DENITRIFICATION & HABITAT BENEFITS OF THE EASTERN OYSTER (*CRASSOSTREA VIRGINICA*)

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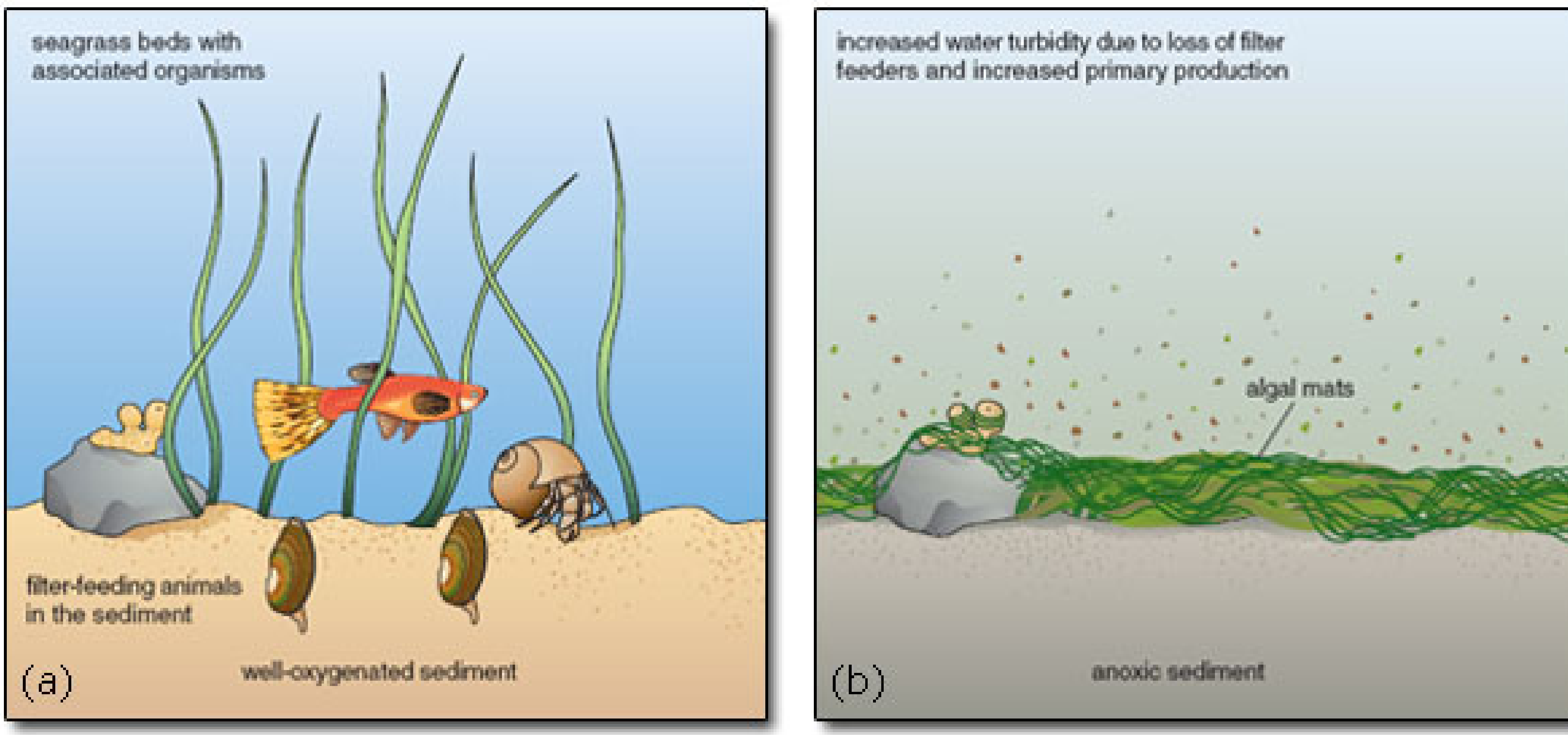
PROBLEM: N LOADING

NITROGEN LOADS TO RECEIVING COASTAL WATERS



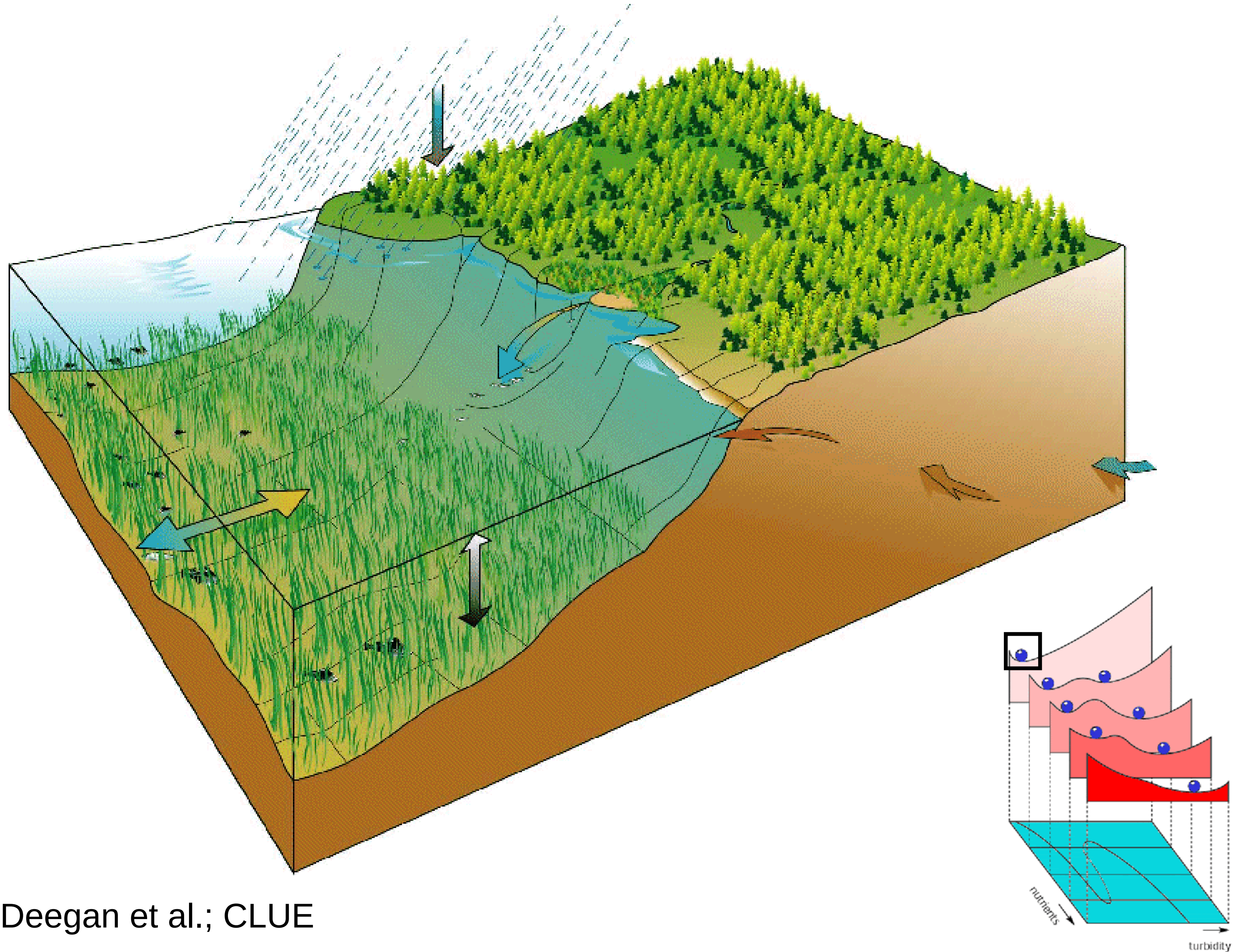
PROBLEM: N LOADING

NITROGEN LOADS TO RECEIVING COASTAL WATERS

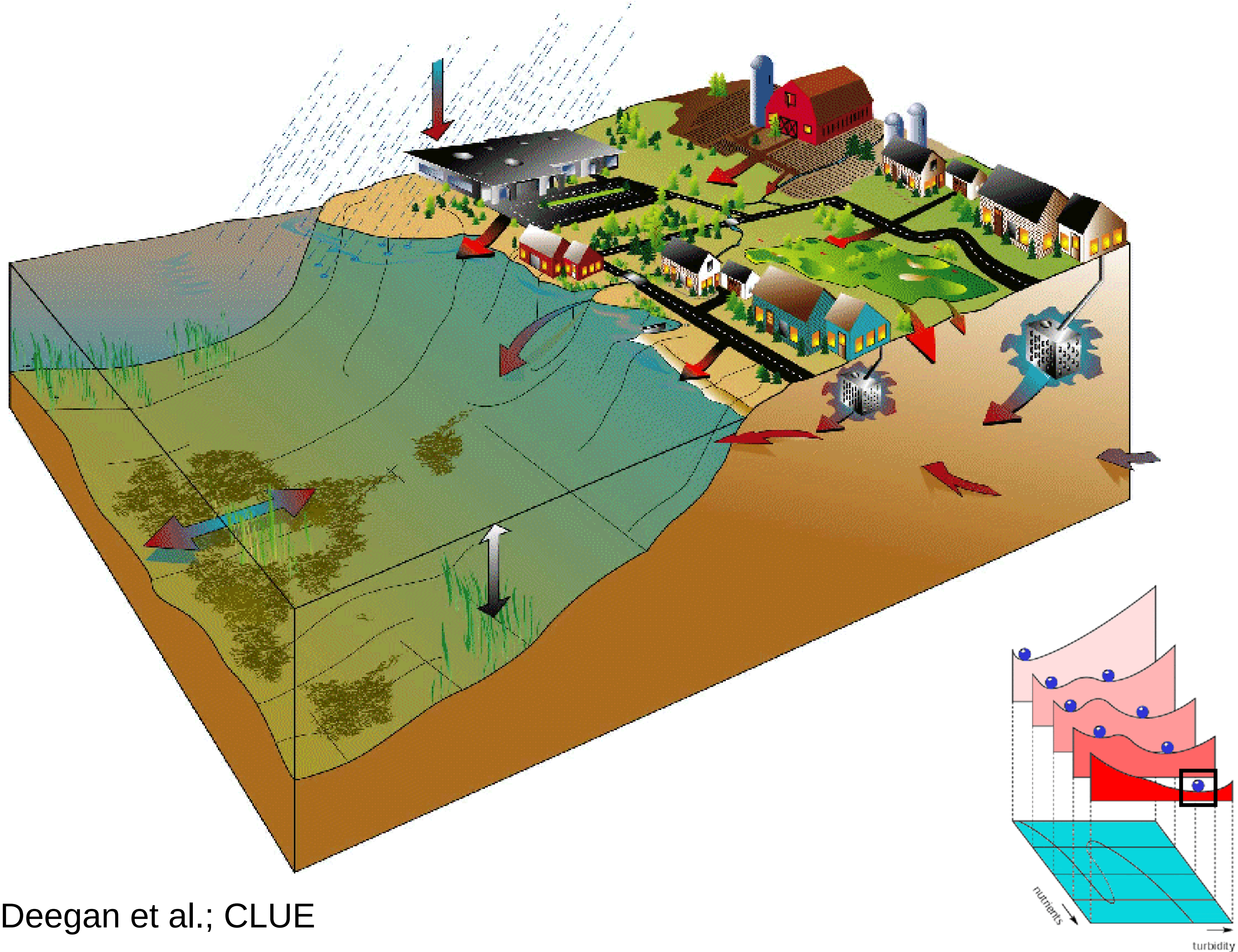
Increase in production rates of both phytoplankton and macroalgae;

Typically a corresponding decrease in [DO] in both the water column and benthos;

Can result in significant changes in ecosystem attributes and functions.

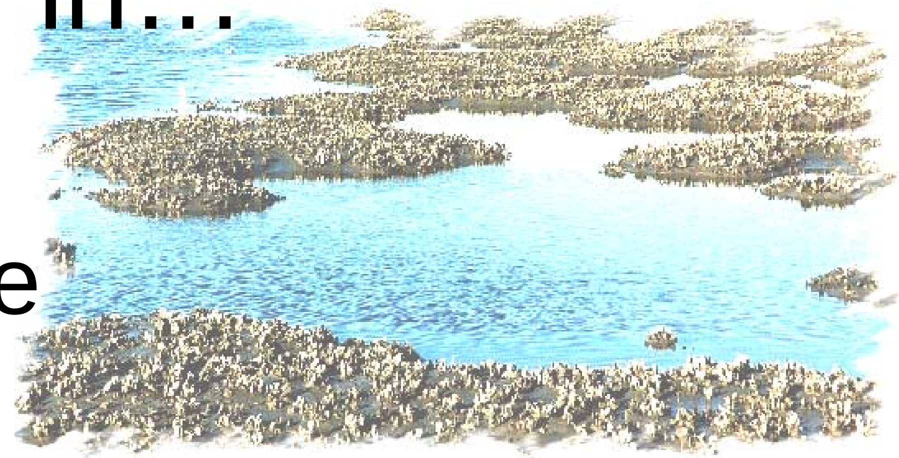


From Deegan et al.; CLUE



From Deegan et al.; CLUE

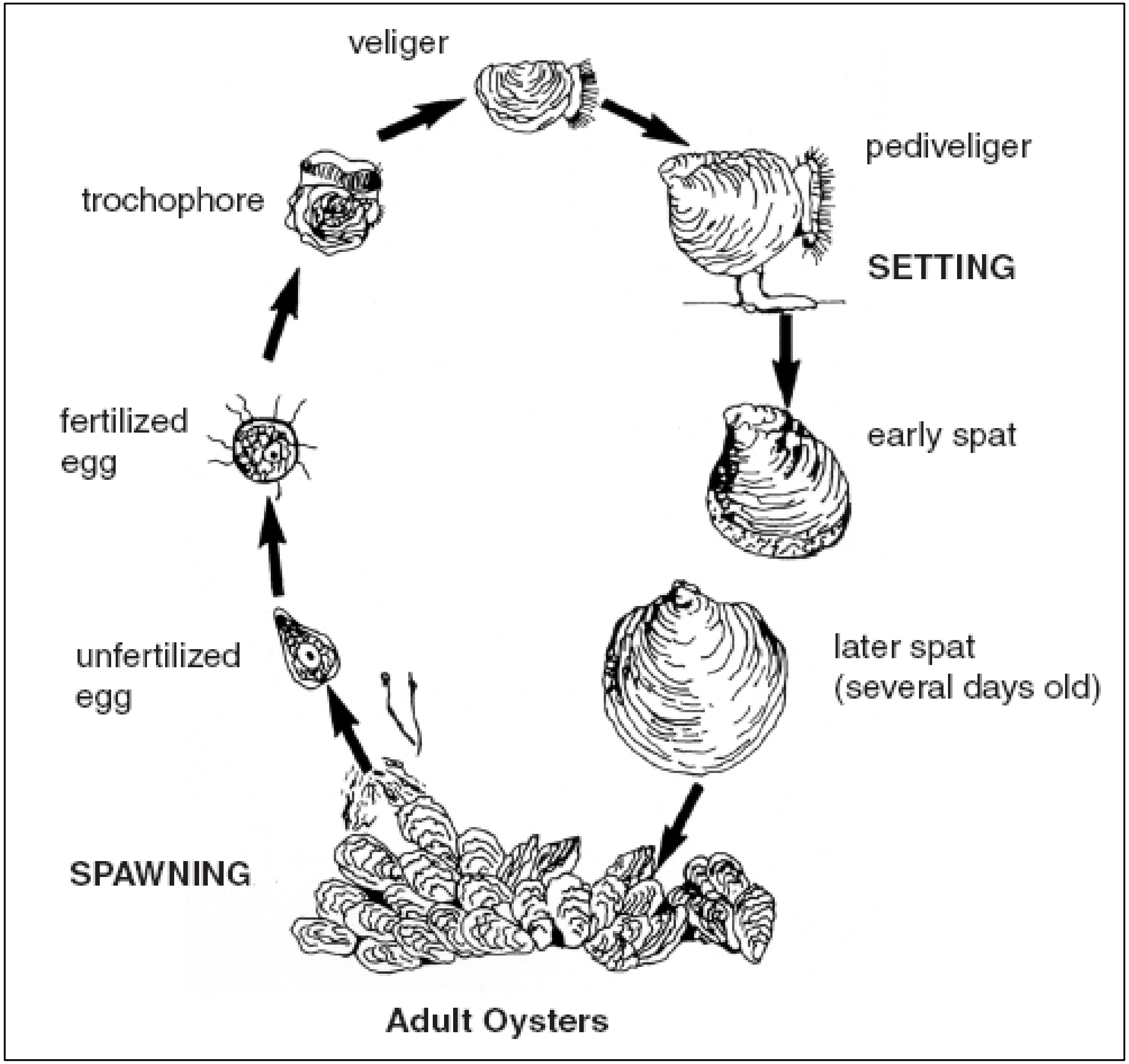
QUESTION: What role do bivalves (specifically oysters) have in…



- The nitrogen cycle
- Providing habitat benefits

….in shallow estuarine systems?

The life cycle of the eastern oyster (*Crassostrea virginica*)



Spawn at
Temp ~ 60 – 68 F.

Over 100 million eggs may be liberated from a single female.

Swims around for 12 to 24 days before "setting"

Individual oysters can change gender over time, …. more than once.

Habitats of the eastern oyster (*Crassostrea virginica*)

Habitat Requirements:

Minimum Dissolved Oxygen Level: 1 ppm *

Optimum Temperature Range:

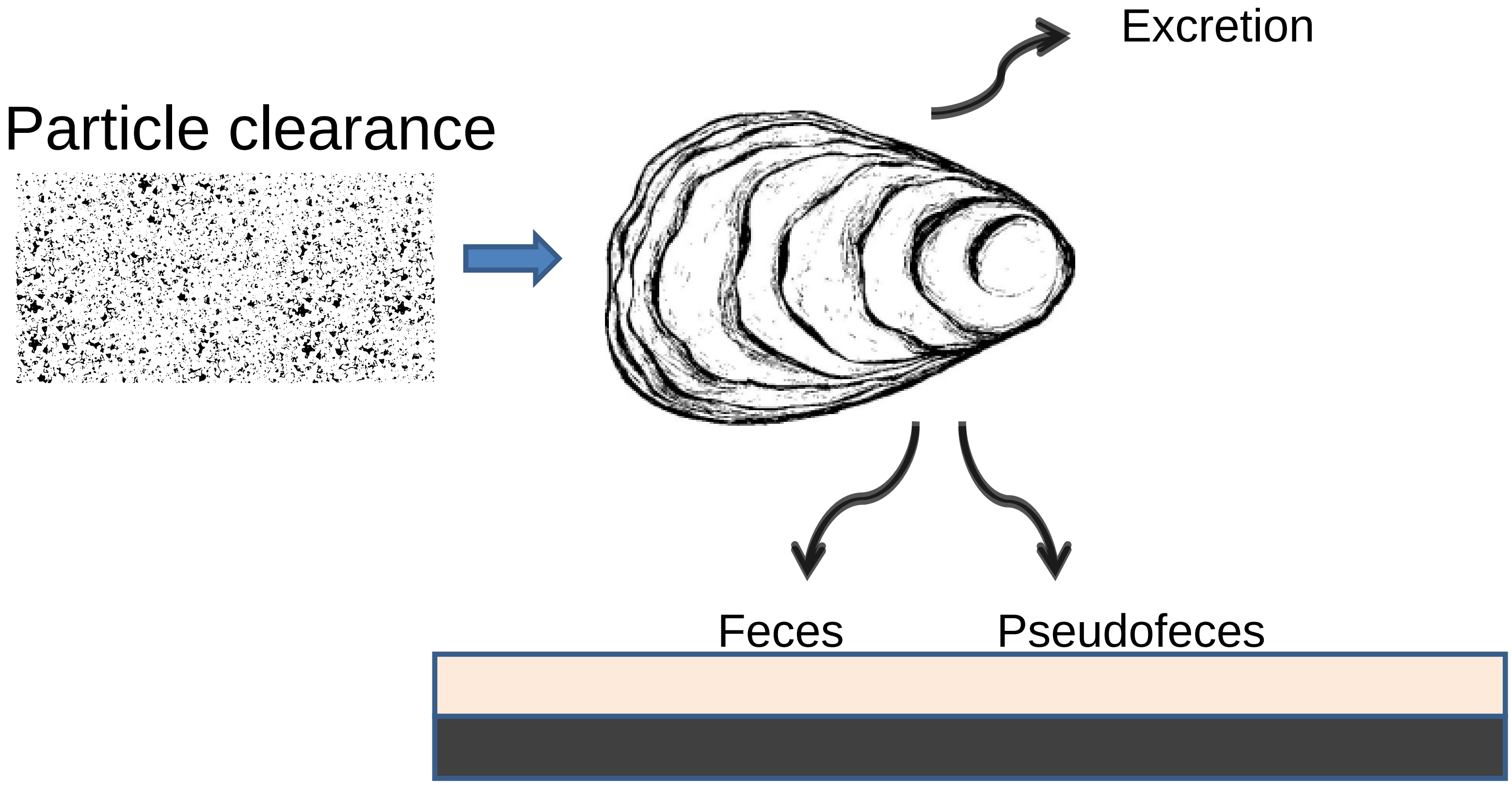
- Eggs: 19^{o}C - 31^{o}C
- Larvae: 19^{o}C - 31^{o}C
- Adults: 7^{o}C - 32^{o}C

Optimum pH Range: 6.75 - 8.75 (eggs, larvae)

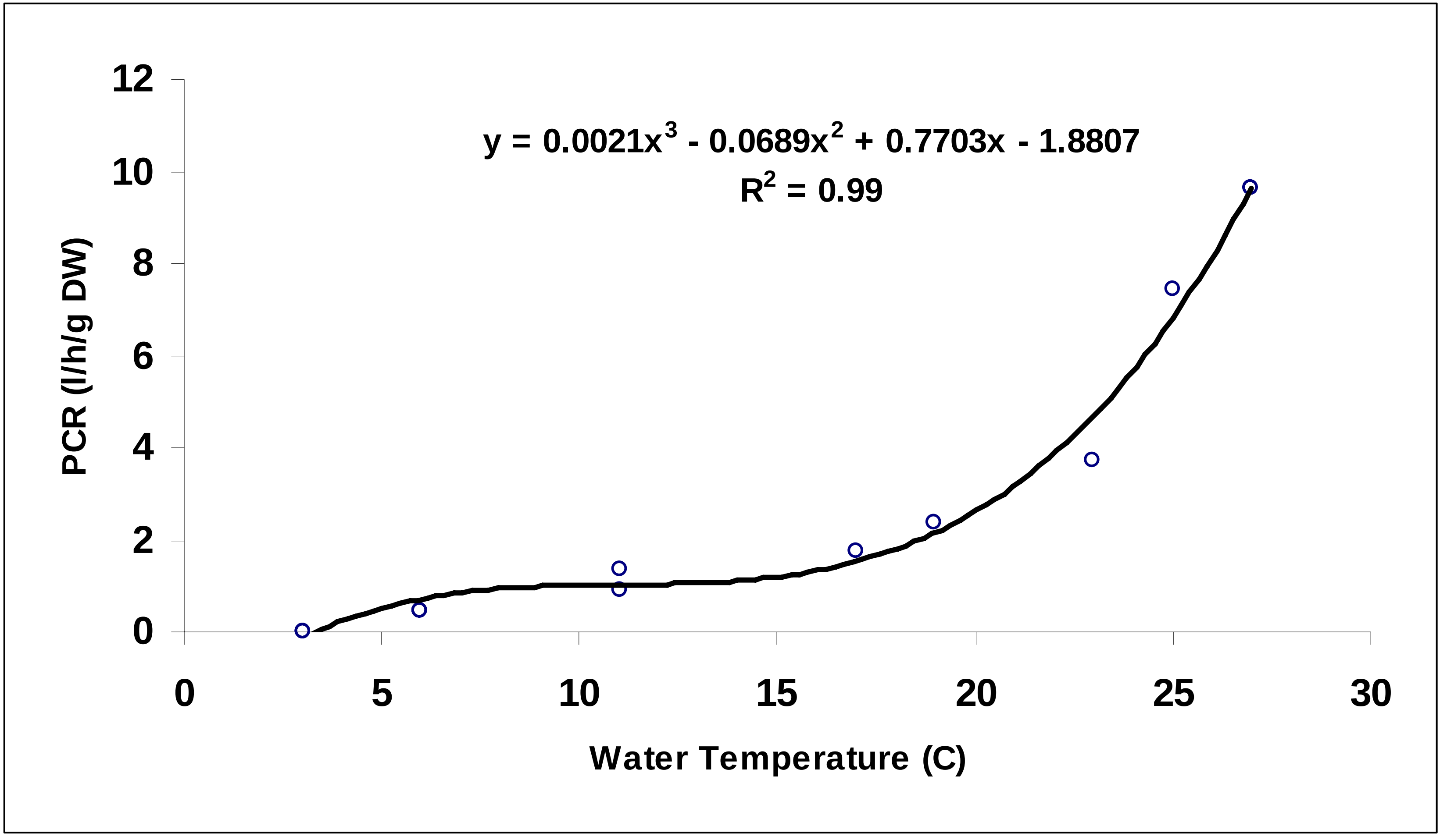
Optimum Salinity Range: 12 - 27 ppt

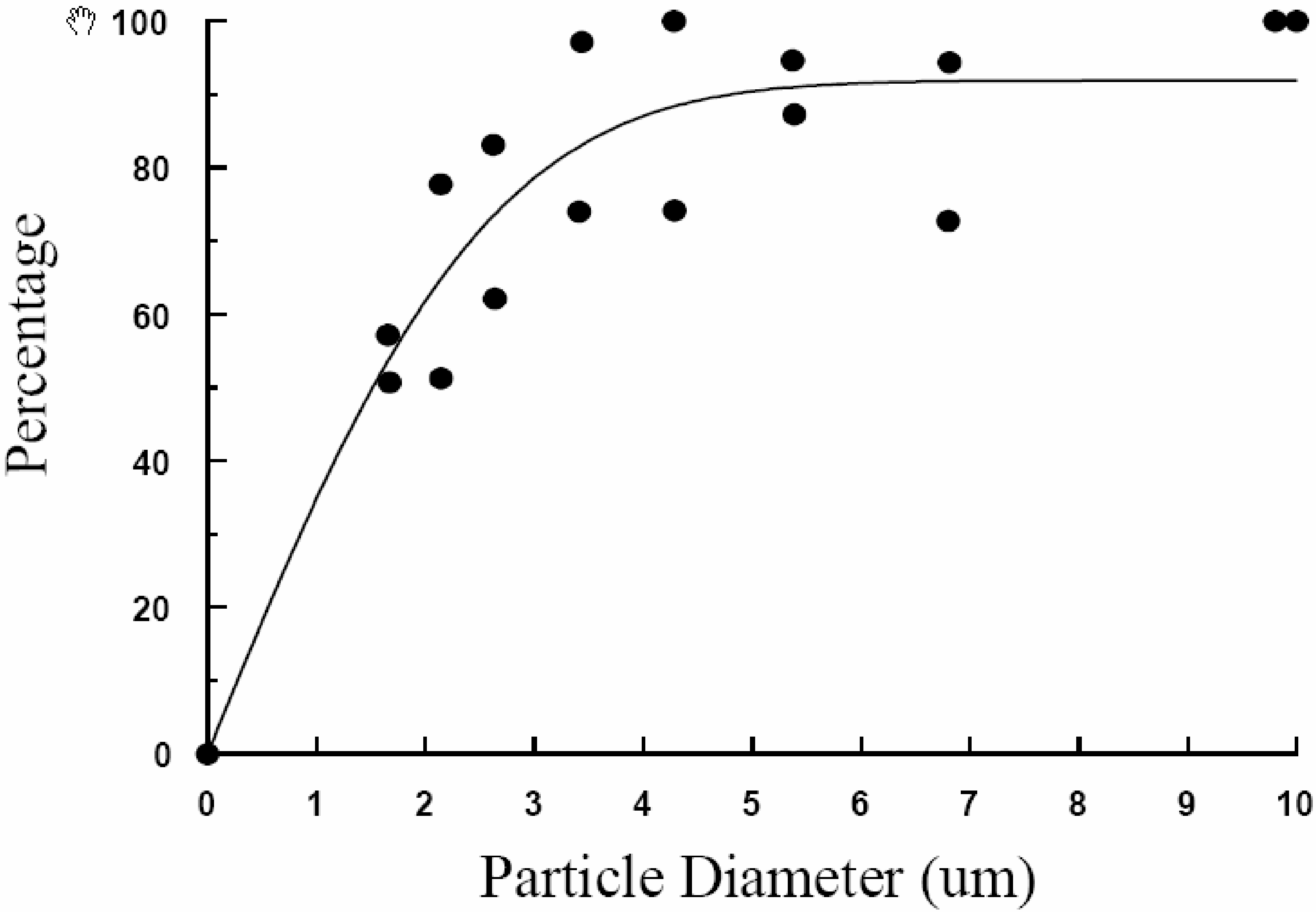

Eastern Oyster Feeding and Particle Removal

Newell (2005) : Emphasizes the importance of bivalve biodeposition in enhancing the process leading to nutrient burial and denitrification.



WATER FILTERING EFFICIENCIES





Percentage
100
80
60
40
20
0
0
1
2
3
4
5
6
7
8
9
10
Particle Diameter (um)

Eastern Oyster Feeding and Particle Removal

Particles are sorted

- Less-nutritious particles are rejected as <u>pseudofeces</u>
- Nutritious particles are ingested

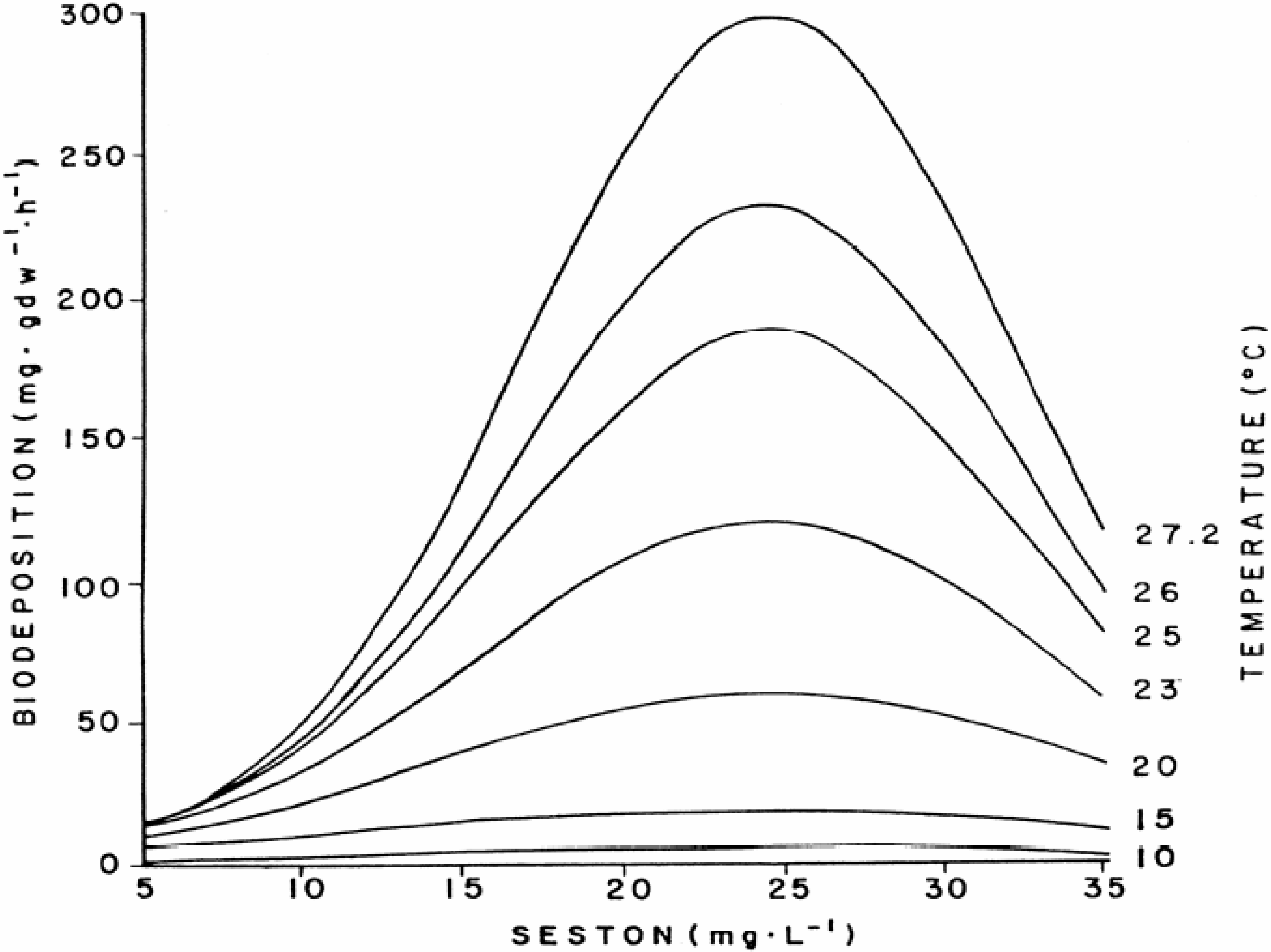
Even when "full" oysters continue to feed ("pump") and more POM composes pseudofeces

Jordan (1987) found biodeposits 2 – 3 X greater C, N, P than background particles.

Table 1. Comparison of mean (SE; n = 20 to 25) concentrations (mg g^{-1}) of carbon, nitrogen, and phosphorus in dry eastern oyster biodeposits and in natural seston that settled from the water. Biodeposits were collected by holding oysters in the Choptank River for 2 to 14 d in May, June, July, August, and November 1983 and in May, June, and July 1984. Seston material that settled from the water due to gravity was collected concurrently in an apparatus identical to that used to hold oysters and collect their biodeposits. Data from Jordan (1987).

	Biodeposits	**Seston Material**
Carbon (mg C g^{-1})	34.8 ± 3.15	14.6 ± 1.19
Nitrogen (mg N g^{-1})	4.8 ± 0.44	2.1 ± 1.19
Phosphorus (mg P g^{-1})	0.58 ± 0.09	0.32 ± 0.03
C:N:P ratio (molar)	154:18:1	117:14:1

Newell, RIE, TR Fisher, RR Holyoke and JC Cornwell, 2005. Pages 93 - 120. In: *The Comparative Roles of Suspension Feeders in Ecosystems. R. Dame and S.Olenin, eds. Vol. 47, NATO Science Series: IV - Earth and Environmental Sciences. Springer, Netherlands*

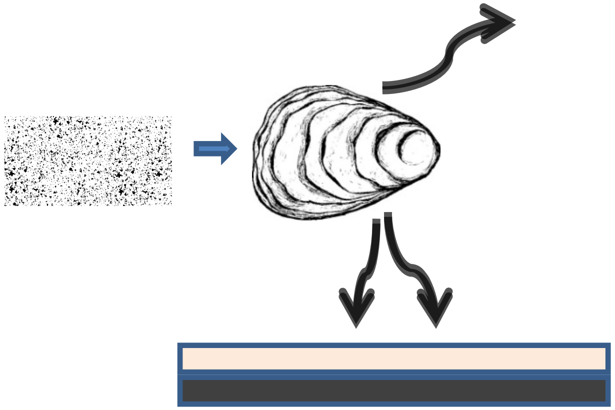

300
250
200
150
100
50
0
BIODEPOSITION (mg · gdw⁻¹ · h⁻¹)
5
10
15
20
25
30
35
SESTON (mg · L⁻¹)
27.2
26
25
23
20
15
10
TEMPERATURE (°C)

Eastern Oyster Digestion and Nitrogen Removal

Nitrogen is assimilated by autotrophs such as phytoplankton, macro and microalgae.

Rate of assimilation and growth (production) has to do with:

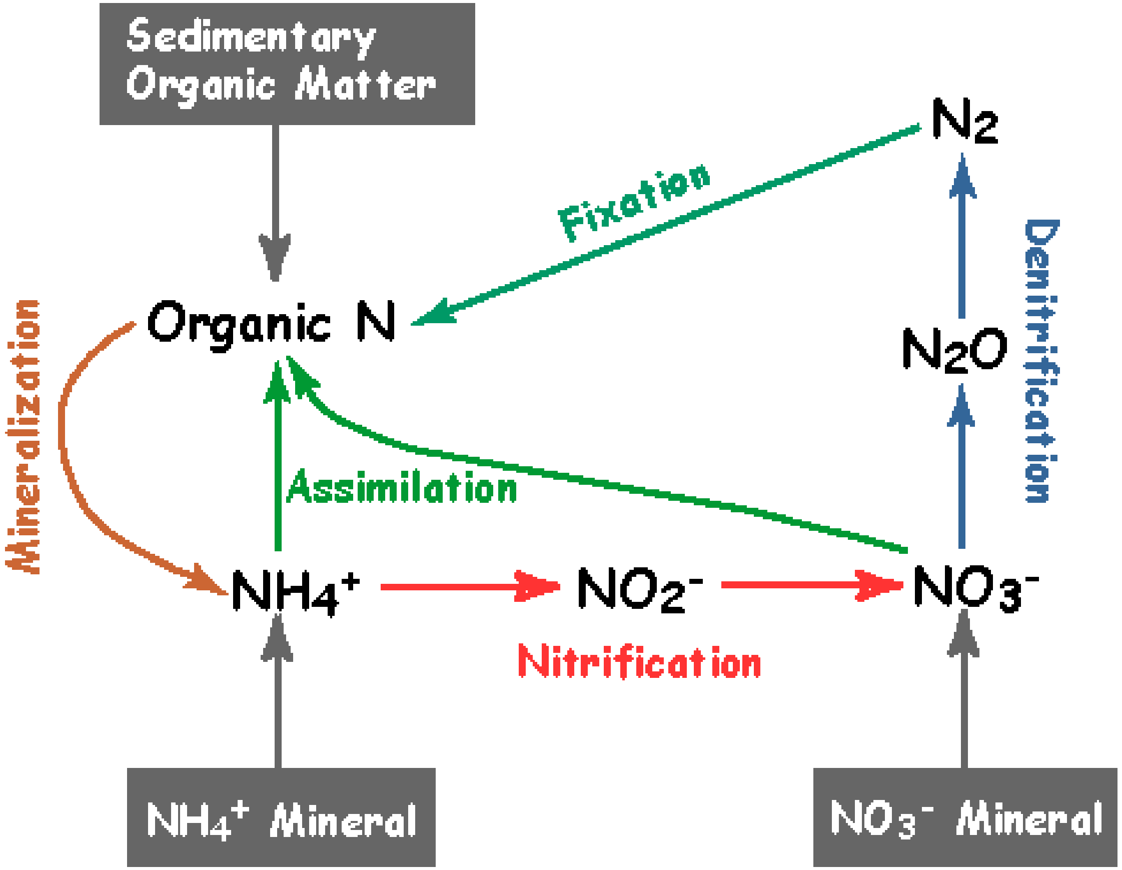
Temp, Light, [N], and T_r.



Assimilated N applied to tissue growth or excreted (~ 6 uM NH_4 g^{-1} DW h^{-1})

What is Denitrification?

Dentrification is the process biologically mediated process of metabolizing inorganic nitrogen (NO_3) resulting in the release of N_2.



Benthic – Pelagic Coupling

Removal of organic and inorganic matter from water column

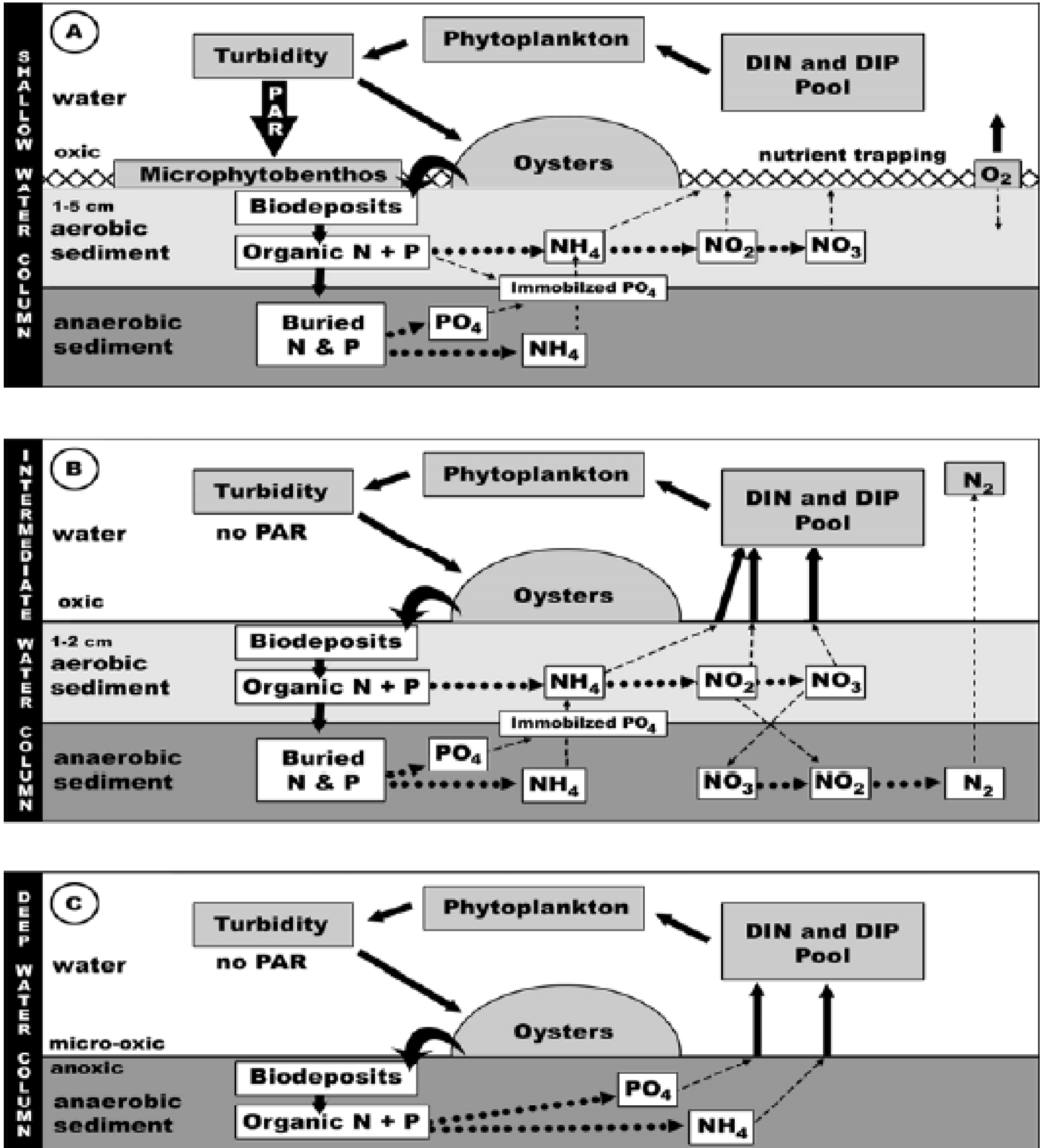
Delivering some portion as biodeposits to benthos

Subject to decomposition by aerobic bacteria

- Oxidation
- Recycled to water column
- Assimilated by benthic microalgae

Or…

NO_3 diffusion to anaerobic sediments where it is denitrified



SHALLOW WATER COLUMN
A
Turbidity
Phytoplankton
DIN and DIP Pool
water
PAR
oxic
Microphytobenthos
Oysters
nutrient trapping
O_2
1-5 cm
aerobic sediment
Biodeposits
Organic N + P
NH_4
NO_2
NO_3
Immobilzed PO_4
anaerobic sediment
Buried N & P
PO_4
NH_4
INTERMEDIATE WATER COLUMN
B
Turbidity
Phytoplankton
DIN and DIP Pool
N_2
water
no PAR
oxic
Oysters
1-2 cm
aerobic sediment
Biodeposits
Organic N + P
NH_4
NO_2
NO_3
Immobilzed PO_4
anaerobic sediment
Buried N & P
PO_4
NH_4
NO_3
NO_2
N_2
DEEP WATER COLUMN
C
Turbidity
Phytoplankton
DIN and DIP Pool
water
no PAR
micro-oxic
Oysters
anoxic
anaerobic sediment
Biodeposits
Organic N + P
PO_4
NH_4

Table 2. Monthly average water temperature (°C), seston concentrations (mg L^{-1}), and phytoplankton chlorophyll *a* (µg L^{-1}) in the Choptank River (EPA Chesapeake Bay Program monitoring station ET 5.2). Eastern oyster clearance rates (L $h^{-1}g^{-1}$ DW) calculated from Jordan (1987) were used to estimate the monthly amount of phytoplankton N filtered from the water column. We then estimated the monthly amounts of N and P biodeposition that were buried (mg $month^{-1}$ g^{-1} DW) and N denitrified (mg $month^{-1}$ g^{-1} DW). See text for complete details of these calculations.

	Water Temp °C	Seston (mg L^{-1})	Chl *a* (µg L^{-1})	Clearance Rate (L h^{-1} g^{-1} DW)	monthly nutrient removal g^{-1} DW		
					Mg N denitrified	**mg N buried**	**mg P buried**
Jan	3	11.4	5.5	0	0	0	0
Feb	3	14.3	8.7	0	0	0	0
Mar	6	13.2	8.9	0.45	4.08	2.04	2.21
Apr	11	16.7	9.6	0.90	8.69	4.35	4.71
May	17	14.5	12.2	1.72	21.20	10.60	11.50
Jun	23	10.7	12.3	3.74	46.35	23.17	25.13
Jul	27	13.0	15.4	9.62	149.26	74.63	80.92
Aug	27	13.0	16.0	9.62	155.08	77.54	84.08
Sept	25	13.4	11.9	7.46	89.52	44.76	48.53
Oct	19	12.8	7.3	2.34	17.25	8.62	9.35
Nov	11	9.4	6.0	1.38	8.36	4.18	4.53
Dec	6	11.4	5.7	0.44	2.52	1.26	1.37
Annual Total					502.31	251.15	272.34

Table 3. Total monthly N and P (kg) inputs into the Choptank watershed and airshed estimated by Lee et al. (2001). Values presented are averages for 1980 to 1996. The total amounts (kg month^{-1}) and % of the monthly N and P inputs that are buried and denitrified associated with biodeposition from oysters at a density of 1 g DW m^{-2} on 1,736 ha of restorable oyster bottom in the Choptank River were calculated as described in the text.

	Total-N inputs (kg)	Total-P inputs (kg)	Monthly nutrient removal for oysters at a density of 1 g DW m^{-2} on 1,736 ha oyster bottom			
			N (kg)	P (kg)	% N inputs	% P inputs
Jan	281,450	5,245	0	0	0.0	0.0
Feb	261,970	4,837	0	0	0.0	0.0
Mar	312,350	5,351	106	38	0.0	0.7
Apr	292,500	5,338	226	82	0.1	1.5
May	243,930	6,022	552	200	0.2	3.3
Jun	148,250	4,641	1,207	436	0.8	9.4
Jul	75,480	4,059	3,887	1,405	5.1	34.6
Aug	80,810	4,274	4,038	1,460	5.0	34.2
Sep	99,140	4,587	2,331	843	2.4	18.4
Oct	97,940	4,015	449	162	0.5	4.0
Nov	114,500	4,344	218	79	0.2	1.8
Dec	254,270	6,373	66	24	0.0	0.4
Total	2,262,580	59,085	13,080	4,728	0.6	8.0

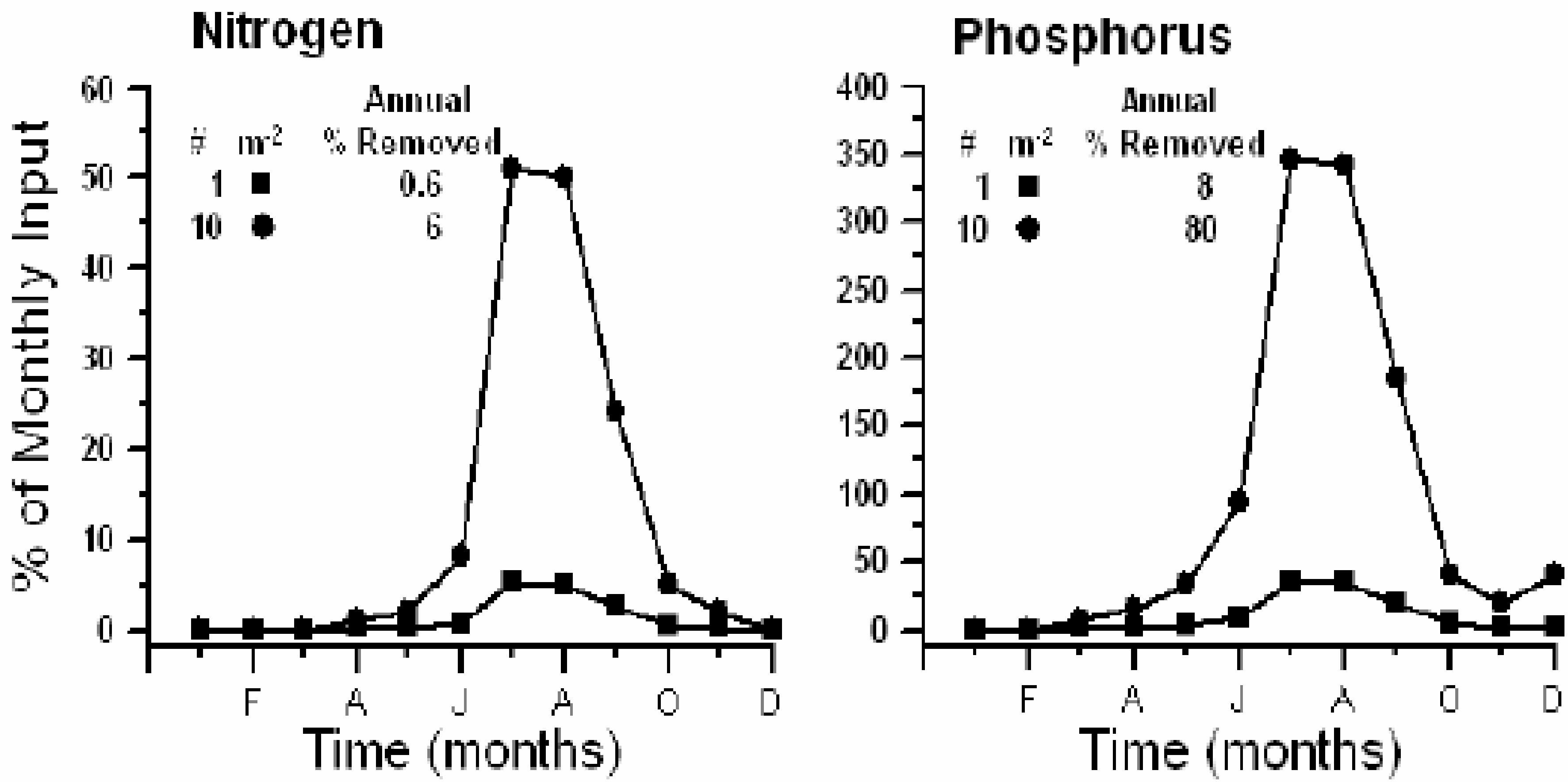


Fig. 4. The monthly amounts of N and P denitrified and buried (Table 3), expressed as % of monthly inputs into the Choptank River MD., associated with eastern oysters at a density of 1(■) and 10 (●) g DW m^{-2} on 1,736 ha of oyster bottom in the Choptank River. The % removal of total annual N and P inputs for oysters at densities of 1 and 10 m^{-2} are tabulated.

Habitat benefits associated with the eastern oyster (*Crassostrea virginica*)

Particle clearance

Improved light penetration

Enhances benthic production → Enhance DO conditions

Nutrient removal

Increase in benthic-pelagic coupling

Long-term DO improvements

Structure

Increased surface area for benthic, demersal, and pelagic habitat

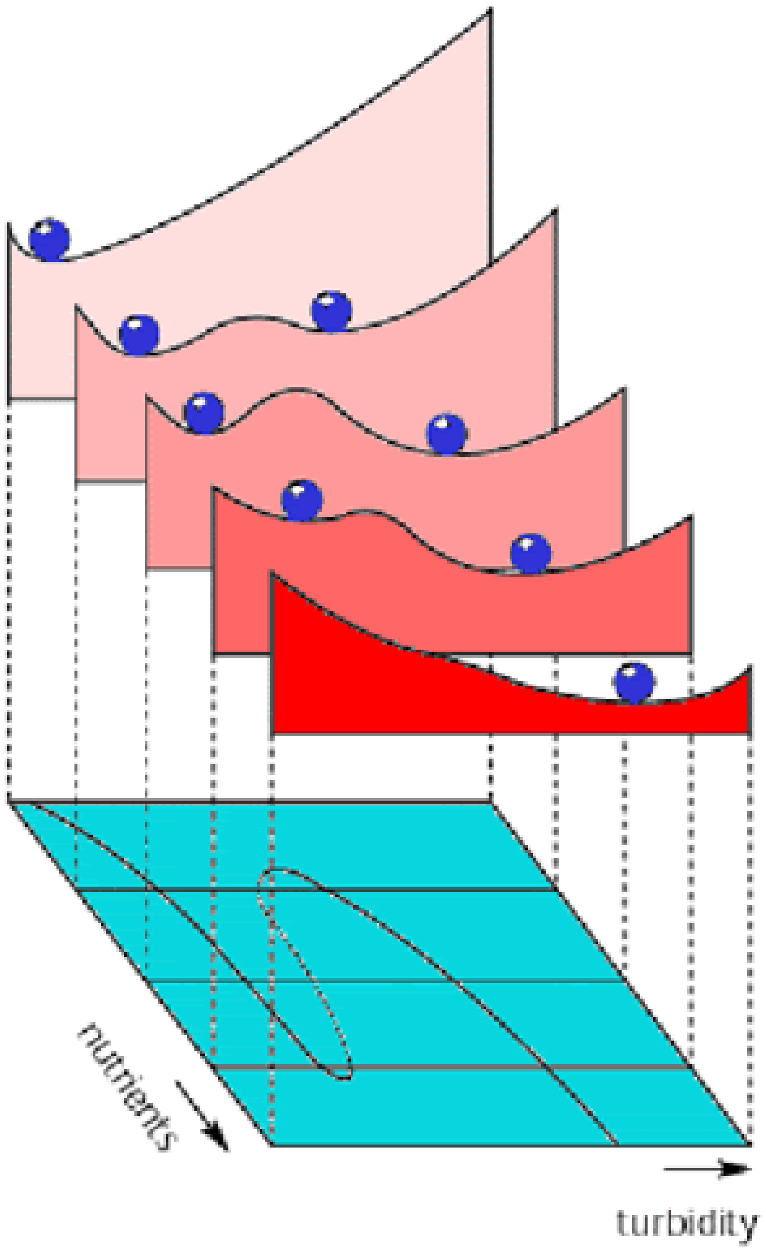
Habitat used by juvenile fish, crustaceans, and other important estuarine life

What is an alternative stable state (ASS)?

In an identical environment, a system can be in more than one contrasting stable state.

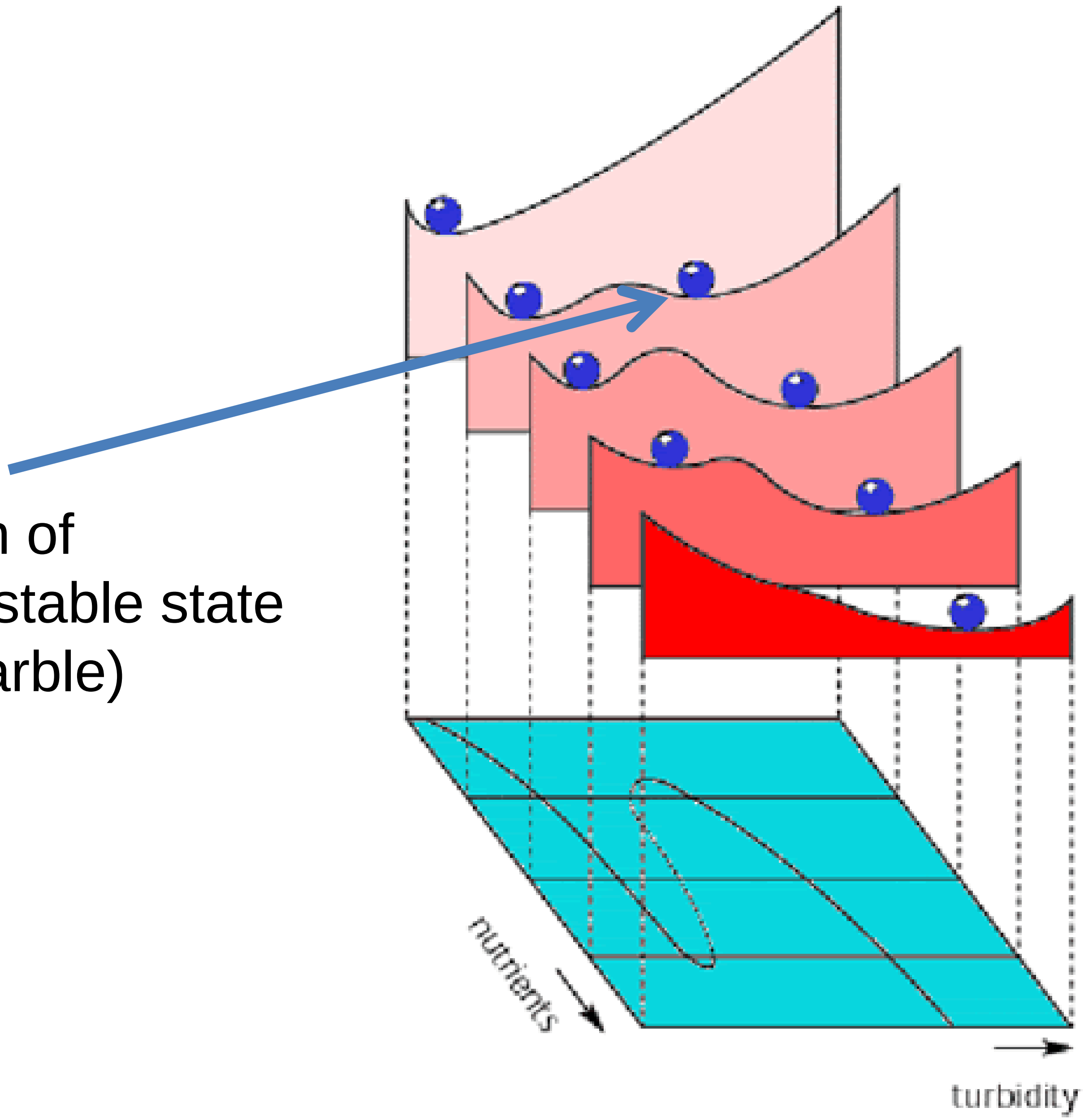
Nutrients

Turbidity



Nutrients

Turbidity

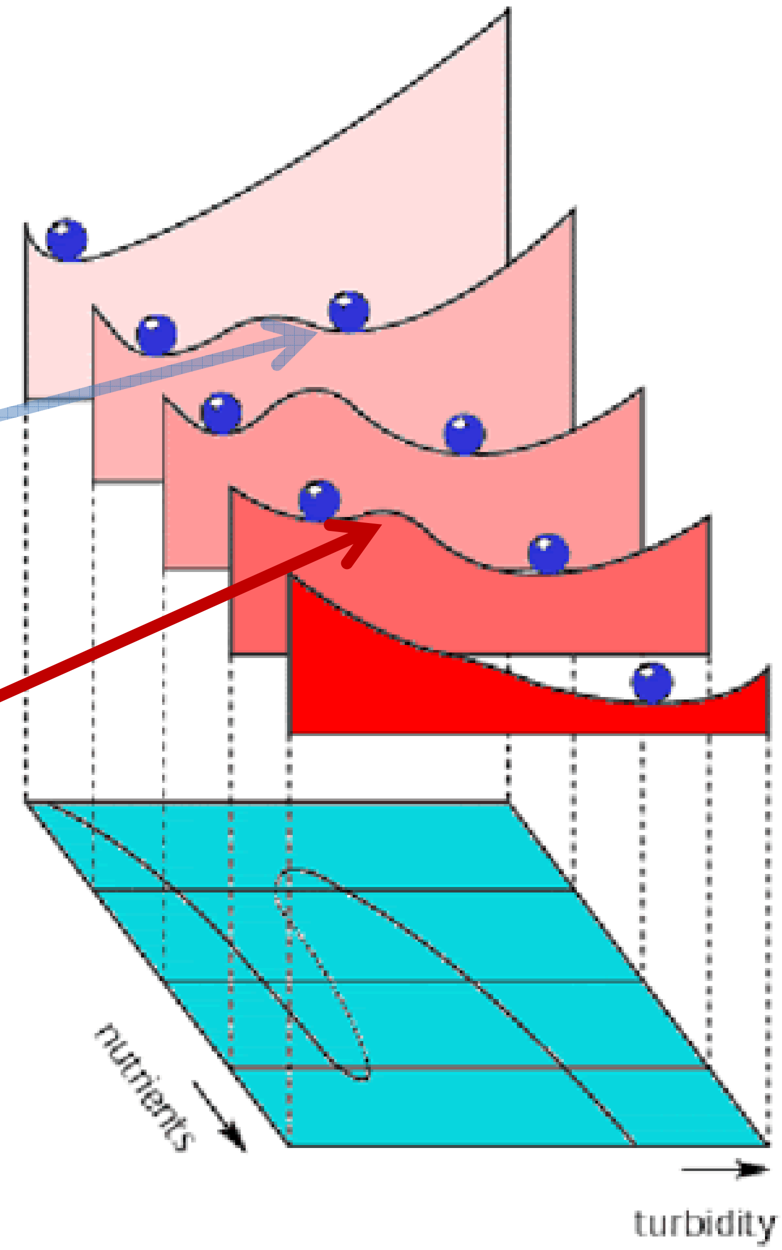


Introduction of
alternative stable state
(second marble)

Nutrients

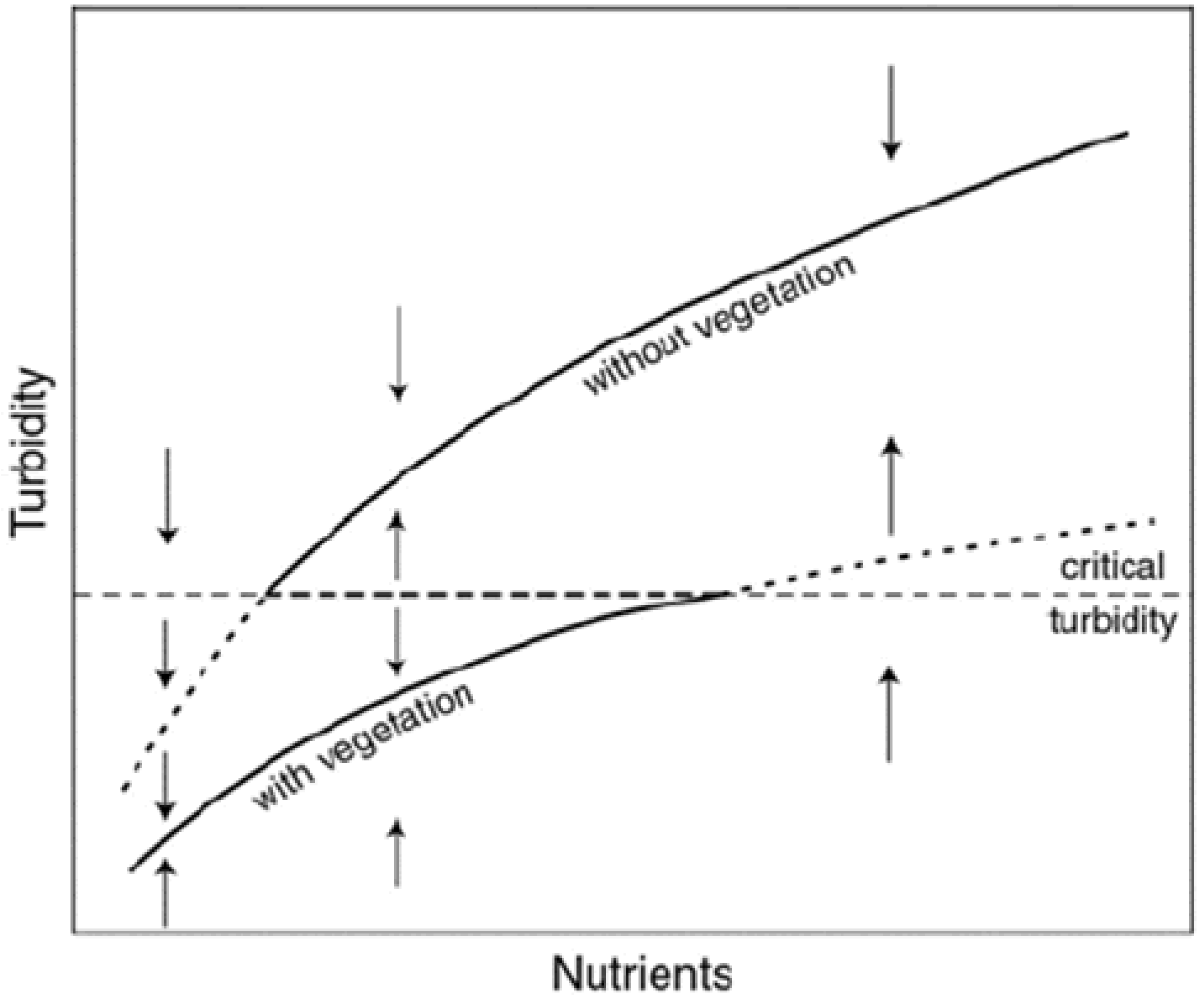
Turbidity

Introduction of
alternative stable state
(second marble)



Resilience can be
illustrated by the
contour (flatness) of the
red areas.

Reverse Transition



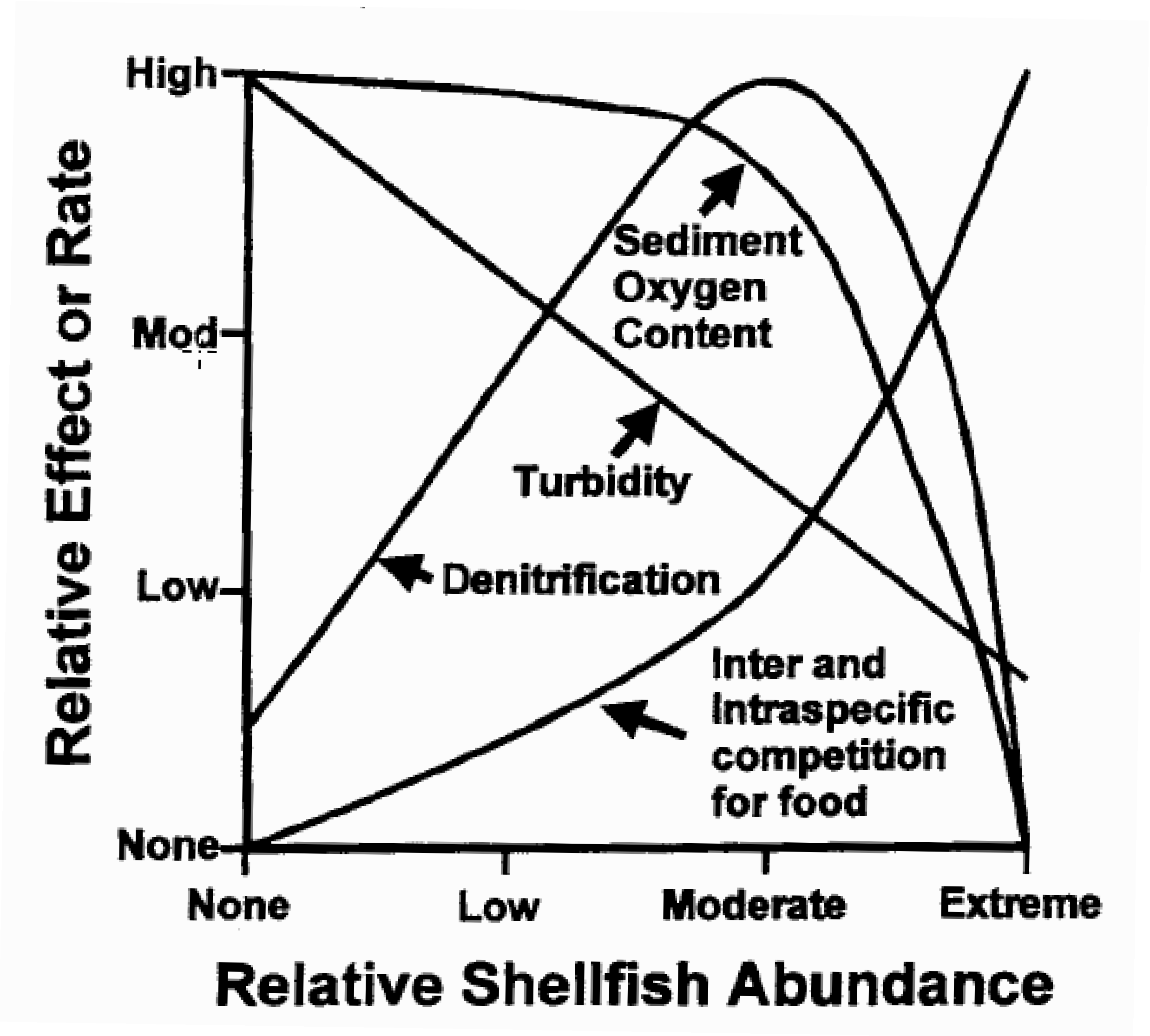
Same external environment but different environmental parameter “response”

The result: a discontinuous response curve.

The arrows indicate the direction of change when the system is not in one of the two alternative stable states.

Scheffer, M. 2001. "Alternative attractors of shallow lakes." *The Scientific World.* Volume 1. Pages 254 to 263.

Questions/Considerations



Questions/Considerations

Water quality and sediment quality: sufficient for growth & survival?

Site locations prioritized for maximum effect (local or widespread?)

Threat of disease (dermo, MSX, JOD)

Threat of predators (crabs, birds, oyster drills, etc.)

Cost and time.

END