INTERNAL REPORT 83

A SIMPLE AQUATIC CARBON CYCLE MODEL

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The biological components within a lake may be modeled in terms of carbon fluxes between delineated carbon-containing compartments or pools. The water column, a subsystem of the entire lake, may be delineated into the six carbon-containing pools: (1) dissolved inorganic carbon (DIC), (2) phytoplankton carbon (PPC), (3) dissolved organic carbon (DOC), (4) detritus carbon (DTC), (5) zooplankton carbon (ZPC), and (6) bacterial carbon (BAC). The pools and the fluxes between the pools are shown in Figure 1 (the boxes represent pools; the arrows, fluxes). The fluxes between pools and the pools are tabulated in Table 1.

A simple compartment model (Atkins 1969) of the elements tabulated in Table 1 was written in DYNAMO, using measurements of these elements made in Lake Washington on 12 October 1972, at a depth of 1 meter. The model was constructed to (1) help focus numerous constants in a much more sophisticated model of the same aquatic carbon system, and (2) to see what pool and flux values measured at noontime would do in a model that integrated an entire day/night cycle.

Assumptions used in the model are:

(1) the model is a closed system except for sunshine that drives the entire system. Sunshine values were five-year mean fall and summer values, measured in Bellingham, Washington.

(2) all inputs or outputs to the pools were in proportion to the initial pool and flux values.

(3) phytoplankton DOC production did not commence until after photosynthesis was an arbitrary value greater than phytoplankton respiration.

The results of the model operated over a fifty-hour period, using 0.1-hour time steps, are shown in Figures 2, 3, and 4. Figures 2 and 3 are for fall and summer sunshine values and the specific photosynthesis/respiration threshold allowing DOC production, and Figure 4 is for fall sunshine and complete blockage of DOC production. It will be noticed that the phytoplankton pool, which is decreasing in the fall (as it probably should), is very sensitive to the effect of limitation of DOC production, and insensitive to increased light. The DOC pool increases rapidly during sunshine, and slowly decreases, because of bacterial uptake, at night. DIC shows a diurnal periodicity, and the bacteria continually increase.

Limitations of the model are numerous and profound, so only a few will be mentioned here: (1) only daytime measurements were used as input to the model, (2) as the model is for a closed system, inputs and outputs to and from the model are neglected, e.g., settling, advection, eddy diffusion, and so on, (3) all the major carbon compartments are not included, e.g., zooplankton and detritus, (4) the model does not include depth, (5) the model is only written for one day, and (6) temperature changes were not taken into account.

Working with this model has brought into focus further questions, solutions to which will be needed for future refinements of the model:

(1) How can death be modeled, and when does it occur?
(2) What are the effects of DOC concentration on bacterial metabolic rates?
(3) What conditions initiate DOC production by the phytoplankton?
(4) How do nighttime pools and fluxes differ from daytime measurements?
(5) How do the measurements of pool sizes and fluxes vary with depth in a lake?
(6) How do temperature, sunshine changes (e.g., cloudiness), hydrostatic pressure, population density, P, N, C, O_2, pH, and eH affect the system?
(7) What are the input rates and sources to the detritus pools? How can these rates be measured?

Although the model is crude, it is a component in a larger overall aquatic model, in which this model fits as the biological description that may be superimposed on a hydrological model of a lake. This model may also fit into fish production models through a fish-zooplankton link.

REFERENCES

ATKINS, G.L. 1969. Multicompartment models for biological systems. Methuen and Co., Ltd., London. 153 p.

Table 1. Pools and fluxes of carbon used in the simplified carbon model, and measurements made at 1 meter depth in Lake Washington on 12 October 1972, during the time from 11 a.m. to 1 p.m.

ELEMENT	POOL/FLUX	VALUE*
DIC	POOL	2010 μgC/l
PPC	POOL	105 μgC/l
DOC	POOL	2040 μgC/l
BAC	POOL	0.36 μgC/l
DIC--PPC	FLUX	12 μgC/l/hr
PPC--DIC	FLUX	5.5 μgC/l/hr (est.)
PPC--DOC	FLUX	1.0 μgC/l/hr
DOC--BAC	FLUX	0.074 μgC/l/hr
BAC--DIC	FLUX	0.037 μgC/l/hr

*Measurements made by Dr. John Bollinger of the Institute for Freshwater Studies, Western Washington State College.

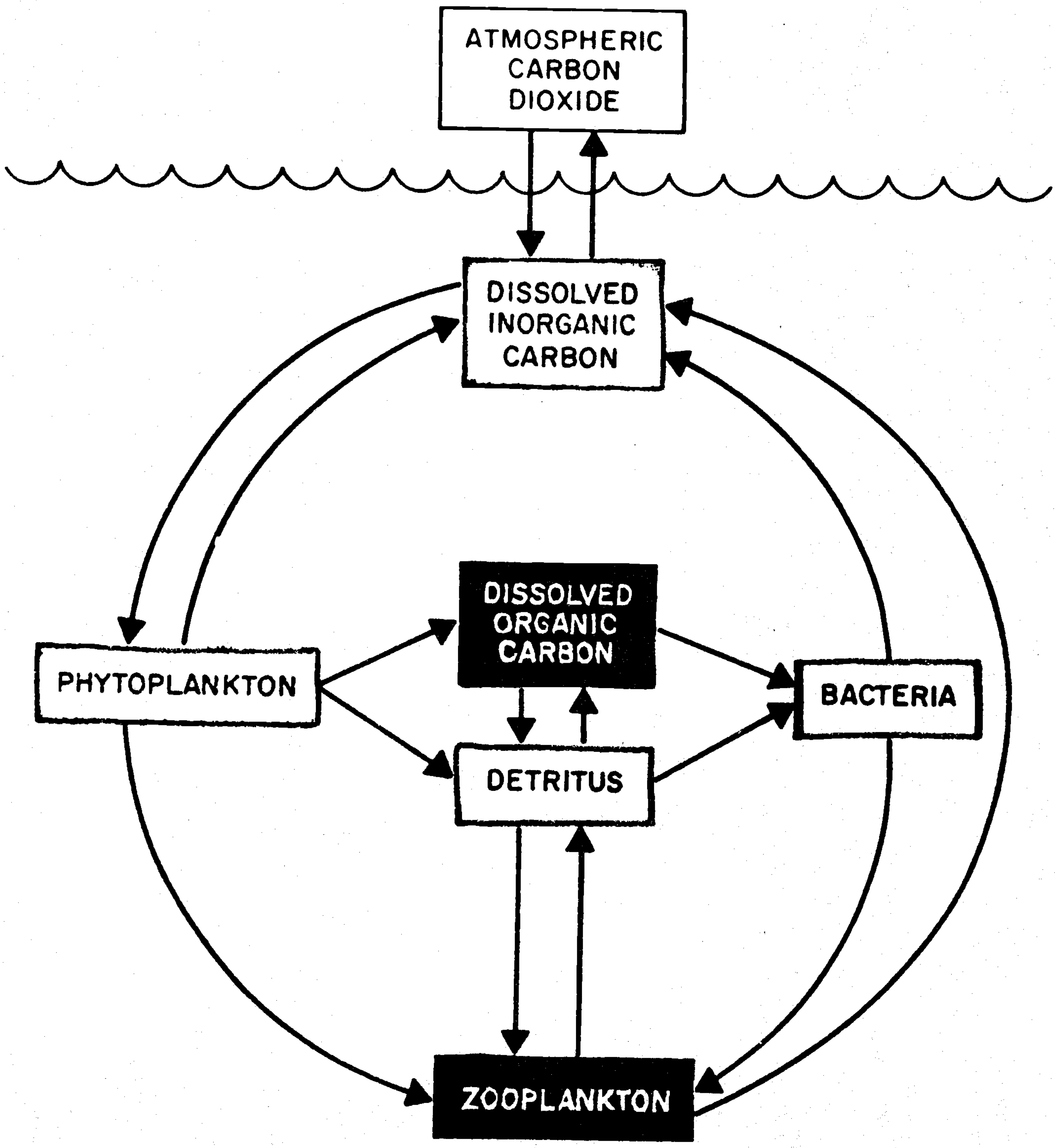

Figure 1. A simplified aquatic carbon cycle.

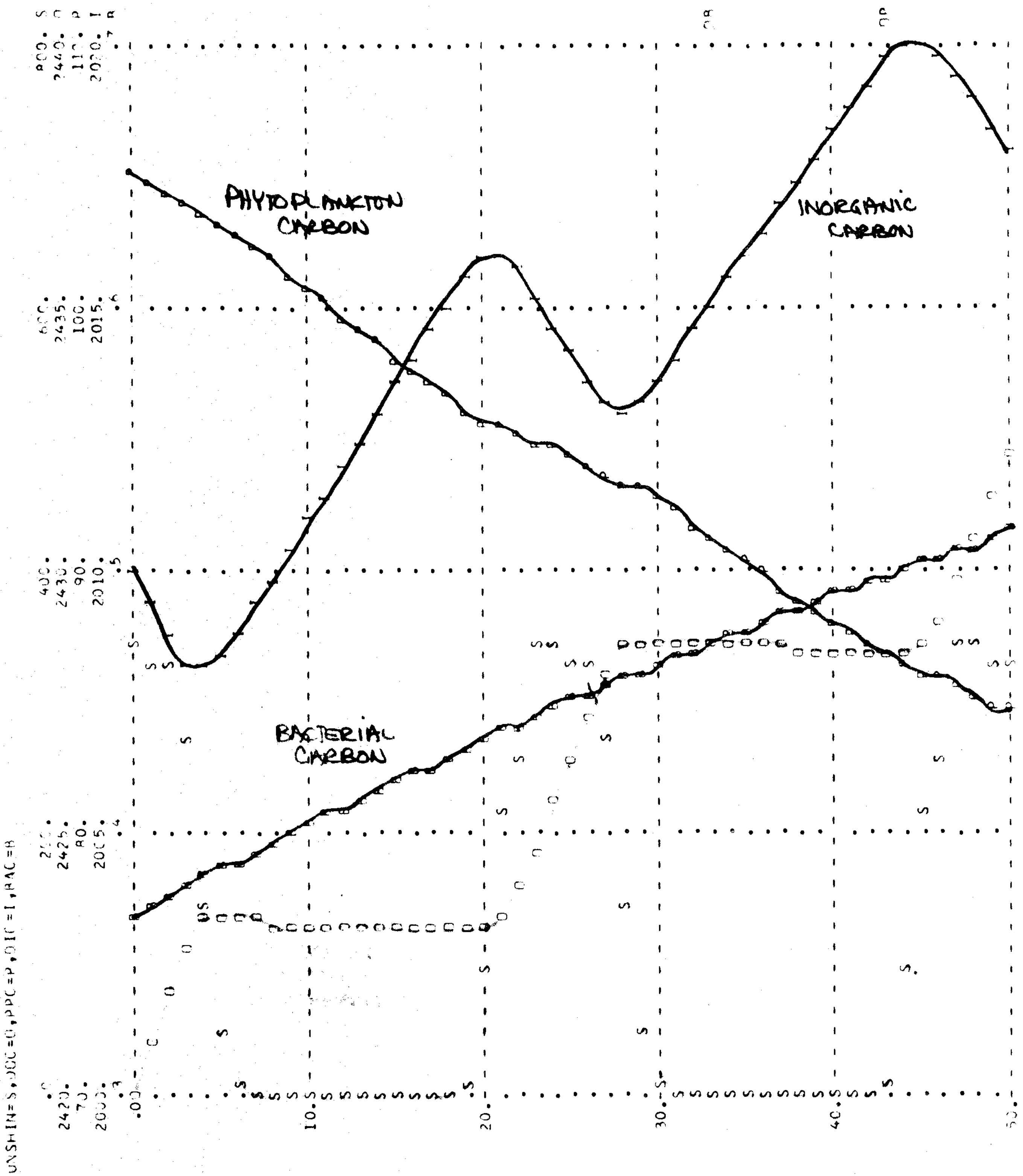

Figure 2.

PAGE 31 PPC/DIC/DOC/BAC MODEL 2/25/73 SUMMER SUNSHINE WITH FALL MEASUREMENTS

SUNSHIN=S,DOC=O,PPC=P,DIC=I,BAC=B

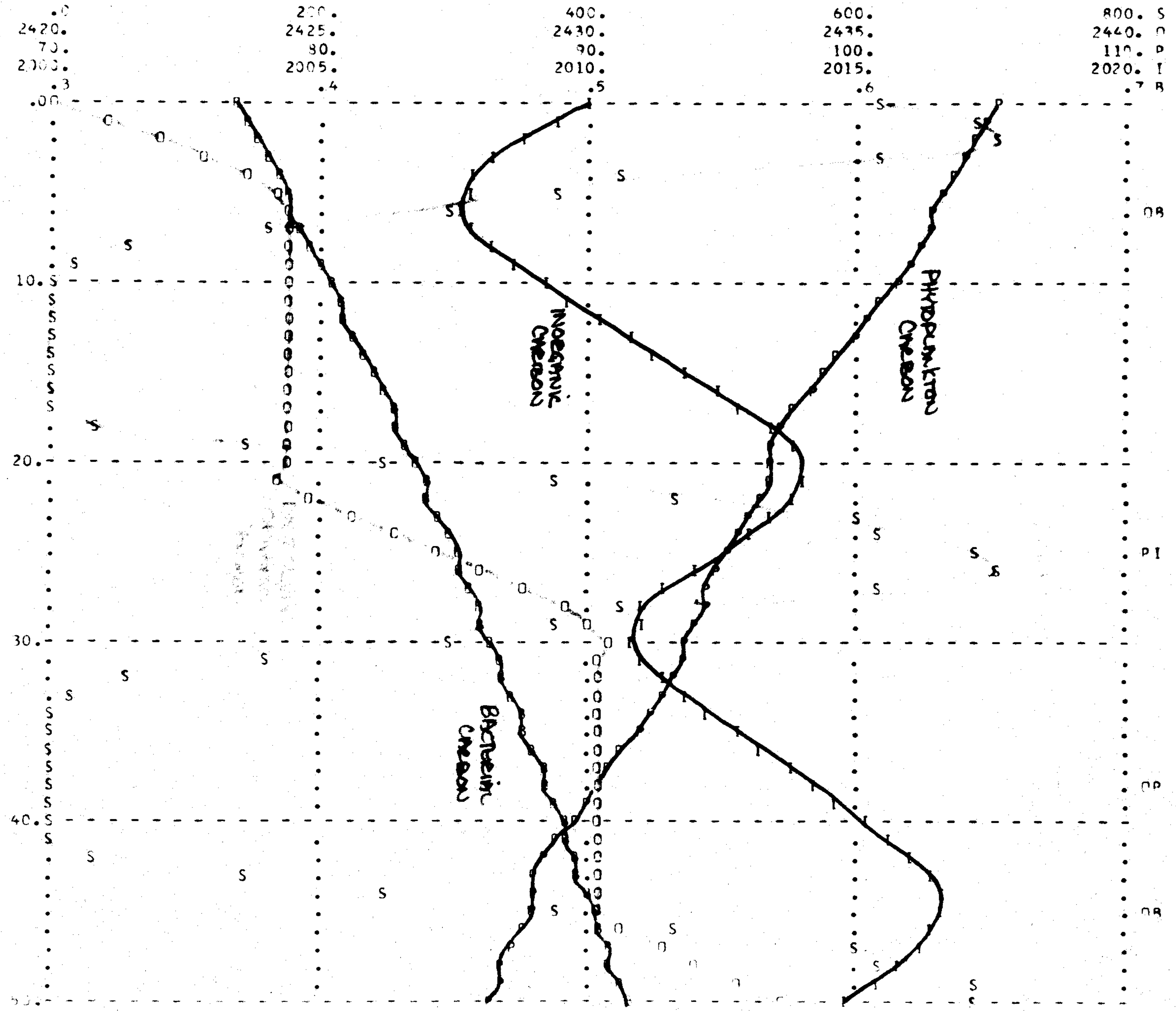

Figure 3.

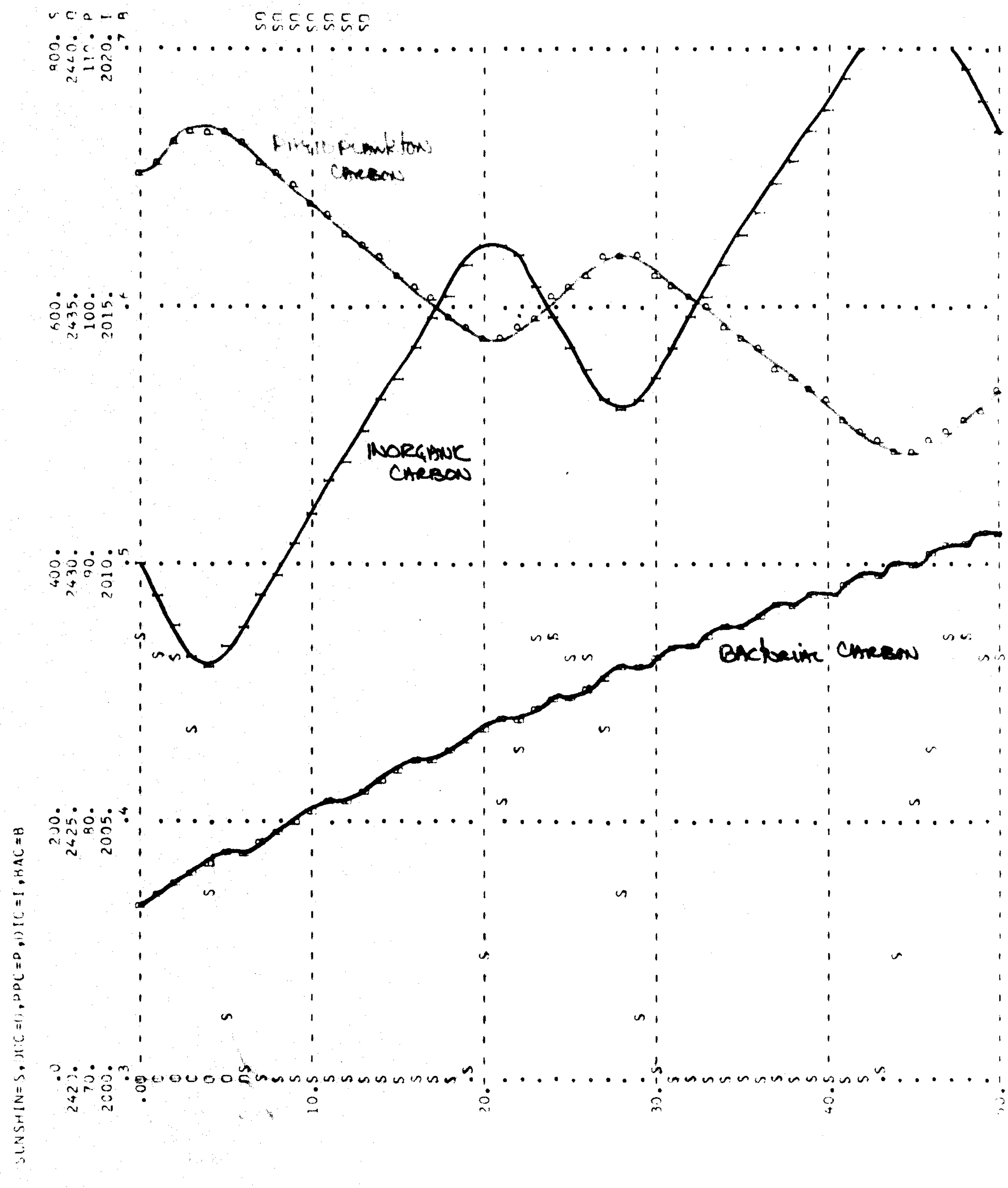
PPC/DIC/DOC/BAC MODEL
EXCESS=5
SUNSHIN=S,DOC=O,PPC=P,DIC=I,BAC=B
PHYTOPLANKTON CARBON
INORGANIC CARBON
BACTERIAL CARBON

Figure 4.