Ecosystem-Level Processes

- Primary Productivity (& nutrients)
- Secondary Productivity
- Decomposition
- Production:Respiration
- Production:Biomass
- Food Web Complexity (energy transfer)
- Nutrient Cycling
- Biodiversity
- Resistance/Resilience to disturbance

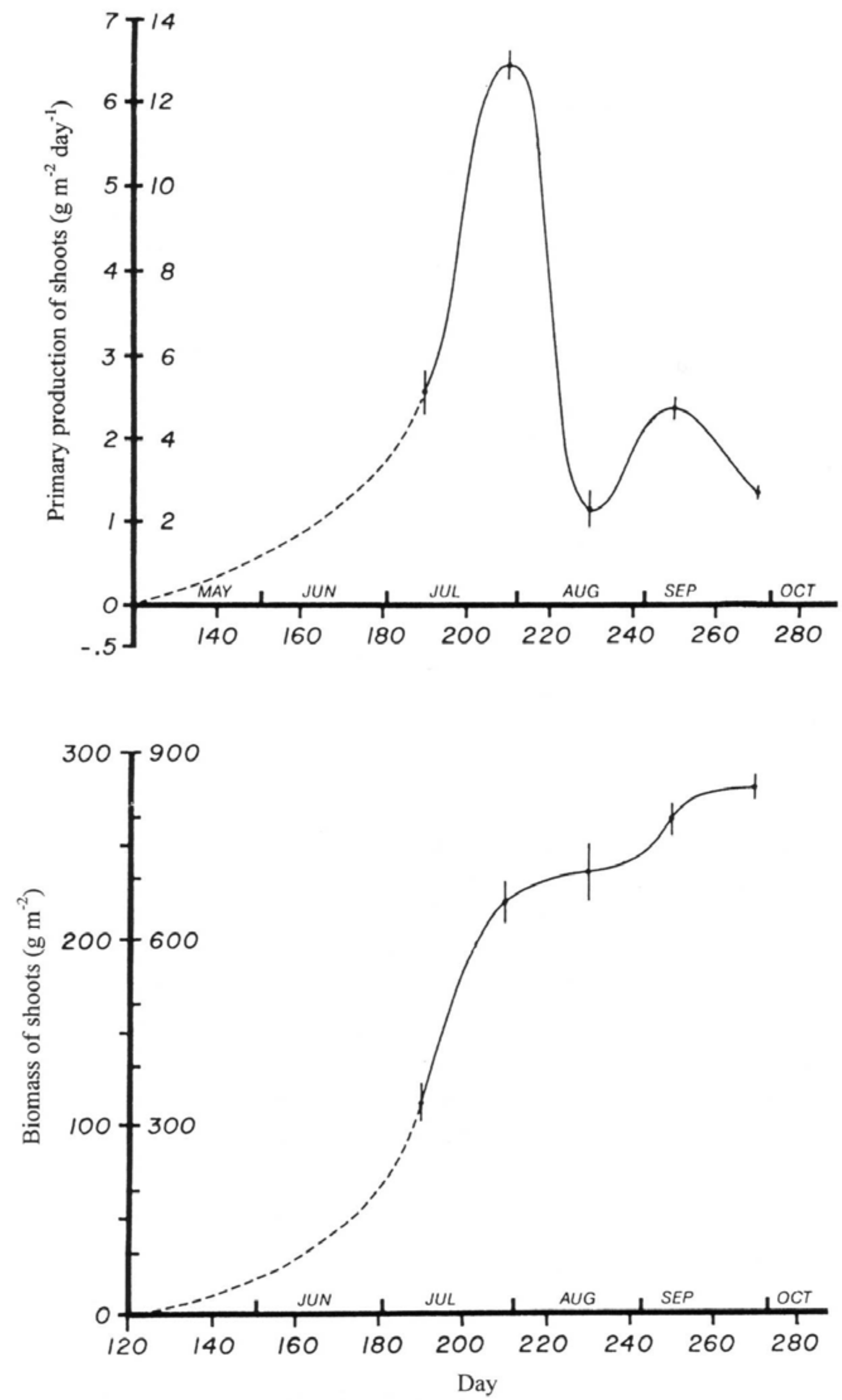
Primary Production

What is it?

How does Net Primary Production differ from primary production?

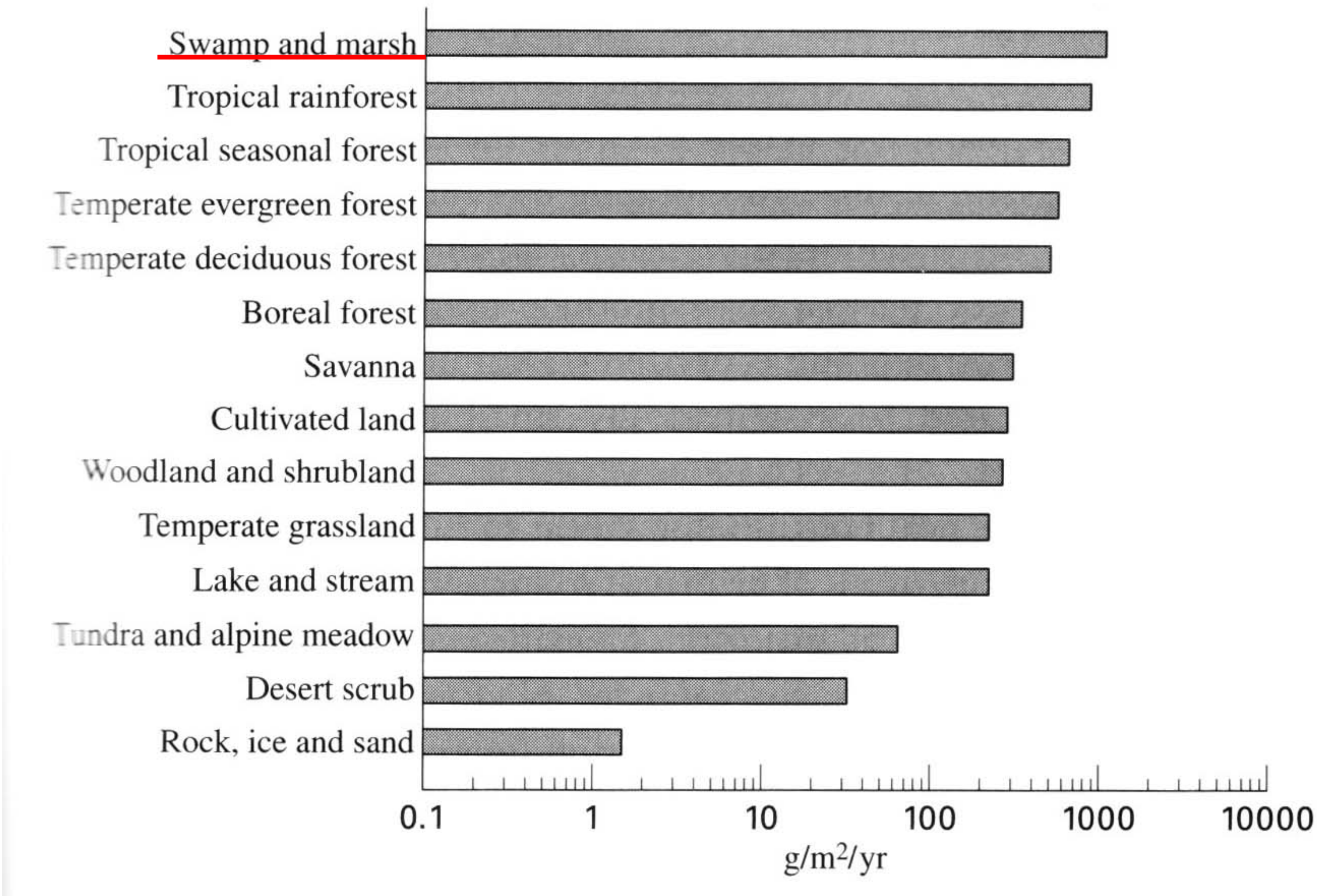
How (and when) is it measured?

Whole system, water column, or plant production?



Auclair 1976

Primary Production



Whittaker & Likens 1973

Hydrology and Primary Productivity

Cypress swamp flow exposure	NPP ($g/m^2/yr$)
Stagnant (cypress domes in Florida)	192
Cypress domes in a riverine system (Florida)	600
Very slowly flowing water (Okefenokee Swamp, Georgia)	692
Riverine edge strand (Big Cypress Swamp, Florida)	1170
Semiriverine with seasonal flooding (des Allemands Swamp, Louisiana)	1140

From Conner & Day, 1976; Gosselink & Turner, 1978

Primary Production

M&G 2000

Wetland type	**NPP (g/m²/yr)**
Northern bog	560
Inland fresh marsh	1980
Tidal fresh marsh	1370
Salt marsh	1950
Riparian forest	1040
Mangal	1500

Correlation matrix of major nutrients in soils from many wetlands in NE North America

	% organic	**P**	**N**	**K**	**Mg**
Stand crop	0.77	0.76	0.66	0.58	0.67
% organic	1	0.77	0.57	0.5	0.51
P		1	0.72	0.56	0.66
N			1	0.53	0.63
K					0.70
Mg					1

Gaudet 1993

Fertility gradients

- Low end of gradient:
  - Ombrotrophic bogs
- Upper end of gradient
  - Floodplain and deltaic swamps
- Spatial heterogeneity attributed to local features
  - Sandy vs silty clay, vs clay soils
  - Coarse vs fine sediments

Limiting Nutrients

N, P, K, C, micronutrients

Plants: N:P < 14 may mean N limitation
N:P > 16 may indicate P limitation
N:P 14-16 may indicate co-limitation

Verhoeven et al. 1996

"Typical" experimental design:

Treatment	**Tests for**
Nothing added	Control
N addition	N limitation
P addition	P limitation
N+P addition	Co-limitation

(K is sometimes also tested)

Controls on fertility and production

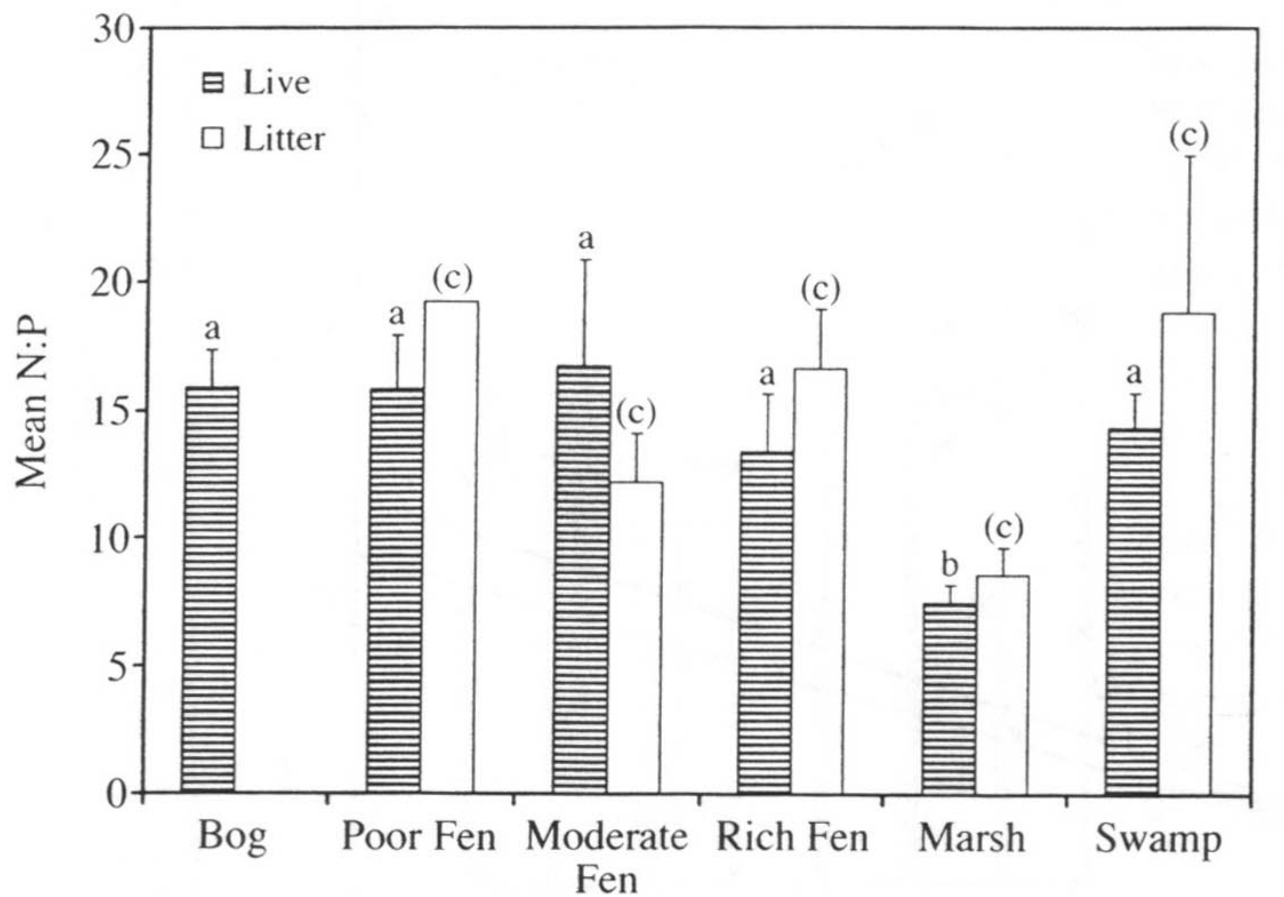
N, P, and N:P of wetland surface soils

Site	Mean N	Mean P	Mean N:P	Observ-ations (n)
Bogs	1.16[b]	0.05[b]	24.1[a]	26
Poor fens	1.35[b]	0.07[b]	24.1[a]	14
Mod-rich fens	1.88[a]	0.08[ab]	26.8[a]	15
Rich fens	1.98[a]	0.09[ab]	23.0[a]	23
Marshes	1.41[b]	0.25[a]	8.7[b]	5
Swamps	1.28[b]	0.09[a]	14.6[ab]	26
Organic soils	1.59[c]	0.08[d]	22.7[c]	98
Mineral soils	0.62[d]	0.13[d]	8.8[d]	11

Bedford et al. 1999

Limiting Nutrients

N:P ratios from plants & plant litter among wetland types



N:P < 14 may mean N limitation
N:P > 16 may indicate P limitation
N:P 14-16 may indicate co-limitation

Bedford et al. 1999

Limiting Nutrients

Number of sites limited by each nutrient or combination of nutrients
(determined by biomass measurements in fertilization experiments)

Habitat	**N**	**P**	**K**	**N + P**	**N + K**	**P + K**
Wet grassland	3	0	2	0	4	0
Wet heath	0	3	0	0	0	0
Rich fen (pH>5.5)	7	5	0	0	0	0
Poor fen (pH 4-5.5)	2	1	0	0	0	0
Litter fen	1	2	0	1	0	0
Bog (pH<4)	1	3	1	0	0	0
Interdunal	5	2	0	2	0	0
Total (45 sites)	**19**	**16**	**3**	**3**	**4**	**0**

Verhoeven et al. 1996

Forested Wetland Characteristics Vary with Flood Characteristics

Table 3. Structural features and indices for the study sites.

Site	Density, trees/ha	Mean DBH, cm (all trees)	Basal area, m^2/ha	Mean height, m	Species, #/0.1 ha	Holdridge complexity index	Mean age, yrs	Total biomass, kg/m^2
Seasonally flooded								
H1	990	17.5	42.0	13.3	16	88.5	50.3	30.3
C1	370	19.9	17.7	15.8	12	12.6	36.4	18.4
Slowly flowing								
H2	800	25.9	32.7	15.0	7	27.7	69.8	31.2
H3	300	29.5	21.9	9.5	1	0.6	60.2	10.2
Stagnant								
C2	350	35.0	35.9	10.5	2	2.7	66.3	9.4

From: Mitsch, Taylor & Benson. 1991. Estimating primary productivity of forested wetland communities in different hydrologic landscapes. Landscape Ecology 5(2):75-92.

Litterfall

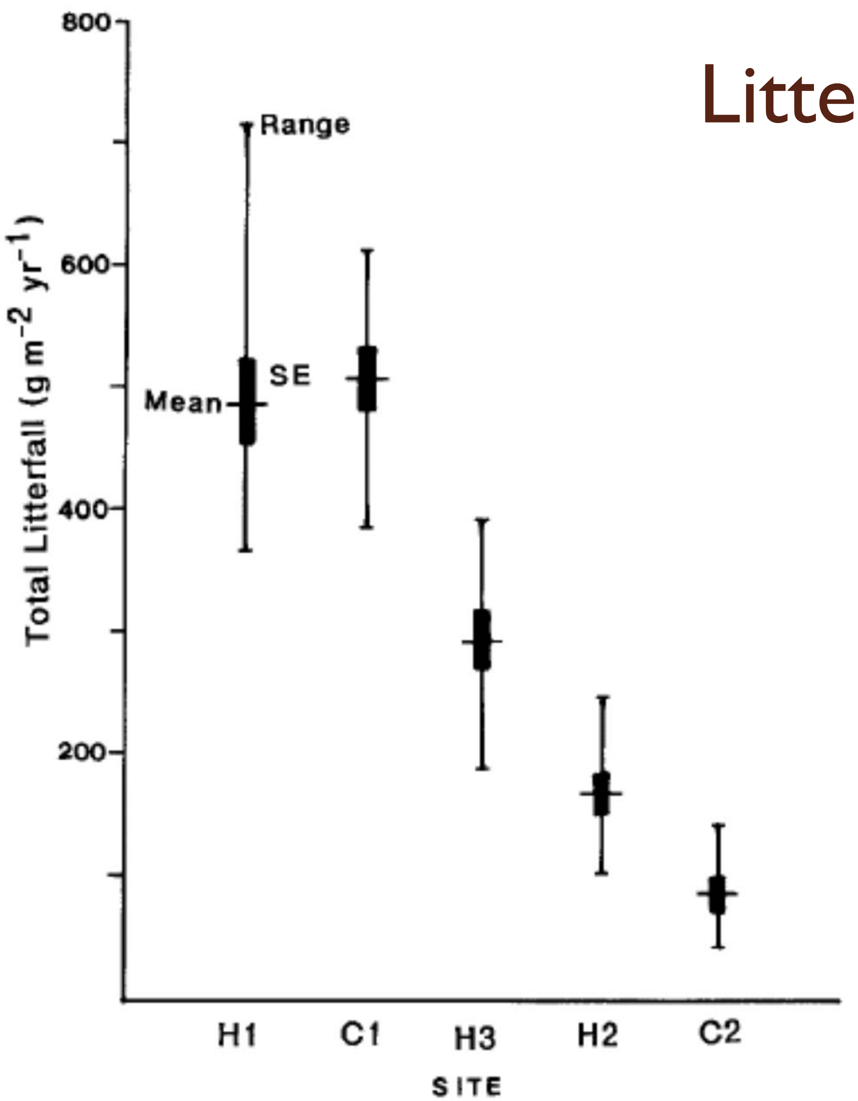


Fig. 4. Mean, standard error, and range of total annual litterfall measurements in western Kentucky wetlands by site.

Seasonal flooded

H1 Green ash
Silver maple
Hackberry
All species

C1 Black willow
Red maple
Sycamore
River birch
All species

Slowly flowing

H2 Bald cypress
Green ash
All species

H3 Bald cypress

Stagnant

C2 Bald cypress

From: Mitsch, Taylor, & Benson 1991. Estimating primary productivity of forested wetland communities in different hydrologic landscapes. Landscape Ecology 5(2):75-92.

Productivity in forested wetlands

Table 5. Net annual tree biomass productivity of forested wetlands study sites.

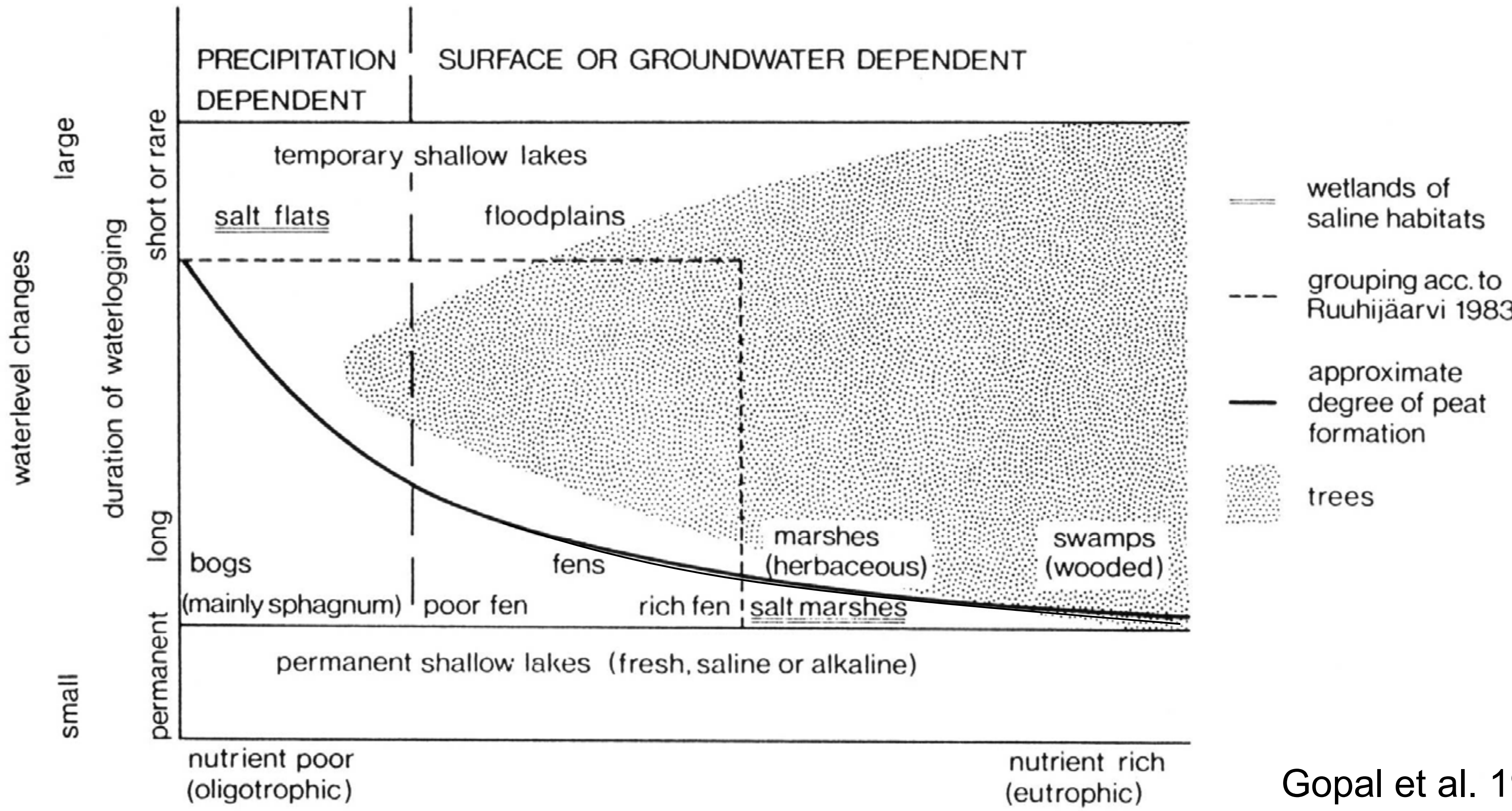
Site	Stem production, g m^{-2} yr^{-1}	Leaf litter and fruit fall, g m^{-2} y^{-1}	Est. net productivity, g m^{-2} yr^{-1}
Seasonally flooded			
H1	914	420	1334
C1	812	468	1280
Slowly flowing			
H2	498	136	634
H3	271	253	524
Stagnant			
C2	142	63	205

From: Mitsch, Taylor, & Benson 1991. Estimating primary productivity of forested wetland communities in different hydrologic landscapes. Landscape Ecology 5(2):75-92.

Productivity Summary & Conclusions

Peatlands: pH-alkalinity and nutrient gradients, including N vs. P limitation shifts

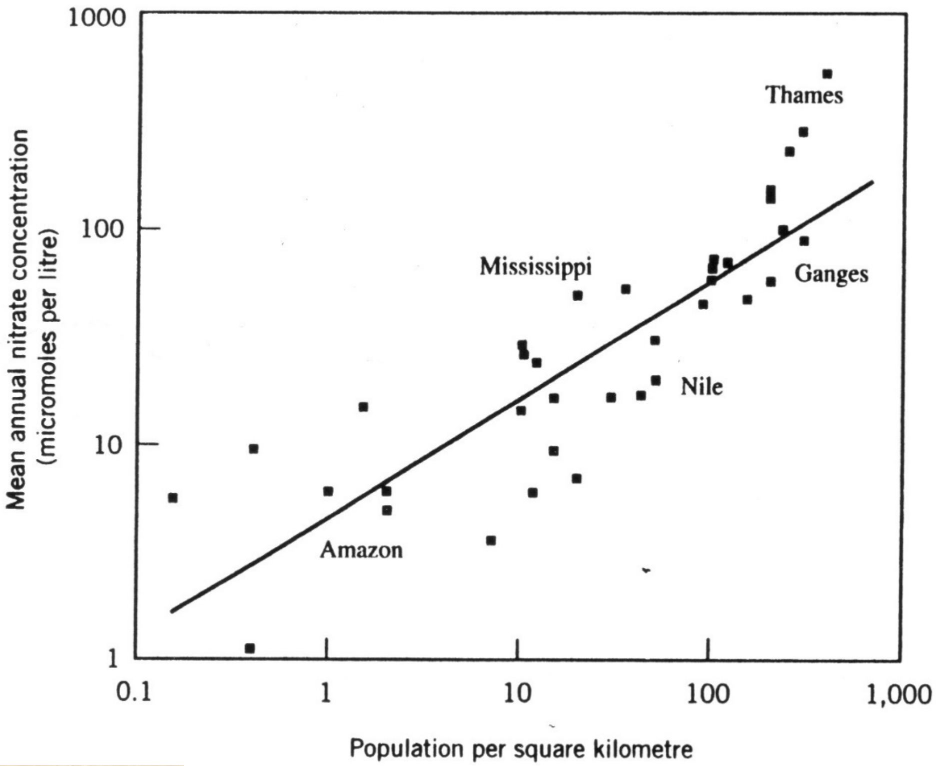
N limitation: primarily for marshes
P limitation: predominates in swamps, fens, and bogs



Gopal et al. 1990

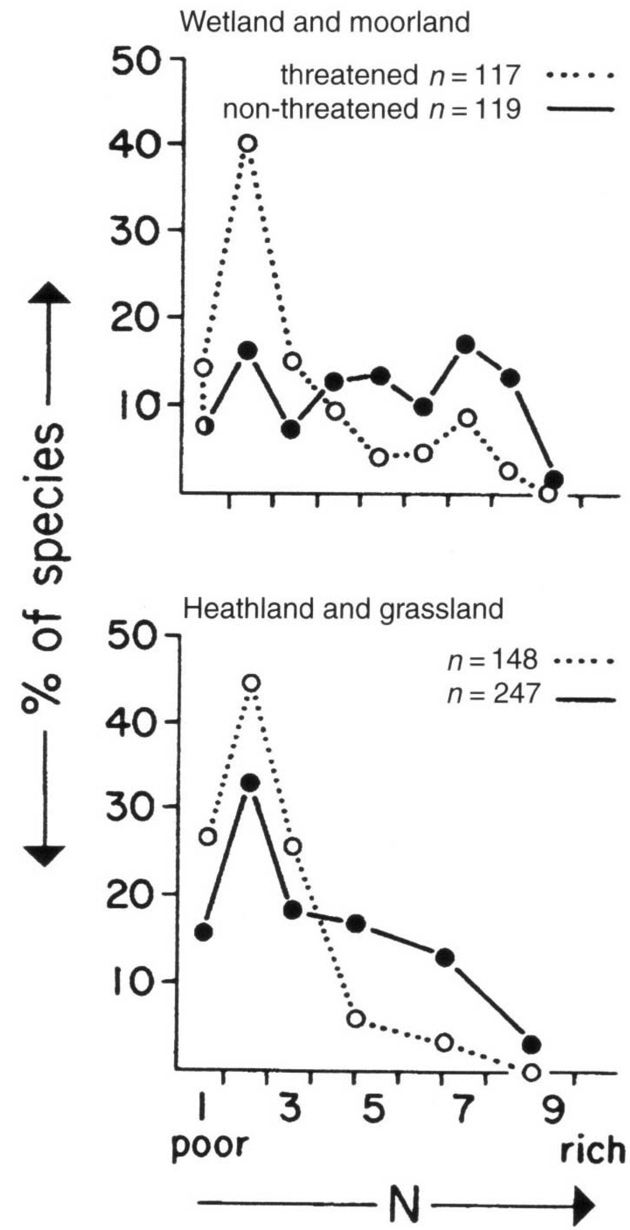
Eutrophication

Nitrate concentration in river water vs population density in watershed



World Resources Institute 1992

Occurrence of threatened and non-threatened plants vs. N concentration



Wisheu & Keddy 1992, Ellenberg 1985

Mechanism for decline in macrophyte community

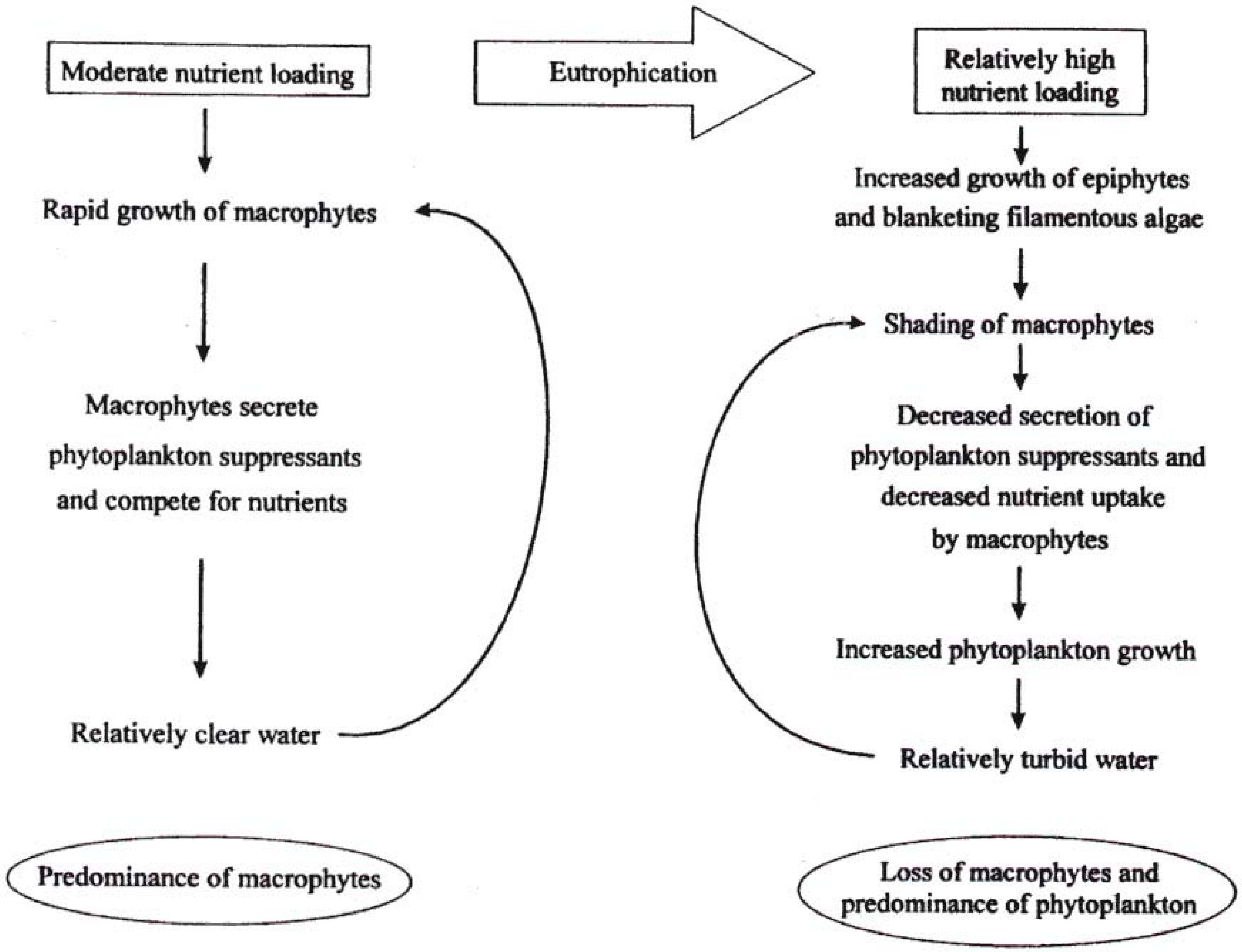


Figure 5.16 Postulated pathway for increased eutrophication causing a decline in macrophyte communities (after Phillips *et al.* 1978).

Keddy 2000

Nutrient Limitation and Animals

Elements	Human	Avg wetl plant	Copepod	Bacteria
C	19.4	41.1	6.1	12.1
H	9.3	v. low	10.2	9.9
N	5.1	2.3	1.5	3.0
O	62.8	v. low	80	73.7
P	0.6	0.3	0.1	0.6
S	0.6	0.4	0.1	0.3

Atomic composition of typical organisms

Morowitz 1968, Boyd 1978, Junk 1983, Keddy 2000

Decomposition

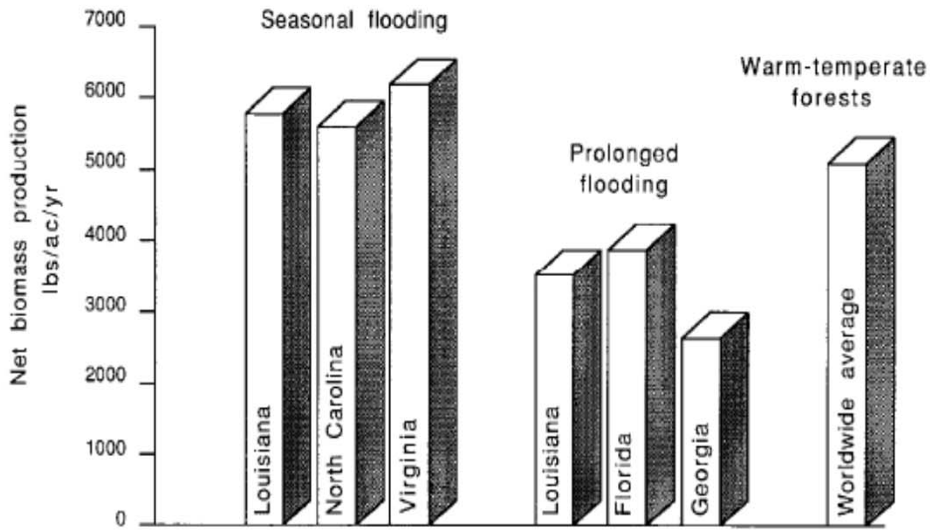


Fig. 1. Litter production varies greatly among wetlands depending on factors, such as plant species, climate, and hydrology. Dynamic hydrology in contrast to prolonged flooding promotes net biomass production in cypress–tupelo forested wetlands. Data presented for Virginia (Great Dismal Swamp) also includes red maple litter production. The worldwide average for warm-temperate forests is shown for comparison.

http://www.nwrc.usgs.gov/wdb/pub/wmh/13_3_14.pdf

Decomposition Rates

Table. *Some factors of litter decomposition rate.*

Properties	Rate of decomposition: Fast	Rate of decomposition: Slow
Intrinsic	Low lignin	High lignin
	High phosphorus	Low phosphorus
	High nitrogen	Low nitroge
	Low carbon to nitrogen	High carbon to nitrogen
	Low carbon to phosphorus	High carbon to phosphorus
	Low tannic acid	High tannic acid
	Few polyphenols	Many polyphenols
	Leaf tissue	Woody tissue
Environmental	Microbes present	Low microbial biomass
	Shredders present	Low shredder biomass
	Water present	Water absent
	Flowing water	Stagnant water (less O_2)
	High water temperature	Low water temperature
	Water with high pH	Water with low pH
	Low latitudes	High latitudes
	Low elevations	High elevations

http://www.nwrc.usgs.gov/wdb/pub/wmh/13_3_14.pdf

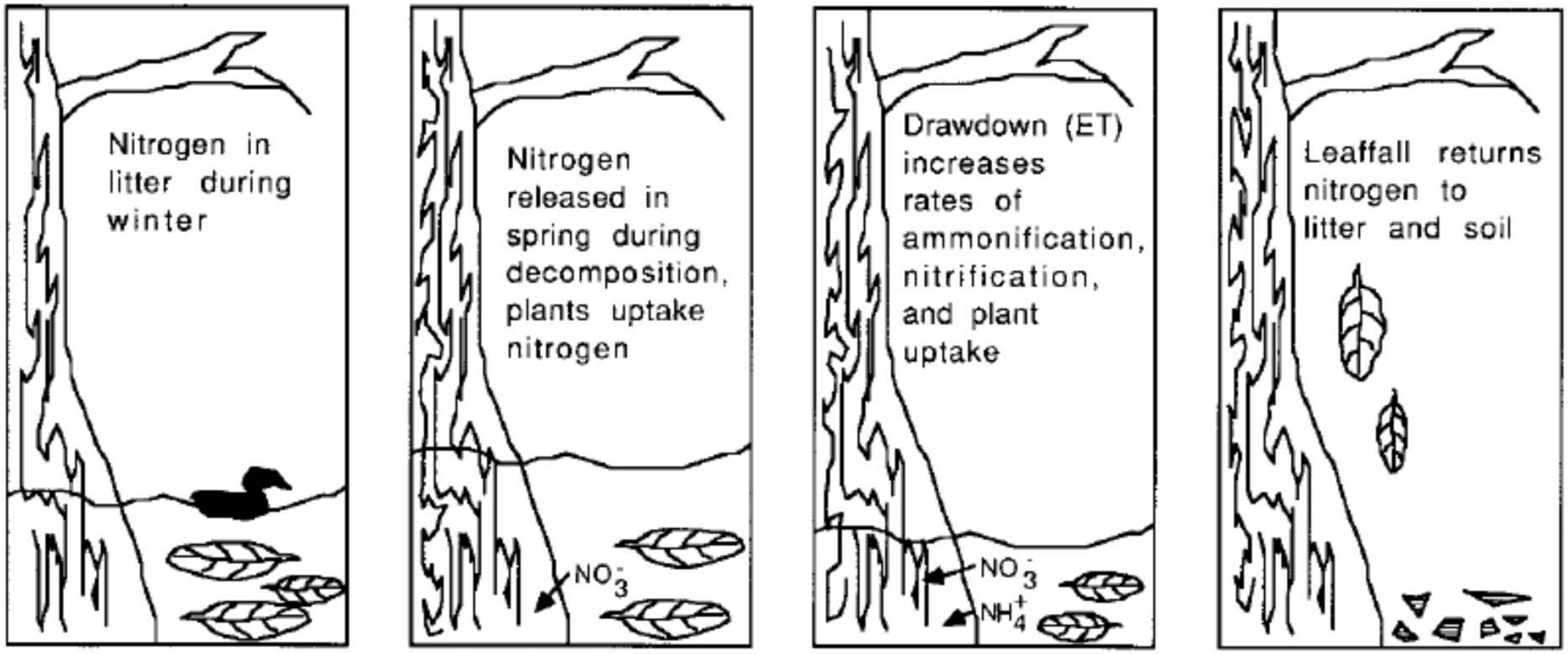


Fig. 4. Nitrogen cycling in wetlands involves a labyrinth of chemical transformations of nitrogen into forms that may or may not be available to plants. Microorganisms play a key role in mediating nitrogen availability in the benthos and soil.