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

Anwên Bill

Dr Nigel Willby

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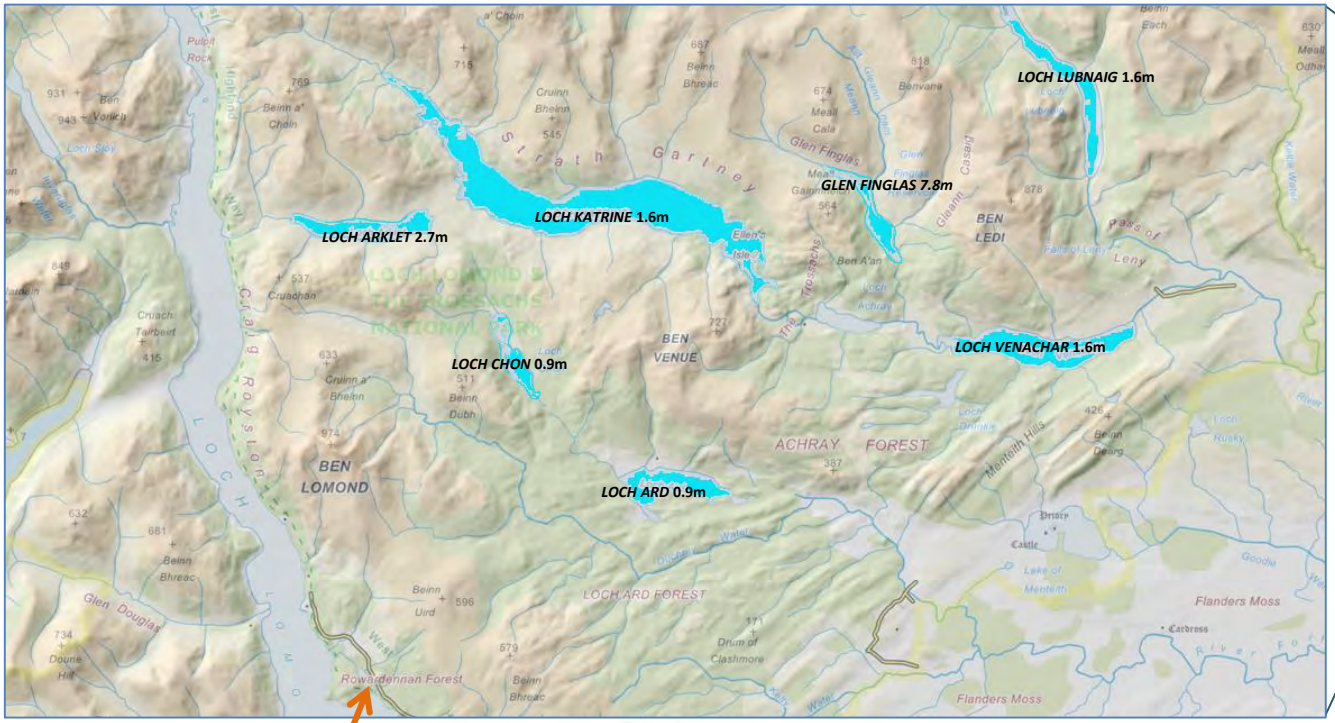
Research Loch's

Loch Lomond & The Trossachs National Park



SCENE –
You are here!

Legend

National Park boundary

Research lake

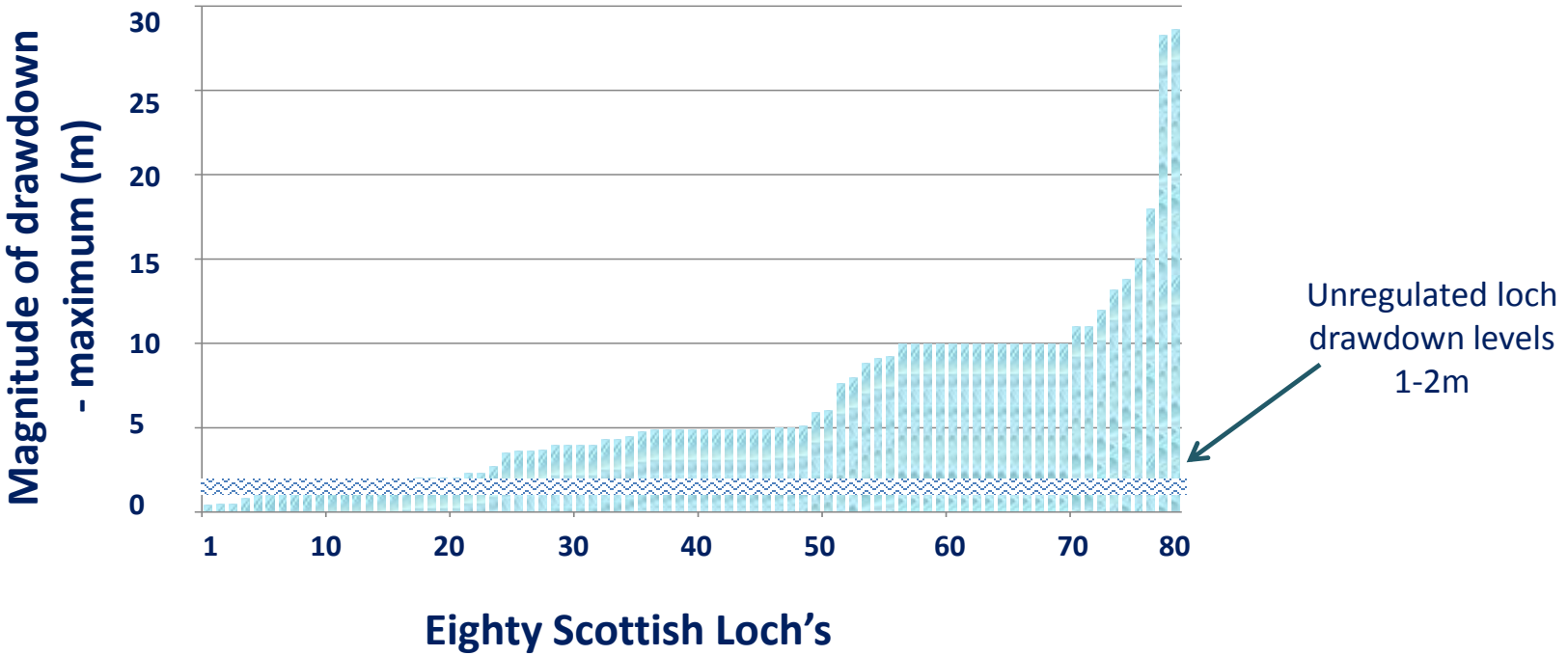
Digimap®

Water level fluctuations of Scottish Loch's

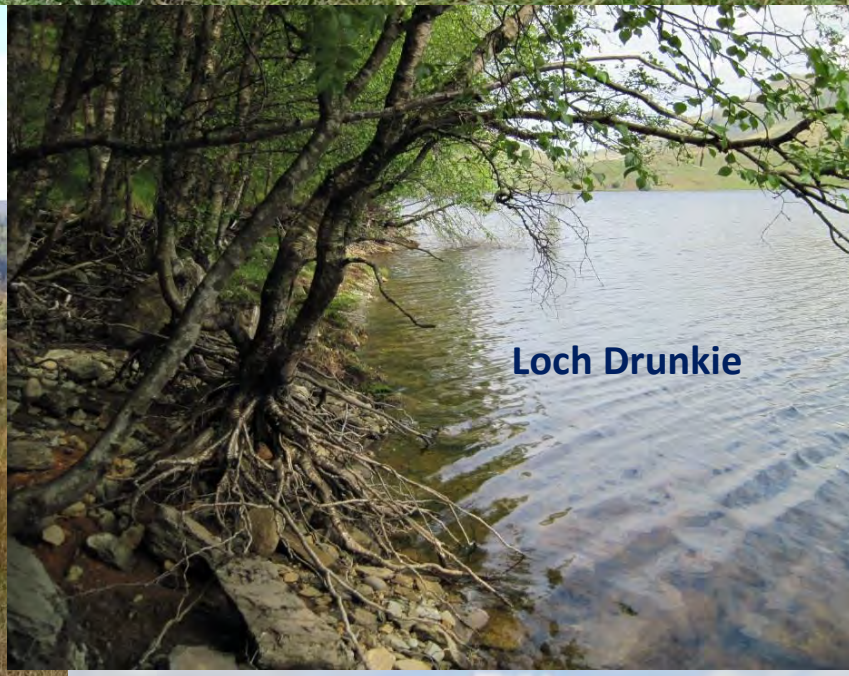
Glen Finglas Reservoir -
8m drawdown

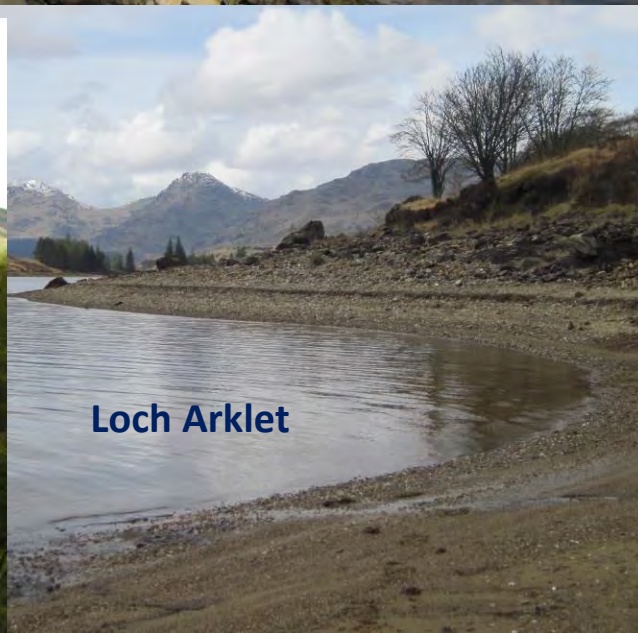
Loch Katrine -
1.6m drawdown

Loch Chon -
1m drawdown
(unregulated)



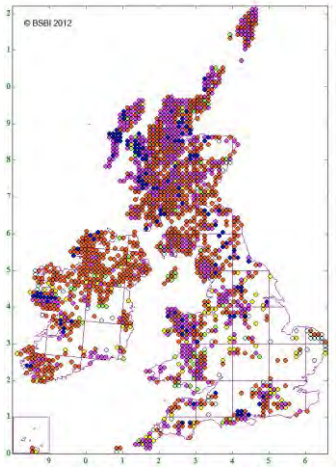
Hydrology and Ecology – the "So what"





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



STRANDPRYL., LITTORELLA UNIFLORA (L) ASCHERS

(data.nbn.org.uk).#sthash.sdo1l1i2.dpuf

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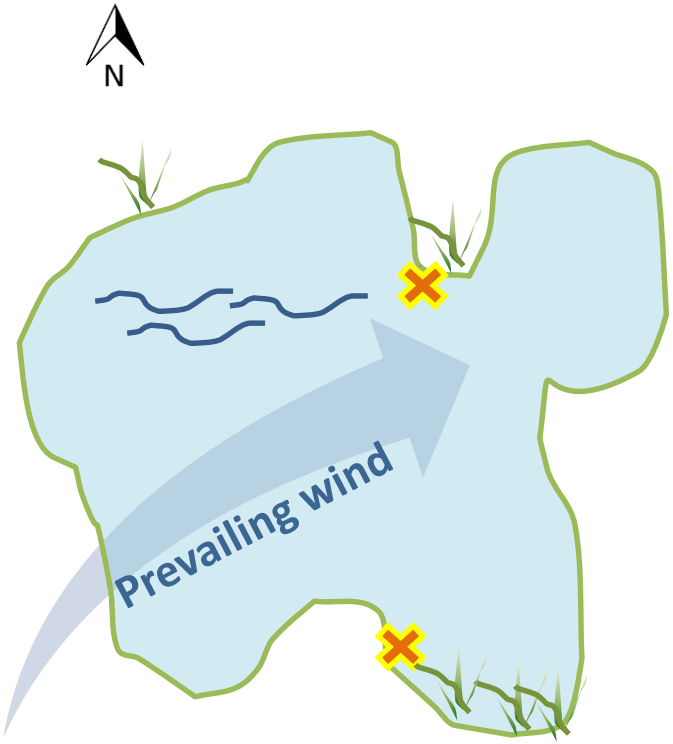
Research questions

- **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**

Aim

**Determine if biological monitoring,
focused on an individual plant, can improve detection of hydromorphological impacts**

Method



X 10 lakes with varying water level regimes & fertility

Survey stations vary with exposure

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)

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

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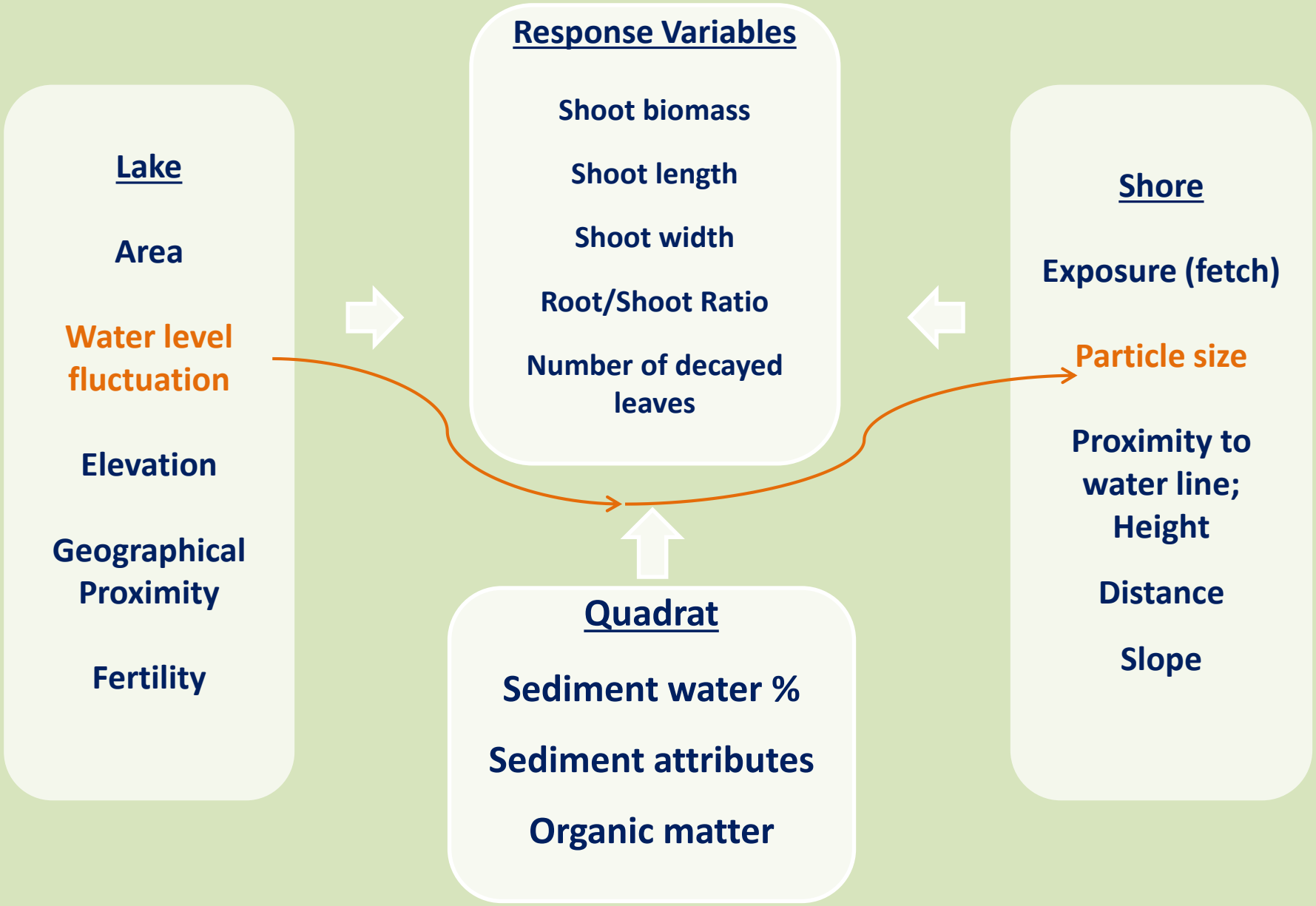
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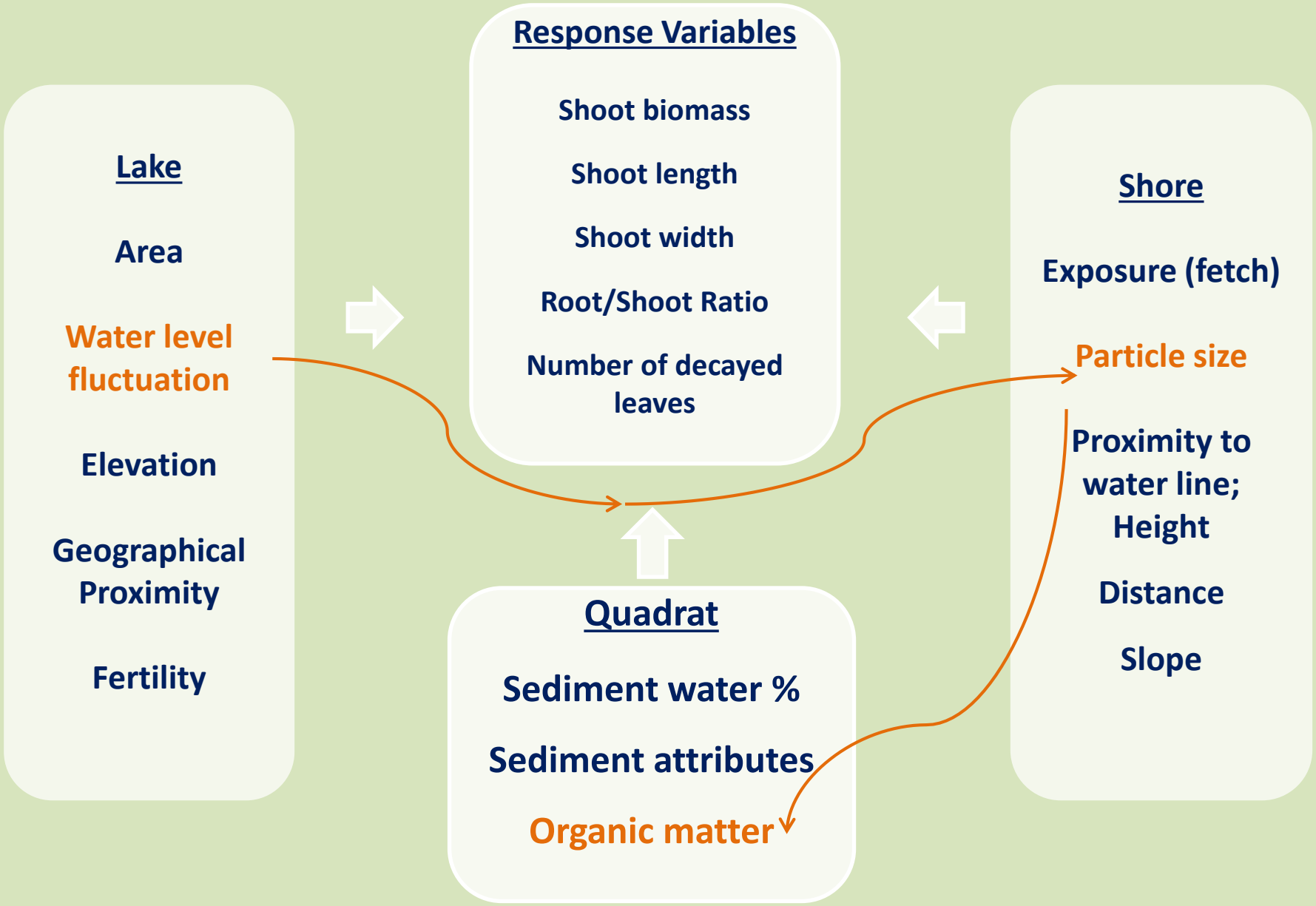
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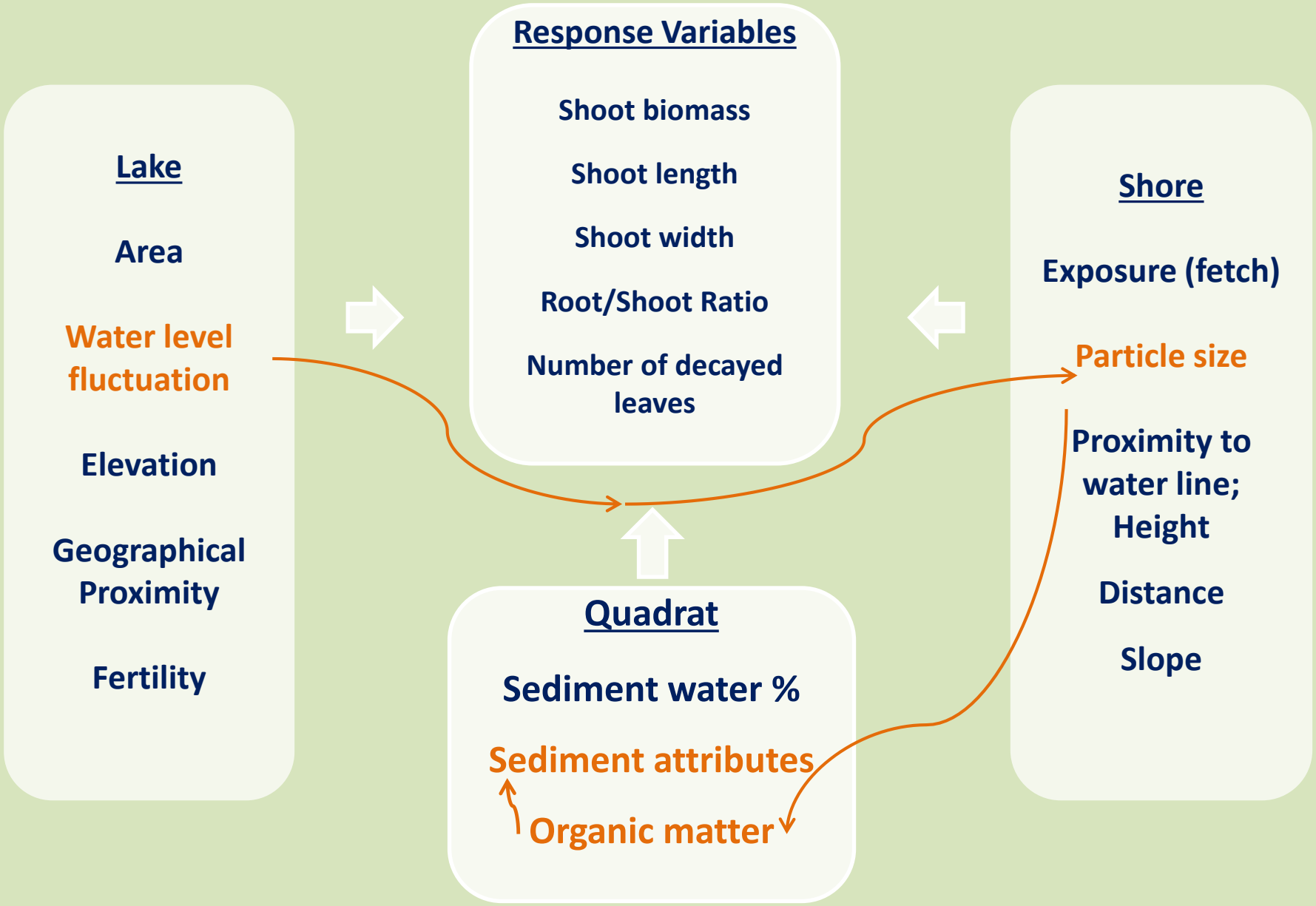
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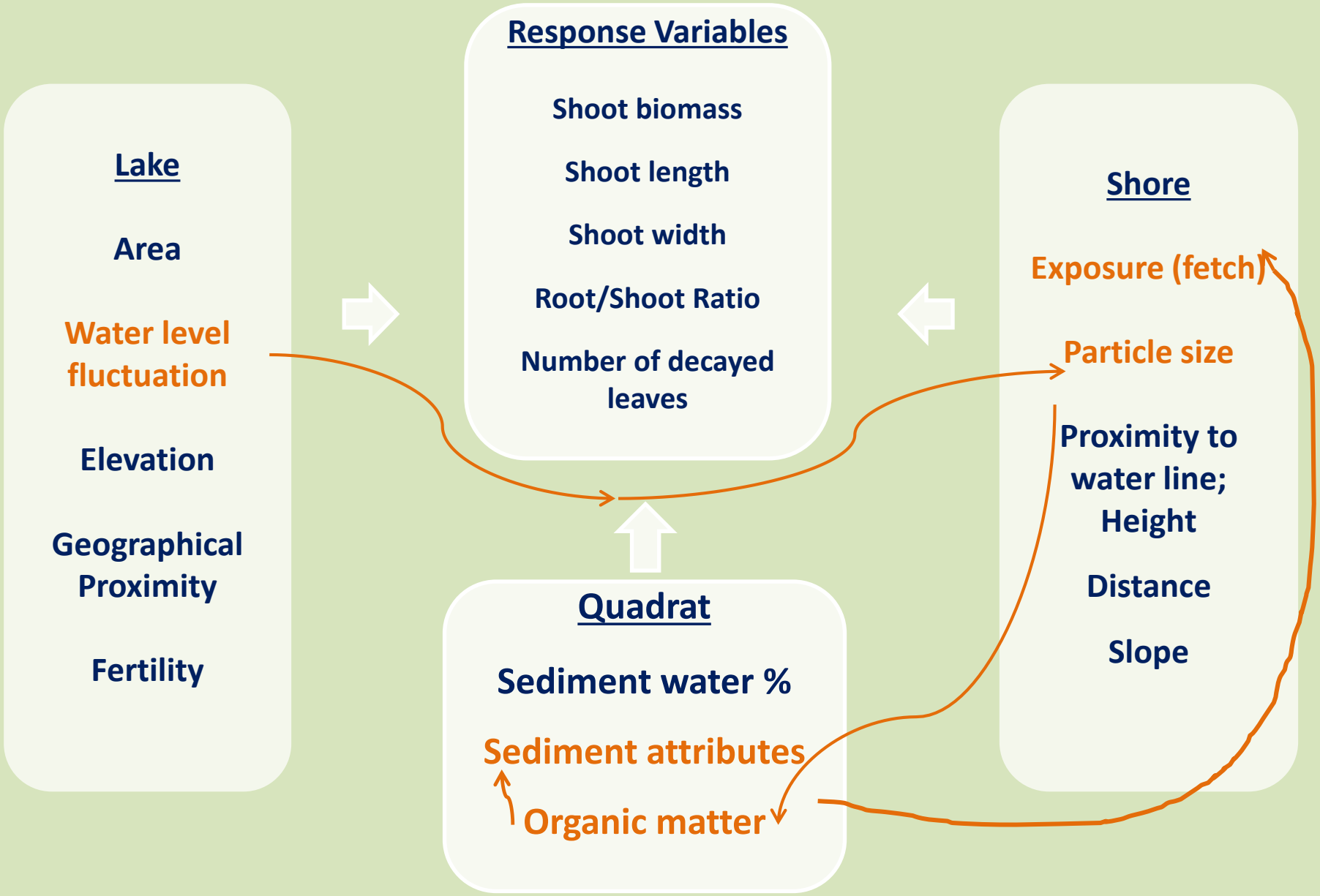
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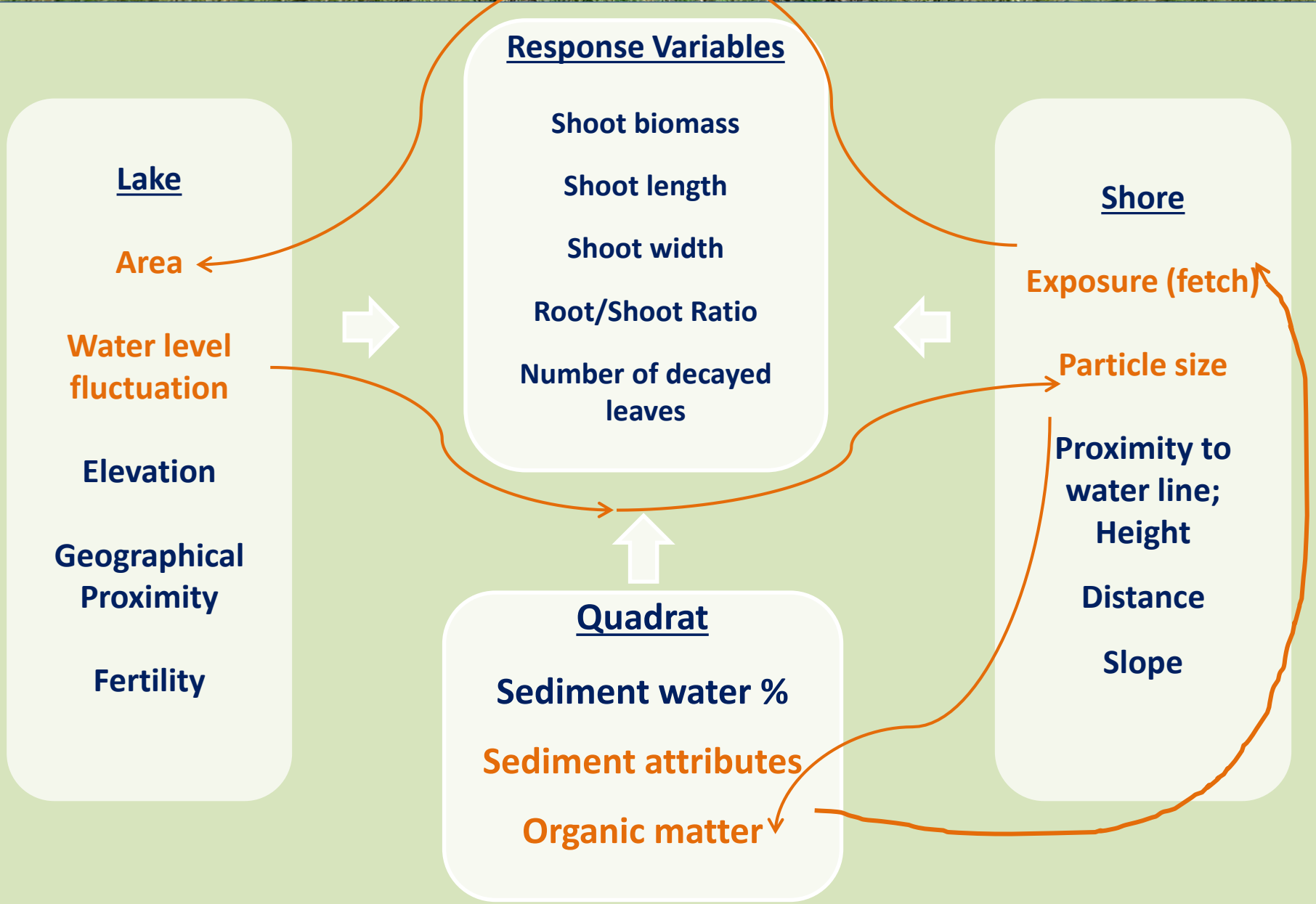
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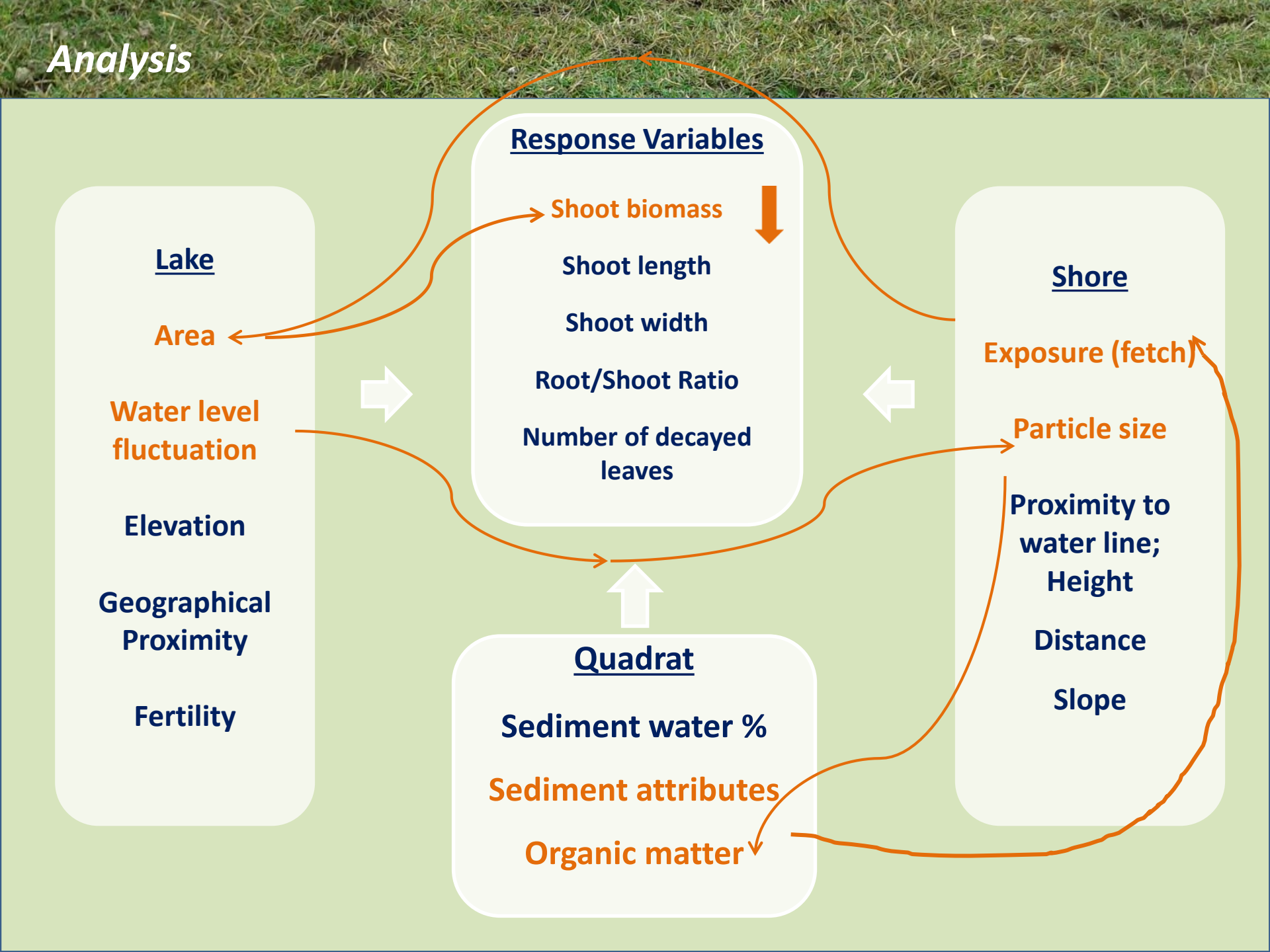
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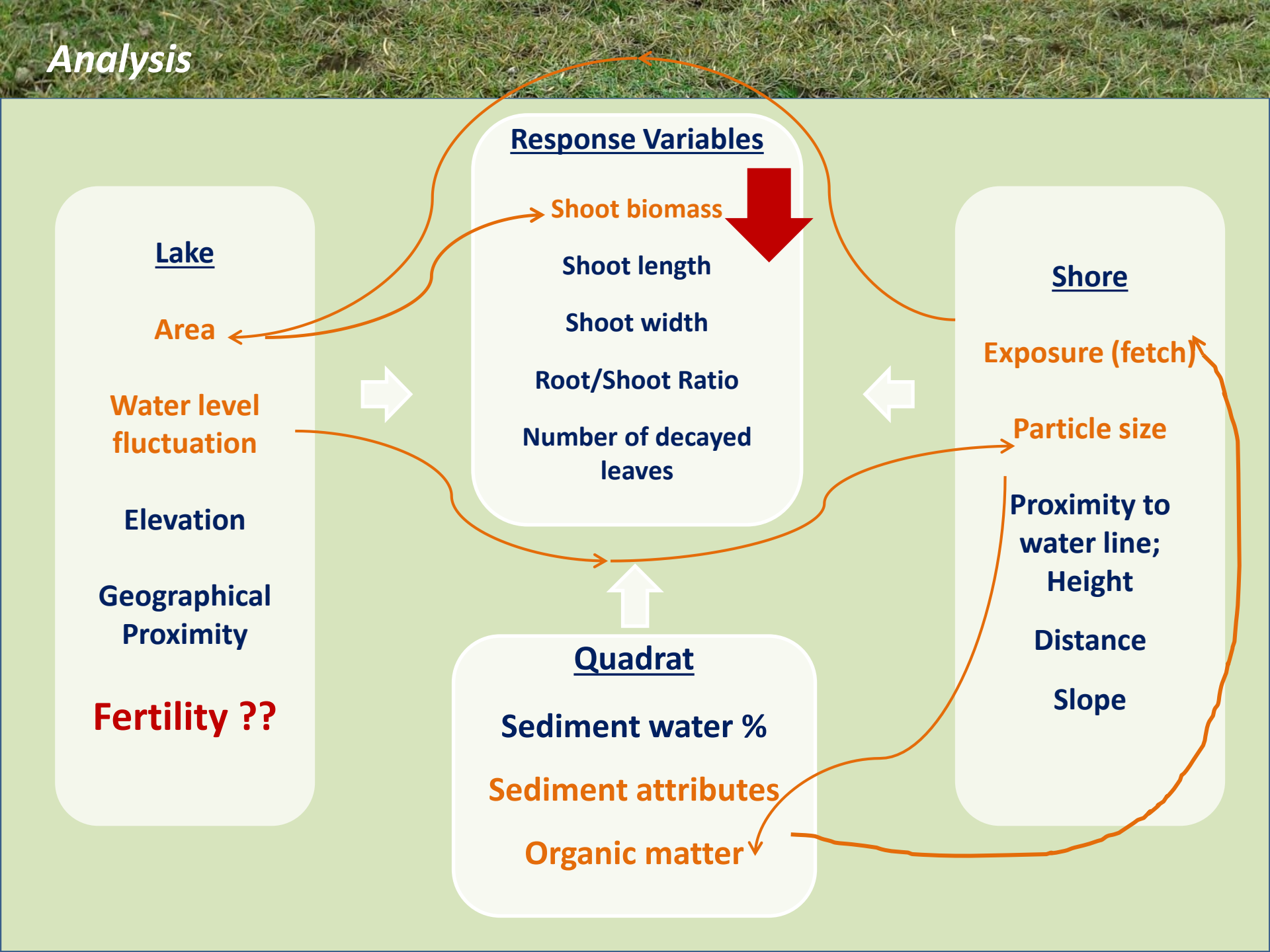
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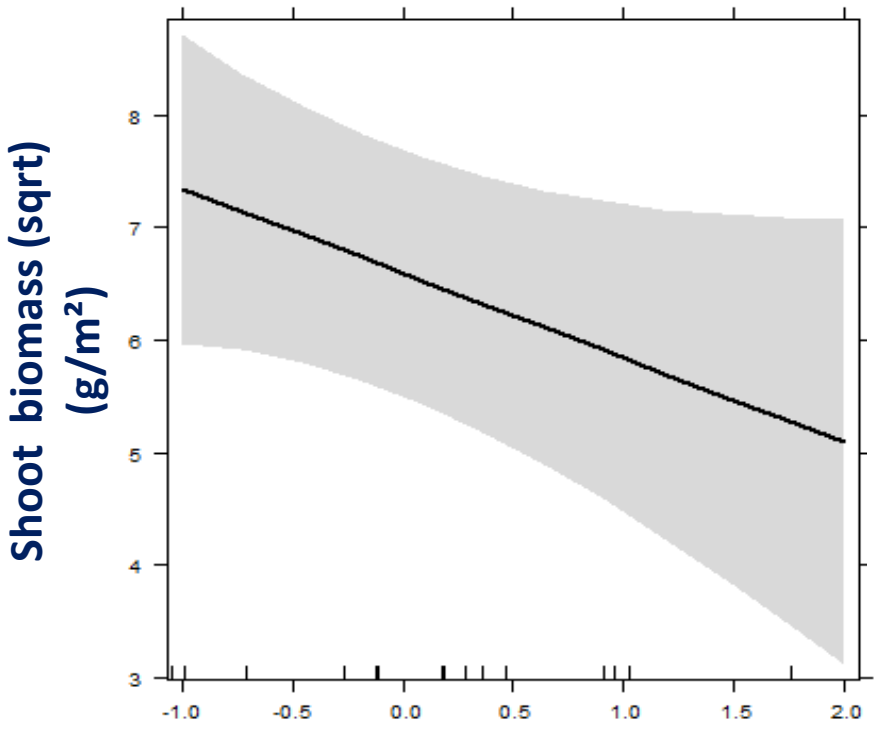
Sediment attributes
Organic matter

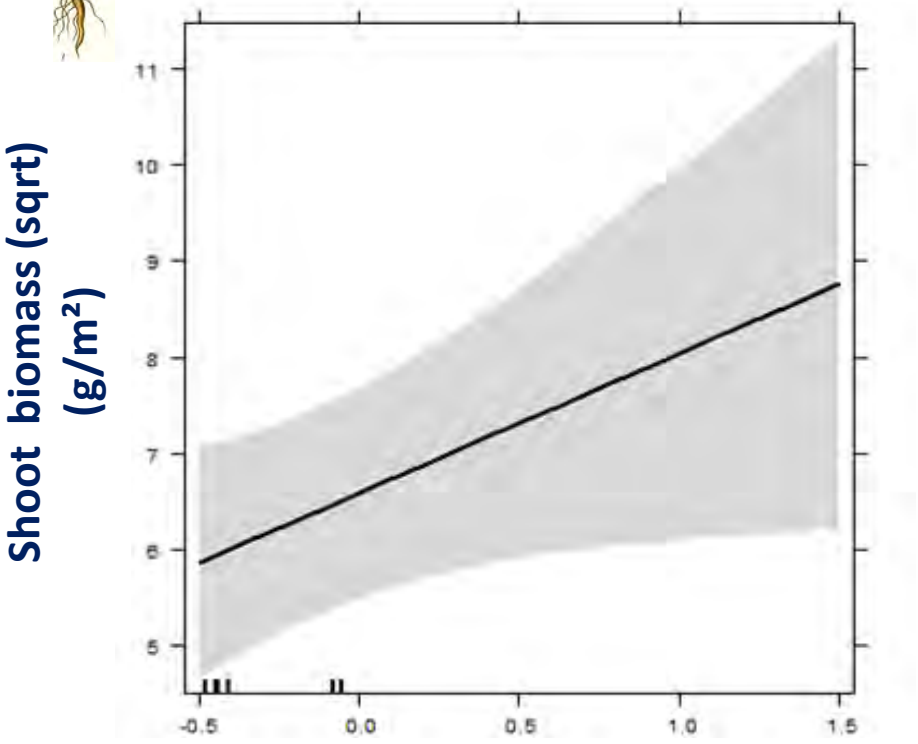
Analysis

Predictor / Response	Water weight %	Water Level range	Shore particle size	Fetch	Area	Distance from water line	Slope from water line	Variation explained (%)
Shoot biomass			1 ↓		2 ↑			34-40%
Shoot length	1 ↑	2 ↑						27-30%
Shoot width	1 ↑						2 ↓	23-32%
Root/Shoot Ratio	2 ↓	1 ↑						15-21%
Number of decayed leaves				2 ↓		1 ↑		40-43%

Shoot biomass decreases with finer shore sediments and reduced lake area

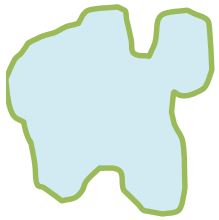
Shoot biomass





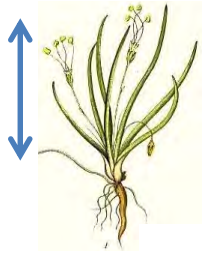
Shore particle size (avg)

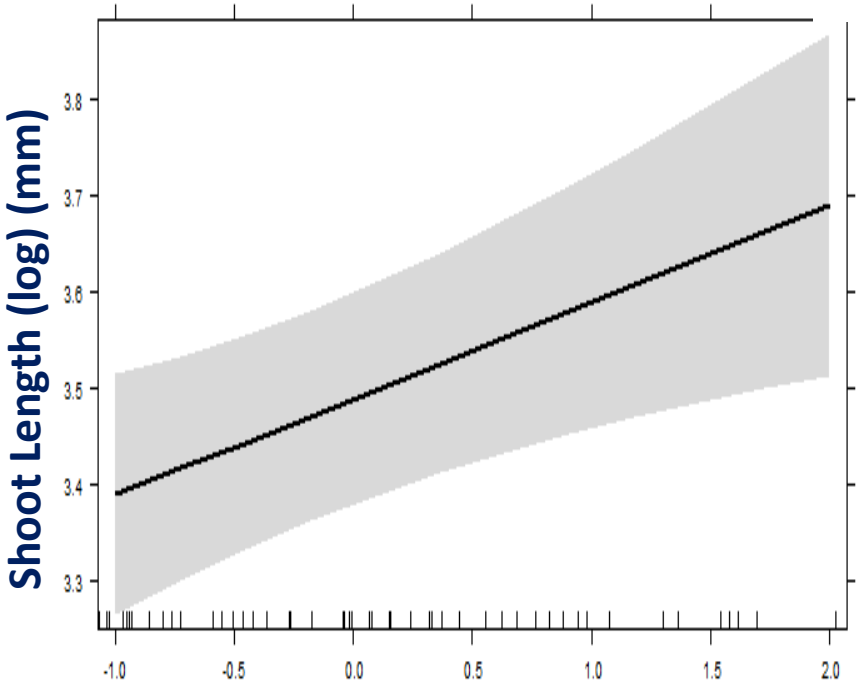
Lake area (km²)



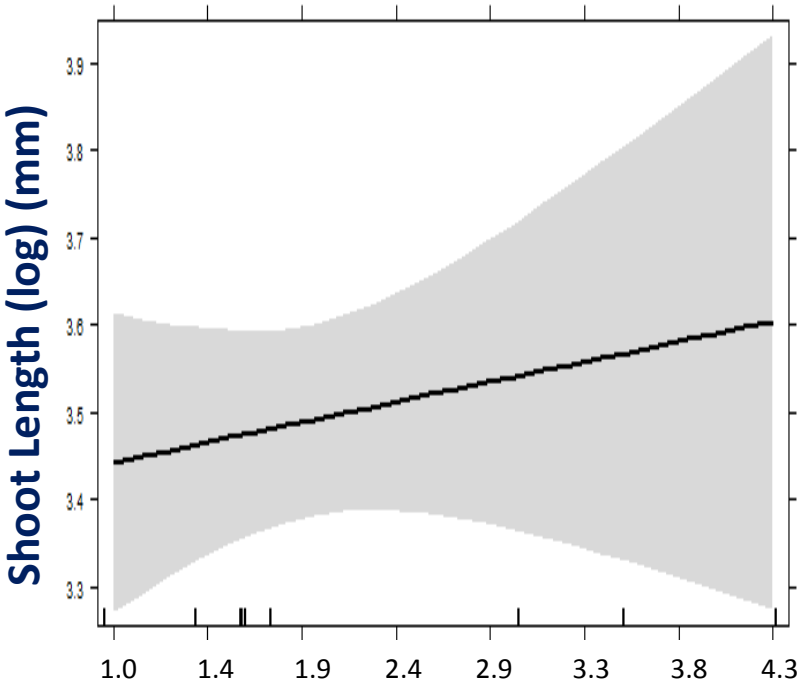
Shoot length increases with sediment water and water level range

Shoot length





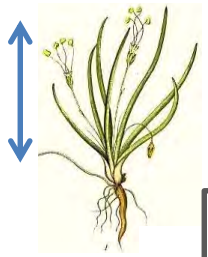
Sediment water weight (std)

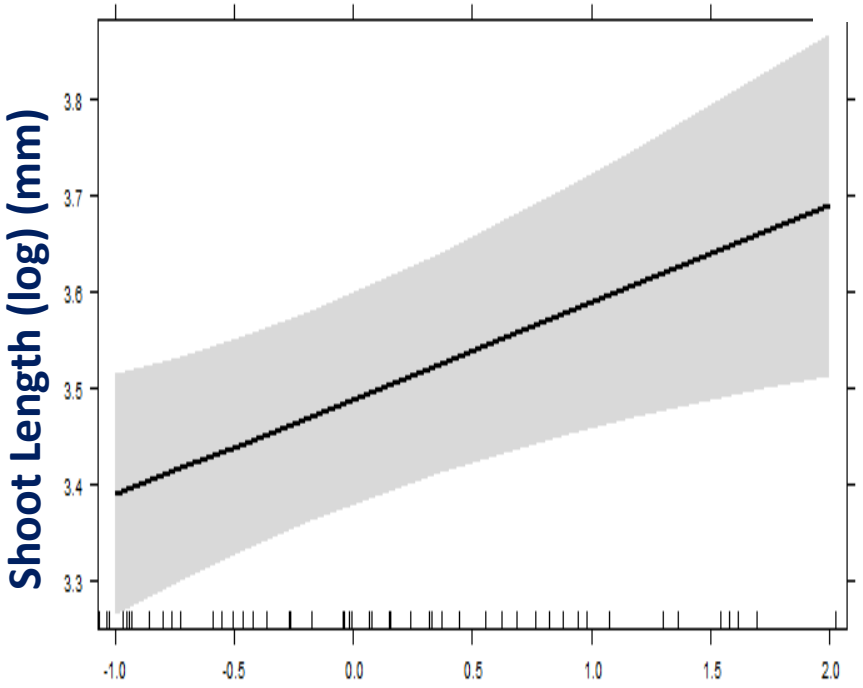


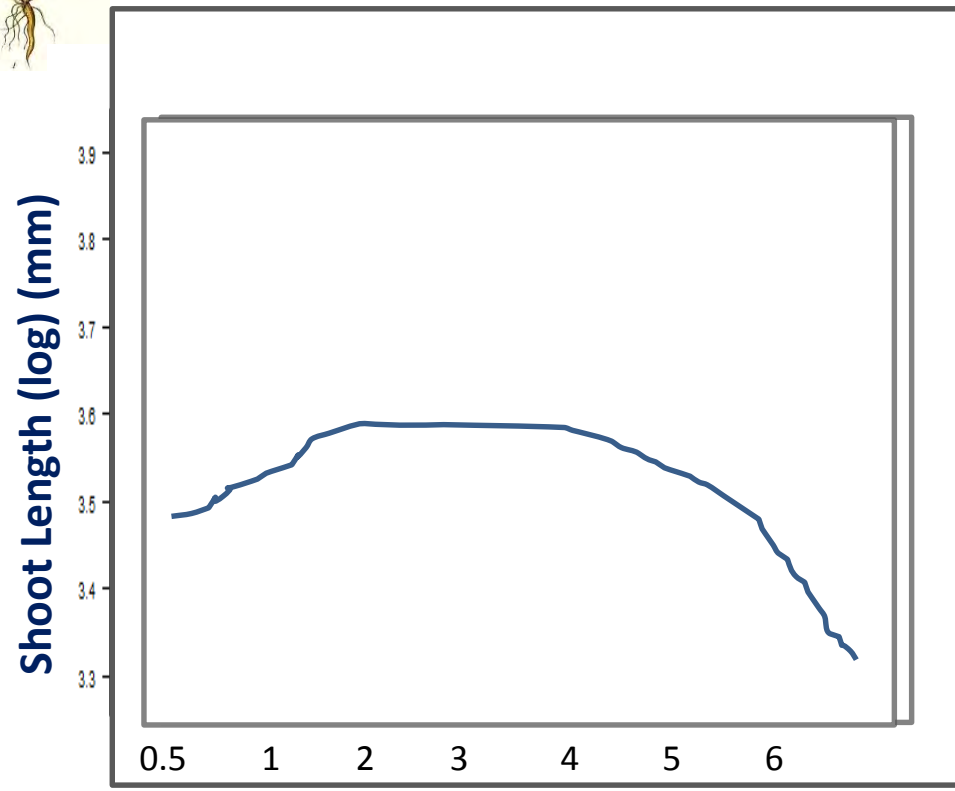
Water level fluctuation (m)

Shoot length increases with sediment water and water level range (up to 5m ?)

Shoot length

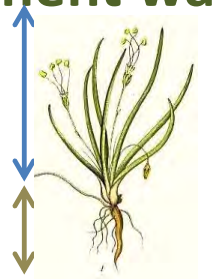


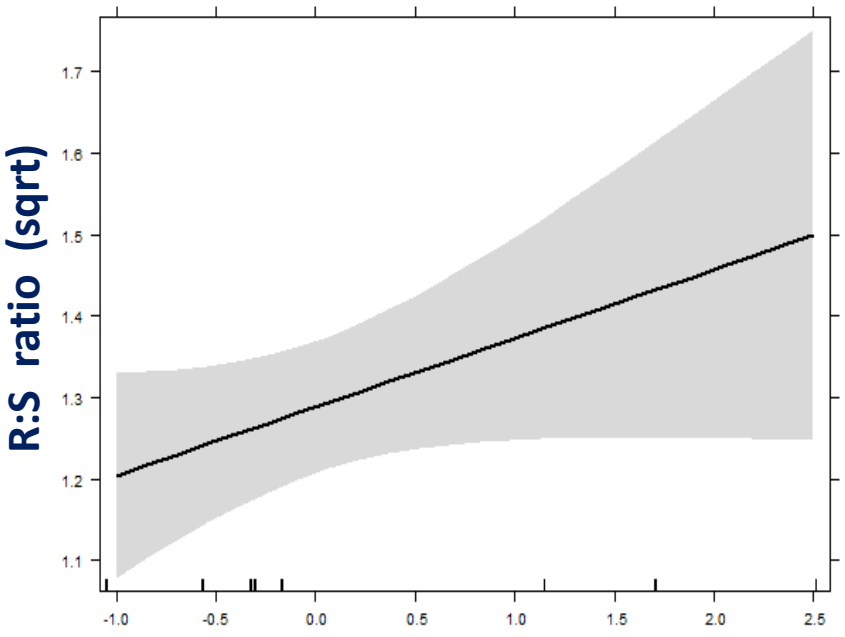




R:S ratio increases with mediated water level range and decreasing sediment water

Root/Shoot ratio





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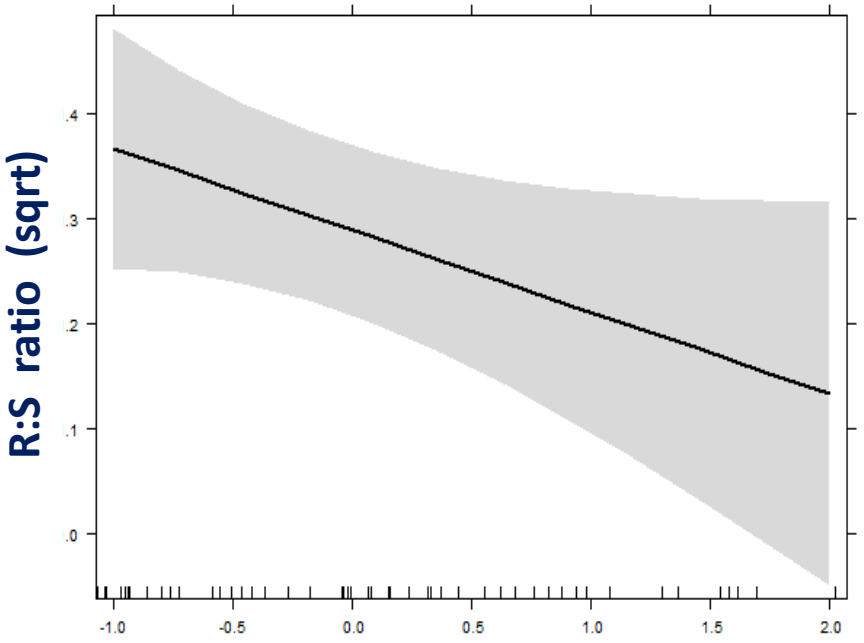
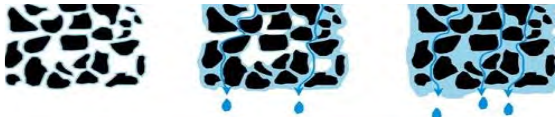
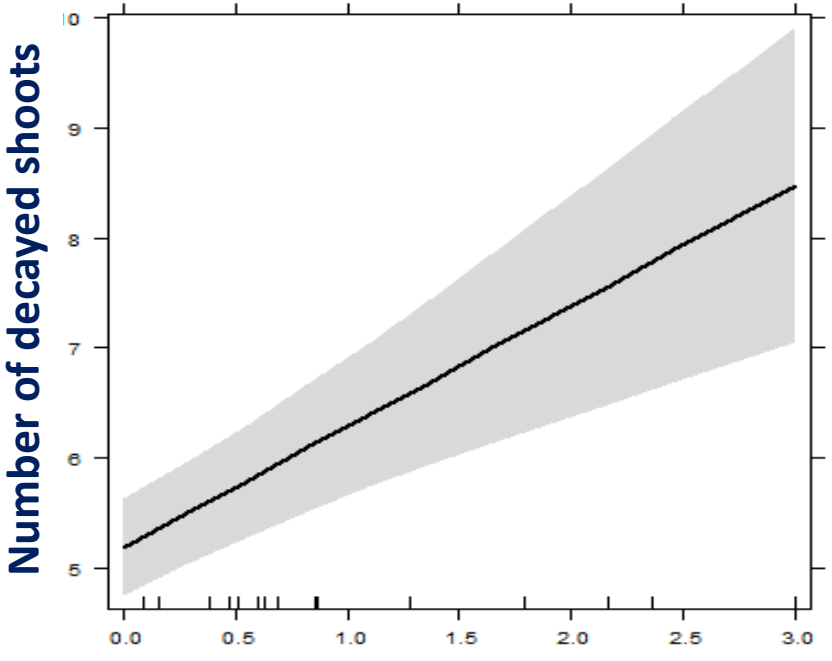


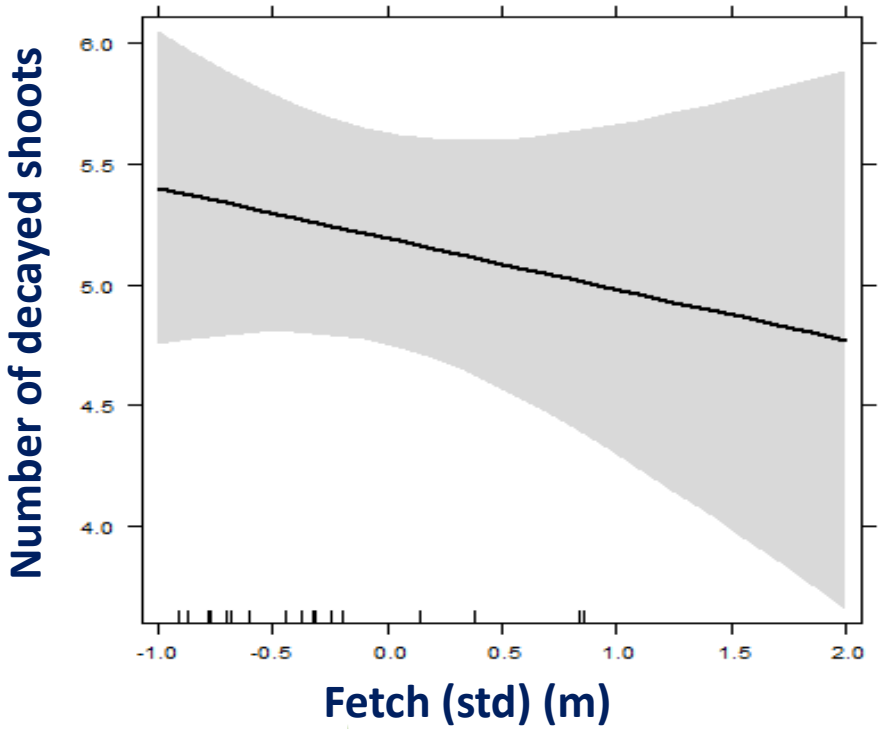
Sediment water weight (std)

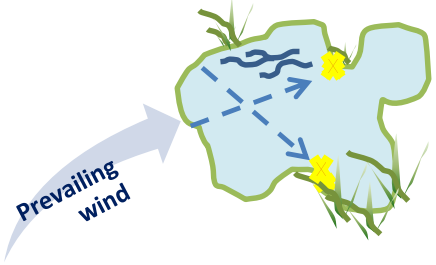


Number of decayed shoots increase farther from the water line and with lower wind/wave exposure

Decayed shoots







Lake habitat factors are interrelated and in turn affect *Littorella uniflora* morphology

Increased R:S

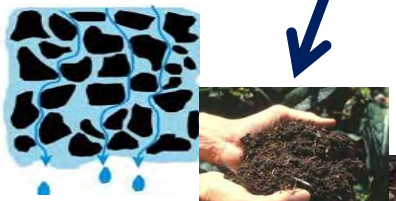
Shoot biomass

Lower leaf turnover?

Water level range

Sediment water
Organic matter
Shore sediment
Fetch / exposure

Littorella uniflora



Decreased R:S

Shoot biomass

Higher leaf turnover?

Water level fluctuations drive environmental attributes and directly affect *Littorella uniflora*

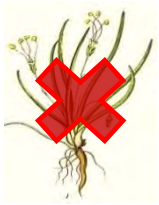
5m

Water level range

1m

Sediment water
Organic matter
Shore sediment
Fetch / exposure

Littorella uniflora



Absent > 5m

Increased R:S

Shoot biomass

Lower leaf turnover?

Decreased R:S

Shoot biomass

Higher leaf turnover?

Future work

- Interactive effects;
  - disturbance
  - stress
  - resources
- Periodicity of water level fluctuations
  - frequency
  - duration
  - seasonality
- Structural Equation Modelling

and more data!

Anwên Bill

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Thank you!

Anna Doeser *Duncan Dowie* *Alan Law*

Megan Layton *Rory Paterson* *Zarah Pattison*

Jeroen Minderman

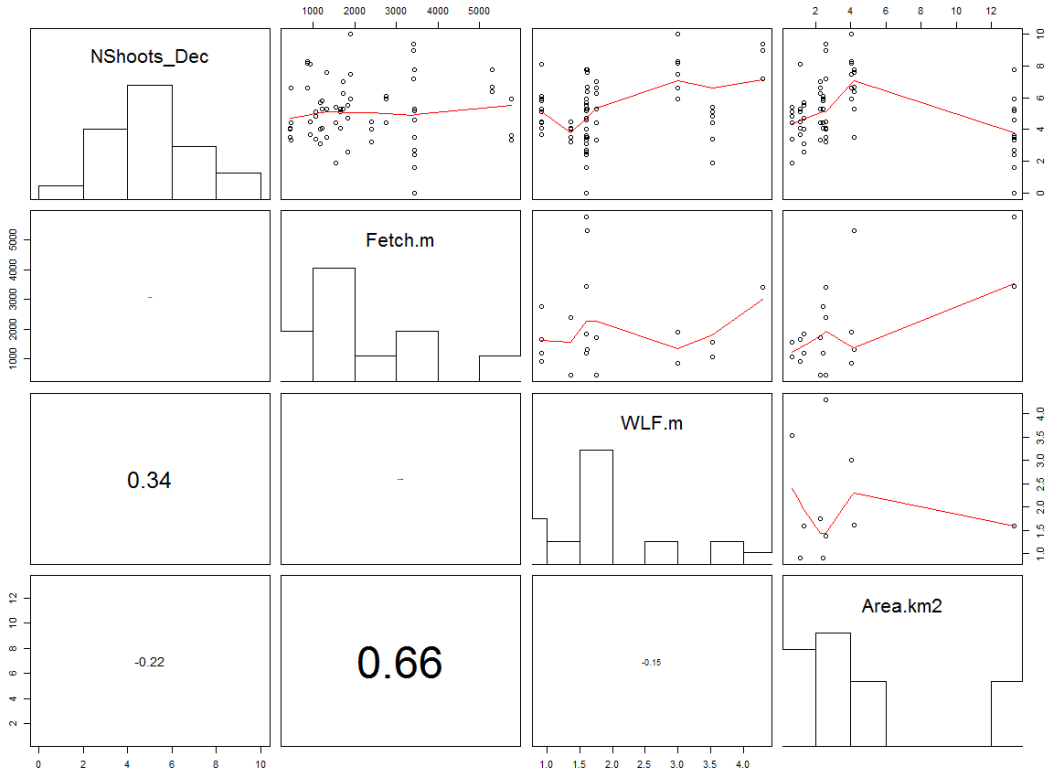
Littorella uniflora (L.) Asch.

Lake variables

Area km

Collinear

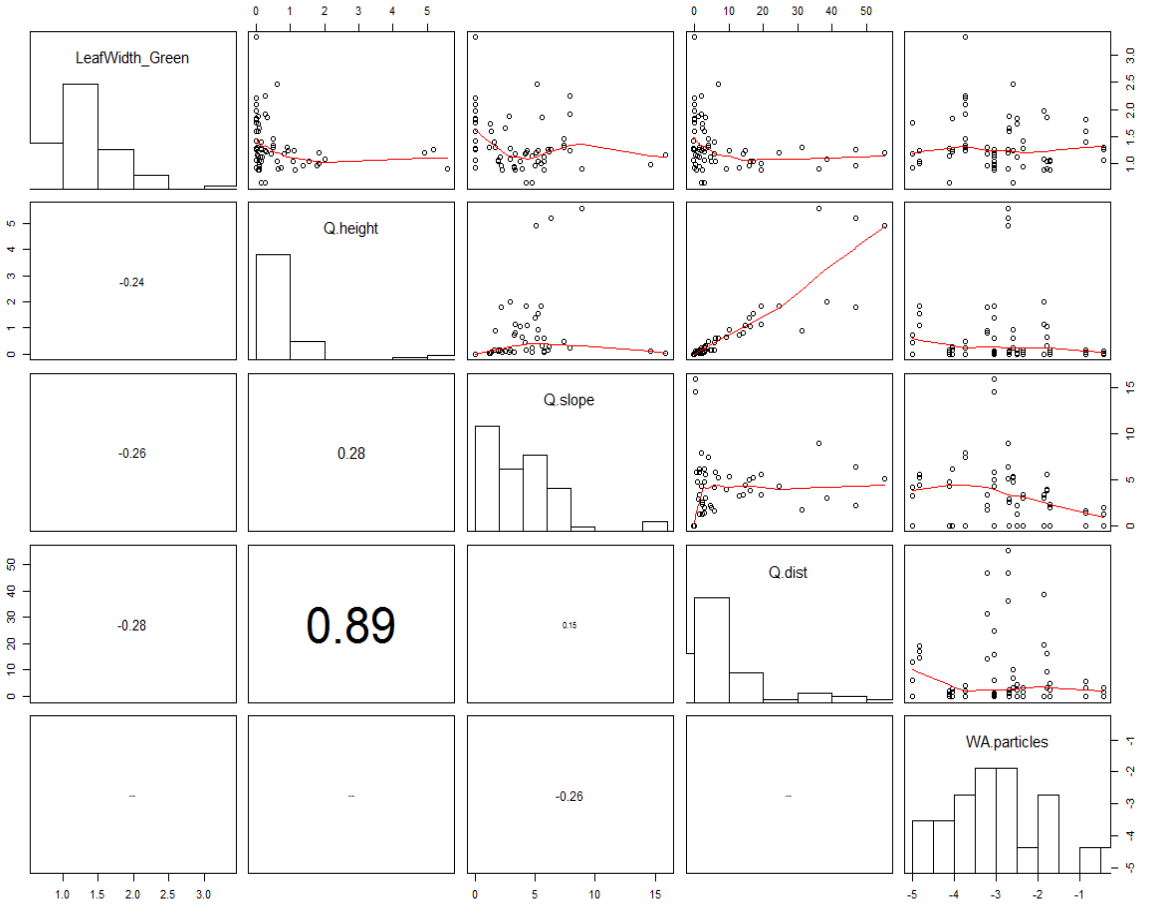
Fetch (m)



Littorella uniflora (L.) Asch.

Lake variables

Q.Height &
Q.distance



Littorella uniflora (L.) Asch.

Morphological

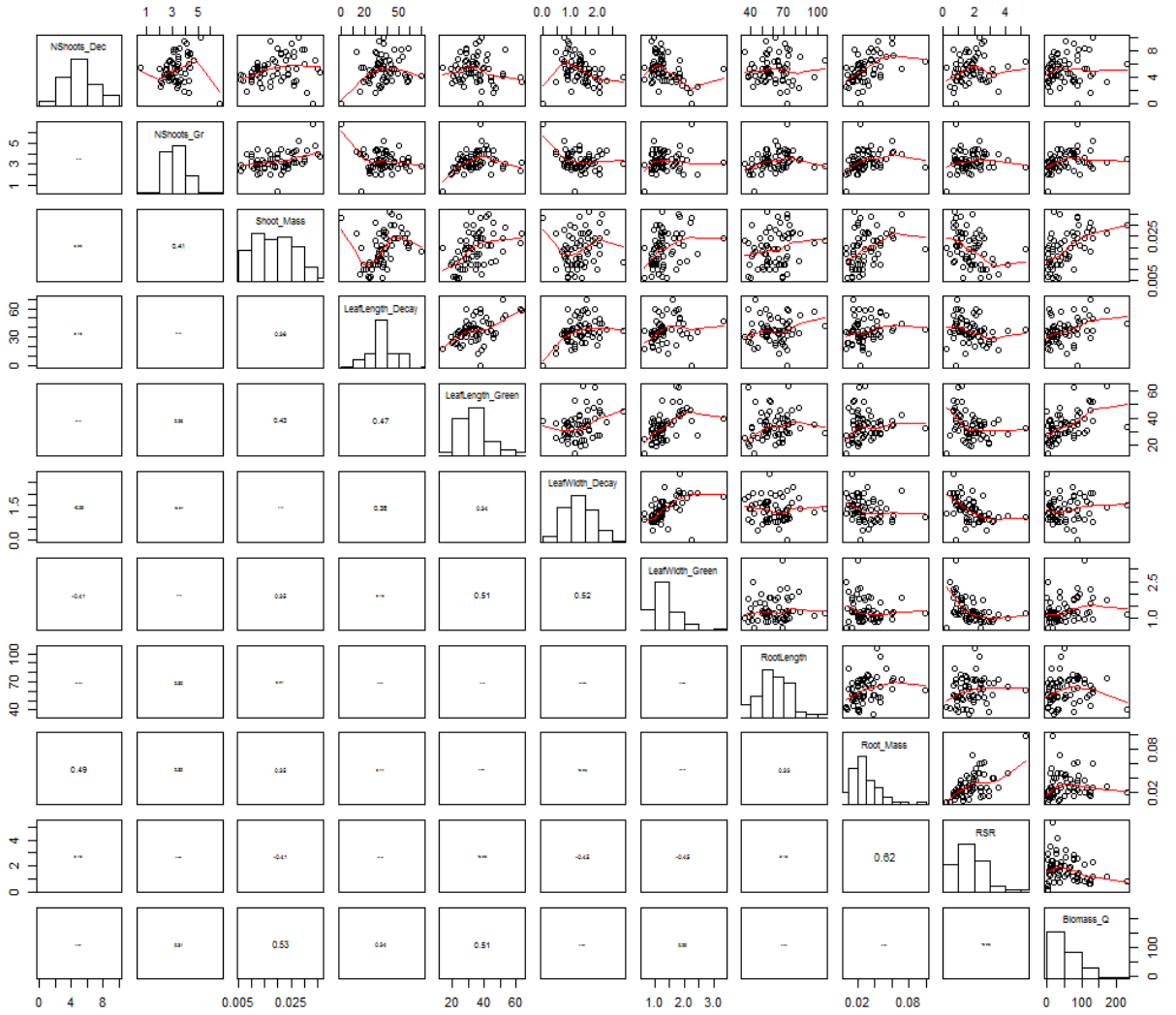
Root Mass and RSR 0.62 so >2.5vif

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.

Water weight %

Collinear

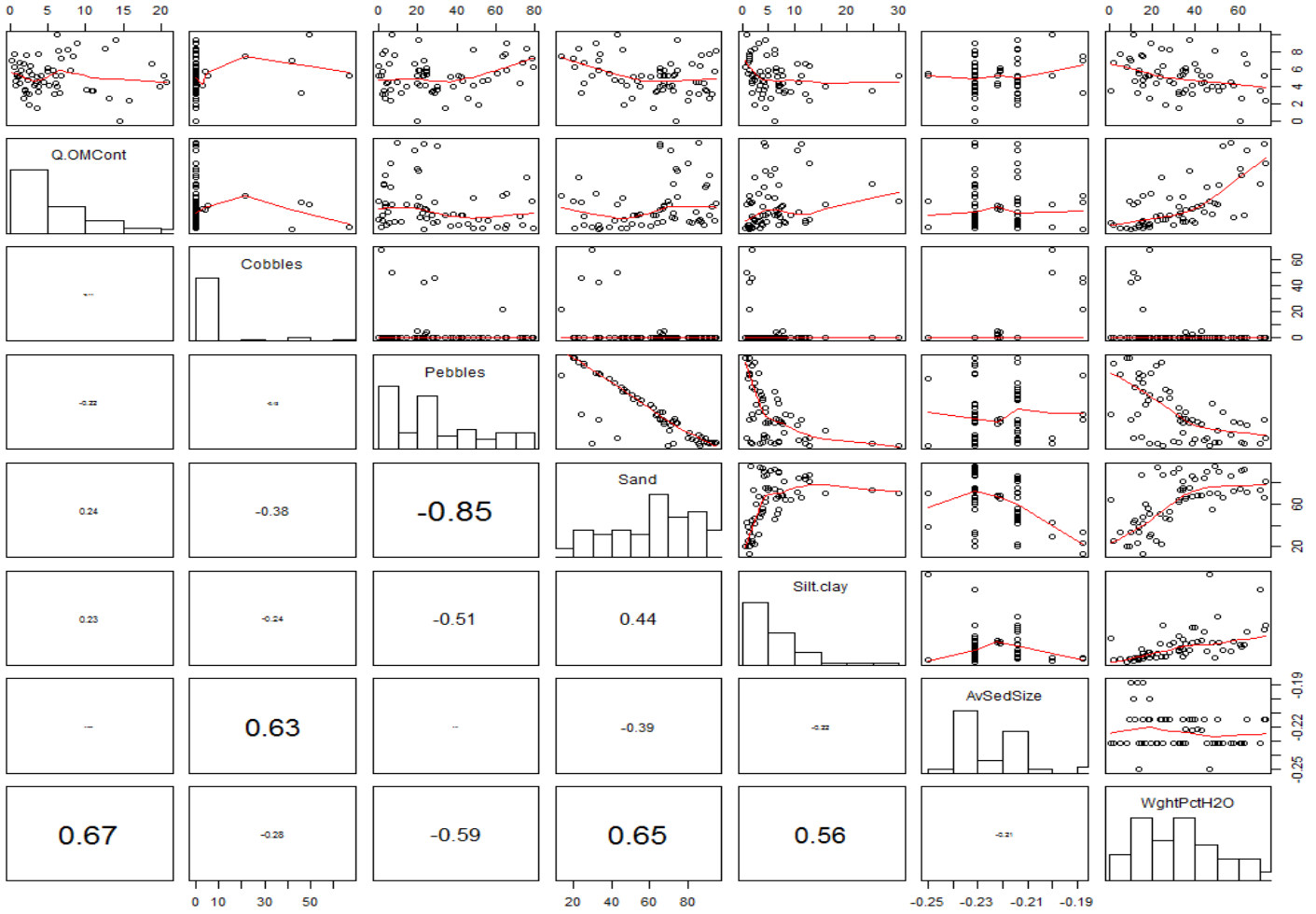
OM content

Pebbles

Sand

Silt/clay

Nutrient variables



Water level regulation

Lake water resource use	Extent of water level change
Hydroelectric power Consumption	1-30m
Flood prevention Industry Irrigation Recreation Transportation	1-12m
Natural lakes (2-3m) Waste water deposits Fisheries Aesthetics/Tourism	1-3m

Lednock- 9m drawdown

Glen Finglas - 5m drawdown

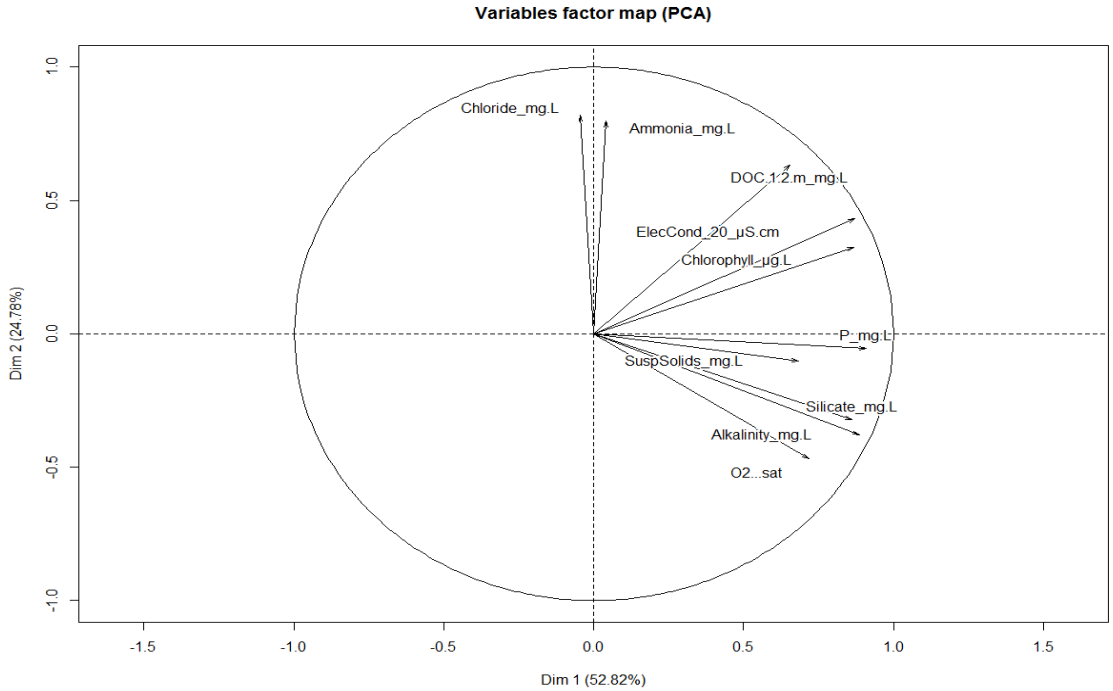
Loch Chon - unregulated

Model response	Water weight %	WLF	Shore particle size	Fetch	Area	Distance from water line	Slope from water line	NH3	Variation explained (%)
Shoot biomass	3 ↑	4 ↑	1 ↓		2 ↑				**34-40%**
Shoot length	1 ↑	2 ↑						3 ↓	**27-30%**
Shoot width	1 ↑				3 ↑		2 ↓		**23-32%**
Root/Shoot Ratio	-ve 2 ↓	+ve 1 ↑						3 ↓	**15-21%**
Number of decayed leaves	-3 ↓			2 ↓		1 ↑		4 ↓	**40-43%**

Littorella uniflora (L.) Asch.

Sampling

Nutrient variables



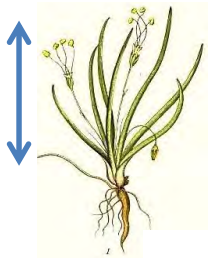
Dim.1

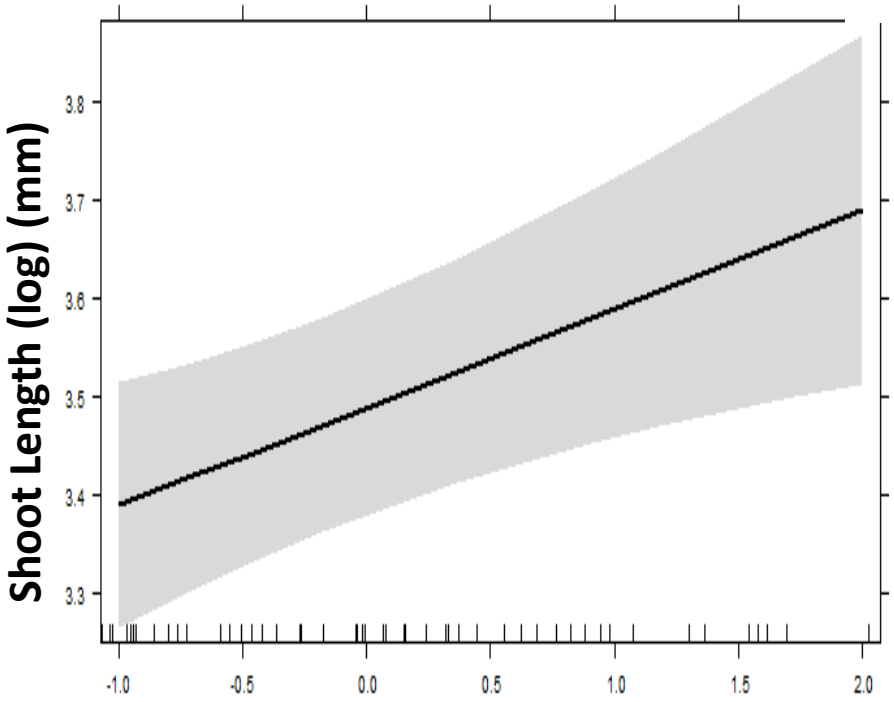
	correlation	p.value
ElecCond_20_µS.cm	0.8923008	0.0005159003
P_mg.L	**0.8881677**	**0.0005966795**
Chlorophyll_µg.L	0.8765492	0.0008732151
Alkalinity_mg.L	0.8683225	0.0011186539

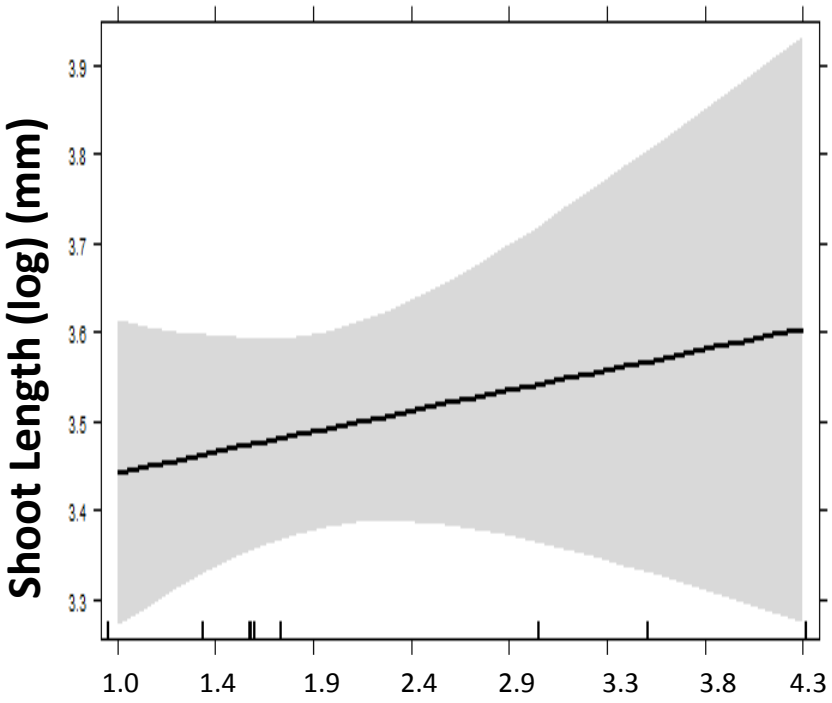
$Dim.2

	correlation	p.value
Chloride_mg.L	0.8118613	0.004338277
Ammonia_mg.L	**0.8008290**	**0.005371858**

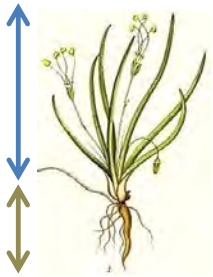
Shoot length

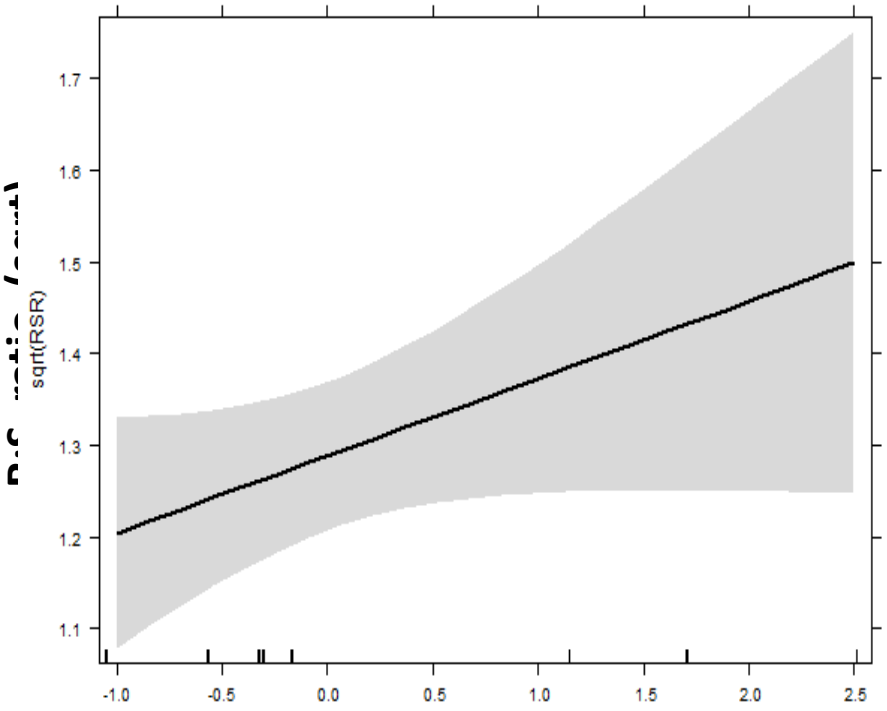




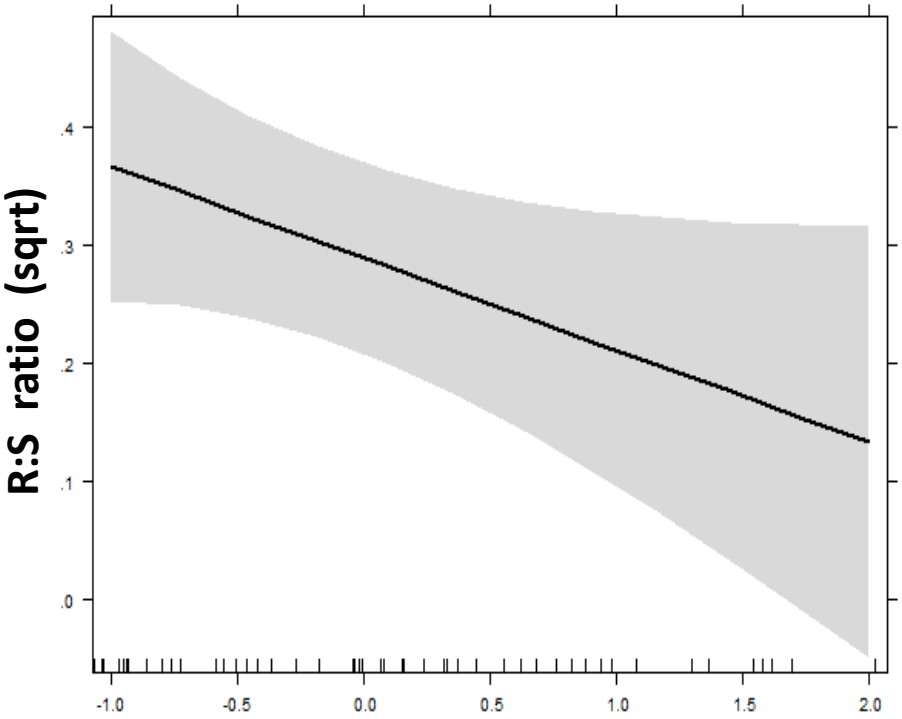


Root/Shoot ratio



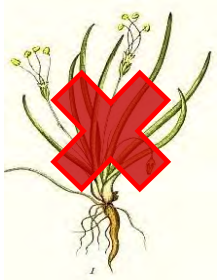


Water level fluctuation (m)



Sediment water weight (std)

Summary



Absent +5m

5m

4m

Water level range

3m

2m

1m

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

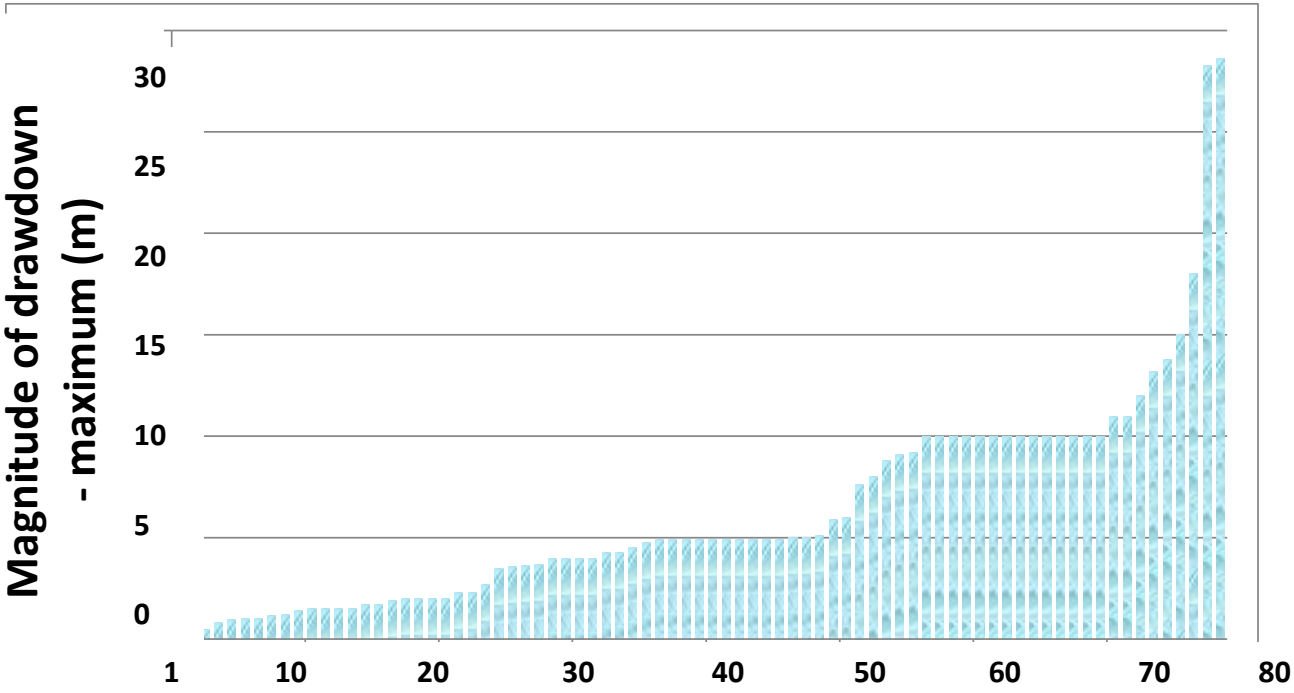
Sediment water
Organic matter
Shore sediment size

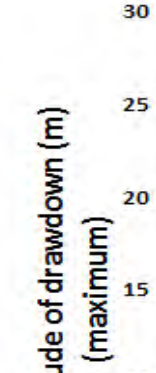
Littorella uniflora

- **Decreased R:S**
- **Shoot biomass**
- **Higher leaf**

Analysis

Predictor / Response	Water weight %	Water Level range	Shore particle size	Fetch	Area	Distance from water line	Slope from water line	Variation explained (%)
Shoot biomass			1 ↓		2 ↑			34-40%
Shoot length	1 ↑	2 ↑						27-30%
Shoot width	1 ↑						2 ↓	23-32%
Root/Shoot Ratio	2 ↓	1 ↑						15-21%
Number of decayed leaves				2 ↓		1 ↑		40-43%


Magnitude of drawdown - maximum (m)
30
25
20
15
10
5
0
1
10
20
30
40
50
60
70
80


30
25
20
15
ude of drawdown (m)
(maximum)

i) Analysis of existing data sets with loch water levels and concurrent biological surveys

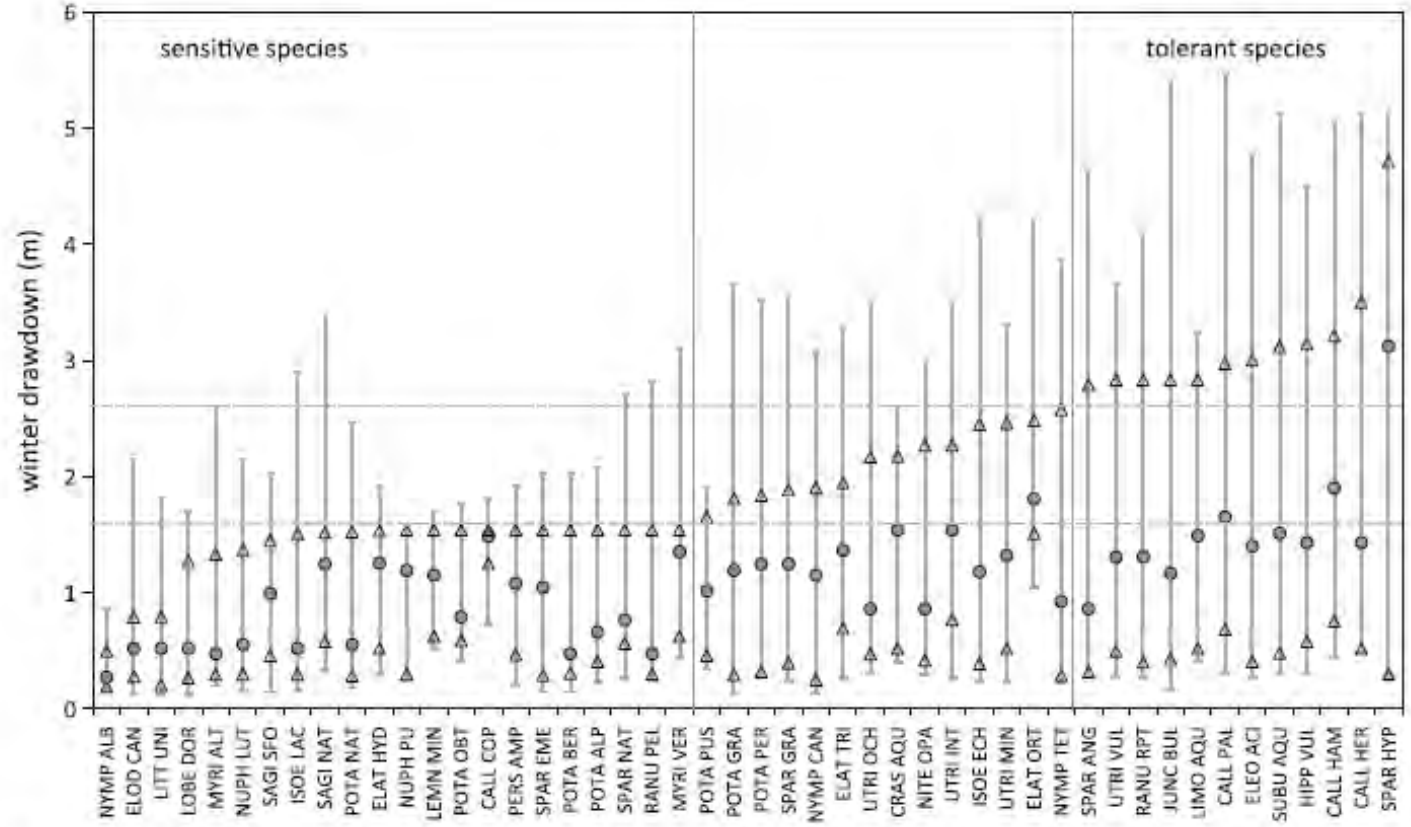


Fig. 3 Distribution of sensitive and tolerant species along a gradient of winter drawdown, based on Finnish, Swedish and Norwegian lakes. The graph includes 10, 25, 50, 75 and 90th percentiles. Species occurring in less than four lakes were excluded. The species were sorted by the 75th percentile. The thresholds for the sensitive and tolerant taxa, corresponding to winter drawdown values at 1.6 and 2.6 m, are indicated

(Mjelde et al., 2012)

Resource use

Extent of water level change

Shoreline modification

Hydroelectric power

Consumption

1-30m

Dams and retaining walls

Rip rap

Flood prevention
Industry
Irrigation
Recreation
Transportation

1-12m

Rip rap

Recreational beaches

Loch Lomond – recreation/consumption

Roads and retaining walls

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

1-4m

Grizedale Reservoir – consumption

Loch Shiel – unregulated
(Steven F Watson 2006)

UNIVERSITY OF STIRLING

SEPA Scottish Environment Protection Agency

Aim: Improve understanding of the empirical relationships between hydromorphological pressures & biological responses within lakes

Impacts

(Barbara Harmon)

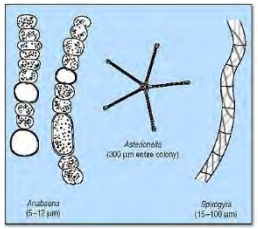
Littoral zone

Energy flow

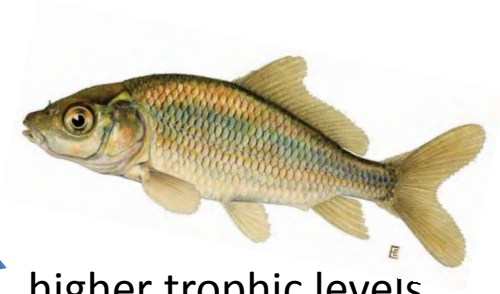
Pelagic

primary producers

microbial decomposers



benthic invertebrates



higher trophic levels

Hydrology and Ecology – the "So what"