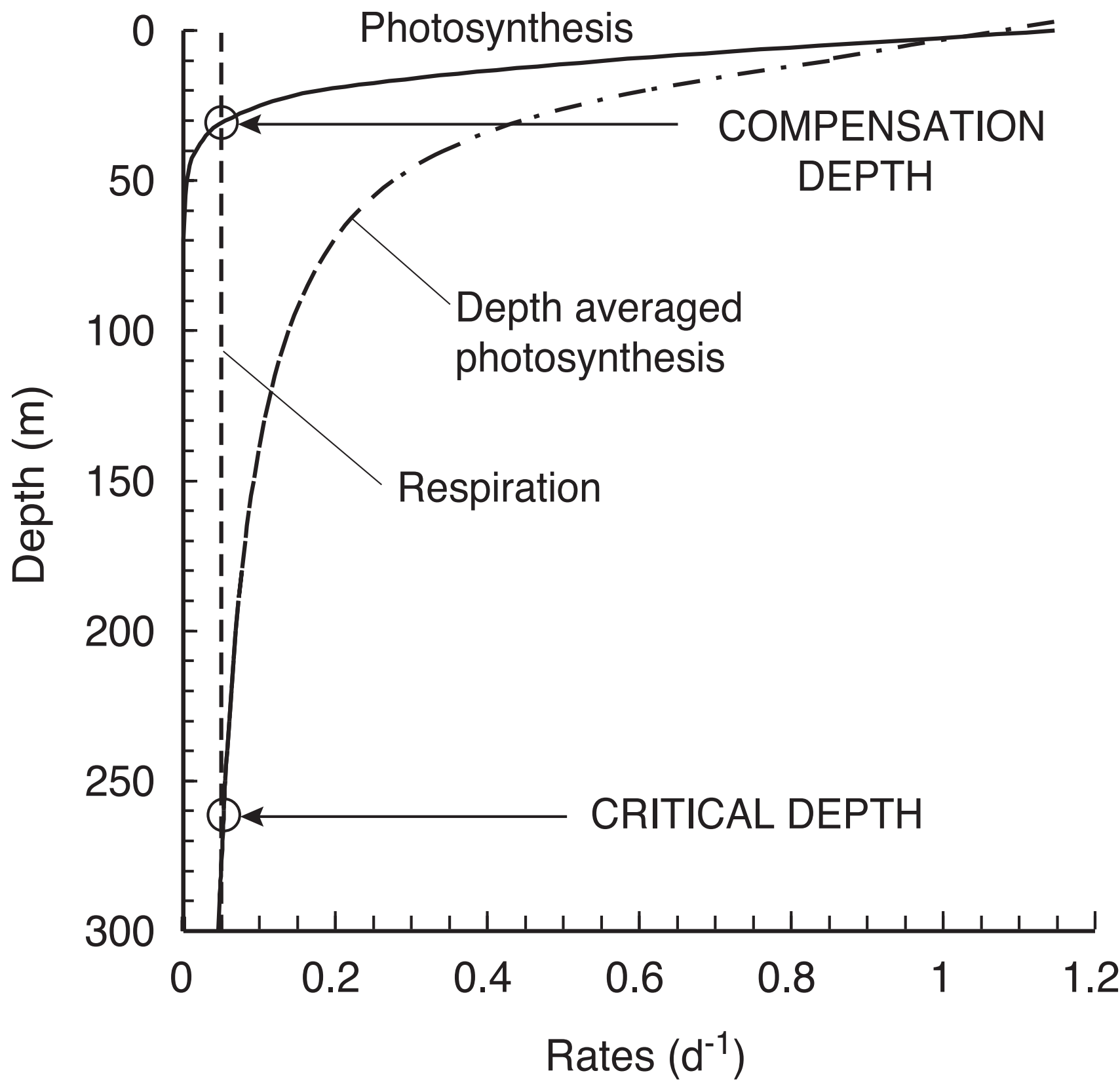
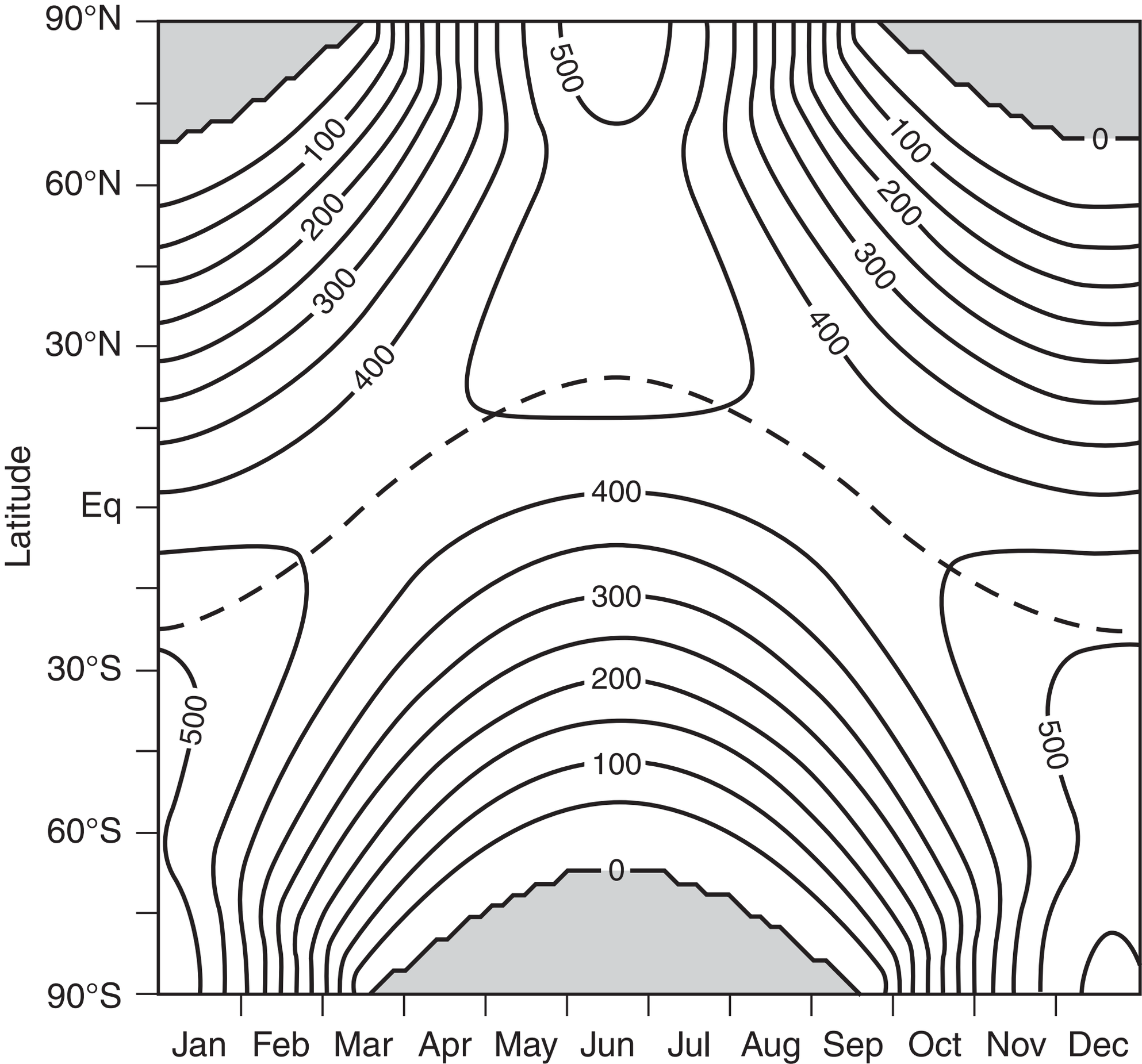
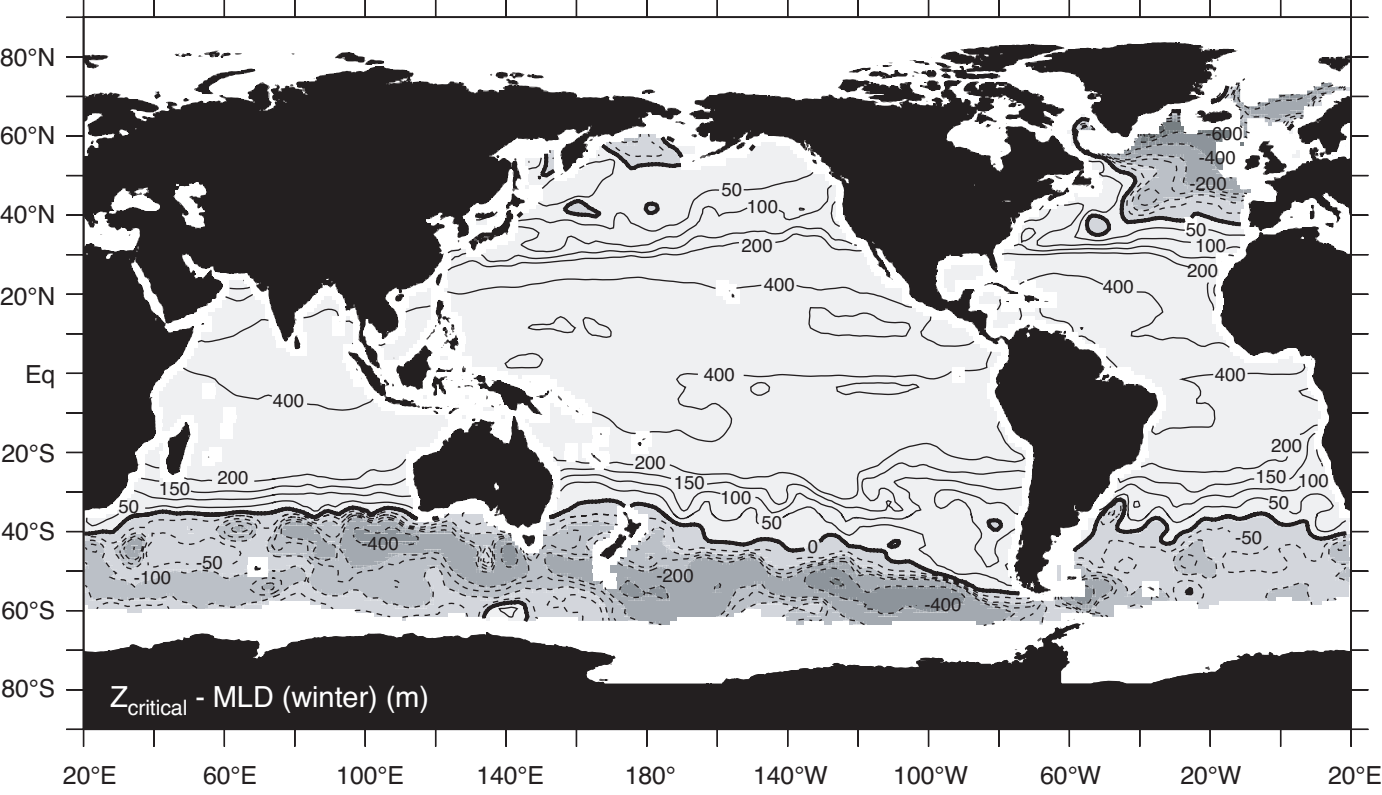
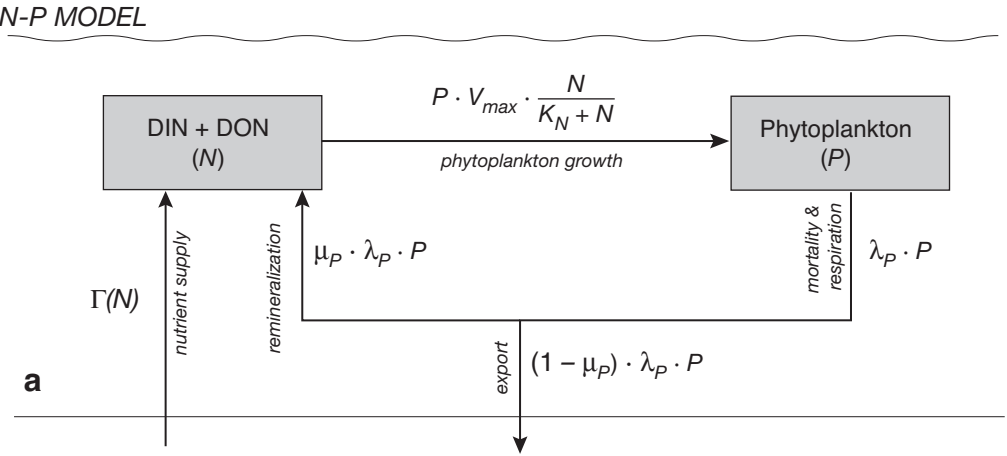
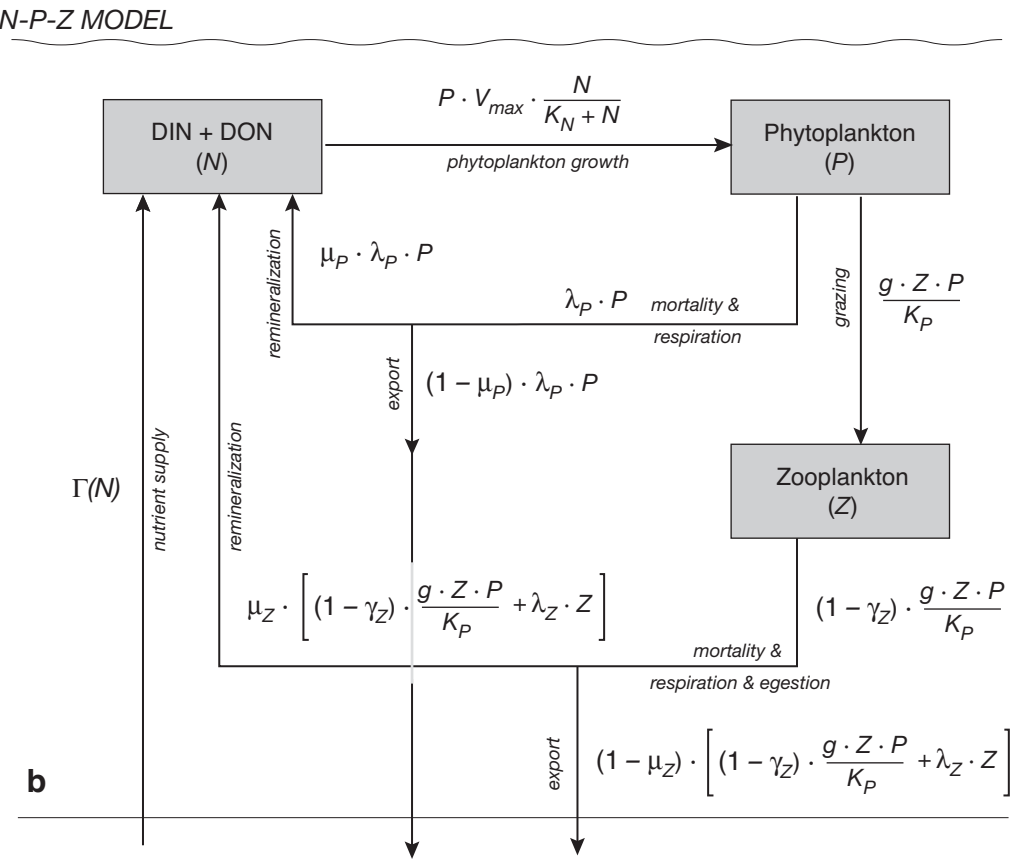
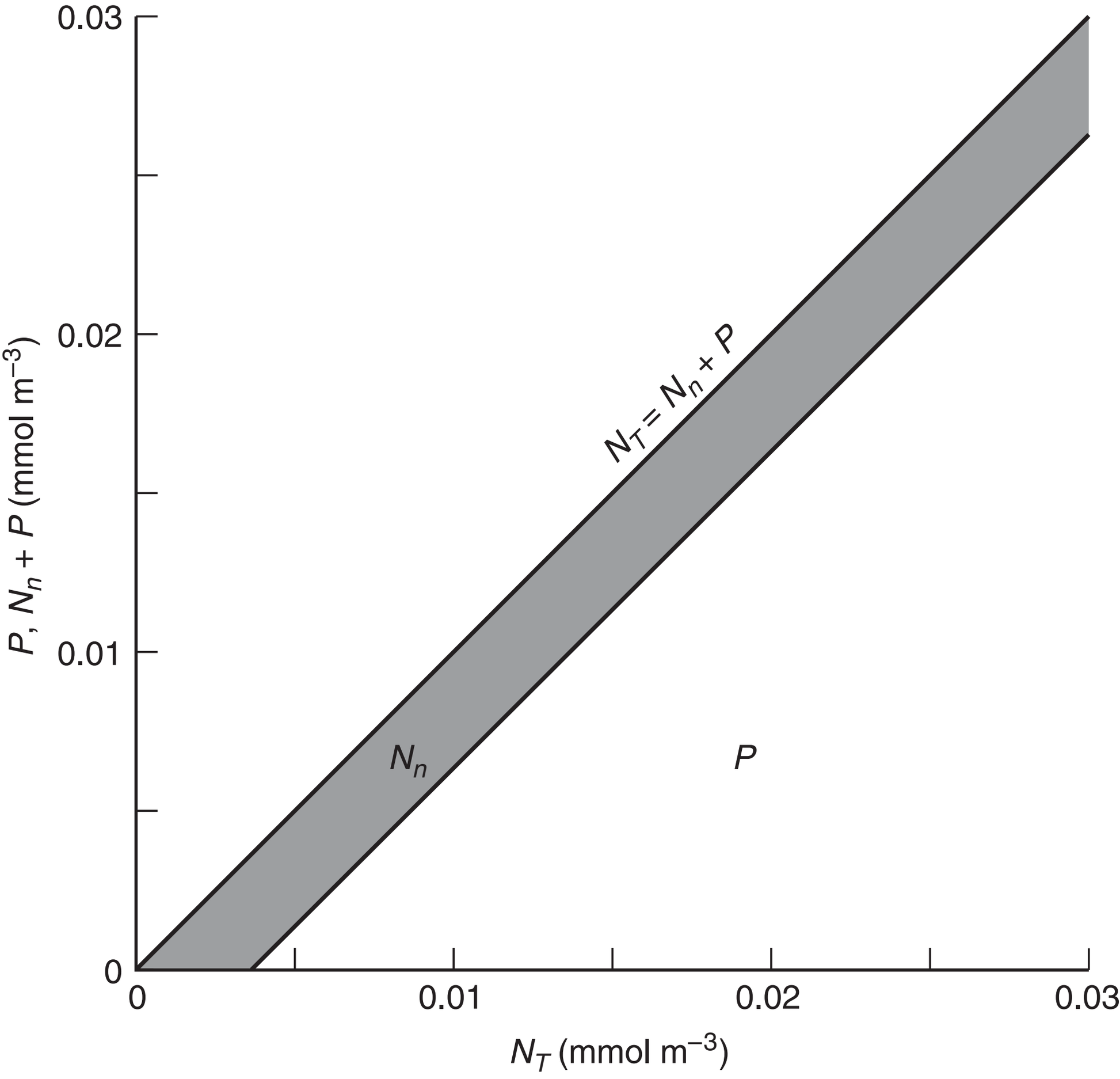

Photosynthesis
COMPENSATION DEPTH
Depth averaged photosynthesis
Respiration
CRITICAL DEPTH
Depth (m)
0
50
100
150
200
250
300
0
0.2
0.4
0.6
0.8
1
1.2
Rates (d-1)

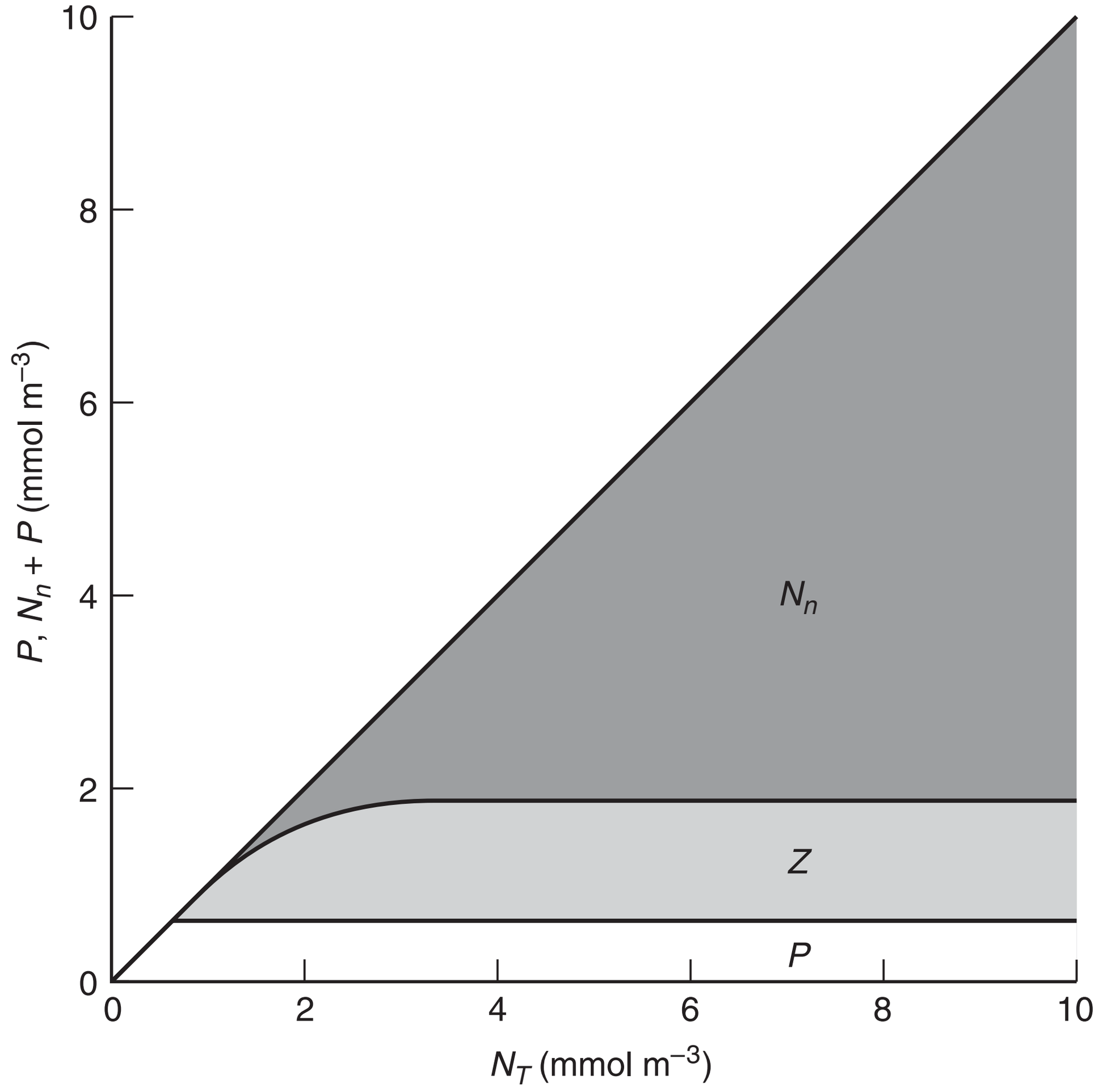

90°N
60°N
30°N
Eq
30°S
60°S
90°S
Latitude
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
0
100
200
300
400
500

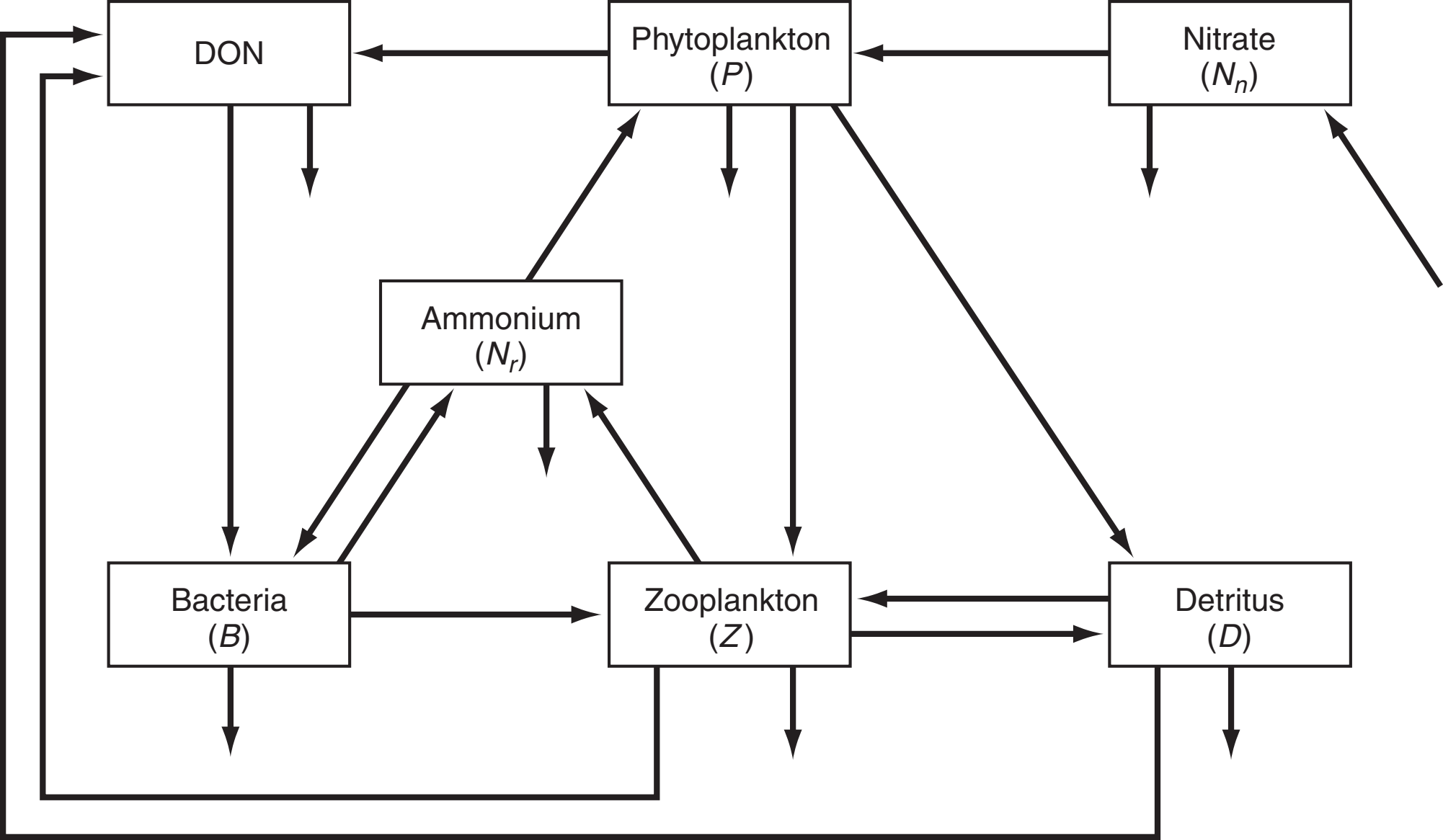

80°N
60°N
40°N
20°N
Eq
20°S
40°S
60°S
80°S
20°E
60°E
100°E
140°E
180°
140°W
100°W
60°W
20°W
20°E
$Z_{critical}$ - MLD (winter) (m)

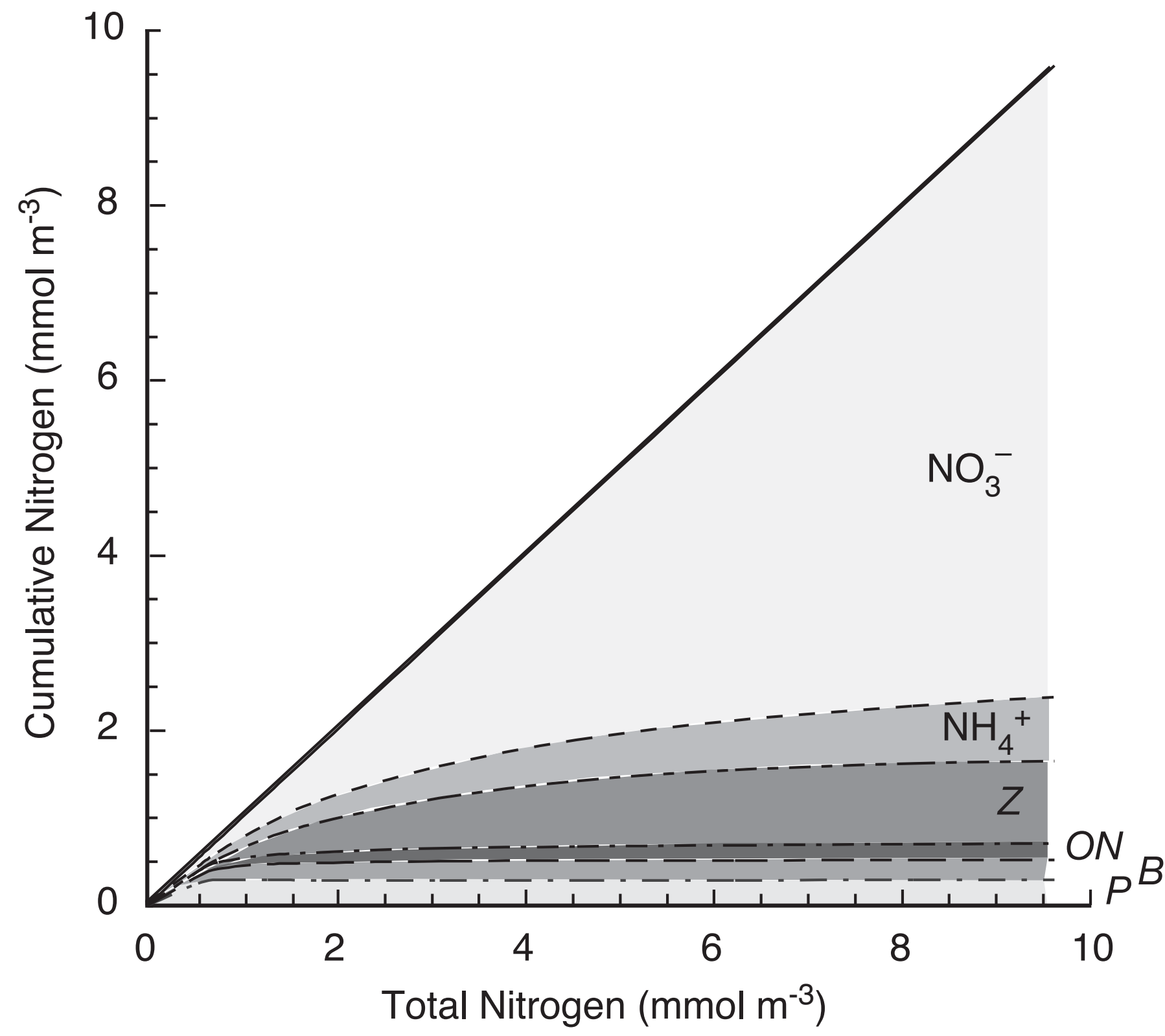

N-P MODEL
DIN + DON
(N)
$P \cdot V_{max} \cdot \frac{N}{K_N + N}$
phytoplankton growth
Phytoplankton
(P)
nutrient supply
remineralization
$\mu_P \cdot \lambda_P \cdot P$
mortality &
respiration
$\lambda_P \cdot P$
$\Gamma(N)$
export
$(1 - \mu_P) \cdot \lambda_P \cdot P$
a

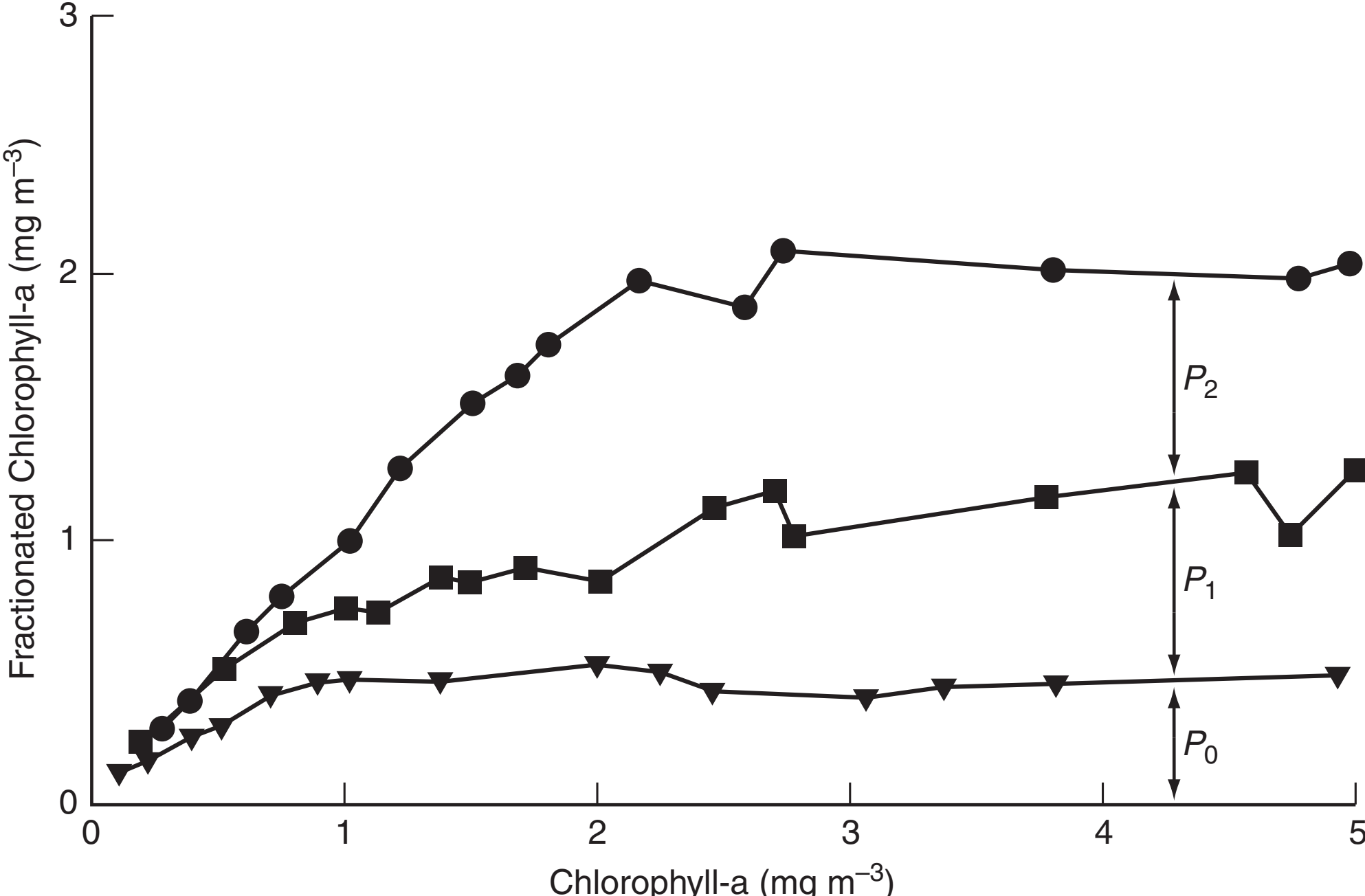

N-P-Z MODEL
DIN + DON
(N)
$P \cdot V_{max} \cdot \frac{N}{K_N + N}$
phytoplankton growth
Phytoplankton
(P)
remineralization
$\mu_P \cdot \lambda_P \cdot P$
$\lambda_P \cdot P$
mortality &
respiration
grazing
$\frac{g \cdot Z \cdot P}{K_P}$
export
$(1 - \mu_P) \cdot \lambda_P \cdot P$
$\Gamma(N)$
nutrient supply
remineralization
Zooplankton
(Z)
$\mu_Z \cdot \left[(1 - \gamma_Z) \cdot \frac{g \cdot Z \cdot P}{K_P} + \lambda_Z \cdot Z \right]$
$(1 - \gamma_Z) \cdot \frac{g \cdot Z \cdot P}{K_P} + \lambda_Z \cdot Z$
mortality &
respiration & egestion
export
$(1 - \mu_Z) \cdot \left[(1 - \gamma_Z) \cdot \frac{g \cdot Z \cdot P}{K_P} + \lambda_Z \cdot Z \right]$
b

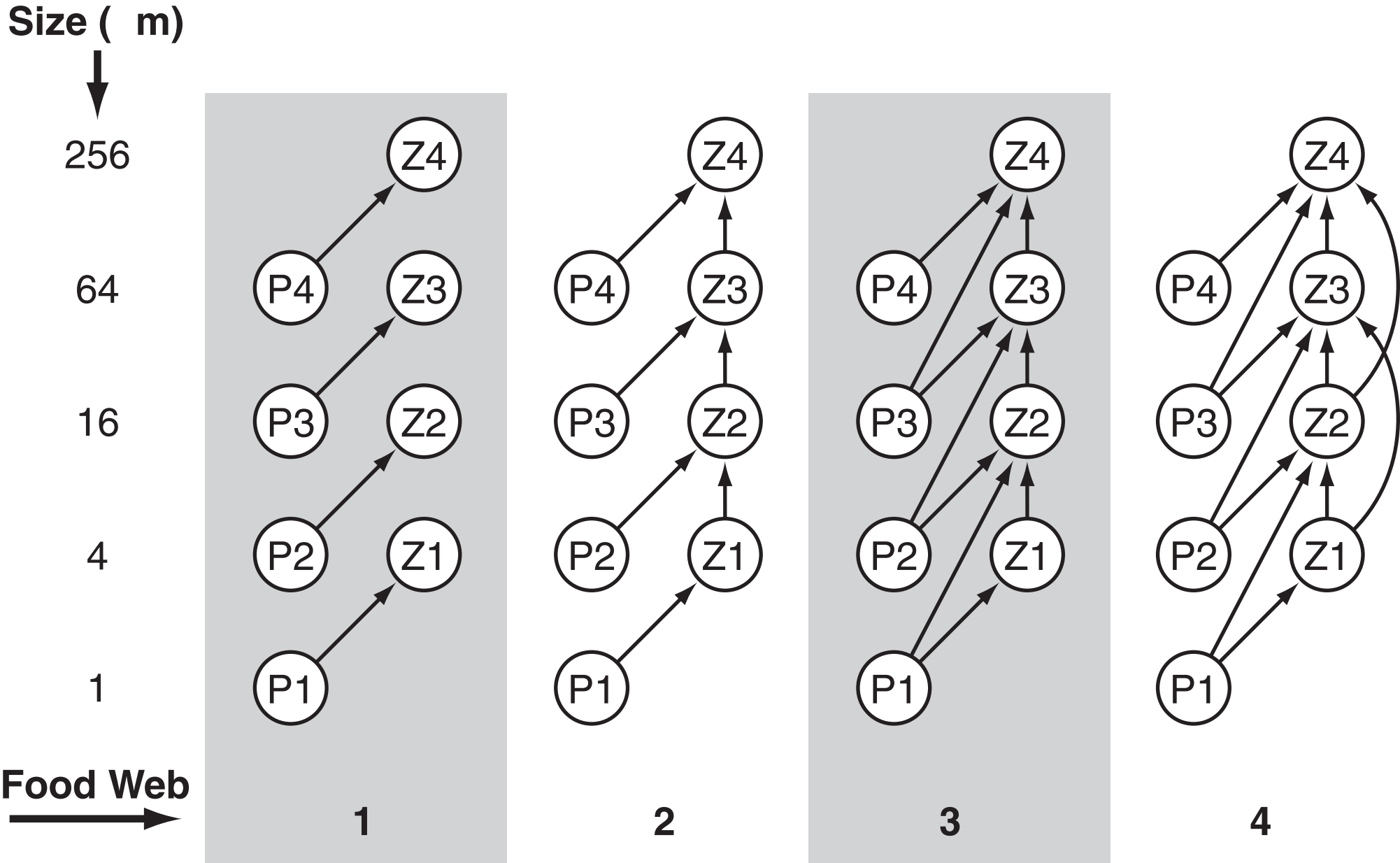

0.03
0.02
0.01
0
0
0.01
0.02
0.03
P, $N_n + P$ (mmol m^{-3})
N_T (mmol m^{-3})
$N_T = N_n + P$
N_n
P

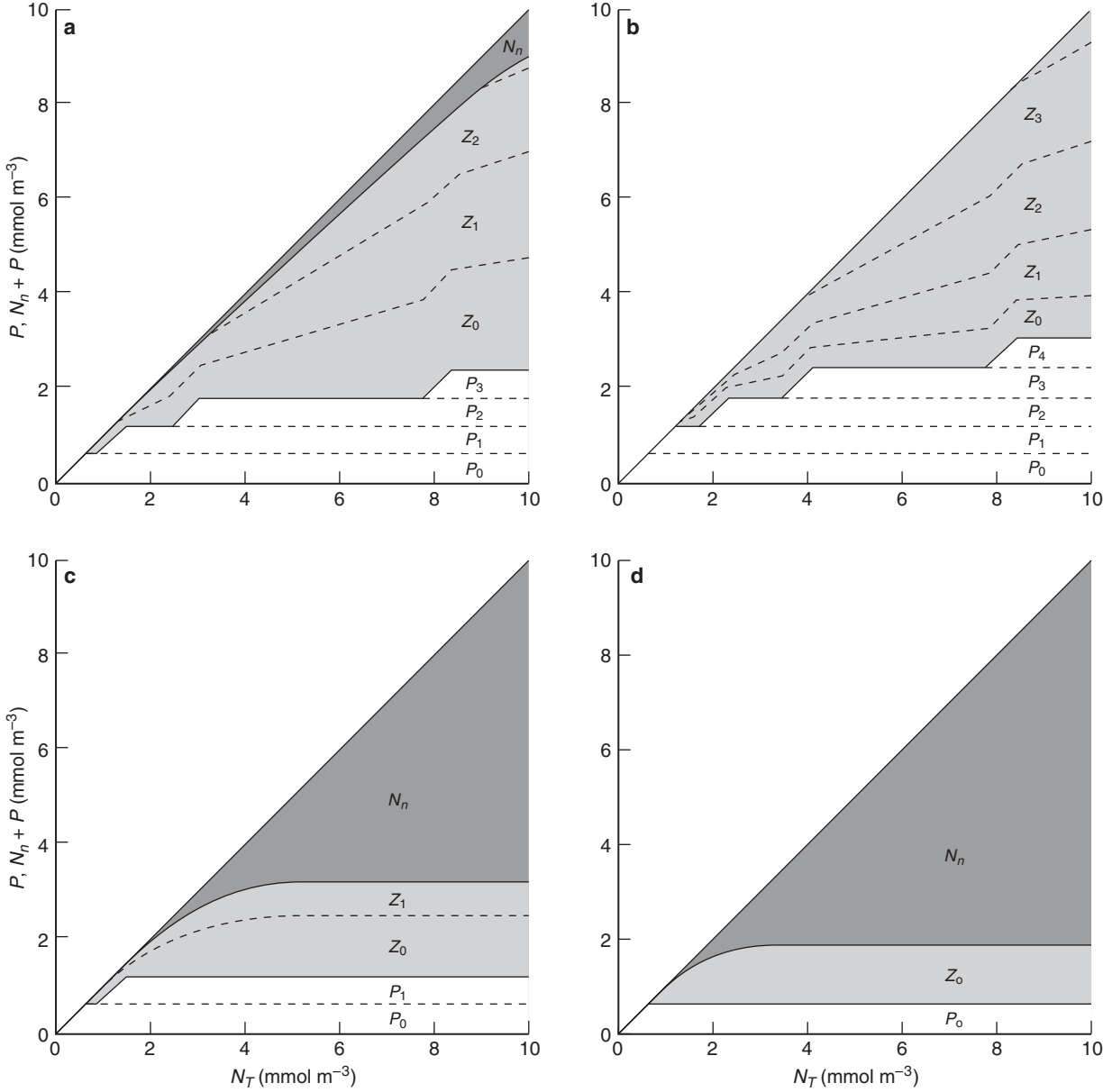

10
8
6
4
2
0
0
2
4
6
8
10
P, $N_n + P$ (mmol m^{-3})
N_T (mmol m^{-3})
N_n
Z
P

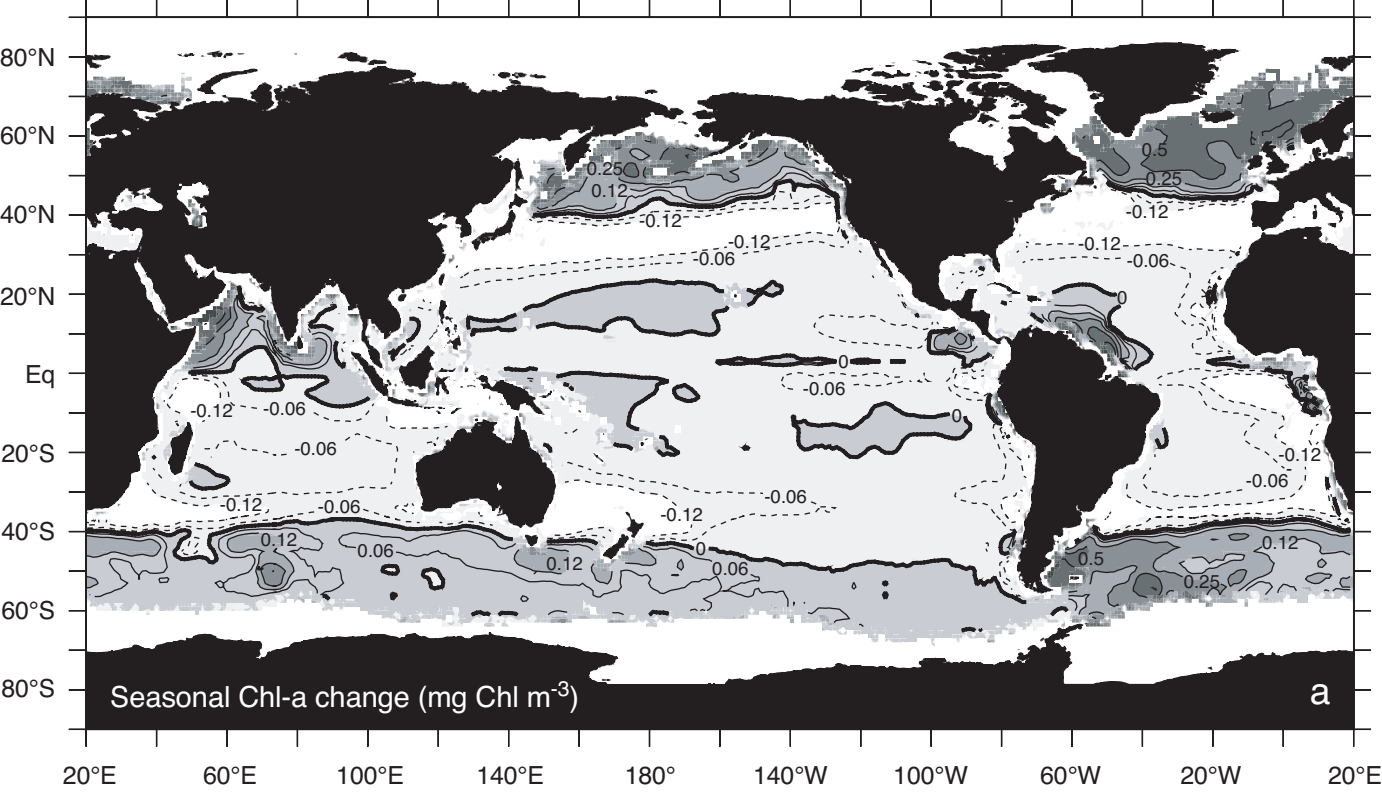

DON
Phytoplankton
(P)
Nitrate
(N_n)
Ammonium
(N_r)
Bacteria
(B)
Zooplankton
(Z)
Detritus
(D)

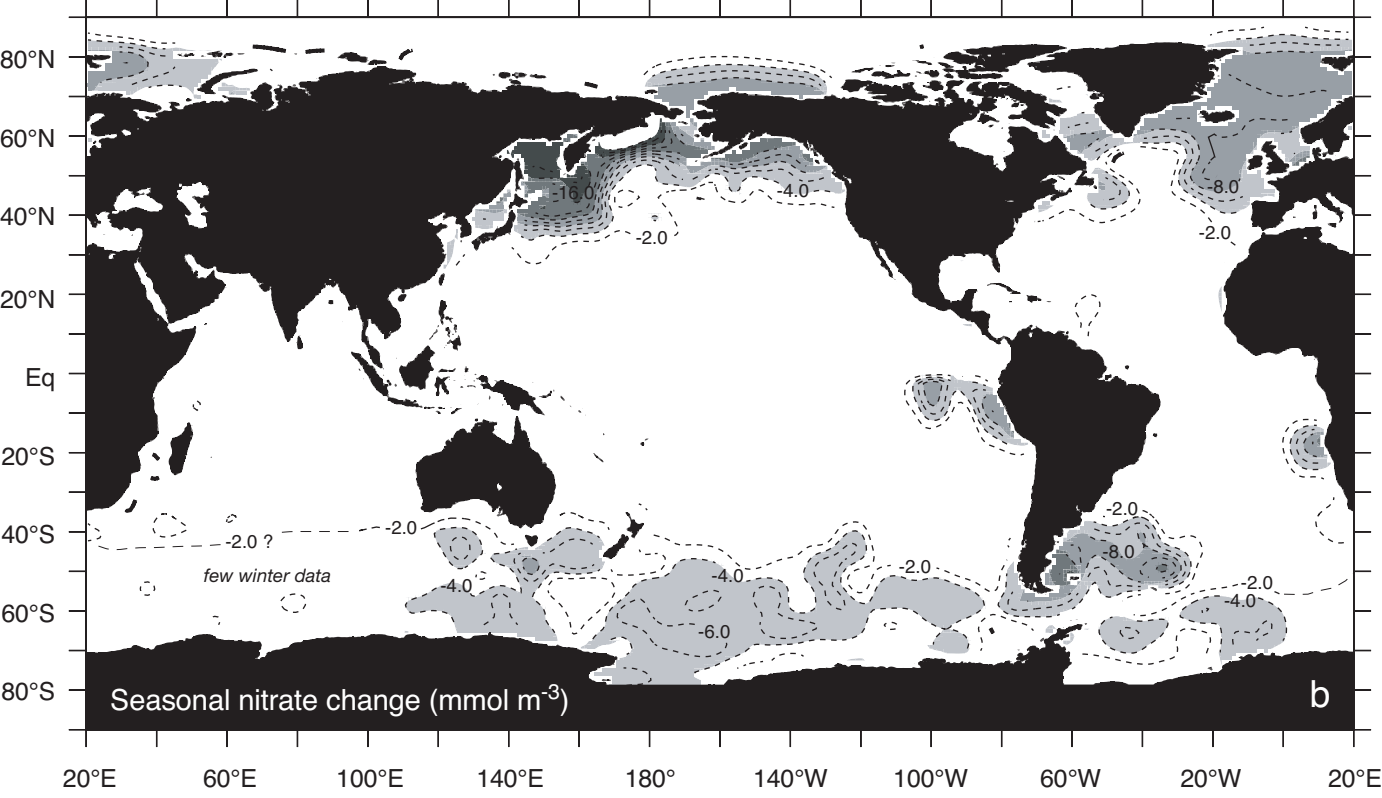

10
8
6
4
2
0
Cumulative Nitrogen (mmol m-3)
0
2
4
6
8
10
Total Nitrogen (mmol m-3)
NO3−
NH4+
Z
ON
P
B

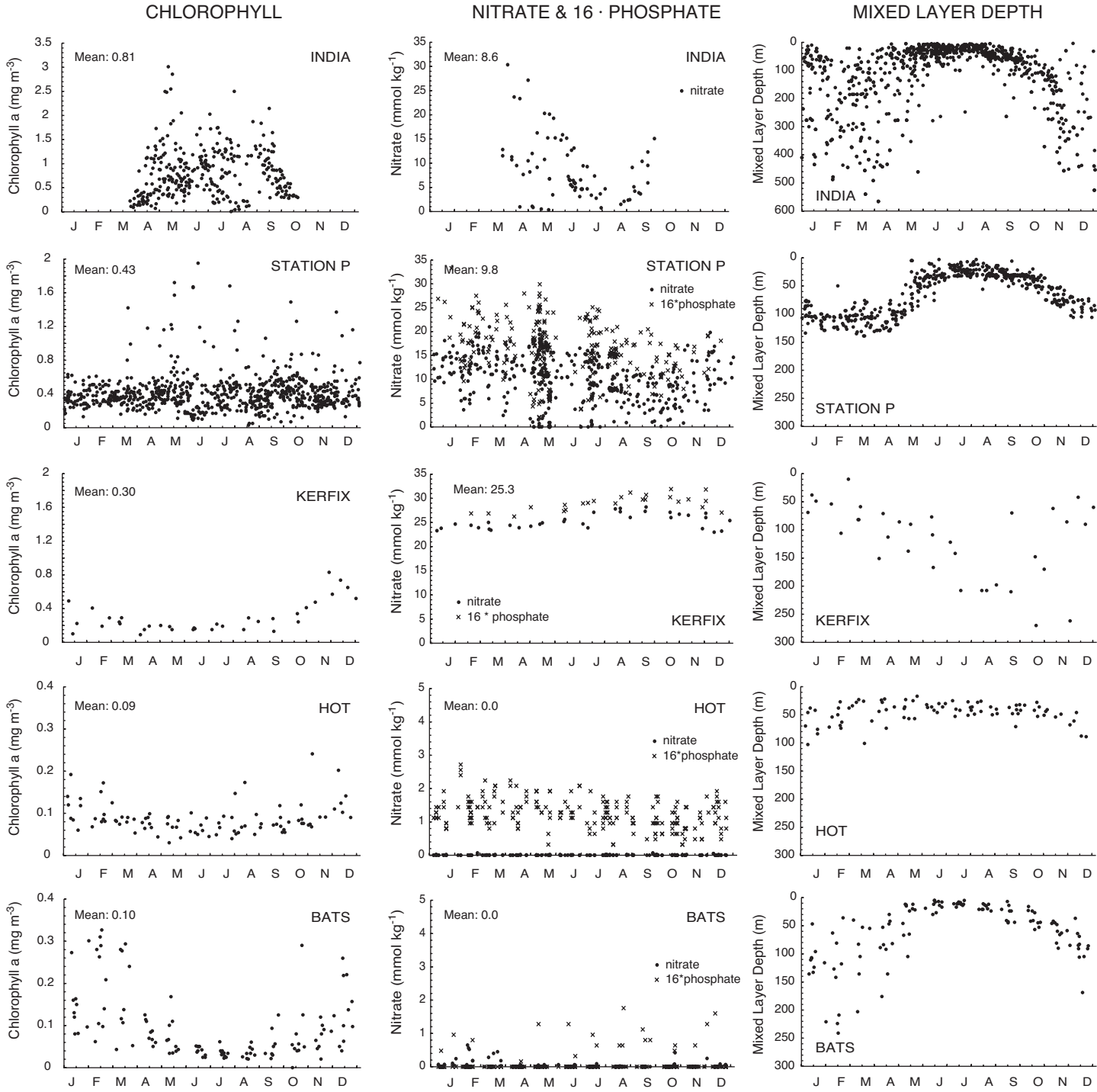

Fractionated Chlorophyll-a (mg m^{-3})
Chlorophyll-a (mg m^{-3})
0
1
2
3
4
5
P_2
P_1
P_0

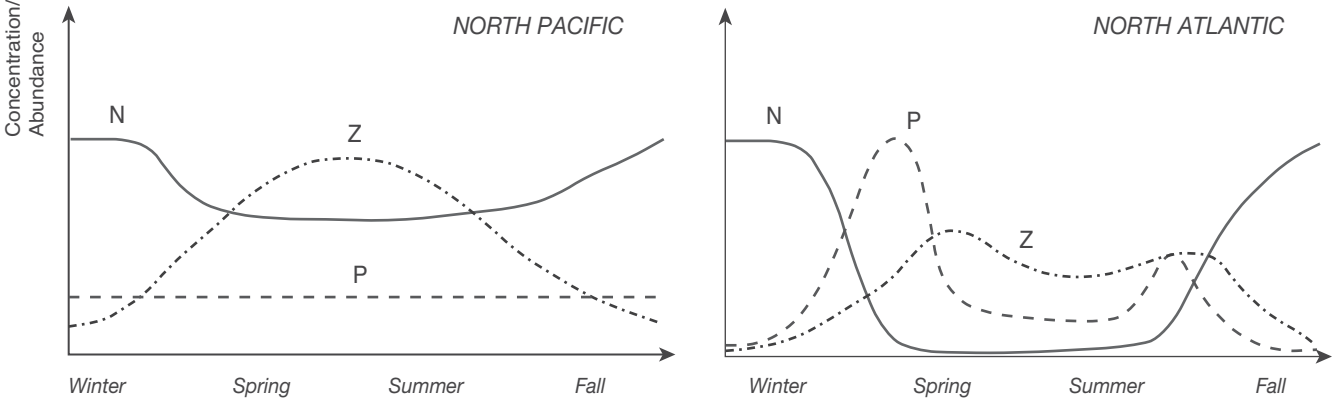

Size (m)
256
64
16
4
1
Food Web
Z4
P4
Z3
P3
Z2
P2
Z1
P1
1
2
3
4

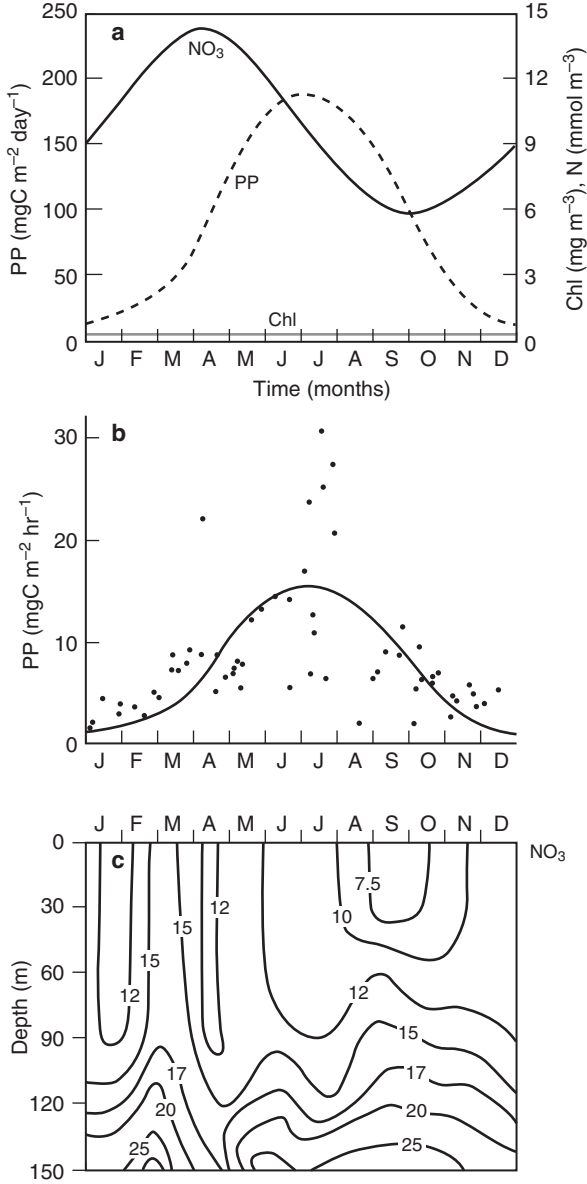

a
b
c
d
N_n
Z_3
Z_2
Z_1
Z_0
Z_o
P_4
P_3
P_2
P_1
P_0
P_o
P, $N_n + P$ (mmol m^{-3})
N_T (mmol m^{-3})
0
2
4
6
8
10

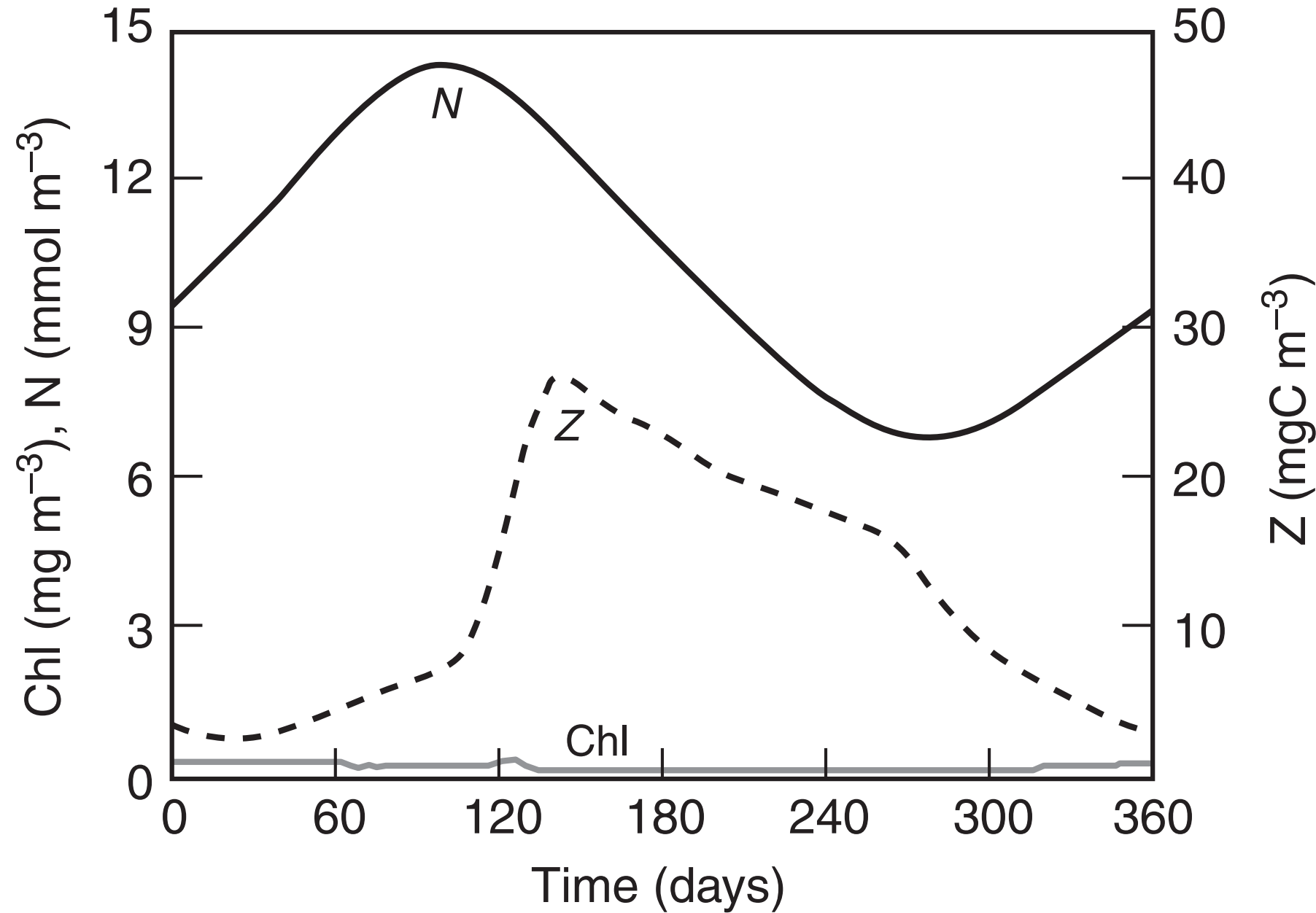

80°N
60°N
40°N
20°N
Eq
20°S
40°S
60°S
80°S
20°E
60°E
100°E
140°E
180°
140°W
100°W
60°W
20°W
20°E
0.5
0.25
0.12
0.06
0
-0.06
-0.12
Seasonal Chl-a change (mg Chl m-3)
a

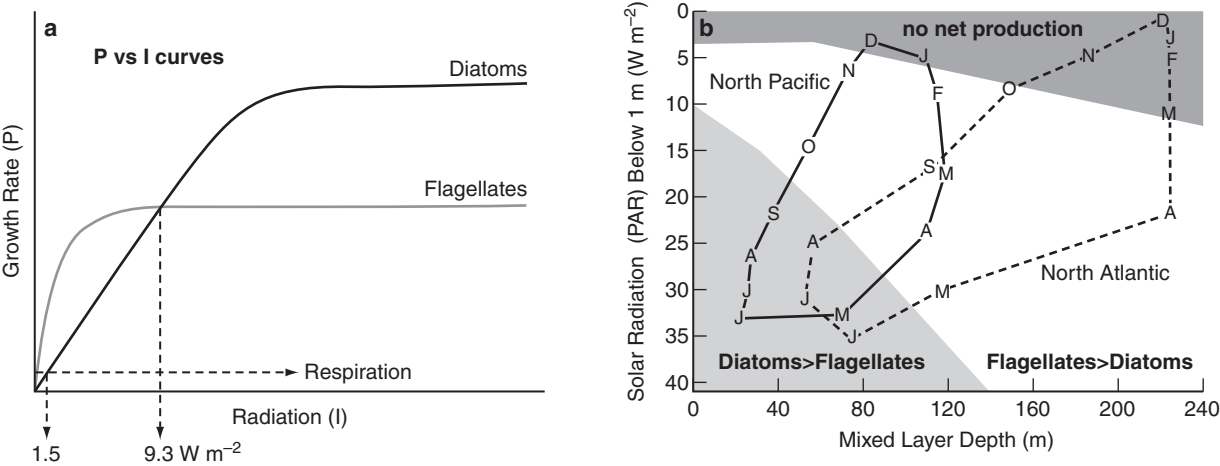

80°N
60°N
40°N
20°N
Eq
20°S
40°S
60°S
80°S
20°E
60°E
100°E
140°E
180°
140°W
100°W
60°W
20°W
20°E
-16.0
-4.0
-2.0
-8.0
-2.0
-2.0
-2.0 ?
few winter data
-4.0
-2.0
-4.0
-6.0
-2.0
-2.0
-8.0
-2.0
-4.0
Seasonal nitrate change (mmol m-3)
b

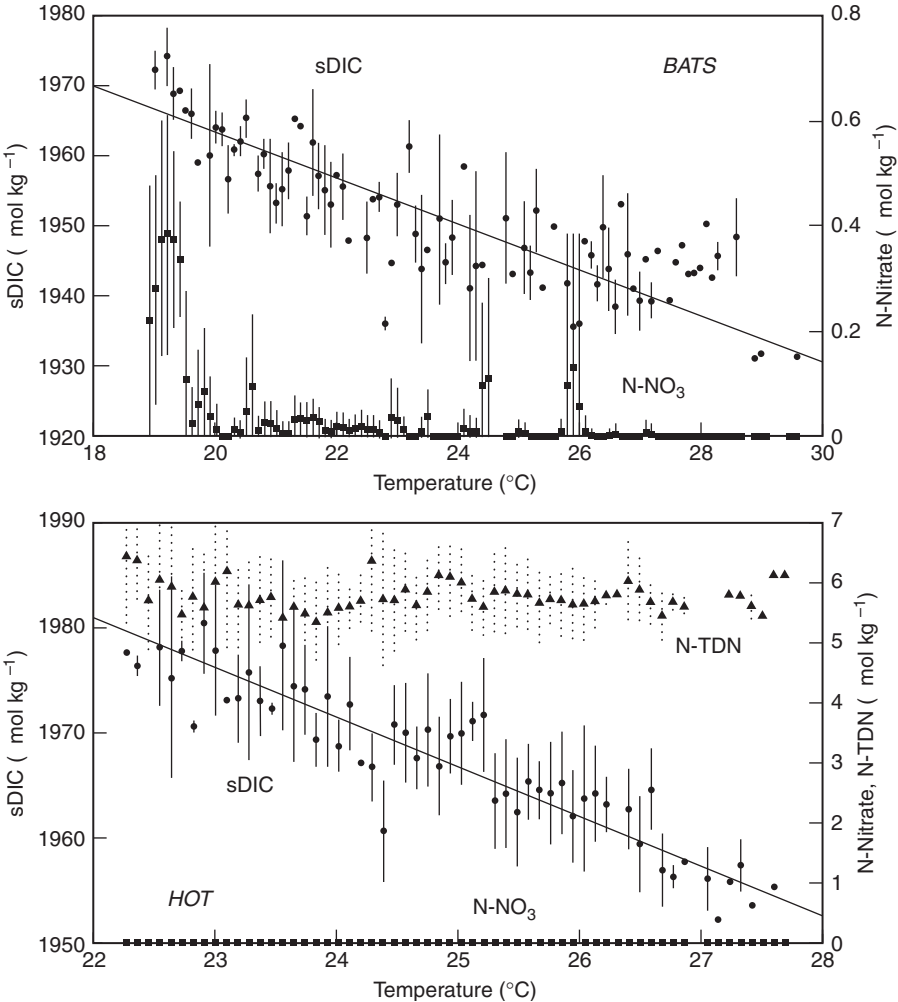

CHLOROPHYLL
NITRATE & 16 · PHOSPHATE
MIXED LAYER DEPTH
Chlorophyll a (mg m-3)
Nitrate (mmol kg-1)
Mixed Layer Depth (m)
Mean: 0.81
INDIA
Mean: 8.6
INDIA
nitrate
INDIA
Mean: 0.43
STATION P
Mean: 9.8
STATION P
nitrate
16*phosphate
STATION P
Mean: 0.30
KERFIX
Mean: 25.3
nitrate
16 * phosphate
KERFIX
KERFIX
Mean: 0.09
HOT
Mean: 0.0
HOT
nitrate
16*phosphate
HOT
Mean: 0.10
BATS
Mean: 0.0
BATS
nitrate
16*phosphate
BATS
J F M A M J J A S O N D

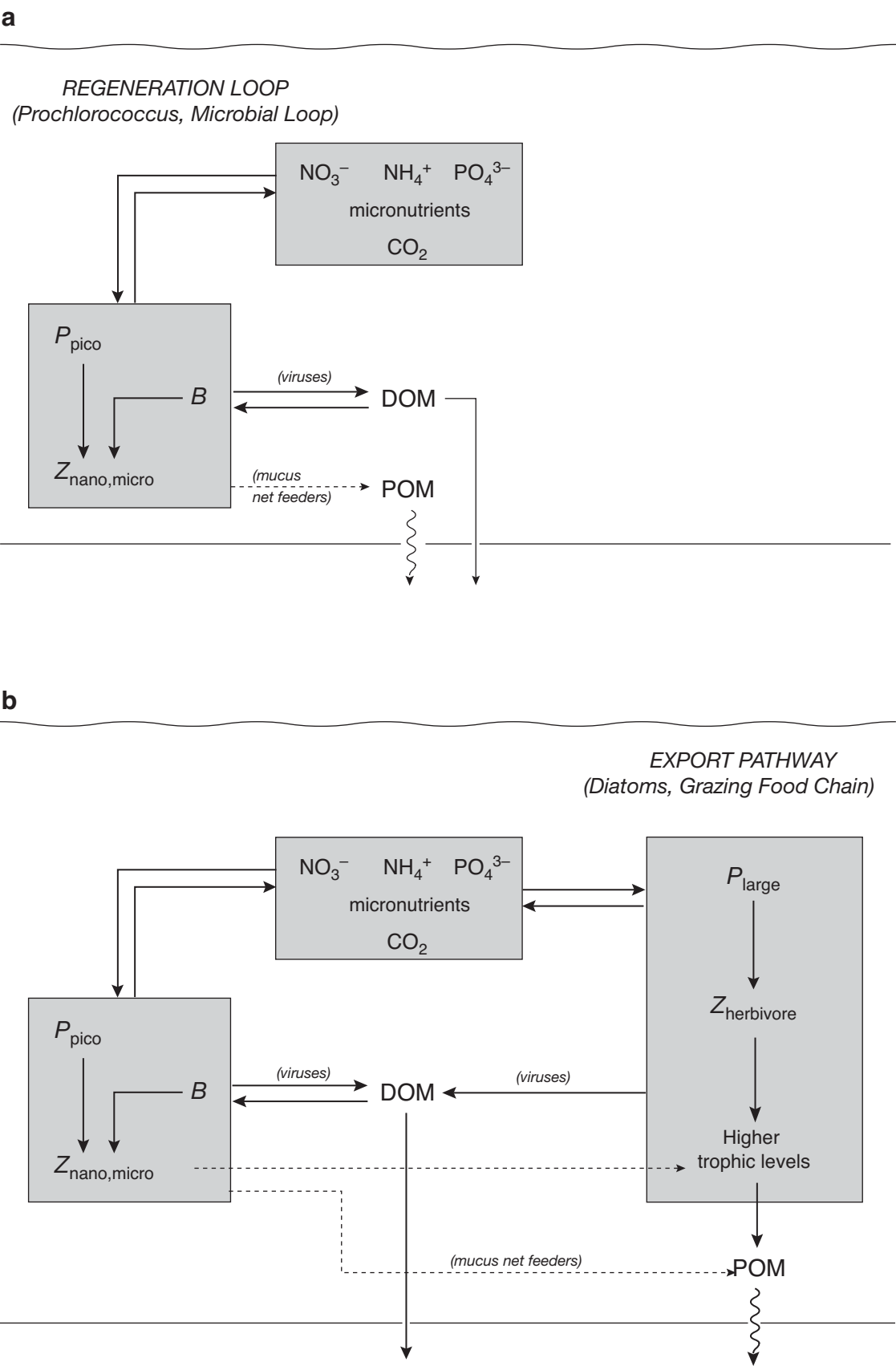

Concentration/
Abundance
NORTH PACIFIC
N
Z
P
Winter
Spring
Summer
Fall
NORTH ATLANTIC
N
P
Z
Winter
Spring
Summer
Fall

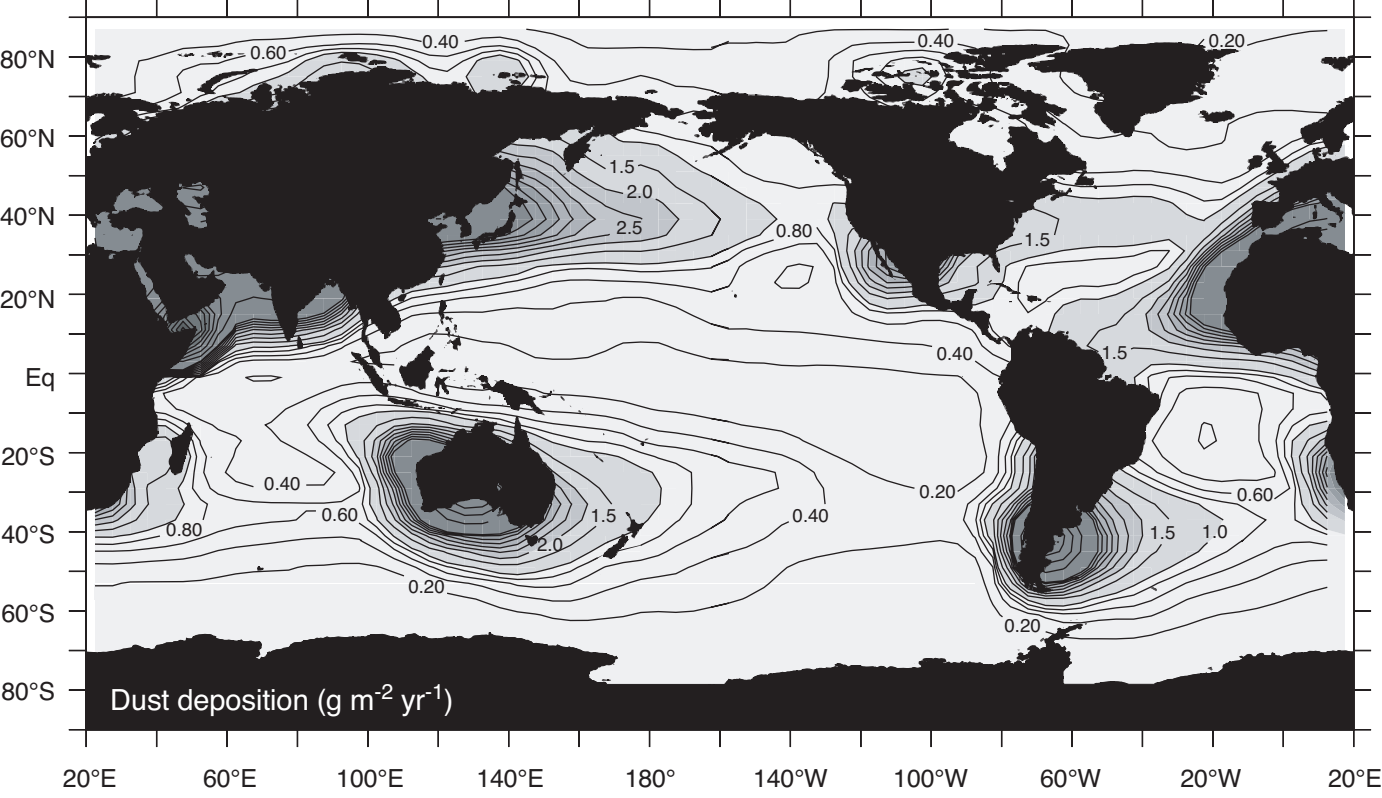

a
NO3
PP
Chl
PP (mgC m−2 day−1)
Chl (mg m−3), N (mmol m−3)
J F M A M J J A S O N D
Time (months)
b
PP (mgC m−2 hr−1)
J F M A M J J A S O N D
c
NO3
Depth (m)
7.5
10
12
15
17
20
25

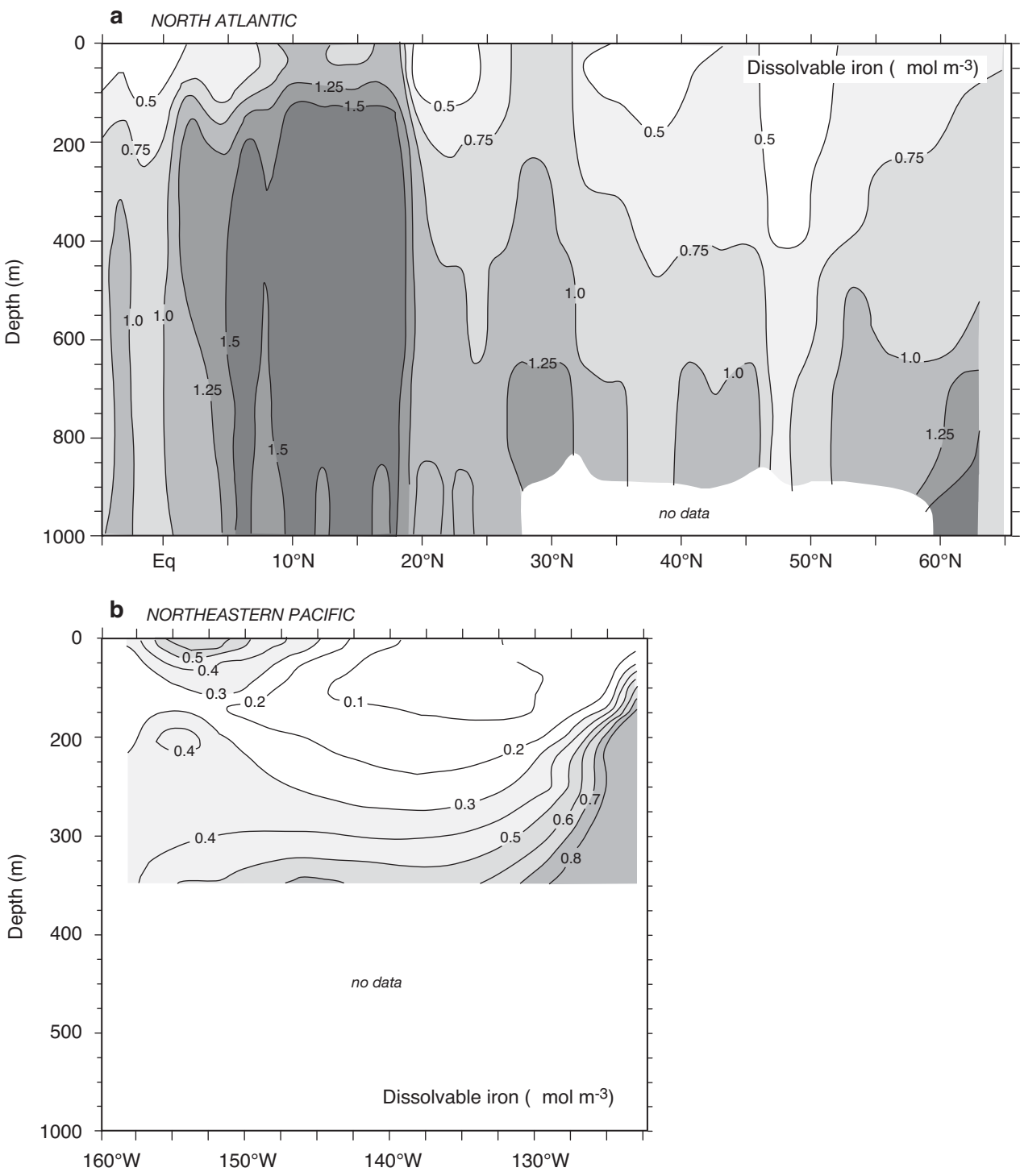

15
12
9
6
3
0
50
40
30
20
10
0
60
120
180
240
300
360
N
Z
Chl
Chl (mg m−3), N (mmol m−3)
Z (mgC m−3)
Time (days)

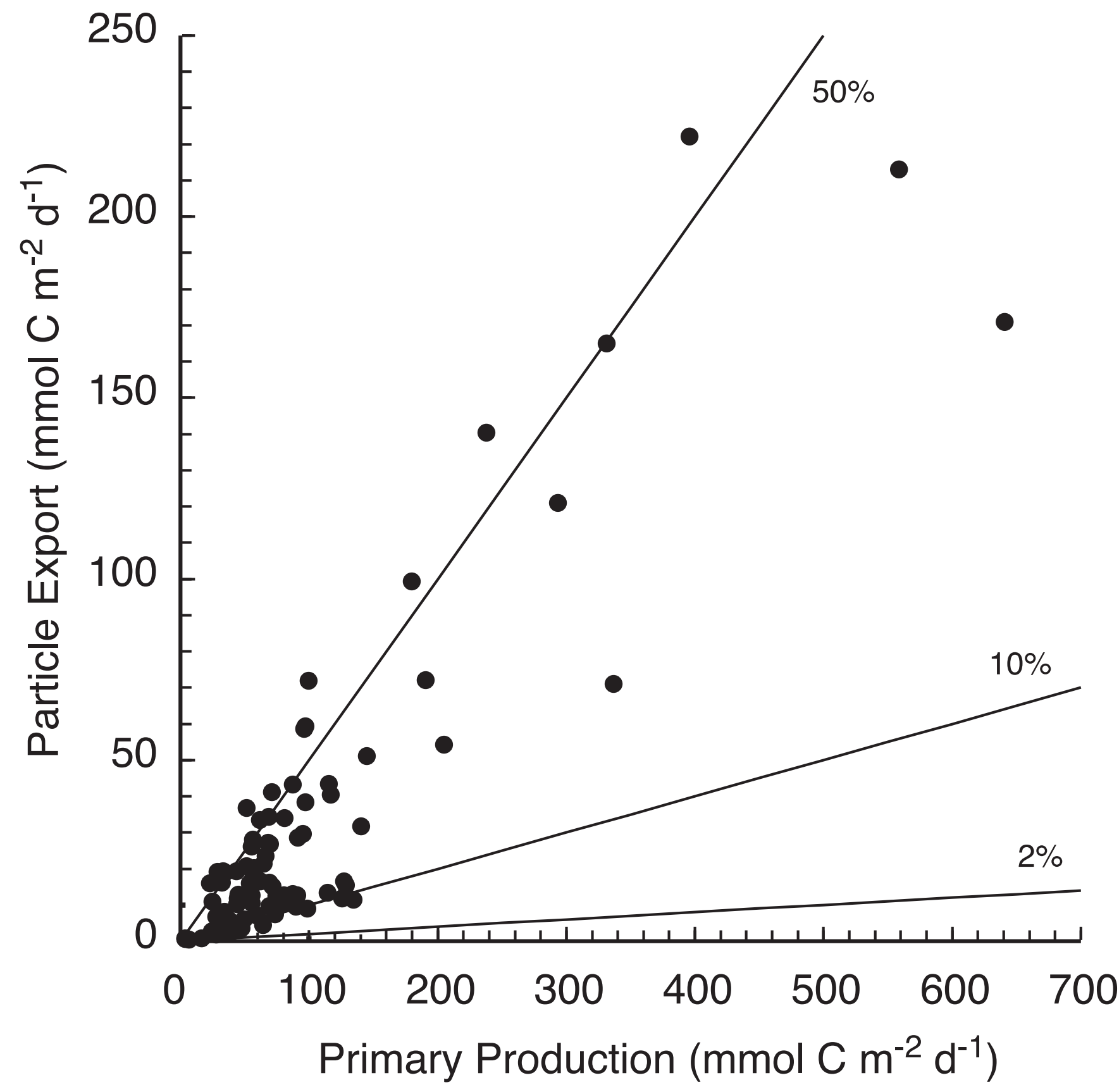

a
P vs I curves
Diatoms
Flagellates
Growth Rate (P)
Respiration
Radiation (I)
1.5
9.3 W m−2
b
no net production
North Pacific
North Atlantic
Diatoms>Flagellates
Flagellates>Diatoms
Solar Radiation (PAR) Below 1 m (W m−2)
Mixed Layer Depth (m)
0
5
10
15
20
25
30
35
40
0
40
80
120
160
200
240
J
F
M
A
M
J
J
A
S
O
N
D

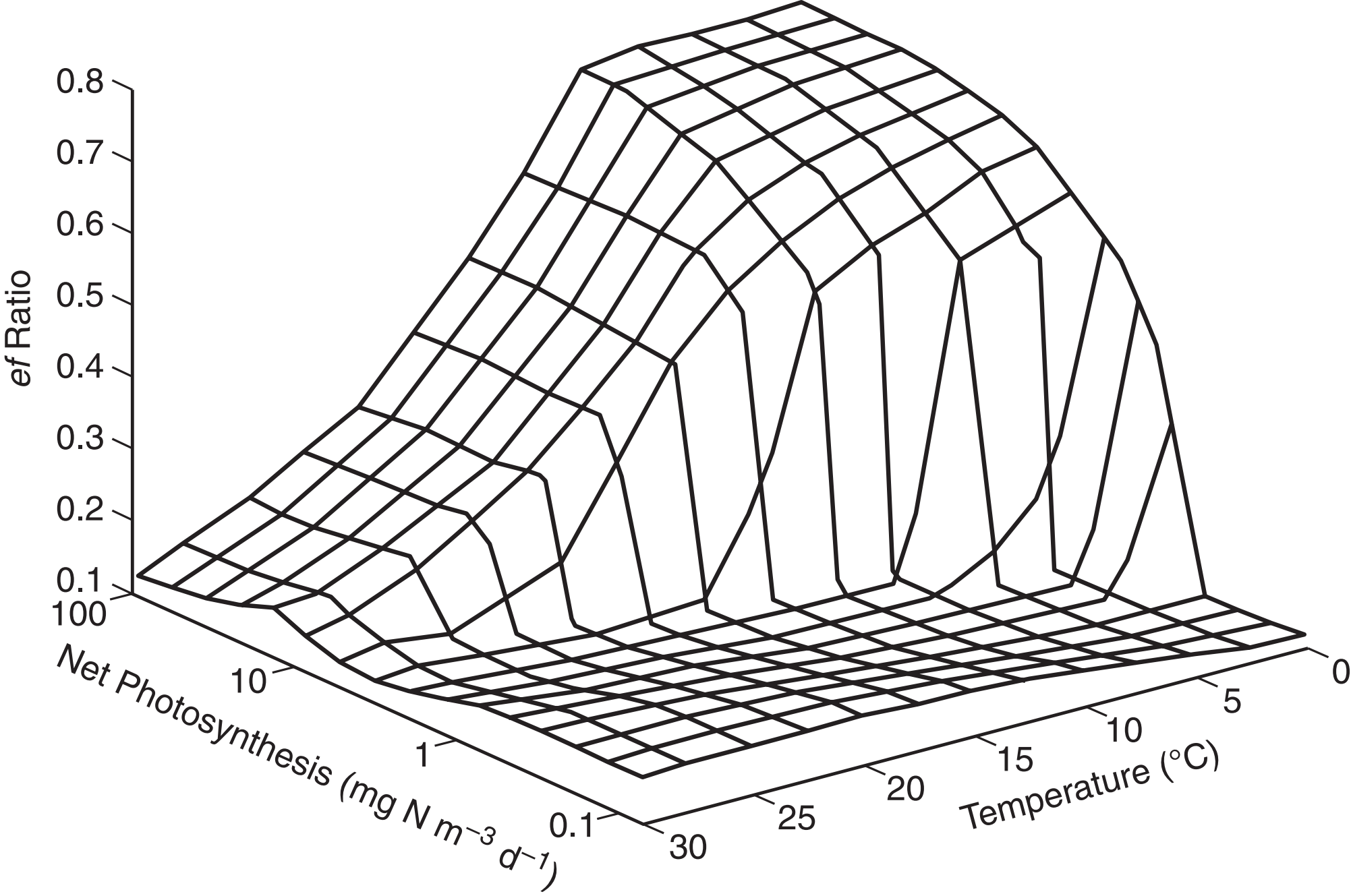

sDIC
BATS
N-NO3
sDIC (mol kg −1)
N-Nitrate (mol kg −1)
Temperature (°C)
1980
1970
1960
1950
1940
1930
1920
0.8
0.6
0.4
0.2
0
18
20
22
24
26
28
30
1990
1980
1970
1960
1950
7
6
5
4
3
2
1
0
N-TDN
sDIC
HOT
N-NO3
N-Nitrate, N-TDN (mol kg −1)
22
23
24
25
26
27
28

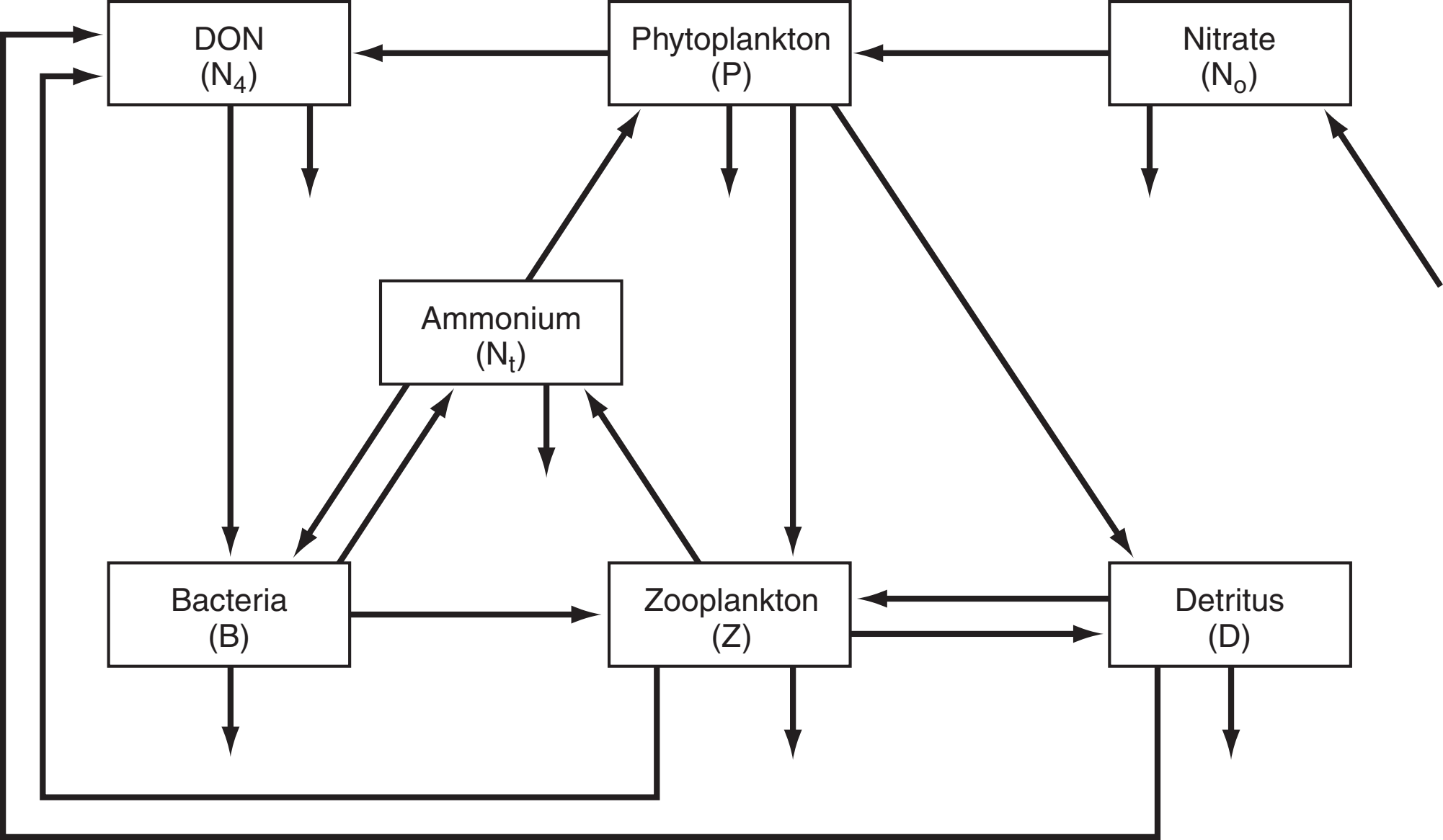

a
REGENERATION LOOP
(Prochlorococcus, Microbial Loop)
NO3− NH4+ PO43−
micronutrients
CO2
Ppico
B
Znano,micro
(viruses)
DOM
(mucus
net feeders)
POM
b
EXPORT PATHWAY
(Diatoms, Grazing Food Chain)
NO3− NH4+ PO43−
micronutrients
CO2
Plarge
Zherbivore
Higher
trophic levels
Ppico
B
Znano,micro
(viruses)
DOM
(viruses)
(mucus net feeders)
POM

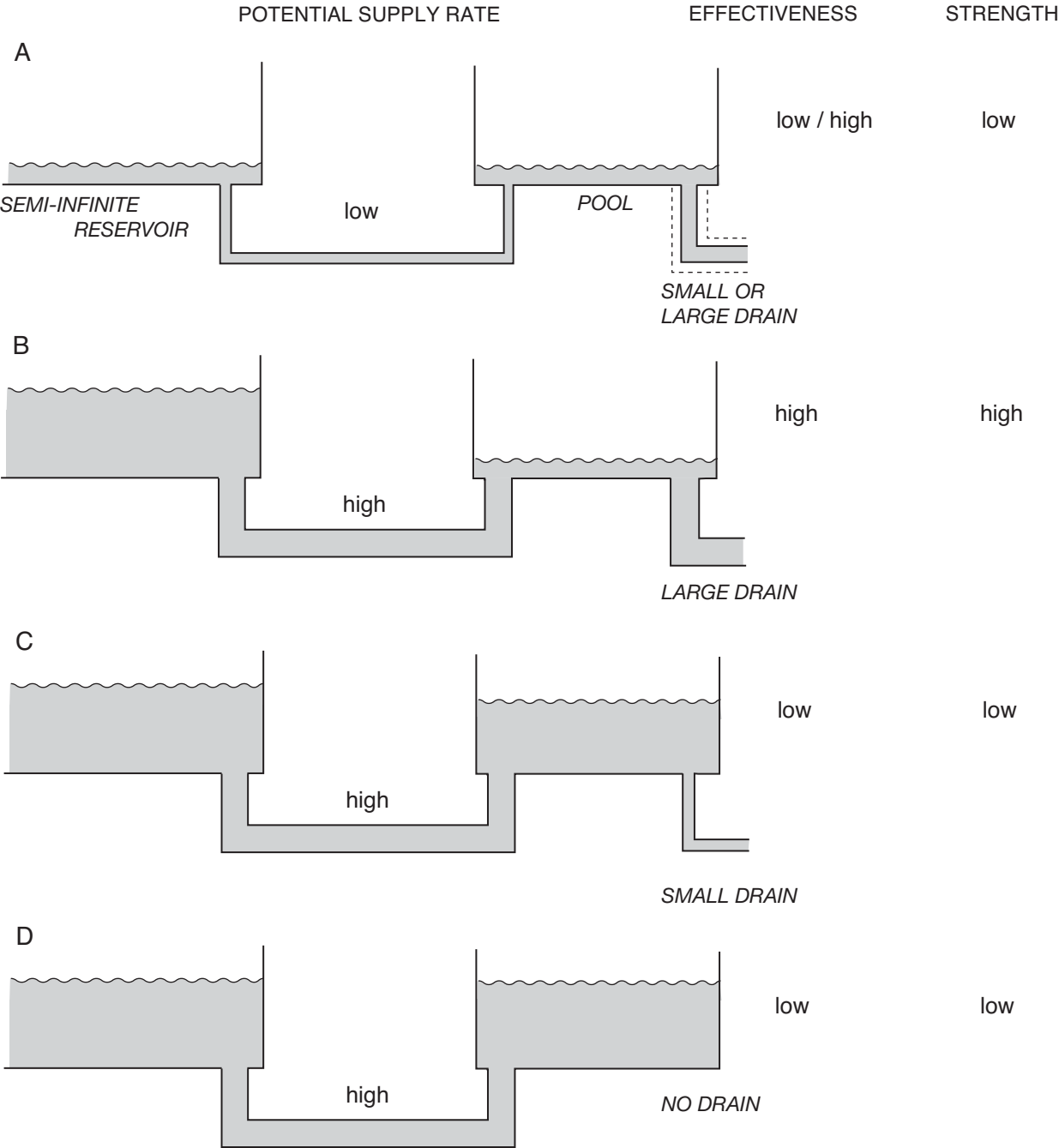

80°N
60°N
40°N
20°N
Eq
20°S
40°S
60°S
80°S
20°E
60°E
100°E
140°E
180°
140°W
100°W
60°W
20°W
20°E
0.60
0.40
0.40
0.20
1.5
2.0
2.5
0.80
1.5
0.40
1.5
0.40
0.60
0.80
0.60
1.5
0.40
0.20
1.5
1.0
2.0
0.20
0.20
Dust deposition (g m-2 yr-1)


a
NORTH ATLANTIC
Dissolvable iron (mol m-3)
Depth (m)
0
200
400
600
800
1000
Eq
10°N
20°N
30°N
40°N
50°N
60°N
0.5
0.75
1.25
1.5
1.0
no data
b
NORTHEASTERN PACIFIC
Depth (m)
0
200
300
400
500
1000
160°W
150°W
140°W
130°W
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
no data
Dissolvable iron (mol m-3)


250
200
150
100
50
0
Particle Export (mmol C m-2 d-1)
50%
10%
2%
0
100
200
300
400
500
600
700
Primary Production (mmol C m-2 d-1)

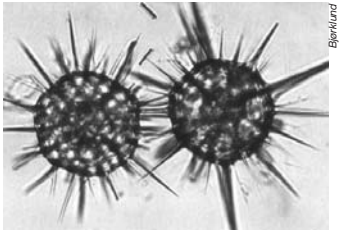

0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
ef Ratio
100
10
1
0.1
Net Photosynthesis (mg N m⁻³ d⁻¹)
30
25
20
15
10
5
0
Temperature (°C)


DON
(N_4)
Phytoplankton
(P)
Nitrate
(N_o)
Ammonium
(N_t)
Bacteria
(B)
Zooplankton
(Z)
Detritus
(D)


POTENTIAL SUPPLY RATE
EFFECTIVENESS
STRENGTH
A
low / high
low
SEMI-INFINITE RESERVOIR
low
POOL
SMALL OR LARGE DRAIN
B
high
high
high
LARGE DRAIN
C
low
low
high
SMALL DRAIN
D
low
low
high
NO DRAIN

PROTOZOA

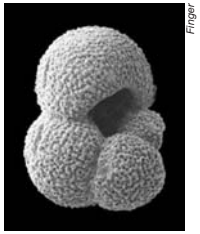
100 m



Drymyomma elegans

Hexastylus sp.

Radiolaria



Globigerina bulloides

Globorotalia menardii

Foraminifera

CHORDATA (URCHORDATA)

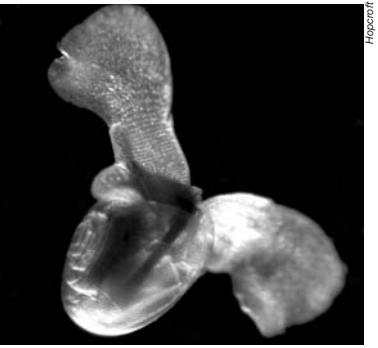
2000 m

Oikopleura labradoriensis

Larvacea

MOLLUSCA

1000 m



Limacina helicina Pteropoda

Gastropoda

ARTHROPODA

4000 m

Calanus hyperboreus Copepoda

10000 m

Euphausia superba Euphausiids

Crustacea