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Zooplankton production in enclosed water columns

by

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Abstract

The population dynamics and production of *Pseudocalanus* sp. and *Acartia longiremis* in large volume enclosures over a 72 day period is described. The maximum conversion of primary productivity to the next trophic level was 29% over a 72 day period.

Introduction

A number of recent papers resulting from the Controlled Ecosystem Pollution Experiment have described the response of plankton ecosystems to pollutant stress (Bulletin of Marine Science, Vol. 27). Included in these experiments, which are conducted in transparent plastic enclosures, are assessments of reproduction, growth and production of mesozooplankton in

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relation to primary productivity. This paper describes aspects of the production of *Pseudocalanus* sp. and *Acartia longiremis*, two species that are generally quite abundant in Saanich Inlet, British Columbia, where the experiments were conducted.

Methods

Three controlled experimental ecosystems (CEEs), 10 m x 23 m in size and holding 1300 m^3 of water, were used in the experiment. They were filled simultaneously by gradually raising them to the surface and attaching them to steel modules floating at the surface (Fig. 1). Two enclosures were dosed with one-shot additions of mercury (as $HgCl_2$) to reach final concentrations of 1 μg/ℓ (CEE 1) and .5 μg/ℓ (CEE 5). The other received no mercury and served as a Control. A variety of chemical and biological parameters were measured during the 72 days of the experiment. These included nutrients, mercury concentrations, bacterial heterotrophy, chlorophyll a, productivity (C^{14}), species abundance of phytoplankton, and zooplankton and fish growth. Some of the results of this experiment have been reported on by Grice *et al.* (1977) and in a series of papers to appear in Marine Science Communications, volume 3. Aspects of the phytoplankton and zooplankton data will be discussed here and these data are further elaborated by Beers *et al.* (1977).

Chlorophyll a was measured twice weekly with a Turner 111 flurometer following filtration through a millipore filter and extraction with acetone. Samples for chlorophyll measurement were collected from the following integrated depths: 0-4, 4-8, and 8-12 m in the center of the CEE. *In situ* productivity was determined by light and dark bottles into which was added 2.5 $\mu CiNa_2CO_3$ solution. Zooplankton was collected twice weekly by a pumping system that passed water through two size nets: a 80 μm net and a 35 μm net. The intake end of the pump was lowered to 16 m at each of three positions in the CEE-center, 1 meter away from the side and at a position one half way between these two. An additional sample was collected in the tapering end of the cone between 16 and 20 m.

Results

Phytoplankton crops. The originally high chlorophyll a values obtained on the day the three water columns were captured was reduced considerably over the first seven days of the experiment (Fig. 2). This reduction was related to the sinking of large chain diatoms. Phytoplankton crops experienced a further decline in CEEs 1 and 5 during days 10-21 following the addition of mercury on day 9. Thereafter chlorophyll a values were similar in all three CEEs until day 42 when they became higher in CEE 5. This increase in chlorophyll in CEE 5 was probably related to the decreased grazing pressure in this CEE due to paucity of zooplankton (see below). The species of phytoplankton predominating in the CEEs following the initial decline of diatoms (*Chaetoceras*) was microflagellates, dinoflagellates and silicoflagellates.

Phytoplankton productivity. Immediately following the addition of mercury primary productivity in CEEs 1 and 5 was reduced in comparison to the Control (Fig. 3). This reduced productivity continued until about day 21 and thereafter productivity remained similar in all three CEEs excepting between days 42 and 56 in CEE 5. During this period the higher productivity in CEE 5 was attributable to decreased grazing pressure.

The total primary productivity for the whole experiment was quite similar in all CEEs. It amounted to 2.6, 2.7 and 2.5 gC/m^3 for the Control, CEE 1 and CEE 5.

<u>Copepods</u>. Copepods generally comprised over 80% of the zooplankton. Their numbers ranged from about 10,000/m^3 at the beginning of the experiment to about 60,000/m^3 in CEE 1 during days 50 to 56 (Fig. 4). The numbers in CEE 5 remained low throughout the experiment. The most abundant species numerically were *Pseudocalanus*, *Oithona* and *Acartia*. The nauplii of *Pseudocalanus* and the copepodid stages of *Pseudocalanus* and *Acartia* in CEE 1 were separately distinguished and identified.

<u>*Pseudocalanus* and *Acartia* dynamics</u>. The abundance of the developmental stages and adults of *Pseudocalanus* is shown in Fig. 5. In CEE 1 the numbers of copepodids were low during the first 39 days, but some reproduction did occur as evidenced by the increasing number of adults after day 39 in CEE 1 and Control. Apparently adults, which can live for several weeks, accumulated from Stage V copepodid animals from more than one sampling day. As nutrient addition on day 39 stimulated phytoplankton growth there was an increased rate of adult accumulation which reached a peak on day 53. Three peaks of early naupliar stages were observed. These were on days 39, 50 and 63. The early nauplii on day 39 appeared in Stage VI as a peak on day 50 and rapidly passed through the copepodid stages reaching the adult stage by day 62. This cohort required about 25-30 days to reach adult from the first stage nauplius. These adults presumably produced eggs which gave rise to the burst of nauplii on day 65. The nauplii seen as a peak on day 50 apparently experienced sub-

stantial mortality (71%) in the later naupliar stages and relatively few reached copepodid stage I. The development time from nauplius I to adult is similar to that reported by Paffenhofer and Harris (1976) for *Pseudocalanus elongatus*. The copepodid stage abundance indicates that similar events occurred in the Control. Within 10 days after the addition of mercury to CEE 5 the copepodid and adult *Pseudocalanus* population was greatly reduced in numbers and it was only near the end of the experiment that a slight increase in numbers was noted.

Acartia longiremis developed higher densities in the Control than in CEE 1, but in neither CEE did the abundance exceed one-fifth of that for *Pseudocalanus* in CEE 1. Cohort development appeared similar to that of *Pseudocalanus* but maximum abundance was reached about day 53 in Control. Cohort development was poorly defined in CEE 1 and numerical densities were substantially less than in Control. Copepodids were practically eliminated in CEE 5 but the few remaining adults produced two cohorts that resulted in adult abundance of over $2,000/m^3$ on day 67. *Acartia* was the most abundant during the later part of the experiment.

Discussion

Although the three CEEs contained at times different proportions of various microflagellates, dinoflagellates, silicoflagellates and diatoms, the total primary productivity for the 72 day experimental period was quite similar in all CEEs. It amounted to 2.6, 2.7 and 2.5 gC/m^3 for the Control, CEE 1 and CEE 5 respectively. Over half of the production was available to the zooplankton during its rapid growth phase during the later 35 days of the experiment.

The production of *Pseudocalanus* and *Acartia* may be calculated from the numbers of adults produced and biomass increase from C I to adult. There were few predators in the CEEs and apparently little mortality during the copepodid stages. As adults may live for varying lengths of time, the numbers of C V are more easily calculated. It has been shown by Paffenhofer and Harris (1976) that *Pseudocalanus* passes through a copepodid stage in a mean time of 2.8 days with longer times indicated for older stages. Considering the duration of copepodid stage V as 3.5 days the total number of C V produced can be estimated by adding the numbers recorded each week and (by interpretation) each half week. Paffenhofer and Harris (op cit) also reported adult carbon weights as 8.2 (female) and 4.8 μg (male). The total production of *Pseudocalanus* for each CEE is therefore the total weight of adults produced based on calculations of the total number of stage V copepodids assuming, of course, no mortality occurs. Similar assumptions are made for *Acartia*.

Table 1 shows the production estimates of *Pseudocalanus* and *Acartia* in comparison to the primary production during the first and second half of the experiment. Production was low in all three CEEs during the first half of the experiment and remained low in CEE 5 throughout the experiment. During the second half of the experiment about 39% of the primary productivity was converted to the next trophic level which consisted of *Pseudocalanus* and *Acartia* which together comprised 85% of the total mesozooplankton. Overall the production of *Pseudocalanus* and *Acartia* was fairly similar in the Control and CEE 1 but greatly exceeded that in CEE 5. The high values for secondary production during the later half of the experiment, 26% in Control, 39% in CEE 1, may be more representative of growth efficiency than ecological efficiency in as much as *Pseudocalanus* was growing near its maximum rate (as observed in laboratory cultures) and there appeared to be little mortality.

A complete understanding of dynamics of *Pseudocalanus* and *Acartia* is not readily apparent from our data but it does appear that large enclosures do provide an additional technique of examining the interrelationships between phytoplankton and secondary production.

References

Beers, J. R., M. R. Reeve and G. D. Grice. 1977. Controlled Ecosystem Pollution Experiment: Effect of mercury on enclosed water columns. IV. Zooplankton population dynamics and production. Marine Science Communications. In press.

Grice, G. D., M. R. Reeve, P. Koeller, and D. Menzel. 1977. The use of large volume (1300 m^3), transparent, enclosed sea-surface water columns in the study of stress on plankton ecosystems. Helgoländer Wissenschaftliche Meeresuntersuchungen. In press.

Paffenhofer, G. A. and R. P. Harris. 1976. Feeding, growth and reproduction of the marine planktonic copepod *Pseudocalanus elongatus* Boeck. J. Mar. Biol. Assoc. U.K. 56: 327-344.

Table 1

Production estimates for *Pseudocalanus* and *Acartia* (combined) as percentage of primary production. Figures in parenthesis are percentage abundances of the two copepods relative to the total mesozooplankton.

	Control	CEE 1	CEE 5
Up to day 35	7 (50)	11 (55)	4 (27)
After day 35	26 (71)	39 (85)	2 (31)
Overall	18 (61)	29 (71)	3 (29)

Figure Legends

Figure 1. The experimental modules (CEEs) in Saanich Inlet. A. The three CEEs showing the sampling barge. B. Zooplankton pumping. C. Diagramatic sketch of a CEE.

Figure 2. Chlorophylla a (0-12 m).

Figure 3. Phytoplankton productivity.

Figure 4. Calanoid copepod abundance.

Figure 5. Developmental stages of *Pseudocalanus* from nauplius to adult. Shaded positions represent ovigerous females, dotted lines represent possible Cohorts (CEE 1 only).

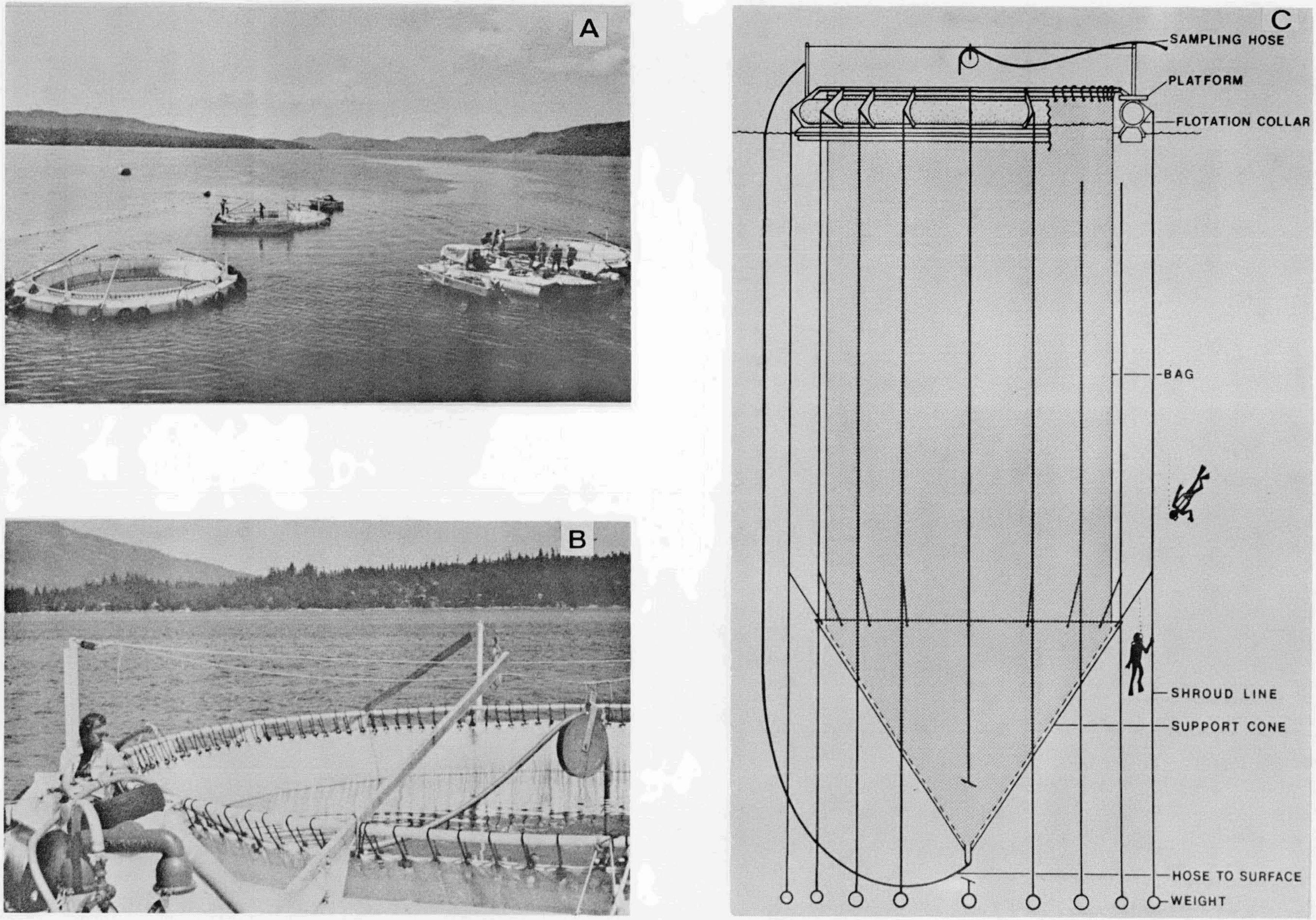

A
B
C
SAMPLING HOSE
PLATFORM
FLOTATION COLLAR
BAG
SHROUD LINE
SUPPORT CONE
HOSE TO SURFACE
WEIGHT

Figure 1

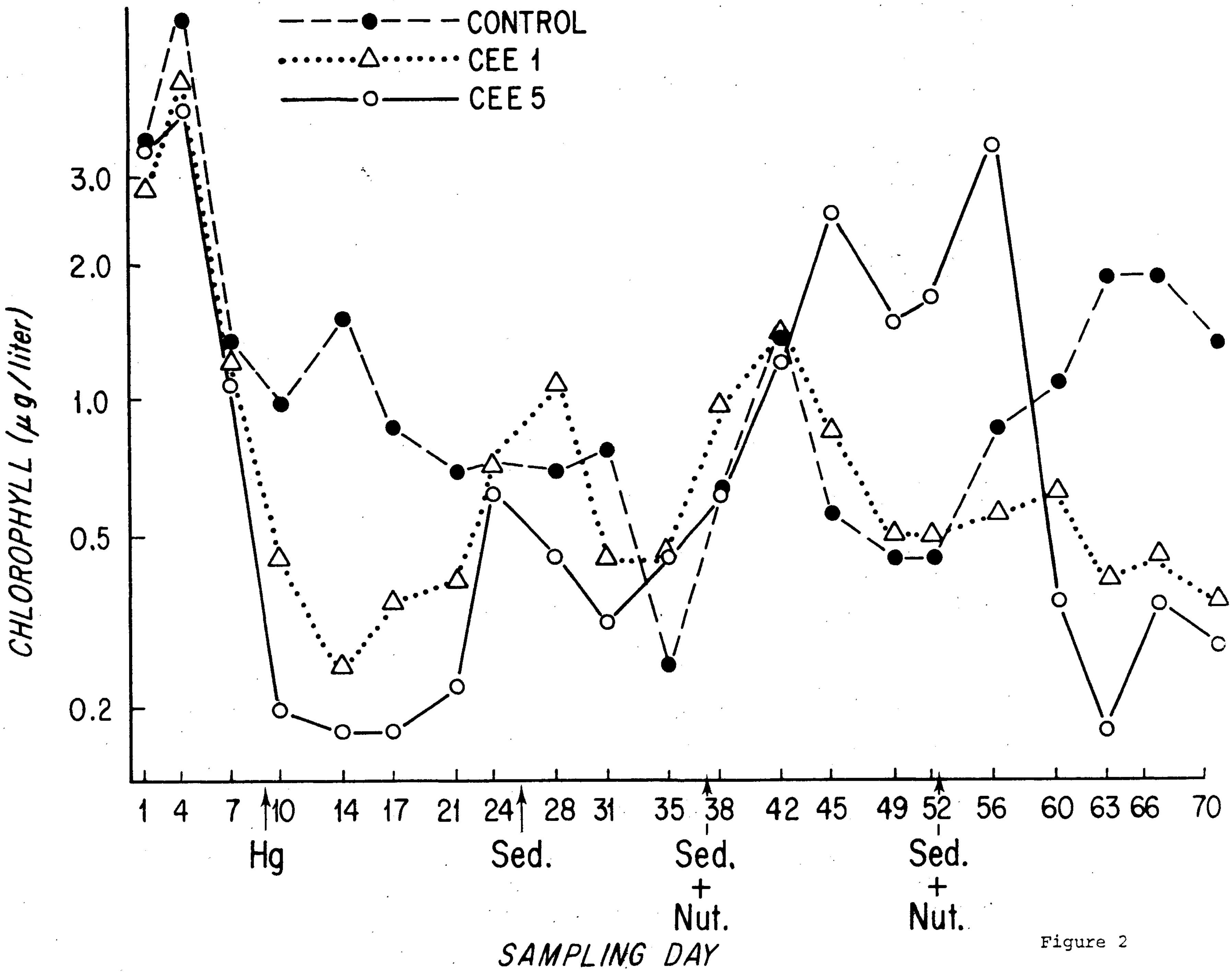
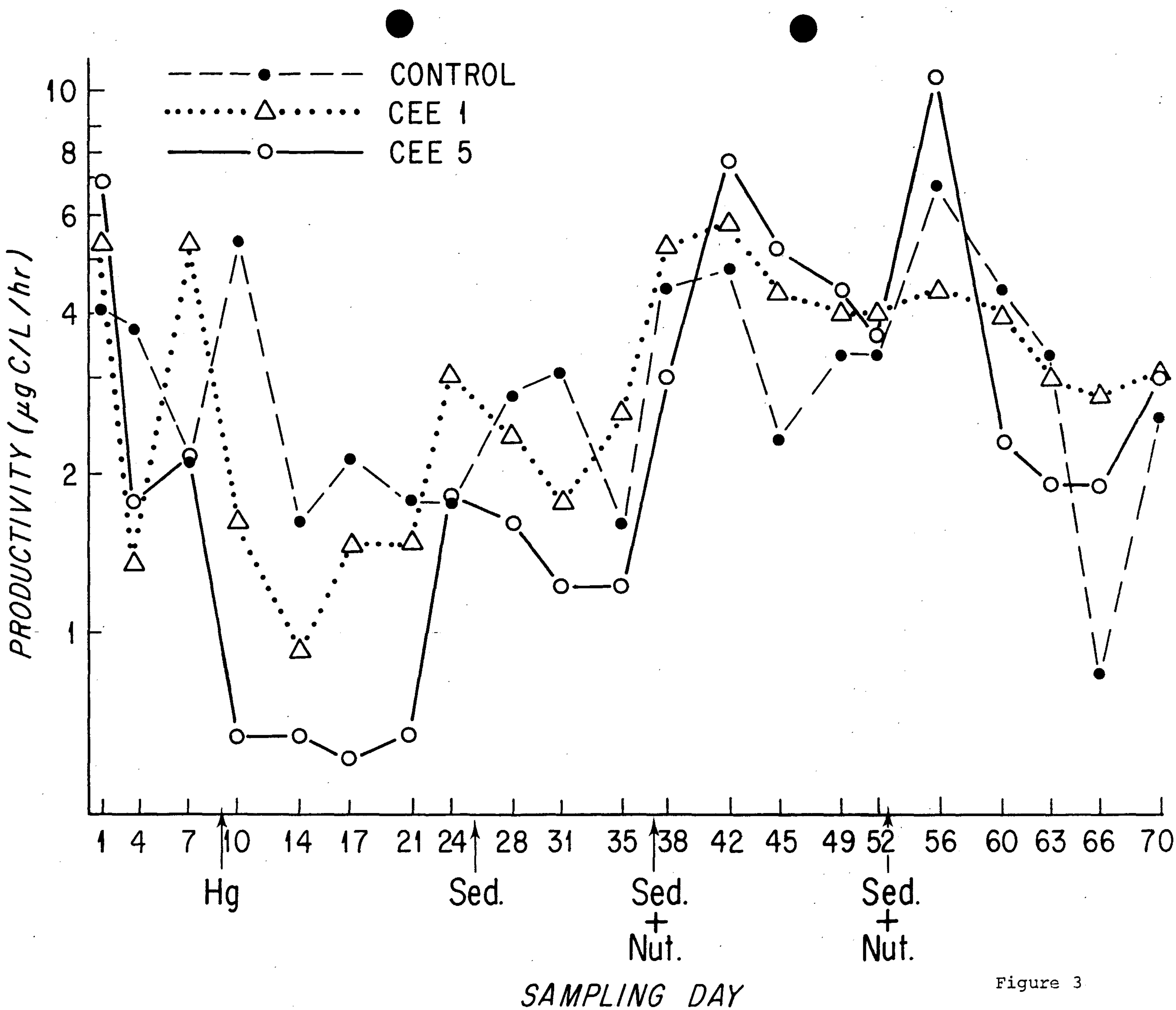

CONTROL
CEE 1
CEE 5
3.0
2.0
1.0
0.5
0.2
CHLOROPHYLL (μg/liter)
1
4
7
10
14
17
21
24
28
31
35
38
42
45
49
52
56
60
63
66
70
Hg
Sed.
Sed. + Nut.
Sed. + Nut.
SAMPLING DAY

Figure 2



CONTROL
CEE 1
CEE 5
PRODUCTIVITY (μg C/L/hr)
10
8
6
4
2
1
1 4 7 10 14 17 21 24 28 31 35 38 42 45 49 52 56 60 63 66 70
Hg
Sed.
Sed. + Nut.
Sed. + Nut.
SAMPLING DAY

Figure 3

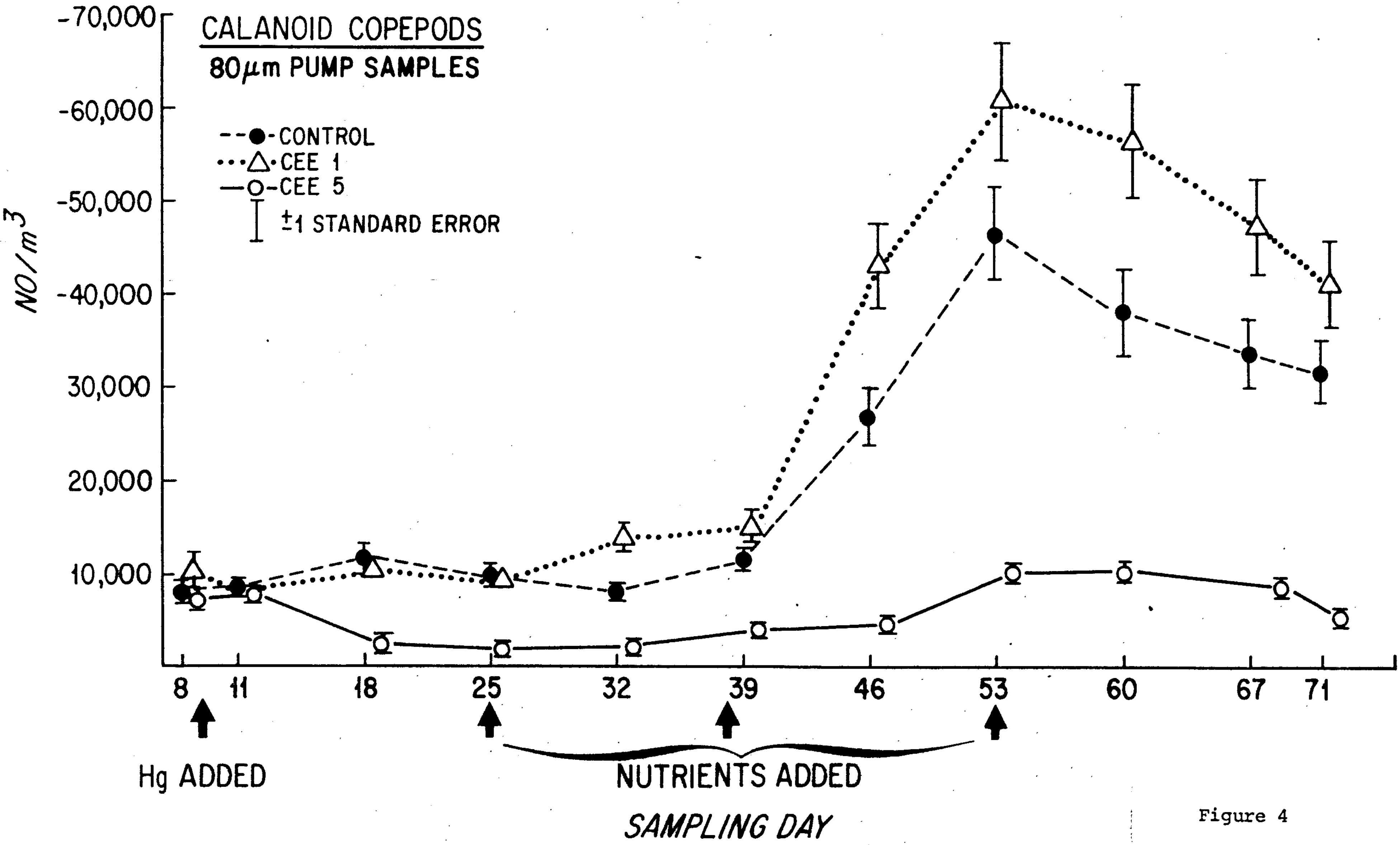
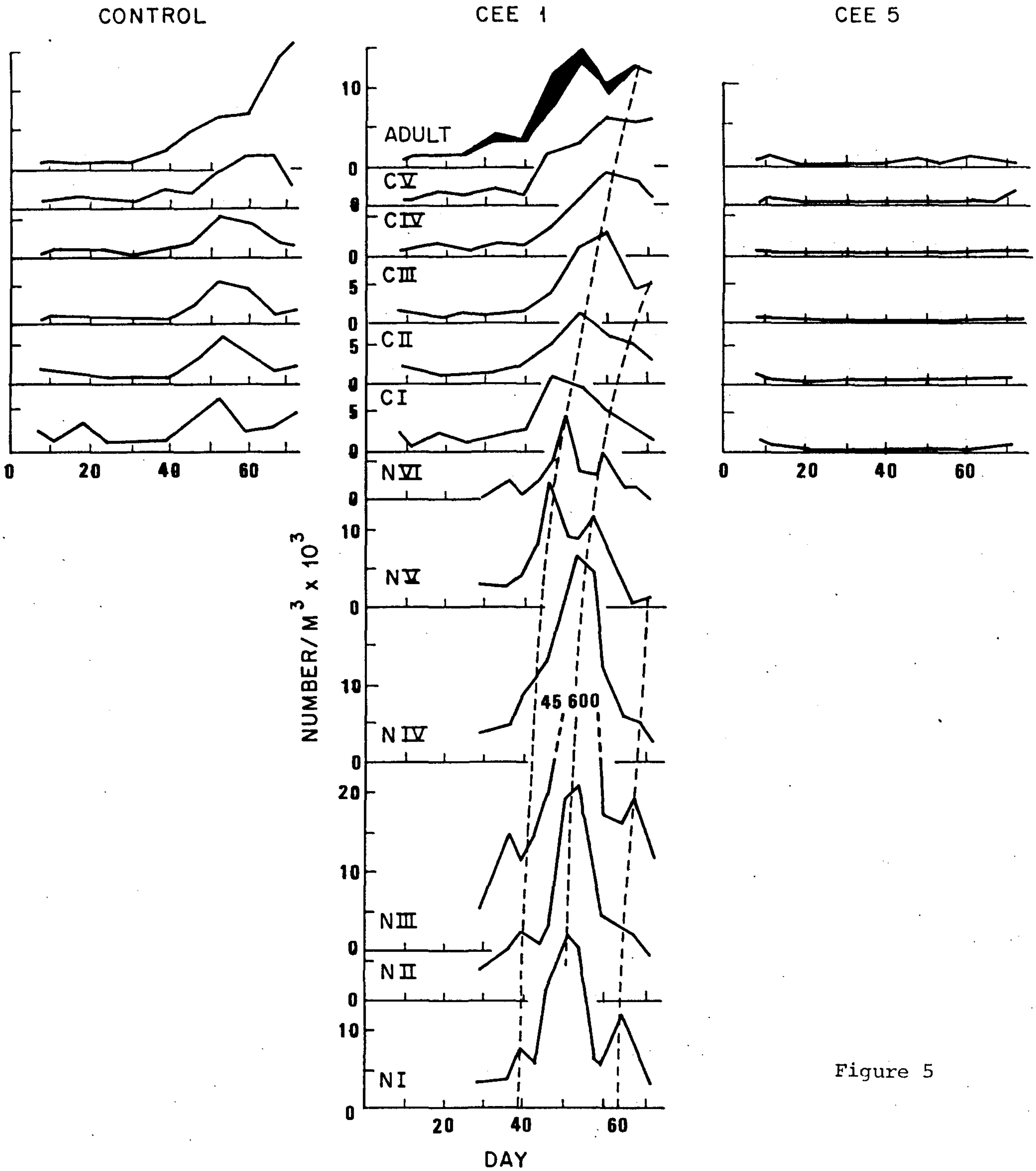

CALANOID COPEPODS
80μm PUMP SAMPLES
CONTROL
CEE 1
CEE 5
±1 STANDARD ERROR
NO/m3
-70,000
-60,000
-50,000
-40,000
30,000
20,000
10,000
8
11
18
25
32
39
46
53
60
67
71
Hg ADDED
NUTRIENTS ADDED
SAMPLING DAY

Figure 4



CONTROL
CEE 1
CEE 5
ADULT
CV
CIV
CIII
CII
CI
NVI
NV
NIV
NIII
NII
NI
45 600
NUMBER/M3 x 10^3
DAY
0
20
40
60
10
5
20

Figure 5