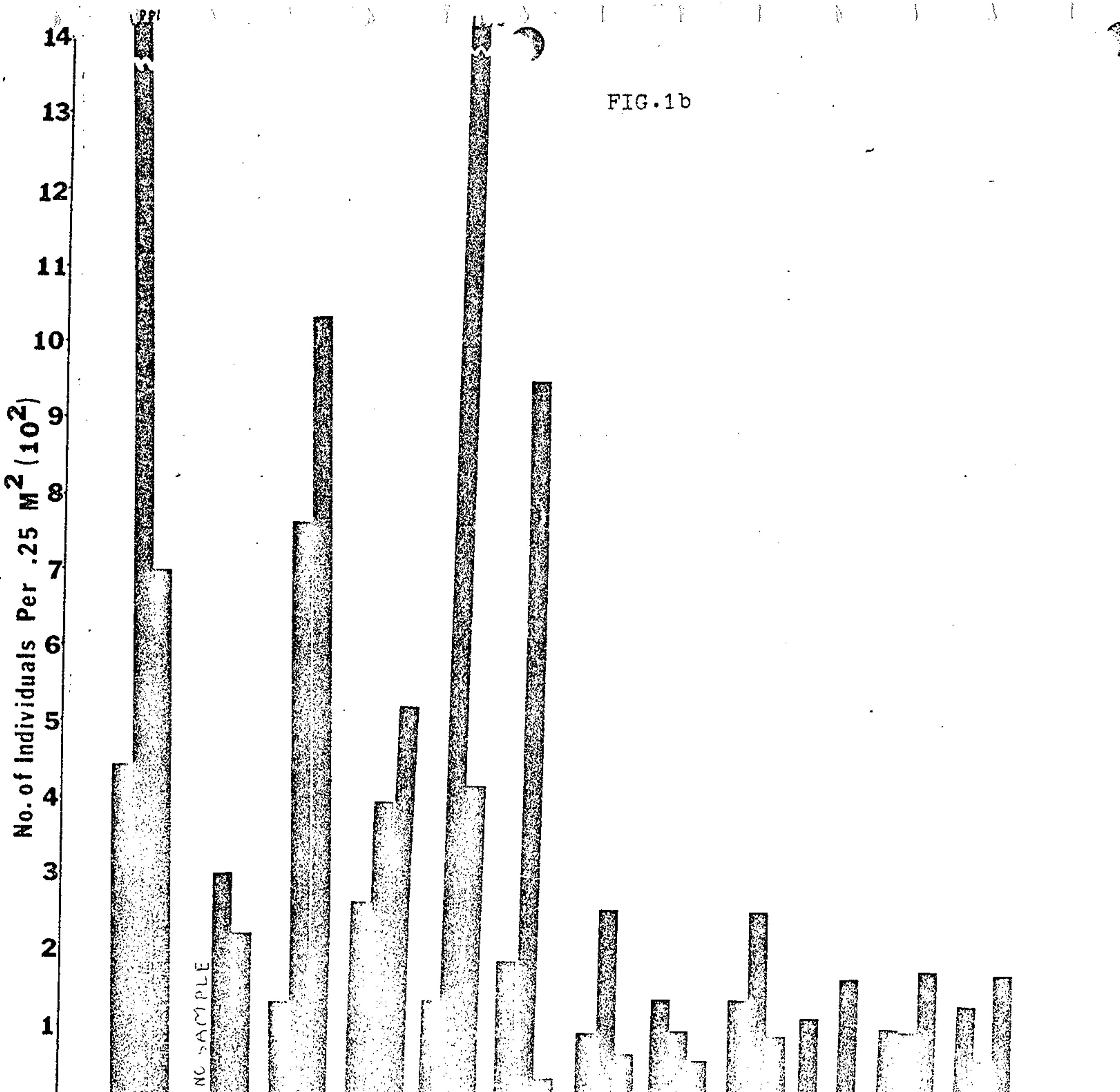
FIG. 1a, b, c, d.

Summary of four years of benthic (frame) sampling, 1970 to 1973

The columns are in groups of three, the left hand column shows the mean number of individuals taken at stations 6 & 9 lying close inshore 2 and 1 mile south of the discharge site to Trinity Bay, the center column shows number of individuals taken at the discharge site (station 19), and the right hand column shows number of individuals taken at stations 21 & 24 1 and 2 miles north of the discharge site respectively. The data show the mean number of individuals per sample (one fourth meter square) for each collecting date.

FIG. 1a

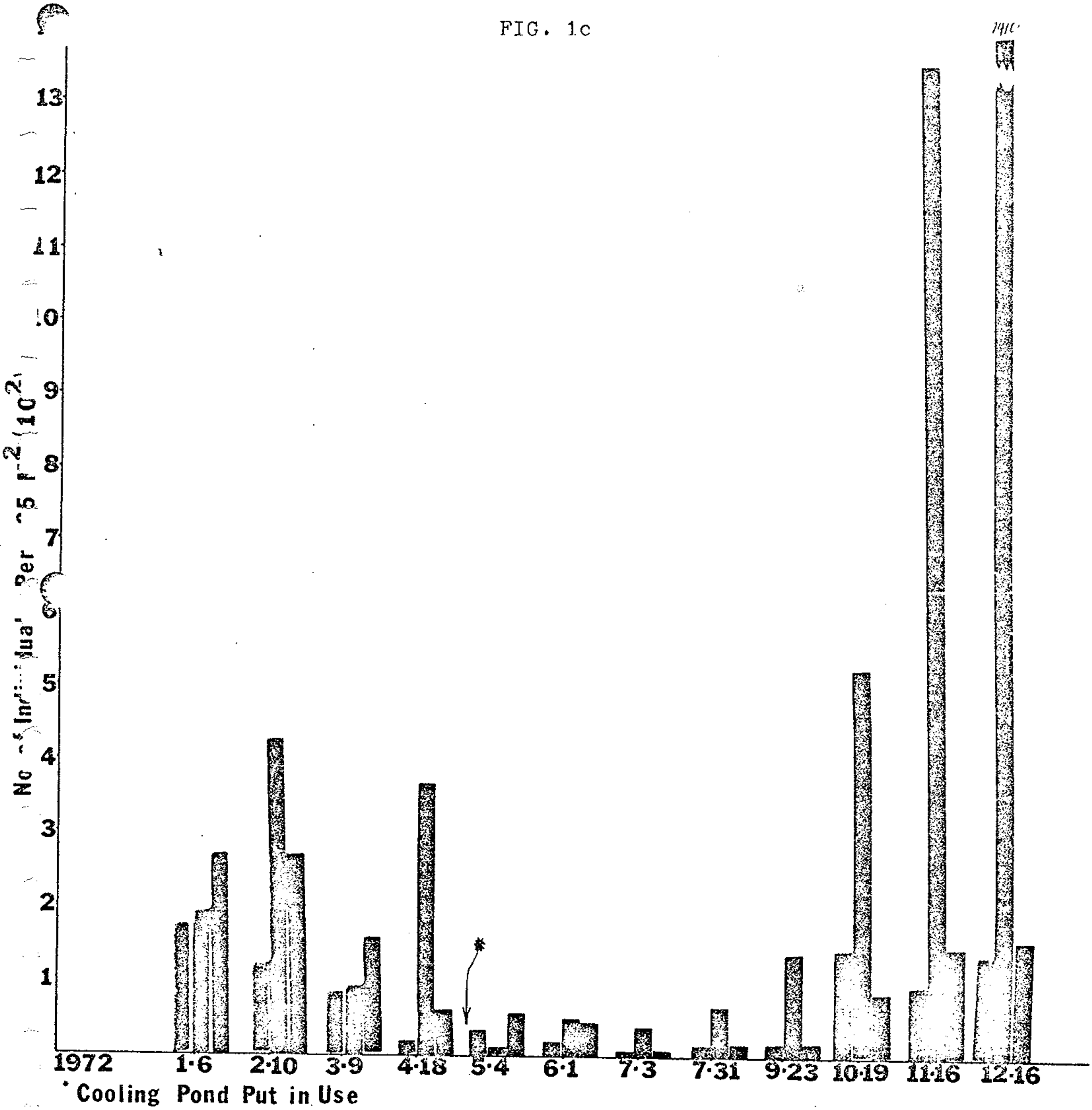

1692 1517
14
13
12
11
10
9
8
7
6
5
4
3
2
1
No. of Individuals Per 25 M² (10²)
1970
1·8
2·27
4·2
5·2
6·6
7·4
8·1
9·3
10·1
10·30
12·3
First Cooling Unit



No. of Individuals Per .25 M2 (102)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1971
1·2
NO SAMPLE
2·12
3·9
4·12
5·11
6·7
7·12
8·9
9·9
10·7
11·4
12·2

FIG.1b

FIG. 1c



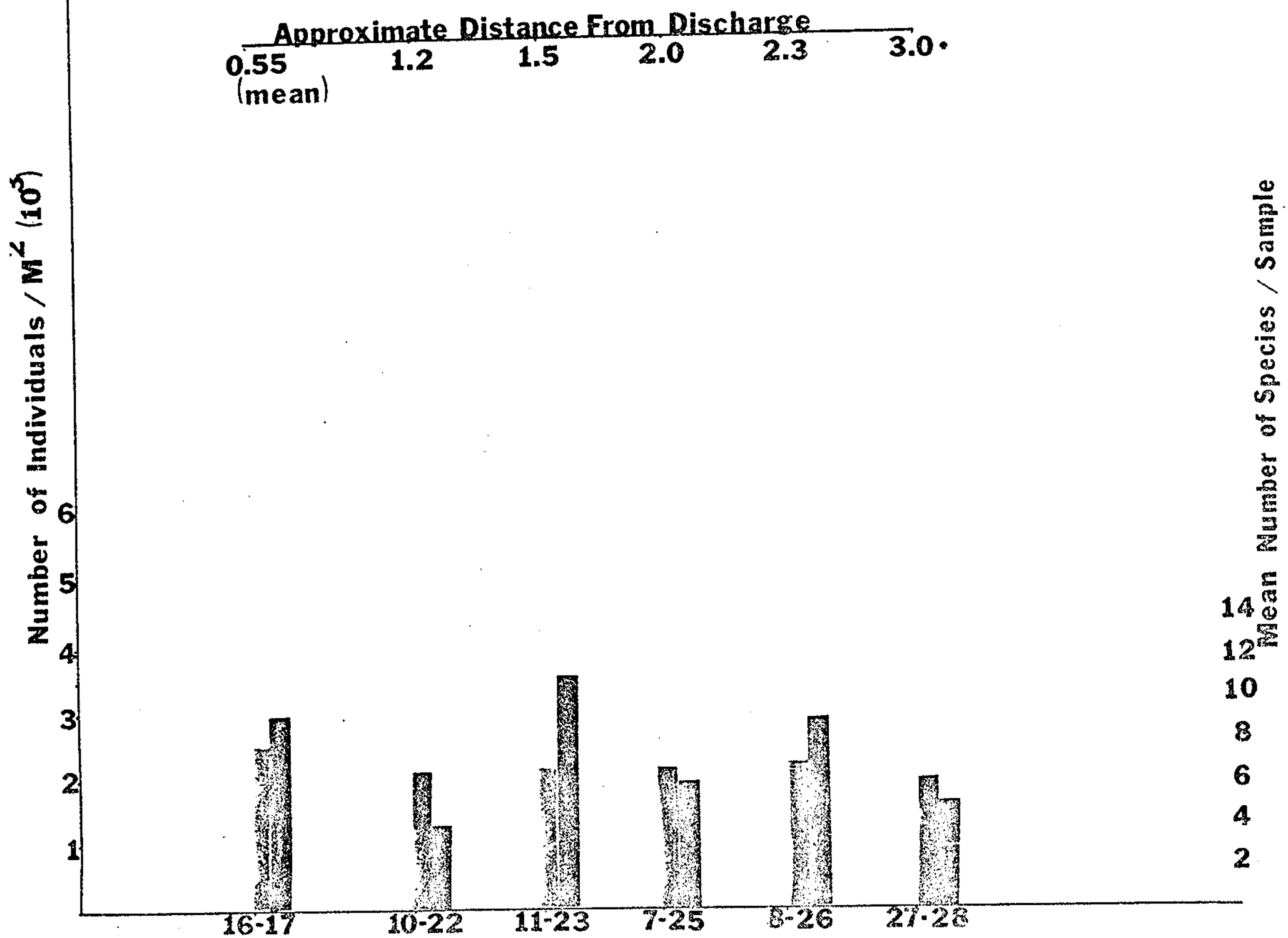
1972
1·6
2·10
3·9
4·18
5·4
6·1
7·3
7·31
9·23
10·19
11·16
12·16
* Cooling Pond Put in Use

FIG. 2

Benthic samples taken with the Ekman dredge in Trinity Bay.

The data are arranged to show the relation of distance of the paired stations from the discharge site into Trinity Bay. Left hand column shows the mean number of species per sample in the period from November 4, 1972 to May 31, 1973; right hand column shows the mean number of individuals per M^2 for the same period. Scale at the top of the graph shows the mean distance in statute miles of each pair of stations from the discharge site. The seven collecting dates were in the peak period of productivity (winter and spring).

FIG. 2



Approximate Distance From Discharge
0.55 (mean)
1.2
1.5
2.0
2.3
3.0
Number of Individuals / M² (10³)
1
2
3
4
5
6
Mean Number of Species / Sample
2
4
6
8
10
12
14
16-17
10-22
11-23
7-25
8-26
27-28

FIG. 3

Number of benthic species and number of benthic individuals per meter square taken at the discharge site into Trinity Bay 1970 to 1974.

Left hand column of each pair shows the mean number of species for all samples taken during the year, and the right hand column shows the mean number of individuals for all samples taken that year. From January 1, 1970 to April 13, 1973, the data are based on the frame samples from station 19 (Wildlife Science Project 1774). From May 21, 1973 to April 16, 1974 data are taken from benthic samples taken by Southwest Research Institute at their stations DS and C1 (means).

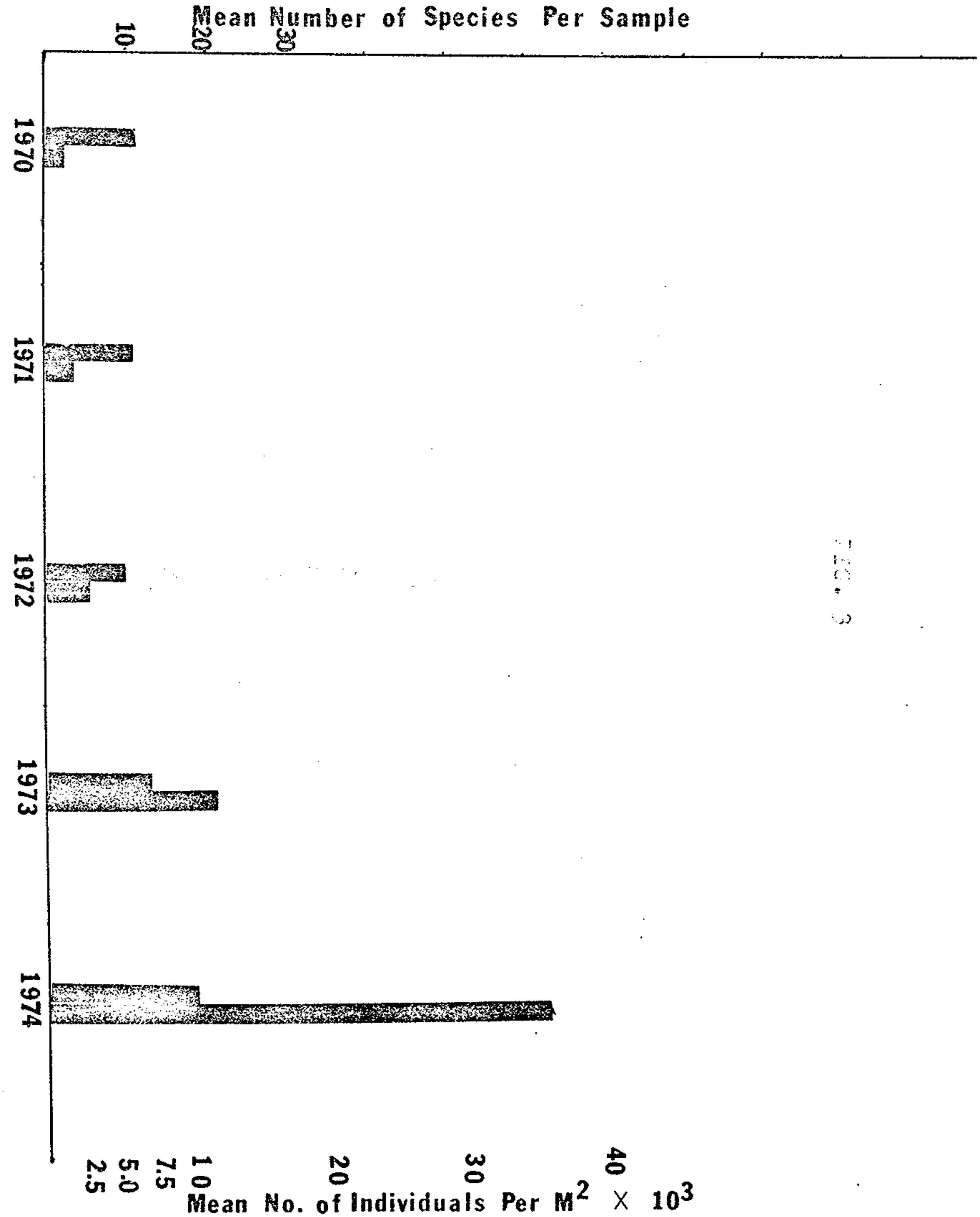

Mean Number of Species Per Sample
10
20
30
1970
1971
1972
1973
1974
2.5
5.0
7.5
10
20
30
40
Mean No. of Individuals Per M2 X 10^3

FIG. 3

FIG. 4

Percentages of crustacean, molluscan, and polychaetan species at station 19, discharge site to Trinity Bay, January 1970 to April, 1973 (frame samples), and at stations DS-C1 (pooled), May 1973 to April 1974, (core samples), also at the discharge site.

The three columns for any one year do not add up to 100% because not all taxa are included in the study.

FIG. 4

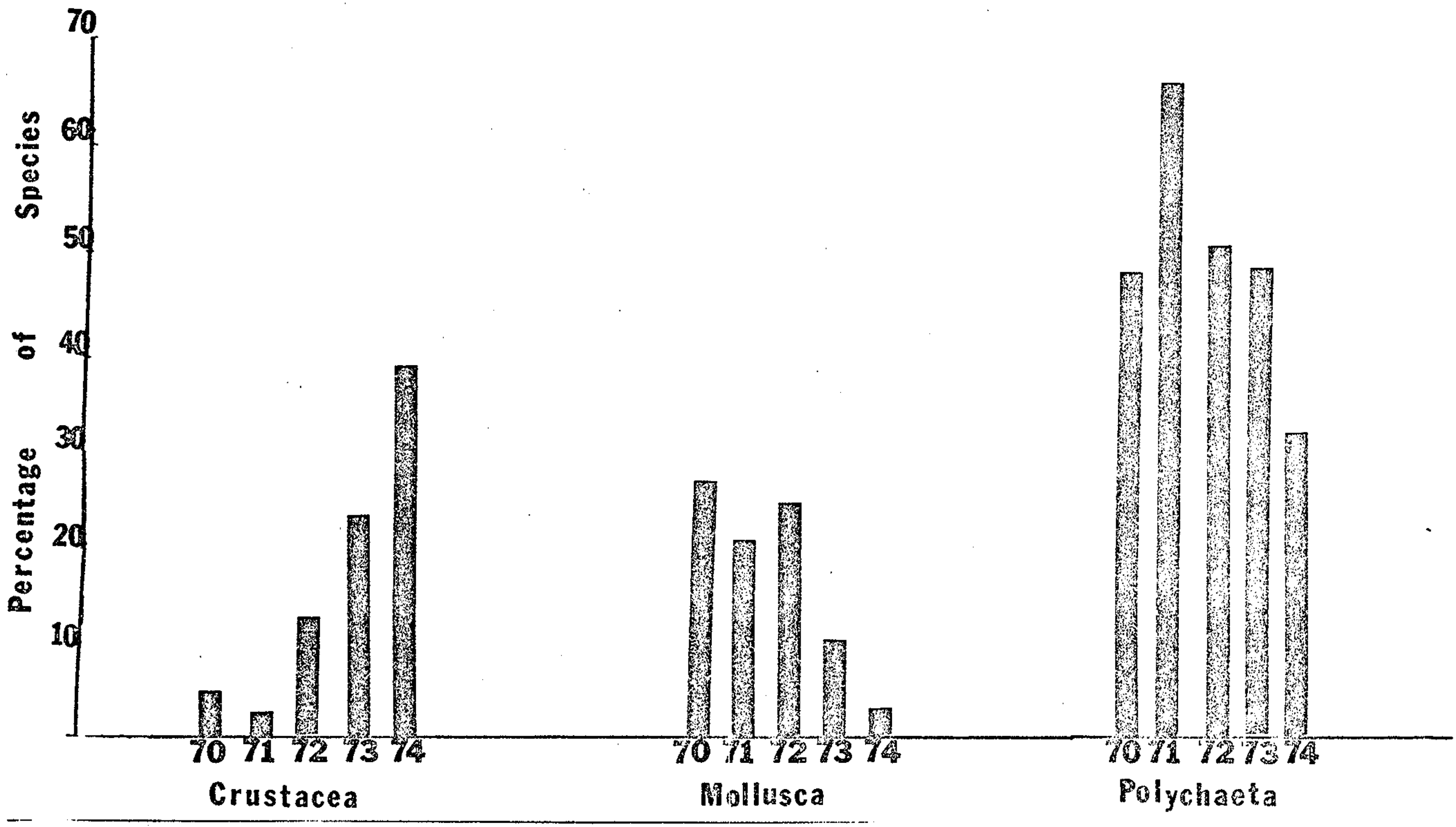

70
60
50
40
30
20
10
Percentage of Species
70 71 72 73 74
Crustacea
70 71 72 73 74
Mollusca
70 71 72 73 74
Polychaeta

FIG. 5

Mean number of benthic species and mean number of benthic individuals/ M^2 by Southwest Research Inst. May, 1973 to April, 1974 at all benthic stations from CP3 (cooling pond) to the most distant controls. The data show the means for the 10 groups of stations, and the groups are numbered from 1 to 10 (see bottom of graph). Stations in each group are as follows:

Number	1	group,	CP3 alone.
"	2	"	DS and C1.
"	3	"	C2 and C3.
"	4	"	B1, B2, B3, C4, D1, D2.
"	5	"	B4, B5, C5, D3, D4, D5.
"	6	"	A1, A2, A3, A4, E1, E2.
"	7	"	E3, A5.
"	8	"	E4, E5.
"	9	"	F1 to F5 (south controls)
"	10	"	G1 to G5 (north controls)

Each group of stations is successively farther away from the discharge site (DS and C1). Left column shows species number and the right column shows number of individuals/ M^2.

FIG. 5

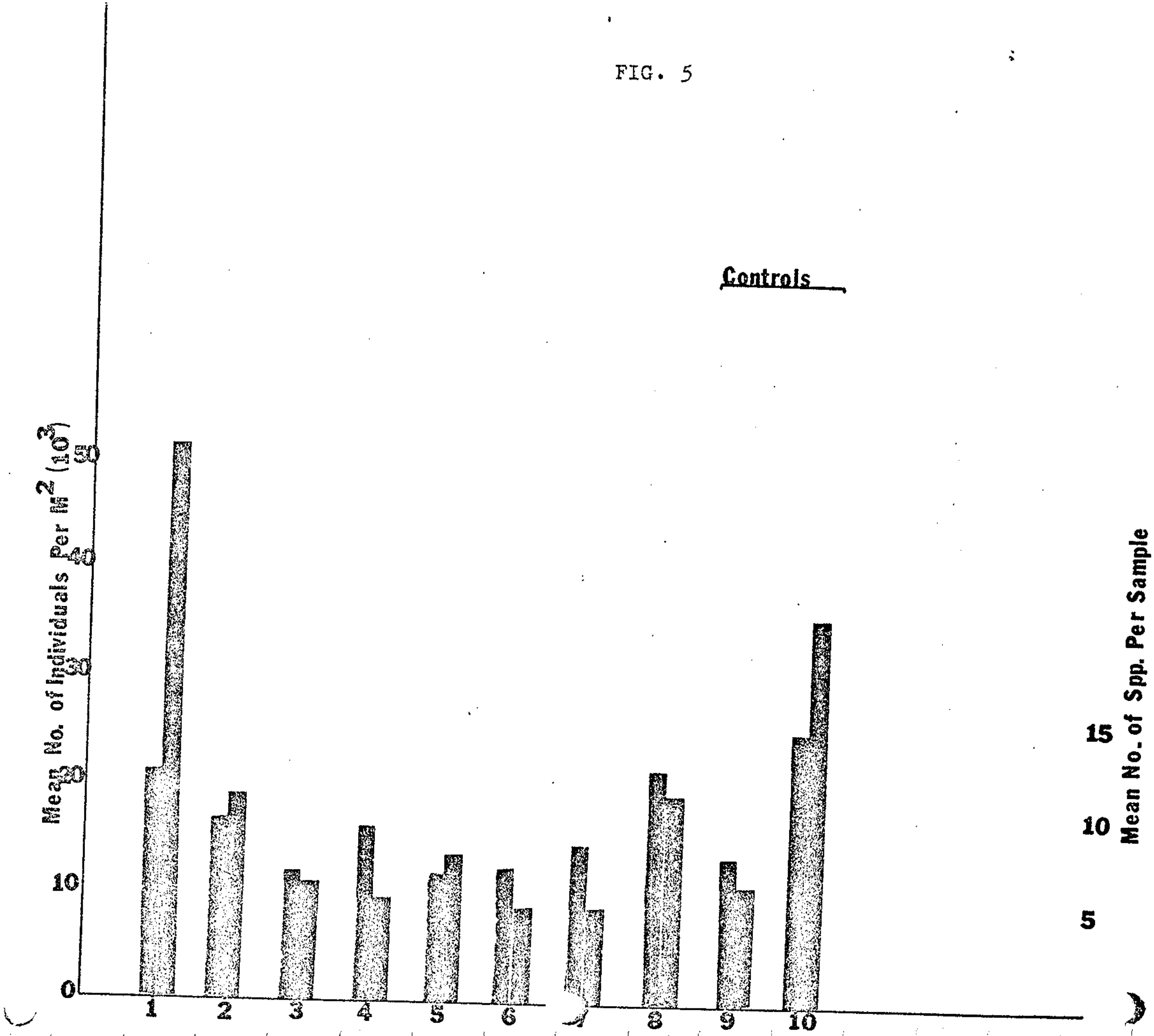
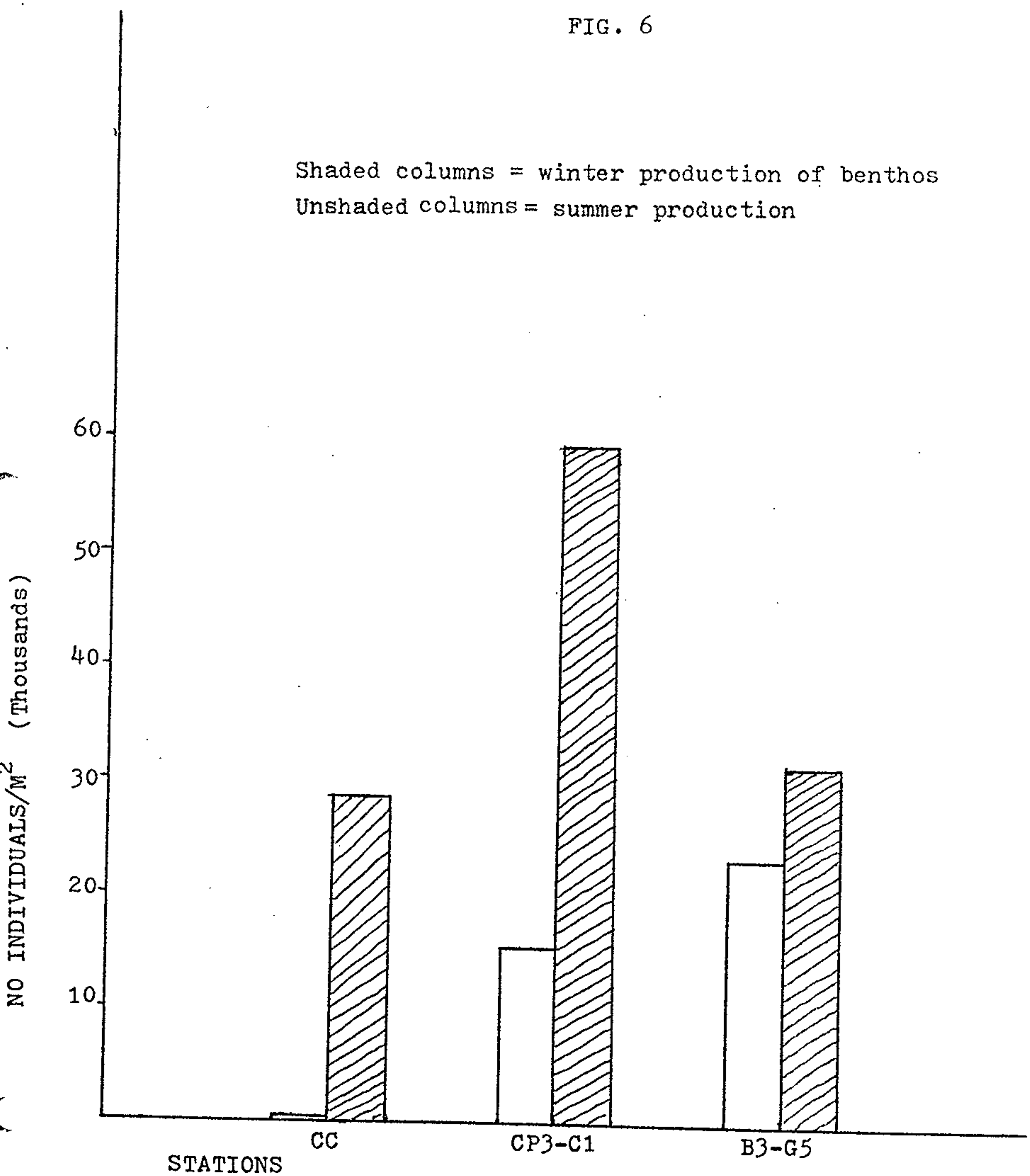

Controls
Mean No. of Individuals Per M^2 (10^3)
0
10
20
30
40
50
1
2
3
4
5
6
8
9
10
5
10
15
Mean No. of Spp. Per Sample

FIG. 6

Comparison of benthic productivity in summer with that in winter at selected stations. Left hand column shows summer (July, August and September) productivity at station CC in the discharge canal, stations CP3, DS, and C1 in the cooling pond and discharge site to Trinity Bay, and stations B3-D3, A4-E4, F5-G5 in Trinity Bay. Data represent the means of each of the three groups of stations. Right hand column shows winter (January, February, and March) productivity at the same stations. Data are from Southwest Research Institute, Houston.

FIG. 6

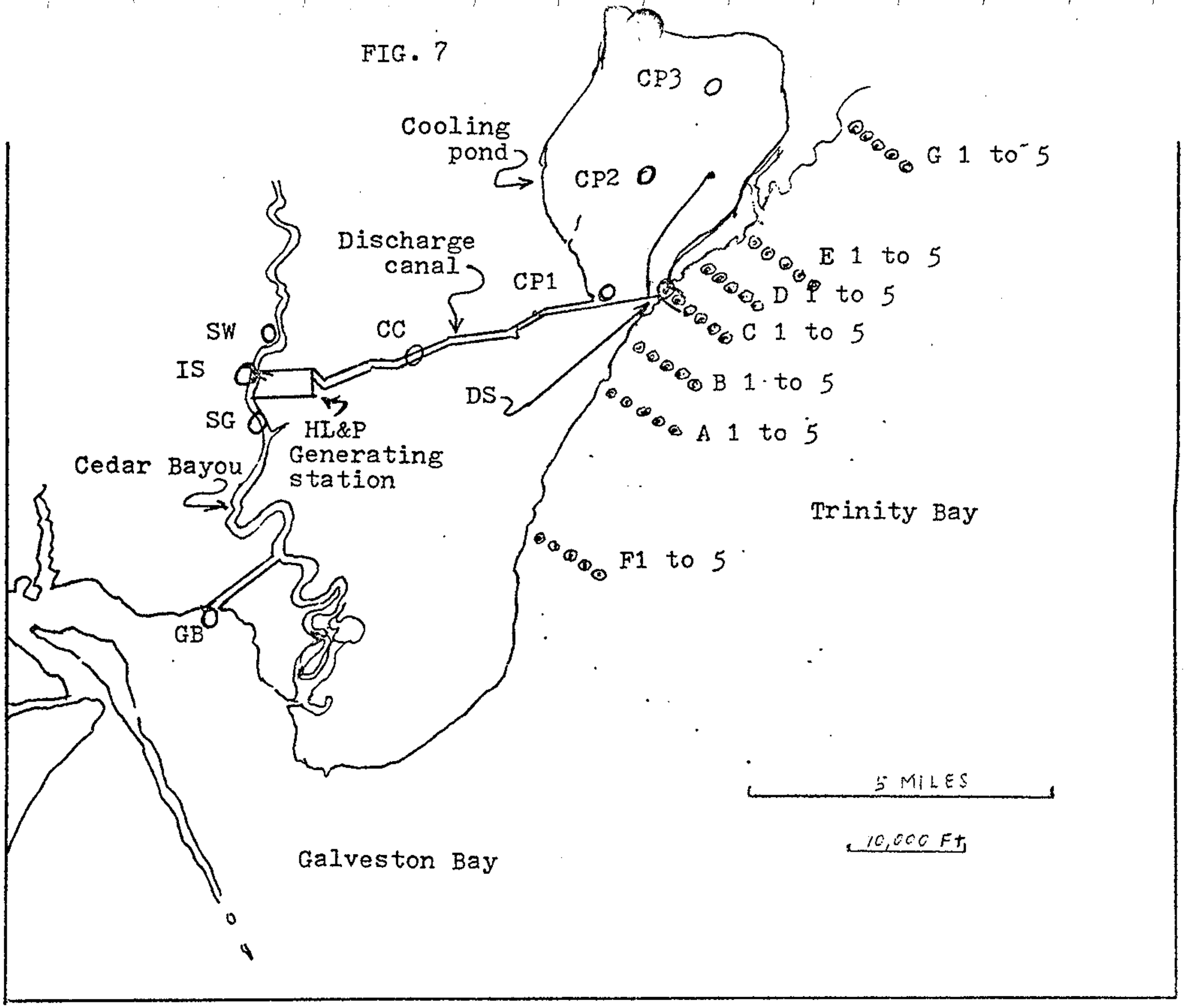


Shaded columns = winter production of benthos
Unshaded columns = summer production
NO INDIVIDUALS/M2 (Thousands)
60
50
40
30
20
10
CC
CP3-C1
B3-G5
STATIONS

FIG. 7

Map showing the locations of collecting stations used by Southwest Research Institute for all types of biological samples.

FIG. 7



LOCATIONS OF SOUTHWEST RESEARCH FOUNDATION SAMPLING STATIONS.

FIG. 8

Map showing the locations of stations used by Dr. Frank G. Schlicht and J. G. Mackin for taking plankton samples, on July 25, 1972. Not indicated on the map is the fact that the cooling pond was in use when the samples were taken. See Table 8.

FIGURE 8

PLANKTON SAMPLE LOCATIONS: JULY 25, 1972

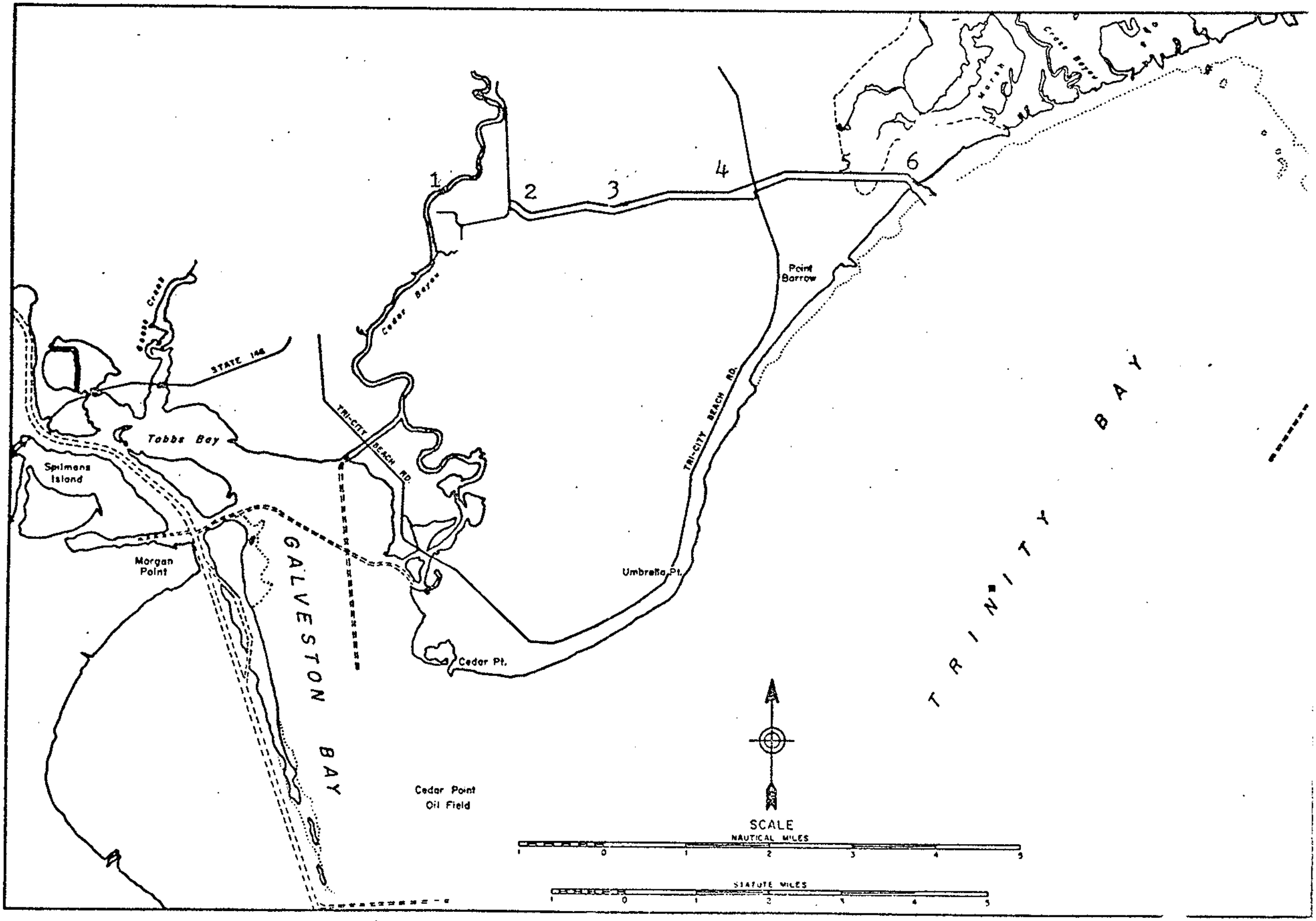
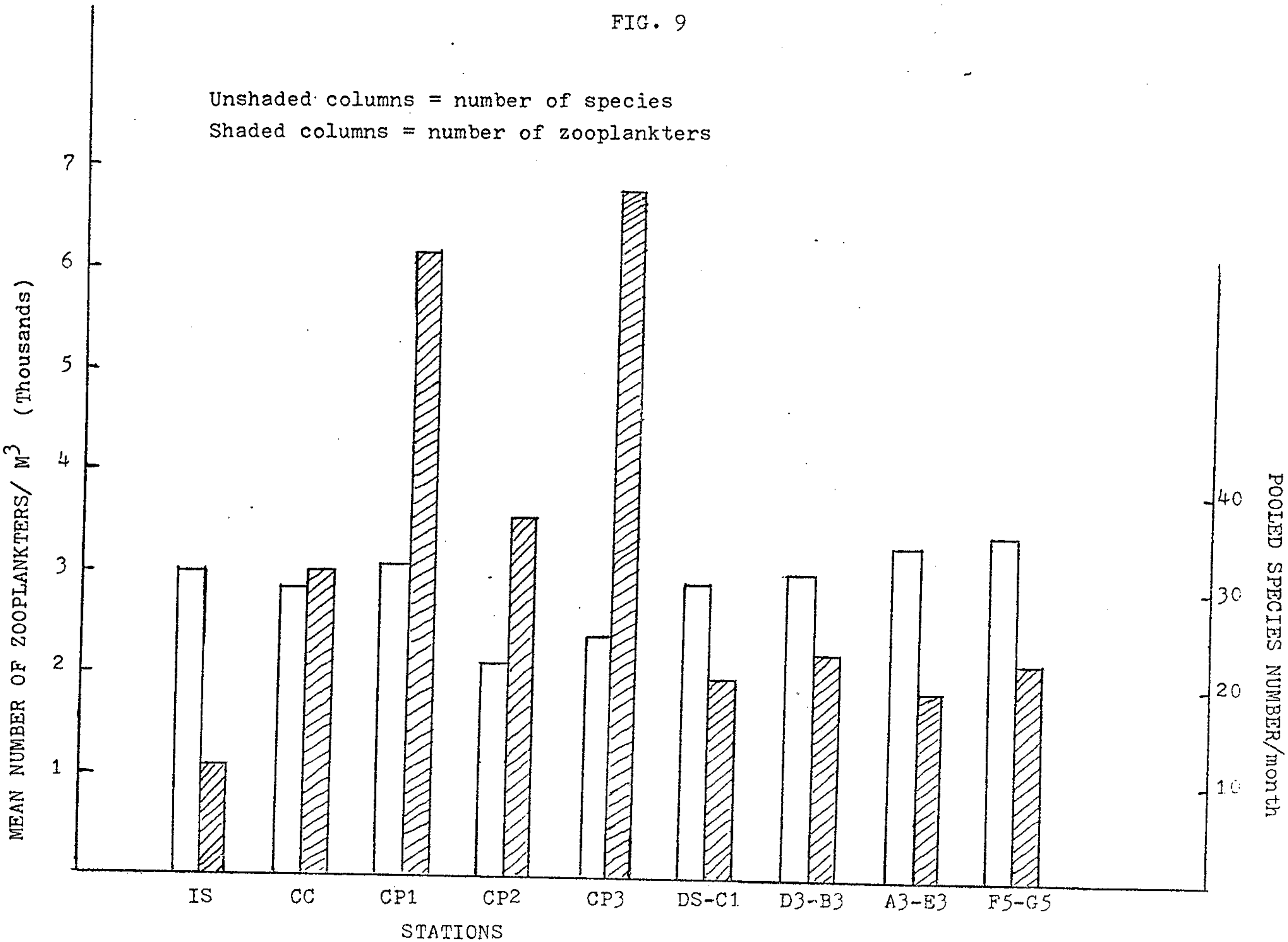


FIG. 9

Comparison of number of species (unshaded columns) and number of zooplankton cells/ M^3 (shaded columns) at selected stations from the intake (IS) through the discharge canal (CC), cooling pond (CP1, CP2, CP3), discharge site to Trinity Bay (DS-C1), Trinity Bay (D3-B3 and A3-E3) and control stations (F5-G5). Values are means for the 10 months from May, 1973 to February, 1974. For more detailed data see Table 10.

FIG. 9



Unshaded columns = number of species
Shaded columns = number of zooplankters
MEAN NUMBER OF ZOOPLANKTERS/ M3 (Thousands)
7
6
5
4
3
2
1
POOLED SPECIES NUMBER/month
40
30
20
10
IS
CC
CP1
CP2
CP3
DS-C1
D3-B3
A3-E3
F5-G5
STATIONS

FIG. 10

Number of species (pooled) and number of zooplankton cells/ M^3 at stations listed for Figure 9 and Table 10 as related to season, (May, 1973 to February, 1974). For seasonal variation at individual stations see Table 10.

FIG. 10

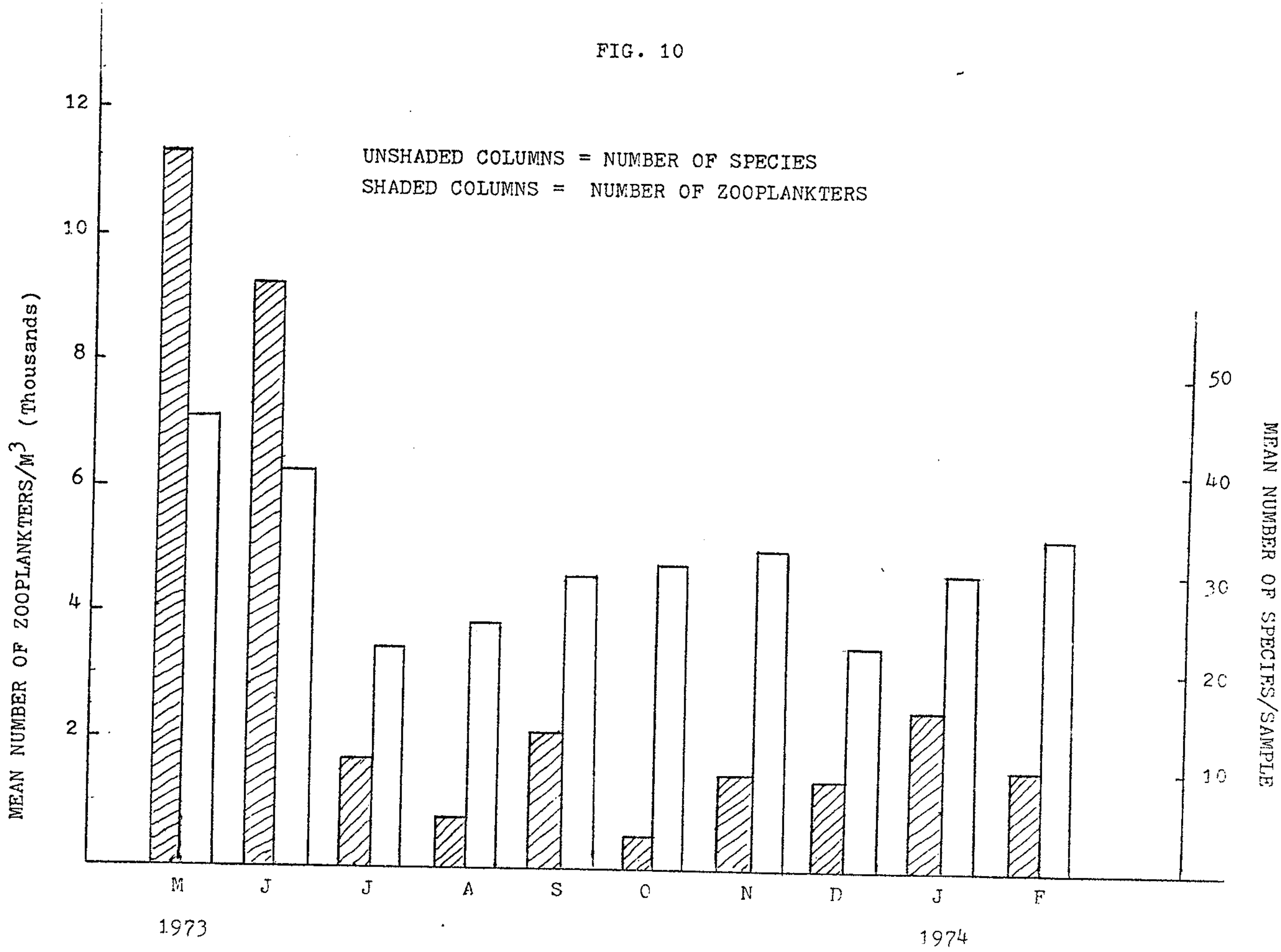
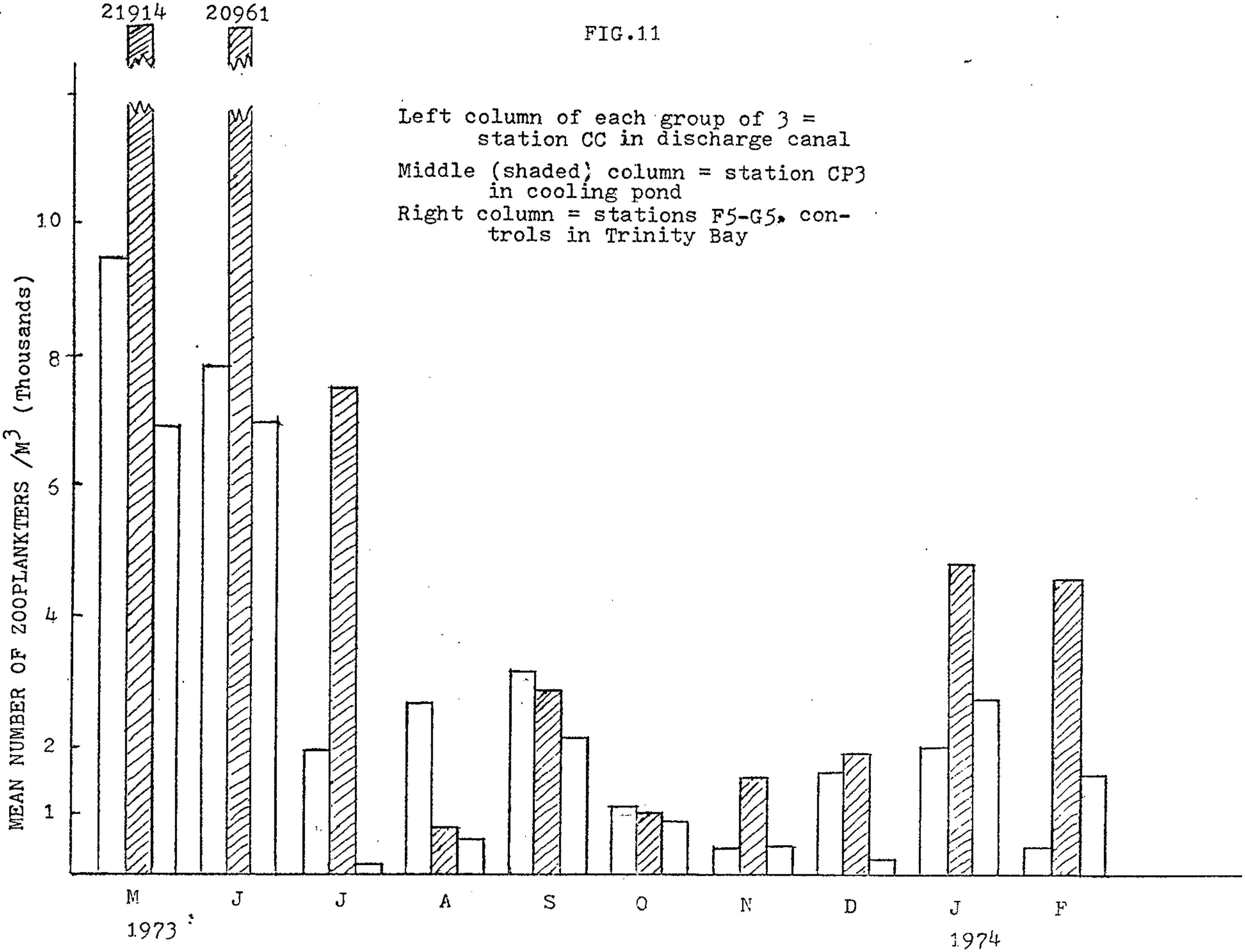

UNSHADED COLUMNS = NUMBER OF SPECIES
SHADED COLUMNS = NUMBER OF ZOOPLANKTERS
MEAN NUMBER OF ZOOPLANKTERS/M3 (Thousands)
12
10
8
6
4
2
MEAN NUMBER OF SPECIES/SAMPLE
50
40
30
20
10
M
J
J
A
S
O
N
D
J
F
1973
1974

FIG. 11

A comparison of three key areas (CC in the discharge canal, CP3 in the cooling pond, and combined F5-G5 controls in Trinity Bay). This graph shows number of zooplankton cells per M^3 through the period from May, 1973 to February, 1974. Left hand column, station CC, Middle column (shaded) is CP3, right hand column combined (means) for F5-G5.

FIG.11

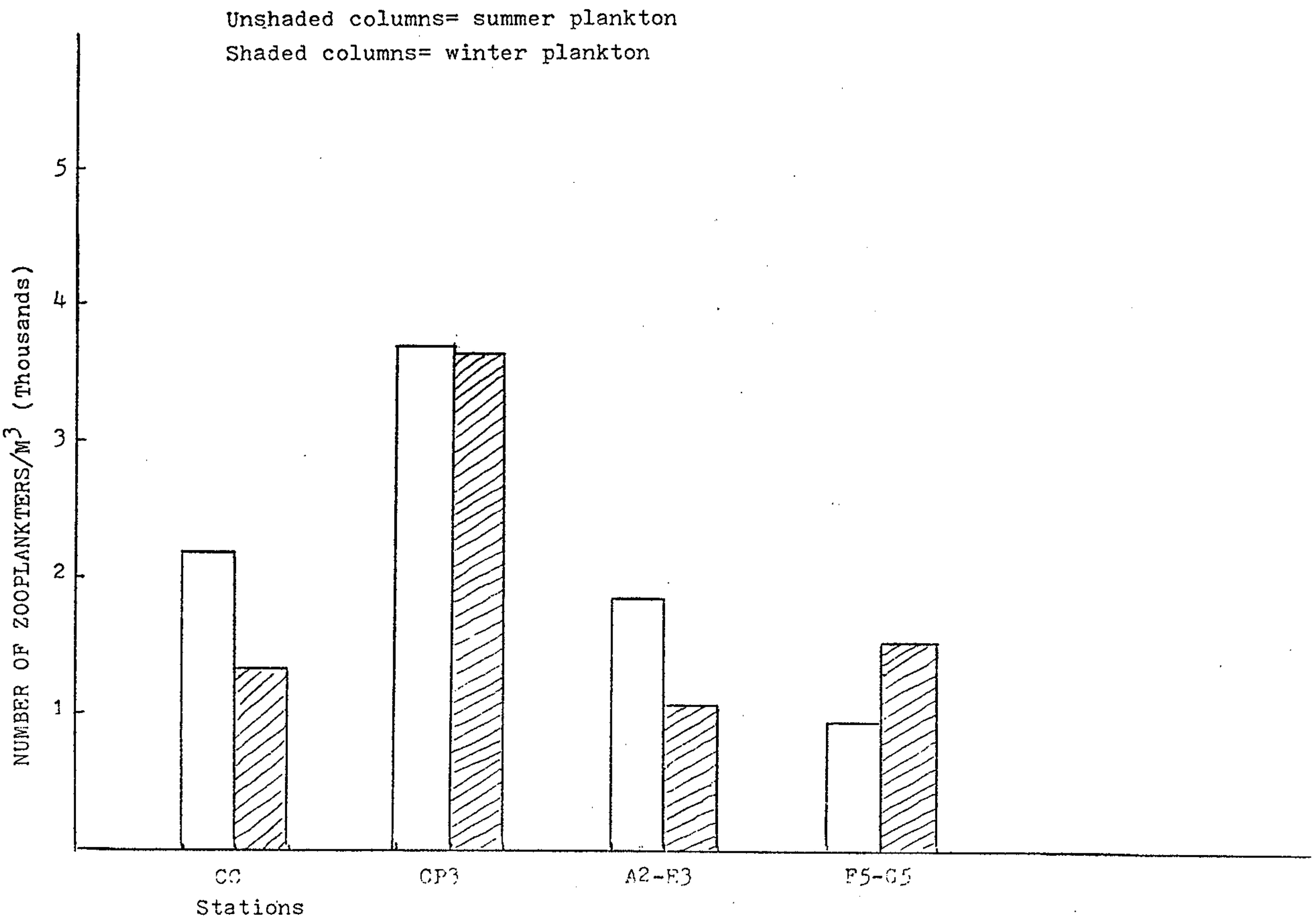


Left column of each group of 3 = station CC in discharge canal
Middle (shaded) column = station CP3 in cooling pond
Right column = stations F5-G5, controls in Trinity Bay
21914
20961
MEAN NUMBER OF ZOOPLANKTERS /M^3 (Thousands)
10
8
6
4
2
1
M
J
J
A
S
O
N
D
J
F
1973
1974

FIG. 12

Comparison of summer (July, August, and September) with winter (January, February, and March) zooplankton production at selected stations in the discharge canal (CC), cooling pond (CP3), and Trinity Bay (A2-E3, and F5-G5). Unshaded column = summer productivity, shaded column = winter productivity, in cells/ M^3.

FIG.12



Unshaded columns= summer plankton
Shaded columns= winter plankton
NUMBER OF ZOOPLANKTERS/M3 (Thousands)
5
4
3
2
1
CC
CP3
A2-E3
F5-G5
Stations

FIG. 13

Number of diatom species and number of diatom cells/ml at selected stations. Values are means for the period from May, 1973 to April, 1973. For more extended data and additional stations see Table 12. Unshaded columns = number of species; shaded columns = diatom cells/ml.

FIG. 1.3

UNSHADED COLUMNS = NUMBER OF SPECIES

SHADED COLUMNS = NUMBER OF CELLS / ML

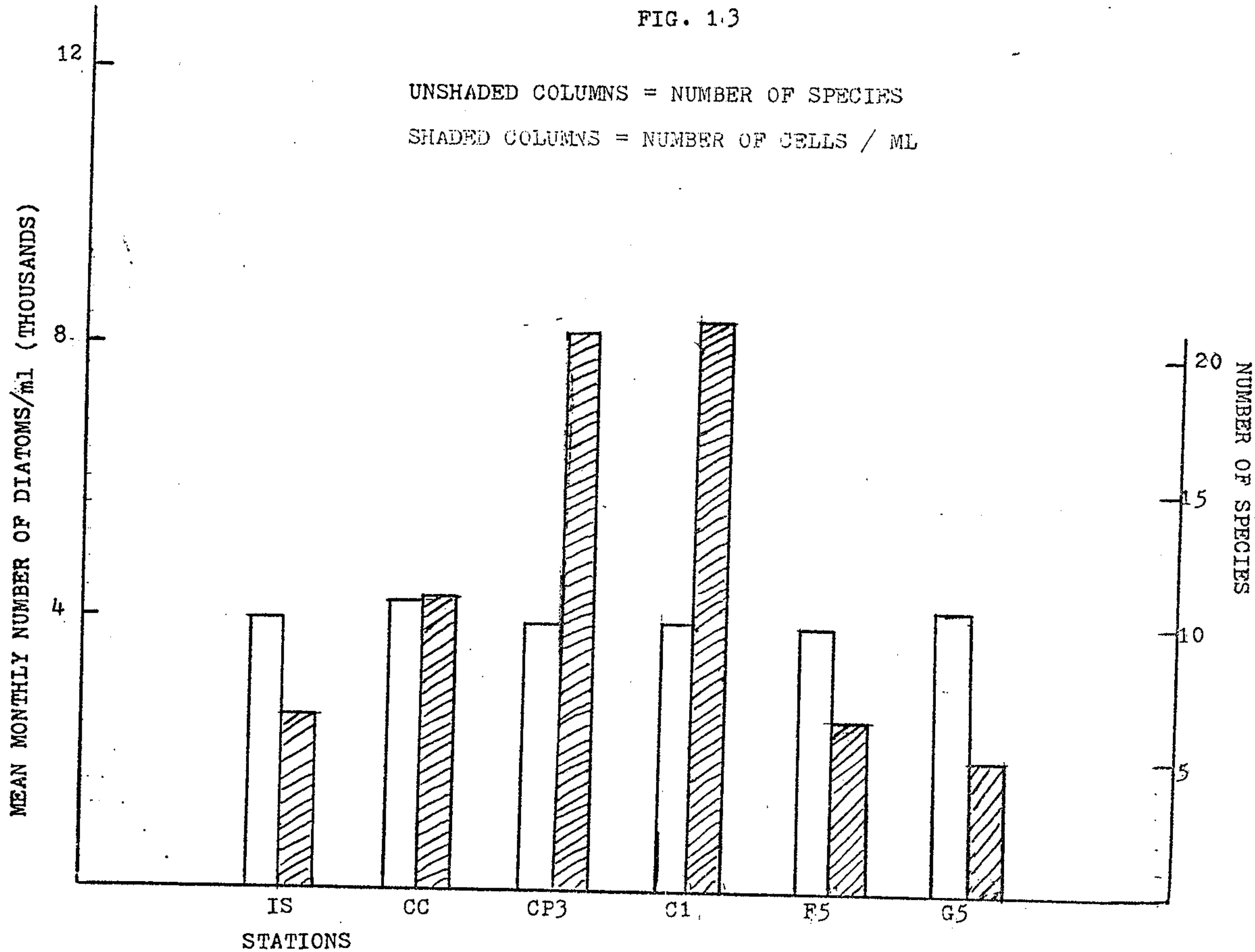


FIG. 14

Number of blue-green species and number of blue-green cells/ml at selected stations. Values are means for the period from May, 1973 to April, 1974. For more extended data see Table 13. Unshaded column = mean number of species; shaded column = number of cells/ml. This figure is not directly comparable to Fig. 13 because of change of scale.

FIG. 14

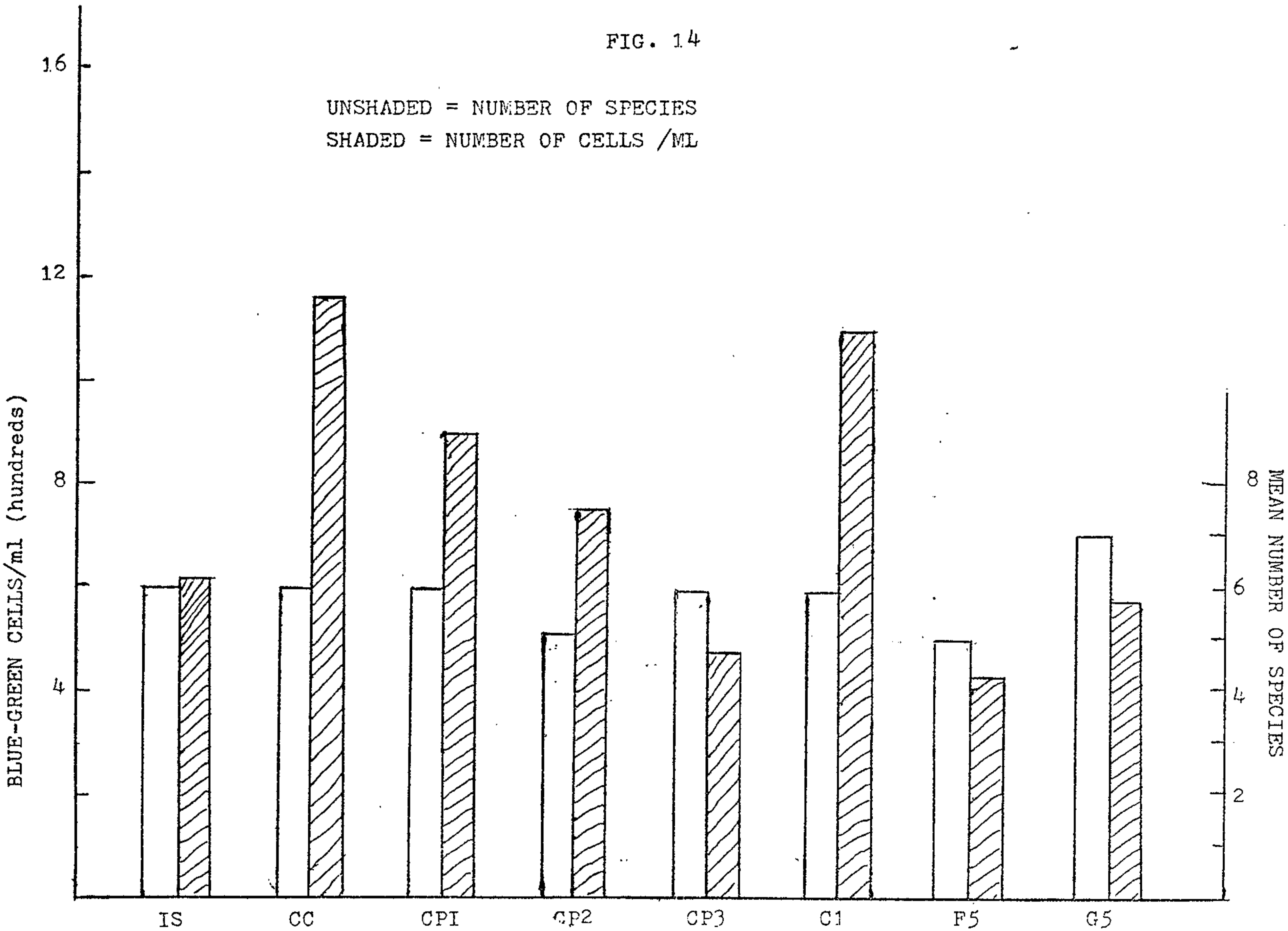
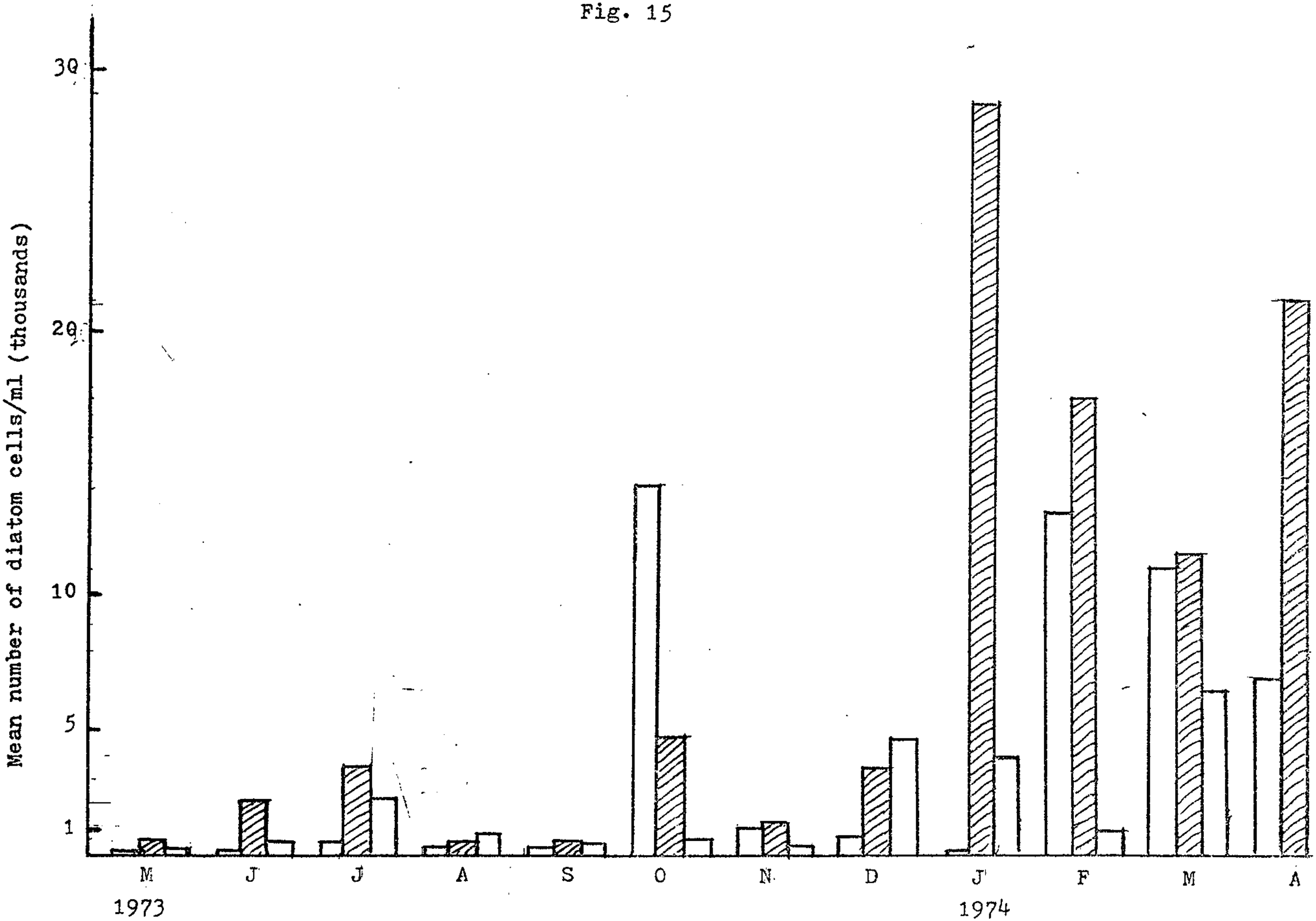

UNSHADED = NUMBER OF SPECIES
SHADED = NUMBER OF CELLS /ML
BLUE-GREEN CELLS/ml (hundreds)
16
12
8
4
MEAN NUMBER OF SPECIES
8
6
4
2
IS
CC
CPI
CP2
CP3
C1
F5
G5

FIG. 15

Seasonal distribution of diatom cells/ml at stations CC (discharge canal), CP3 (cooling pond), and F5 (control in Trinity Bay). Left hand column = CC, middle column (shaded) = CP3, right hand column = F5. Values are means of from 6 to 18 samples per month, top and bottom.

Fig. 15

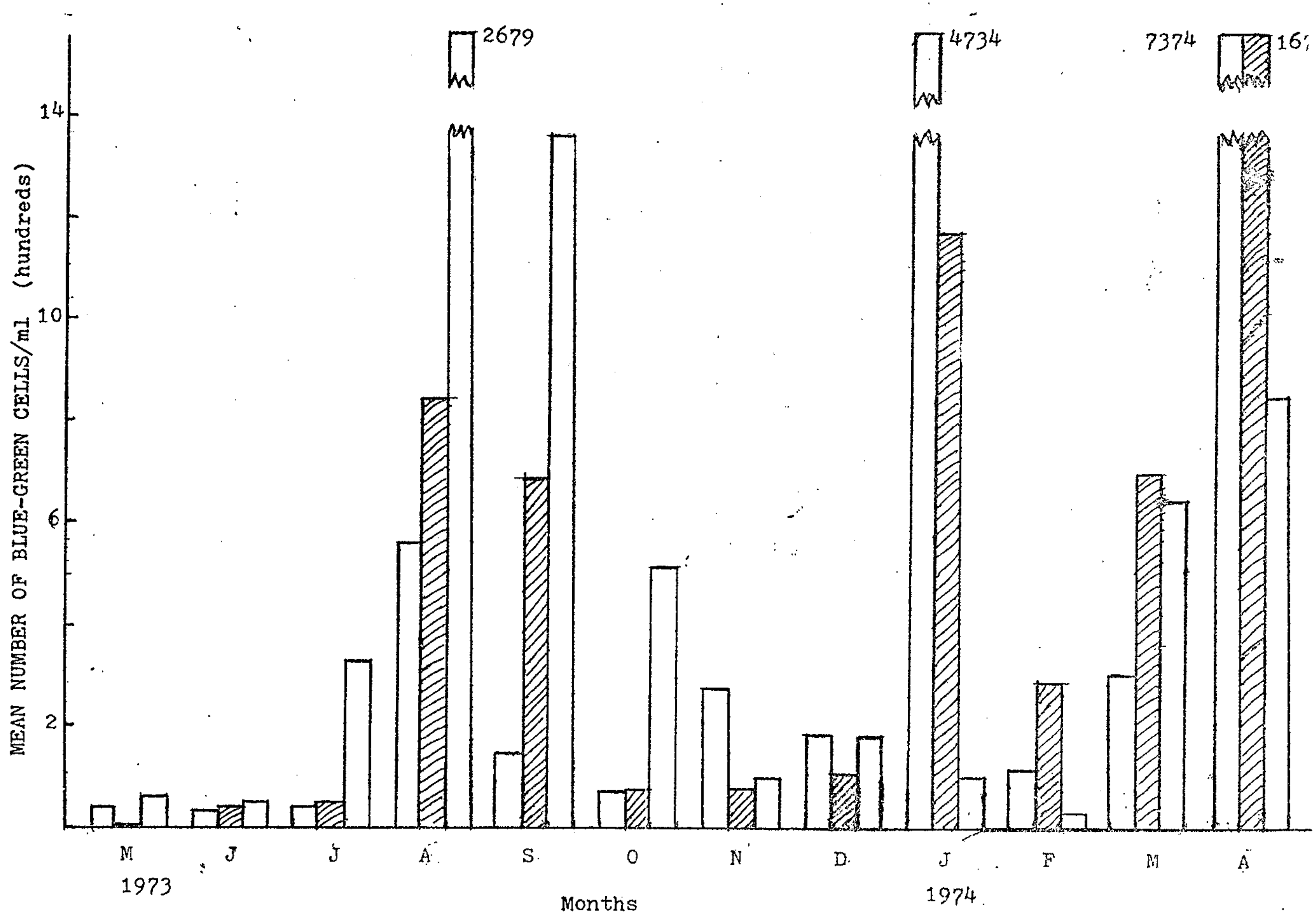


Mean number of diatom cells/ml (thousands)
30
20
10
5
1
M
J
J
A
S
O
N
D
J
F
M
A
1973
1974

FIG. 16

Seasonal distribution of blue-green cells/ml at stations CC (discharge canal), CP3 (cooling pond), and G5 (control in Trinity Bay). Left hand column = CC, middle (shaded) column = CP3, right hand column = G5. Values are means of from 6 to 18 samples per month, top and bottom.

Fig. 16

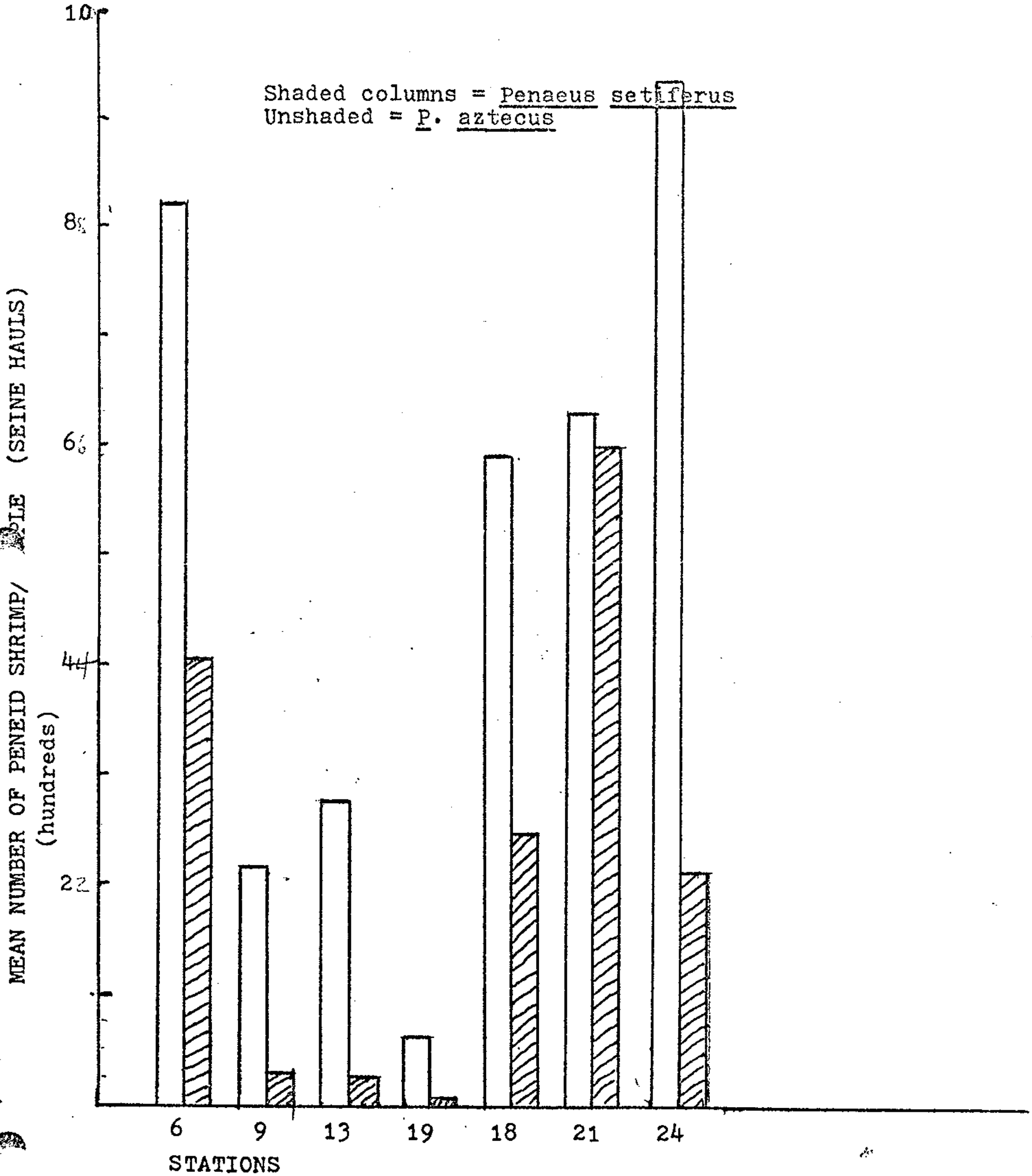


2679
4734
7374
16?
14
10
6
2
MEAN NUMBER OF BLUE-GREEN CELLS/ml (hundreds)
M
J
J
A
S
O
N
D
J
F
M
A
1973
1974
Months

FIG. 17

Numbers of Peneid shrimp (P. aztecus and P. setiferus) at stations 6, 9, 13, 19, 18, 21, and 24 in Trinity Bay in the period from December, 1971 to October, 1972. Unshaded column = Penaeus aztecus; shaded is P. setiferus. Station 19 (pre-cooling pond era), station 13 (post cooling pond era) are the discharge stations. Shrimp were taken in seine hauls at the shallow inshore stations. Cooling pond put in operation in late April, 1972.

Fig. 17



Shaded columns = Penaeus setiferus
Unshaded = P. aztecus
MEAN NUMBER OF PENEID SHRIMP/ SAMPLE (SEINE HAULS)
(hundreds)
10
8
6
4
2
6
9
13
19
18
21
24
STATIONS

FIG. 18

Number of species and number of individuals taken in trawl drags by Southwest Research Institute at selected stations in Galveston Bay, Cedar Bayou, discharge canal, cooling ponds, and Trinity Bay. See map, Fig. 7 for locations of stations. Unshaded columns = number of species/ drag; shaded columns = number of individuals/ drag. For more extensive data on nekton samples see Table 14. Data are the means of monthly trawls from April, 1973 to March, 1974.

Fig. 18

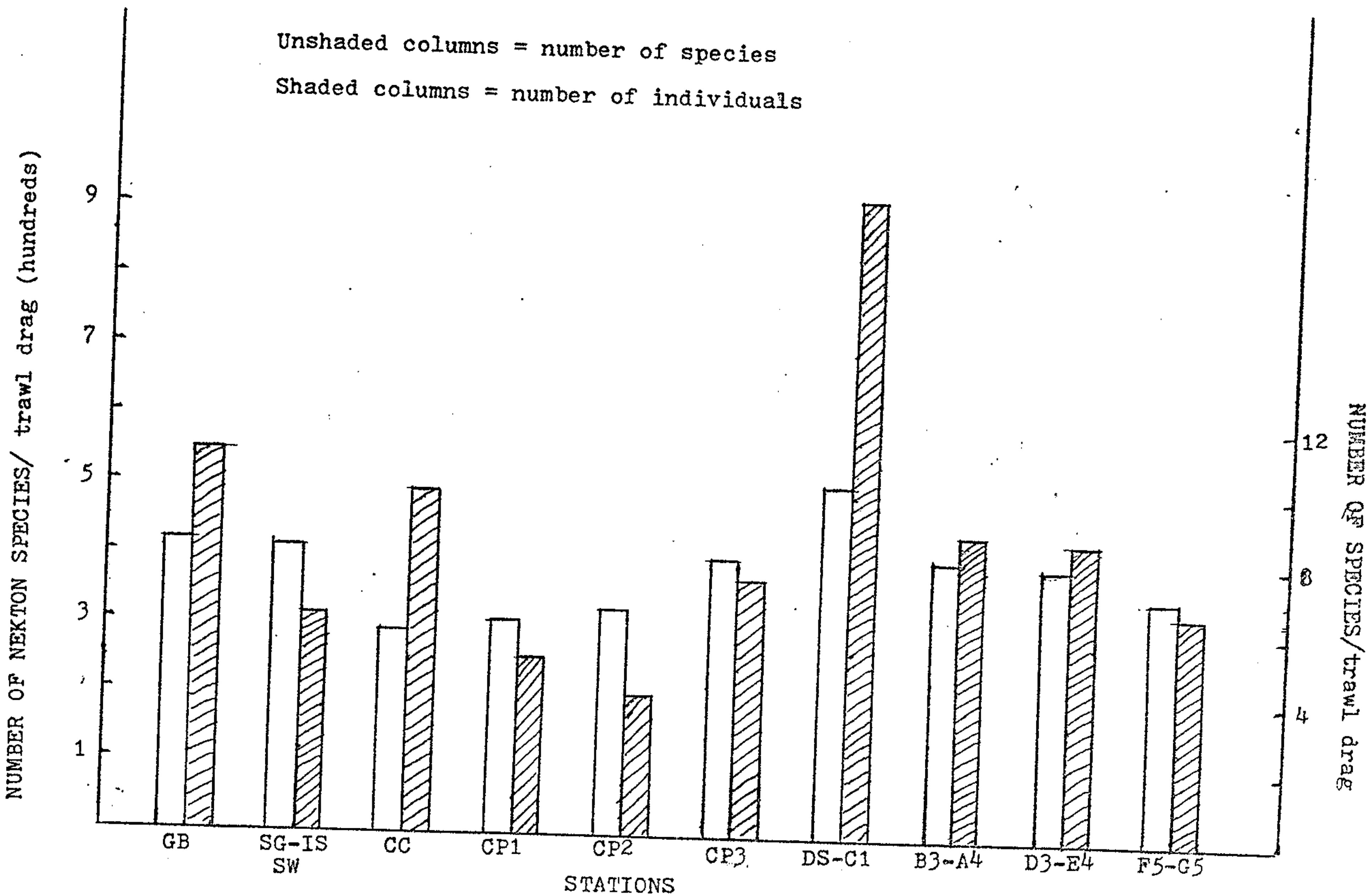

Unshaded columns = number of species
Shaded columns = number of individuals
NUMBER OF NEKTON SPECIES/ trawl drag (hundreds)
9
7
5
3
1
NUMBER OF SPECIES/trawl drag
12
8
4
GB
SG-IS SW
CC
CP1
CP2
CP3
DS-C1
B3-A4
D3-E4
F5-G5
STATIONS

FIG. 19

Seasonal variation in number of individuals/ trawl at stations CC (discharge canal), CP3 (cooling pond), DS-C1 (discharge to Trinity Bay), and F5-G5 (Trinity Bay controls). Values are the means of the monthly trawls from April, 1973 to March, 1974.

Fig. 19

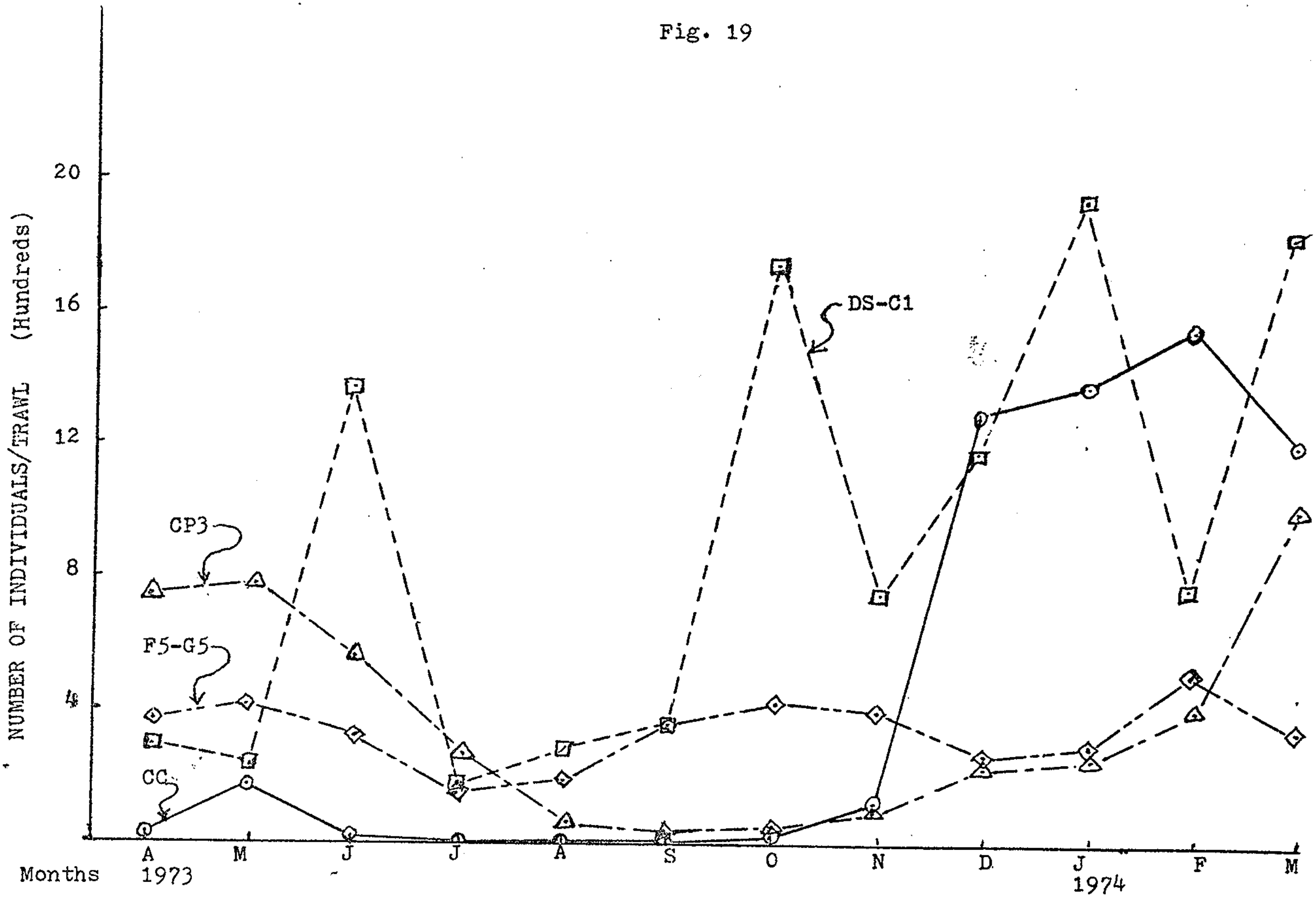

NUMBER OF INDIVIDUALS/TRAWL (Hundreds)
20
16
12
8
4
CP3
F5-G5
CC
DS-C1
A
M
J
J
A
S
O
N
D
J
F
M
Months
1973
1974

FIG. 20

Seasonal changes in numbers of nektonic individuals/trawl at station CC (discharge canal), DS-C1 (discharge to Trinity Bay), and the combined GB, SG-IS-SW, CP1, CP2, CP3, B3-A4, D3-E4, F5-G5, CC, and DS-C1. For further details see Table 14. Period was from April, 1973 to March, 1974.

TABLE 3
Comparison of species number and number of individuals/ M^2 of benthic samples from selected stations, Cedar Bayou to Trinity Bay

Dates/stations		SG	IS	CC	CP1	CP2	CP3	DS	C1	B3	D3	A4	E4	F5	G5	Mean
MAY 73	Spp	--	1	1	10	1	5	6	4	9	7	4	8	2	15	5.6
	Ind	--	165	141	5763	329	1647	1482	2635	8563	8069	4611	4940	2305	9880	3887
June	Spp	1	1	1	3	4	4	9	6	7	7	4	6	4	9	4.7
	Ind	165	165	165	986	823	1317	26676	3623	4775	5599	3293	1647	3250	5928	4172
July	Spp	1	1	2	--	1	8	9	6	4	5	5	7	5	15	5.3
	Ind	329	165	329	--	165	2685	8069	2305	4446	3623	4940	5105	4775	51541	6805
Aug	Spp	17	11	3	3	7	16	9	9	9	9	4	12	13	20	10.1
	Ind	24371	11361	659	3293	18281	54175	12021	12679	6257	17784	4611	16961	18607	61585	18761
Sept	Spp	9	6	--	3	2	9	12	11	10	10	8	11	10	18	9.1
	Ind	6751	2799	--	823	494	16631	17619	12350	13667	17455	8398	16631	5599	109503	17594
Oct	Spp	11	8	4	6	9	18	9	11	14	9	6	8	12	11	9.7
	Ind	21407	14820	13503	29475	31616	87438	6751	9880	18443	19595	9715	23877	11033	166313	33132
Nov	Spp	6	7	--	12	11	17	9	9	9	7	4	6	6	17	9.2
	Ind	8892	1605	--	21291	22847	35691	8151	8768	9262	10621	3087	10003	3705	115349	19944
Dec	Spp	7	9	--	15	14	15	10	10	8	12	6	13	7	12	10.6
	Ind	8274	6545	--	47917	41619	34209	10621	11485	8645	24206	3952	14573	18895	72247	23322
Jan 74	Spp	8	21	--	17	12	12	8	8	11	11	8	15	7	31	13.0
	Ind	16302	53599	--	18895	40508	52364	116954	18031	12226	28899	8521	16919	5063	68914	35169
Feb	Spp	25	18	15	16	16	11	11	12	13	9	15	17	7	32	15.5
	Ind	35444	84352	41833	16302	118807	138320	21736	29640	16919	24823	25317	23341	19513	78916	48233
Mar	Spp	6	14	9	25	19	17	13	15	21	10	20	22	10	26	16.9
	Ind	18154	18648	14079	61873	174505	106950	15808	33062	43303	22106	41743	41125	37661	57268	49085
April	Spp	12	11	19	23	14	19	17	16	19	13	10	17	11	33	16.7
	Ind	24576	17537	63602	361855	31369	92007	26923	34456	44089	20748	14079	31369	24832	100776	63444
Mean	Spp	9.4	9.0	6.8	12	9.2	12.6	10.2	9.8	11.2	9.0	7.8	11.9	7.8	20.8	10.5
Mean	Ind	14969	17647	16789	51679	40114	51953	22734	14984	15883	16961	11022	17208	12937	74856	26962

TABLE 3
Comparison of species number and number of individuals/ M^2 of benthic samples from selected stations, Cedar Bayou to Trinity Bay

Dates/stations		SG	IS	CC	CP1	CP2	CP3	DS	C1	B3	D3	A4	E4	F5	G5	Mean
MAY 73	Spp	--	1	1	10	1	5	6	4	9	7	4	8	2	15	5.6
	Ind	--	165	141	5763	329	1647	1482	2635	8563	8069	4611	4940	2305	9880	3887
June	Spp	1	1	1	3	4	4	9	6	7	7	4	6	4	9	4.7
	Ind	165	165	165	986	823	1317	26676	3623	4775	5599	3293	1647	3250	5928	4172
July	Spp	1	1	2	--	1	8	9	6	4	5	5	7	5	15	5.3
	Ind	329	165	329	--	165	2685	8069	2305	4446	3623	4940	5105	4775	51541	6805
Aug	Spp	17	11	3	3	7	16	9	9	9	9	4	12	13	20	10.1
	Ind	24371	11361	659	3293	18281	54175	12021	12679	6257	17784	4611	16961	18607	61585	18761
Sept	Spp	9	6	--	3	2	9	12	11	10	10	8	11	10	18	9.1
	Ind	6751	2799	--	823	494	16631	17619	12350	13667	17455	8398	16631	5599	109503	17594
Oct	Spp	11	8	4	6	9	18	9	11	14	9	6	8	12	11	9.7
	Ind	21407	14820	13503	29475	31616	87438	6751	9880	18443	19595	9715	23877	11033	166313	33132
Nov	Spp	6	7	--	12	11	17	9	9	9	7	4	6	6	17	9.2
	Ind	8892	1605	--	21291	22847	35691	8151	8768	9262	10621	3087	10003	3705	115349	19944
Dec	Spp	7	9	--	15	14	15	10	10	8	12	6	13	7	12	10.6
	Ind	8274	6545	--	47917	41619	34209	10621	11485	8645	24206	3952	14573	18895	72247	23322
Jan 74	Spp	8	21	--	17	12	12	8	8	11	11	8	15	7	31	13.0
	Ind	16302	53599	--	18895	40508	52364	116954	18031	12226	28899	8521	16919	5063	68914	35169
Feb	Spp	25	18	15	16	16	11	11	12	13	9	15	17	7	32	15.5
	Ind	35444	84352	41833	16302	118807	138320	21736	29640	16919	24823	25317	23341	19513	78916	48233
Mar	Spp	6	14	9	25	19	17	13	15	21	10	20	22	10	26	16.9
	Ind	18154	18648	14079	61873	174505	106950	15808	33062	43303	22106	41743	41125	37661	57268	49085
April	Spp	12	11	19	23	14	19	17	16	19	13	10	17	11	33	16.7
	Ind	24576	17537	63602	361855	31369	92007	26923	34456	44089	20748	14079	31369	24832	100776	63444
Mean	Spp	9.4	9.0	6.8	12	9.2	12.6	10.2	9.8	11.2	9.0	7.8	11.9	7.8	20.8	10.5
Mean	Ind	14969	17647	16789	51679	40114	51953	22734	14984	15883	16961	11022	17208	12937	74856	26962

TABLE 2

The group numbers 1 to 10 of this table correspond to stations as follows:

1 = CP3 (cooling pond)
2 = DS-C1 (discharge to Trinity Bay)
3 = C2-C3
4 = B1-B2-B3-C4-D1-D2
5 = B4-B5-C5-D3-D4-D5
6 = A1-A2-A3-A4-E1-E2
7 = E3-A5
8 = E4-E5
9 = F1 to F5 inclusive
10 = G1 to G5 inclusive

Station groups 3 to 10 inclusive are successively farther from the discharge site into Trinity Bay.

TABLE 2

The group numbers 1 to 10 of this table correspond to stations as follows:

1 = CP3 (cooling pond)
2 = DS-C1 (discharge to Trinity Bay)
3 = C2-C3
4 = B1-B2-B3-C4-D1-D2
5 = B4-B5-C5-D3-D4-D5
6 = A1-A2-A3-A4-E1-E2
7 = E3-A5
8 = E4-E5
9 = F1 to F5 inclusive
10 = G1 to G5 inclusive

Station groups 3 to 10 inclusive are successively farther from the discharge site into Trinity Bay.

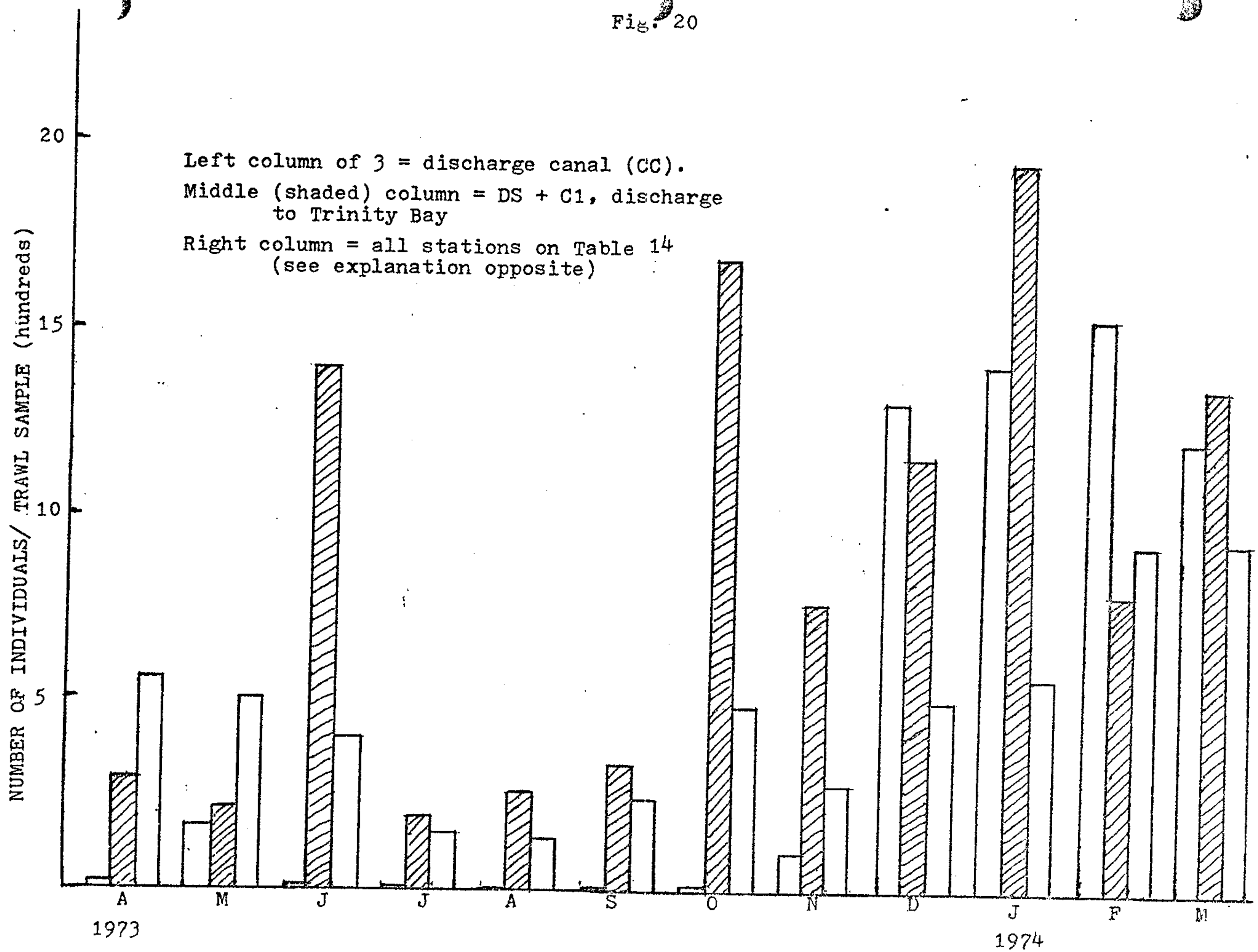
TABLE 2

Benthic Productivity as related to distance from the Trinity Bay discharge

(Ind.M^2)

Date/Group		1	2	3	4	5	6	7	8	9	10
May, 73	sp	5	5	6.5	5.4	7.3	4.0	6.0	8.0	5.0	7.8
	ind	1647	2058	4610	3842	6258	2387	3952	5599	3952	4413
June		4	7.5	3	4.3	6.1	1.1	4.5	7.0	3.8	5.0
		1317	15149	2634	2442	4337	1783	1646	3376	2568	2107
July		8	7.5	3.5	5.0	8.0	3.8	6.0	7.5	5.6	6.8
		2635	5187	5515	6064	8179	3512	3458	5846	3544	13535
August		16	9.0	7.0	5.7	7.2	7.8	7.0	12.0	9.6	14.0
		54175	12350	9715	4446	7159	6998	4199	13997	9024	20781
September		9	11.5	8.0	8.3	9.3	7.5	8.5	13.0	9.2	9.8
		16634	14984	8398	6530	12844	5977	5999	20748	8497	27729
October		18	10.0	9.0	8.0	10.0	8.0	8.0	8.5	7.8	11.0
		87438	8315	18608	7877	12542	9052	7657	17537	9484	45514
November		17	9.0	6.0	5.8	7.0	6.2	8.5	7.5	6.4	16.6
		35691	8459	3952	5063	6874	4219	7472	8509	5212	39791
December		15	10.0	5.5	6.5	8.8	7.0	8.0	13.0	7.0	17.6
		34209	11053	3458	7595	9649	5640	7348	16302	10547	33814
January		12	8.0	8.0	6.7	9.7	8.8	6.0	17.5	8.0	23.0
		52364	67492	17537	11983	12659	9983	3396	17229	6885	52537
February		11	11.5	7.0	9.2	11.2	8.7	10.5	19.0	9.4	26.8
		138320	25668	16610	14552	15869	13173	9880	32480	15239	60266
March		17	14.0	10.0	11.4	16.2	13.0	19.5	23.5	13.4	29.0
		106950	24885	12659	30781	39602	26326	33900	61565	32553	70167
April		19	16.5	9.5	11.0	13.0	9.3	9.5	16.5	11.0	20.8
		92007	30689	17537	28590	25502	16446	18557	31183	25264	52763
Means	spp	12.5	10.0	6.9	7.3	9.5	7.2	8.5	12.8	8.0	15.7
	ind	51949	18857	10103	10813	13456	8741	8955	19531	11064	35285

Fig. 20



NUMBER OF INDIVIDUALS/ TRAWL SAMPLE (hundreds)
20
15
10
5
Left column of 3 = discharge canal (CC).
Middle (shaded) column = DS + C1, discharge to Trinity Bay
Right column = all stations on Table 14 (see explanation opposite)
A
M
J
J
A
S
O
N
D
J
F
M
1973
1974

Fig. 20

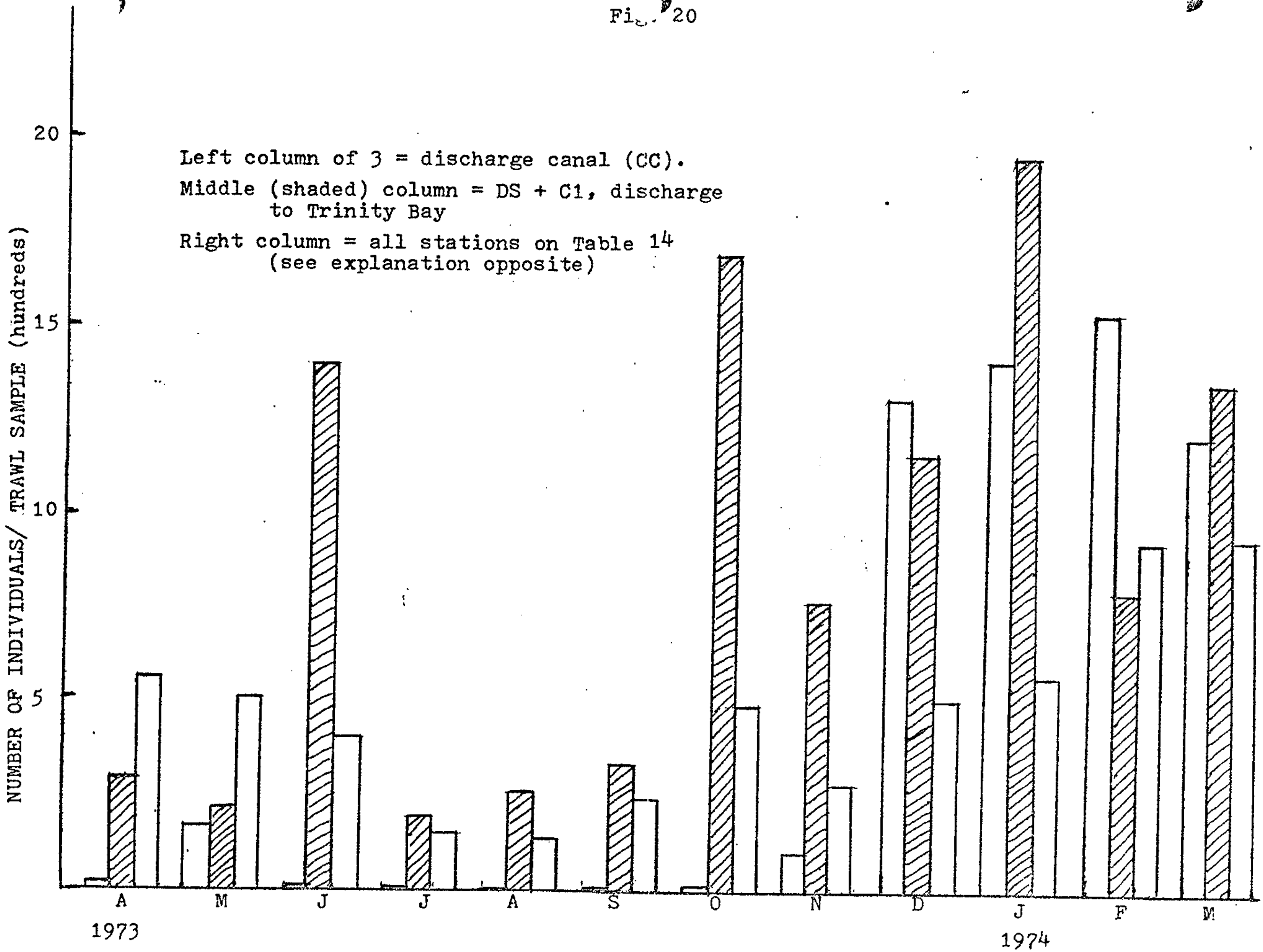

Left column of 3 = discharge canal (CC).
Middle (shaded) column = DS + C1, discharge to Trinity Bay
Right column = all stations on Table 14 (see explanation opposite)
NUMBER OF INDIVIDUALS/ TRAWL SAMPLE (hundreds)
20
15
10
5
A
M
J
J
A
S
O
N
D
J
F
M
1973
1974

Table 1 Summary of the data from Stations 19, and C1-DS having to do with community structure, productivity and species diversity based on the benthic samples. Data from 1970 to April 1973 are from frame station 19, those data from April, 1973 to April, 1974 are based on core sampling at the combined stations DS and C1.

1970

Dates	1-8	2-27	4-2	5-2	6-6	7-4	8-1	9-1	10-1	10-30	12-1	Means
NO. Spp	16	10	9	13	16	13	9	15	12	8	13	12.18
No. Ind/M^2	440	316	476	916	860	452	1744	1332	4516	1468	6796	1756
$\bar{H}$ diversity	1.73	1.63	1.01	1.08	1.40	1.50	1.37	1.71	1.62	1.48	1.23	1.43
% Annelida	56.2	40.0	44.4	30.7	56.2	38.4	66.6	60.0	41.6	62.5	46.1	49.34
% Crustacea	6.2	0.0	11.1	15.3	0.0	0.0	0.0	13.3	8.3	0.0	0.0	4.93
% Mollusca	37.5	40.0	33.3	38.4	25.0	38.4	22.2	13.3	16.6	25.0	16.6	27.03

1971

Dates	1-2	2-12	3-9	4-12	5-11	6-7	7-12	8-9	9-9	11-4	12-2	
No spp.	12	14	11	9	12	12	13	14	11	11	8	11.5
No Ind/M^2	7220	1176	1560	3106	7490	2732	1008	404	1016	408	252	2397
$\bar{H}$ Diver.	1.27	1.65	1.45	1.14	1.47	1.52	1.26	1.39	1.78	1.68	1.69	1.48
% Annelida	83.3	71.4	63.6	77.7	75.0	66.7	61.5	64.2	81.8	63.6	62.5	70.11
% Crustacea	0.0	0.0	0.0	0.0	0.0	8.3	7.6	7.1	0.0	0.0	0.0	2.09
% Mollusca	16.6	21.4	27.2	11.1	16.6	25.0	23.1	21.5	9.1	27.2	25.0	20.35

1972

Dates	1-6	2-10	3-9	4-18*	5-4	6-1	7-3	7-31	8-26	9-23	10-19	11-16	12-16	
No. Spp.	7	12	9	9	3	10	11	10	14	6	12	15	11	9.9
No. Ind/M^2	800	1732	444	1528	76	212	160	297	1460	560	1632	5376	27852	3240
$\bar{H}$ Diver.	0.93	1.52	1.43	1.02	1.23	1.37	1.43	1.25	-	1.42	1.30	1.81	0.28	1.15
% Annelida	57.1	58.3	55.5	55.5	33.3	60.0	54.5	40.0	50.0	33.3	66.7	53.3	63.7	52.4
% Crustacea	0.0	8.3	11.1	11.1	0.0	20.0	18.1	20.0	14.2	33.3	8.3	13.4	9.1	12.8
% Mollusca	28.6	16.6	22.2	33.3	33.3	20.0	18.1	30.0	28.6	33.3	16.7	26.7	18.2	25.0

1973

Dates	1-4	2-7	3-21	4-13	5-21**	6-20	7-18	8-18	9-13	10-15	11-8	12-5	
No. Spp.	16	15	18	19	10	11	10	11	15	12	10	13	13.3
No Ind/M^2	27116	36752	5088	4780	2058	15149	5186	12350	14985	8316	8458	11053	12608
$\bar{H}$ Diver.	0.53	0.26	1.40	1.98	1.20	1.34	1.47	1.41	1.89	1.71	1.68	1.50	1.36
% Annelida	56.2	60.0	50.0	52.6	83.3	45.4	50.0	45.4	33.3	30.0	30.0	46.1	49.35
% Crustacea	18.7	13.3	16.6	15.8	16.7	27.2	30.0	27.3	33.3	33.3	40.0	15.3	23.95
% Mollusca	18.7	13.3	16.6	15.8	0.0	9.1	0.0	9.1	6.7	0.0	10.0	15.3	9.55

1974

Dates	1-17	2-13	3-12	4-16	Means
No. Spp.	14	16	12	17	15
No. Ind/M^2	67493	25689	24885	30690	37189
$\bar{H}$ Diver.	1.05	1.34	1.63	1.81	1.46
% Annelida	21.4	29.4	50.0	39.1	34.98
% Crustacea	50.0	43.8	27.7	34.7	39.05
% Mollusca	0.0	0.0	5.6	4.4	2.5

* Cooling pond put in operation April 28. 1972

** Begins DS-C1 data

TABLE 4

Comparison of benthos (frame samples) at station 19 for three winter months and three summer months for the years 1970 to 1973.

Average no/ M^2 period	1970	1971	1972	1973
Winter				
species	11.0	13.0	11.7	17.3
individuals	396	3936	976	23104
Summer				
species	12.3	13.3	10.0	9.5
individuals	1064	812	216	10785

TABLE 4, Explanation

Winter months are January, February, and March, and the summer months are July, August and September. Because no data are available for frame samples for the summer of 1973, data from Southwest Research Foundation stations DS-C1 (average) are substituted for the missing period. Discharge of hot water began in September of 1970, rose in 1971 and reached a peak in the summer and fall of 1972. The cooling pond was put in service in the end of April, 1972.

TABLE 5

Diversity as measured by the Shannon-Weaver Formula*
applied to benthic samples

Stations:	CC	DS	C1	F5	G5
May, 1973	0.0	1.58	0.82	0.68	2.33
June	0.0	1.42	1.26	0.84	1.73
July	0.69	1.71	1.23	0.69	0.86
August	1.04	1.22	1.60	1.75	1.38
September	0.0	1.92	1.85	2.04	1.59
October	0.80	1.39	2.03	1.58	0.56
November	----	1.56	1.78	1.13	1.13
December	----	1.40	1.69	1.01	1.56
January 74	----	1.38	1.06	1.32	1.85
February	1.97	1.26	1.43	0.90	2.18
March	1.38	1.20	2.07	0.65	2.16
April	1.92	1.67	1.94	1.09	2.19
Means	0.87	1.44	1.39	1.14	1.54

$$*\bar{H} = -\Sigma\ (^{n}/N)\ \mathrm{Ln}\ (^{n}/N)$$

when n = the number of individuals of the ith species, and N = total number of individuals in the sample.

TABLE 7

Number of zooplankton, diatom, blue-green and other phytoplankton species at stations at the intake side, discharge side, and in the discharge canal at the Robinson Plant
July 14, 1972*

Site/ of Sample	Number of Species Blue-Greens	Diatoms	Zooplankters	Others	Totals
Intake (7-25-72)	1	4	11	0	16
Intake	2	14	12	1	29
Discharge (7-25-72)	3	6	12	0	21
First platform, discharge canal	1	10	18	3	32
1/4 mile below 1st platform	1	9	13	5	28
1/4 mile above 2nd platform	0	12	14	2	28
At 2nd platform	2	8	15	2	27
Above sand pit	1	10	16	1	28
2nd point below sandpit	1	8	16	0	25
Hwy 517 bridge	0	9	19	1	29
In Bay between groins	2	9	11	2	24
Control in Bay	2	8	12	0	22

*Two samples taken 7-25-72; see in the "sites" column.

TABLE 8

Numbers of zooplankters, blue-green algae, diatoms, and other phytoplankters taken at the intake structure, discharge cubical, fish platform in the discharge canal, CIWA bridge and the Trinity Bay discharge point.

Phytoplankton and zooplankton taken by Drs. Frank Schlicht and J. G. Mackin, July 25, 1972.

Stations	zooplankton spp	blue-green spp	diatom spp	other phytoplankton spp	Totals
1. Intake structure in Cedar Bayou	13	7	9	7	36
2. Discharge cubicle at plant exit.	14	3	3	2	22
3. At Fish Platform in discharge canal	11	2	5	7	25
4. CIWA Bridge, discharge canal	7	3	4	2	16
5. Drop Structure to cooling pond	10	2	4	5	21
6. Discharge to Trinity Bay, above the drop structure	11	5	7	2	25
Means	11	3.7	5.3	4.2	24.2

TABLE 9

Analysis of winter conditions in the cooling pond, discharge to Trinity Bay, and in north and south Trinity Bay The analysis is based on collections of Phytoplankton on December 19, 1972, about 8 months after the pond was put in use.
(Note: values in parentheses are for chlorophyll A.)

Stations	No. of diatom species	No. blue-green species	Other Phyto-plankton spp	Totals
1. North end cooling pond	10	0	12	22 (14)
2. Discharge to Trinity Bay	8	0	3	11 (44)
3. N. Trinity Bay	19	0	3	22 (31)
4. S. Trinity Bay	11	0	4	15 (29)
Means	12	0	5.5	17.6 (29.5)

TA[illegible]10

Summary of zooplankton samples taken by Southwest Research Institute at selected stations from the intake to Trinity Bay.

(IND./M^3)

					Stations					
Months	IS	CC	CP1	CP2	CP3	DS-C1	D3-B3	A3-E3	F5-G5	Means
May, 73										
spp	43	37	39	31	37	40	38	47	45	45
ind	570	9490	17640	9863	21914	10268	17352	7623	6580	11256
June										
spp	39	37	40	31	30	38	43	45	47	39
ind	4715	7837	27550	5548	20761	1695	947	1593	6985	8626
July										
spp	22	27	29	12	24	28	23	23	28	22
ind	237	1866	3054	2087	7590	210	100	120	188	1717
Aug.										
spp	25	25	23	21	18	24	22	27	30	24
ind	1131	2596	994	209	702	336	357	435	553	813
Sept.										
spp	42	37	29	19	25	24	27	26	29	29
ind	2578	3242	707	477	2873	1235	1901	4922	2166	2233
Oct.										
spp	27	30	28	26	27	32	30	32	43	31
ind	475	1220	569	377	1002	371	123	204	844	576
Nov.										
spp	34	18	32	21	21	36	37	39	46	32
ind	237	486	6847	3221	1597	223	178	179	518	1498
Dec.										
spp	24	24	34	13	15	24	23	25	27	23
ind	513	1617	1031	5008	1924	1687	133	466	249	1403
Jan., 74										
spp	30	22	34	18	26	28	38	38	34	30
ind	670	2040	1976	5162	4727	2165	778	1926	2741	2465
Feb.										
spp	31	32	32	24	30	34	39	41	34	33
ind	66	445	1683	4235	4535	296	805	932	1472	1608
Means										
spp	32	29	32	22	25	31	32	34	36	
ind	1119	3084	6205	3619	6763	1849	2267	1840	2230	

.LE 11

Zooplankton summary. A comparison of species number and number of individuals/M^3 in the summer season and in winter. Winter months included are December, January, and February, and summer months are July, August, and September. Stations compared are IS (intake), CC (discharge canal), CP1, CP2, and CP3 (cooling pond), DS-C1 (discharge to Trinity Bay), D3-B3, A3, E3 (in Trinity Bay), and F5-G5 (controls).

	IS	CC	CP1	CP2	CP3	DS-C1	D3-B3	A3-E3	F5-G5	Means
Summer										
No. spp	30	30	27	17	22	25	24	25	29	25.5
No. ind/M^3	1315	2268	1585	924	3722	594	786	1826	969	1554
Winter										
No. spp	28	26	33	18	24	29	33	35	32	28.7
No. ind/M^3	416	1367	1563	4802	3695	1383	572	1108	1487	1821
Winter-summer ratio										
species	0.94	0.88	1.23	1.06	1.06	1.13	1.39	1.37	1.09	1.12
individuals	0.32	0.60	0.99	5.20	0.99	2.33	0.73	0.61	1.53	1.17

TABLE 12

Numbers of diatoms at the various stations are based on means of 3 surface and three bottom samples, taken twice a month. Sometimes the number of samples is reduced, but is never less than 6 in any one month, and may be as many as 18. Species number is the pooled number for all sub-samples for each monthly period. Means are calculated to the nearest whole number.

Footnotes as follows:

(1) Coscinodiscus bloom

(2) Cyclotella bloom

(3) Nitzschia bloom, with Cyclotella

(4) Navicula and Cyclotella bloom

(5) Nitzschia bloom

(6) Thallassiosira blooms

(7) Thallassiosira bloom with subblooms of Cyclotella and Chaetoceros

Table

Numbers and seasonal distribution of diatoms at selected stations

(Cells/ml)

Months		IS	CC	CP1	CP2	CP3	C1	F5	G5	Means
May, 73	Spp	6	8	8	6	5	8	5	8	7
	Ind	35	43	108	333	417	110	38	68	144
June	Spp	10	10	9	11	9	10	8	11	10
	Ind	120	62	94	1885	2728(1)	1155	438	293	847
July	Spp	11	12	11	15	10	8	13	4	10
	Ind	4566(2)	473	480	2951(3)	3536(3)	9010(3)	3509	752	3160
Aug	Spp	6	6	7	7	7	6	7	7	7
	Ind	226	328	464	3133(5)	555	1868	862	1149	1073
Sept	Spp	9	10	8	7	8	8	6	9	8
	Ind	232	269	313	490	518	271	479	700	409
Oct	Spp	13	10	8	9	12	12	10	12	11
	Ind	1969	14256(6)	10713(6)	2149	4717	507	558	547	4427
Nov	Spp	11	12	11	11	11	11	11	12	11
	Ind	339	900	524	492	1312	224	321	245	545
Dec	Spp	14	14	11	12	12	11	15	16	13
	Ind	220	713	4051	10081(6)	3723	16730(6)	5021	1144	5210
Jan, 74	Spp	14	16	20	12	13	10	15	14	14
	Ind	259	158	204	33908(7)	28795(7)	29761(7)	4133	795	12252
Feb	Spp	18	14	12	12	15	15	11	13	14
	Ind	7823	13308(7)	13702(7)	11441(7)	17671(7)	6260	1019	1240	9058
March	Spp	7	10	15	10	11	8	8	13	10
	Ind	11037(7)	11312(7)	10793(7)	15159(7)	11972(7)	27113(7)	6630	10913	13116
April	Spp	8	11	11	13	10	9	10	9	10
	Ind	5369	7043	4815	20369(7)	21021(7)	6304	8025	6240	9898
Means	Spp	11	11	11	10	10	10	10	11	
	Ind	2683	4072	3855	8533	8080	8276	2586	2007	

TABLE 13

Numbers of blue-green cells at the various stations are based on the means of 3 surface and 3 bottom samples, taken twice a month. Sometimes the number of samples is reduced but is never less than 6 in any month, and may be as many as 18. Species number is the pooled number for all samples taken that month. Species means are calculated for the nearest whole number.

Footnotes as follows:

(1) Coccochloris bloom

(2) Raphidiopsis bloom

BLE --

Numbers and seasonal di[illegible]ibution of blue-green algae at selected stations

(Cells/ml)

Months	IS	CC	CP1	CP2	CP3	C1	F5	G5	Means
May, 73									
spp	4	3	1	1	1	1	2	2	2
ind	40	36	18	9	1	1	56	61	28
June									
spp	3	2	2	2	3	3	2	2	2
ind	72	32	18	62	35	20	10	49	37
July									
spp	6	5	5	4	5	7	7	8	6
ind	27	44	19	63	52	435	959	333	242
August									
spp	8	7	9	7	6	6	8	8	7
ind	177	564	617	519	846	626	1857	2679	986
September									
spp	8	9	8	7	7	8	6	8	8
ind	51	150	195	524	693	456	43	1370	435
October									
spp	6	8	7	8	7	8	8	8	8
ind	72	72	22	117	75	115	1286	521	285
November									
spp	8	8	8	5	6	8	6	8	7
ind	119	289	83	56	82	81	154	100	121
December									
spp	7	7	7	7	5	4	7	9	7
ind	73	195	92	104	109	213	200	190	147
January, 74									
spp	5	6	8	5	10	8	8	9	7
ind	20	4734(1)	1628(1)	2984(1)	1158(1)	12094(1)	110	102	2858
February									
spp	5	7	4	10	10	5	4	6	6
ind	328	122	201	467	248	267	53	25	214
March									
spp	7	6	5	6	3	6	3	10	6
ind	307	317	200	1109(2)	703	1175(2)	136	665	576
April									
spp	6	1	3	3	6	5	3	3	4
ind	6079(2)	7374(2)	7665(2)	3017(2)	1676(2)	3733(2)	344	850	3842
Means									
spp	6	6	6	5	6	6	5	7	
ind	614	1161	897	753	473	1601	434	579	

TABLE 14

Values for number of nekton species are the mean of two trawl samples per month for all single stations; for those representing the mean of two or 3 stations the number of samples used would be 4 or 6 respectively. Numbers of species are adjusted to the nearest whole number. Values for number of individuals are arrived at in the same way as are those for species.

Table

Numbers and seasonal distribution of nekton species at selected stations

Months		GB	SG-IS-SW	CC	CP1	CP2	CP3	DS-C1	B3-A4	DS-E4	F5-G5	Means
April, 73	Spp	8	6	4	7	10	10	8	6	8	6	8
	Ind	1011	404	244	280	434	756	294	560	1013	374	515
May	Spp	10	9	7	10	10	12	12	7	9	7	9
	Ind	1431	612	164	467	479	773	222	437	168	411	516
June	Spp	9	8	3	8	6	8	13	11	9	9	8
	Ind	171	224	13	246	310	560	1380	443	480	319	415
July	Spp	12	8	2	1	7	7	8	9	7	9	7
	Ind	188	295	8	3	270	259	216	161	227	179	161
Aug	Spp	12	8	0	2	4	7	10	9	9	8	7
	Ind	571	150	0	2	68	56	274	167	105	188	158
Sept	Spp	12	9	2	3	5	7	13	11	9	10	8
	Ind	820	281	6	3	17	35	351	335	342	351	254
Oct	Spp	8	8	3	4	2	3	9	6	7	6	6
	Ind	1089	427	16	18	2	19	1751	856	297	412	489
Nov	Spp	9	9	6	6	6	7	10	8	8	7	7
	Ind	323	340	120	26	53	101	754	540	166	404	283
Dec	Spp	6	8	12	10	6	9	10	7	8	7	8
	Ind	192	212	1294	129	94	226	1185	519	856	236	494
Jan, 74	Spp	6	6	10	10	5	8	11	7	7	7	8
	Ind	179	117	1386	994	164	241	1948	252	115	282	568
Feb	Spp	6	9	11	9	7	9	9	8	9	8	8
	Ind	118	450	1554	207	154	399	789	281	292	505	475
Mar	Spp	7	9	9	9	12	10	12	9	7	9	9
	Ind	404	398	1205	978	716	1005	1848	764	1269	341	893
Means	Spp	8	8	6	6	6	8	10	8	8	7	8
	Ind	541	326	483	279	214	369	918	443	444	334	435

Table 15

The biotic community at station DS during July, August, and September, 1973

1. Chordata, Pisces

Anchoa mitchilli
Micropogon undulatus
Brevoortia patronus
Arius felis
Cynocion arenarius
Ictalurus furcatus
Bagre marinus
Lagodon rhomboides
Bairdiella chrysura
Chaetodipterus faber
Leiostomus xanthurus
Polydactylus octonemus
Dasyatus octonemus
Dorosoma petense
Sciaenops ocellatus
Pogonias cromis
Membras martinica
Syngnathus scovelli
Gobiidae sp (larvae)

2. Rhyncocoelida

Rhyncocoele sp

3. Aschelminthes

Nematoda sp 1
Nematoda sp 2

4. Rotifera

Asplanchna sp
Brachionus sp
Bdelloidea sp
Colonial rotifera

5. Mollusca

Littoridina sphinctostoma

6. Arthropoda, Insecta

Tendipes sp
Plecoptera sp
Homoptera sp

7. Arthropoda, Arachnida

Acari sp

8. Arthropoda, Crustacea
Cladocera

Ilyocriptus spinifer
Moina sp
Ceriodaphnia sp
Diaphanosoma sp

10. Crustacea, Ostracoda

Cypridopsis cf. *C. vidua*
Limnocythere sp
Perrissocytheridea brachyforma
Potamocypris smaragdina
Ostracoda sp
Cytherura johnsoni
Physocypria cf *P. pustulosa*

11. Crustacea, Copepoda

Acartia tonsa
Diaptomus sp
Canuella sp
Diaptomus dorsalis
Epactophanes sp
Nitroca sp
Schizopera sp
Ergasilus sp
Microcyclops sp
Halicyclops sp
Tropocyclops sp
Cletocamptus sp
Onycocamptus sp

12. Crustacea, Branchiura

Argulus alosae

13. Crustacea, Tanaidacea

Tanaidacea sp

14. Crustacea, Amphipoda

Corophium louisianae
Erichthonius braziliensis
Melita sp

15. Crustacea, Isopoda

Aegothoa oculata
Isopoda sp 1
Isopoda sp 2

16. Crustacea, Decapoda

Penaeus setiferus
Penaeus aztecus
Palaemonetes pugio
Palaemonetes intermedius
Callianassa sp
Callinectes sapidus
Rithropanopeus harrisi
Grapsid (zoea)

17. Crustacea, Mysidacea

Mysidopsis almyra

19. Annelida, Oligochaeta

Peloscolex gabriellae
Dero sp

20. Annelida, Polychaeta

Streblospio benedicti
Hypaniola gunneri florida
Mediomastus californiensis
Parandalia americana
Polydora sp

21. Coelenterata, Hydrozoa

Hydrozoa sp(Hydroid)
Hydrozoa sp (medusa)

22. Platyhelminthes

Turbellaria sp

23. Cyanophyceae

Agmenellum quadriplicatum
Agmenellum thermale
Anabaena sp
Raphidiopsis sp
Anacystis aeruginosa
Anacystis thermalis
Spirulina sp
Anabaenopsis sp
Coccochloris sp
Oscillatoria sp

24. Bacillariaceae

Coscinodiscus sp
Cyclotella sp
Navicula sp
Nitzschia sp
Pinnularia sp
Cocconeis sp
Amphora sp
Eunotogramma sp
Triceratium sp
Surirella sp
Cymbella sp
Melosira sp
Pleurosigna sp
Thallasiothrix sp

25. Dinoflagellaceae

Exuviella sp
Gymnodinium sp
Dinoflagellate sp
Amphidinium sp
Gymnodinium brevis
Peridinium sp

26. Chrysophyseae

Isochrysis sp

27. Chlorophyseae

Euglena sp
Phacus sp
Chlamydomonas sp 1
Chlamydomonas sp 2
Chlorococcum sp
Coelastrum sp
Ankistrodesmus sp
Closterium sp
Radiococcus sp
Closteridium sp

27. Chlorophyseae (con)

Scenedesmus sp
Tetrastrum sp
Staurastrum sp
Cosmarium sp
Eutreptia sp

Chlorella sp
Crucigenia sp
Tetraedrom sp
Eunotia sp

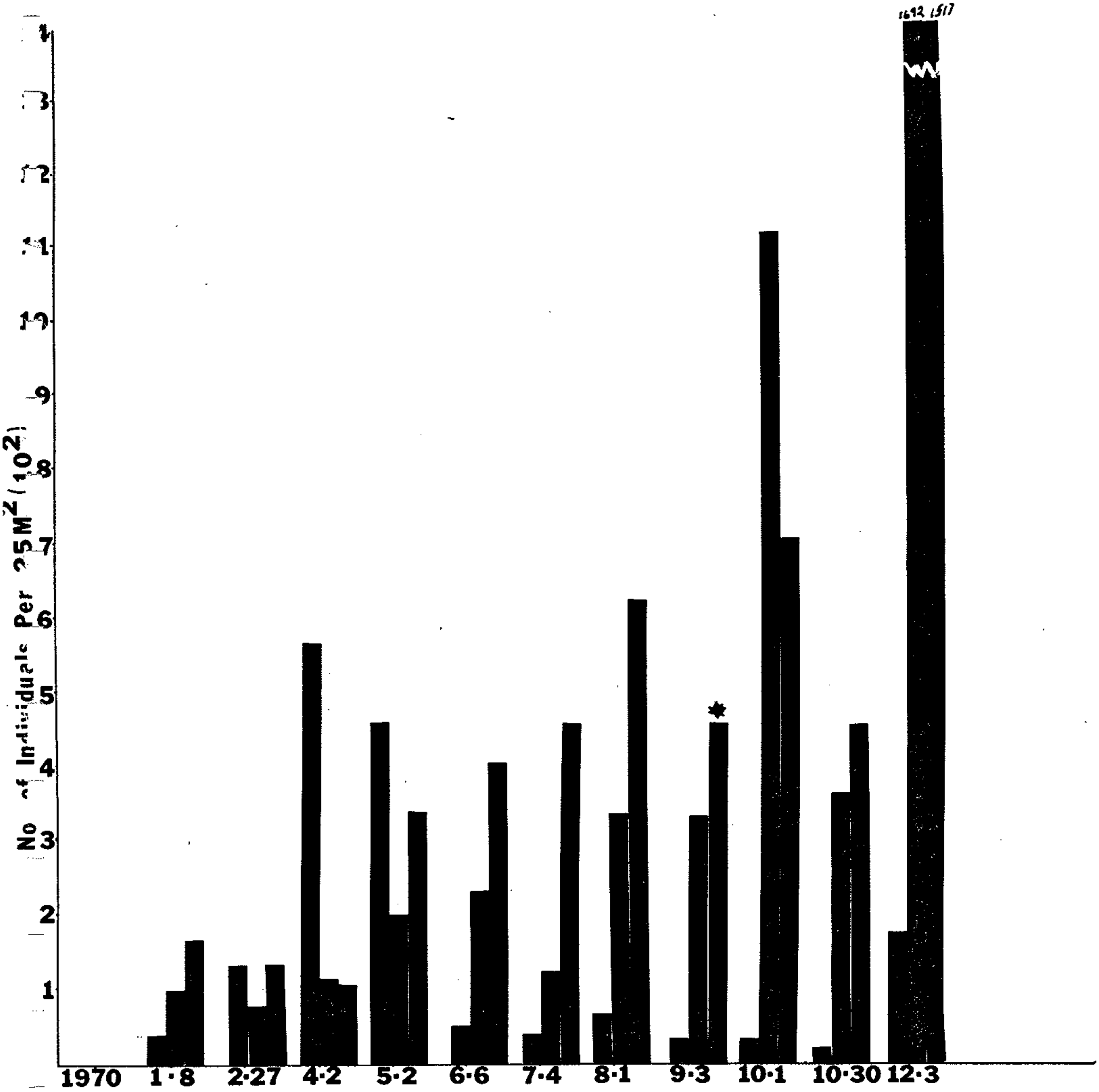
28. Cryptophyceae

Cryptomonas sp
Ochramonas sp
Oliscodiscus sp

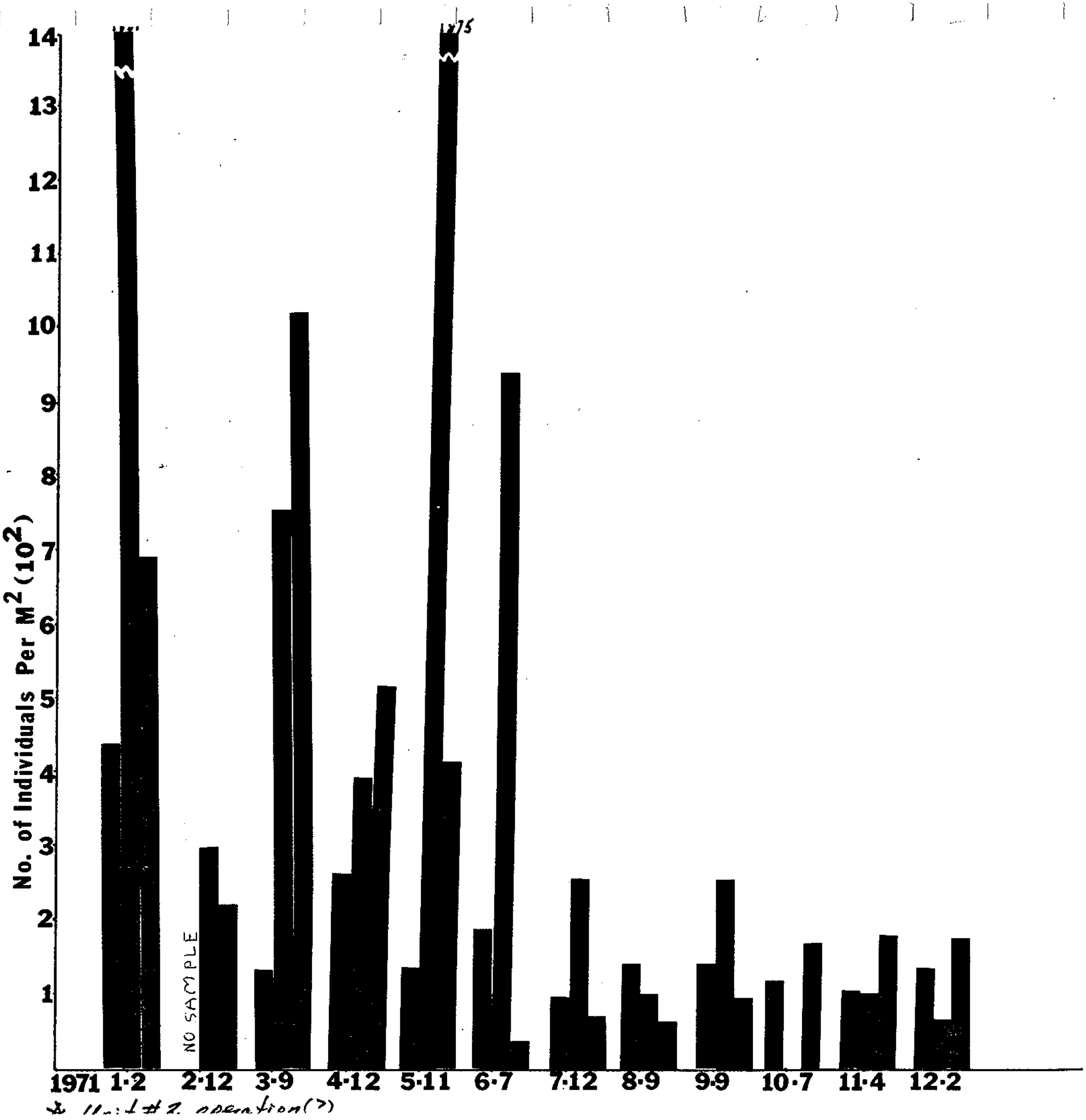
Calicomonas sp
Tetradinis sp
Pyramimonas sp

FIG.1a, b, c, d.

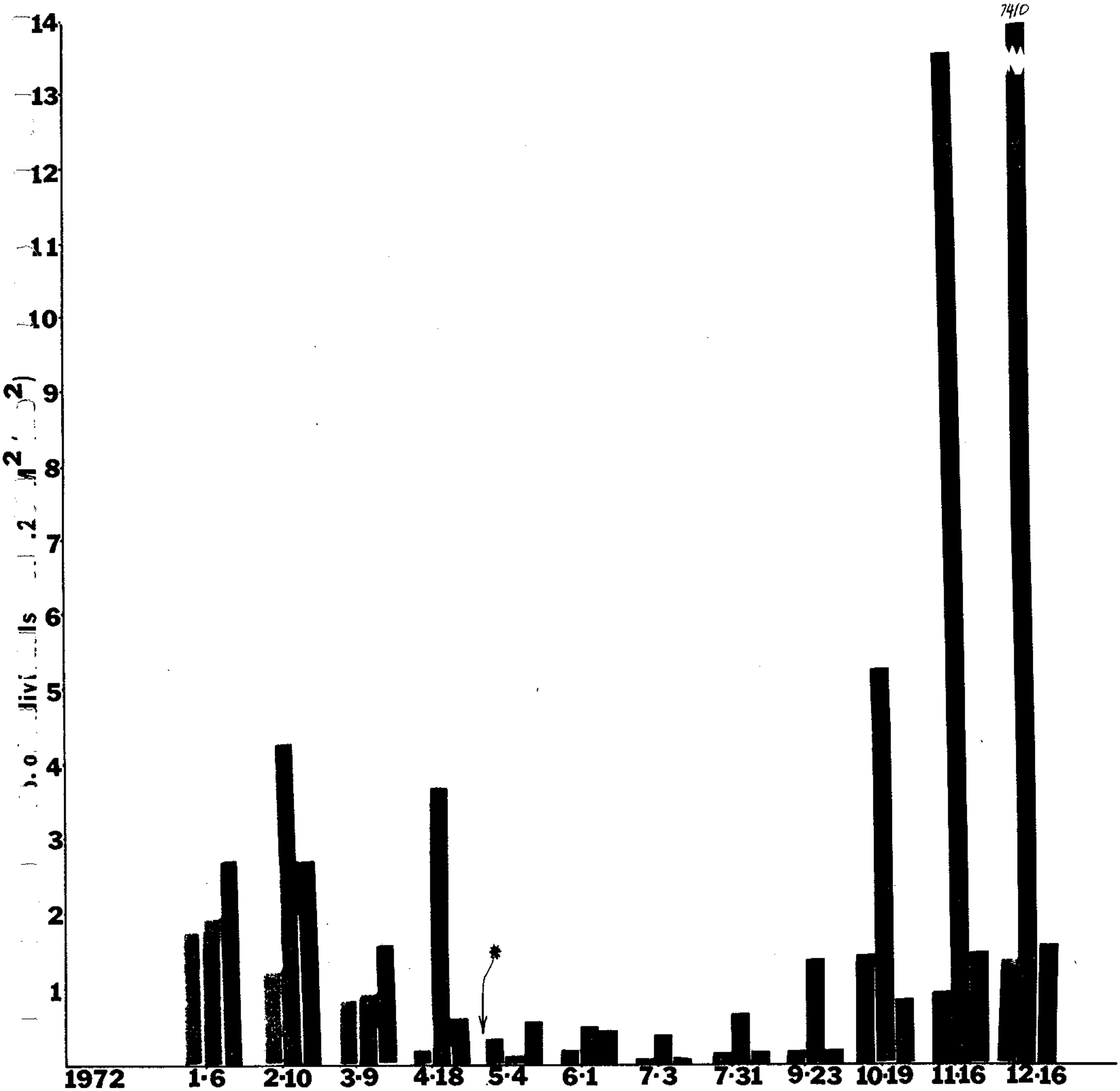
SUMMARY OF FOUR YEARS OF BENTHIC (FRAME) SAMPLING, 1970 TO 1973
The columns are in groups of three, the left hand column shows the mean number of individuals taken at Stations 6 & 9 lying close inshore 2 and 1 mile south of the discharge site to Trinity Bay, the center column shows number of individuals taken at the discharge site (Station 19), and the right hand column shows number of individuals taken at stations 21 & 24 1 and 2 miles north of the discharge site respectively. The data show the mean number of individuals per sample (one fourth meter square) for each collecting date



* First Cooling Unit



1775
No. of Individuals Per M^2 (10^2)
14
13
12
11
10
9
8
7
6
5
4
3
2
1
NO SAMPLE
1971 1·2
2·12
3·9
4·12
5·11
6·7
7·12
8·9
9·9
10·7
11·4
12·2



* Cooling Pond Put in Use

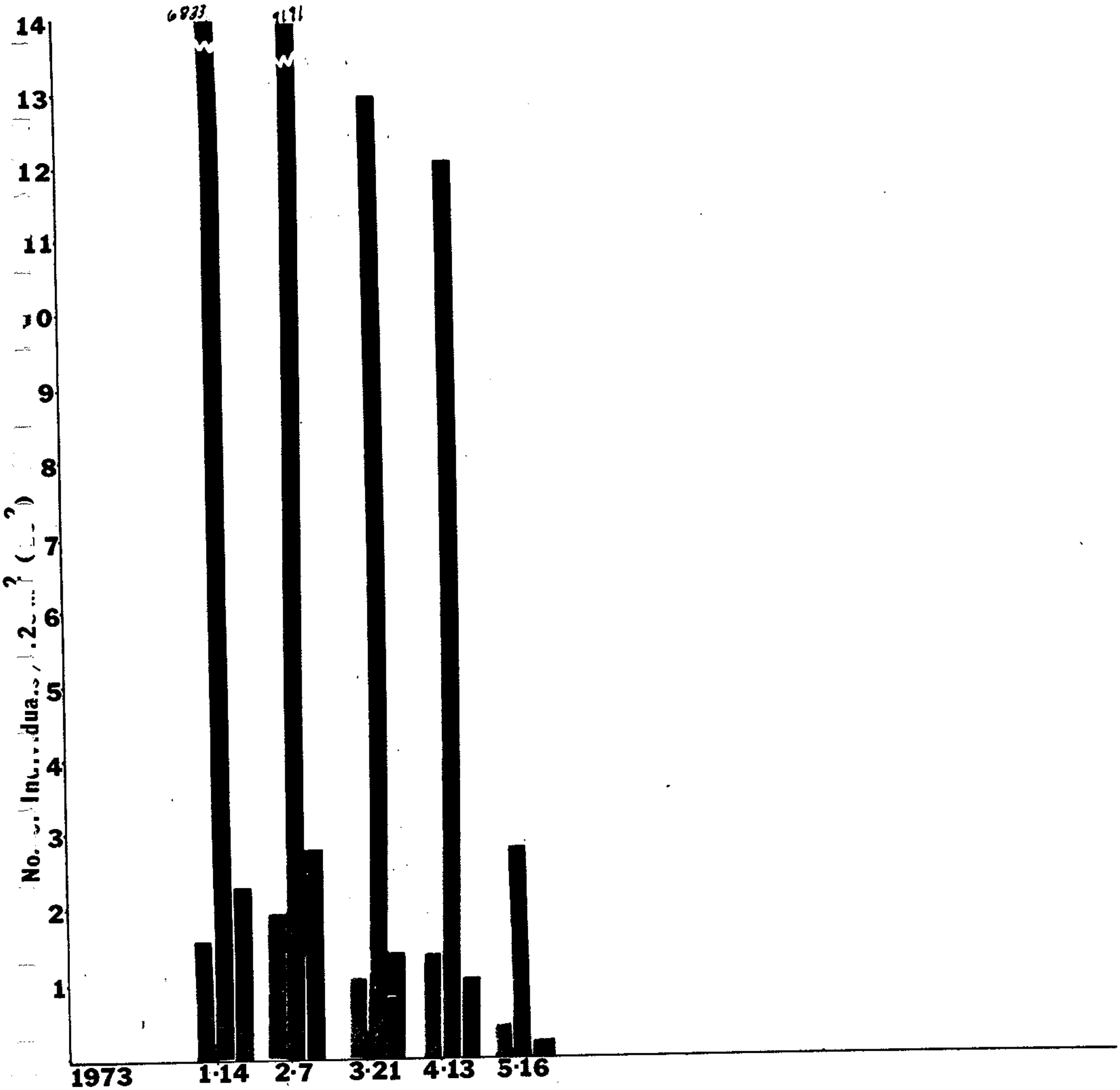

6833
1191
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1973
1·14
2·7
3·21
4·13
5·16

FIG. 2

NUMBER OF BENTHIC SPECIES AND NUMBER OF BENTHIC INDIVIDUALS PER METER SQUARE TAKEN AT THE DISCHARGE SITE INTO TRINITY BAY, 1970 TO 1974. Left hand column of each pair shows the mean number of species for all samples taken during the year, and the right hand column shows the mean number of individuals for all samples taken that year. From Jan. 1, 1970 to April 13, 1973, the data are based on the Frame samples from Station 19 (Wildlife Science Project 1774). From May 21, 1973 to April 16, 1974 data are taken frombenthic samples taken by Southwest Research Institute at their stations DS and C1 (means).

Fig 2

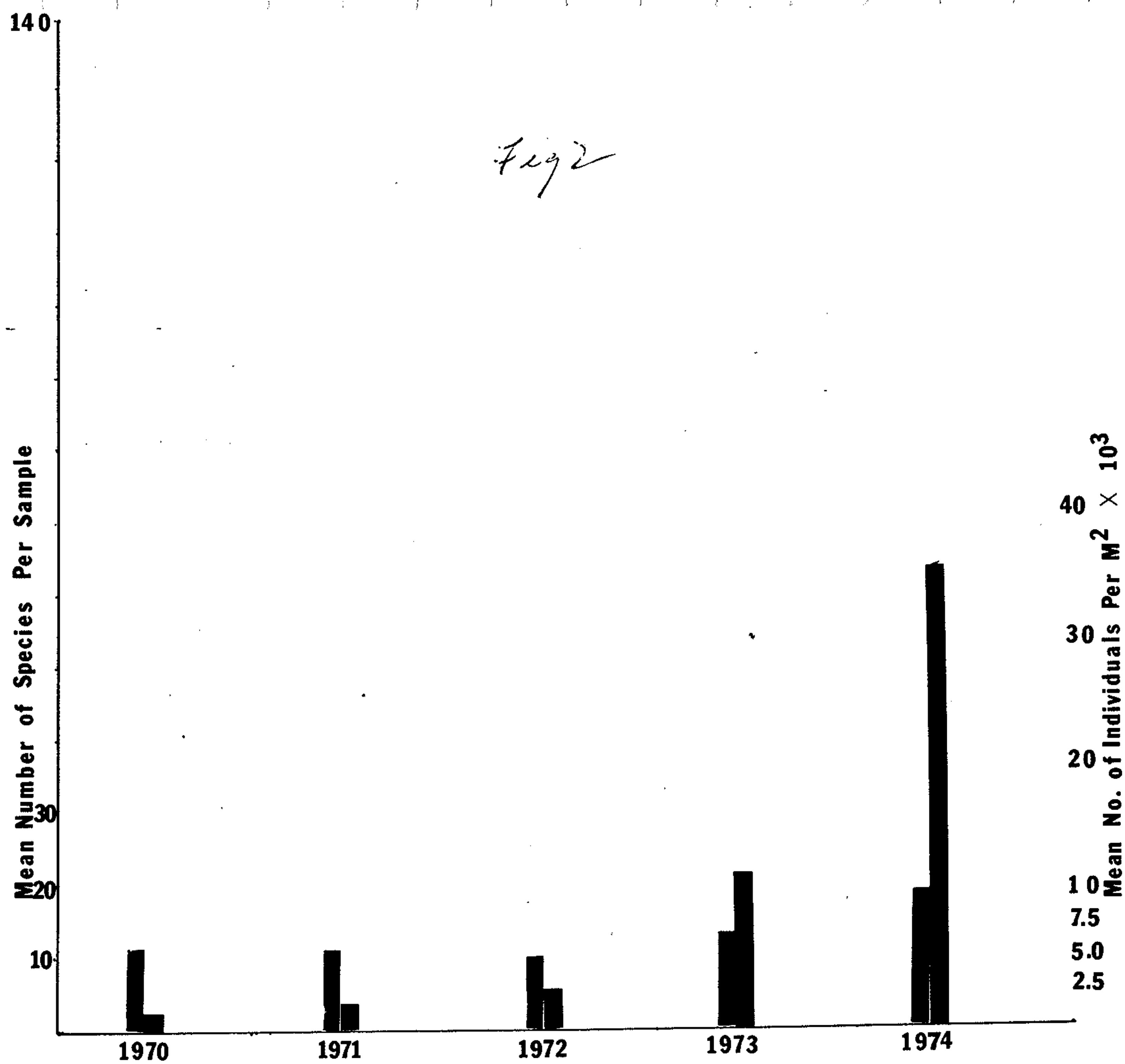


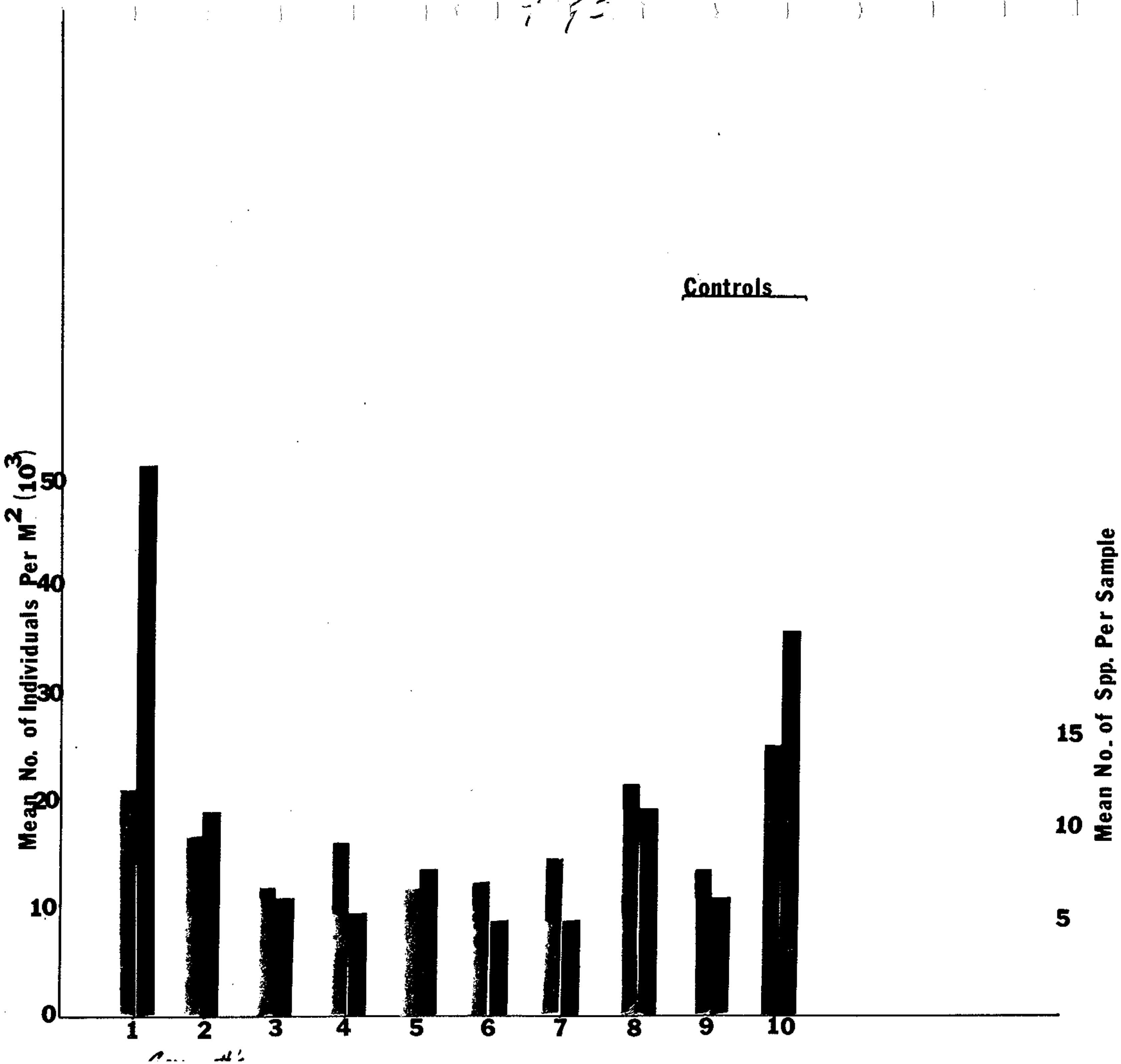
Fig 2
140
30
20
10
Mean Number of Species Per Sample
1970
1971
1972
1973
1974
40
30
20
10
7.5
5.0
2.5
Mean No. of Individuals Per M2 × 103

FIG. 3

MEAN NUMBER OF BENTHIC SPECIES AND MEAN NUMBER OF BENTHIC INDIVIDUALS/M^2 BY SOUTHWEST RESEARCH INST. MAY, 1973 TO APRIL, 1974 at all benthic stations from CP3 (cooling pond) to the most distant controls. The data show the means for the 10 groups of ststions, and the groups are numbered from 1 to 10 (see bottom of graph) Stations in each group are as follows:

Number	1	group,	CP3 alone.
"	2	"	DS and C1.
"	3	"	C2 and C3.
"	4	"	B1, B2, B3, C4, D1, D2.
"	5	"	B4, B5, C5, D3, D4, D5.
"	6	"	A1, A2, A3, A4, E1, E2.
"	7	"	E3, A5.
"	8	"	E4, E5.
"	9	"	F1 to F5 (south controls)
"	10	"	G1 to G5 (north controls)

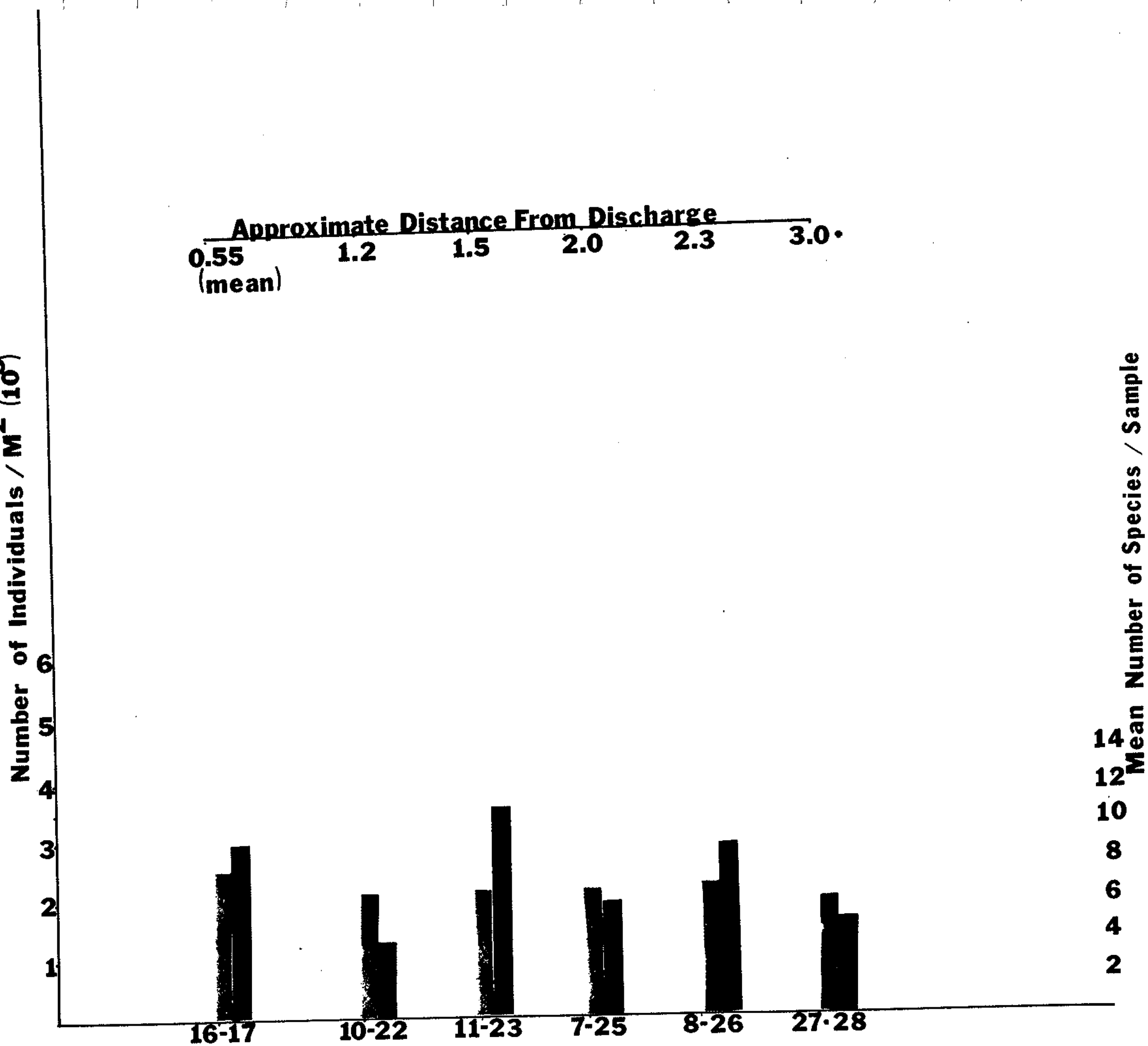
Each group of stations is successively farther away from the discharge site (DS and C1).



Controls
Mean No. of Individuals Per M2 (10 3)
0
10
20
30
40
50
Mean No. of Spp. Per Sample
5
10
15
1
2
3
4
5
6
7
8
9
10

FIG. 4

BENTHIC SAMPLES TAKEN WITH THE EKMON DREDGE IN TRINITY BAY. The data are arranged to show the relation of distance of the paired stations from the discharge site into Trinity Bay. Left hand column shows the mean number of species per sample in the period from November 4, 1972 to May 31, 1973; right hand column shows the mean number of individuals per M^2 for the same period. Scale at the top of the graph shows the mean distance in statute miles of each pair of stations from the discharge site. The seven collecting dates were in the peak period of productivity (winter and spring)..



Approximate Distance From Discharge
0.55 (mean)
1.2
1.5
2.0
2.3
3.0
Number of Individuals / M^2 (10^3)
1
2
3
4
5
6
Mean Number of Species / Sample
2
4
6
8
10
12
14
16-17
10-22
11-23
7-25
8-26
27-28

FIG.5

COMPARISON OF BENTHIC PRODUCTIVITY IN SUMMER WITH THAT IN WINTER, AT SELECTED STATIONS. Left hand column shows summer (July, Aug., and Sept.,) productivity Station CC in the discharge canal, Stations CP1, CP2, CP3, DS and C1 in the cooling pond and discharge site, and Stations B3 - D3, A4 - E4, F5 and G5, each pair successively farther out into Trinity Bay. Right hand column shows winter (Jan, Feb, and Mar.) productivity at the same Stations. Southwest Research Inst. benthic core samples.

Fig 5

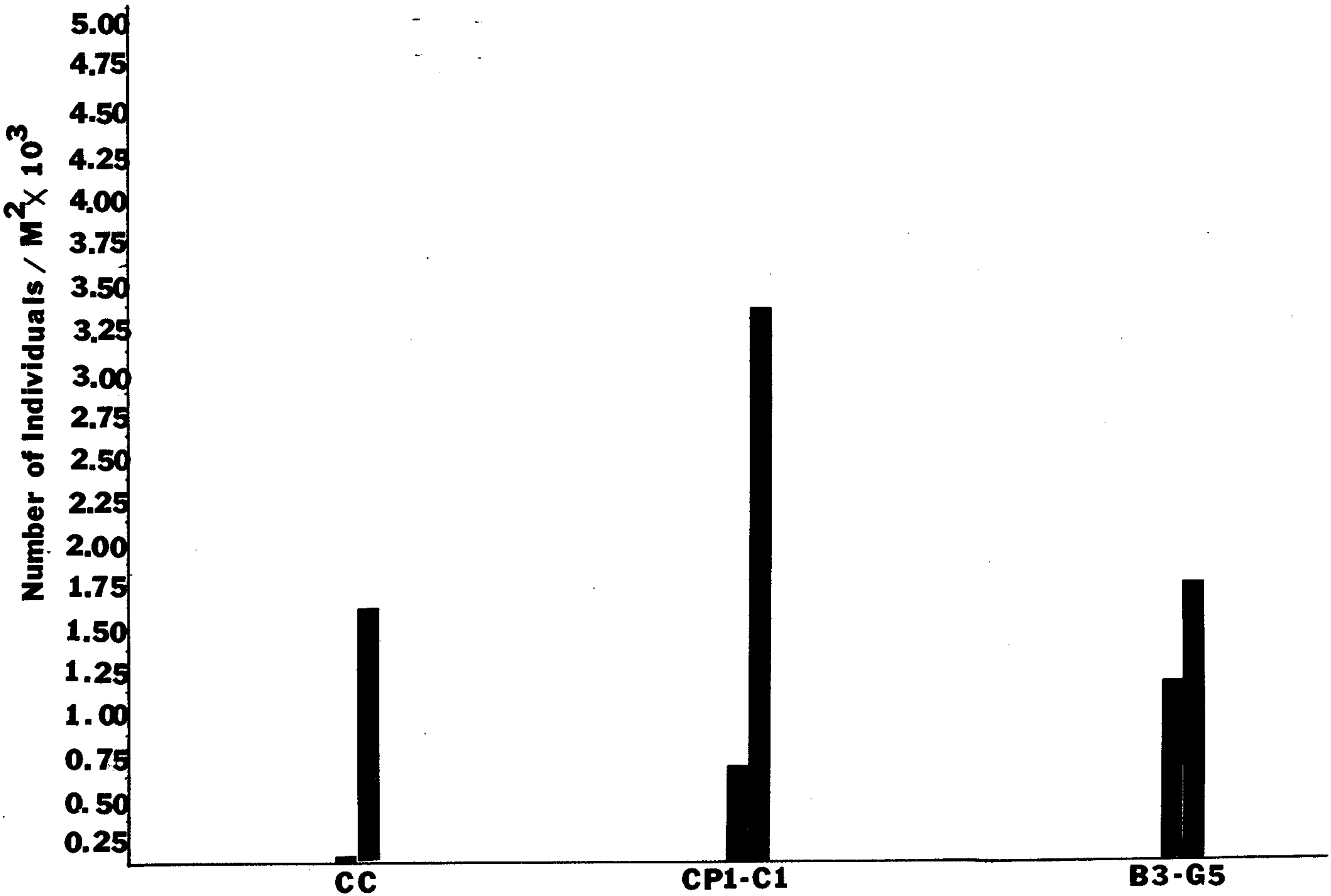
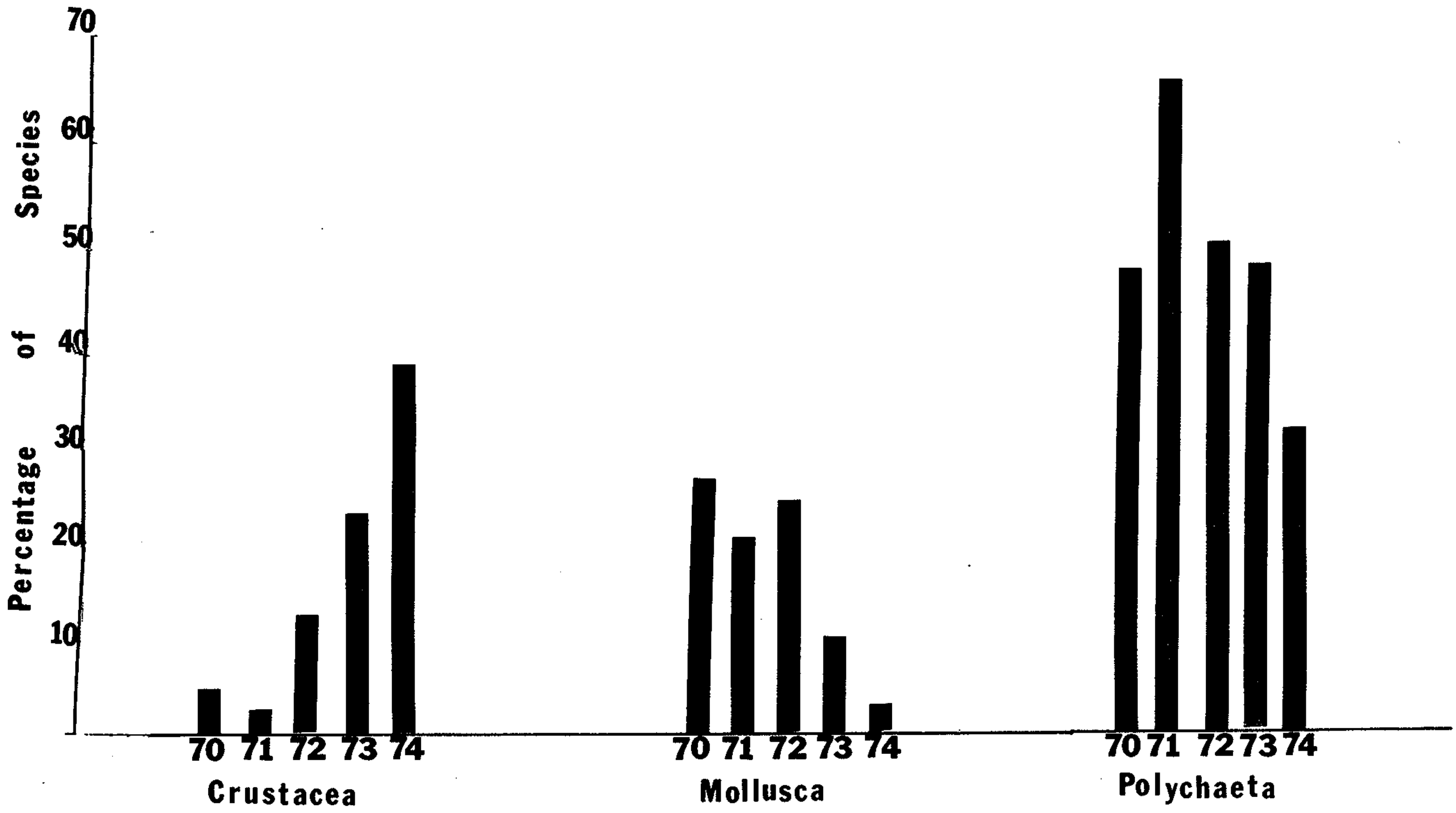

Number of Individuals / $M^2 \times 10^3$
5.00
4.75
4.50
4.25
4.00
3.75
3.50
3.25
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
CC
CP1-C1
B3-G5

FIG. 6

PERCENTAGES OF CRUSTACEAN, MOLLUSCAN, AND POLYCHAETAN SPECIES AT STATION 19, DISCHARGE SITE TO TRINITY BAY, JAN. 1970 TO APRIL, 1973 (FRAME SAMPLES), AND AT STATIONS DS-C1 (POOLED), MAY 1973 TOAPRIL, 1974,(CORE SAMPLES), ALSO AT THE DISCHARGE SITE. The three columns for any one year do not add up to 100 % because not all taxa are included in the study.

Fig 6



Percentage of Species
70
60
50
40
30
20
10
70 71 72 73 74
Crustacea
70 71 72 73 74
Mollusca
70 71 72 73 74
Polychaeta

Table Summary of the data from Stations 19, and C1-DS having to do with community structure, productivity and species diversity based on the benthic samples. Data from 1970 to April 1973 are from frame station 19, those data from April, 1973 to April, 1974 are based on core sampling at the combined stations DS and C1.

1970

Dates	1-8	2-27	4-2	5-2	6-6	7-4	8-1	9-1	10-1	10-30	12-1	Means
NO. Spp	16	10	9	13	16	13	9	15	12	8	13	12.18
No. Ind/M^2	440	316	476	916	860	452	1744	1332	4516	1468	6796	1756
$\bar{H}$ diversity	1.73	1.63	1.01	1.08	1.40	1.50	1.37	1.71	1.62	1.48	1.23	1.43
% Annelida	56.2	40.0	44.4	30.7	56.2	38.4	66.6	60.0	41.6	62.5	46.1	49.34
% Crustacea	6.2	0.0	11.1	15.3	0.0	0.0	0.0	13.3	8.3	0.0	0.0	4.93
% Mollusca	37.5	40.0	33.3	38.4	25.0	38.4	22.2	13.3	16.6	25.0	16.6	27.03

1971

Dates	1-2	2-12	3-9	4-12	5-11	6-7	7-12	8-9	9-9	11-4	12-2	Means
No spp.	12	14	11	9	12	12	13	14	11	11	8	11.5
No Ind/M^2	7220	1176	1560	3106	7490	2732	1008	404	1016	408	252	2397
$\bar{H}$ Diver.	1.27	1.65	1.45	1.14	1.47	1.52	1.26	1.39	1.78	1.68	1.69	1.48
% Annelida	83.3	71.4	63.6	77.7	75.0	66.7	61.5	64.2	81.8	63.6	62.5	70.11
% Crustacea	0.0	0.0	0.0	0.0	0.0	8.3	7.6	7.1	0.0	0.0	0.0	2.09
% Mollusca	16.6	21.4	27.2	11.1	16.6	25.0	23.1	21.5	9.1	27.2	25.0	20.35

1972

Dates	1-6	2-10	3-9	4-18*	5-4	6-1	7-3	7-31	8-26	9-23	10-19	11-16	12-16	Means
No. Spp.	7	12	9	9	3	10	11	10	14	6	12	15	11	9.9
No Ind/M^2	800	1732	444	1528	76	212	160	297	1460	560	1632	5376	27852	3240
$\bar{H}$ Diver.	0.93	1.52	1.43	1.02	1.23	1.37	1.43	1.25	-	1.42	1.30	1.81	0.28	1.15
% Annelida	57.1	58.3	55.5	55.5	33.3	60.0	54.5	40.0	50.0	33.3	66.7	53.3	63.7	52.4
% Crustacea	0.0	8.3	11.1	11.1	0.0	20.0	18.1	20.0	14.2	33.3	8.3	13.4	9.1	12.8
% Mollusca	28.6	16.6	22.2	33.3	33.3	20.0	18.1	30.0	28.6	33.3	16.7	26.7	18.2	25.0

1973

Dates	1-4	2-7	3-21	4-13	5-21**	6-20	7-18	8-18	9-13	10-15	11-8	12-5	Means
No. Spp.	16	15	18	19	10	11	10	11	15	12	10	13	13.3
No Ind/M^2	27116	36752	5088	4780	2058	15149	5186	12350	14985	8316	8458	11053	12608
$\bar{H}$ Diver.	0.53	0.26	1.40	1.98	1.20	1.34	1.47	1.41	1.89	1.71	1.68	1.50	1.36
% Annelida	56.2	60.0	50.0	52.6	83.3	45.4	50.0	45.4	33.3	30.0	30.0	46.1	49.35
% Crustacea	18.7	13.3	16.6	15.8	16.7	27.2	30.0	27.3	33.3	33.3	40.0	15.3	23.95
% Mollusca	18.7	13.3	16.6	15.8	0.0	9.1	0.0	9.1	6.7	0.0	10.0	15.3	9.55

1974

Dates	1-17	2-13	3-12	4-16	Means
No. Spp.	14	16	12	17	15
No. Ind/M^2	67493	25689	24885	30690	37189
$\bar{H}$ Diver.	1.05	1.34	1.63	1.81	1.46
% Annelida	21.4	29.4	50.0	39.1	34.98
% Crustacea	50.0	43.8	27.7	34.7	39.05
% Mollusca	0.0	0.0	5.6	4.4	2.5

* Cooling pond put in operation April 28. 1972

** Begins DS-C1 data

TABLE .

Zooplankton summary. A comparison of species number and number of individuals/M^3 in the summer season and in winter. Winter months included are December, January, and February, and summer months are July, August, and September. Stations compared are IS (intake), CC, (discharge canal), CP1,CP2, andCP3,(cooling pond), DS-C1, (discharge to Trinity Bay), D3-B3, A3,E3, (in Trinity Bay), and F5-G5, (controls).

	IS	CC	CP1	CP2	CP3	DS-C1	D3-B3	A3-E3	F5-G5	Means
Summer No. Spp	30	30	27	17	22	25	24	25	29	25.5
No. Ind/M^3	1315	2268	1585	924	3722	594	786	1826	969	1554
Winter No. Spp	28	26	33	18	24	29	33	35	32	28.7
No. Ind/M^3	416	1367	1563	4802	3695	1383	572	1108	1487	1821
Winter-summer ratio Species	0.94	0.88	1.23	1.06	1.06	1.13	1.39	1.37	1.09	1.12
Individuals.	0.32	0.60	0.99	5.20	0.99	2.33	0.73	0.61	1.53	1.17

TABLE .

NUMBERS OF ZOOPLANKTERS, BLUE_GREEN ALGAE, DIATOMS, AND OTHER PHYTOPLANKTERS TAKEN AT THE INTAKE STRUCTURE, DISCHARGE CUBICAL, FISH PLATFORM IN THE DISCHARGE CANAL, CIWA BRIDGE AND THE TRINITY BAY DISCHARGE POINT.

Phytoplankton and zooplankton taken by Dr Frank Schlicht and J. G. Mackin, July 25, 1972.

Stations:	zooplankton spp	Blue-green spp	Diatom spp	Other Phyton spp.	Totals
1. Intake structure in Cedar Bayou.	13	7	9	7	36
2. discharge cubicle at plant exit.	14	3	3	2	22
3. At Fish Platform in discharge canal	11	2	5	7	25
4. CIWA Bridge, discharge canal	7	3	4	2	16
5. Drop Structure to cooling pond.	10	2	4	5	21
6. Discharge to Trinity Bay, above the drop structure	11	5	7	2	25
Means	11	3.7	5.3	4.2	24.2

Table .

Analysis of winter conditions in the cooling pond, discharge to Trinity Bay, and in north and south Trinity Bay. The analysis is based on collections of Phytoplankton on December 19, 1972, about 8 months after the pond was put in use.
(Note: values in parentheses are for chlorophyll A.)

Stations	No. of diatom Species	No. Blue-green Species	Other Phyto-plankton spp	Totals
1. North end cooling pond	10	0	12	22 (14)
2. Discharge to Trinity Bay	8	0	3	11 (44)
3. N. Trinity Bay	19	0	3	22 (31)
4 S. Trinity Bay	11	0	4	15 (29)
Means	12	0	5.5	17.6 (29.5)