Managing environmental flows to an Australian Ramsar wetland, the Macquarie Marshes: flooding regimes for wetland vegetation

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Floodplain wetlands in semi-arid regions of Australia rely on highly variable river flows:

- dynamic flooding regime of wet and dry phases
- supports a diverse mosaic of flood dependent vegetation
Macquarie Marshes

- Located in semi-arid region of the Murray-Darling Basin (MDB).
  - rely on river flows from the regulated Macquarie River.

- A long history of river regulation:
  - Burrendong (B) (1967) and Windamere (W) (1984) Dams
    - alters flow regimes and reduces variability

- Macquarie River supports agriculture:

![Irrigated cropping](image)

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Macquarie Marshes

- Are a dryland alluvial plain with anastomosing and distributary channels.
- Recognised in 1986 as an international wetland of importance under the Ramsar Convention criteria:
  1. Representative example of inland floodplain wetland
  2. Nationally threatened species
  3. Regionally significant populations of plants and animals
  4. Significant waterbird breeding events
  5. Large waterbird abundance and diversity
Ecological decline

- Semi-arid region wetlands:
  - vulnerable to river regulation and extended drought,
  - ecological integrity compromised

- Article 3.2 of Ramsar Convention
  - notification that the ecological character of a wetland:
    - has changed,
    - is changing, or
    - is likely to change
  - evidence based

Macquarie Marshes have a long history of environmental flow management:
- first allocation 1980

Managed to maintain and restore ecological structure and function.

Restoration of environmental flows to rivers of the Murray-Darling Basin:
- AUD$3.1 billion buyback of irrigation entitlements plus AUD$5.8 billion in infrastructure

Management requires a quantitative understanding of water requirements.
Water requirements

- Floodplain wetlands are large and diverse and river flows are highly variable
  - landscape scale (>2000 km²), and
  - water regime scale (long-term data e.g. 20 years).
  
(Ward et al. 2002; Puckridge et al. 1998)

- Flooding regime variables critical for flood dependent vegetation include:
  - flood frequency
  - dry interval

(Roberts and Marston 2000; Rogers 2011; Casanova and Brock 2000;)

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Vegetation responses are relative to structural growth form, longevity and flood dependencies. (Roberts et al. 2000; Brock and Casanova 1997)

Response variables include:
- species composition
- tree canopy health
Flooding regime variables

Flooding Frequency

- Average Return Interval (ARI) zones

<table>
<thead>
<tr>
<th>Probability</th>
<th>ARI (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.65-0.99</td>
<td>&gt;1 in 1</td>
</tr>
<tr>
<td>0.49-0.63</td>
<td>1 in 1</td>
</tr>
<tr>
<td>0.37-0.48</td>
<td>1 in 1-2</td>
</tr>
<tr>
<td>0.22-0.35</td>
<td>1 in 3-4</td>
</tr>
<tr>
<td>0.15-0.20</td>
<td>1 in 4-5</td>
</tr>
<tr>
<td>0.05-0.14</td>
<td>1 in 6-8</td>
</tr>
<tr>
<td>0.01-0.04</td>
<td>1 in 10-20</td>
</tr>
</tbody>
</table>

Flooding regime variables

Dry Interval

- Number of dry years prior to the vegetation observations (May 2008)

<table>
<thead>
<tr>
<th>Years</th>
<th>Number of Dry Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
</tr>
</tbody>
</table>

Vegetation groups

Vegetation Communities

- Grouped according to relative flood dependencies and structural growth forms:
  - Aquatic
    - Semi-permanent wetland (1991)
    - River Red Gum
    - Lignum - River Cooba
    - Coolibah - Black Box
  - Terrestrial
    - Dryland floodplain
    - Cultivation

Source Data:
Among vegetation groups

- Probability of flooding

- Flood frequency

- Vegetation Groups:
  - Semi-permanent wetland
  - River Red Gum
  - Lignum - River Cooba
  - Coolibah - Black Box
  - Dryland floodplain
  - Cultivation

- ARI Zone:
  - < 1
  - 1
  - 1-2
  - 3-4
  - 4-5
  - 6-8
  - 10-20

- $p < 0.0001$
Response variable: % cover/abundance of terrestrial opportunistic colonising chenopods: (Sclerolaena muricata and Salsola kali)

<table>
<thead>
<tr>
<th>Health Class</th>
<th>Chenopod %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>0-10</td>
</tr>
<tr>
<td>Moderate</td>
<td>10-50</td>
</tr>
<tr>
<td>Poor</td>
<td>&gt;50</td>
</tr>
</tbody>
</table>
Flood frequency

Among semi-permanent wetland health classes

- Probability of flooding
  - $p$ value < 0.0001

- % Chenopod
  - 0-10
  - 10-50
  - >50

Reported frequency requirements#

<table>
<thead>
<tr>
<th>Plant species</th>
<th>Ideal flood frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common reed*</td>
<td>1-2 years</td>
</tr>
<tr>
<td>Water couch</td>
<td>Annual</td>
</tr>
<tr>
<td>Cumbungi</td>
<td>Annual</td>
</tr>
</tbody>
</table>

#Source: Roberts and Marston (2011); Rogers, K. (2011)
Among semi-permanent wetland health classes

\[ p \text{ value} < 0.0001 \]

- **Common reed**: A few, 12 OR extended drought?
- **Water couch**: 7-8, 9-10
- **Cumbungi**: 0-3, 3-4

Published dry period requirements

<table>
<thead>
<tr>
<th>Vegetation community</th>
<th>Ideal (months)</th>
<th>Maximum (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common reed</td>
<td>A few</td>
<td>12 OR extended drought?</td>
</tr>
<tr>
<td>Water couch</td>
<td>7-8</td>
<td>9-10</td>
</tr>
<tr>
<td>Cumbungi</td>
<td>0-3</td>
<td>3-4</td>
</tr>
</tbody>
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#Source: Roberts and Marston (2011); Rogers, K. (2011)
Response variable: % dead canopy

Health Class (% canopy dead)

- **Good (0-10)**
- **Intermediate (10-40)**
- **Declining (40-80)**
- **Poor (80-100)**

- Delineated from high resolution imagery (ADS40) and validated on-ground (Nairn 2008; Bowen and Simpson 2010)
Flood frequency

Among River Red Gum canopy health classes

$p$ value $< 0.0001$

Published frequency requirements$#$:

<table>
<thead>
<tr>
<th>Plant species</th>
<th>Ideal flood frequency</th>
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<tr>
<td>River red gum</td>
<td>1-3 years*</td>
</tr>
</tbody>
</table>

* Reduced when:
  - watertable is shallow or trees have access to permanent water
  - community characterised as a woodland

#Source: Roberts and Marston (2011); Rogers, K. (2011)
Among River Red Gum canopy health classes

$p$ value $< 0.0001$

Published dry interval requirements

<table>
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<tr>
<th>Plant species</th>
<th>Ideal</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>River red gum</td>
<td>5-15 months*</td>
<td>3-4 years</td>
</tr>
</tbody>
</table>

* Reduced when:
  - watertable is shallow or trees have access to permanent water
  - community characterised as a woodland

#Source: Roberts and Marston (2011); Rogers, K. (2011)
Conclusions

- For environmental flow management:
  - Semi-permanent wetland
    - Ideally requires flooding at least once a year.
    - As dry period extends from 3 to 6 years there is significant colonisation of terrestrial species.
    - Significant replacement by terrestrial species at extended periods (>6 years) of no flooding.
For environmental flow management:

River red gum

- Ideally requires flooding once in 1 to 3 years.
- Must receive adequate flooding within a six year period to maintain moderate health.
- Health is compromised (i.e. significant canopy death (>40%)) if the dry interval extends over a 6 year period.
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