Water Quality Issues in Ramsar Wetlands

Jos T.A. Verhoeven

Department of Biology
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
Ramsar’s Hydrogeomorphic wetland classification (Manual 12)

Precipitation and Evaporation are also important

<table>
<thead>
<tr>
<th>Landscape location</th>
<th>Subtype based on water transfer mechanism</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat upland wetlands</td>
<td>Upland surface water fed</td>
</tr>
<tr>
<td>Slope wetlands</td>
<td>Surface water-fed</td>
</tr>
<tr>
<td></td>
<td>Surface and groundwater-fed</td>
</tr>
<tr>
<td></td>
<td>Groundwater-fed</td>
</tr>
<tr>
<td>Valley bottom wetlands</td>
<td>Surface water-fed</td>
</tr>
<tr>
<td></td>
<td>Surface and groundwater-fed</td>
</tr>
<tr>
<td></td>
<td>Groundwater-fed</td>
</tr>
<tr>
<td>Underground wetlands</td>
<td>Groundwater-fed</td>
</tr>
<tr>
<td>Depression wetlands</td>
<td>Surface water-fed</td>
</tr>
<tr>
<td></td>
<td>Surface and groundwater-fed</td>
</tr>
<tr>
<td></td>
<td>Groundwater-fed</td>
</tr>
<tr>
<td>Flat lowland wetlands</td>
<td>Lowland surface water fed</td>
</tr>
<tr>
<td>Coastal wetlands</td>
<td>Surface water-fed</td>
</tr>
<tr>
<td></td>
<td>Surface and groundwater-fed</td>
</tr>
<tr>
<td></td>
<td>Groundwater-fed</td>
</tr>
</tbody>
</table>

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
- 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

N loading affects biodiversity and water quality

Species composition

Greenhouse gas emissions

production

denitrification

leaching

ammonium toxicity

Water quality

N loading

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

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

– 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

<table>
<thead>
<tr>
<th>Type of criterion</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical variables</td>
<td>Easily measured</td>
<td>Many different variables</td>
</tr>
<tr>
<td></td>
<td>Many data available</td>
<td>High temporal variation</td>
</tr>
<tr>
<td></td>
<td>Universal in functioning</td>
<td></td>
</tr>
<tr>
<td>Ecological variables (species combinations)</td>
<td>Integrate condition over time</td>
<td>Need taxonomic specialists</td>
</tr>
<tr>
<td></td>
<td>More direct measurement of ecosystem health</td>
<td>Species combinations often too rigid</td>
</tr>
<tr>
<td>Functional variables (nutrient loading, productivity)</td>
<td>Most targeted criteria</td>
<td>Need considerable research effort</td>
</tr>
</tbody>
</table>
Sampling design: 3 options

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