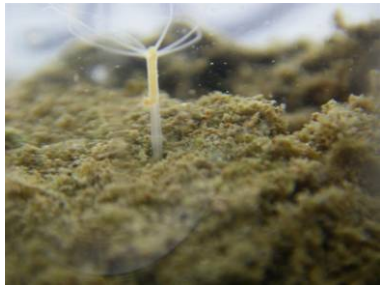
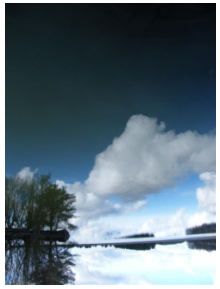
Using Phoslock® to control cyanobacteria in a shallow eutrophic Scottish reservoir - assessing its impact on sediment phosphorus pools

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Content:

I) Lake remediation

Scientific background

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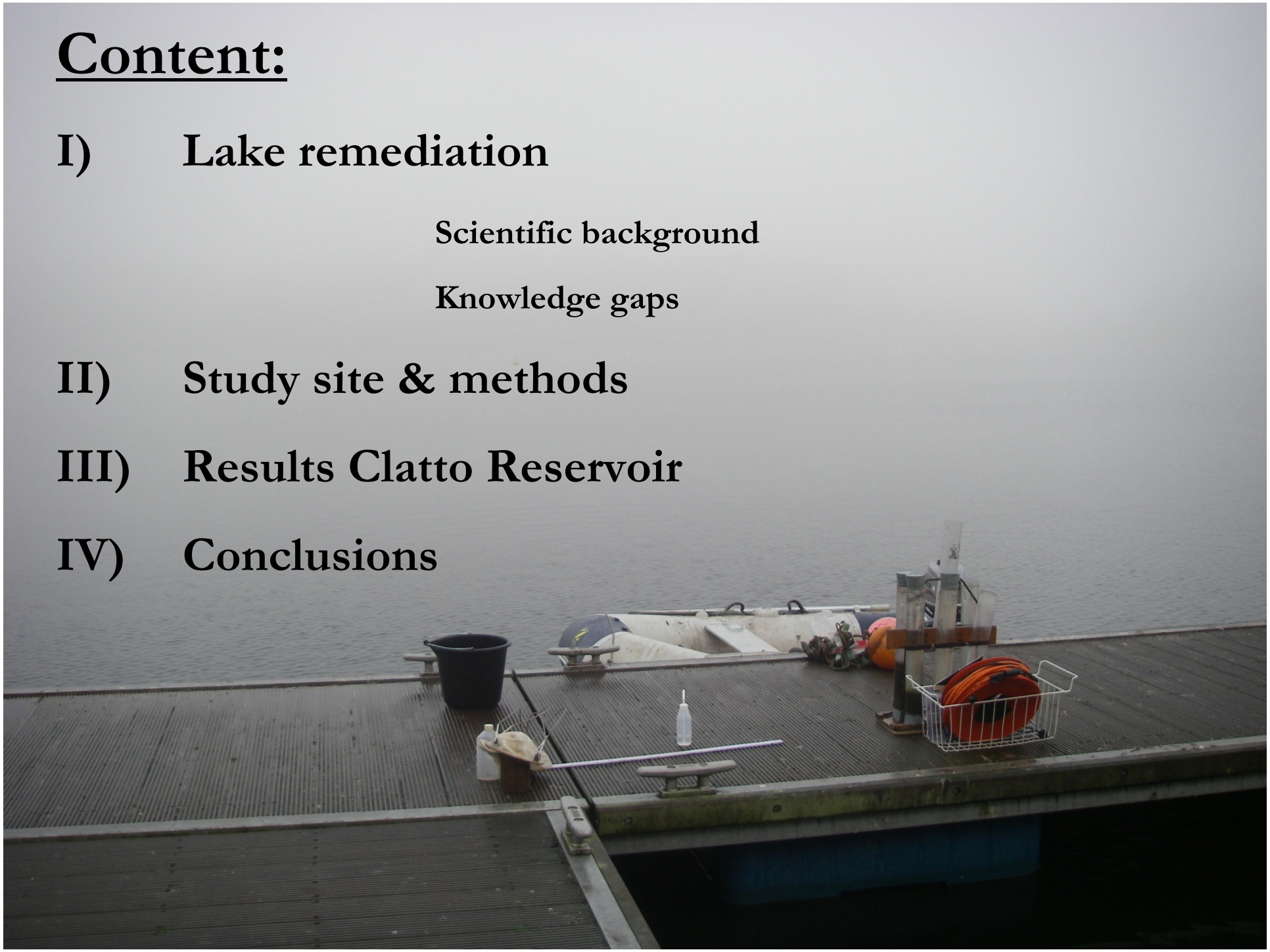

I) Scientific background

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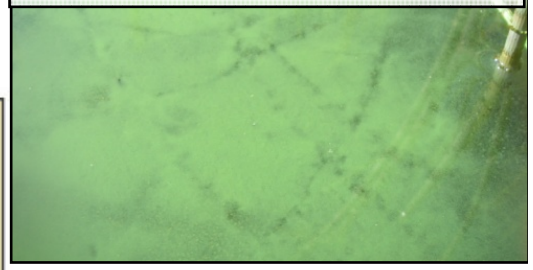
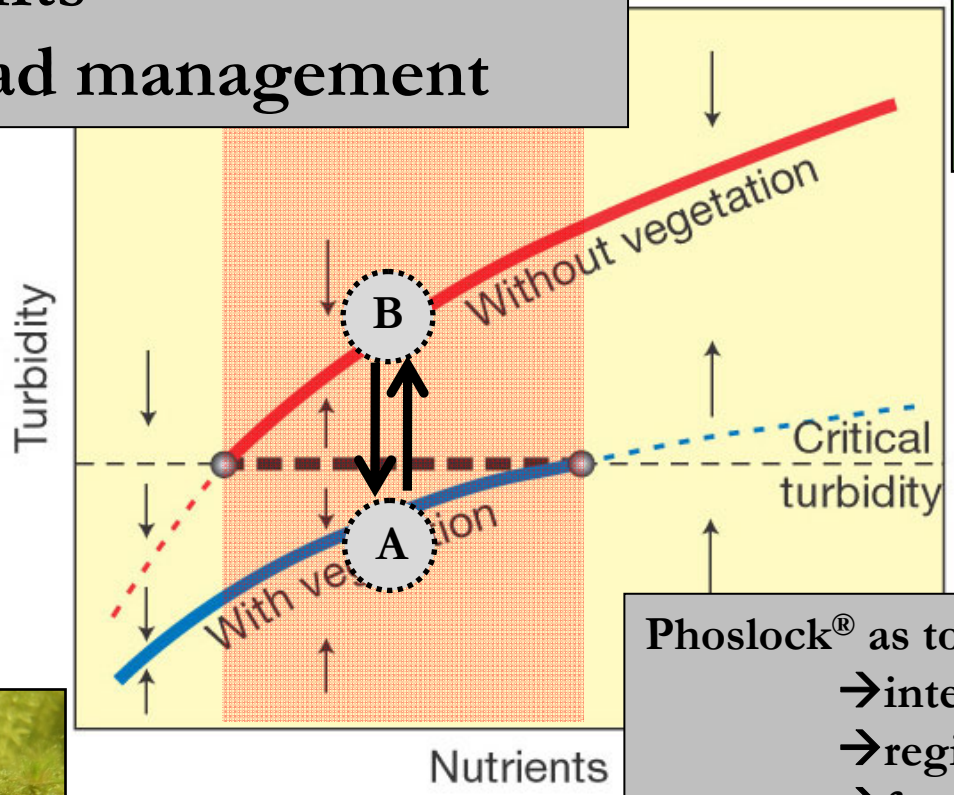
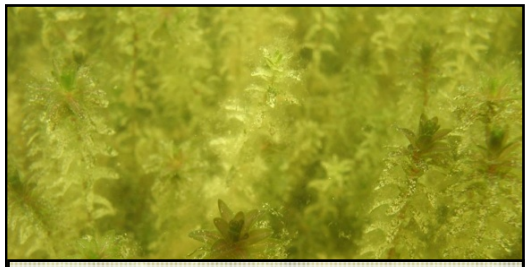
-Alternative stable states
-Regime shifts
-Internal load management

Phytoplankton dominance





Phoslock® as tool:
→intercept internal loading
→regime shift
→forced state change



Macrophyte dominance

Scheffer *et al.* (2001) Catastrophic shifts in ecosystems. *Nature*, 413, 591-596.

I) Knowledge gaps

1) *Where* is Phoslock® following a common application?

2) *How* does Phoslock® effect P pools?

3) *When* does Phoslock® alter P pools? Timing of application?

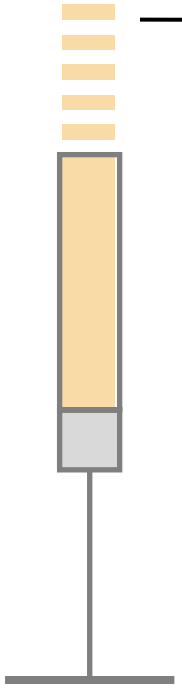
II) Study site & methods

Clatto Reservoir (Dundee, UK)

Area:	9.4 ha
Mean depth:	2.75 m
Max depth:	7 m

Water depth

Sediment depth



2 cm slices (0 – 10 cm depth)

Homogenized

Analyses of P pools/fractions

Elemental analyses (ICPOES, ICPMS)

Psenner *et al.*,1988 modified by Hupfer *et al.*, 1995

II) Study site & methods

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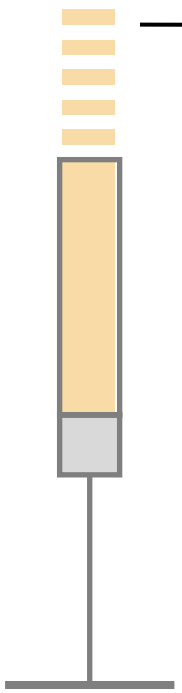
Sampling

05.02.2009 begin monitoring

02.03.2009 pre-application cores

04.03.2009 start application
06.03.2009 end application

03.04.2009 post-application cores



2 cm slices (0 – 10 cm depth)

Homogenized

Analyses of P pools/fractions

Elemental analyses (ICPOES, ICPMS)

Psenner *et al.*,1988
modified by Hupfer *et al.*, 1995

1) *Where* is Phoslock® following a common application?

III) Where is Phoslock®?

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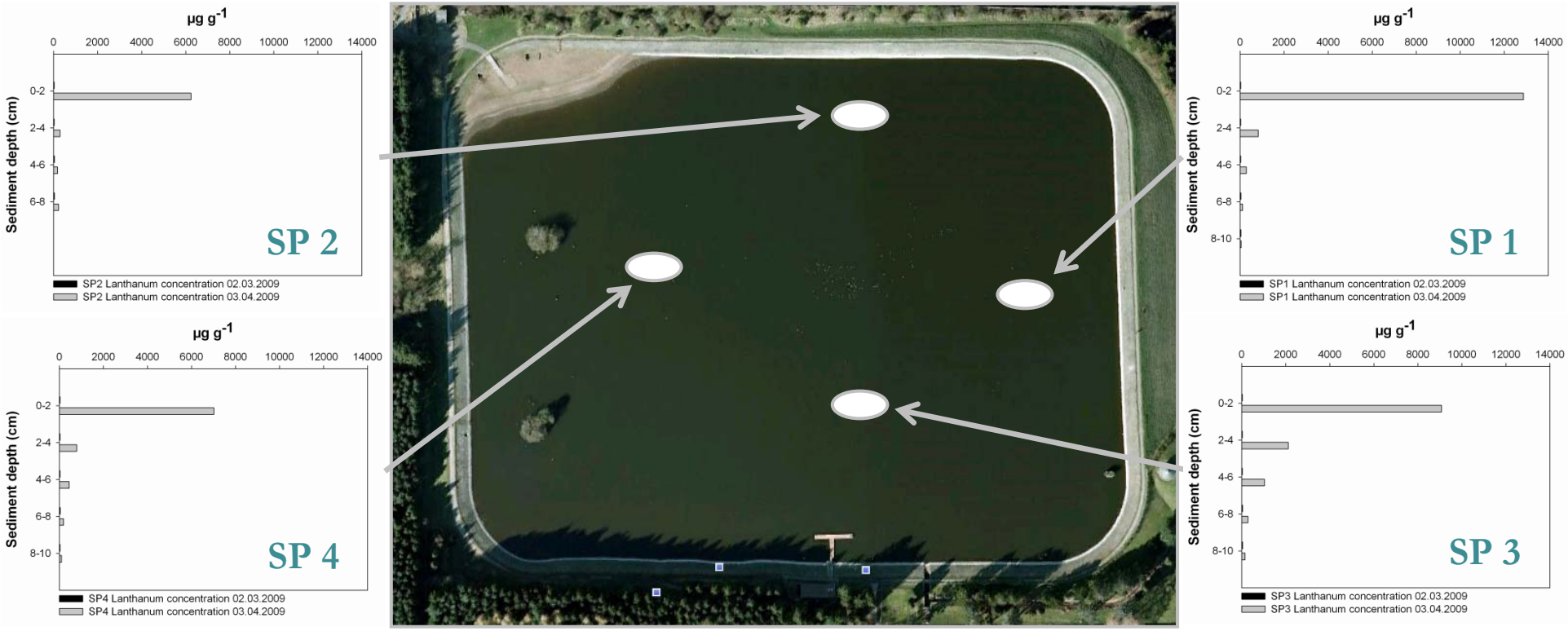
Use of lanthanum as 'tracer'

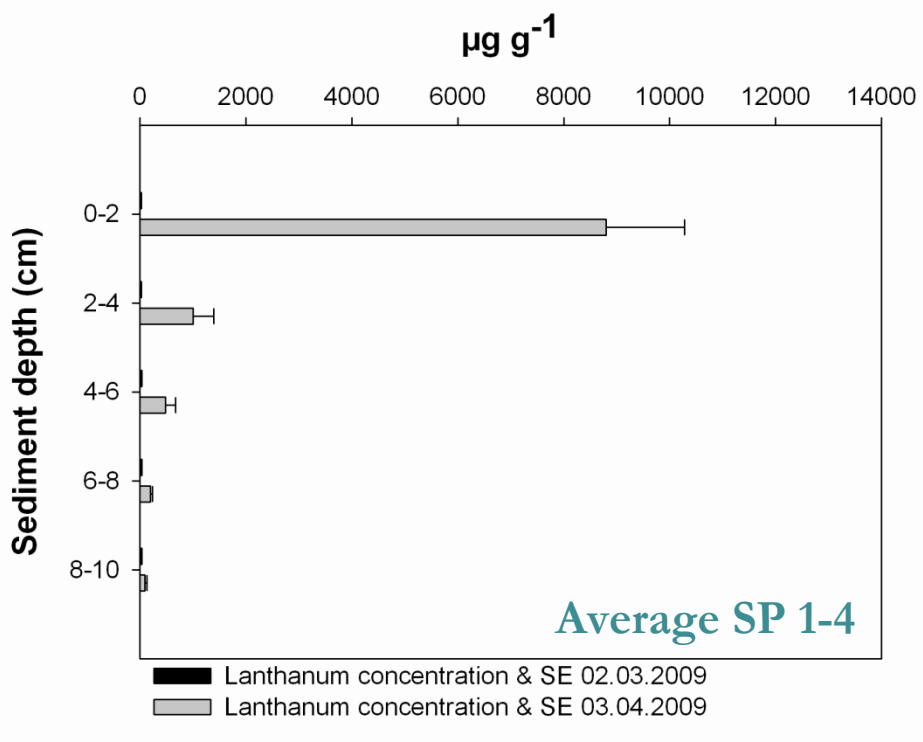


Variability in horizontal distribution

→ higher lanthanum concentrations in deeper (targeted) areas

III) Where is Phoslock®?

Use of lanthanum as 'tracer'



Variability in vertical distribution

→ higher lanthanum concentrations at sediment surface

III) Where is Phoslock®?

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Potential driver of changes in horizontal and vertical Phoslock ® distribution:

- bio-turbation (vertical)
- macrophyte growth (vertical)
- wind induced sediment re-suspension (horizontal)
- sediment 'focussing' (horizontal)

Magnitude and combinations of drivers are likely to be highly site specific.

2) *How* does Phoslock® effect P pools?

III) How does Phoslock® affect P pools?

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'Pool' or 'Fraction'	Example	P release – driver	P release – seasonality
Labile P	PO_4-P	Diffusion	W S S A
Reductant soluble P	Predominantly P bound to Fe(III) and Mn(IV) hydroxides	Anoxia	- - **S A**
Organic P	Various organic compounds (i.e. algae, microorganism, detritus)	Mineralization (Temperature)	W S **S A**
Metal oxide adsorbed P	Predominantly P bound to Al, Fe and other metal oxides	High pH (Photosynthetic activity)	- - **S A**
Apatite P	Carbonate bound P	Low pH	- - - -
Residual P	Various refractory compounds	---	- - - -

W	winter	(December, January, February)
S	spring	(March, April, May)
S	summer	(June, July, August)
A	autumn	(September, October, November)

Bold letter P release predominantly in this month

III) How does Phoslock® affect P pools?

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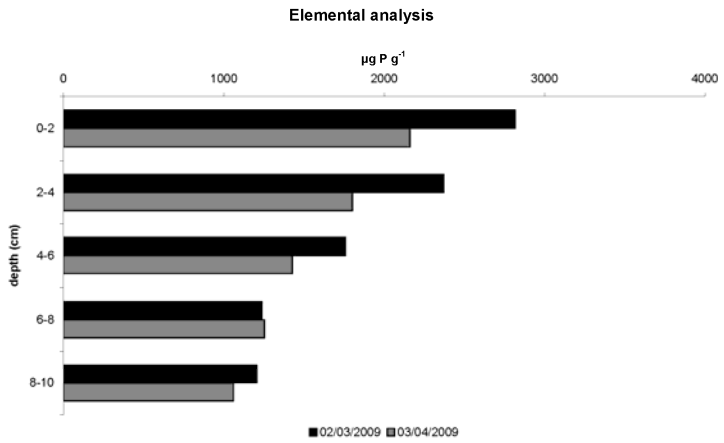
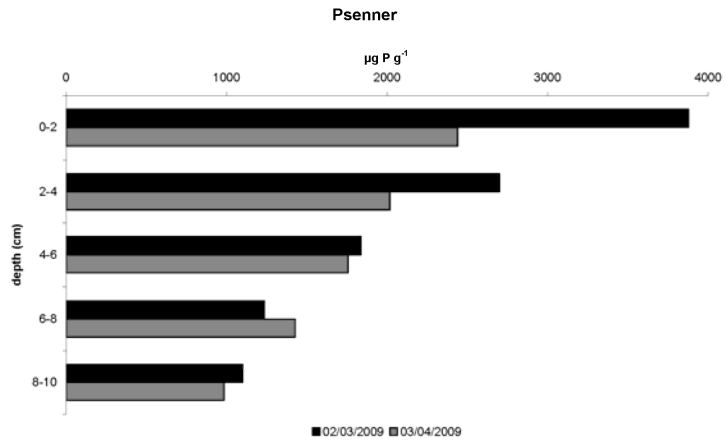
-Reductant soluble P pool = largest P pool pre & post application

-Reduction in reductant soluble P pool

-No obvious increase in other P pool

III) How does Phoslock® affect P pools?





Changes in sediment P concentration

→ potential causes of reduction:

→hypothesis I: dilution effect

III) How does Phoslock® affect P pools?

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Investigation of potential **dilution effect** – *mass balance estimate*

Elemental analyses

sediment depth	calculated post-application concentration	measured post-application post-application	difference calculated vs. measured
	µg P g^{-1} sed.	µg P g^{-1} sed	µg P g^{-1} sed
0-2	2322	2160	163
2-4	2324	1802	522
4-6	1743	1427	316
6-8	1232	1253	-21
8-10	1204	1059	145

→Data from elemental analyses supports dilution theory

III) How does Phoslock® affect P pools?

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Investigation of potential **dilution effect** – *mass balance estimate*

Elemental analyses				Psenner analyses
sediment depth	calculated post-application concentration	measured post-application post-application	difference calculated vs. measured	difference calculated vs. measured
	µg P g^{-1} sed.	µg P g^{-1} sed	µg P g^{-1} sed	µg P g^{-1} sed
0-2	2322	2160	163	758
2-4	2324	1802	522	632
4-6	1743	1427	316	64
6-8	1232	1253	-21	-198
8-10	1204	1059	145	115

→Psenner underestimation of post-application concentrations (=large difference)
→Larger error using Psenner for absolute concentrations

III) How does Phoslock® affect P pools?

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Changes in sediment P pools

→ potential causes of reduction:

→ hypothesis I: dilution effect

→ Reduction in pool resulting from dilution

→ Phoslock® (i.e. lanthanum) does not compete with existing pools

1) *When* does Phoslock® alter P pools?

III) When does Phoslock® alter P pools?

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So far…

→Phoslock® does not compete with existing pools

Hypothesis…

→Phoslock® binds P as soon as it is released from any given pool

→Clatto: largest amount of P stored in reductant soluble pool → release in late summer/autumn

Future work…

→ Analysis of sediment cores from late summer/autumn to verify or reject hypothesis

III) When does Phoslock® alter P pools?

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So far…

→Phoslock® does not compete with existing pools

Suggested timing of application:

Trade-off between maximum instant P binding
(=application during period when P has been released from major pool, often late summer/autumn)

vs.

Periods of high biological activity

IV) Conclusions

- **Spatial Phoslock® distribution:** Phoslock layer varies spatially (horizontally & vertically)

  → additional temporal variation likely in shallow lakes

- **Effect on P pools:** No competition between lanthanum and sediment P pools

  → here: reduction in sediment P concetration dilution effect

- **Timing of effect on P pools:** Hypothesis: Phoslock® (i.e. lanthanum) binds P as soon P is released from pools under natural conditions

- **Sampling & methods:** P content & elemental composition of sediments spatially variable

  → high spatial coverage required

  → complementary analyses required (i.e. check of Psenner vs. EA)