Water Quality Issues in Ramsar Wetlands

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Challenges of Ramsar context

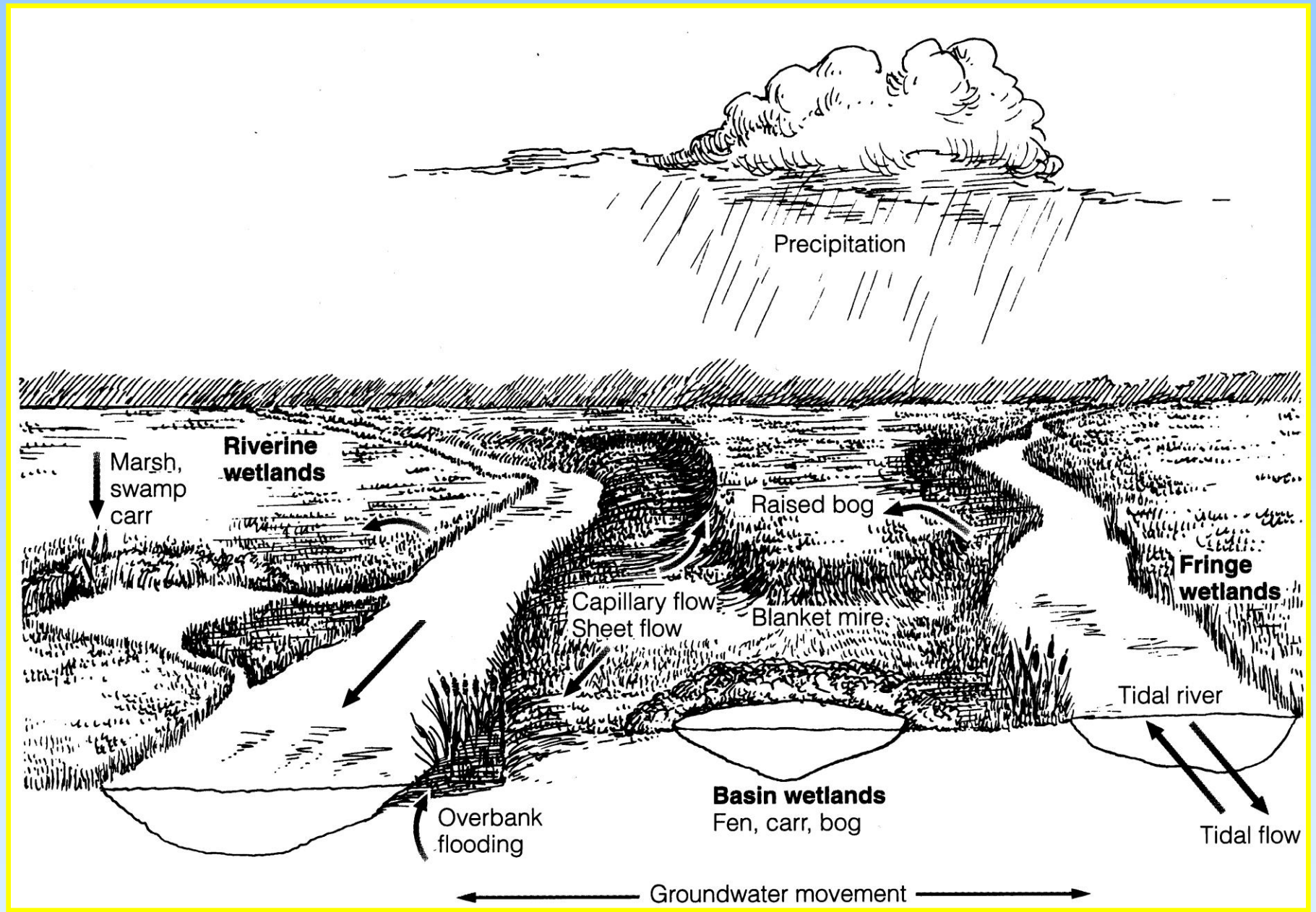
- Very wide-ranging definition of wetlands, including shallow coastal waters, rivers and lakes
- World-wide scope, with diversity in climate, socio-economic condition and availability of information
- How to reconcile:
  - Protection of Wetland Character
  - Enhancement of ecosystem services

Wetlands and water quality: 3 aspects

1. Different wetland types are characterized by specific hydrochemical conditions (pH, salinity, element composition)
2. Wetlands have a characteristic profile of nutrients (N, P, Si, K), driven by net inputs and complex cycling processes
3. Wetlands are subject to loading with toxic substances (arsenic, heavy metals, organic micropollutants), which may have drastic effects on biota

Contents of this presentation

- Wetlands and water chemistry: systems to characterize wetland types
- Wetlands and nutrients/toxicants: eutrophication; effects on wetland biodiversity; wetlands as nutrient filters
- Critical loading rates of wetlands
- Identify Ramsar tasks and link these to international policies


Precipitation
Marsh, swamp carr
Riverine wetlands
Raised bog
Fringe wetlands
Capillary flow
Sheet flow
Blanket mire
Tidal river
Basin wetlands
Fen, carr, bog
Overbank flooding
Tidal flow
Groundwater movement

Ramsar's Hydrogeo-morphic wetland classification

(Manual 12)

Precipitation and Evaporation are also important

Table A2.1 Wetland landscape location types and hydrological subtypes

Landscape location	Subtype based on water transfer mechanism
Flat upland wetlands	Upland surface water fed
Slope wetlands	Surface water-fed
	Surface and groundwater-fed
	Groundwater-fed
Valley bottom wetlands	Surface water-fed
	Surface and groundwater-fed
	Groundwater-fed
Underground wetlands	Groundwater-fed
Depression wetlands	Surface water-fed
	Surface and groundwater-fed
	Groundwater-fed
Flat lowland wetlands	Lowland surface water fed
Coastal wetlands	Surface water-fed
	Surface and groundwater-fed
	Groundwater-fed

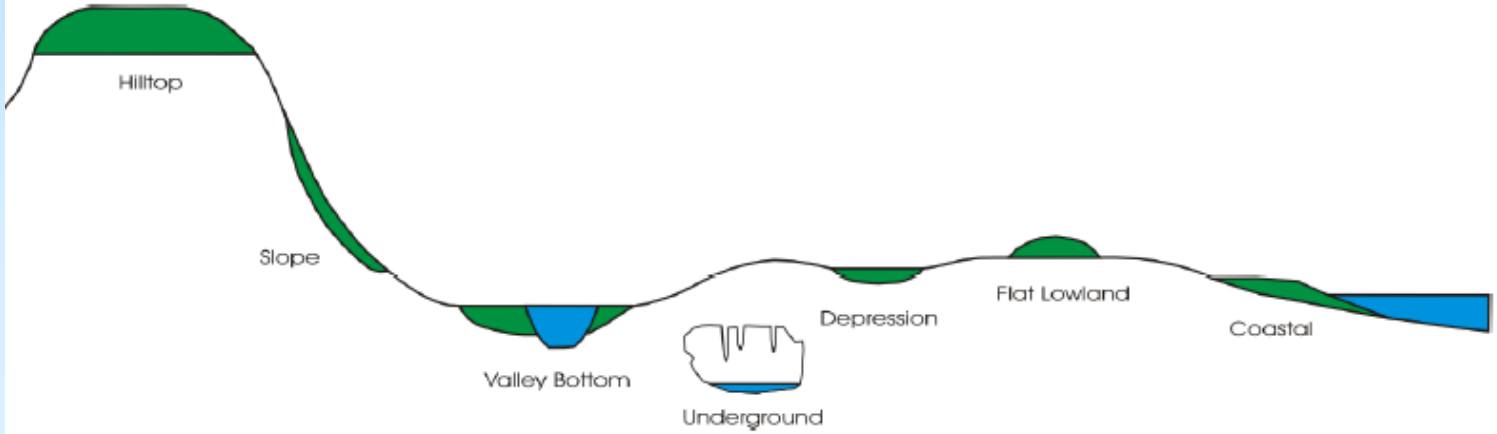
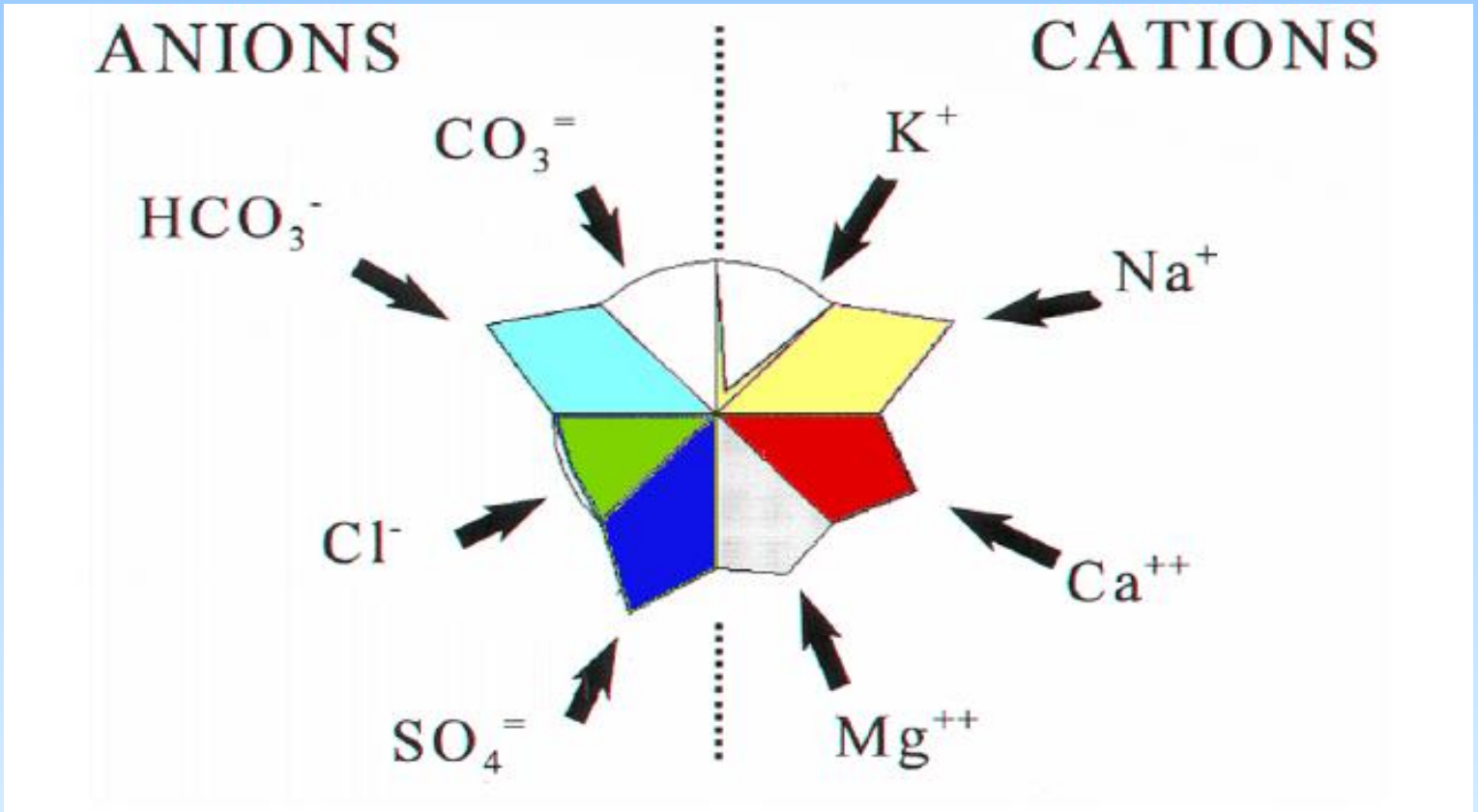


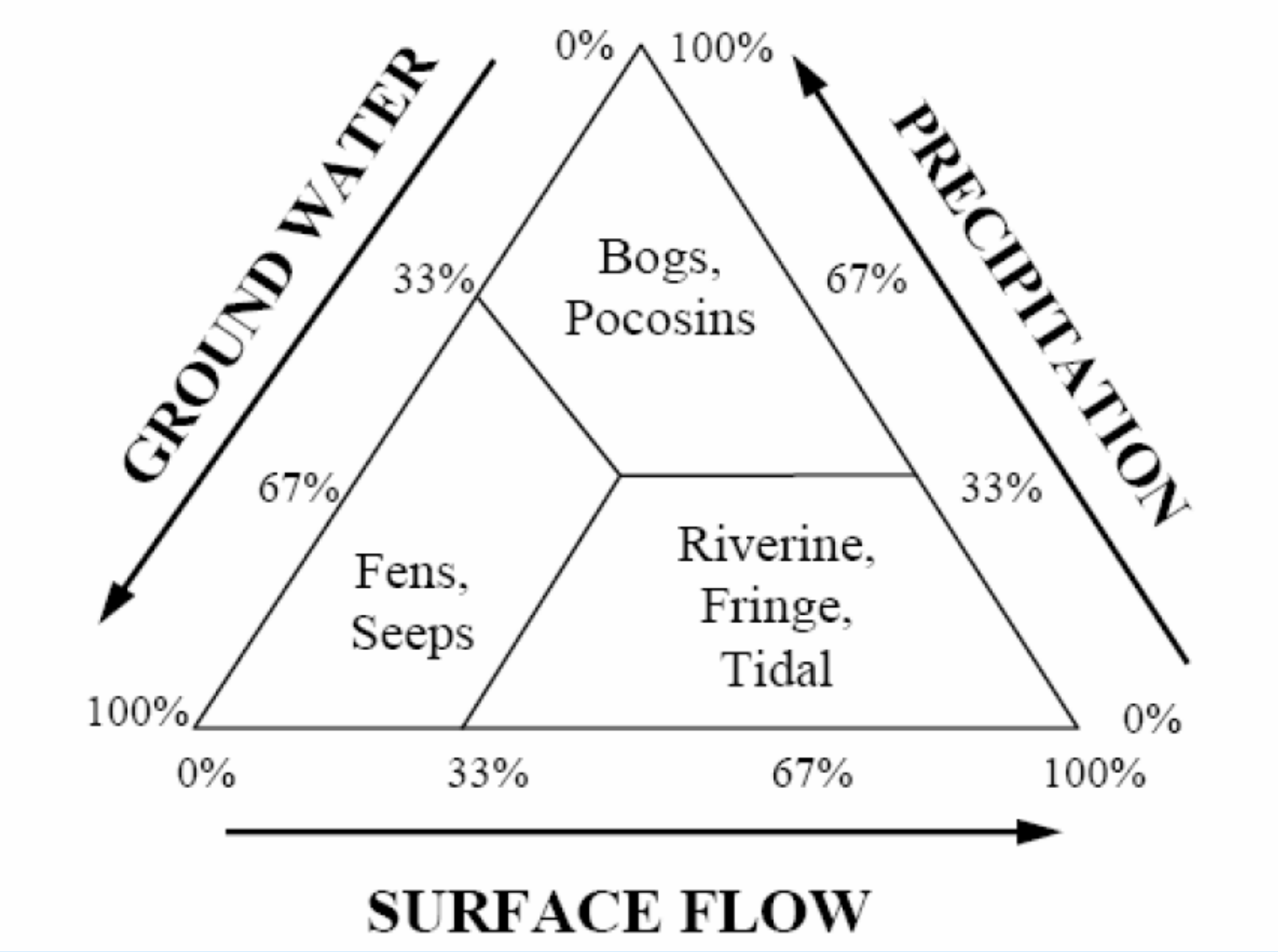
Figure A2.1. Landscape locations of wetlands



The Maucha diagram: proportional plots of 8 ions

Wetland types and water chemistry

- Wetlands can be classified based on their position in the hydrological setting of landscapes
- These hydrogeomorphic classes also show characteristic ranges in pH, EC and macroionic concentrations
- The quantitative importance of 3 main water sources determines water chemistry (rain, groundwater, surface water)
- Maucha diagrams and IonicRatio-EC diagrams illustrate differences among types



Water sources and wetland vegetation

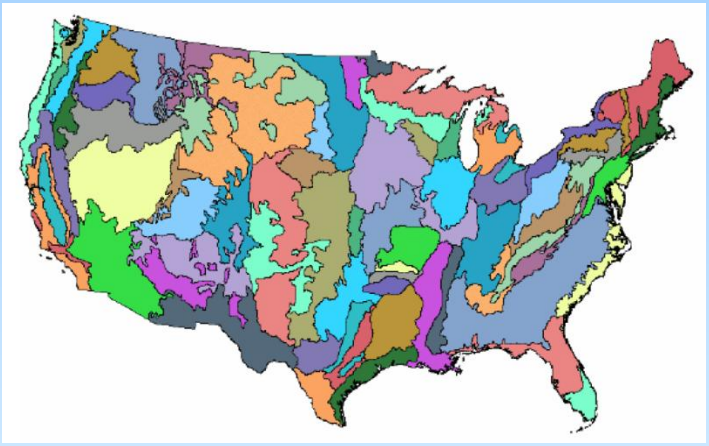
Brinson 1993

Water chemistry and wetlands: what kind of guidance?

- Assessment of condition of wetlands compared to reference (‘pristine’; ‘least disturbed’)
- Identification of importance of water sources
- Identification of effects of water quantity management on water chemistry
- Assessments should take account of the variation in aquatic ecoregions

Scale/region considerations

- Assessments need to be ecoregion-specific

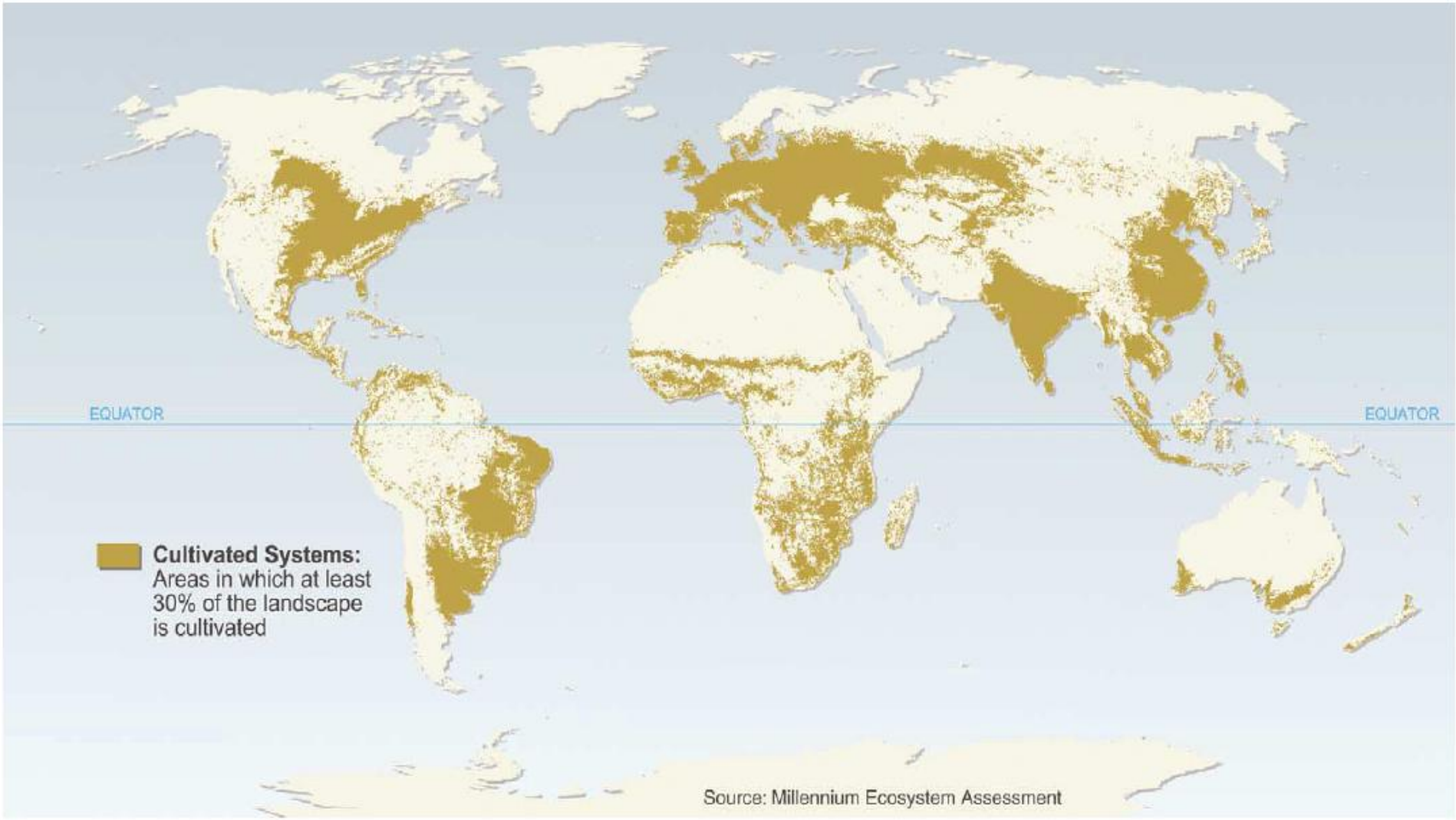


Map of aquatic ecoregions (Omernik 1987)

- And need to address HydroGeoMorphic wetland types

Nutrient loading in landscapes

- Agricultural and aquacultural activities and human waste discharge result in high nutrient inputs:
  - Nitrate leaching to the groundwater
  - Nitrate and phosphate loading of wetlands and surface waters
  - Atmospheric N deposition
- Eutrophication: loss of biodiversity and ecosystem integrity
- Risk of enhanced GHG emissions



Millennium Ecosystem Assessment (2005): agricultural use

Water quality: N and P

- P is often the algal growth-limiting factor in fresh water, N in coastal waters
- Point sources: sewage treatment plants
- Non-point sources: agriculture, industry
- Eutrophication has led to dramatic problems, e.g. fish kills in lakes and hypoxia in coastal areas (Gulf of Mexico)
- Loss of biodiversity in wetlands

Eutrophication of wetlands: effects

- Increase of primary productivity and loss of plant species
- Shifts in species composition of algae, aquatic plants and fauna
- Shifts from one stable state to another (e.g. shallow lakes)
- Loss of functional integrity, dramatic fish kills and nutrient flush

N loading affects biodiversity and water quality

Species composition

Greenhouse gas emissions

production

denitrification

leaching

ammonium toxicity

Water quality

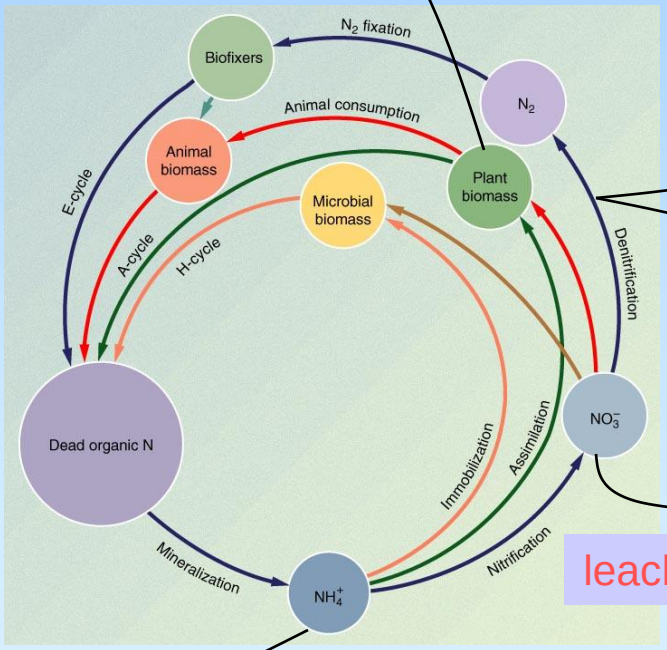
N loading

-

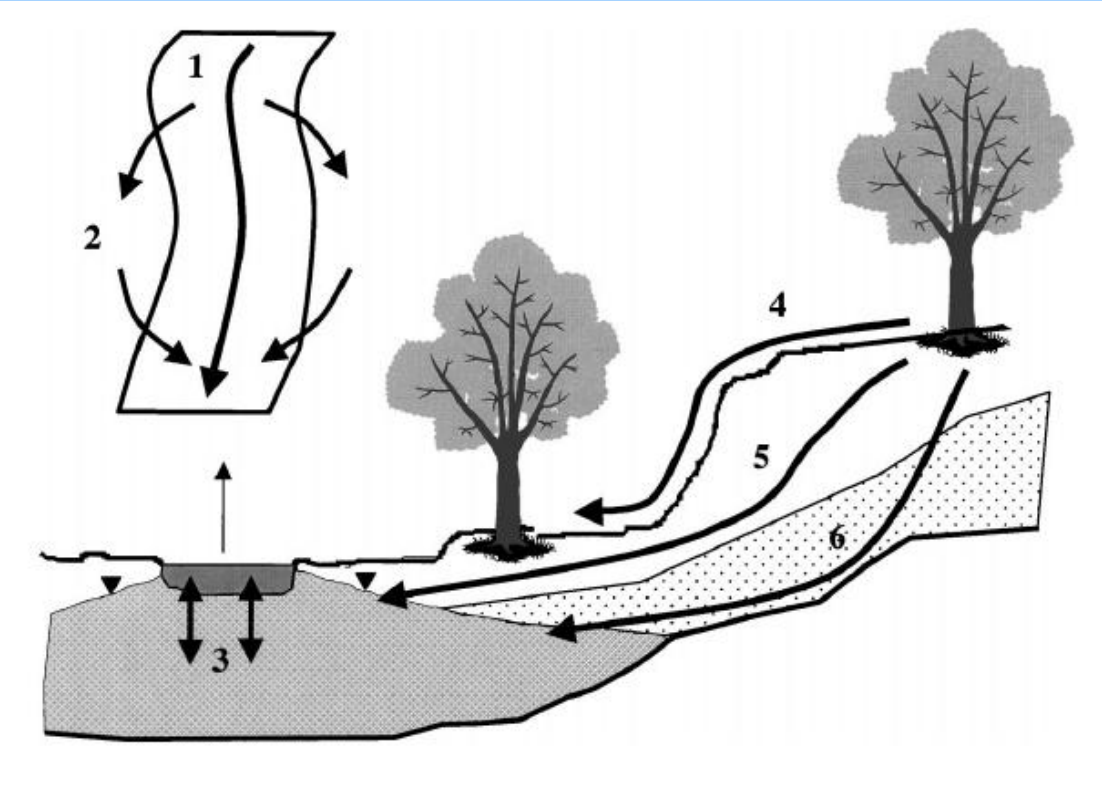
-

-

+



Lateral connections: hydrologic flowpaths



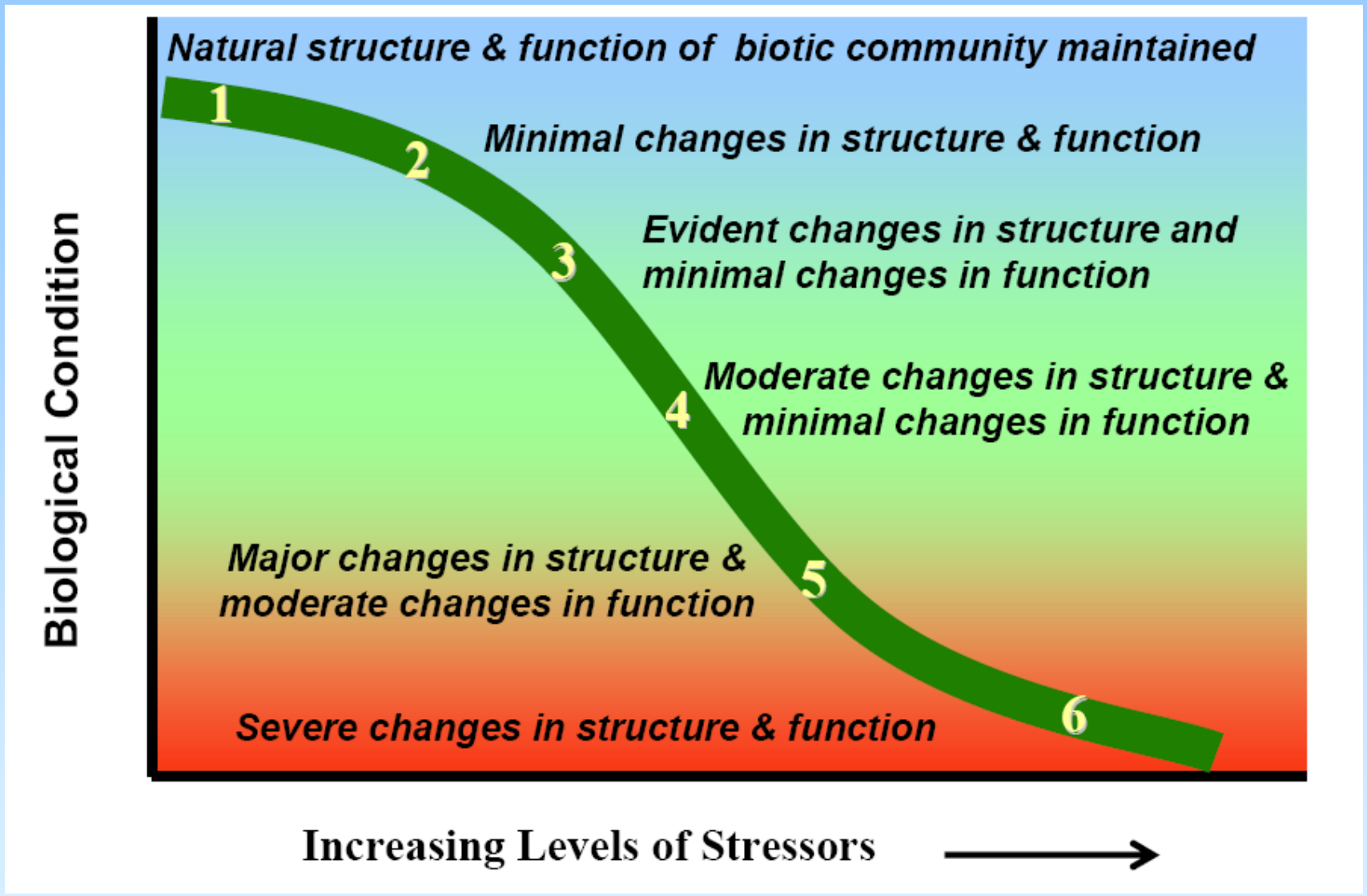
1. Surface stream
2. Exchange with riparian zone
3. Vertical exchange with hyporheic zone
4. Overland flow
5. Subsurface runoff
6. Deep groundwater flows through inactive sediment

Fisher et al. 2004

“Wetlands are good for water quality”

- Riparian zones are capable of reducing nitrate load of rivers
- Loading rates are high locally
- Nitrate reducing capacity is high but not unlimited
- Loading affects species composition
- Extreme loading leads to collapse of functioning (GHG emissions, leaching)

The Everglades: *Cladium* wetland with tree islands



Stevenson & Hauer: effects of stressors on ecosystems

Loading rates in wetlands: literature data

Catchment	Location	Wetland type	Origin	**N load** $g\ m^{-2}y^{-1}$	**P load** $g\ m^{-2}y^{-1}$	References
Liuchahe	PR China	Multipond	Constructed	>50	>5	(Yin *et al.* 1993; Yan *et al.* 1998; Yin and Shan, 2001)
Regge, Twente	Netherlands	Riparian	Natural	20 – 114		(Hefting *et al.* 2003; Hefting *et al.* 2004)
Everglades	USA	Marsh	Natural		0.2 – 4	(Qualls and Richardson, 1995; Vaithiyanathan and Richardson, 1999)
Mississippi	USA	Forested	Natural	1.9 – 3.9	0.02 – 0.09	(Day *et al.* 2004)
Various	USA	Riparian	Natural	2 – 15.5		(Mitsch *et al.* 2001; Day *et al.* 2004)
Treatment wetlands in USA and Europe			Constructed	50 – 900	10 – 200	(Kadlec & Knight, 1996; Mitsch *et al.* 2001)
Maximum load				***100***	***6***	(Kadlec & Knight, 1996; Mitsch *et al.* 2001; Groffman & Crawford, 2003)
Critical load ***- mesotrophic*** ***- eutrophic riparian***				***4*** ***50***	***0.5*** ***4***	(Richardson *et al.* 1997; Bobbink *et al.* 1998; Richardson & Qian, 1999; Bobbink & Lamers, 2002)

Verhoeven et al. 2006; Hefting et al. 2012

Wetlands and nutrients: what guidance is needed?

- Assess natural nutrient richness of the wetlands under study
- Assess early signs of eutrophication (disappearance of species (groups); turbidity)
- Assess responses of different wetland types to nutrient and pollutant loading, differences in vulnerability

Wetlands and nutrients: what guidance is needed?

- Make managers aware of water quality issues when they make decisions on water management
- Including water quality issues in assessments of Environmental Water Requirements
- Make managers aware of a potential water purification function to make a better case for protection of the wetland
- Assist managers to make decisions whether or not they should increase nutrient inputs to a wetland

Water quality & wetlands in large generic water quality policy systems

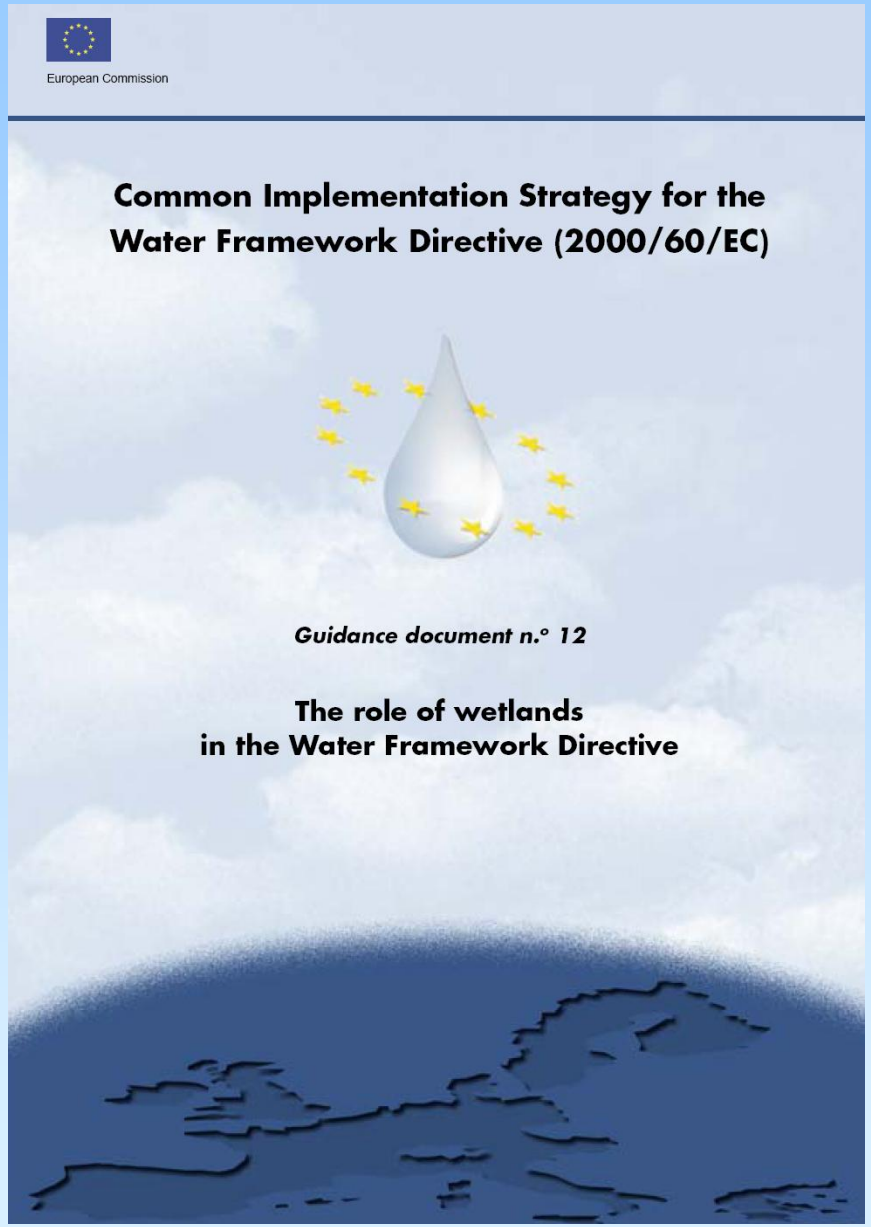
- Water Framework Directive: extensive policy targeting the improvement of water quality of Europe's fresh waters
- Maximum Ecological Potential and Good Ecological Condition have to be determined by all member states for their fresh water bodies
- Ecological criteria are used (plant, fish and macrofauna species composition)
- The Ramsar definition of wetlands is not used by the WFD

EU-WFD: document on the role of wetlands (2003):

– Attempt to give wetlands a specific role in the WFD implementation

– Emphasis on nutrient removal capabilities of certain wetland types

– Examples of the functioning of large wetland systems, their vulnerability to eutrophication and capacity for purification



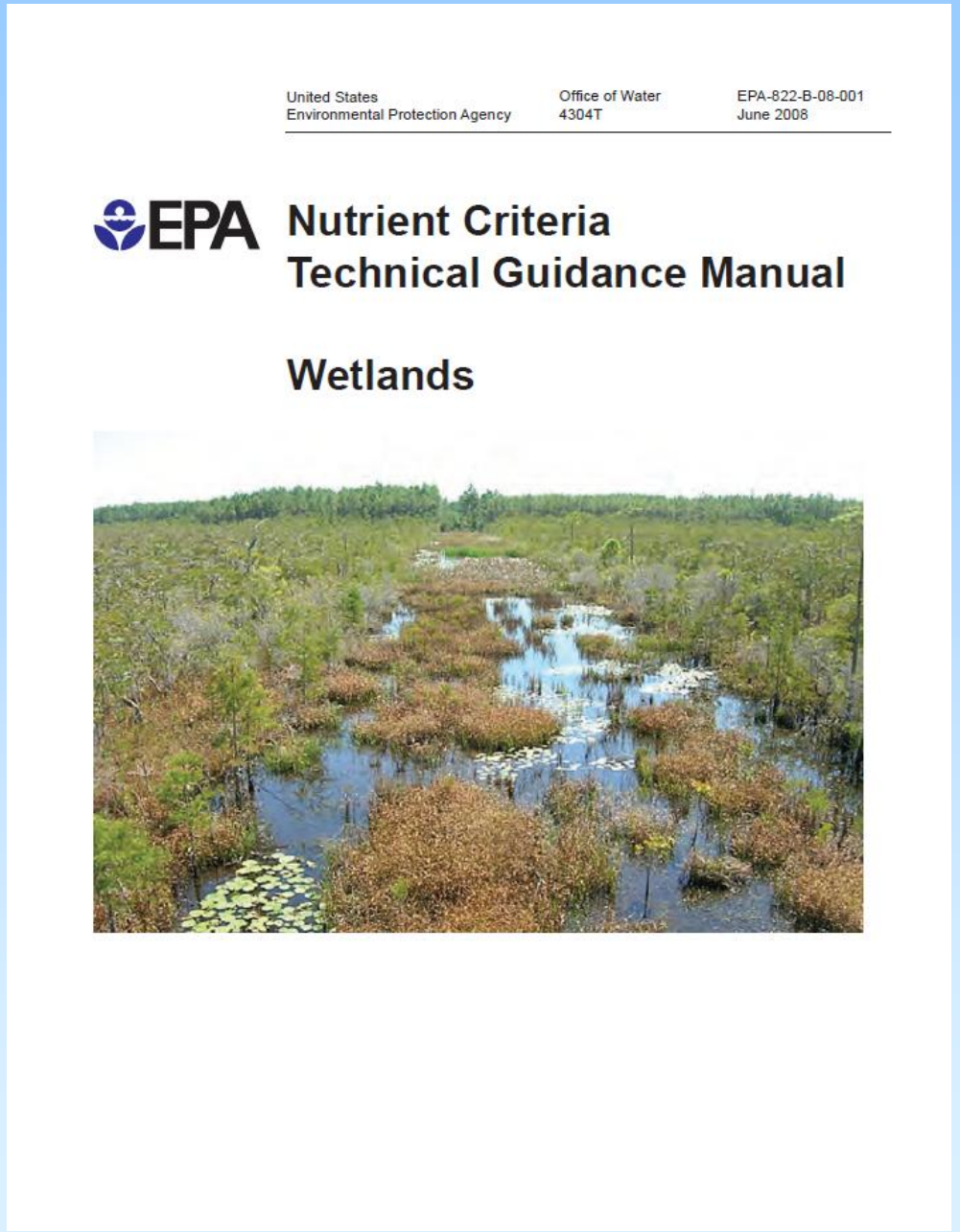
Current discussion on water quality standards for wetlands: US-EPA

– Wetlands are recognized as water bodies under the Clean Water Act

– Criteria for nutrient concentrations have been developed for other freshwater bodies in the last 10 years

– EPA Wetland modules are available for states & tribes

– Useful ideas for Ramsar?



Types of assessment schemes to be developed

- Ramsar needs assessment schemes at two levels:
  1. Detailed schemes with good predictions but high data requirements
  2. Basic schemes with only indications but minor data requirements
- For three types of guidance:
  1. Assessment of condition of wetland
  2. Advice on management options to improve the situation
  3. Dealing with impacts/scenarios

Chemical versus ecological criteria

Type of criterion	Advantages	Disadvantages
Chemical variables	Easily measured Many data available Universal in functioning	Many different variables High temporal variation
Ecological variables (species combinations)	Integrate condition over time More direct measurement of ecosystem health	Need taxonomic specialists Species combinations often too rigid
Functional variables (nutrient loading, productivity)	Most targeted criteria	Need considerable research effort

Sampling design: 3 options

Probabilistic	**Targeted**	**BACI**
Random selection of wetlands from all wetlands	Selection of problematic and reference wetlands	Selection of wetlands based on impacts
Minimal prior knowledge required	Some prior knowledge on wetlands required	Knowledge of impact required
Requires most financial resources	Requires limited resources	Requires least resources
Best for regional characterization of wetland types	Best for site-specific and watershed-specific criteria development	Best for monitoring restored and created wetlands or for wetlands with known stressors

Ramsar guidance on water quality……

- Sequence:
  - Ecoregion identification
  - Hydrogeomorphic classification
  - Targets for water quality criteria
  - Criteria development (chemical, biological)
- Questions:
  - Data requirements: what can be expected/asked?
  - How do we deal with the purification function of wetlands: separate / inclusive guidance?
  - Constructed wetlands?
- Strategy:
  - Link to existing Ramsar obligations, e.g., Ecological Character and Wise Use
  - Identification of specific benefits to people as well as wildlife

What criteria should be used in the assessments: causal, or response variables?