The effects of pulpmill effluent on phytoplankton production in coastal waters of British Columbia

by John G. Stockner, D. D. Cliff and K. Munro

FISHERIES AND MARINE SERVICE
SERVICE DES PÊCHES ET DES SCIENCES DE LA MER

TECHNICAL REPORT No.
RAPPORT TECHNIQUE N° 578

1975

Environment Canada | Environnement Canada

Fisheries and Marine Service | Service des pêches et des sciences de la mer

Technical Reports

Technical Reports are research documents that are of sufficient importance to be preserved, but which for some reason are not appropriate for primary scientific publication. Inquiries concerning any particular Report should be directed to the issuing establishment.

Rapports Techniques

Les rapports techniques sont des documents de recherche qui revêtent une assez grande importance pour être conservés mais qui, pour une raison ou pour une autre, ne conviennent pas à une publication scientifique prioritaire. Pour toute demande de renseignements concernant un rapport particulier, il faut s'adresser au service responsable.

Department of the Environment
Fisheries and Marine Service
Research and Development Directorate

Ministère de l'Environnement
Service des Pêches et des Sciences de la mer
Direction du Recherche et Développement

TECHNICAL REPORT No. 578

RAPPORT TECHNIQUE N^{o}. 578

(Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. The series name was changed with report number 457).

(Les numéros 1-456 dans cette série furent utilisés comme Rapports Techniques de l'office des recherches sur les pêcheries du Canada. Le nom de la série fut changé avec le rapport numero 457).

The effects of pulpmill effluent on phytoplankton production in coastal waters of British Columbia

by

John G. Stockner, D.D. Cliff and K. Munro

This is the twenty-first Technical Report from the Research and Development Directorate Pacific Environment Institute West Vancouver, B.C.

Ceci est le vingt-et-unième Rapport Technique de la Direction du Recherche et Développement Institut de l'environnement du Pacifique Vancouver-Quest

1975

TABLE OF CONTENTS

Page

INTRODUCTION 1

STATION LOCATIONS 2

METHODS 2

Physical & Chemical 2

Biological 4

RESULTS 6

Physical-Chemical Parameters 6

Biological Parameters 13

Primary Production 17

Special Light-Production Experiments,
Stations 3 and 4 18

Production-chlorophyll data from other
B.C. coastal pulp mills and their controls. 19

DISCUSSION 20

BIBLIOGRAPHY 29

TABLES 31

APPENDIX TABLES 71

FIGURES 79

ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance of the officers and crew of CFAV ENDEAVOUR and LAYMORE and Messrs. Ken Shortreed, Doug Buchanan and Sandy Matheson for their assistance in the field aspects of the program. We are grateful to Miss Anne Costella who has contributed time and effort in carrying out the axenic culture work. Special thanks are extended to Drs. M. Waldichuk and N. Antia for critical review of the manuscript. We are most grateful to Environmental Protection Service, Department of Environment, for providing funds to support the axenic culture work on kraft mill effluent toxicity.

ABSTRACT

Stockner, John G., D.D. Cliff and K. Munro. 1975. The effects of pulp mill effluent on phytoplankton production in coastal waters of British Columbia. Fish. Mar. Serv. Res. Dev. Tech. Rep. 578: 99 p.

Phytoplankton production in waters adjacent to two kraft pulp mills in Howe Sound, British Columbia, was considerably lower than daily rates at control stations removed from the zone of influence. Average production at Station 4 (Port Mellon mill) was 29 and 24 mg C m^{-2} day^{-1} in 1973 and 1974, in contrast with 332 and 367, in respective years at the control. Less difference in production was seen between the woodfibre mill (Station 8) and its control, because this mill is situated in a more actively flushed location from the direct influence of the Squamish River. Cursory data from six other mills on the coast of British Columbia showed trends similar to those seen in Howe Sound, with the least difference in production between mill and control sites occurring at the most actively flushed locations. Howe Sound studies showed little qualitative or quantitative differences between phytoplankton assemblages among mill and control stations, with *Skeletonema costatum* and *Thalassiosira* spp. as dominants. Light attenuation by whole kraft mill effluents (KME) is considered the major factor responsible for production depression in water within the zone of influence (stain gradient). Axenic culture work showed that phytotoxicity occurs at high concentrations of KME, but given sufficient time, it is possible for most of the hardier species to adapt to the effluent, if pH remains normal. Nutrient enrichment may occur with improved light penetration some distance from the discharge point, and may enhance production at certain locations at times of nutrient scarcity.

RÉSUMÉ

Stockner, John G., D.D. Cliff and K. Munro. 1975. The effects of pulp mill effluent on phytoplankton production in coastal waters of British Columbia. Fish. Mar. Serv. Res. Dev. Tech. Rep. 578: 99 p.

La production de phytoplancton dans les eaux adjacentes à deux usines de pâte kraft situées dans la baie Howe (Colombia-Britannique) a été considérablement inférieure à celle enregistrée à des stations de contrôle situées à l'extérieur de la zone d'influence. La production moyenne quotidienne à la station 4 (usine de Port Mellon) a été, respectivement, de 29 et de 24 mg de C par m^2 par jour pour 1973 et 1974 comparativement à 332 et à 367 mg aux stations de contrôle pour ces mêmes années. On a trouvé use différence moins importante entre la production de phytoplancton pris de l'usine de Woodfibre (station 8) et celle constatée à la station de contrôle, car l'usine est située dans un endroit où l'eau est plus fortement renouvelée d'une influence directe de la rivière Squamish. Des données fragmentaires provenant de six autres usines situées sur la côte de la Colombie-Britannique ont montré des tendances similaires à celles de la baie Howe, les différences de production de phytoplancton entre les eaux se trouvant à proximité des usines et celles des stations de contrôle étant moindres là où les eaux sont plus activement renouvelées. Les études effectuées dans la baie Howe ont montré peu de différences quantitatives ou qualitatives entre les groupes de phytoplancton présents dans les eaux proches des usines et des stations de contrôle. *Skeletonema costatum* et *Thalassiosira* spp. représentaient les groupes les plus importants. On pense que la diminution de l'éclairement due aux effluents est le principal facteur de réduction de la production dans les eaux situées dans la zone d'influence (gradient de matière colorée). Des

cultures axéniques ont montré que les fortes concentrations d'effluents étaient phytotoxiques mais qu-après un certain temps la plupart des espèces les plus résistantes pouvaient s'adapter à l'effluent à condition que le pH demeure normal. Il peut y avoir un enrichissement en substances nutritives combiné à un éclaireissement de l'eau à distance de la décharge favorisant la production à certains endroits aux périodes où il y a peu de matière nutritives.

INTRODUCTION

The environmental effects of pulp mill effluent discharge on marine phytoplankton communities in British Columbia coastal waters is not well understood. Tully (1949), Waldichuk (1954), Parker and Sibert (1972) and Sibert and Parker (1972) have studied effects of kraft mill effluent (KME) discharge in Alberni Inlet, B.C. as it relates to depressed oxygen levels, but with the exception of the latter two studies, the effect of light attenuation by KME stain on phytoplankton photosynthesis has been ignored. Practically nothing is known of the potential toxicity of mill effluent to marine algae.

Since April 1972, the plankton ecology group at the Pacific Environment Institute has been interested in the production and distribution of phytoplankton in Howe Sound and the Strait of Georgia. This work has included sampling two stations in Howe Sound located adjacent to two kraft process pulp mills, Woodfibre and Port Mellon. A significant reduction in primary production was noted in water adjacent to these mills, when compared with controls situated a few kilometers removed. Attempts were made in 1973 and 1974 to elucidate whether phytotoxicity or light attenuation were involved in the observed production depression.

This report presents results of data gathered over a three-year period at mill and control stations. The data base represents over 200 "in situ" experiments. Supportive information from a cursory examination of an additional six pulp mills situated on the B.C. coast are also presented, together with results of laboratory work conducted in 1975 to test KME for phytotoxicity.

STATION LOCATIONS

Stations 3, 4, 6 and 8 were situated in Howe Sound, a coastal embayment located close to Vancouver, British Columbia (Fig. 1). Station 4 (Z_b = 40 m) was located approximately 50 meters from the acid-sewer discharge at Port Mellon. Station 3, (Z_b = 150 m), the control for Station 4, was located 100 m off the southern tip of Woolridge Island, 2 km from Station 4. Station 8 (Z_b = 65 m), off Woodfibre, was 50 m east of the Mill Creek discharge. Station 6, (Z_b = 50 m), the control for Station 8, was situated on the "sill" at the constriction of Howe Sound, 11 km south of Woodfibre. All stations were sampled monthly commencing in February - March, 1973.

In 1973 and 1974 one experiment to determine daily production was conducted off six mills located along the B.C. coast (Fig. 2).

METHODS

Physical & Chemical

Light. Total incident solar radiation (gram-calories·cm^{-2}) was recorded on a Belfort Pyrheliometer. Extinction of surface light with depth was measured by a Montedoro-Whitney Underwater Illuminance meter (Model LMT-8A). These data were plotted on a Hewlett Packard Calculator plotter, and a line was regressed through the points whose slope gave a mean extinction coefficient, k. Intensity of surface radiation (in foot-candles) was measured by a Gossen hand-held light meter. A standard 30-centimeter white Secchi disc was used to measure water transparency at every set. In measuring light penetration adjacent to pulp mills, special care had to be taken to drift onto the station so as not to disturb the surface stain.

Temperature. Temperature profiles to a depth of 60 meters were obtained with a bathythermograph A bucket thermometer was used to measure surface temperatures for B.T. calibration.

Alkalinity. Water samples were collected from 1, 3, 5 & 20 meter depths, and stored in acid-rinsed 100 ml polyethylene bottles. Samples were analyzed for alkalinity using an Orion digital pH meter (Model 801). The method of Strickland & Parsons (1968) was used to determine carbonate alkalinity. However, if after acid addition final pH values fell below 3.00, then the sample titration was repeated using the APHA (1971) standard titrimetric method.

Salinity & Density. Water samples were taken from 1, 3, 5 & 20 meter depths, and analyzed with an Auto-Lab salinometer (Model 601), to an accuracy of ± 5%. Density was computed by nomograph from temperature and salinity records.

Dissolved Oxygen. Samples were analyzed from 1, 3, 5 & 20 meter depths using the Winkler titration method (Strickland & Parsons, 1968). Samples in standard 300 ml glass-stoppered BOD bottles were fixed within an hour of being taken, and dissolved oxygen was determined the same day.

Nutrients. Samples for nutrient analysis were obtained from 1, 3, 5 & 20 meter depths, and immediately frozen. Samples were analyzed by the Fisheries Operations/Environmental Protection Service analytical laboratories, Pacific Environment Institute, West Vancouver. Methods used are as outlined in their manual (Fisheries/EPS, 1974).

Biological

Primary Production. The standard ^{14}C method, as initially proposed by Steemann Nielsen (1952), was used, with some minor modifications incorporated. Water was collected from surface, 0, 1, 2, 3, 5, 10, 20 & 30 m depths using a 6 litre polyvinylchloride Van Dorn bottle. Productivity bottles (two 125 ml light and one 125 ml dark) were inoculated with 1 ml $NaH^{14}CO_3$ (1 μc) radioisotope stock using an automatic pipette. For each experiment, the number of DPM's ml^{-1} was determined by placing 1 ml in each of three scintillation vials. In most cases, samples were incubated for 4 - 5 hours, normally from 0930 to 1430 hours. Water was filtered through 0.45 μ BDH cellulose nitrate filters, and placed in 10 ml of a specially prepared toluene based fluor[1]. Samples were analyzed for activity in a Packard Tri-Carb Liquid Scintillation Spectrometer (Model 3375). The equation of Strickland (1960) was used to convert DPM's to mg $C \cdot m^{-3}$. Profiles were integrated by a Hewlett Packard Calculator Plotter (Model 9820A) to give phytoplankton production on an areal basis ($mgC \cdot m^{-2} \cdot day^{-1}$).

Phytoplankton Standing Crop. Detailed examination was made of phytoplankton samples from 1 and 5 m depths in order to assess: (a) species composition, and (b) phytoplankton volumes during key spring and fall bloom periods. Phytoplankton samples were preserved in Lugol's solution and enumerated, using the Utermöhl (1958) sedimentation method. Volumes were determined by equating phytoplankton cells to known geometrical shapes. Each phytoplankton sample was examined under 175 & 700X magnification using a Wild M40 inverted plankton microscope. Results were expressed as cells and total volume $\cdot m^{-3}$.

[1] POPOP, PPO, ethyleneglycolmonoethylether, & toluene

Chlorophyll a. One liter of sea water was taken from 1, 3, 5 & 20 meter depths, and filtered onto Whatman GF/C glass fibre filters with a small amount of $MgCO_3$ added to prevent acidification of filters with freezing. Filters were macerated in a tissue grinder with 10 ml of 90% acetone, and the filtrate analyzed for chlorophyll a and phaeophytin on a Cary recording spectrophotometer (Model 15). The equation of Strickland & Parsons (1968) was used to calculate chlorophyll a. Considerable problem was encountered with colour interference of KME stain, making results from the mill stations difficult to interpret accurately.

Seston. One-liter samples were obtained from 1, 3, 5 & 20 meter depths; and filtered on preweighed Whatman GF/C glass fibre filters. Filters were dried to constant weight at 105°C, weighed, and ashed in a muffle furnace at 500°C for 4 hours. Percent loss on ignition was used to estimate particulate organic seston.

Zooplankton. Vertical hauls from 100 m to surface were made in 1973 and changed to 50 m to surface in 1974. Hauls were made with a SCOR-UNESCO plankton net, with mouth diameter of 57 cm and screen mesh size of 350 μ. Samples were preserved in 5% formalin, returned to the laboratory and split into two equal subsamples. Zooplankton volume was determined from one portion in an Imhoff cone, and the other portion was filtered onto a preweighed GF/C filter and dried to constant weight at 105°C. After dry weight determination they were placed in a muffle furnace at 500°C for four hours to estimate ash-free dry weight. Values are expressed as $ml \cdot m^{-3}$ and $mg \cdot m^{-3}$.

Special Light Experiments. During regular monthly cruises to Port

Mellon, daily areal production was obtained at Station 4 (directly in front of the mill) and at Station 3, the control (2 km east of the mill). On five occasions, special light experiments were run which differed from the aforementioned in the following way: two sets of ^{14}C incubation bottles (4 light, 2 dark) were filled at each station, one set (2 light, 1 dark) was incubated "in situ" at the normal location; the other was incubated at the other station. This meant that for station 4, one set received normal light during incubation, while the second set received strongly attenuated light under the KME stain. The reverse situations occurred at Station 4, where one set was in its normal location under the stain, while the other was brought to Station 3 and received normal light.

Toxicity Experiments. A series of phytoplankton bioassays was conducted using KME, from a number of mills. Methods used in the axenic pure culture work are as described by Antia & Cheng (1975) and Stockner (1975). Some results from the latter work will be presented in the discussion section to substantiate the "in situ" findings from Port Mellon cross-incubation experiments.

RESULTS

Physical-chemical Parameters

Temperature

Stations 3 & 4 (Table 1). In both 1973 and 1974 isothermal conditions prevailed in November and early April with stratification developing in late April. A negative temperature gradient occurred throughout the winter months, with temperatures averaging 5°C from 0 to 10 m and 7.5°C at greater depths. Mixed layer depth in summer varied from 4 to 5 m in June, July, deepening to 7 - 10 m in August and September. Surface temperatures ranged from a low of 4.7°C in January to a high of 17.5°C in August.

Stations 6 & 8 (Table 2). The temperature regime at both these stations was somewhat similar to those seen at Station 3 and 4, except summer surface maxima were considerably lower owing to the strong surface outflow of the Squamish River. Surface values were generally 3 - 4°C lower, except at 20 m, where they were similar to those at Stations 3 and 4. During strong freshet periods, the colder Squamish River water imparted a double thermocline to the temperature/depth profile. This colder surface layer was seldom greater than 2 m thick, with the "normal" thermocline occurring between 7 and 10 meters.

Salinity

Stations 3 & 4 (Table 3). Salinity values at 20 m remained relatively stable throughout the year, ranging from a low of 27.8 to a high of 29.9 ^{0}/oo. There was a marked seasonal trend in surface salinities at both stations. Because of the influence of both Fraser and Squamish River systems on surface salinities, the depth of the halocline from May to November varied from 3 to 7 m. Surface salinities ranged from winter highs of about 27 ^{0}/oo to lows in August of 8.6 ^{0}/oo. Surface salinities at Station 4 tended to be slightly lower than at 3 because of the discharge of the Rainy River (adjacent to the mill) and consisting largely of freshwater mill effluent.

Stations 6 & 8 (Table 4). Salinity values at 20 m were relatively stable, ranging from 27.9 to 29.8 ^{0}/oo. Surface salinities to a depth of about 5 m were strongly influenced from June to September by Squamish River flow. As the Squamish water travels seaward it entrains underlying water of high salinity. This surface layer attains a depth of about 2 m at Woodfibre and 3 m at Station 6 on the sill. This lower salinity water overlies a second layer of warmer, more saline water, ranging in depth from 2 - 5 m. The dynamics of this multi-layered system are described in greater detail by Giovando (MS 1972). Surface salinities at Station 8 are lower than at Station 6, ranging from 2 to 24^{0}/oo, compared to 4 to 26^{0}/oo, at the latter.

Density

Stations 3 & 4 (Table 5). Density (σt) structure was very similar to that of salinity. At 20 m there was little seasonal variation with σt values ranging from 21.40 to 23.40. Fluctuations in surface waters were much greater, ranging from 5.41 in August to 20.91 in January. The pycnocline in summer was at aproximately 5 to 7 m depth, varying with the halocline and thermocline depth.

Stations 6 & 8 (Table 6). Density structure at these stations was strongly influenced by Squamish River flows. Density at 20 m was seasonally stable, with σt's ranging from 21.00 in August to 23.40 in March. Surface values were extremely variable and strongly influenced by Squamish River flow. In May, during river freshet, values were as low as 1.32, while two months previously they were 20.66. A double pycnocline occurs at both stations throughout the summer, as the Squamish River water flows seaward on the surface of Howe Sound. This surface low-density layer extends to a depth of about 2 meters off Woodfibre (slightly deeper at Station 6) and overlays a more dense, often warmer layer of water, extending to a depth of about 5 to 7 m.

Dissolved oxygen

Stations 3 & 4 (Table 7). Several trends were observed in oxygen profiles. There was no indication of oxygen depletion to a depth of 20 m in water adjacent to the mill. Highest values occurred in surface waters, especially during phytoplankton bloom periods, and lowest values were at 20 m. Seasonally, values ranged from a low of 3.5 mg/l at 20 m at Station 4 in December to a high of 10.6 mg/l at 1 m depth at Station 3 in April.

Stations 6 & 8 (Table 8). Dissolved oxygen adjacent to Woodfibre was often less than at Station 6 at the sill. On several occasions, 1 m samples were lower than those at 3 m. Similar variations with depth and season, as discussed for Stations 3 & 4 were also seen here. Values at 20 m ranged from 2.8 to 8.6 mg O_2 liter^{-1}. At 1 m depth values ranged from a low of 4.7 at Station 8 in May to a high of 10.7 mg O_2 liter^{-1} at Station 6 in April, 1974.

Total carbonate carbon

Stations 3 & 4 (Table 9). Wide variations in carbonate carbon were seen in surface values, reflecting seasonal changes in surface salinities. Beneath the pycnocline little variation was noted. Values increased with increasing salinity and depth and were lowest during the summer when surface waters were influenced by river freshet. At 20 m depth values ranged from 18,000 to 24,000 mgC$\cdot$m^{-3}, while at the surface they ranged from 6,000 in summer months to 21,000 in February.

Stations 6 & 8 (Table 10). Carbonate carbon showed similar variations as noted at Stations 3 & 4, with the exception of surface values which tended to be lower due to Squamish River discharge. At 20 m, values ranged from 20,000 to 25,000 $mgC \cdot m^{-3}$, while surface values ranged from mid-summer lows of 4,000 to highs of 21,000 in February.

Light

Stations 3 & 4 (Tables 11 & 12). Total available light energy showed typical seasonal variation with maximums in June - July and minimums in December - January. Total light on bright days was reduced at Station 4 by haze from stack emissions. This haze on certain days with no wind also reduced total radiation at Station 3.

There was a marked difference in extinction coefficients between stations. This can be seen in both individual daily readings and in grand means for both years. Seasonal averages for Station 3 were 0.42 and 0.38 in summer contrasted to 1.65 and 2.37 for Station 4, in respective years.

Secchi disc depth values (transparency) were considerably different between stations. These differences were reflected in both means and their respective ranges for 1973 and 1974. Secchi disc depths varied from 1.0 to 8.5 m at Station 3 and from 0.1 to 6.5 m at Station 4.

Two representative plots of light as a function of depth, one from relatively clear water at Station 3 and the other in KME stain at Station 4, serve to illustrate the light-attenuating properties of KME and seawater in surface waters of Howe Sound (Figures 3a & 3b).

Stations 6 & 8 (Tables 13 & 14). Since Stations 6 & 8 were often sampled on consecutive days, comparisons of total light energy available are subject to daily variations, and hence it is difficult to draw valid comparisons between these stations. One can conclude from these data that total light energy was basically similar at both stations. Because the pyranometer was placed at a central location, true variation between stations is not shown. Station 8 receives, on the average, considerably less light than Station 6, owing to an almost constant haze from stack emission around the mill.

There was again a marked difference in both daily and seasonal mean extinction coefficients between stations. Seasonal means for 1973 and 1974 for Station 6 were 0.40 and 0.49 while at Station 8 they were 0.99 and 1.7 in respective years. During Squamish River freshet, it is difficult to separate attenuating properties of KME from glacial flour turbidity, both of which affect light adjacent to the mill.

Secchi depth values varied widely with season and were lowest during Squamish freshet at both stations. Annual means at Station 6 in 1973 and 1974 were 4.2 and 4.3 m in contrast with 1.9 and 1.3 m at Station 8, respectively. Secchi values ranged from 1.0 to 7.0 m at Station 6 and from 0.6 to 4.0 at Station 8.

Light conditions, occurring on one-day visits to six additional coastal mills in 1973 and 1974, are presented in Appendix Tables 1 & 2.

Nutrients

Stations 3 & 4 (Tables 15, 16 & 17).

Nitrate (NO_3 N). A distinct seasonal pattern was noted both years in the temporal and vertical distribution of NO_3(N) (Table 15). Seasonally, values in the euphotic zone (0 - 7 m) were highest at both stations in early spring and late autumn, and lowest following the spring bloom in April. Values remained low throughout the summer in both years and rose again in November. Values at 20 m showed less seasonal variation. Highest values at all depths occurred in winter. The greatest rate of change in nutrient concentration occurs proportionally with the rate of onset of the spring bloom, dropping in both years to undetectable levels.

Total Phosphate (TPO_4 P). Values of this parameter showed little seasonal variation at Stations 3 and 4 in both years (Table 16). A slight decrease was noted commensurate with the vernal bloom, but with this exception, values showed no relation to other physical or biological parameters. Average values of TPO_4 in the euphotic zone was slightly lower than the 20 m average values at both stations in 1973 and 1974.

Silicate (SiO_2). In general, silicates increased with increasing depth and were highest in late autumn and during winter months (Table 17). In the euphotic zone, throughout the growing season, values were considerably less than those at 20 m, reflecting the uptake of this nutrient by common diatoms.

Stations 6 & 8 (Tables 18, 19 & 20).

Nitrate (NO_3 N). Similar seasonal trends to those discussed for nitrate at Station 3 & 4 were also seen at these stations (Table 18). Summer values here did not fall as low as at Stations 3 & 4 and were seasonally more variable. In 1974, values in the 0 - 5 m layer at Station 8 were consistently higher than from a similar depth range at Station 6.

Total Phosphate (TPO_4 P). No clear seasonal patterns in spatial or temporal distribution were evident, with the exception of 20 m values, which were consistently higher than 0 - 5 m values (Table 19).

Silicate (SiO_2). Highest values occurred in the winter months and as observed at Stations 3 and 4 (Table 20), there was no noticeable increase with increasing depth in 1974.

Biological Parameters

Phytoplankton

Species Composition (Table 21 - 24, Figure 4 & 5). At all four stations, the phytoplankton community was composed of diatoms, dinoflagellates, cryptophytes, silicoflagellates, chrysophytes and euglenoids, with diatoms making the major contribution in terms of both number and volume. There was no significant variation in class composition of phytoplankton among stations. A species list for each station is presented in Tables 21 - 24.

Skeletonema costatum and *Thalassiosira* spp. (*T. pacifica, T. nordenskioldii* and *T. aestivalis*) were dominant spring bloom species at all stations. Other species commonly found at all stations were *Chaetoceros* spp., *Nitzschia seriata, N. closterium, Navicula* spp., *Thalassionema nitzschoides*, and small unidentified flagellates (mainly cryptomonads and chrysomonads). Three species of dinoflagellates were common at Stations 3 and 4; but not at 6 and 8: *Gymnodinium* (sp. 1), *Glenodinium danicum,* and a very small species of *Gymnodinium* (sp. 2).

Standing Stock - seasonal maxima. A Station 3, algal blooms occurred in June 1973 and May 1974 (Fig. 4). No distinct spring maximum was noted at Station 4 in 1973, but cell volumes and numbers increased during the 1973 May - July period. However, in 1974, a bloom was recorded at this station in May. Blooms were noted in both years at Station 6. At Station 8, a bloom was sampled in April 1973. Unfortunately, no sampling was done in the spring of 1974 (Fig. 5). Autumnal peaks in total cell volumes were noted in September - October, 1974, at Stations 3, 4 and 6, but not at Station 8. The blooms in 1974 were far greater than those in 1973, and total cell volumes were higher at Station 6 than at Stations 3, 4 and 8.

Bloom dominants, 1973 - 1974. During the bloom in 1973 at Station 3, *Skeletonema costatum* contributed about half of the total cell volume, and *Thalassiosira* spp. about a quarter of the total. At Station 4, *Thalassiosira* spp. were responsible for most of the increase in total cell volume. In 1973 the bloom consisted almost totally of *Thalassoisira* spp., at Station 6, while at Station 8, *Skeletonema costatum* was the major contributor.

In 1974, spring blooms at Station 3, 4 and 6 were dominated by *S. costatum*, which contributed 84 - 93% of the cell volume. Station 8 was not sampled at this time period. Total cell volumes noted during bloom periods, showing as differences in timing and magnitude at each station were as follows:

	Total cell volume spring bloom ($mm^3 \cdot m^{-3}$)			
Station	3	4	6	8
1973	June 20 8947	May-July 2400-3200	April 4 19,990	April 17 16,786
1974	May 9 19,634	May 9 20,972	May 9 24,280	-

Chlorophyll a.

Stations 3 & 4 (Table 25). Mean values of chlorophyll a at both stations were highest during bloom periods and lowest in winter months. Most of the chlorophyll was concentrated in the euphotic zone (0 - 5 m) from April to

October of both years at both stations. Highest concentrations were 6.8 and 4.6 $mg \cdot m^{-3}$ at Stations 3 and 4 respectively, in April 1973. The 20 m values were consistently lower than surface values at most observational periods.

Station 6 & 8 (Table 26). The trends discussed for Stations 3 and 4 were also seen at Stations 6 and 8, with the exception that Station 8 had considerably less chlorophyll $\cdot m^{-3}$ than Stations 3 and 4 in 1974. June - July periods were characterized by low chlorophyll values due to the turbid Squamish River discharge which effects both stations. The 1974 bloom at Station 6 in 1974 was not accompanied by significant increases in chlorophyll a, perhaps because of flushing.

Seston

Stations 3 & 4 (Tables 27 & 28). Seston varied both seasonally and with depth, and displayed little relation to the distribution of phytoplankton or chlorophyll a. Means were higher in both years at all depths at Station 4, owing to the discharge by the mill of particulate wood fibres to surface waters. In April - June, values were often higher at 20 m than in surface waters. This was likely due to senescent phytoplankton sinking from the euphotic zone. Seston was lowest at both stations in November - December and highest in the phytoplankton bloom period, March - June.

The discharge of fine particulate wood fibers is more clearly seen in percent loss-on-ignition (%LOI organic) values, where means for Station 4 were higher than for Station 3 in both years. Highest percent organic content was in May - June at Station 3, following the vernal bloom. Highest value at Station 4 was in March 1974 in the 1 m layer.

Station 6 & 8 (Tables 29 and 30). Dry seston values were considerably higher at Station 8 off Woodfibre. The mean value for 1973 was over 3 times higher than the mean for Station 6. This difference was caused by the discharge of wood fibers to surface waters by the mill. Highest values occurred in October 1973 at both stations at all depths. In 1974 the highest value, 263 $mg \cdot m^{-3}$, was noted in May, at a depth of 3 m off Woodfibre. Bloom periods could not be discerned by increases in seston; in fact, seston values dropped at both stations from relatively high April values in May of both years.

Differences between stations were not as readily apparent in means of organic seston ($\%LOI \cdot m^{-3}$). In 1973, means of organic seston of both stations were similar, but in 1974, average values at Station 8 were about a third higher. Greatest percentages of organics at all depths were in the winter, when the flow of the Squamish was low and the water was relatively clear. Lowest values coincided with freshet and turbid water conditions. This relationship was evident in 1973 at Station 6, but not in 1974, when river discharge was considerably less. Woodfibre is closer to the river and should also show this trend; however, the strong back-eddy effects, coupled with the discharge of particulate organics, obscures the trend.

Zooplankton

Stations 3 & 4 (Table 31). Seasonally, both stations had comparable amounts of zooplankton in 1973, but in 1974, Station 4 had on the average twice the biomass of Station 3, however the 1974 average was considerably less than the 1973 average. At Station 3, greatest biomass occurred in July and September of 1973 and in May of 1974. Peak periods at Station 4 were in February and July of 1973, and in May of 1974.

Stations 6 & 8 (Table 32). Comparisons between stations are very difficult, because of the large wood fiber content in zooplankton caught in the net off Station 8. This cannot be readily separated, and therefore, biases the values accordingly. Biomass averages for Station 6 were similar to those of Station 3 and 4 with maxima in April and December, 1973, and in January and May, 1974.

Station 8 values were nearly 3 times greater than those at Station 6, and averaged 47 $mg \cdot m^{-3}$ each year. Greatest amounts were seen in April, 1973, and in January and October, 1974, but all values were high and showed no obvious trends.

Primary Production

Areal rates

Stations 3 & 4 (Table 33, Fig. 6). There was nearly an order of magnitude difference in average areal production between Station 3 and 4. The seasonal pattern at Station 3 was typical of many stations in Howe Sound, displaying clear spring and fall phytoplankton peaks. Production at Station 4 was consistently low, averaging only 29 $mg\ C \cdot m^{-2}\ day^{-1}$, contrasted with an average of 332 at Station 3. A typical vertical production profile from April 4, 1974 shows most production occurred in the top 3 m, with some surface light inhibition on bright days (Fig. 6).

Stations 6 & 8 (Table 33, Fig. 7). Average seasonal production at Station 6 was nearly double the average at Station 8. The typical bimodal seasonal pattern, with spring and fall peaks, was not obvious at these stations, especially Station 8, where Squamish River turbidity and KME stain in surface waters suppressed production throughout much of the growing season.

Vertical production profiles from the July river freshet period illustrate the lack of significant production in surface layers at these stations (Fig. 7).

Special Light-Production Experiments, Stations 3 and 4 (Tables 34, Figs.8 & 9).

On certain dates special light-production experiments were conducted to test the effects of light on the slope of the production profile around the KME cloud. Results from one experiment in May,1975 illustrates the type of data obtained from cross incubation (Figs. 8 & 9). When one control set from Station 3 is incubated beneath the KME stain layer at Station 4, a significant reduction in production results (Fig. 8). Conversely, when a set from beneath the cloud is brought to Station 3 for incubation a significant increase is noted (Fig. 9). Since the magnitude of increase of production by Station 4 phytoplankton at Station 3 does not come close to production observed at Station 3, either phytotoxicity, absence of phytoplankton, or time adaptation are suggested as relevant causative factors. Data in Table 34 show that production cannot be restored to "normal levels" by a simple improvement in light quality and quantity. Either the phytoplankton require a suitable time period to adapt (which may be too short in the 4-hour incubation period) or the physiological state of individual plankters has been altered by components of KME. It is interesting to note that the "factor of increase" (column 4, Table 34) is usually larger than the "decrease factor" (column 2, Table 34), noted when algae from the control are incubated in the KME stain. Adaptation rates by phytoplankton to such large light shifts are likely much slower than the experimental incubation period.

When one examines the vertical profiles of volumetric production accompanying these cross-incubation experiments, interesting trends can be seen. Depth production maxima move upward when the control is incubated under the stain (Fig. 8), and the maxima never occur in the 0 - 1 meter layer when the stain-adapted phytoplankton are brought into bright light at Station 3 (Fig. 9). Much of the variation seen in the vertical profiles can be explained by simple light-adaption processes discussed in later sections.

Mill Closure, summer 1975 (Fig. 10A,B).

The restoration of primary production to near normal conditions following cessation of effluent discharge at Port Mellon is illustrated in Figures 10A. When compared with production measured at the control (Fig. 10B) on the same days over the same time period, the proportionate increase adjacent to the mill after 14 days was 56 times compared with less than 2 at the control. The light regime on each of the three days of measurement were similar at both mill and control stations.

Production-chlorophyll data from other B.C. coastal pulp mills and their controls (Table 35).

Six mills were visited in 1974 and two in 1973. In most experiments, production was higher at the control station, following the trend seen in Howe Sound Stations 3, 4, 6 and 8. Those mills situated in areas of rapid tidal flushing showed practically no effect of KME (Harmac, Elk Falls), while those located in inlets with little flushing showed the greatest inhibition (Port Alice, Port Edward). In the fall of 1974, greatest production occurred near the Harmac and Elk Falls mills, and the least was observed off Powell River, Port Alice and Port Edward mills.

DISCUSSION

Pulpmill effluents, in particular KME, can reduce primary production in two ways: a) by light attenuation caused by the brown stain and, b) by phytotoxicity or physiological stress induced by various components in the effluent. Regardless of pathway, the net effect is a reduction in phytoplankton growth in waters adjacent to mills. The results presented in this report have amply demonstrated the field effects. However, the elucidation of mechanisms, limiting concentrations, etc., required laboratory experimentation, where better control of parameters affecting growth can be maintained. The combination of both laboratory and field experimentation is the only sensible approach to solving problems related to pulp mill effluent discharge.

Light

Parker and Sibert (1972) were among the first to quantify the potential effect stain has on phytoplankton growth. They hypothesized that the "black stain cloud" attenuates light sufficiently to retard photosynthesis in all but surface layers in the zone of influence, thereby diminishing the oxygen concentration in waters beneath the halocline. They maintained that removal of the stain would restore O_2 levels to sufficient concentrations to ensure safe passage for fish in waters adjacent to the Alberni mill. Unfortunately their *in situ* ^{14}C assimilation studies were too infrequent to significantly test the null hypothesis.

The strong light attenuating properties of KME in sea water have been shown by our numerous *in situ* light measurements (Table 11). Our field studies have documented the reduction in primary production adjacent to pulp mills in Howe Sound and also at most stations adjacent to six mills along the British Columbia coast. If the cause(s) of this production sag were related mainly to phytotoxicity, then one would expect to see a significant reduction of phytoplankton density and/or in altered community structure in waters affected by KME. We have not observed these conditions in Howe Sound, and, in fact, have noted a basic similarily in density and species composition of phytoplankton assemblages between mill and control station. In the light of this observation it is tempting to speculate that light rather than toxicity is the major factor responsible for the decrease in primary production adjacent to pulp mills.

A recent *in situ* experiment off Woodfibre illustrates the relation between production by natural phytoplankton and light across a stain gradient (Fig. 11). As can readily be seen, there was a positive relation between light and production. The relation was linear for both the 0.5 and 1.0 m depths and the correlation coefficients were 0.95 and 0.96, respectively. This indicates that in this particular experiment, over 90% of the variation in production was attributable to light. In another similar experiment off Port Mellon, using axenic cultures of *Skeletonema costatum*, nearly identical results were obtained (Fig. 12). Using data obtained from this experiment, the relation between light and production for *S. costatum* under field conditions were quantified (Fig. 13). In the same study the spatial change in quality and quantity of light as a function of stain (color) concentration was demonstrated. When the "absorption spectrum" for *S. costatum* and absorbance curves for various concentrates of KME in the stain gradient at Port Mellon are compared, one can see the preferential absorbance of blue (400 - 450 n m) wave light by KME, which coincides with the peak of chlorophyll and carotenoid pigment absorbance in *S. costatum* (Fig. 14 & 15). Thus a good portion of the wavelengths of light necessary for photosynthesis are excluded by KME in surface waters.

Pulp mills on the British Columbia coast were closed from July to October, 1975. This situation offered an opportunity to observe production adjacent to the Woodfibre and Port Mellon pulp mills without the presence of stain. Results at Woodfibre were not as striking as at Port Mellon because Squamish River turbidity in surface layers obscured any trends. At Port Mellon, however, a striking 56 fold increase was noted 14 days after closure, while the increase at the control (Station 3) over the same time period was only 1.7 times.

Mean areal production, adjacent to Port Mellon in 1973 and 1974 was 29 and 24 mg $C \cdot m^{-2}$ day^{-1}, in respective years (Table 33). After 14 days of mill closure with no effluent being discharged, it increased to 497 nearly doubling again to 810 mg $C \cdot m^{-2}$ day^{-1} after 35 days (Fig. 10A).

Incident radiation on days of measurement were similar, but the underwater light climate changed appreciably. Secchi values increased from 1.2 to 7.0 m after 35 days of no effluent discharge, while those of the control (Station 3) increased from 3.0 to 7.0 m.

A survey in September, 1975 of coastal mills on Vancouver Island and at Powell River showed no differences in primary production between mill and control, which is further evidence of the rapid restoration of production adjacent to mills following effluent removal.

On the basis of these field and laboratory studies one can postulate that as phytoplankton encounter effluent and the accompanying reduced light conditions, they become metabolically inactive and remain quiescent until light conditions improve, i.e. tides or currents disperse the KME or move them out of the zone of influence. The numerous *in situ* cross-incubation experiments at Station 3 and 4 in Howe Sound have demonstrated that phytoplankton, when suddenly removed from darkness beneath the KME cloud, are incapable, over the 4-hour incubation time period, of metabolically reactivating the necessary photosynthetic pathways to attain growth equal to light-adapted phytoplankton. Numerous studies have demonstrated this lag effect and have shown that often days are required before normal growth commences. Conversely, light adapted phytoplankton when placed beneath the cloud, produce less carbon (see Figs. 8 and 9).

Reduced light often lessens the toxic effect of various substances to algae because plants in the light are metabolically much more active than in dim light or total darkness. Phytoplankton then, moving into a stain gradient with increasing concentrations of effluent and diminishing light, may encounter better conditions for adaptation than would plankton encountering an ever-increasing KME concentration without diminished light (color removed).

Toxicity

Several KME addition laboratory experiments, both short-term and long-term, have been conducted using both natural assemblages and axenic cultures of phytoplankton. Most of the earlier *in situ* results of short-term (one-two days) duration have been discounted, due to insufficient time to allow for phytoplankton adaptation. The long-term axenic culture work has, however, been most promising in methodological reliability and in results produced thus far.

Cultures of *Skeletonema costatum*, one of the dominant diatoms in British Columbia coastal waters, show normal growth in media containing 30% KME, which is equivalent to dilution occurring at about 30 - 50 m from the discharge point at Port Mellon (Fig. 16). Had the experiment been terminated after 5 days, the conclusions reached would have been different than those obtained after 30 days, which demonstrates the importance of time adaptation in such studies. In this experiment, at a 20% concentration of KME, 3 days were required before the log-phase of growth was attained, while at a 30% concentration, 10 days were required (Fig. 16). In an experiment with color-less, whole untreated KME known to be toxic to fish, normal growth occurred at all concentrations (Stockner, 1975), and in the same study the green alga *Dunaliella tertiolecta* showed good growth in 80% KME from Crofton. In a study by Rainville *et al* (1975), no phytotoxicity was found when *Cocco-chloris elebans,* a marine phytoplankton alga, was exposed to KME discharged from three pulp mill biobasins in the southern United States. Results of these studies indicate that algae are capable of adapting to relatively high concentrations of KME and may be the group least affected by KME discharge to coastal waters.

It appears that we are dealing more with an adaptation problem than acute phytotoxicity. That certain species of phytoplankton are under some physiological stress upon exposure to concentrated KME cannot be discounted; however, in a natural assemblage, hardier species will replace less resistant ones and the net areal production rates will doubtless remain unchanged. If KME selectivly enhances the growth of certain species at the exclusion of the more sensitive ones, the nature of phytoplankton assemblages around mills could be altered. We have not observed this in Howe Sound, but it may occur elsewhere. This change could be detrimental if enhanced species are not an important food source to grazing zooplankton, invertebrate larvae or sessile filter feeding invertebrates (e.g. oysters, clams, mussels). If favoured species are a good food source for herbivorous organisms, then the overall trophicity of the region would be improved.

It would require years of continued study to elucidate which species of phytoplankton are sensitive to pulp mill effluent and to which specific compounds among a myriad of chemicals contained in the effluent. We doubt this is necessary at this time, for phytoplankton have been shown to be adaptable organisms, and insensitive to concentrations of toxicants which fish physiologists would consider deleterious (Antia and Cheng, 1975; Lewin, 1963; Rainville, *et al*, 1975). We suspect that the more sensitive larval stages of marine invertebrates and many zooplankton are more sensitive, and further work should be done on the susceptability of these organisms to KME. Evidence is already indicating toxicity to many species of zooplankton (Klimastiauskene, 1973).

Flushing

Flushing and the resultant rapid dilution of KME is certainly an important physical factor which aids in reducing the effects of both light and toxicity to phytoplankton. Rainville *et al* (1975) have demonstrated the effects of flushing on potential phytotoxicity in southern U.S. mills where toxicity was greatly reduced by flushing. The Elk Falls mill near Campbell River, B.C. is located on the tide-swept Discovery Passage and is close to Seymour Narrows, a constriction known for its swift tidal currents. Plankton production in waters adjacent to this mill was very similar to the control in 1974 and in 1973, production off the mill exceeded the control value. At Harmac, on Northumberland Channel, with moderate tidal mixing, production in September, 1974, exceeded the value at the control station. In Howe Sound, Station 8 off Woodfibre did not show the same degree of phytoplankton production depression as Station 4 (Port Mellon), which is located in a less actively flushed region of Howe Sound.

Eutrophication

Eutrophication (nutrient enrichment) adjacent to mills may in certain situations be a positive attribute, balancing the negative effects of light reduction and toxicity. The increased load of nutrients (nitrogen and phosphorus compounds, and especially carbon (wood sugars)) would certainly provide ample nutrients to enhance phytoplankton growth beyond "normal" levels, given sufficent light. Bacterial activity (heterotrophic uptake) is noticeably higher in waters adjacent to mills, and this energy source may in turn be utilized by herbivorous zooplankton (Sibert, personal communication). The prolific growth of benthic algae at the head of Neroutsos Inlet is likely caused by nutrients (mainly nitrogen compounds from the ammonia base) from the Port Alice sulfite mill. Similar observations by others of eutrophication of waters around pulp mills may be attributable to the "nutrients" in their effluent.

Assessing the Impact of KME Discharge to Howe Sound

In addition to documenting the effects of KME discharge on marine phytoplankton communities, it is of interest to assess the impact such waste discharge has on annual production in B.C. coastal waters. Such estimates provide some basis for judging the environmental costs of effluent disposal from mills operating on the coast.

Howe Sound was divided into five zones and the area of each estimated planimetrically (see Fig. 1). Estimates of mean annual production for each zone (Stockner *et al*, unpublished data) were multiplied by zonal area to give annual production of carbon·year^{-1} by zone (Table 36). If one assumes the zone of influence of the mill to be a 2 km radius semicircle around each mill, then the production for this zone can be calculated, and some understanding of the net effects of KME discharge to Howe Sound can be gained. If no mills were situated in Howe Sound in 1973 and 1974, total production would have been 30 and 48 metric tons·year^{-1}, respectively. The operation of the mills reduces this Howe Sound total by 2 - 4%, depending on year (Table 36). However, in a given region (zone) the effect is considerably greater, 26 and

22% in zones 4 and 5, respectively.

Caution must be invoked when using these data in interpreting environmental impact. First, though the effect on primary production appears localized, the effects on more sensitive invertebrate larvae and copepods may be substantial. We have observed many herring and juvenile salmonids stunned by pockets of high concentration effluent. Also, diminishment of primary production, the base of the food web, by as much as 25% will affect higher trophic levels and reduce the carrying capacity of a given region. When additional data are gathered on the impact to all trophic levels of KME discharge to receiving waters, then prudent decisions on implementation of standards will follow.

CONCLUSIONS

1. Strong light attenuating properties of KME were shown to be the major cause of reduced primary production adjacent to British Columbia coastal mills.
2. A significant positive relation was observed between quantity of light and rate of carbon assimilation under field conditions.
3. A large portion of photosynthetically available light is selectively absorbed by KME, most notably the shorter wave lengths (400 - 500 nm)
4. Cross-incubation experiments conducted in Howe Sound showed that phytoplankton beneath the stain gradient were in a quiescent stage and were incapable of immediate growth (within 4 hours) in response to improved light when removed from the KME influence.
5. Production adjacent to mills in British Columbia was restored to near normal levels following mill closure and effluent removal during July - October, 1975.
6. Axenic algal culture work demonstrated the adaptability of a diatom

(*Skeletonema costatum*) and a green (*Dunaliella tertiolecta*) to growth in concentrations of KME ranging from 10 to 80% in sea water.

7. On the basis of laboratory and field experiments with axenic cultures, light attenuation, as opposed to phytotoxicity, was considered the main factor causing reduced carbon assimilation.

8. Flushing was considered the most important physical factor in reducing the impact of KME discharge to coastal waters.

9. As KME mixes with seawater and the light regime improves, nutrients in the effluent may stimulate primary production adjacent to some mills.

10. The impact of KME discharge to Howe Sound production was estimated to be 2 - 4% reduction because of the mills, but up to 26% in specific regions of the Sound.

BIBLIOGRAPHY

Antia, N.J. and J.Y. Cheng. 1975. Culture Studies on the Effects from Borate Pollution on the Growth of Marine Phytoplankters. Fish. Res. Board Can., 32: (in press).

A.P.H.A. 1971. Standard Methods for the examination of water and wastewater. 13th ed. American Public Health Assoc. Inc. New York. 769 p.

Fisheries/E.P.S. Laboratory Manual, 1974. Dept. of Environment, Fisheries/ Marine Service, Pacific Region.

Giovando, L.G. MS 1972. Physical oceanographic characteristics of the Squamish Estuary. Appendix A. Federal-Provincial Task Force Study on the Squamish Harbour Development. 22 p.

Klimashauskene, V.P. 1973. Effect of pulp and paper mill effluents on zooplankton. Vop. Epidemiol. Gigieny Litovskoi SSR. 51-53 (Russ.).

Lewin, J.C. and R.R.L. Guillard. 1963. Diatoms. Ann. Rev. Microbiol. 17: 373-414.

Parker, R.R. and J. Sibert. 1972. Effect of pulp mill effluent on dissolved oxygen in a stratified estuary - I. Empirical observations. Water Research 7: 503-514.

Rainville, R.P., B.J. Copeland and W.T. McKean. 1975. Toxicity of kraft mill wastes to an estuarine phytoplankter. Journal WPCF 47: 487-503.

Sibert, J. and R.R. Parker. 1972. Effect of pulp mill effluent on dissolved oxygen in a stratified estuary - II. Numerical model. Water Research 7: 515-523.

Steemann Neilsen, R. 1952. The use of radioactive carbon (^{14}C) for measuring organic production in the sea. Journal du Conseil. 18: 117-140.

Strickland, J.D.H. and T.R. Parsons. 1968. A Practical Handbook of Seawater Analysis. Fish. Res. Bd. Canada Bull. #167. 311 p.

Strickland, J.D.H. 1960. Measuring the production of marine phytoplankton. Fish. Res. Bd. Canada Bull. #122. 173 p.

Tully, J.P. 1949. Oceanography and prediction of pulp mill pollution in Alberni Inlet. Fish. Res. Bd. Canada Bull. #83. 169 p.

Utermöhl, H. 1958. Fur vervollkommung der quantitativen Phytoplankton-methodik. Mitt. Int. Ver. Limnol. 9: 1-38.

Waldichuk, M. 1954. Effect of pulp mill waste in Alberni Harbour. Fish. Res. Bd. Canada Progress Report No. 101: 23-26.

TABLES

TABLE LEGEND

TABLE 1	Depth and seasonal variation in temperature (^{o}C) at Stations 3 and 4, Howe Sound.
TABLE 2	Depth and seasonal variation in temperature (^{o}C) at Stations 6 and 8, Howe Sound.
TABLE 3	Depth and seasonal variation in salinity ($^{o}/oo$) at Stations 3 and 4, Howe Sound.
TABLE 4	Depth and seasonal variation in salinity ($^{o}/oo$) at Stations 6 and 8, Howe Sound.
TABLE 5	Depth and seasonal variation in density (σt) at Stations 3 and 4, Howe Sound.
TABLE 6	Depth and seasonal variation in density (σt) at Stations 6 and 8, Howe Sound.
TABLE 7	Depth and seasonal variation in dissolved oxygen ($mgO_2.liter^{-1}$) at Stations 3 and 4, Howe Sound.
TABLE 8	Depth and seasonal variation in dissolved oxygen ($mgO_2.liter^{-1}$) at Stations 6 and 8, Howe Sound.
TABLE 9	Depth and seasonal variation in total carbonate carbon ($mgC.liter^{-1}$) at Stations 3 and 4, Howe Sound.
TABLE 10	Depth and seasonal variation in total carbonate carbon ($mgC.liter^{-1}$) at Stations 6 and 8, Howe Sound.
TABLE 11	Total radiation and percent of light day utilized for ^{14}C incubation, Stations 3 and 4, Howe Sound.

TABLE 12 Light extinction coefficients (k) and Secchi depth (m) at Stations 3 and 4, Howe Sound.

TABLE 13 Total radiation and percent of light day utilized for ^{14}C incubation, Stations 6 and 8, Howe Sound.

TABLE 14 Light extinction coefficients (k) and Secchi depth (m) at Stations 6 and 8, Howe Sound.

TABLE 15 Depth and seasonal variation in total nitrate (TNO_3) ($mgN.liter^{-1}$) at Stations 3 and 4, Howe Sound.

TABLE 16 Depth and seasonal variation in total phosphate (TPO_4) ($mgP.liter^{-1}$) at Stations 3 and 4, Howe Sound.

TABLE 17 Depth and seasonal variation in silicate ($mgSi.liter^{-1}$) at Stations 3 and 4, Howe Sound.

TABLE 18 Depth and seasonal variation in total nitrate (TNO_3) ($mgN.liter^{-1}$) at Stations 6 and 8, Howe Sound.

TABLE 19 Depth and seasonal variation in total phosphate (TPO_4) ($mgP.liter^{-1}$) at Stations 6 and 8, Howe Sound.

TABLE 20 Depth and seasonal variation in silicate ($mgSi.liter^{-1}$) at Stations 6 and 8, Howe Sound.

TABLE 21 Phytoplankton species list and relative abundance, Station 3, Howe Sound.

TABLE 22 Phytoplankton species list and relative abundance, Station 4, Howe Sound.

TABLE 23 Phytoplankton species list and relative abundance, Station 6, Howe Sound.

TABLE 24 Phytoplankton species list and relative abundance, Station 8, Howe Sound.

TABLE 25 Depth and seasonal variation in Chlorophyll a. ($mg\text{-}m^{-3}$) at Stations 3 and 4, Howe Sound.

TABLE 26 Depth and seasonal variation in Chlorophyll a. ($mg\text{-}m^{-3}$) at Stations 6 and 8, Howe Sound.

TABLE 27 Depth and seasonal variation in particulate matter (seston) ($mg.m^{-3}$) at Stations 3 and 4, Howe Sound.

TABLE 28 Percentage organic content of dry seston at Stations 3 and 4, Howe Sound.

TABLE 29 Depth and seasonal variation in particulate matter (seston) ($mg.m^{-3}$) at Stations 6 and 8, Howe Sound.

TABLE 30 Percentage organic content of dry seston at Stations 6 and 8, Howe Sound.

TABLE 31 Zooplankton biomass in vertical hauls at Stations 3 and 4, Howe Sound.

TABLE 32 Zooplankton biomass in vertical hauls at Stations 6 and 8, Howe Sound.

TABLE 33 Daily areal primary production rates ($mgC.m^{-2}.day^{-1}$) at Stations 3 & 4 and 6 & 8, Howe Sound.

TABLE 34 Special cross-incubation production experiments at Stations 3 and 4, Howe Sound ($mgC.m^{-2}.day^{-1}$).

TABLE 35 Daily areal primary production and chlorophyll at six British Columbia coastal mills.

TABLE 36 Annual Production in Howe Sound by zone.

TABLE 1 Depth and seasonal variation in temperature (^{o}C) at Stations 3 and 4, Howe Sound.

date \ depth (m)	Station 3				Station 4			
	1	3	5	20	1	3	5	20
1973								
Feb.	-	-	-	-	-	-	-	-
Mar. 15	7.2	7.2	7.2	7.0	6.7	6.8	6.6	6.3
Apr. 10	9.7	9.7	9.6	7.3	11.3	11.1	10.8	9.0
May 24	11.3	11.9	12.4	7.3	11.3	12.0	12.4	7.3
June 20	-	-	-	-	17.2	13.5	12.2	8.4
Jul. 12	16.7	16.4	15.5	8.9	17.0	16.7	16.1	9.0
Aug. 28	16.0	16.0	14.5	9.4	16.2	16.1	15.0	9.4
Sept. 25	14.9	14.4	13.0	9.1	14.4	14.3	12.2	9.1
Oct. 18	10.7	10.6	10.5	8.7	10.9	10.6	10.5	8.6
Nov. 21	6.3	6.3	6.4	7.8	6.7	7.1	7.3	8.3
Dec. 19	6.6	6.8	7.0	8.4	6.6	6.7	6.8	8.3
1974								
Jan. 10	4.7	4.8	5.1	7.5	4.7	4.9	4.9	7.2
Feb. 22	5.4	5.5	5.6	6.9	5.6	5.6	5.7	6.9
Mar. 14	5.3	5.1	5.1	6.5	5.2	5.1	5.1	6.3
Apr. 4	7.7	7.5	7.3	6.6	7.7	7.3	7.0	6.6
May 9	12.3	12.0	10.6	6.9	11.5	12.0	9.5	6.7
June 11	15.6	14.0	11.7	8.2	14.2	12.6	10.1	7.2
Jul. 23	15.7	13.5	11.4	9.5	16.0	13.0	12.0	9.7
Aug. 22	17.5	16.0	14.5	10.3	17.2	15.8	14.7	10.0
Sept. 10	16.5	16.7	16.3	10.0	16.2	16.3	16.4	9.8
Oct. 3	13.5	13.0	12.5	10.7	13.8	13.4	12.7	10.7
Nov. 14	9.7	9.8	9.8	9.7	9.6	9.8	9.9	9.7
Dec. 5	8.7	8.8	9.2	9.1	8.3	8.4	8.6	9.5

TABLE 2 Depth and seasonal variation in temperature (°C) at Stations 6 and 8, Howe Sound.

Station 6 date \ depth (m)	1	3	5	20	Station 8 date \ depth (m)	1	3	5	20
1973									
Feb. 27	6.1	6.2	6.2	6.5	Feb.	-	-	-	-
Mar.	-	-	-	-	Mar. 28	7.2	6.7	6.5	6.7
Apr. 4	8.0	6.7	6.3	5.8	Apr. 17	7.3	8.0	8.3	6.6
Apr. 24	10.6	10.2	9.0	6.7	Apr. 25	10.0	10.0	10.3	7.2
May 29	12.3	11.4	10.7	7.3	May 30	10.3	10.5	10.4	7.0
June 22	12.6	12.2	11.5	8.5	June 21	12.6	10.6	10.0	8.7
Jul. 24	14.7	15.5	15.5	9.5	Jul. 25	11.0	15.5	14.0	9.2
Aug. 24	15.1	15.5	15.8	9.4	Aug. 23	14.0	14.2	13.8	9.2
Sept.	-	-	-	-	Sept. 28	12.2	11.8	11.5	8.6
Oct. 12	10.9	11.1	11.3	9.3	Oct. 17	9.7	10.1	9.9	8.2
Nov.	-	-	-	-	Nov. 22	5.0	7.2	7.3	8.1
Dec. 14	6.3	6.4	6.6	7.2	Dec. 18	5.4	6.3	7.8	8.3
1974									
Jan. 22	4.0	5.1	5.5	7.5	Jan. 23	5.0	5.5	5.7	7.5
Feb. 14	5.5	5.5	5.5	6.7	Feb. 12	5.8	6.3	6.5	7.1
Mar. 8	5.1	5.1	5.3	6.8	Mar. 12	5.6	5.9	6.2	6.7
Apr. 3	7.2	7.3	7.3	6.5	Apr. 9	6.7	6.8	6.7	6.8
May 7	11.3	10.5	8.7	6.7	May 17	10.0	10.2	9.7	6.8
June 10	12.2	11.0	9.3	8.2	June 13	9.0	8.4	8.2	7.2
Jul. 22	15.5	13.8	11.7	9.7	Jul. 24	9.0	11.5	11.1	8.7
Aug. 9	14.0	15.2	14.2	10.5	Aug.	-	-	-	-
Sept. 11	13.5	14.5	14.5	9.5	Sept. 3	12.8	13.5	13.2	10.0
Oct. 4	11.7	12.7	12.8	10.5	Oct. 9	12.2	11.4	11.2	9.3
Nov. 15	9.0	9.1	9.3	9.5	Nov. 6	8.0	8.6	8.6	8.7
Dec. 10	7.2	7.3	7.5	8.6	Dec. 12	7.5	7.8	8.7	9.0

TABLE 3 Depth and seasonal variation in salinity ($^{o}/oo$) at Stations 3 and 4, Howe Sound.

date \ depth (m)	Station 3				Station 4			
	1	3	5	20	1	3	5	20
1973								
Feb. 7	-	-	-	28.8	25.1	25.3	26.0	29.1
Mar. 15	23.7	25.2	26.2	29.2	24.9	25.6	26.1	29.1
Apr. 10	26.2	26.5	27.0	29.5	26.4	26.6	28.1	29.5
May 24	12.8	16.5	16.7	29.9	11.1	15.8	16.8	28.9
June 20	13.2	14.1	20.4	29.4	10.4	13.5	20.7	29.4
Jul. 12	12.6	-	20.2	29.5	12.3	-	19.6	29.8
Aug. 28	19.2	20.6	23.9	29.2	18.1	20.7	25.8	29.2
Sept.25	21.3	25.8	28.8	29.6	15.8	17.2	19.3	29.2
Oct. 18	22.6	23.9	25.4	29.7	22.5	24.1	24.0	29.4
Nov. 21	26.2	26.2	26.6	29.0	25.9	26.4	26.6	29.2
Dec. 19	23.9	24.6	25.3	29.4	21.5	24.3	24.9	29.2
1974								
Jan. 10	26.4	27.5	27.5	28.9	25.3	27.4	27.5	29.0
Feb. 22	23.9	24.4	24.7	29.1	23.5	24.3	24.3	29.1
Mar. 14	24.6	24.7	25.6	28.3	22.8	23.9	24.9	27.9
Apr. 4	17.4	22.3	24.3	28.8	22.3	22.8	24.1	28.8
May 9	11.0	13.8	19.8	28.7	9.5	11.9	19.3	28.6
June	-	-	-	-	-	-	-	-
Jul. 23	10.5	12.6	20.1	28.1	8.9	11.8	22.3	27.8
Aug. 22	10.0	17.9	22.3	28.1	8.6	15.9	23.1	28.5
Sept.10	13.9	16.0	18.3	28.6	14.1	14.7	16.4	28.4
Oct. 3	21.0	22.2	26.0	28.2	21.5	23.2	26.1	28.4
Nov. 14	24.8	25.6	26.0	29.6	24.6	25.4	26.8	29.8
Dec. 5	23.8	25.0	26.7	29.6	24.5	25.4	26.1	29.6

TABLE 4 Depth and seasonal variation in salinity ($^{o}/oo$) at Stations 6 and 8, Howe Sound.

date \ depth (m)	Station 6: 1	3	5	20	Station 8: 1	3	5	20
1973								
Feb. 27/14	25.0	26.9	27.7	29.1	27.3	28.1	28.2	29.6
Apr.4/Mar.28	24.4	26.3	27.5	29.2	19.2	27.9	28.6	29.8
Apr. 24/17	22.5	25.4	26.6	29.6	9.7	23.6	25.0	29.1
May 29/30	13.1	14.9	26.6	29.8	4.1	7.5	23.4	29.6
June 22/21	17.2	18.9	24.9	29.5	12.6	25.9	26.8	29.6
Jul. 24/25	-	19.3	22.6	28.7	9.5	20.3	22.5	28.7
Aug. 24/23	19.5	23.5	26.3	29.5	12.7	16.0	23.1	28.1
Sept. /28	-	-	-	-	15.7	25.6	27.0	29.6
Oct. 12/17	20.6	22.2	23.0	29.2	19.1	24.9	26.4	29.7
Nov. /22	-	-	-	-	16.2	27.2	27.3	29.1
Dec. 14/18	18.2	20.9	21.9	29.1	17.4	24.8	27.8	29.8
1974								
Jan. 22/23	17.0	22.2	23.5	29.3	13.3	23.8	25.3	28.6
Feb. 14/12	24.6	24.7	24.9	28.1	23.7	25.7	27.2	28.9
Mar. 8/12	26.1	26.1	26.1	28.2	23.9	24.6	26.2	28.1
Apr. 3/ 9	17.6	22.2	23.0	28.7	16.7	24.0	25.2	28.9
May 7/17	10.5	17.1	23.2	28.4	2.0	13.2	19.4	29.2
June /13	-	-	-	-	3.5	23.5	25.8	28.9
Jul. 22/24	4.0	10.3	19.7	28.0	4.2	9.0	19.4	28.0
Aug. 9	4.0	-	-	-	-	-	-	-
Sept. 11/ 3	10.3	15.9	22.8	28.7	3.9	16.6	24.1	27.9
Oct. 4/ 9	13.5	19.9	18.2	28.2	17.0	26.2	27.5	28.6
Nov. 15/ 6	25.3	25.4	25.4	29.7	15.7	26.1	26.2	28.8
Dec. 10/12	23.1	24.4	25.3	28.9	20.6	23.2	25.4	28.8

TABLE 5 Depth and seasonal variation in density (σt) at Stations 3 and 4, Howe Sound.

depth (m) / date	Station 3				Station 4			
	1	3	5	20	1	3	5	20
1973								
Mar. 15	18.51	19.72	20.52	22.85	19.54	20.10	20.52	22.90
Apr. 10	20.16	20.44	20.79	23.10	20.06	20.24	21.46	22.81
May 24	9.57	12.37	12.42	23.40	8.32	11.79	12.51	22.67
June 20	-	-	-	-	6.77	9.78	15.54	22.86
July 12	8.54	-	14.50	22.89	9.85	-	13.99	23.10
Aug. 28	13.69	14.70	17.60	22.55	12.80	14.83	14.20	22.51
Sept. 25	15.50	19.07	21.63	22.86	11.42	12.48	14.48	22.60
Oct. 18	17.24	18.26	19.40	23.01	17.10	18.40	18.34	22.85
Nov. 21	20.62	20.66	20.91	22.62	20.30	20.65	20.81	22.74
Dec. 19	18.81	19.31	19.80	22.87	16.86	19.09	19.52	22.74
1974								
Jan. 10	20.91	21.79	21.77	22.60	20.80	21.67	21.73	22.70
Feb. 22	18.85	19.25	19.56	22.75	18.75	19.19	19.18	22.85
Mar. 14	19.48	19.56	20.25	22.25	18.07	18.90	18.93	21.94
Apr. 4	13.57	17.38	18.52	22.57	17.34	17.80	18.81	22.64
May 9	8.01	10.23	14.99	20.96	7.00	8.75	14.80	22.48
June	-	-	-	-	-	-	-	-
July 23	7.10	9.09	15.18	21.70	5.84	8.56	16.80	21.42
Aug. 22	6.38	12.76	16.37	21.60	5.41	11.23	16.94	21.88
Sept. 10	9.55	11.15	12.91	21.96	9.76	10.23	11.43	21.87
Oct. 3	15.53	16.57	19.53	21.48	15.86	17.24	19.63	21.73
Nov. 14	19.10	19.67	19.98	22.78	18.94	19.53	20.64	22.92
Dec. 5	18.44	19.37	20.60	22.84	19.03	19.71	20.27	22.88

TABLE 6 Depth and seasonal variation in density (σt) at Stations 6 and 8, Howe Sound.

date \ depth (m)	Station 6				Station 8			
	1	3	5	20	1	3	5	20
1973								
Feb. 27	19.70	21.14	21.78	22.84	-	-	-	-
Apr. 4/ Mar. 28	18.97	20.65	21.62	23.02	15.20	21.95	22.43	23.40
Apr. 24/17	17.15	19.44	20.60	23.21	7.52	18.34	19.47	22.82
May 29/30	9.65	11.16	20.30	23.28	2.94	5.58	17.86	23.22
June 22/21	12.76	14.10	18.85	22.94	9.24	19.82	20.63	22.97
July 24/25	-	13.83	16.34	22.10	7.02	14.71	16.55	22.19
Aug. 24/23	14.10	17.06	19.18	22.77	9.60	11.59	17.12	21.70
Sept. /28	-	-	-	-	11.68	19.38	20.52	22.97
Oct. 12/17	15.60	16.86	17.44	22.52	14.66	19.10	23.20	23.14
Nov. /22	-	-	-	-	12.87	21.34	21.36	22.64
Dec. 14/18	14.33	16.37	17.23	-	13.76	19.54	21.68	23.18
1974								
Jan. 22/23	13.58	17.56	18.59	22.86	10.67	18.81	19.95	22.28
Feb. 14/12	19.46	19.50	19.70	22.50	18.69	20.21	21.38	22.64
Mar. 8/12	20.66	20.64	20.60	22.13	18.87	19.41	20.61	22.60
Apr. 3/ 9	13.74	17.36	18.01	22.57	13.15	18.83	19.79	22.66
May 7/17	7.76	12.97	18.00	22.28	1.32	10.03	14.86	22.87
June /13	-	-	-	-	2.59	18.25	20.07	22.63
July 22/24	2.17	10.47	14.81	21.57	3.14	6.60	14.70	21.71
Aug. 9	2.39	10.60	18.40	21.00	-	-	-	-
Sept.11/ 3	7.33	11.46	18.14	22.11	2.60	12.21	19.34	21.47
Oct. 4/ 9	10.05	14.80	13.51	21.71	12.68	19.91	20.96	22.06
Nov. 15/ 6	19.53	19.67	19.65	22.87	12.22	20.23	20.30	22.36
Dec. 10/12	18.04	19.07	19.77	22.44	16.06	18.10	19.72	22.45

TABLE 7 Depth and seasonal variation in dissolved oxygen ($mgO_2.liter^{-1}$) at Stations 3 and 4, Howe Sound.

date \ depth (m)	Station 3				Station 4			
	1	3	5	20	1	3	5	20
1973								
Feb. 7	7.01	7.01	6.24	5.92	7.11	7.10	7.03	5.47
Mar. 15	6.68	6.87	6.77	5.36	6.67	6.56	6.68	5.60
Apr. 10	10.45	10.52	7.05	5.65	10.56	10.34	6.51	5.57
May 24	7.64	7.50	7.23	5.41	6.49	7.44	7.44	5.31
June 20	7.97	7.77	6.30	5.01	6.30	7.30	6.18	4.89
July 12	6.10	-	4.98	4.42	5.70	-	4.55	4.22
Aug. 28	6.48	6.51	6.14	4.64	6.05	6.28	6.14	4.59
Sept. 25	5.64	6.30	5.13	4.09	6.82	5.53	4.25	4.09
Oct. 18	6.01	5.67	5.40	5.20	7.36	5.67	5.53	3.85
Nov. 21	6.34	6.13	6.27	4.27	6.07	6.13	6.00	4.09
Dec. 19	6.59	6.29	6.28	4.00	6.52	6.21	6.25	3.97
1974								
Jan. 10	6.91	6.94	6.85	5.47	6.80	6.89	6.78	5.33
Feb. 22	7.43	7.36	7.09	5.49	6.14	6.21	5.94	5.87
Mar. 14	7.29	7.16	7.16	6.07	6.89	7.02	7.02	6.21
Apr. 4	9.99	9.32	9.45	5.49	7.02	7.29	8.23	6.48
May 9	8.91	9.11	8.80	5.99	8.91	9.13	9.18	5.55
June 11	7.63	7.42	7.42	5.22	6.75	6.82	6.88	5.33
July 23	7.02	7.06	6.02	5.01	6.62	5.68	5.52	5.00
Aug. 22	6.49	6.39	6.21	4.54	5.67	5.89	6.38	4.54
Sept. 10	7.02	6.82	6.68	4.52	7.08	7.02	6.62	4.19
Oct. 3	7.42	7.29	6.28	4.39	7.02	7.29	6.62	4.32
Nov. 14	6.12	6.37	6.14	3.78	5.83	6.32	5.29	3.58
Dec. 5	6.35	6.21	5.53	3.51	6.14	6.08	5.80	3.58

TABLE 8 Depth and seasonal variation in dissolved oxygen ($mgO_2.liter^{-1}$) at Stations 6 and 8, Howe Sound.

date \ depth (m)	Station 6				Station 8			
	1	3	5	20	1	3	5	20
1973								
Feb. 27	6.98	6.74	6.64	5.82	-	-	-	-
Apr. 4	10.23	8.91	7.53	6.23	-	-	-	-
Apr. 24/17	7.92	9.14	8.82	5.45	8.80	9.65	9.21	5.81
May 29/30	7.44	7.31	6.04	5.00	7.59	6.70	6.01	4.43
June /21	-	-	-	-	6.79	5.12	5.15	4.49
July 24/25	6.98	6.92	6.83	5.27	6.75	6.75	6.59	4.61
Aug. 24/23	7.48	7.48	7.46	4.82	6.64	6.45	6.08	4.47
Sept. /28	-	-	-	-	6.33	5.67	5.00	4.29
Oct. 12/17	7.71	7.16	7.22	6.82	7.16	4.46	4.72	2.77
Nov. /22	-	-	-	-	6.78	5.68	5.49	4.50
Dec. 14/18	7.10	6.98	6.95	5.42	7.09	6.08	4.81	3.85
1974								
Jan. 22/23	6.89	7.16	7.11	5.29	6.97	6.97	6.59	5.01
Feb. 14/12	10.65	9.84	9.84	8.57	8.94	9.02	8.17	7.78
Mar. 8/12	6.89	7.16	6.89	6.21	6.07	6.07	6.07	5.27
Apr. 3/ 9	10.66	9.99	7.43	6.08	7.56	6.89	6.75	5.67
May 7/17	9.22	9.60	8.14	5.95	4.73	7.09	8.24	5.40
June 10/13	7.76	7.29	6.35	5.54	8.17	6.08	5.76	5.31
July 22/24	7.55	7.44	6.20	5.05	7.96	7.70	6.08	5.00
Aug. 9	7.67	7.74	7.67	4.62	-	-	-	-
Sept. 11/ 3	7.22	6.82	5.94	4.65	7.56	6.75	5.94	4.32
Oct. 4/ 9	7.83	8.10	7.90	4.25	4.85	4.78	4.51	4.05
Nov. 15/ 6	5.94	5.87	5.83	3.58	5.67	6.41	5.17	3.92
Dec. 10/12	6.68	6.55	6.28	4.32	6.07	5.94	5.40	4.25

TABLE 9 Depth and seasonal variation in total carbonate carbon ($mgC.liter^{-1}$) at Stations 3 and 4, Howe Sound.

depth (m) / date	Station 3				Station 4			
	1	3	5	20	1	3	5	20
1973								
Jul. 12	14256	19238	23847	24190	11398	13812	20856	24009
Aug. 28	17417	18149	20518	23417	15678	19356	21305	23306
Sept. 25	16899	21339	13279	22234	8666	8958	20895	22572
Oct. 18	8161	10771	20051	23000	13565	19246	20426	-
Nov. 21	21093	22320	21627	23364	19699	21501	21226	23199
Dec. 19	19618	20090	20889	23489	16960	20032	20334	23889
1974								
Jan. 10	21689	21611	21901	22980	19916	21750	21781	22250
Feb. 22	17772	19995	20517	23645	18249	20517	20334	23066
Mar. 14	18816	19758	20517	22897	17772	19857	21635	22942
Apr. 4	7209	11564	14068	19375	12867	13044	14068	23552
May 9	14394	16477	19577	23645	12687	14394	22943	24161
June 11	11507	11890	13670	22079	10304	10304	13678	23588
July 23	8105	9884	16420	21476	6154	11061	17215	21758
Aug. 22	7634	15859	18870	22498	9015	12264	19400	22886
Sept. 10	11058	11450	14280	20634	10039	9398	12021	18747
Oct. 3	15274	13383	18834	20146	12464	16768	20895	20386
Nov. 14	17260	19238	16634	20440	13451	19724	20538	21178
Dec. 5	19802	18298	20963	22108	16170	20294	21276	22426

TABLE 10 Depth and seasonal variation in total carbonate carbon ($mgC.liter^{-1}$) at Stations 6 and 8, Howe Sound.

date \ depth (m)	Station 6				Station 8			
	1	3	5	20	1	3	5	20
1973								
Jul.	10597	16633	19530	23306	9325	18833	20147	23525
Aug.	14577	16079	17411	23525	16748	17272	19841	23516
Sept.	-	-	-	-	13954	10247	14280	21575
Oct.	15541	15801	18877	22769	15166	18132	18848	21602
Nov.	-	-	-	-	16115	22136	22164	21627
Dec.	14931	17039	17821	22019	15237	19955	22292	23920
1974								
Jan.	13902	18249	19758	22444	18661	18266	20785	23317
Feb.	20445	21276	21405	23078	20661	21373	22686	23837
Mar.	21990	21841	20517	22814	19658	21533	20334	22136
Apr.	11947	11947	11947	23550	16199	20147	21373	23858
May	13394	17272	19558	24161	20872	22417	-	25529
June	8105	11890	18870	23010	6831	20090	21785	23130
July	8723	14152	16143	21632	4469	5012	16302	22360
Aug.	7561	11890	19295	20986	-	-	-	-
Sept.	8161	14068	19758	22553	5350	10771	20147	22553
Oct.	10371	15599	14020	22804	16925	21606	21743	23308
Nov.	19744	19802	19783	23133	12645	20422	20706	22702
Dec.	18019	18298	19524	22439	17900	18183	20184	22624

TABLE 11 Total radiation and percent of light day utilized for ^{14}C incubation, Stations 3 and 4, Howe Sound.

Date	Total Light	Station 3	Station 4
	g cal. $cm^{-2}day^{-1}$	Percent	Percent
1973			
Feb. 7	154	77	74
Mar. 15	47	97	99
Apr. 10	332	51	64
May 24	392	46	51
June 20	599	34	45
July 12	622	47	46
Aug. 28	173	21	24
Sept. 25	302	64	60
Oct. 18	189	-	-
Nov. 21	75	69	83
Dec. 19	40	95	97
1974			
Jan. 10	-	-	-
Feb. 22	219	76	69
Mar. 14	286	64	47
Apr. 4	193	78	65
May 9	235	63	56
May 13	168	30	30
June 11	589	35	44
July 23	621	54	54
Aug. 22	410	51	46
Sept. 10	528	49	52
Oct. 3	516	66	53
Nov. 14	85	56	56
Dec. 5	77	53	42

TABLE 12 Light extinction coefficients (k) and Secchi depth (m) at Stations 3 and 4, Howe Sound.

Date	Station 3		Station 4	
	Extinction Coefficients	Secchi (m)	Extinction Coefficients	Secchi (m)
1973				
Feb. 7	.3049	6.0	.9412	6.5
Mar. 15	.2644	6.5	.7593	3.0
Apr. 10	.3929	3.0	2.4809	0.3
May 24	[a]1.0553	1.0	3.1073	0.7
June 20	.2887	3.5	.4680	3.1
July 12	.3645	3.5	1.1841	1.8
Aug.	-	-	-	-
Sept.	-	-	-	-
Oct. 18	.3403	5.0	2.3026	2.5
Nov. 21	.3750	8.5	.9494	5.5
Dec. 19	.3792	6.0	2.6492	1.4
$\bar{x}$	.4184	5.1	1.6491	2.9
1974				
Feb. 7	.3697	8.0	2.0764	0.3
Feb. 22	-	-	.6846	3.6
Mar. 14	.5982	8.0	2.0253	3.3
Apr.	-	-	-	-
May 9	.4922	2.0	1.2513	1.0
May 13	.4607	3.0	1.0164	0.3
June 11	.4315	2.8	1.6971	0.3
July 23	.4862	2.7	5.9915	0.2
Aug. 22	.2324	5.7	2.5580	0.5
Sept. 10	.2291	4.8	5.2983	0.1
Oct. 3	.2818	8.0	2.9046	0.3
Nov. 14	.3930	8.0	1.4628	0.5
Dec. 5	.3660	5.3	1.4509	1.0
$\bar{x}$	.3796	5.8	2.3681	1.0

a - KME stain in area

TABLE 13 Total radiation and percent of light day utilized for ^{14}C incubation, Stations 6 and 8, Howe Sound.

Date	Total Light	Stn. 6	Date	Total Light	Stn. 8
	g cal. $cm^{-2} day^{-1}$	Percent		g cal. $cm^{-2} day^{-1}$	Percent
1973					
Feb. 27	40 [a]	80	Feb. 14	107	81
Mar.	-	-	Mar. 28	368	66
Apr. 4	400 [a]	55	Apr. 17	500	43
Apr. 24	244	48	Apr. 25	400 [a]	44
May 29	505	45	May 30	694	36
June 22	650 [a]	35	June 21	675 [a]	38
July 24	371	24	July 25	358	38
Aug. 24	57	38	Aug. 23	406	28
Sept.	-	-	Sept. 28	317	45
Oct. 12	34	78	Oct. 17	200	52
Nov. 14	150 [a]	60	Nov. 22	42	47
Dec. 14	50 [a]	70	Dec. 18	42	57
1974					
Jan. 22	50 [a]	70	Jan. 23	50 [a]	70
Feb. 14	126	86	Feb. 12	42	69
Mar. 8	100 [a]	65	Mar. 12	100 [a]	65
Apr. 3	278	42	Apr. 9	581	55
May 7	185	27	May 17	497	37
June 10	606	36	June 13	657	51
July 22	399	52	July 24	649	64
Aug. 9	696	35	Aug.	-	-
Sept. 11	487	39	Sept. 3	581	49
Oct. 4	494	43	Oct. 9	416	55
Nov. 15	59	50	Nov. 6	235	41
Dec. 10	34	56	Dec. 12	44	50

a - estimate based on cruise surface light readings.

TABLE 14 Light extinction coefficients (k) and Secchi depth (m) at Stations 6 and 8, Howe Sound.

Date	Station 6		Station 8	
	Extinction Coefficients	Secchi (m)	Extinction Coefficients	Secchi (m)
1973				
February	.3456	6.0	.9663	1.2
Early April	.4399	2.5	.7223	3.5
Late April	.2835	6.0	.8250	2.0
May	.5173	3.0	1.4039	1.5
June	.5442	3.5	1.2382	2.0
July	.4015	2.2	.9466	0.9
August	.2863	5.5	1.5689	1.5
September	-	-	.4474	1.7
October	.4492	4.5	1.2093	0.8
November	-	-	.6228	4.0
$\bar{x}$	.4084	4.2	.9951	1.9
1974				
February	.2748	7.0	2.0999	0.3
March	.1978	7.0	1.9373	3.5
May	-	-	2.0290	1.0
June	1.0131	2.8	.9742	1.5
July	.9239	1.5	1.6929	0.8
August	.2681	1.3	-	-
September	.6386	1.0	1.2055	1.0
October	.5375	1.8	1.8762	0.6
November	.3038	9.0	1.4642	2.0
December	.2939	7.0	2.0684	1.3
$\bar{x}$	.4946	4.3	1.7053	1.3

TABLE 15 Depth and seasonal variation in TNO_3 ($mgN.liter^{-1}$) at Stations 3 and 4, Howe Sound.[a]

date \ depth (m)	Station 3: 1	3	5	20	$\bar{x}$	date \ depth (m)	Station 4: 1	3	5	20	$\bar{x}$
1973						**1973**					
Apr. 10	N/D	N/D	.225	.445	.335	Apr. 10	N/D	N/D	.34	.41	.380
May 24	-	<.008	<.008	-	<.008	May 24	<.008	<.008	<.008	<.008	<.008
June 20	<.01	<.01	-	.23	.058	June 20	<.01	<.01	.07	.28	.088
July 12	<.01	.08	.24	.26	.140	July 12	<.01	.08	.26	.27	.152
Aug. 28	<.01	.03	.08	.24	.088	Aug. 28	<.01	.03	.09	.27	.098
Sept. 25	<.01	.14	.19	.26	.147	Sept. 25	.03	.02	.14	.22	.103
Oct. 18	.04	.03	.08	.24	.098	Oct. 18	.04	.08	.01	.24	.090
Nov. 21	.37	-	-	.27	.320	Nov. 21	.25	.29	.31	.24	.270
Dec. 19	.24	.33	.38	.39	.330	Dec. 19	.22	.35	.35	.38	.320
$\bar{x}$	.099	.090	.140	.292		$\bar{x}$	.072	.109	.176	.258	
1974						**1974**					
Feb. 22	.300	.320	.310	.410	.330	Feb. 22	.300	.300	.330	.350	.324
May 9	<.010	<.010	.019	.250	.110	May 9	<.010	<.010	<.010	.290	.072
July 23	<.010	.021	.096	.288	.100	July 23	<.010	.040	.049	.232	.080
Oct. 3	<.010	.016	.085	.250	.088	Oct. 3	.026	.051	.124	.337	.135
Dec. 5	.355	.312	.331	.420	.350	Dec. 5	.338	.396	.376	.430	.385
$\bar{x}$	.135	.136	.168	.324		$\bar{x}$	.137	.159	.179	.328	

a - conversion to µg atoms·$liter^{-1}$, divid values by 14.

TABLE 16 Depth and seasonal variation in TPO_4 ($mgP.liter^{-1}$) at Stations 3 and 4, Howe Sound.[a]

depth (m) / date	Station 3: 1	3	5	20	$\bar{x}$
1973					
Apr. 10	.100	.048	.080	.110	.084
May 24	-	.033	.020	-	.026
June 20	.068	.029	-	.085	.059
July 12	.035	.055	.085	.085	.060
Aug. 28	.065	.073	.102	.092	.082
Sept.25	.013	.025	.026	.037	.025
Oct. 18	.042	.043	.045	-	.043
Nov. 21	.094	-	.080	.058	.077
Dec. 19	.050	.066	.066	.090	.068
$\bar{x}$	.058	.046	.062	.078	
1974					
Feb. 22	.060	.070	.070	.080	.070
May 9	.013	.013	.019	.076	.030
July 23	.045	.063	.038	.058	.051
Oct. 3	.015	.098	.031	-	.048
Dec. 5	.065	.065	.066	.087	.071
$\bar{x}$	.040	.062	.045	.075	

depth (m) / date	Station 4: 1	3	5	20	$\bar{x}$
1973					
Apr. 10	.040	.053	.096	.098	.072
May 24	.017	.020	.019	.044	.025
June 20	.051	.047	.049	.090	.059
July 12	.030	.050	.080	.155	.077
Aug. 28	.035	<.01	.027	.069	.033
Sept.25	.044	<.01	.022	.048	.029
Oct. 18	.040	.044	.046	.075	.051
Nov. 21	-	.051	-	.06	.055
Dec. 19	.064	.067	.070	.078	.070
$\bar{x}$	.040	.039	.051	.079	
1974					
Feb. 22	.070	.060	.070	.070	.068
May 9	.018	.015	.014	.073	.030
July 23	.034	.054	.063	.054	.051
Oct. 3	.051	.013	.055	.160	.070
Dec. 5	.071	.069	.073	.085	.074
$\bar{x}$	.049	.042	.056	.088	

a - conversion to μg atoms·liter, divide value by 32.

TABLE 17 Depth and seasonal variation in silicate (mgSi.liter^{-1}) at Stations 3 and 4, Howe Sound.[b]

depth (m) / date	Station 3: 1	3	5	20	$\bar{x}$
1973					
Apr. 10	.53	1.14	1.13	1.43	1.06
May 24	-	-	-	-	-
June 20	-	-	-	-	-
July 12	-	-	-	-	-
Aug. 28	.60	.66	.80	.98	.76
Sept. 25	.48	.91	.73	.93	.76
Oct. 18	1.18	1.01	.92	1.14	1.06
Nov. 21	1.36	-	-	1.03	1.19
Dec. 19	1.05	1.44	1.55	1.38	1.36
$\bar{x}$	.87	1.03	1.03	1.15	
1974					
Feb. 22	1.65	1.66	1.65	1.52	1.62
May 9	-	-	-	-	-
July 23	<.20	.35	<.20	.55	.30[a]
Oct. 3	.25	.20	.30	1.07	.45
Dec. 5	1.35	1.35	1.32	1.40	1.36
$\bar{x}$	.87	.89	.87	1.14	

depth (m) / date	Station 4: 1	3	5	20	$\bar{x}$
1973					
Apr. 10	.54	.58	1.29	1.36	.94
May 24	-	-	-	-	-
June 20	-	-	-	-	-
July 12	-	-	-	-	-
Aug. 28	.65	.66	.85	1.14	.82
Sept. 25	.87	.70	.81	.79	.79
Oct. 18	.97	1.16	1.04	1.25	1.10
Nov. 21	1.18	1.33	1.30	1.02	1.21
Dec. 19	1.38	1.55	1.55	1.38	1.46
$\bar{x}$	.93	.99	1.44	1.16	
1974					
Feb. 22	1.55	1.66	1.65	1.50	1.59
May 9	-	-	-	-	-
July 23	<.20	.35	<.20	.35	.25[a]
Oct. 3	.35	.25	.45	1.35	.60
Dec. 5	1.35	1.36	1.40	1.39	1.37
$\bar{x}$	.86	.91	.93	1.15	

a - <.20 taken as .15

b - conversion to μg atom·liter, divide value by 28

TABLE 18 Depth and seasonal variation in TNO_3 ($mgN.liter^{-1}$) at Stations 6 and 8, Howe Sound.

depth (m) / date	Station 6					depth (m) / date	Station 8				
	1	3	5	20	$\bar{x}$		1	3	5	20	$\bar{x}$
1973						1973					
Apr. 4	.03	-	.39	-	.213	Mar. 28	.02	.26	.24	.16	.17
Apr.	-	-	-	-	-	Apr. 17	.03	<.01	<.01	.09	.03
May 29	.02	.03	.13	.27	.110	May 30	-	.04	<.01	.23	.09
June 22	.03	.10	.14	.21	.120	June 21	-	-	.14	.24	.19
July 24	.01	<.01	<.01	.25	.060	July 25	<.01	<.01	.02	.25	.07
Aug. 24	-	<.01	<.01	.29	.100	Aug. 23	<.01	.01	-	.29	.10
Sept.	-	-	-	-	-	Sept. 28	.04	.09	.19	.34	.16
Oct. 12	.01	.03	-	.31	.120	Oct. 17	.02	.12	.39	.15	.17
Nov. 14	.03	.16	.16	.21	.140	Nov. 22	.23	.24	.30	.27	.26
Dec. 30	.18	.30	.33	.36	.293	Dec. 18	.22	.29	.32	.35	.30
$\bar{x}$	.045	.091	.167	.271			.073	.119	.180	.237	
1974						1974					
Jan. 22	.18	.30	.330	.360	.290	Jan.	-	-	-	-	-
Feb. 14	.39	.32	.320	.330	.340	Feb. 12	.690	.220	.560	.380	.460
May 7	<.01	<.01	.030	.240	.070	May 17	.040	.010	.030	.330	.100
July 22	.025	.125	.336	.300	.200	July 24	.035	.024	.103	.180	.090
Oct. 4	.017	<.01	.048	.347	.100	Oct. 9	.127	.207	.286	.302	.230
Dec. 10	.340	.376	.315	.398	.357	Dec. 12	.184	.151	.241	.349	.230
$\bar{x}$	.160	.190	.230	.329			.215	.122	.244	.308	

TABLE 19 Depth and seasonal variation in TPO_4 ($mgP.liter^{-1}$) at Stations 6 and 8, Howe Sound.

date \ depth (m)	Station 6: 1	3	5	20	$\bar{x}$	date \ depth (m)	Station 8: 1	3	5	20	$\bar{x}$
1973						**1973**					
Apr. 4	.055	.059	.088	-	.067	Mar. 28	.070	.090	.100	.110	.09
Apr.	-	-	-	-	-	Apr. 17	.160	.093	.087	.092	.108
May 29	.028	.037	.060	.077	.051	May 30	-	.023	.045	.047	.038
June 22	.076	.058	.092	.104	.082	June 21	-	-	.064	.082	.073
July 24	.030	.040	.040	.060	.042	July 25	.050	.040	.050	.080	.055
Aug. 24	-	.010	<.010	.078	.026	Aug. 23	.018	.022	-	.065	.035
Sept.	-	-	-	-	-	Sept. 28	.040	.040	.050	.070	.055
Oct. 12	.035	.039	.078	.084	.059	Oct. 17	.080	.040	.050	.080	.065
Nov. 14	-	.065	.093	.054	.070	Nov. 22	.093	.071	.105	.080	.087
Dec. 31[a]	.039	.056	.066	.078	.060	Dec. 18	.064	.086	.076	.088	.078
$\bar{x}$	.044	.046	.066	.076		$\bar{x}$	.072	.056	.070	.080	
1974						**1974**					
Jan. 22	.040	.060	.070	.080	.060	Jan.	-	-	-	-	-
Feb. 14	.060	.080	.060	.070	.070	Feb. 12	.060	.050	.060	.060	.060
May 7	.015	.014	.025	.063	.029	May 17	.057	.160	.025	.102	.086
July 22	.027	.029	.039	.082	.044	July 24	.027	.037	.043	.054	.040
Oct. 4	.072	.025	.029	.077	.051	Oct. 9	.108	.072	.097	.094	.093
Dec. 10	.063	.066	.063	.083	.069	Dec. 12	.053	.050	.054	.067	.056
$\bar{x}$	.046	.046	.048	.076		$\bar{x}$	.061	.074	.056	.075	

a - early 1975 data

TABLE 20 Depth and seasonal variation in silicate (mgSi.liter^{-1}) at Stations 6 and 8, Howe Sound.

depth (m) / date	Station 6					depth (m) / date	Station 8				
	1	3	5	20	$\bar{x}$		1	3	5	20	$\bar{x}$
1973						1973					
Apr. 4	-	-	-	-	-	Mar. 28	-	-	-	-	-
Apr.	-	-	-	-	-	Apr. 17	.75	.71	.18	.75	.60
May 29	-	-	-	-	-	May 30	-	-	-	-	-
June 22	-	-	-	-	-	June 21	-	-	-	-	-
July 24	-	-	-	-	-	July 25	-	-	-	-	-
Aug. 24	.93	.91	.78	1.08	.92	Aug. 23	1.07	.98	-	1.20	1.08
						Sept. 28	.90	.50	.89	1.20	.87
Oct. 12	1.16	1.06	-	1.06	1.09	Oct. 17	1.03	.94	1.20	1.29	1.12
Nov. 14	1.50	.94	.91	.97	1.08	Nov. 22	2.30	1.40	1.31	1.08	1.52
						Dec. 18	1.65	1.24	1.26	1.28	1.36
$\bar{x}$	1.20	.97	.85	1.04		$\bar{x}$	1.28	.96	.97	1.13	
1974						1974					
Jan. 22	.99	1.52	1.55	1.51	1.39	Jan.	-	-	-	-	-
Feb. 14	1.70	1.65	1.60	1.50	1.61	Feb. 12	1.90	1.23	1.38	1.38	1.47
May 7	-	-	-	-	-	May 17	-	-	-	-	-
July 22	.35	.20	<.20	.55	.31	July 24	.55	.40	.55	.45	.49
Oct. 4	.51	.25	.45	1.30	.63	Oct. 9	1.00	.86	1.1	1.3	1.06
Dec. 10	1.51	1.48	1.92	1.40	1.58	Dec. 12	1.51	.95	1.08	1.25	2.10
$\bar{x}$	1.01	1.02	1.14	1.25		$\bar{x}$	1.24	.86	1.03	1.10	

TABLE 21 Phytoplankton species list and relative abundance, Station 3, Howe Sound.

Diatoms	Dinoflagellates
***Thalassiosira pacifica*	*Exuviella apora*
***Thalassiosira nordenskioldii*	**Gymnodinium sp. 1*
***Thalassiosira aestivalis*	*Gymnodinium sp. 2*
Thalassiosira (very small)	*Glenodinium danicum*
***Skeletonema costatum*	**Glenodinium* (small)
**Cerataulina bergonii*	*Peridinium depressum*
**Chaetoceros spp.*	*Amphidinium crassum*
Chaetoceros debilis	*Dinophysis spp.*
**Ditylum brightwellii*	*Gonyaulax triacantha*
Melosira moniliformis	*Gonyaulax cf. catenella*
**Corethron hystrix*	*Gonyaulax sp.* (small)
Coscinodiscus sp. (large)	*Prorocentrum gracile*
Coscinodiscus sp. (small)	*Polykrikos sp.*
Eucampia zoodiacus	*Protoceratium reticulatum*
Leptocylindrus danicus	
Biddulphia longicruris	
Rhizosolenia stolterfothii	*Miscellaneous Flagellates*
**Navicula spp.*	
Navicula sp. (large)	*Chrysomonad* (large)
**Thalassionema nitzschioides*	**Chrysomonad* (small)
**Nitzschia seriata*	**Assorted unidentified flagellates*
**Nitzschia closterium*	*Eutreptia sp. (Euglenoid)*
Nitzschia sp. 1	*Olisthodiscus luteus (Crypto monad)*
Achnanthes cf. longipes	*Distephanus speculum (silico-flagellate)*
Pleurosigma sp.	
Cymbella sp.	
Eunotia sp.	
Licmophora abbreviata	
Asterionella kariana	
Asterionella japonica	
Grammatophora sp.	

* - Common

** - Abundant

TABLE 22 Phytoplankton species list and relative abundance, Station 4, Howe Sound.

Diatoms	Dinoflagellates
Coscinodiscus sp. (large)	**Gymnodinium sp. 1*
***Thalassiosira nordenskioldii*	**Glenodinium danicum*
***Thalassiosira pacifica*	**Glenodinium* (small)
***Thalassiosira aestivalis*	*Gonyaulax triacantha*
Thalassiosira (very small)	*Gonyaulax sp.* (small)
***Skeletonema costatum*	*Dinophysis sp.*
**Chaetoceros spp.*	*Peridinium depressum*
Chaetoceros debilis	*Ceratium fusus*
Ditylum brightwellii	*Amphidinium crassum*
Melosira moniliformis	*Prorocentrum gracile*
Melosira nummuloides	*Oxytoxum diploconus*
Cerataulina bergonii	*Polykrikos sp.*
Corethron hystrix	
Rhizosolenia stolterfothii	
Eucampia zoodiacus	**Miscellaneous flagellates**
Leptocylindrus danicus	
**Navicula spp.*	*Eutreptia (Englenoid)*
Thalassiothrix sp.	**Assorted unidentified flagellates*
**Thalassionema nitzschioides*	**Chrysomonad* (small)
Pleurosigma sp.	*Chrysomonad* (large)
Amphiprora sp.	*Olisthodiscus luteus (Cryptomonad)*
**Nitzschia closterium*	*Distephanus speculum (silicoflagellate)*
**Nitzschia seriata*	
Nitzschia sp. 1	
Nitzschia sp. 2	
Cymbella sp.	
Synedra cf.	
Achnanthes cf. longipes	
Asterionella japonica	
Asterionella kariana	
Nitzschia bilobata	

* - Common

** - Abundant

TABLE 23 Phytoplankton species list and relative abundance, Station 6, Howe Sound.

Diatoms	Dinoflagellates
***Thalassiosira pacifica*	*Gymnodinium sp. 1*
Thalassiosira (very small)	*Gonyaulax triacantha*
Thalassiosira nordenskioldii	*Gonyaulax sp.*
Thalassiosira aestivalis	*Phalacroma rotundatum*
***Skeletonema costatum*	*Glenodinium danicum*
Rhizosolenia setigera	*Glenodinium* (small)
Rhizosolenia stolterfothii	*Dinophysis*
**Chaetoceros spp.*	*Ceratium fusus*
Chaetoceros debilis	*Peridinium depressum*
**Cerataulina bergonii*	*Prorocentrum gracile*
**Ditylum brightwellii*	*Exuviella apora*
Corethron hystrix	
Eucampia zoodiacus	
**Navicula spp.*	Miscellaneous flagellates
**Nitzschia seriata*	
**Nitzschia closterium*	*Eutreptia sp. (Euglenoid)*
Nitzschia sp. 1	*Ebria tripartita (silicoflagellate)*
Nitzschia sp. 2	*Olisthodiscus luteus (Cryptomonad)*
Achnanthes cf. longipes	**Chrysomonad* (small)
Synedra cf.	*Chrysomonad* (large)
**Thalassionema*	**Assorted unidentified flagellates*
Cymbella sp.	
Asterionella japonica	

* - Common

** - Abundant

TABLE 24 Phytoplankton species list and relative abundance, Station 8, Howe Sound.

Diatoms

**Skeletonema costatum
Coscinodiscus sp. (large)
Melosira nummuloides
**Thalassiosira pacifica
Chaetoceros spp.
Cerataulina bergonii
Ditylum brightwellii
Thaslassiosira (very small)
Corethron hystrix
*Navicula spp.
Amphiprora sp.
Hannaea arcus
*Nitzschia closterium
*Nitzschia seriata
Asterionella cf. formosa
Achnanthes cf. longipes
Thalassionema nitzschioides
Cymbella sp.
Licmophora abbreviata
Synedra cf.

Dinoflagellates

Gymnodinium sp. l
Gonyaulax triacantha
Dinophysis sp.
Peridinium depressum
Glenodinium danicum
Glenodinium (small)
Prorocentrum gracile

Miscellaneous flagellates

Ebria tripartita (silicoflagellate)
*Assorted unidentified flagellates
Eutreptia (Euglenoids)
*Chrysomonad (small)
Chrysomonad (large)

* - Common
** - Abundant

TABLE 25 Depth and seasonal variation in Chlorophyll a. (mg-m^{-3}) at Stations 3 and 4, Howe Sound.

date \ depth (m)	Station 3					Station 4				
	1	3	5	20	$\bar{x}$	1	3	5	20	$\bar{x}$
1973										
Feb. 7	.40	.19	-	-	.14	.21	-	-	-	.05
Mar. 15	.42	.03	.04	.05	.13	.51	.37	.33	.14	.33
Apr. 10	2.22	4.37	6.85	1.23	3.66	2.49	3.98	4.58	0.81	2.96
May 24	1.73	2.44	1.78	-	1.48	.19	1.59	1.47	.09	.83
June 20	1.83	2.69	0.73	.37	1.40	1.02	2.40	.53	.40	1.08
July 12	1.36	.89	.38	.58	.80	2.00	-	1.02	.23	1.08
Aug. 28	.53	.29	.44	.14	.35	3.42	.65	.38	.26	1.17
Sept. 25	3.42	3.01	1.40	.14	1.99	2.91	1.16	.54	.37	1.24
Oct. 18	1.40	1.16	.86	.09	.87	1.51	1.01	1.15	.14	.95
Nov. 21	.21	-	-	-	.21	.23	.14	-	-	.09
Dec. 19	.15	.17	.10	.04	.11	.33	.13	.16	.05	.16
$\bar{x}$	1.24	1.52	1.25	.26		1.34	1.14	.92	.22	
1974										
Jan. 10	.29	.29	.33	-	.22	.23	.37	.27	-	.21
Feb. 22	.40	.23	.24	.17	.26	.05	.09	.04	-	.04
Mar. 14	.22	.24	.22	.23	.23	.43	.43	.26	.16	.32
Apr. 4	1.38	.65	-	.23	.75	.73	.58	.45	.17	.48
May 9	.96	.88	.48	.27	.64	1.20	.91	-	.27	.59
June 11	.86	2.06	3.19	.53	1.66	.78	1.63	1.94	.40	1.18
July 23	3.65	2.88	1.79	.77	2.27	1.81	.97	1.63	.53	1.23
Aug. 22	1.17	.99	.65	.20	.75	.59	.80	.31	.29	.49
Sept. 10	3.53	4.38	3.15	.45	2.87	2.66	2.88	3.52	.47	2.38
Oct. 3	1.33	1.62	1.78	1.28	1.50	1.27	1.76	1.97	1.15	1.53
Nov. 14	.85	.53	.53	.05	.49	.58	.37	.32	.21	.37
Dec. 5	.64	.26	.37	-	.32	.64	.53	.26	.05	.37
$\bar{x}$	1.27	1.25	1.15	.34		.91	.94	.99	.30	

TABLE 26 Depth and seasonal variation in Chlorophyll a. (mg-m^{-3}) at Stations 6 and 8, Howe Sound.

date \ depth (m)	Station 6					Station 8				
	1	3	5	20	$\bar{x}$	1	3	5	20	$\bar{x}$
1973										
Feb. 27/14	.19	.16	.21	.07	.15	.12	.09	.12	-	.08
Apr.4/Mar.28	-	-	-	-	-	-	-	-	-	-
Apr. 24/17	6.56	3.37	1.33	.39	2.91	5.89	6.00	6.35	1.45	4.92
May 29/30	.23	.21	.21	.02	.16	-	-	-	-	-
June 22/21	.69	-	.68	.19	.52	.40	.22	.22	.12	.24
July 24/25	.25	.25	.21	.25	.22	.20	.18	.18	.24	.20
Aug. 24/23	.90	.95	.33	.97	.78	2.18	1.51	.80	-	1.12
Sept. /28	-	-	-	-	-	2.15	2.97	.90	.17	1.54
Oct. 12/17	2.05	3.33	2.06	.11	1.88	.65	.78	.33	.08	.46
Nov. /22	-	-	-	-	-	.33	.18	-	-	.12
Dec. 14/18	.20	.21	.18	.04	.15	-	.03	.02	-	.01
$\bar{x}$	1.38	1.21	.65	.25		1.32	1.32	.99	.22	
1974										
Jan. 22/23	.31	.07	.05	-	.10	.08	.15	.06	.02	.07
Feb. 14/12	.30	.34	.26	.14	.26	.29	.20	.07	-	.14
Mar. 8/12	-	.05	.05	-	.02	.37	.43	.35	.13	.32
Apr. 3/ 9	.86	.65	.59	.21	.57	.36	.39	-	.21	.24
May 7/17	1.18	.73	1.12	.71	.93	.26	.40	.20	.17	.25
June 10/13	1.62	1.74	.90	.24	1.12	.19	.27	.13	.05	.01
July 22/24	1.55	3.19	3.33	.65	2.18	.43	.40	1.06	.26	.53
Aug. 9	.65	.56	.78	.54	.63	-	-	-	-	-
Sept. 11/ 3	.58	1.53	.81	.15	.76	.32	1.24	.68	.40	.66
Oct. 4/ 9	1.52	1.96	1.28	.33	1.27	1.36	1.00	.84	.52	.93
Nov. 15/ 6	.48	.42	.37	-	.32	.53	.58	.48	.26	.46
Dec. 10/12	.69	.32	.26	.21	.37	.48	.64	.37	.26	.23
$\bar{x}$	.81	.96	.81	.26		.42	.51	.38	.41	

TABLE 27 Depth and seasonal variation in particulate matter (seston) ($mg.m^{-3}$) at Stations 3 and 4, Howe Sound.

date \ depth (m)	Station 3					Station 4				
	1	3	5	20	$\bar{x}$	1	3	5	20	$\bar{x}$
1973										
Feb. 7	9.1	14.9	20.4	11.2	13.9	11.8	6.5	18.2	11.7	12.1
Mar. 15	3.5	5.2	3.1	8.7	5.1	4.6	5.3	3.5	7.4	5.2
Apr. 10	8.5	10.5	10.7	10.0	9.9	9.2	9.5	9.4	8.8	9.2
May 24	16.1	8.0	16.0	-	13.4	15.4	16.8	12.2	10.7	13.8
June 20	5.1	7.2	7.3	9.2	7.2	9.0	5.5	5.3	4.0	5.9
July 12	3.9	4.4	7.8	10.9	6.8	16.3	21.9	-	8.0	15.4
Aug. 28	5.8	2.5	3.2	4.0	3.9	2.9	3.0	2.1	1.8	2.5
Sept. 25	14.6	14.5	14.3	15.1	14.6	18.3	25.5	25.1	14.7	20.9
Oct. 18	17.9	16.8	19.0	18.3	18.0	15.9	19.0	16.6	16.8	17.1
Nov. 21	20.0	18.0	20.7	23.1	20.5	11.6	13.4	9.5	11.5	11.5
Dec. 19	9.3	7.3	4.6	7.0	7.1	5.5	6.0	3.7	4.1	4.8
$\bar{x}$	10.3	9.9	11.5	11.7	10.9	10.9	12.0	10.6	10.0	10.8
1974										
Jan. 10	3.2	2.5	3.1	2.7	2.9	2.4	2.4	2.4	3.0	2.6
Feb. 22	17.2	16.4	15.9	21.0	17.6	17.1	16.4	17.3	22.0	18.2
Mar. 14	9.3	10.4	11.0	12.2	10.7	8.4	9.3	10.7	12.6	10.3
Apr. 4	15.8	21.1	17.2	21.6	18.9	14.2	16.1	17.7	19.7	16.9
May 9	5.5	4.7	6.2	8.3	6.2	6.8	7.5	5.3	7.8	6.9
June 11	8.6	10.3	10.3	17.9	11.8	10.3	11.7	10.7	15.2	12.0
July 23	10.5	10.1	13.3	17.1	12.8	12.2	15.3	17.1	17.1	15.4
Aug. 22	3.8	3.2	3.4	7.7	4.5	7.3	8.5	3.1	3.4	5.6
Sept. 10	14.4	11.7	14.6	19.5	15.1	12.9	12.4	15.0	20.4	15.2
Oct. 3	14.5	10.9	22.4	19.4	16.8	16.4	14.5	21.6	24.1	19.1
Nov. 14	15.3	15.1	16.0	19.3	16.4	17.1	18.2	15.7	17.5	17.1
Dec. 5	14.8	14.9	16.3	19.9	16.5	15.7	16.0	16.5	18.4	16.7
$\bar{x}$	11.1	10.9	12.5	15.6	12.5	11.7	12.4	12.8	15.1	13.0

TABLE 28 Percentage organic content of dry seston at Station 3 and 4, Howe Sound.

date \ depth (m)	Station 3					Station 4				
	1	3	5	20	$\bar{x}$	1	3	5	20	$\bar{x}$
1973										
Feb. 7	26.4	19.5	16.7	17.9	20.1	21.2	32.2	17.0	18.8	22.3
Mar. 15	20.0	15.4	19.4	11.5	16.6	36.7	22.6	34.3	23.0	29.2
Apr. 10	27.1	27.6	26.2	30.0	27.7	35.9	36.8	35.1	26.1	33.5
May 24	15.5	26.3	16.9	25.0	20.9	33.8	21.4	22.1	17.8	23.8
June 20	39.2	33.3	19.2	17.4	27.3	40.0	32.7	18.9	30.0	30.4
July 12	33.3	27.3	-	15.6	19.1	16.6	14.6	-	24.2	18.5
Aug. 28	12.1	24.0	15.6	12.5	16.1	17.2	16.7	19.1	11.1	16.0
Sept. 25	8.2	6.9	6.3	8.0	7.4	22.4	9.4	8.4	5.4	11.4
Oct. 18	6.2	5.4	4.7	3.8	5.0	7.6	7.4	7.8	6.0	7.2
Nov. 21	9.0	7.2	11.6	7.8	8.9	13.7	17.5	6.8	12.8	12.7
Dec. 19	9.7	8.2	15.2	17.1	12.6	32.7	33.3	21.6	19.5	26.8
$\bar{x}$	18.8	18.3	15.2	15.1		25.3	22.2	19.1	17.7	21.1
1974										
Jan. 10	37.5	24.0	9.7	22.3	23.4	16.7	20.8	20.8	16.7	18.8
Feb. 22	-	-	-	-	-	-	-	-	-	-
Mar. 14	30.1	28.9	25.5	27.0	27.9	47.6	36.6	34.6	30.9	37.4
Apr. 4	20.3	15.6	17.4	18.5	17.9	18.3	16.3	18.1	14.7	16.9
May 9	45.5	40.4	25.8	18.1	32.5	30.9	25.3	26.4	23.1	26.4
June 11	27.9	27.2	26.2	15.1	24.1	35.9	32.5	25.2	22.4	29.0
July 23	-	-	-	-	-	-	-	-	-	-
Aug. 22	31.6	31.3	29.4	15.6	26.9	32.9	28.2	29.0	35.3	31.3
Sept. 10	26.3	19.7	15.8	13.9	18.9	20.2	21.8	24.0	17.7	20.9
Oct. 3	22.1	21.9	13.8	17.5	18.8	32.3	23.4	18.5	16.2	22.6
Nov. 14	11.1	12.6	11.3	11.4	11.6	24.6	18.1	22.3	20.6	21.4
Dec. 5	9.5	13.4	9.2	11.6	10.9	15.9	11.3	18.2	20.1	16.4
$\bar{x}$	26.2	23.5	18.4	17.1	21.3	27.5	23.4	23.7	21.8	24.1

TABLE 29 Depth and seasonal variation in particulate matter (seston) ($mg.m^{-3}$) at Stations 6 and 8, Howe Sound.

date \ depth (m)	Station 6					Station 8				
	1	3	5	20	$\bar{x}$	1	3	5	20	$\bar{x}$
1973										
Feb. 27/14	10.8	11.1	8.4	10.3	10.2	10.5	9.8	9.0	11.4	10.2
Apr.4/Mar.28	14.8	12.0	7.0	7.2	10.3	16.2	5.1	4.3	4.0	7.4
Apr. 24/17	15.2	16.7	12.7	18.9	15.9	19.7	14.7	15.3	9.7	14.9
May 29/30	9.1	7.5	18.9	23.0	14.6	8.4	9.7	8.7	11.2	9.5
June 22/21	14.4	17.0	17.5	17.2	16.5	13.0	6.5	4.3	4.9	7.2
July 24/25	5.0	3.8	3.1	3.0	3.7	12.8	10.6	6.5	6.6	9.1
Aug. 24/23	2.6	2.7	2.4	1.3	2.3	5.4	3.3	2.8	3.2	3.7
Sept. /28	-	-	-	-	-	20.2	18.1	18.5	19.5	19.1
Oct. 12/17	27.6	19.3	19.3	18.4	21.2	29.6	18.5	24.8	18.6	22.9
Nov. /22	-	-	-	-	-	24.2	19.0	18.0	20.3	20.4
Dec. 14/18	1.0	1.3	1.4	1.4	1.3	4.9	7.3	5.6	7.7	6.4
$\bar{x}$	11.2	10.2	10.1	11.2	10.7	15.0	11.1	10.7	10.6	32.7
1974										
Jan. 22/23	6.9	4.6	5.3	5.4	5.6	18.7	7.0	8.3	7.7	10.4
Feb. 14/12	14.7	16.9	14.9	19.3	16.5	17.3	16.4	18.4	18.1	17.6
Mar. 8/12	13.5	18.3	12.8	14.9	14.9	11.0	11.0	11.0	13.0	11.5
Apr. 3/ 9	13.0	15.2	17.5	20.0	16.5	16.2	8.8	8.5	10.1	10.9
May 7/17	8.1	5.8	11.1	7.5	8.1	73.8	263.4	24.3	47.8	102.4
June 10/13	9.3	11.3	13.6	15.0	12.3	10.6	19.9	22.7	21.1	18.6
July 22/24	12.0	13.1	18.3	20.9	16.1	22.7	21.7	16.9	18.5	19.9
Aug. 9	10.6	7.1	9.0	7.6	8.6	-	-	-	-	-
Sept.11/ 3	18.7	16.1	17.3	19.7	17.9	16.8	18.9	18.1	20.9	18.7
Oct. 4/ 9	14.6	20.2	20.3	22.6	19.4	19.6	24.8	20.2	19.5	21.1
Nov. 15/ 6	15.9	15.9	16.9	20.2	17.3	16.3	22.8	21.6	20.5	20.3
Dec. 10/12	14.3	15.6	15.6	17.6	15.8	13.5	16.7	13.4	17.4	15.3
$\bar{x}$	12.6	13.3	14.4	15.9	14.1	21.5	39.2	16.7	19.5	24.2

TABLE 30 Percentage organic content of dry seston at Station 6 and 8, Howe Sound.

depth (m) / date	Station 6					Station 8				
	1	3	5	20	$\bar{x}$	1	3	5	20	$\bar{x}$
1973										
Feb. 27/14	24.1	23.4	32.1	23.3	25.7	38.1	25.5	32.2	27.2	30.8
Apr.4/Mar.28	28.4	25.8	44.3	29.2	31.9	80.2	37.3	34.9	25.0	44.3
Apr. 24/17	20.4	19.8	25.2	19.0	21.1	72.6	34.0	33.3	26.8	41.7
May 29/30	17.6	20.0	13.8	11.3	15.7	28.6	30.9	32.2	19.6	27.8
June 22/21	11.8	12.9	9.7	9.9	11.1	21.5	30.8	30.2	28.6	27.8
July 24/25	24.0	10.5	19.4	16.7	17.7	14.8	21.7	21.5	27.3	21.3
Aug. 24/23	-	29.6	33.3	23.1	28.6	33.3	39.4	35.7	40.6	37.2
Sept. /28	-	-	-	-	-	17.3	14.9	12.4	11.3	14.0
Oct. 12/17	1.1	1.0	1.0	0.5	0.9	2.4	2.7	4.0	0.5	2.4
Nov. /22	-	-	-	-	-	21.5	4.7	3.9	6.9	9.3
Dec. 14/18	80.0	46.2	50.0	50.0	56.6	12.2	20.6	7.1	11.7	12.9
$\bar{x}$	23.0	21.0	25.4	20.3	23.2	31.1	23.9	22.5	20.5	24.5
1974										
Jan. 22/23	21.7	15.2	18.9	13.0	17.2	45.5	51.4	32.5	33.8	40.8
Feb. 14/12	9.5	10.1	11.4	10.4	10.4	13.3	12.8	12.5	11.6	12.6
Mar.	-	-	-	-	-	-	-	-	-	-
Apr. 3/ 9	17.7	13.8	14.9	14.0	15.1	30.3	19.3	16.5	14.9	20.3
May 7/17	29.6	31.0	18.9	20.0	24.9	11.4	6.6	28.8	16.3	15.8
June 10/13	30.1	27.4	19.1	21.3	24.5	22.6	21.1	21.6	26.5	22.9
July	-	-	-	-	-	-	-	-	-	-
Aug. 9	7.5	15.5	14.4	10.5	11.9	-	-	-	-	-
Sept.11/ 3	9.6	12.4	15.0	13.7	12.7	8.3	11.1	12.2	13.9	11.3
Oct. 4/ 9	32.6	20.3	18.2	17.3	22.1	29.6	24.6	16.3	15.9	21.6
Nov. 15/ 6	8.2	8.2	9.5	9.4	8.8	18.4	18.4	17.6	13.7	17.0
Dec. 10/12	15.4	15.4	13.5	37.5	20.4	19.3	22.8	11.2	16.7	16.3
$\bar{x}$	18.2	16.9	15.4	16.7	16.8	22.1	20.9	18.8	18.1	19.8

TABLE 31 Zooplankton biomass vertical haul at Station 3 and 4, Howe Sound

date	Station 3 % loss on ignition	Station 3 biomass ($mg \cdot m^{-3}$)	Station 4 % loss on ignition	Station 4 biomass ($mg \cdot m^{-3}$)
1973				
Feb. 7	82.7	6.25	89.7	47.23
Mar. 15	86.1	5.63	82.9	10.20
Apr. 10	79.2	8.29	83.5	7.85
May 24	63.4	17.75	61.6	12.87
June 20	44.5	9.94	43.5	22.73
July 12	68.3	56.06	72.1	65.84
Aug. 28	54.4	5.90	60.2	7.75
Sept.25	31.8	104.79	50.0	12.36
Oct. 18	49.0	2.81	63.8	13.82
Nov. 21	72.2	15.63	52.0	5.20
Dec. 19	65.6	7.13	53.7	16.30
$\bar{x}$	63.4	21.83	64.8	20.19
1974				
Jan. 10	67.2	8.12	75.0	11.87
Feb. 22	88.7	1.11	98.6	5.39
Mar. 14	82.4	4.19	93.4	16.26
Apr. 4	76.5	3.73	77.9	5.03
May 9	92.4	35.96	92.1	38.28
June 11	87.2	8.97	93.2	19.17
July 23	68.5	1.94	86.6	5.60
Sept.10	69.5	5.71	85.2	9.24
Oct. 3	71.3	5.19	84.8	7.94
Nov. 14	65.7	3.75	96.8	31.23
Dec. 5	-	-	49.5	4.91
$\bar{x}$	76.9	7.87	84.8	14.08

TABLE 32 Zooplankton biomass vertical haul at Station 6 and 8, Howe Sound.

Station 6			Station 8		
date	% loss on ignition	biomass ($mg.m^{-3}$)	date	% loss on ignition	biomass ($mg.m^{-3}$)
1973					
Feb. 27	84.7	6.74	Feb. 14	97.2	45.82
Apr. 4	72.1	7.88	Apr. 17	81.7	70.68
Apr. 24	80.2	16.63	Apr. 25	85.9	139.40
May 29	62.0	5.65	May 30	67.9	63.65
June 22	51.4	7.32	June 21	71.7	39.61
July 24	44.9	3.87	July 25	69.7	40.67
Aug. 24	53.0	6.26	Aug. 23	63.7	22.72
			Sept.28	16.1	.90
Oct. 12	53.4	6.11	Oct. 17	46.4	6.44
			Nov. 22	75.4	44.99
Dec. 14	73.6	109.48	Dec. 18	75.4	44.73
$\bar{x}$	63.9	18.88	$\bar{x}$	68.2	47.51
1974					
Jan. 22	86.1	48.73	Jan. 23	93.2	56.72
Feb. 14	71.0	1.57	Feb. 12	98.9	62.06
Mar. 8	68.9	1.87	Mar. 12	94.4	32.80
Apr. 3	69.7	3.46	Apr. 9	97.3	39.93
May 7	79.1	31.52	May 17	94.0	56.21
June 10	92.2	7.68	June 13	97.4	68.33
July 22	85.4	3.21	July 24	95.3	19.97
Aug. 9	89.5	7.15			
Sept.11	75.3	5.97	Sept. 3	54.0	28.72
Oct. 4	74.3	3.35	Oct. 9	95.8	106.42
Nov. 15	81.4	7.40	Nov. 6	94.3	24.63
Dec. 10	44.8	4.10	Dec. 12	94.2	26.85
$\bar{x}$	76.5	10.50	$\bar{x}$	91.7	47.50

TABLE 33 Daily areal primary production rates ($mgC.m^{-2}.day^{-1}$) at Stations 3 & 4 and 6 & 8, Howe Sound.

Date	Station 3	Station 4	Date	Station 6	Station 8
1973					
Feb. 7	25	6	Feb. 14	14	0
Apr. 10	602	81	Mar. 28	1,122	27
May 24	407	16	Apr. 17	170	351
June 20	714	14	Apr. 25	167	461
July 12	426	33	May 30	74	65
Aug. 28	295	117	June 21	802	60
Sept. 25	764	26	July 25	190	18
Oct. 18	21	0	Aug. 23	368	531
Nov. 21	44	0.8	Sept. 28	324	244
Dec. 19	22	1	Oct. 17	281	38
			Nov. 22	45	0
			Dec. 18	7	0
$\bar{x}$	332	29		297	149
1974					
Jan. 10	36	0.5	Jan. 23	24	13
Feb. 22	118	2	Feb. 12	69	13
Mar. 14	109	12	Mar. 12	89	40
Apr. 4	516	128	Apr. 9	310	210
May 9	320	103	May 17	666	761
June 11	880	32	June 13	750	19
July 23	340	0.6	July 24	243	12
Aug. 22	178	0			
Sept. 10	898	11	Sept. 3	86	41
Oct. 3	806	0	Oct. 9	285	32
Nov. 14	109	0	Nov. 6	55	17
Dec. 5	100	4	Dec. 12	20	21
$\bar{x}$	367	24		236	107

TABLE 34 Special cross-incubation production experiments at Stations 3 and 4, Howe Sound ($mgC.m^{-2}.day^{-1}$).

Date	Station 3 incubated control	Station 3 incubated at Stn. 4	(a)	Station 4 incubated at Stn. 4	Station 4 incubated at Stn. 3	(b)
1974						
Feb. 9	19	20	-	16	26	1.6
May 13	167	37	4.5	-	-	-
June 11	897	267	3.4	31	174	5.6
July 23	340	27	13.1	0.6	29	48.3
1975						
Mar. 6	222	20	11.1	38	36	-
May 6	536	74	7.2	60	213	3.5
$\bar{x}$	364	74	7.8	29	96	14.7

(a) - Decrease factor

(b) - Increase factor

TABLE 35 Daily areal primary production and chlorophyll at six British Columbia coastal mills.

A. Primary production ($mgC.m^{-2}.day^{-1}$)

Date	Location	Mill	Control
1973			
Oct. 2	Powell River	762	1,125
Oct. 3	Campbell River (Elk Falls)	357	205
1974			
Sept.20	Nanaimo (Harmac)	1,958	1,920
Sept.21	Port Alberni	160	313
Sept.22	Port Alice	119	721
Sept.24	Prince Rupert (Pt. Edward)	34	136
Sept.26	Campbell River (Elk Falls)	1,269	1,489
Sept.27	Powell River	49	450

B. Chlorophyll concentrations at surface (1,3,5m) and 20 m ($mg.m^{-3}$).

Date	Location	Mill		Control	
		Surface	20 m	Surface	20 m
1973					
Oct. 2	Powell River	2.05	.22	2.69	.24
Oct. 3	Campbell River (Elk Falls)	.69	.52	.04	0
1974					
Sept.20	Nanaimo (Harmac)	2.69	.96	1.42	1.02
Sept.21	Port Alberni	.82	.26	1.60	.40
Sept.22	Port Alice	.21	1.54	1.12	1.11
Sept.24	Prince Rupert	1.39	.45	.82	.28
Sept.26	Campbell River	1.48	-	2.51	1.93
Sept.27	Powell River	.24	.26	.61	.23

TABLE 36 Annual Production in Howe Sound by zone. (See Figure 1.)

Zone	Area (Km^2)	Areal Production $KgC.m^{-2}.year^{-1}$		Zonal Production metric tons $x\ 10^3.year^{-1}$	
		1973	1974	1973	1974
1	29.3	0.316	0.512	9.25	14.99
2	43.9	0.140	0.183	6.15	8.03
3	44.5	0.235	0.440	10.46	19.59
4	17.9	0.113	0.127	2.03	2.28
5	21.4	0.081	0.090	1.74	1.93
Port Mellon	6.3	0.012	0.009	0.07	0.06
Woodfibre	6.3	0.044	0.038	0.28	0.24
Total	169.6			29.98	47.12

	Metric Tons $x\ 10^3.year^{-1}$ 1973	1974
a. Production in Zone 4 without mill:	2.74	3.08
b. Production in Zone 5 without mill:	2.24	2.49
c. Production in Zone 4 with mill:	2.03	2.28
d. Production in Zone 5 with mill:	1.74	1.93
e. Production loss in Zone 4 attributable to mill:	0.71	0.80
f. Production loss in Zone 5 attributable to mill:	0.50	0.56

	%	
g. Percentage loss in production in Zone 4:	26	26
h. Percentage loss in production in Zone 5:	22	22
i. Percentage loss in production in Howe Sound attributable to both mills:	4	3

APPENDIX TABLES

APPENDIX TABLE 1 Total radiation and percent of light day utilized for ^{14}C incubation at six British Columbia coastal mill stations.

Date	Total Light g cal. $cm^{-2}day^{-1}$	Mill Site % total light	Control % total light
1973			
Powell River Oct. 2	300 [a]	75	70
Campbell River Oct. 3	300 [a]	70	65
1974			
Nanaimo Sept. 20	422	56	62
Port Alberni Sept. 21	471	51	61
Port Alice Sept. 22	424	31	68
Prince Rupert Sept. 24	222	33	70
Campbell River Sept. 26	474	56	70
Powell River Sept. 27	333	53	44

APPENDIX TABLE 2 Light extinction coefficients (k) and Secchi depth (m) at six British Columbia coastal mills.

Date	Mill Site		Control	
	Extinction Coefficients	Secchi (m)	Extinction Coefficients	Secchi (m)
1973				
Powell River Oct. 2	.4533	3.5	.4609	4.5
Campbell River Oct. 2	.2038	8.0	.2562	7.5
1974				
Nanaimo Sept. 20	2.2343	1.5	-	5.5
Port Alberni Sept. 21	.8326	1.3	.3599	2.3
Port Alice Sept. 22	.8099	1.0	.4499	6.0
Prince Rupert Sept. 24	1.3981	2.0	.3962	4.3
Campbell River Sept. 26	-	7.0	.1707	7.5
Powell River Sept. 27	-	5.0	-	15.0

APPENDIX TABLE 3 Depth and seasonal variation in phytoplankton volume ($mm^3.m^{-3}$) at Stations 3 and 4, Howe Sound.

date \ depth (m)	Station 3		Station 4	
	1	5	1	5
1973				
Feb. 7	68	65	211	18
Mar. 15	152	74	191	342
Apr. 10	701	1,567	1,646	1,968
May 24	1,593	3,560	2,555	3,809
June 20	8,947	238	2,409	418
July 12	3,123	278	3,259	149
Aug. 28	616	210	867	683
Sept. 25	752	162	597	204
Oct. 18	112	239	485	521
Nov. 21	118	66	97	111
Dec. 19	22	62	45	25
1974				
Jan. 10	77	173	-	52
Feb. 22	613	346	189	243
Mar. 14	81	147	419	112
Apr. 4	1,312	236	630	364
May 9	19,634	2,876	20,972	960
June 11	5,930	6,270	4,557	5,265
July 23	3,363	1,085	1,404	428
Aug. 22	1,631	741	336	258
Sept. 10	4,277	2,710	1,950	1,270
Oct. 3	5,659	829	1,508	1,813
Nov. 14	165	56	118	150
Dec. 5	634	40	95	36

APPENDIX TABLE 4 Depth and seasonal variation in phytoplankton numbers (no.m^{-3}) at Stations 3 and 4, Howe Sound.

date \ depth (m)	Station 3		Station 4	
	1	5	1	5
1973				
Feb. 7	31	60	135	41
Mar. 15	35	20	53	60
Apr. 10	148	390	196	199
May 24	634	1,628	986	1,140
June 20	2,373	271	1,127	175
July 12	3,056	303	2,358	365
Aug. 28	275	525	265	597
Sept. 25	696	248	1,615	104
Oct. 18	136	311	452	442
Nov. 21	448	269	356	320
Dec. 19	81	151	112	110
1974				
Jan. 10	322	143	-	193
Feb. 22	1,026	312	654	246
Mar. 14	324	273	326	364
Apr. 4	1,484	410	745	497
May 9	12,860	2,025	25,699	795
June 11	6,343	4,040	3,885	3,213
July 23	2,929	1,455	2,257	654
Aug. 22	2,226	998	1,269	615
Sept. 10	3,430	2,436	1,633	1,433
Oct. 3	2,631	477	922	614
Nov. 14	342	222	379	174
Dec. 5	713	301	465	261

APPENDIX TABLE 5 Depth and seasonal variation in phytoplankton volume ($mm^3.m^{-3}$) at Stations 6 and 8, Howe Sound.

depth (m) / date	Station 6		depth (m) / date	Station 8	
	1	5		1	5
1973					
Feb. 27	22	17	Feb. 14	66	40
Apr. 4	19,990	3,742	Mar. 28	141	218
	-	-	Apr. 17	16,786	9,791
Apr. 24	473	992	Apr. 25	10,250	1,926
May 29	73	137	May 30	103	222
June 22	1,510	208	June 21	812	77
July 24	522	214	July 25	158	48
Aug. 24	2,512	1,280	Aug. 23	1,463	79
	-	-	Sept.28	811	113
Oct. 12	563	423	Oct. 17	44	110
	-	-	Nov. 22	13	18
Dec. 14	69	60	Dec. 18	25	145
1974					
Jan. 22	117	44	Jan. 23	24	2
Feb. 14	64	72	Feb. 12	662	25
Mar. 8	69	258	Mar. 12	161	257
Apr. 3	952	68		-	-
May 7	24,280	5,362	May 17	146	431
June 10	1,900	695	June 13	175	74
July 22	387	2,500	July 24	44	309
Aug. 9	413	927		-	-
Oct. 4	3,000	1,574	Oct. 9	130	182
Nov. 15	41	53	Nov. 6	94	164
Dec. 10	91	83	Dec. 12	60	44

APPENDIX TABLE 6 Depth and seasonal variation in phytoplankton numbers (no.m^{-3}) at Stations 6 and 8, Howe Sound.

date \ depth (m)	Station 6		date \ depth (m)	Station 8	
	1	5		1	5
1973					
Feb. 27	15	13	Feb. 14	8	5
Apr. 4	1,110	210	Mar. 28	42	86
	-	-	Apr. 17	15,189	612
Apr. 24	183	216	Apr. 25	11,445	132
May 29	45	22	May 30	33	69
June 22	700	212	June 21	324	105
July 24	438	399	July 25	112	191
Aug. 24	1,233	428	Aug. 23	887	204
	-	-	Sept.28	242	253
Oct. 12	1,079	1,778	Oct. 17	157	204
	-	-	Nov. 22	51	51
Dec. 14	300	259	Dec. 18	98	10
1974					
Jan. 22	487	153	Jan. 23	102	24
Feb. 14	267	181	Feb. 12	94	27
Mar. 8	283	295	Mar. 12	643	631
Apr. 3	699	180		-	-
May 7	26,190	2,447	May 17	133	31
June 10	2,394	1,053	June 13	277	318
July 22	601	292	July 24	83	477
Aug. 9	582	1,204		-	-
Oct. 4	1,659	1,097	Oct. 9	566	491
Nov. 15	131	216	Nov. 6	195	658
Dec. 10	562	242	Dec. 12	397	289

FIGURES

FIGURE LEGEND

Figure 1. Map of Howe Sound showing pulp mill locations (solid circles) and zones (circled numbers) mentioned in text.

Figure 2. Map of British Columbia coast showing location of pulp mills visited in 1973 and 1974.

Figure 3A,B. Plot of extinction coefficients (k) as a function of depth on August 22, 1974. (A) Station 3, (B) Station 4.

Figure 4. Seasonal variation in phytoplankton number (cells x $10^6 \cdot m^{-3}$) and volume ($mm^3 \cdot m^{-3}$) at a depth of 1 m at Stations 3 and 4, 1973 and 1974.

Figure 5. Seasonal variation in phytoplankton number (cells x $10^6 \cdot m^{-3}$) and volume ($mm^3 \cdot m^{-3}$) at a depth of 1 m at Stations 6 and 8, 1973 and 1974.

Figure 6. Production - depth profile at Port Mellon (Station 4) and control (Station 3) on April 4, 1974.

Figure 7. Production - depth profile from Woodfibre (Station 8) and control (Station 6) in July, 1973, during Squmish River freshet.

Figure 8. Production - depth profile from control cross-incubation experiment (3/3 = Station 3 plankton incubated at Station 3; 3/4 = Station 3 plankton incubated at Station 4).

Figure 9. Production - depth profile from mill cross-incubation experiment (4/4 = Station 4 plankton incubated at Station 4; 4/3 = Station 4 plankton incubated at Station 3).

Figure 10A,B. Primary production profiles at Port Mellon (Station 4) and control (Station 3) on day of pulp mill closure (0), and on 14 and 35 days following. (A) mill, (B) control.

Figure 11. Growth of natural phytoplankton assemblages collected near control (Station 6) and incubated off Woodfibre pulp mill at four stations in representative stain gradient. Experiment conducted June 5, 1975. k = mean light extinction coefficient m^{-1}, (⅄) = mean Secchi depth.

Figure 12. Growth of *Skeletonema costatum* at 1 and 2 m depth after 4 hour *in situ* incubation at 3 stations representative of the stain gradient at Port Mellon, and at the control, Station 4. Experiment conducted July 11, 1975. k = mean extinction coefficient, (▲) = mean Secchi depth.

Figure 13. The relation between production and light for *Skeletonema costatum* under field light conditions beneath the stain gradient, Station 4, (see Fig. 12). Pmax = photosynthetic maximum, I_k = light intensity at intersection of initial slope with Pmax, I = light intensity.

Figure 14. Absorption spectrum for an axenic culture of *Skeletonema Costatum*. (Curve of absorbance by culture media substracted).

Figure 15. Absorption of light by three KME concentrations off Port Mellon (PM 1-3) and at control Station 3 (PM 4). Number on line = apparent color.

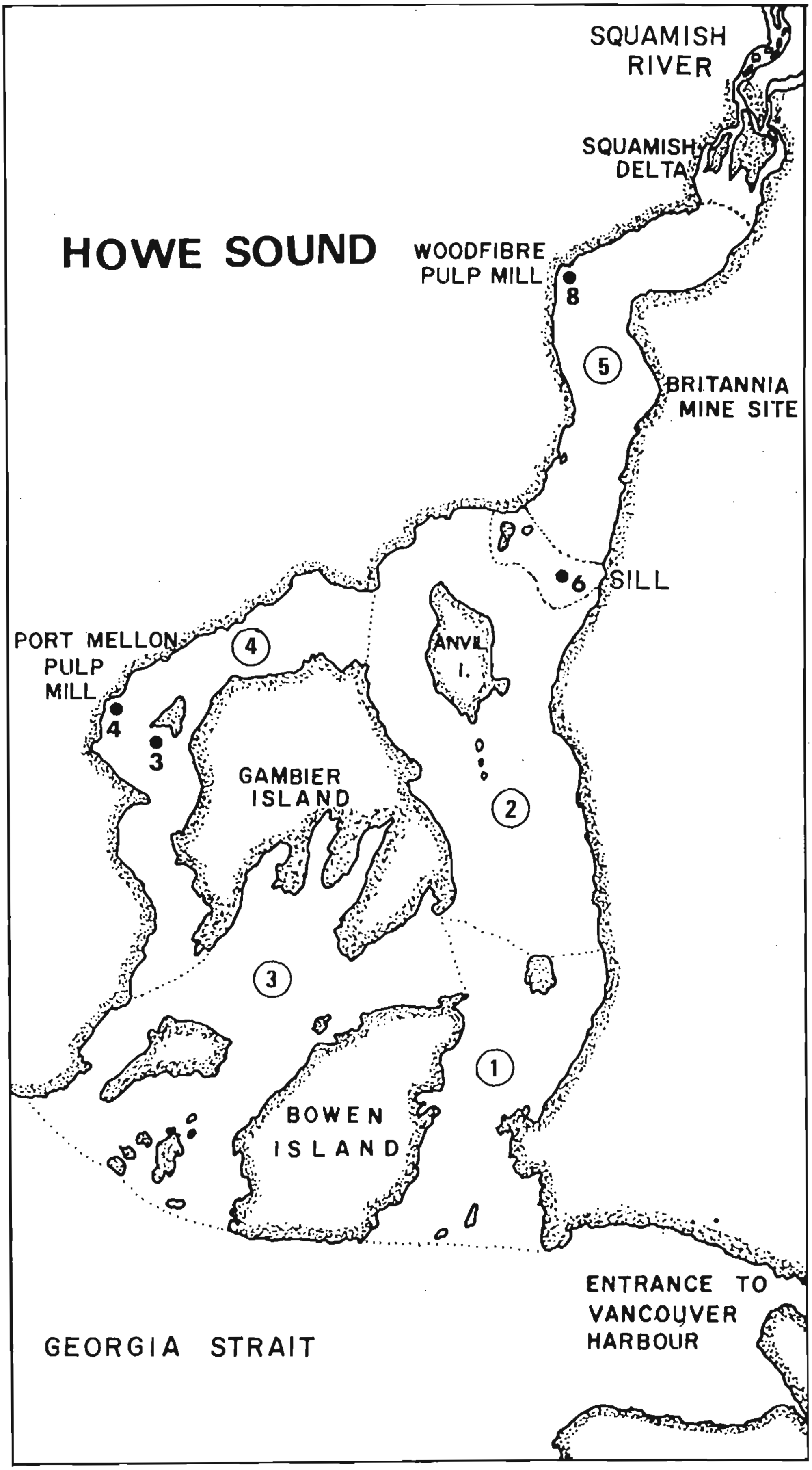

SQUAMISH
RIVER
SQUAMISH
DELTA
HOWE SOUND
WOODFIBRE
PULP MILL
8
5
BRITANNIA
MINE SITE
6
SILL
PORT MELLON
PULP
MILL
4
4
3
ANVIL
I.
GAMBIER
ISLAND
2
3
1
BOWEN
ISLAND
ENTRANCE TO
VANCOUVER
HARBOUR
GEORGIA STRAIT

FIG. 1

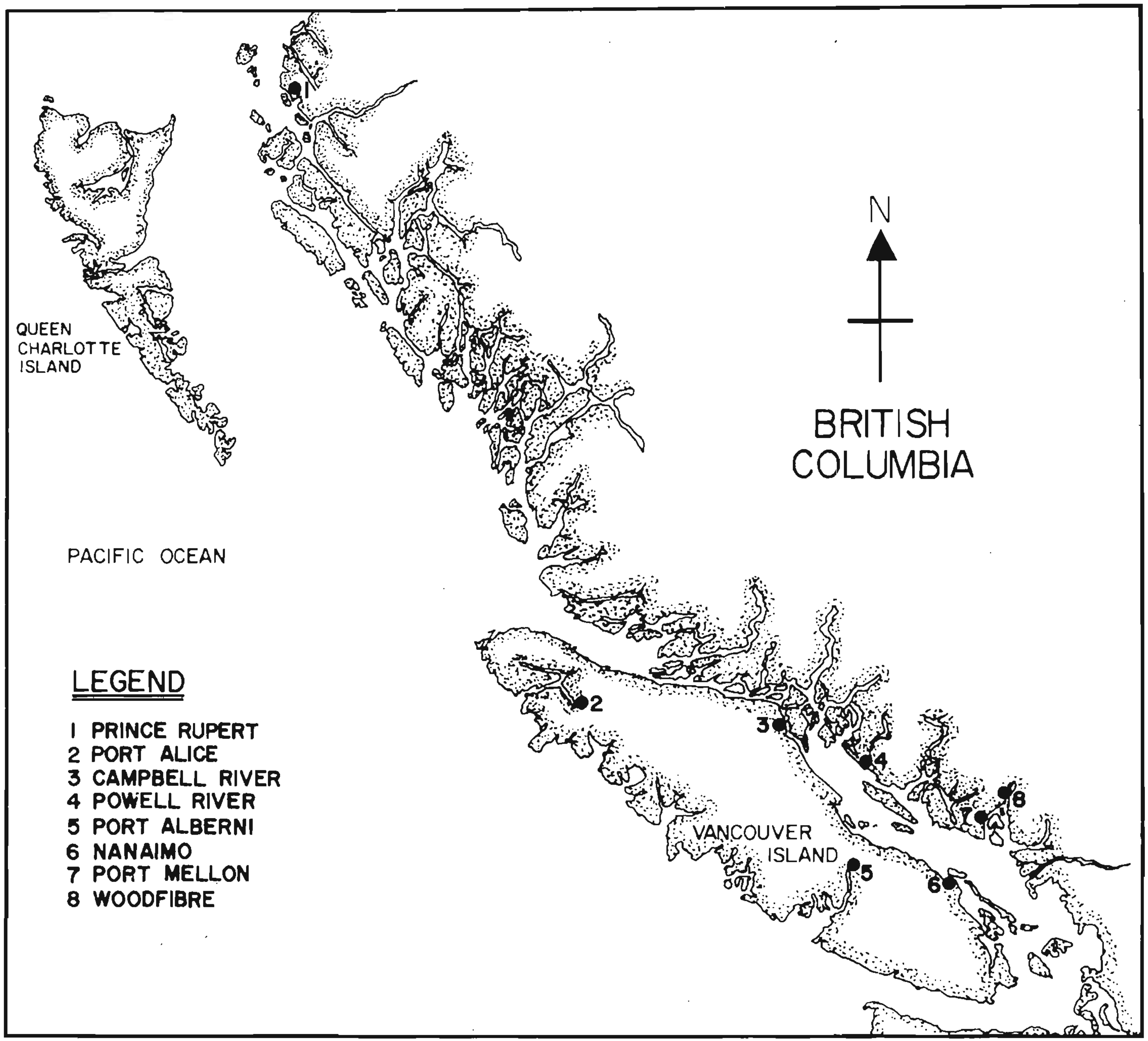
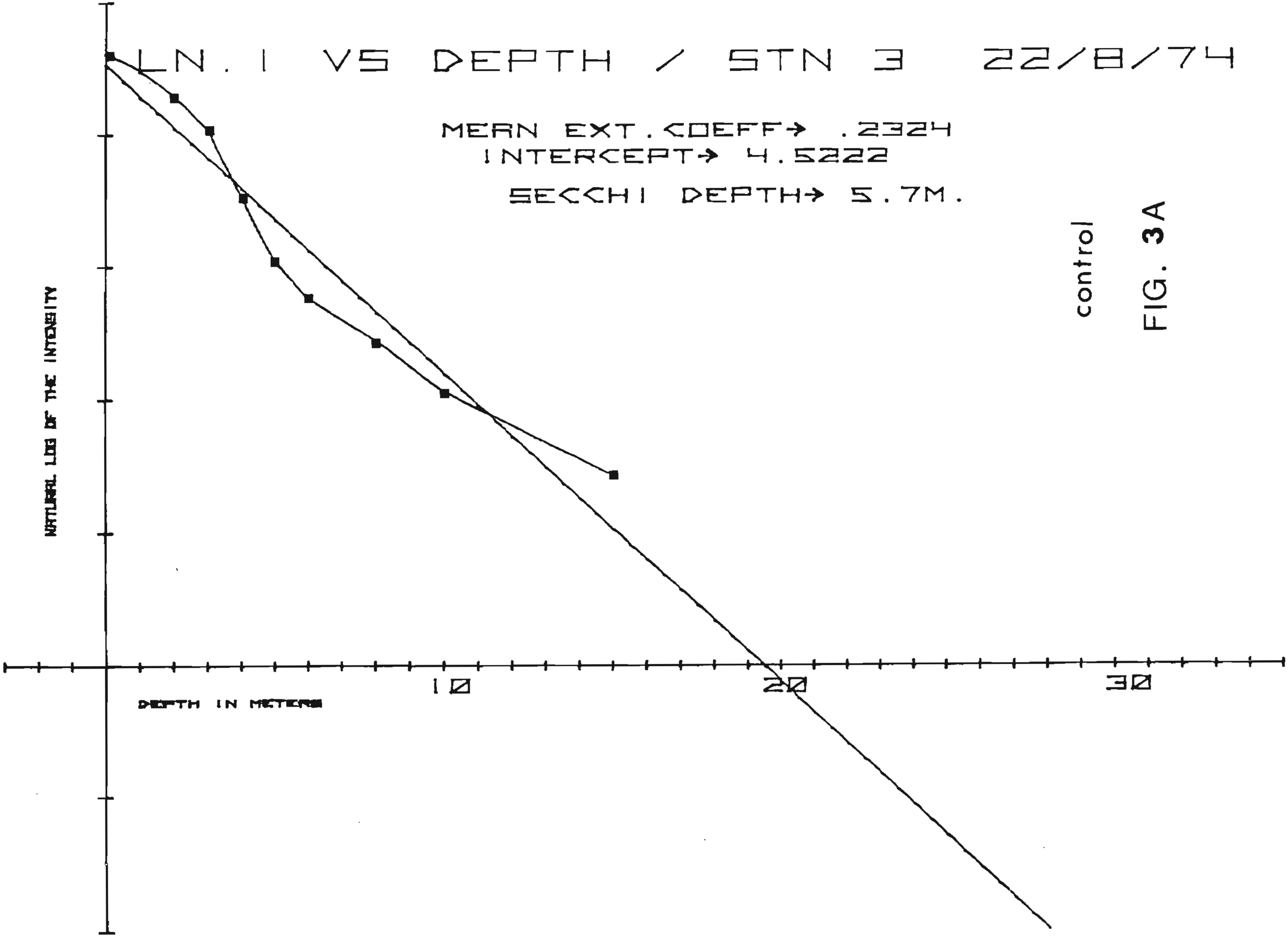
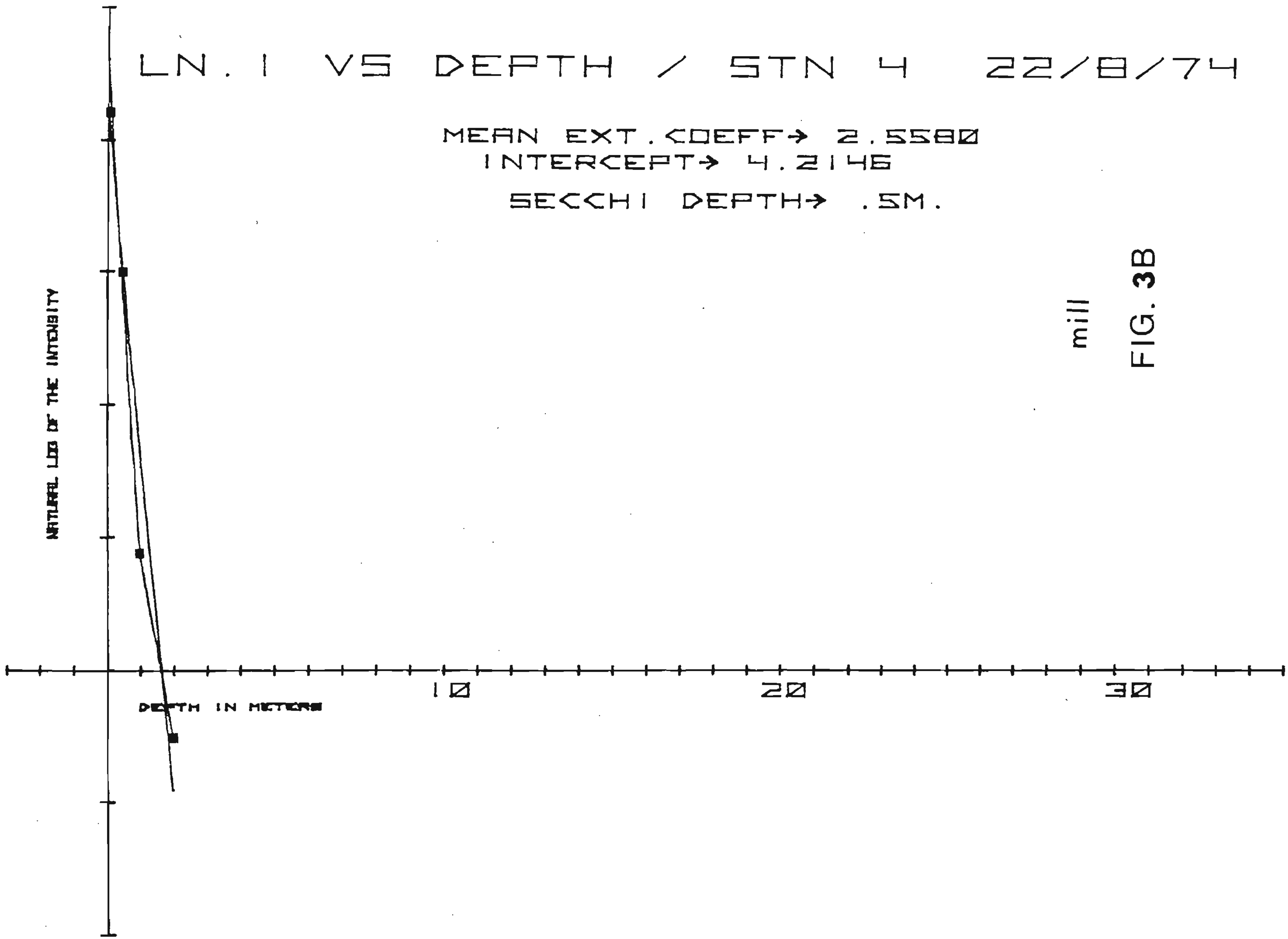

QUEEN
CHARLOTTE
ISLAND
PACIFIC OCEAN
N
BRITISH
COLUMBIA
VANCOUVER
ISLAND
LEGEND
1 PRINCE RUPERT
2 PORT ALICE
3 CAMPBELL RIVER
4 POWELL RIVER
5 PORT ALBERNI
6 NANAIMO
7 PORT MELLON
8 WOODFIBRE

FIG. 2



control

FIG. 3A


LN. I VS DEPTH / STN 4 22/8/74
MEAN EXT. COEFF→ 2.5580
INTERCEPT→ 4.2146
SECCHI DEPTH→ .5M.
NATURAL LOG OF THE INTENSITY
DEPTH IN METERS
10
20
30

mill

FIG. 3B

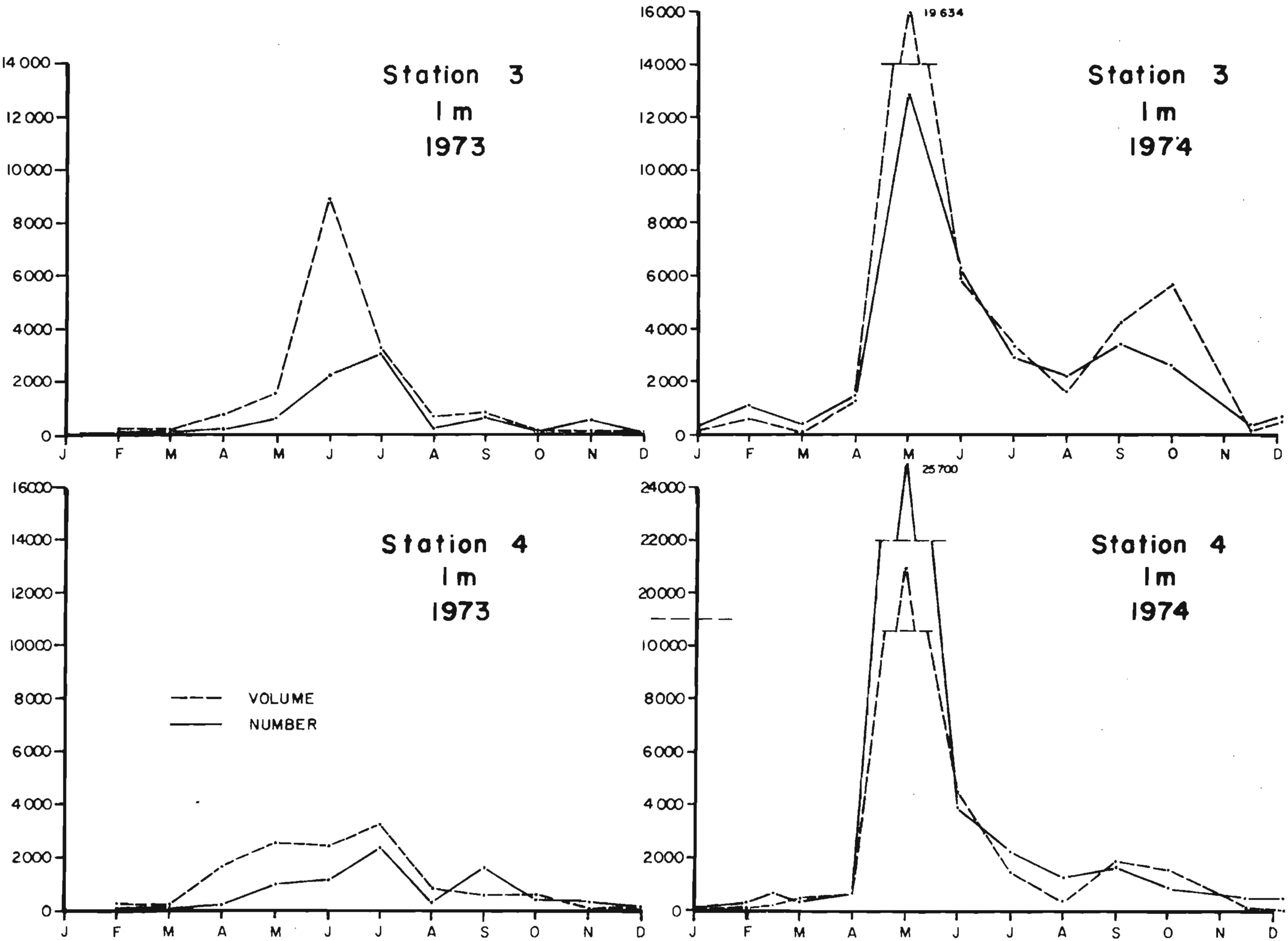
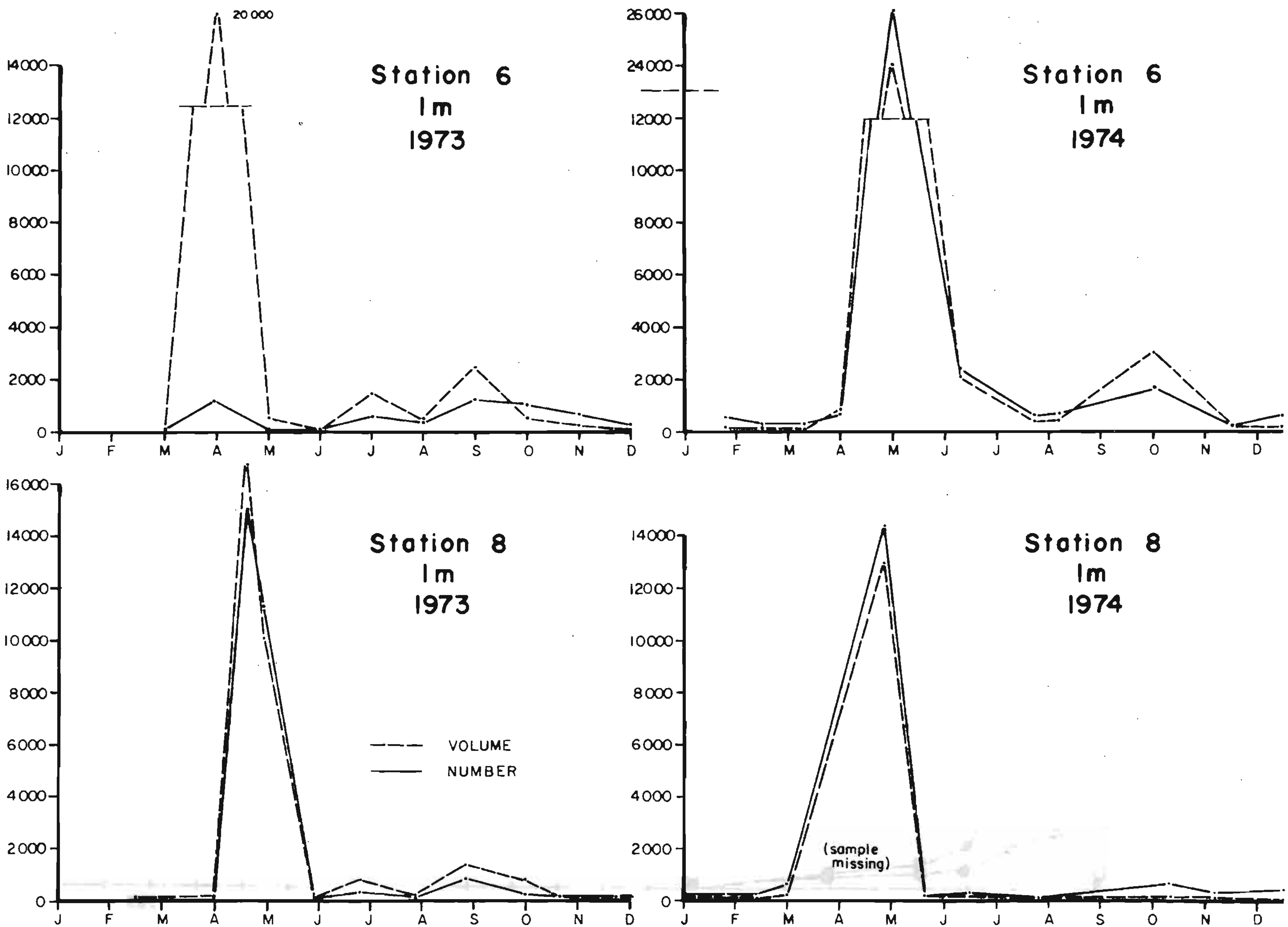

Station 3
1m
1973
Station 3
1m
1974
19 634
Station 4
1m
1973
Station 4
1m
1974
25 700
VOLUME
NUMBER
J F M A M J J A S O N D

FIG. 4



Station 6
Im
1973
20 000
Station 6
Im
1974
Station 8
Im
1973
Station 8
Im
1974
VOLUME
NUMBER
(sample
missing)
J F M A M J J A S O N D

FIG. 5

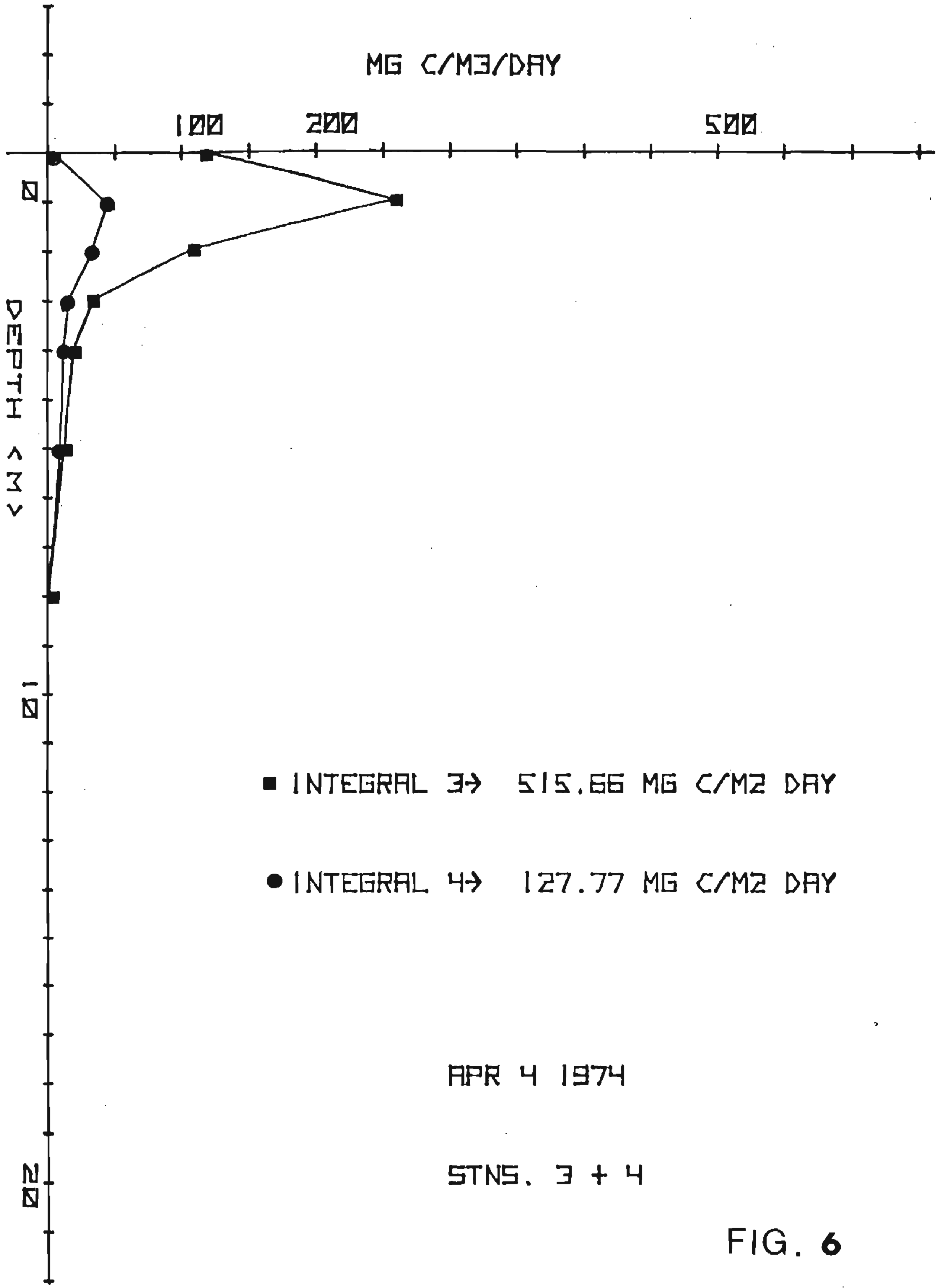

MG C/M3/DAY
100
200
500
0
10
20
DEPTH <M>
■ INTEGRAL 3→ 515.66 MG C/M2 DAY
● INTEGRAL 4→ 127.77 MG C/M2 DAY
APR 4 1974
STNS. 3 + 4

FIG. 6

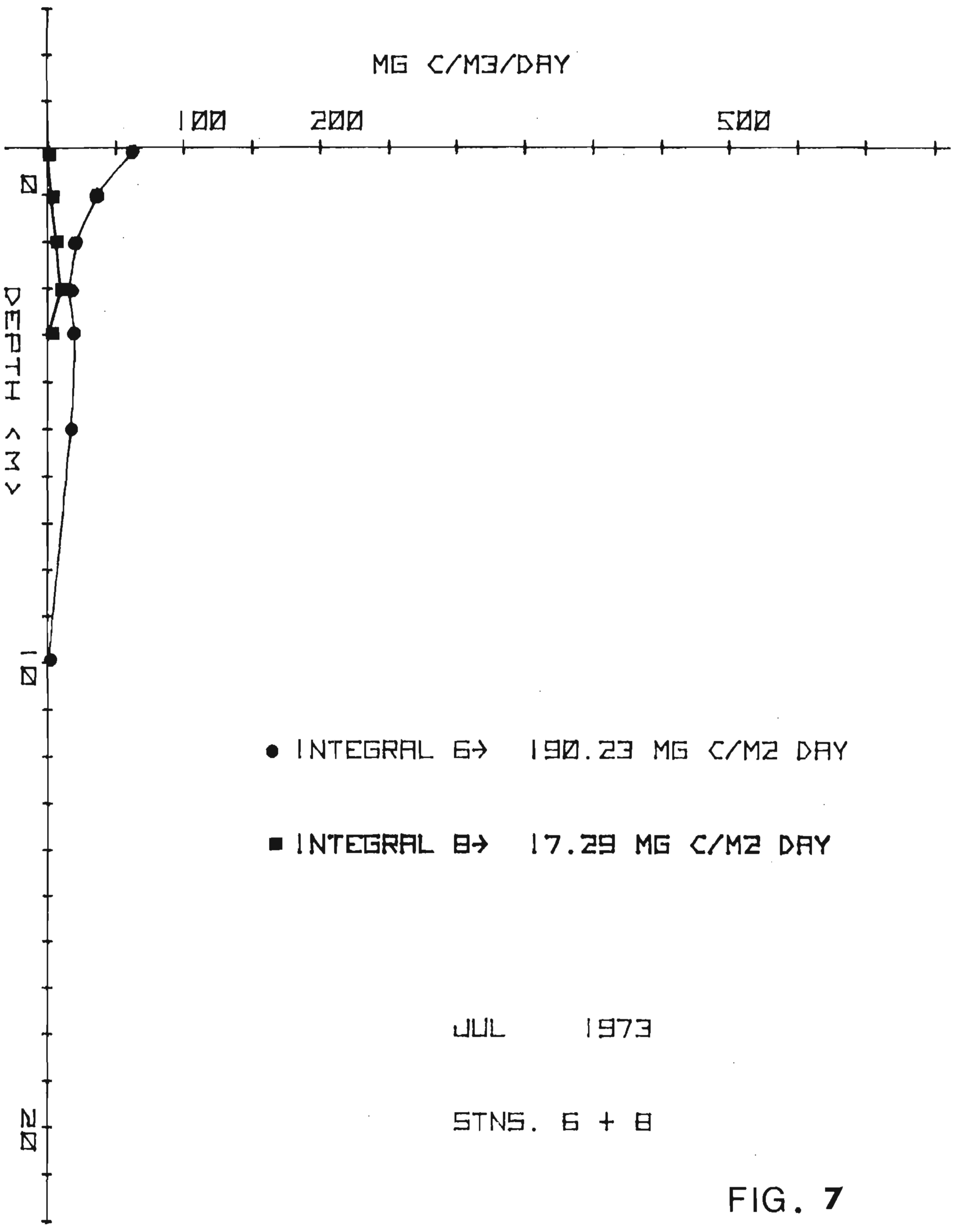

MG C/M3/DAY
100
200
500
0
10
20
DEPTH <M>
● INTEGRAL 6→ 190.23 MG C/M2 DAY
■ INTEGRAL 8→ 17.29 MG C/M2 DAY
JUL 1973
STNS. 6 + 8

FIG. 7

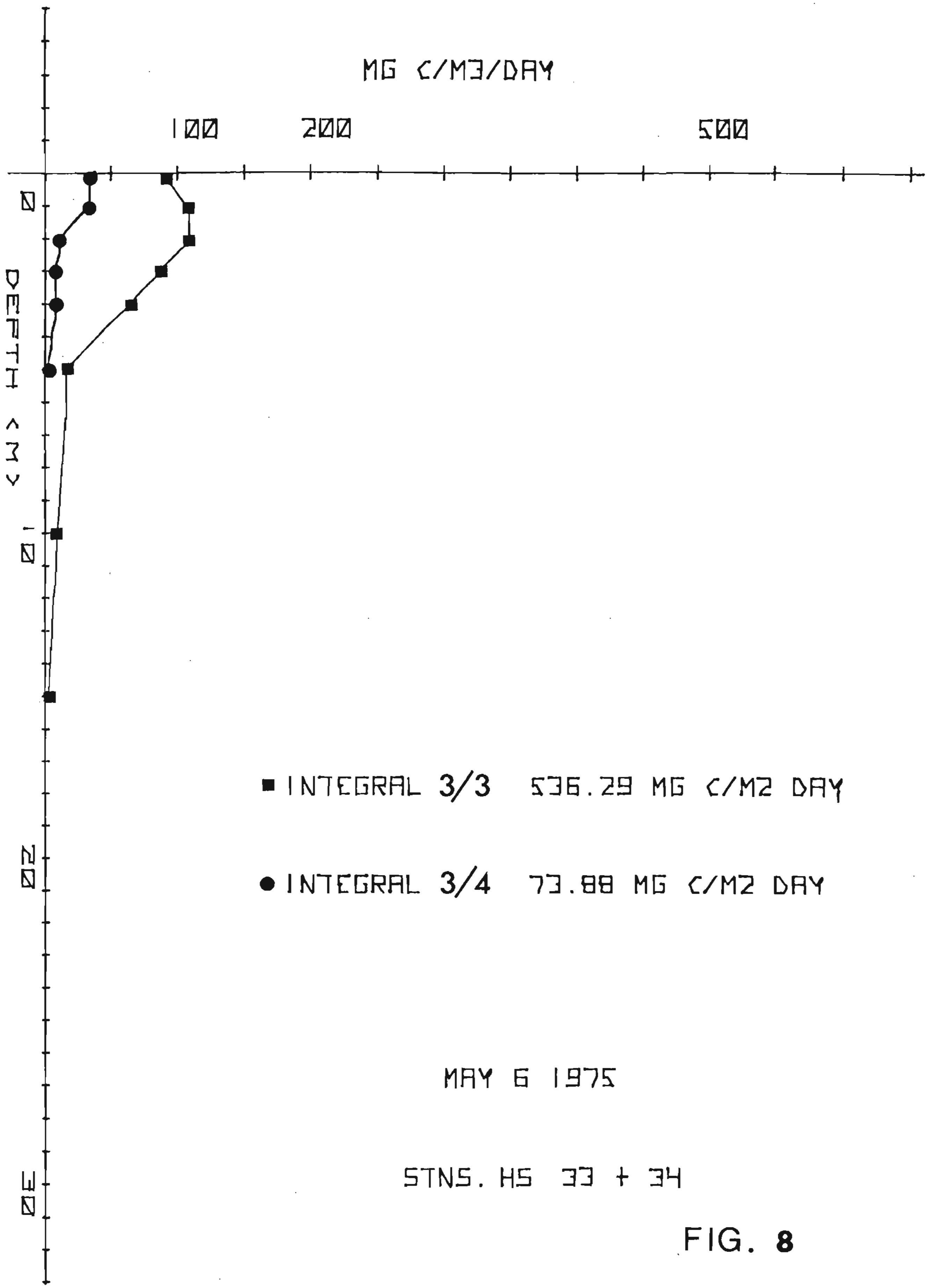

MG C/M3/DAY
100
200
500
DEPTH <M>
0
10
20
30
INTEGRAL 3/3 536.29 MG C/M2 DAY
INTEGRAL 3/4 73.88 MG C/M2 DAY
MAY 6 1975
STNS. HS 33 + 34

FIG. 8

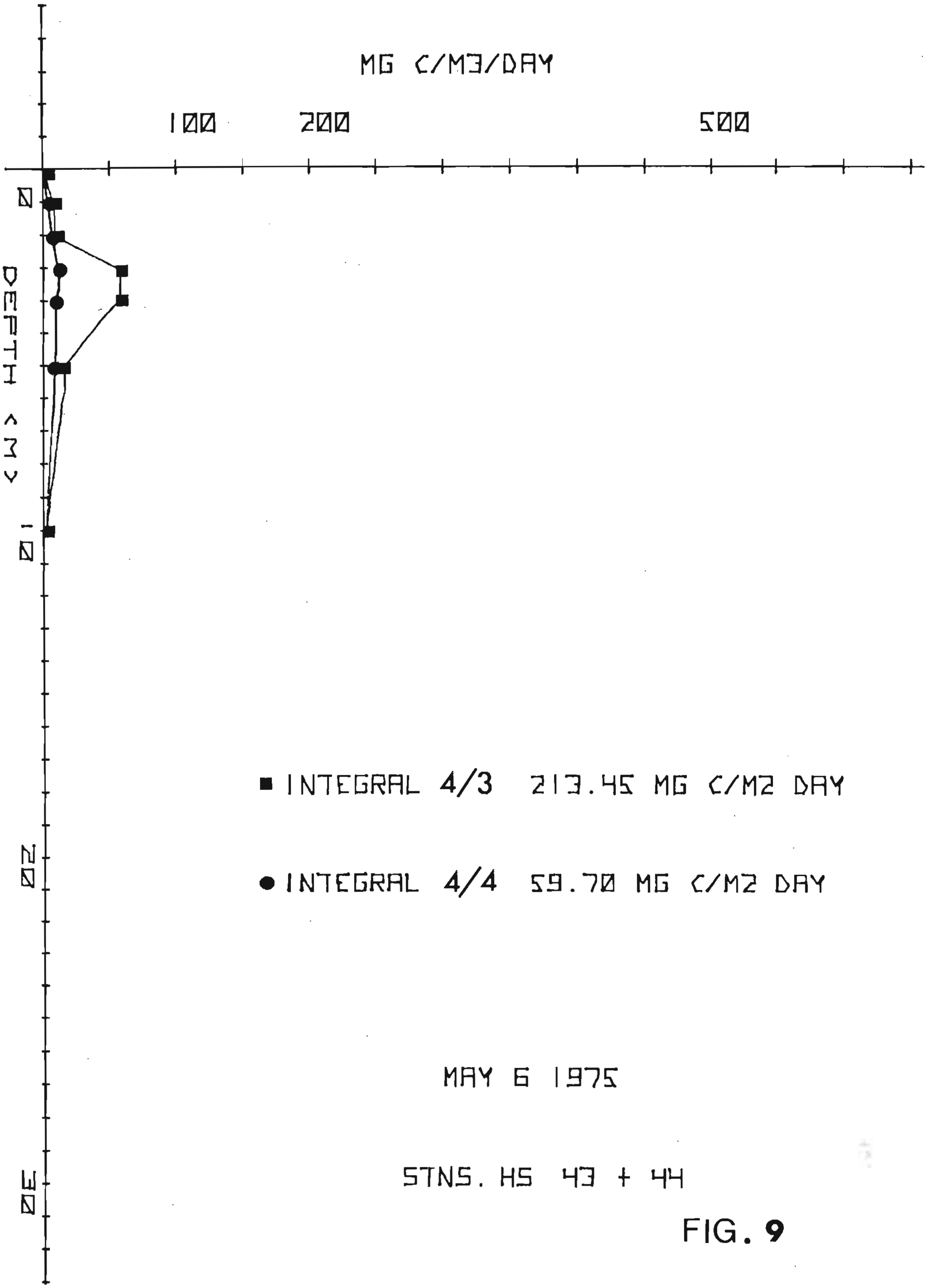

MG C/M3/DAY
100
200
500
0
DEPTH (M)
10
20
30
■ INTEGRAL 4/3 213.45 MG C/M2 DAY
● INTEGRAL 4/4 59.70 MG C/M2 DAY
MAY 6 1975
STNS. HS 43 + 44

FIG. 9

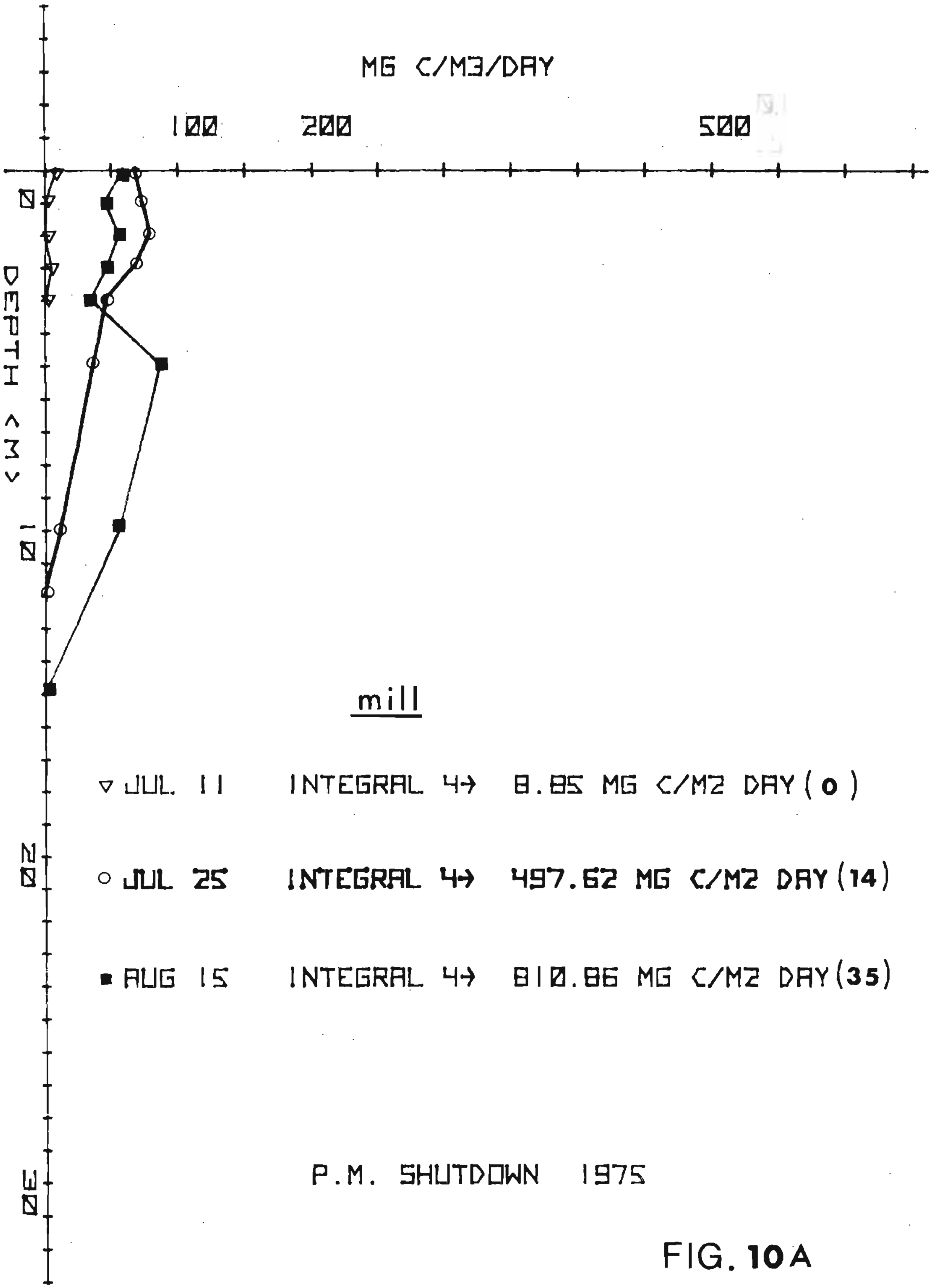

MG C/M3/DAY
100
200
500
DEPTH <M>
0
10
20
30
mill
▽ JUL. 11 INTEGRAL 4→ 8.85 MG C/M2 DAY (o)
○ JUL 25 INTEGRAL 4→ 497.62 MG C/M2 DAY (14)
■ AUG 15 INTEGRAL 4→ 810.86 MG C/M2 DAY (35)
P.M. SHUTDOWN 1975

FIG. 10A

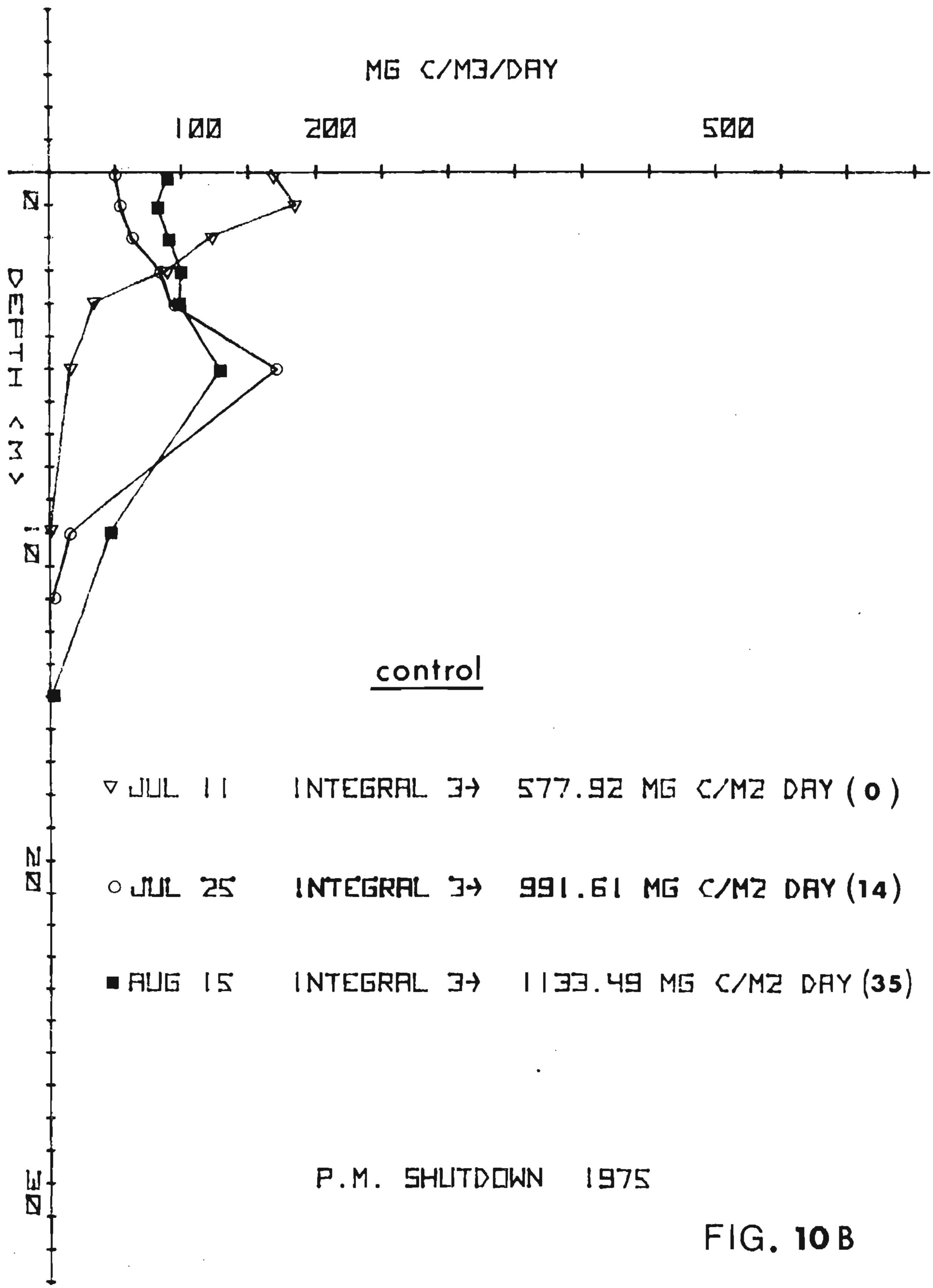
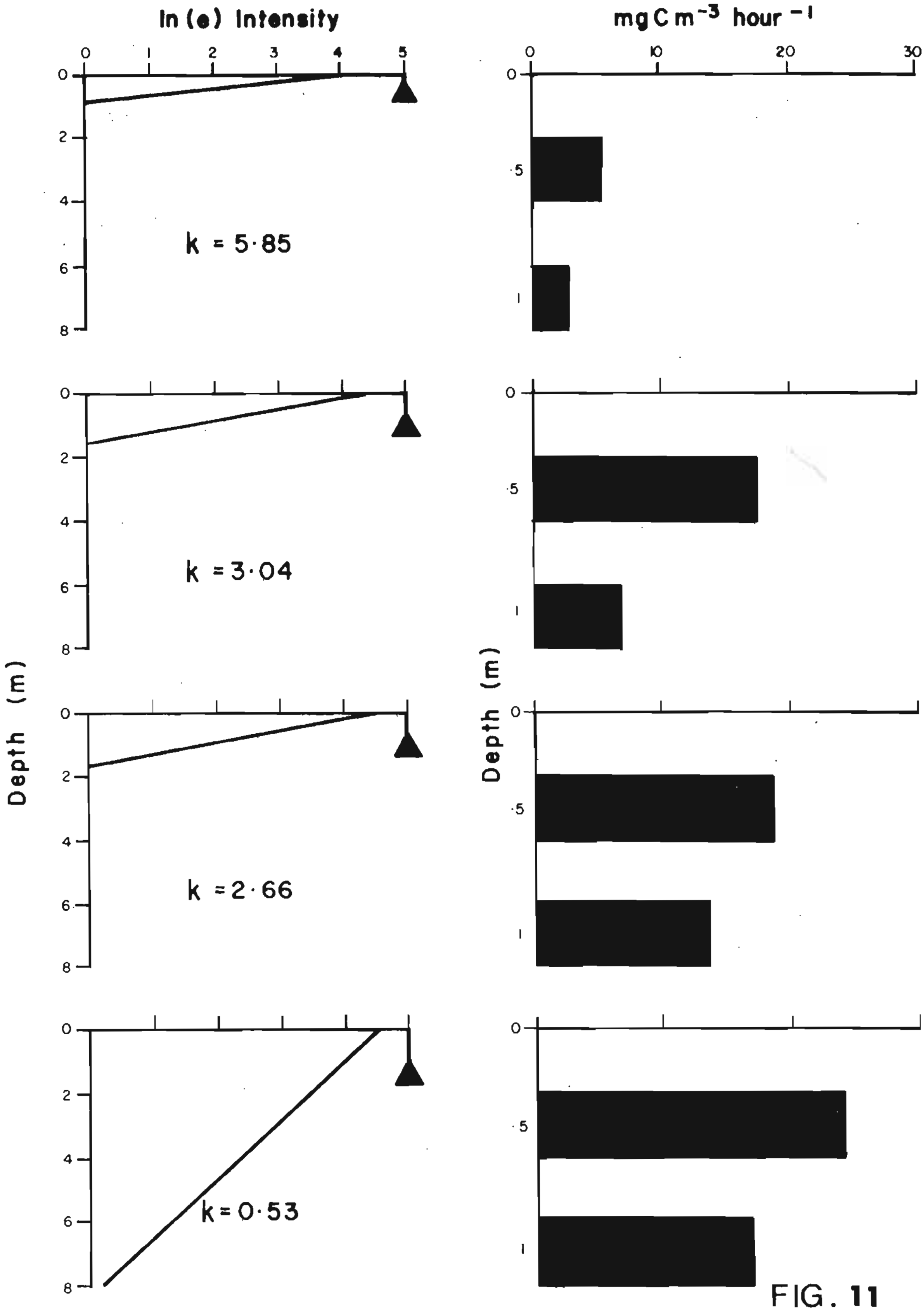

MG C/M3/DAY
100
200
500
0
DEPTH <M>
10
20
30
control
▽ JUL 11 INTEGRAL 3→ 577.92 MG C/M2 DAY (0)
○ JUL 25 INTEGRAL 3→ 991.61 MG C/M2 DAY (14)
■ AUG 15 INTEGRAL 3→ 1133.49 MG C/M2 DAY (35)
P.M. SHUTDOWN 1975

FIG. 10B



ln (e) Intensity
mg C m-3 hour -1
0
1
2
3
4
5
10
20
30
Depth (m)
Depth (m)
6
8
·5
1
k = 5·85
k = 3·04
k = 2·66
k = 0·53

FIG. 11

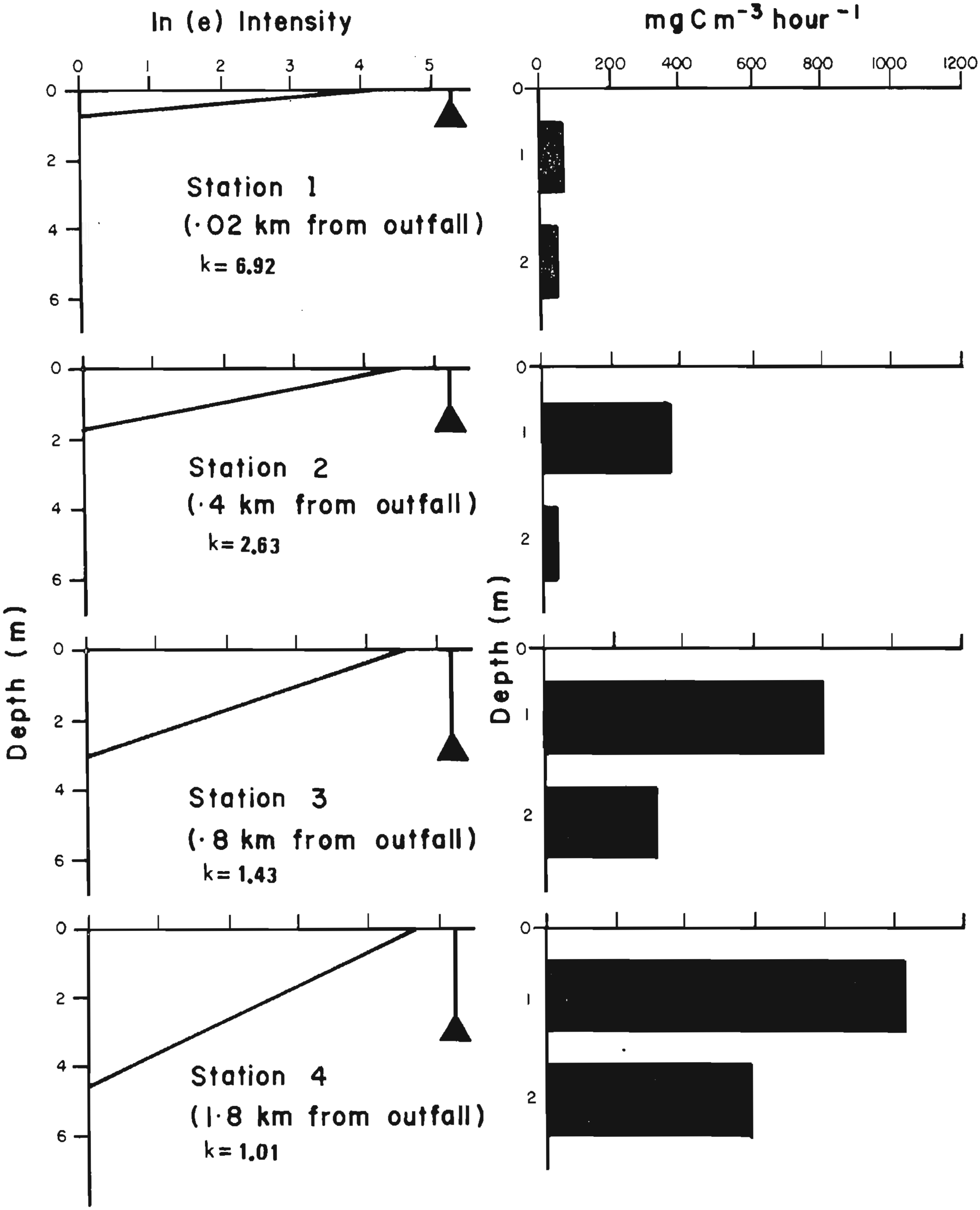

ln (e) Intensity
mg C m^{-3} hour^{-1}
0
1
2
3
4
5
0
200
400
600
800
1000
1200
0
2
4
6
Depth (m)
Station 1
(·02 km from outfall)
k= 6.92
Station 2
(·4 km from outfall)
k= 2.63
Station 3
(·8 km from outfall)
k= 1.43
Station 4
(1·8 km from outfall)
k= 1.01

FIG. 12

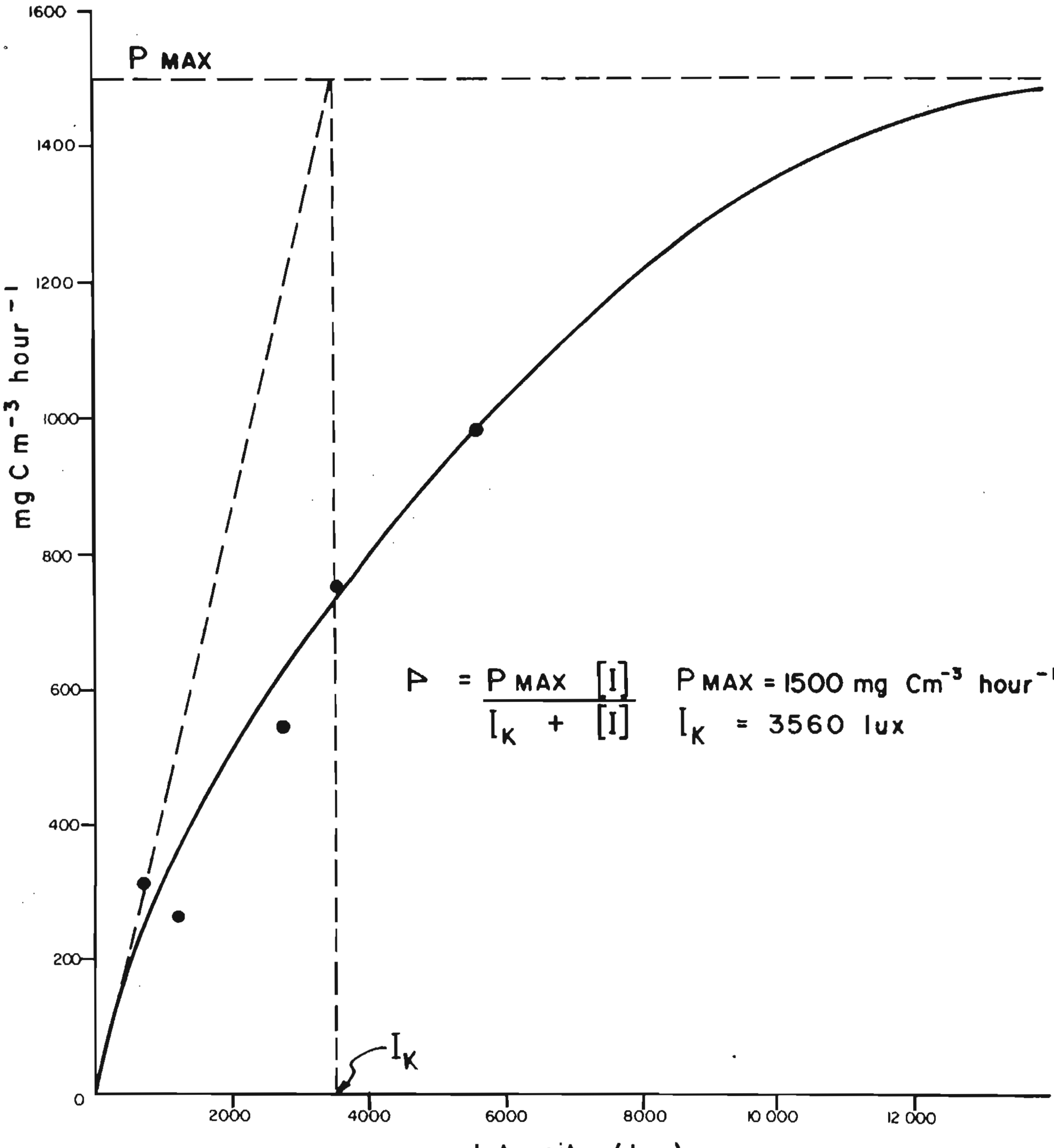

1600
1400
1200
1000
800
600
400
200
0
P MAX
mg C m-3 hour-1
P = P MAX [I] / I_K + [I]
P MAX = 1500 mg Cm-3 hour-1
I_K = 3560 lux
I_K
2000
4000
6000
8000
10 000
12 000
Intensity (lux)

FIG. **13**

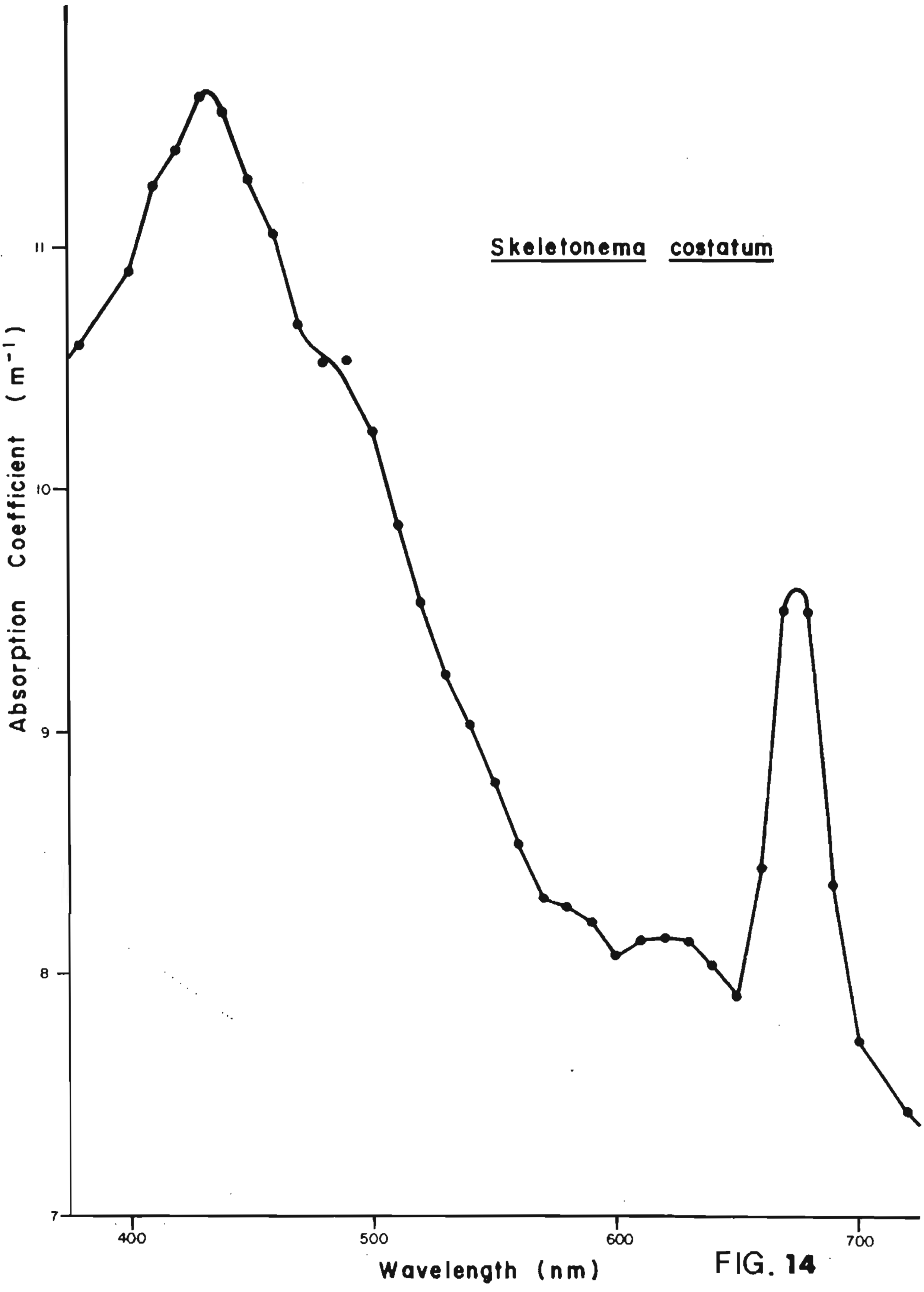

Skeletonema costatum
Absorption Coefficient (m^{-1})
11
10
9
8
7
400
500
600
700
Wavelength (nm)

FIG. **14**

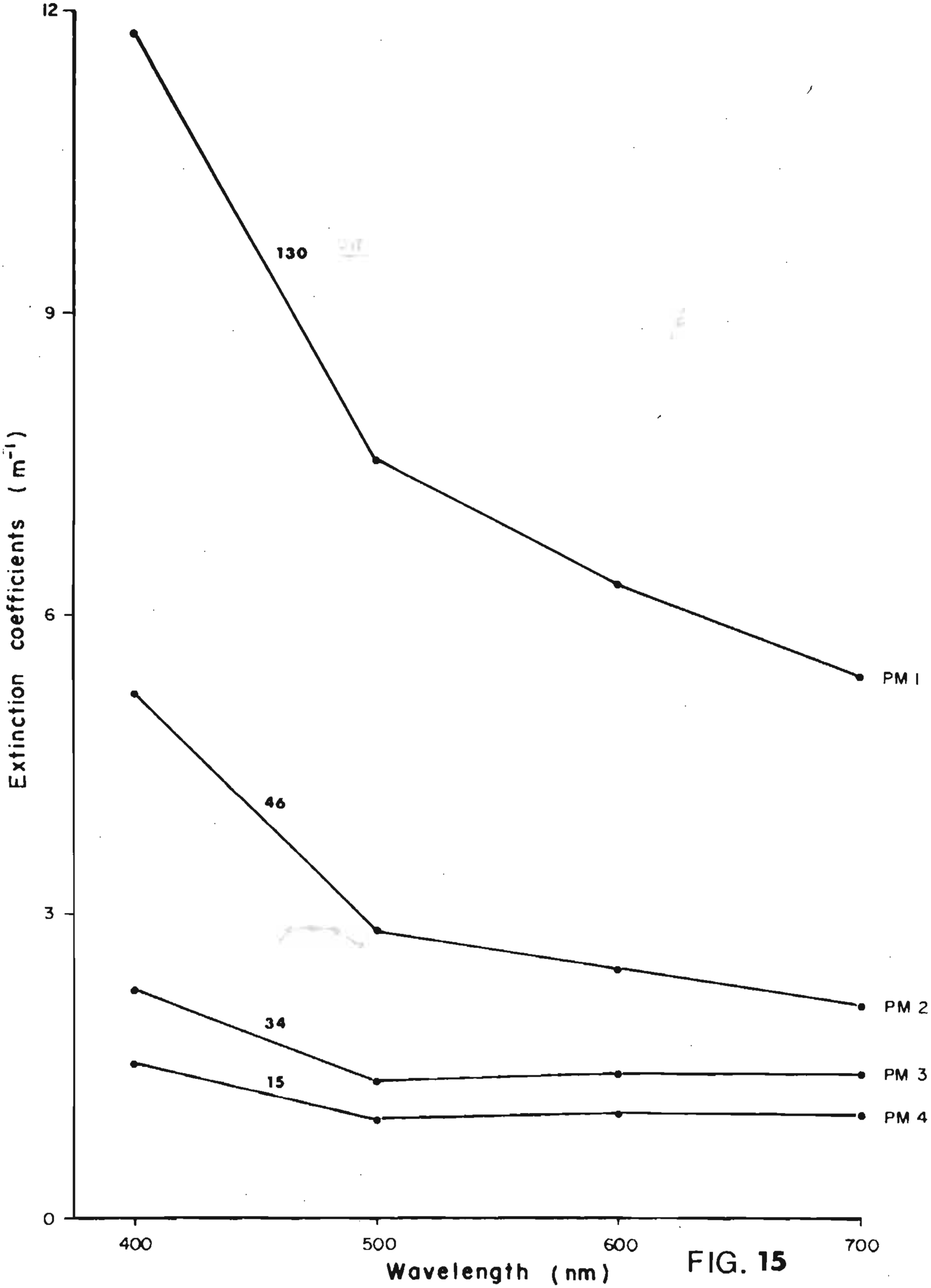

12
9
6
3
0
Extinction coefficients (m^{-1})
130
46
34
15
PM 1
PM 2
PM 3
PM 4
400
500
600
700
Wavelength (nm)

FIG. **15**

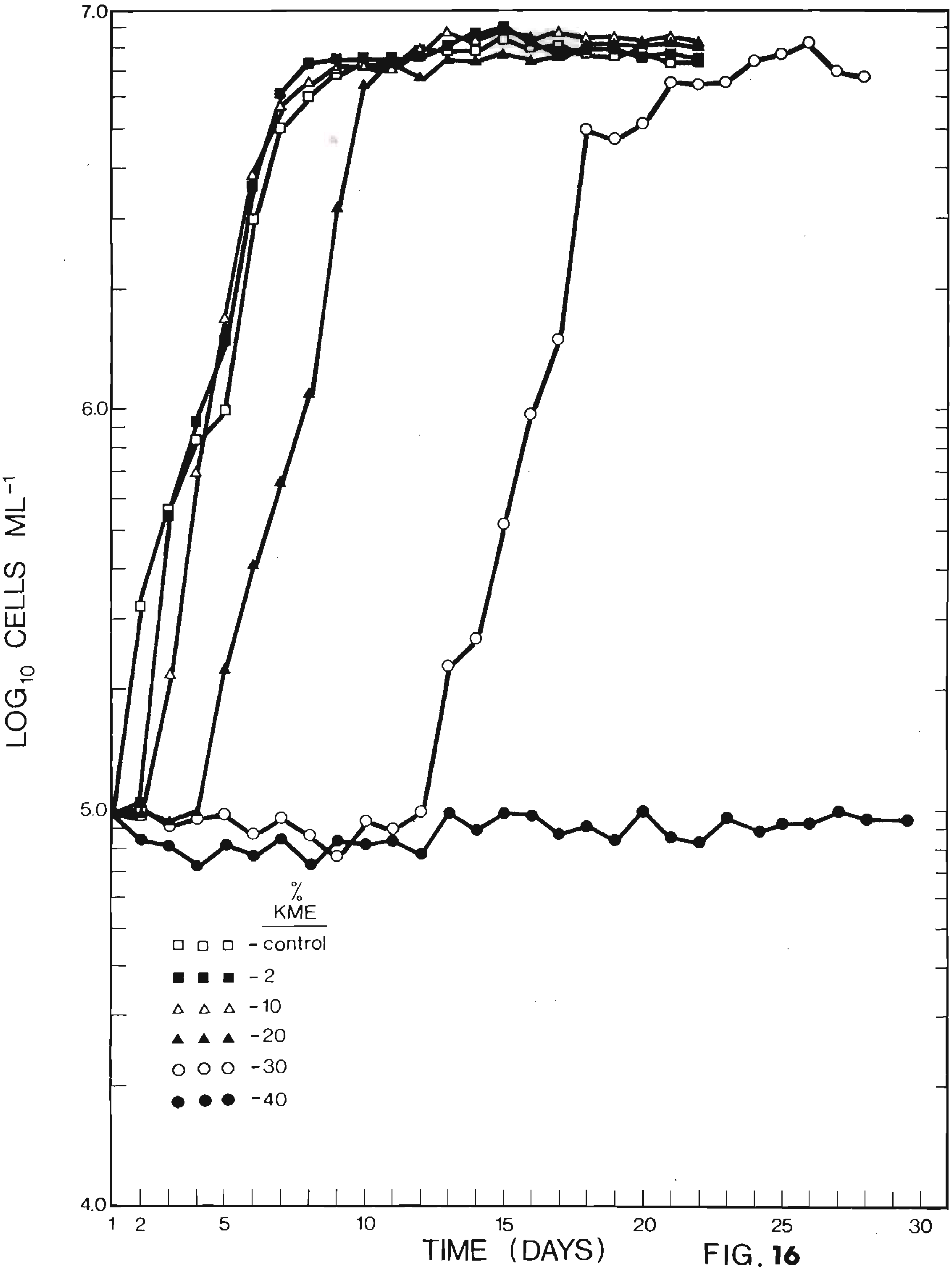

7.0
6.0
5.0
4.0
LOG$_{10}$ CELLS ML^{-1}
%
KME
- control
- 2
- 10
- 20
- 30
- 40
1 2 5 10 15 20 25 30
TIME (DAYS)

FIG. 16