Effects of water level fluctuation and habitat on *Littorella uniflora* - morphology and productivity in Scottish lochs

Anwên Bill
Dr Nigel Willby

Twitter: @AnwenBill, email: a.r.bill@stir.ac.uk
Research Loch’s

Loch Lomond & The Trossachs National Park

Legend

National Park boundary
Research lake

SCENE – You are here!
Water level fluctuations of Scottish Loch’s

Glen Finglas Reservoir - 8m drawdown

Loch Katrine - 1.6m drawdown

Loch Chon - 1m drawdown (unregulated)

Magnitude of drawdown (m)

Magnitude of drawdown - maximum (m)

Eighty Scottish Loch’s

Unregulated loch drawdown levels 1-2m
Hydrology and Ecology – the “So what”
Littorella uniflora (L.) Asch. (Shoreweed).

- Isoetid, Evergreen, Amphibious
- Widely distributed
- Common on shores of Northern Britain
- Rapid morphological change in response to water stress
  Robe & Griffiths, 2000: Mjelde et al., 2012
- Key to littoral zone ecology
  Spierenburg et al., 2012
- Feedbacks to wider lake ecology
  Andersen et al., 2006
Littorella uniflora (L.) Asch. (Shoreweed).

- Isoetid, Evergreen, Amphibious
- Widely distributed
- Common on shores of Northern Britain
- Rapid morphological change in response to water stress
  Robe & Griffiths, 2000: Mjelde et al., 2012
- Key to littoral zone ecology
  Spierenburg et al., 2012
- Feedbacks to wider lake ecology
  Andersen et al., 2006
Isoetid, Evergreen, Amphibious

Widely distributed

Common on shores of Northern Britain

Rapid morphological change in response to water stress
  Robe & Griffiths, 2000: Mjelde et al., 2012

Key to littoral zone ecology
  Spierenburg et al., 2012

Feedbacks to wider lake ecology
  Andersen et al., 2006
Research questions

• How are different physical variables related to each other, and *L. uniflora*

• What are the mechanisms involved

• How do water level fluctuations superimpose environmental attributes to affect vegetation production
Determine if biological monitoring, focused on an individual plant, can improve detection of hydromorphological impacts
Method

- **3 x 25cm² quadrats per station**
- **Distance, height and slope from high waterline to each quadrat**
- **Littorella removed to maximum root depth**
- **Substrate sampled adjacent to each quadrat**
- **Lake Habitat Survey of shore particle distribution** (CSM, Gunn et al., 2003)

X 10 lakes with varying water level regimes & fertility

Survey stations vary with exposure
Analysis

Response Variables
- Shoot biomass
- Shoot length
- Shoot width
- Root/Shoot Ratio
- Number of decayed leaves

Lake
- Area
- Water level fluctuation
- Elevation
- Geographical Proximity
- Fertility

Shore
- Exposure (fetch)
- Particle size
- Proximity to water line; Height
- Distance
- Slope

Quadrat
- Sediment water %
- Sediment attributes
- Organic matter
Analysis

**Lake**
- Area
- Water level fluctuation
- Elevation
- Geographical Proximity
- Fertility

**Shore**
- Exposure (fetch)
- Particle size
- Proximity to water line; Height
- Distance
- Slope

**Quadrat**
- Sediment water %
- Sediment attributes
- Organic matter

**Response Variables**
- Shoot biomass
- Shoot length
- Shoot width
- Root/Shoot Ratio
- Number of decayed leaves
Analysis

Lake
Area
Water level fluctuation
Elevation
Geographical Proximity
Fertility

Response Variables
Shoot biomass
Shoot length
Shoot width
Root/Shoot Ratio
Number of decayed leaves

Shore
Exposure (fetch)
Particle size
Proximity to water line; Height
Distance
Slope

Quadrat
Sediment water %
Sediment attributes
Organic matter
Analysis

**Response Variables**
- Shoot biomass
- Shoot length
- Shoot width
- Root/Shoot Ratio
- Number of decayed leaves

**Lake**
- Area
- Water level fluctuation
- Elevation
- Geographical Proximity
- Fertility

**Shore**
- Exposure (fetch)
- Particle size
- Proximity to water line; Height
- Distance
- Slope

**Quadrat**
- Sediment water %
- Sediment attributes
  - Organic matter
Analysis

Lake
- Area
- Water level fluctuation
- Elevation
- Geographical Proximity
- Fertility

Response Variables
- Shoot biomass
- Shoot length
- Shoot width
- Root/Shoot Ratio
- Number of decayed leaves

Shore
- Exposure (fetch)
- Particle size
- Proximity to water line; Height
- Distance
- Slope

Quadrat
- Sediment water %
- Sediment attributes
- Organic matter

Fertility
Analysis

Response Variables
- Shoot biomass
- Shoot length
- Shoot width
- Root/Shoot Ratio
- Number of decayed leaves

Quadrat
- Sediment water %
- Sediment attributes
- Organic matter

Lake
- Area
- Water level fluctuation
- Elevation
- Geographical Proximity
- Fertility

Shore
- Exposure (fetch)
- Particle size
- Proximity to water line; Height
- Distance
- Slope

Sediment water %
Sediment attributes
Organic matter
Analysis

Response Variables
- Shoot biomass
- Shoot length
- Shoot width
- Root/Shoot Ratio
- Number of decayed leaves

Lake
- Area
- Water level fluctuation
- Elevation
- Geographical Proximity
- Fertility

Shore
- Exposure (fetch)
  - Particle size
  - Proximity to water line; Height
  - Distance
  - Slope

Quadrat
- Sediment water %
- Sediment attributes
- Organic matter
**Analysis**

**Lake**
- Area
- Water level fluctuation
- Elevation
- Geographical Proximity
- Fertility ??

**Response Variables**
- Shoot biomass
- Shoot length
- Shoot width
- Root/Shoot Ratio
- Number of decayed leaves

**Shore**
- Exposure (fetch)
- Particle size
- Proximity to water line; Height
- Distance
- Slope

**Quadrat**
- Sediment water %
- Sediment attributes
- Organic matter

**Fertility ??**
<table>
<thead>
<tr>
<th>Predictor</th>
<th>Response</th>
<th>Water weight %</th>
<th>Water Level range</th>
<th>Shore particle size</th>
<th>Fetch</th>
<th>Area</th>
<th>Distance from water line</th>
<th>Slope from water line</th>
<th>Variation explained (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoot biomass</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
<td>34-40%</td>
</tr>
<tr>
<td>Shoot length</td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>27-30%</td>
</tr>
<tr>
<td>Shoot width</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td>23-32%</td>
</tr>
<tr>
<td>Root/Shoot Ratio</td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15-21%</td>
</tr>
<tr>
<td>Number of decayed leaves</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td>40-43%</td>
</tr>
</tbody>
</table>
Shoot biomass decreases with finer shore sediments and reduced lake area.

**Shoot biomass**

- Shore particle size (avg)
- Lake area (km²)
Shoot length increases with sediment water and water level range.
Shoot length increases with sediment water weight and water level range (up to 5m?)

Shoot length

Sediment water weight (std)

Water level fluctuation (m)
R:S ratio increases with mediated water level range and decreasing sediment water. Root/Shoot ratio
Number of decayed shoots increase farther from the water line and with lower wind/wave exposure.
Lake habitat factors are interrelated and in turn affect *Littorella uniflora* morphology.
Water level fluctuations drive environmental attributes and directly affect *Littorella uniflora*.

- **Increase in water level**
  - Water level range
  - Sediment water
  - Organic matter
  - Shore sediment
  - Fetch / exposure
  - Increased R:S
  - Shoot biomass
  - Lower leaf turnover?

- **Decrease in water level**
  - Water level range
  - Shoot biomass
  - Higher leaf turnover?

*Littorella uniflora* is absent when the water level is greater than 5m.
Future work

- Interactive effects; disturbance stress resources
- Periodicity of water level fluctuations frequency duration seasonality
- Structural Equation Modelling
- and more data!
Thank you!

Anna Doeser
Megan Layton
Jeroen Minderman

Duncan Dowie
Rory Paterson

Alan Law
Zarah Pattison

Anwên Bill
Twitter: @AnwenBill email: a.r.bill@stir.ac.uk
Lake variables

Area km

Collinear

Fetch (m)
Lake variables

Q.Height & Q.distance

Littorella uniflora (L.) Asch.
Littorella uniflora (L.) Asch.

Morphological

Root Mass and RSR 0.62
so >2.5vif

Root mass and **N decayed shoots** 0.49

Leaf widths of green and decayed are close 0.52

Leaf width green and **leaf length green** are close but not collinear

**Biomass w shoot mass**
0.53 (as you’d expect it to be as is shoot biomass)
Biomass with leaf length green 0.51
Littorella uniflora (L.) Asch.

Nutrient variables

Water weight %

Collinear

OM content

Pebbles

Sand

Silt/clay

Nutrient variables

Water weight %

Collinear

OM content

Pebbles

Sand

Silt/clay

Nutrient variables
Water level regulation

Lake water resource use

- Hydroelectric power
- Consumption

- Flood prevention
- Industry
- Irrigation
- Recreation
- Transportation

Extent of water level change

- Natural lakes (2-3m)
- Waste water deposits
- Fisheries
- Aesthetics/Tourism

Lednock - 9m drawdown
Glen Finglas - 5m drawdown
Loch Chon - unregulated
<table>
<thead>
<tr>
<th>Model response</th>
<th>Water weight %</th>
<th>WLF</th>
<th>Shore particle size</th>
<th>Fetch</th>
<th>Area</th>
<th>Distance from water line</th>
<th>Slope from water line</th>
<th>NH3</th>
<th>Variation explained (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoot biomass</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>34-40%</td>
</tr>
<tr>
<td>Shoot length</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>27-30%</td>
</tr>
<tr>
<td>Shoot width</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>23-32%</td>
</tr>
<tr>
<td>Root/Shoot Ratio</td>
<td>-ve 2</td>
<td>+ve 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15-21%</td>
</tr>
<tr>
<td>Number of decayed leaves</td>
<td>-3</td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td>40-43%</td>
</tr>
</tbody>
</table>
### Nutrient variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Correlation</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ElecCond_20_µS.cm</td>
<td>0.8923008</td>
<td>0.0005159003</td>
</tr>
<tr>
<td>P_mg.L</td>
<td>0.8881677</td>
<td>0.0005966795</td>
</tr>
<tr>
<td>Chlorophyll_µg.L</td>
<td>0.8765492</td>
<td>0.0008732151</td>
</tr>
<tr>
<td>Alkalinity_mg.L</td>
<td>0.8683225</td>
<td>0.0011186539</td>
</tr>
<tr>
<td>Chloride_mg.L</td>
<td>0.8118613</td>
<td>0.004338277</td>
</tr>
<tr>
<td>Ammonia_mg.L</td>
<td>0.8008290</td>
<td>0.005371858</td>
</tr>
</tbody>
</table>
Root/Shoot ratio

Water level fluctuation (m)

Sediment water weight (std)
Summary

Water level range

Sediment water
Organic matter
Shore sediment size

Littorella uniflora

- Increased R:S
- Shoot biomass
- Lower leaf turnover?

- Decreased R:S
- Shoot biomass
- Higher leaf turnover?

Absent +5m
## Analysis

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Water weight %</th>
<th>Water Level range</th>
<th>Shore particle size</th>
<th>Fetch</th>
<th>Area</th>
<th>Distance from water line</th>
<th>Slope from water line</th>
<th>Variation explained (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoot biomass</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>2</td>
<td></td>
<td>34-40%</td>
</tr>
<tr>
<td>Shoot length</td>
<td>1 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>27-30%</td>
</tr>
<tr>
<td>Shoot width</td>
<td>1</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23-32%</td>
</tr>
<tr>
<td>Root/Shoot Ratio</td>
<td>2 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15-21%</td>
</tr>
<tr>
<td>Number of decayed leaves</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>1</td>
<td></td>
<td>40-43%</td>
</tr>
</tbody>
</table>
i) Analysis of existing data sets with loch water levels and concurrent biological surveys

(Mjelde et al., 2012)
Resource use

- Hydroelectric power
- Consumption
- Flood prevention
- Industry
- Irrigation
- Recreation
- Transportation

Natural lakes (2-3m)
- Waste water deposits
- Fisheries
- Aesthetics/Tourism

Extent of water level change

- 1-30m
- 1-12m
- 1-4m

Shoreline modification

- Dams and retaining walls
- Rip rap
- Recreational beaches
- Roads and retaining walls

Examples:
- Grizedale Reservoir – consumption
- Loch Shiel – unregulated (Steven F Watson 2006)
- Loch Lomond – recreation/consumption
Aim: Improve understanding of the empirical relationships between hydromorphological pressures & biological responses within lakes
Impacts

Littoral zone

Energy flow

primary producers

microbial decomposers

benthic invertebrates

Pelagic

higher trophic levels
Hydrology and Ecology – the “So what”