# ISEO: Improving the lake status from Eutrophy towards Oligotrophy

## Work-package 3: Quantification of internal phosphorus fluxes


*Final ISEO-Meeting*
*June 2019*
*Brescia*

IGB
Leibniz Institute of Freshwater Ecology and Inland Fisheries
Berlin, Germany

fondazione cariplo

# Focus of WP 3

**Determination of pools and fluxes of phosphorus**

Distribution of P in the water

P pools in the sediment

Fluxes from and to sediment

**Impact of (discontinuous) meromixis on the internal P cycle**

Oxygen depletion (anoxic P mobilisation)

Trap effect of monimolimnion

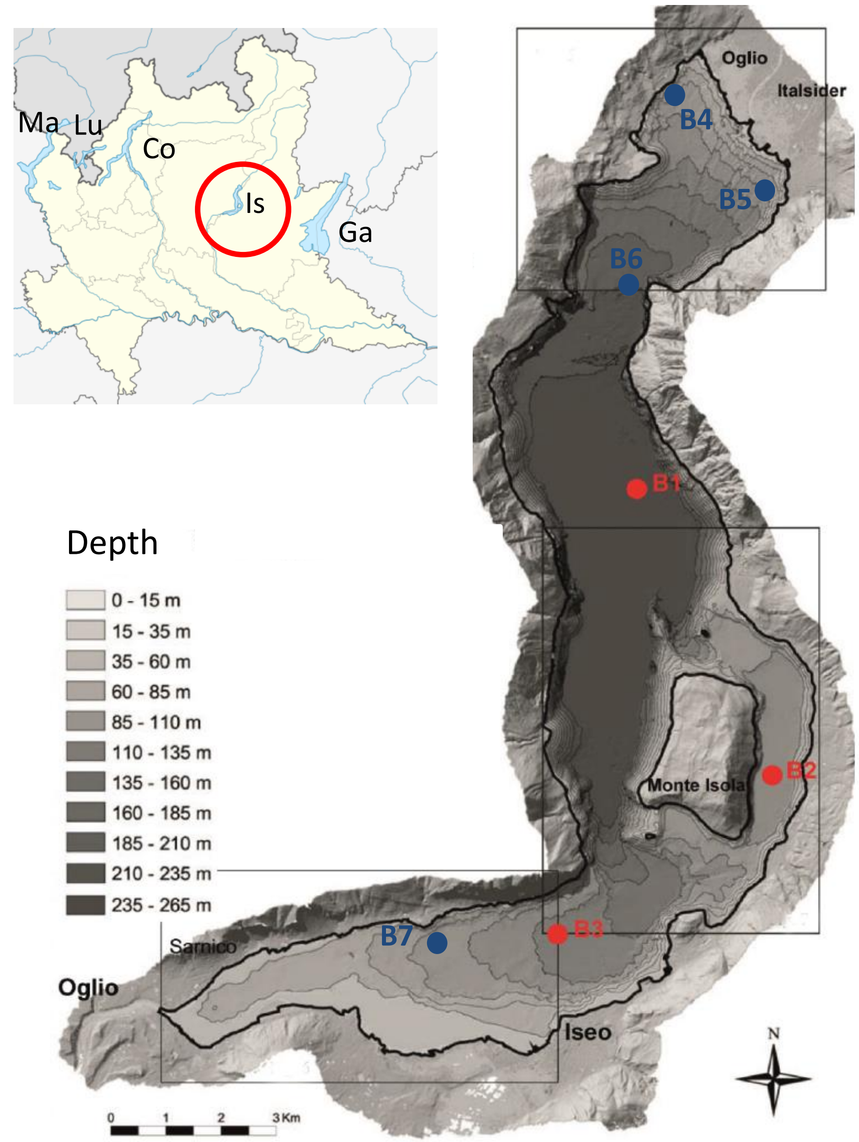
**Consequences for the lake management**

# Methods

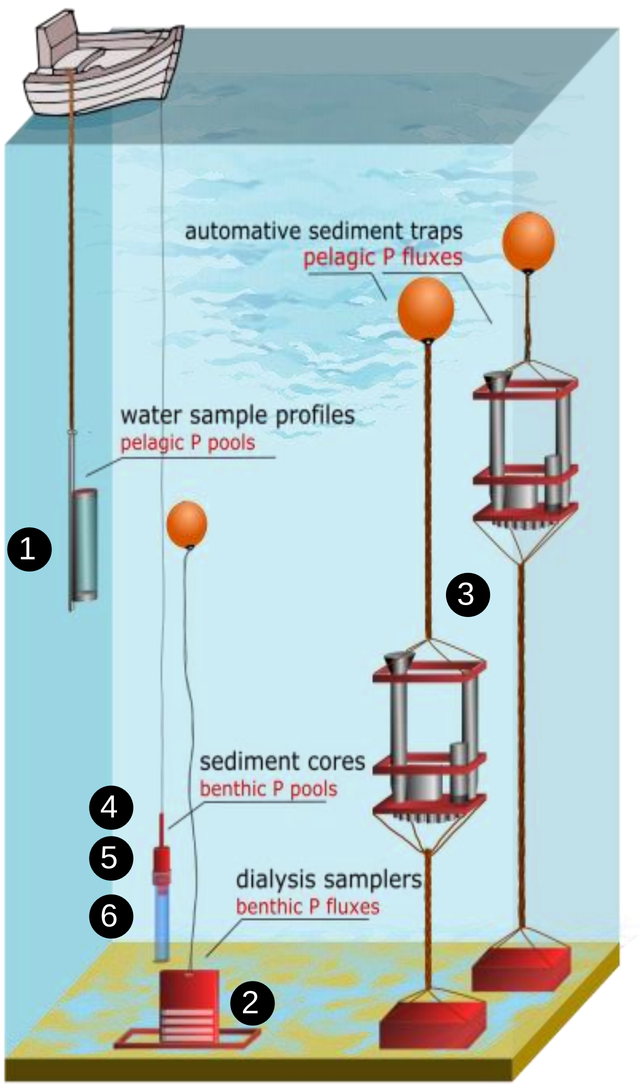
Sampling campaigns
2016: April, October
2017: April, July, October
2018: April, October

Three main sampling points
B1, B2 and B3

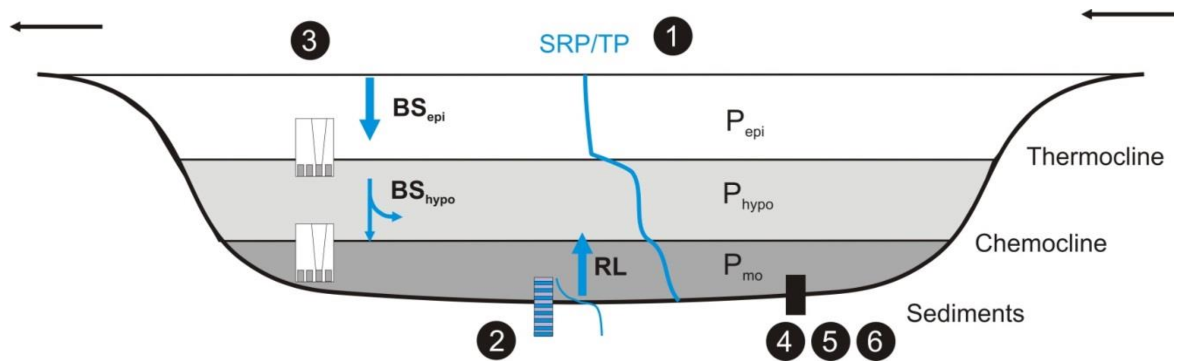
Additional points
N-S transect
B4, B5, B6 and B7



# Methods

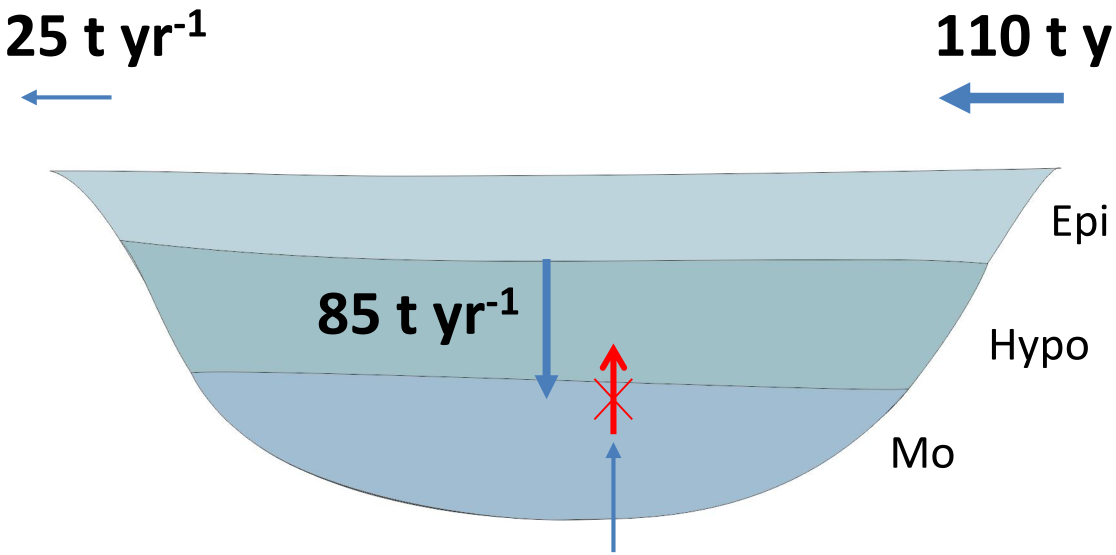


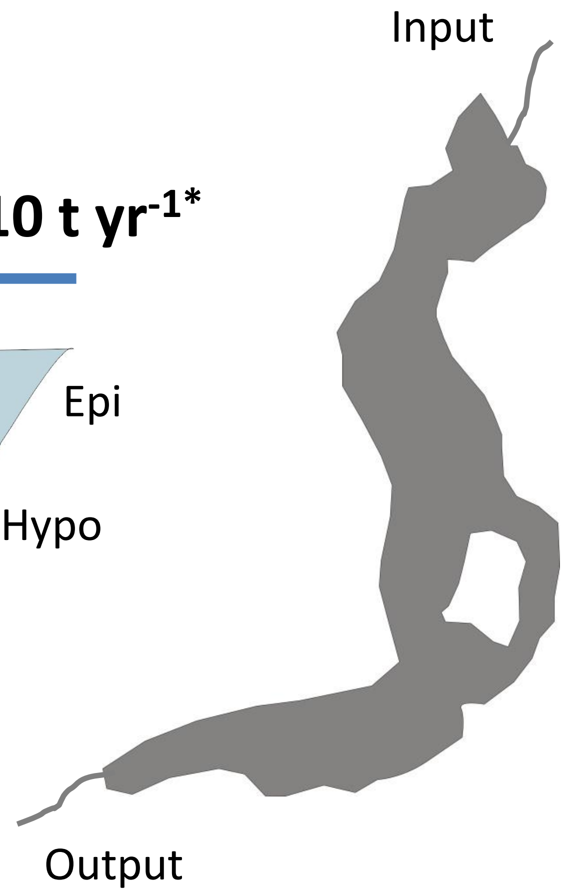

*Lau et al. (in prep)*




1. P pool in different water bodies
2. P release from sediments
3. P sedimentation
4. Mobile P in sediments
5. Redox controlled P mobility
6. P diagenesis and P retention

# Balance



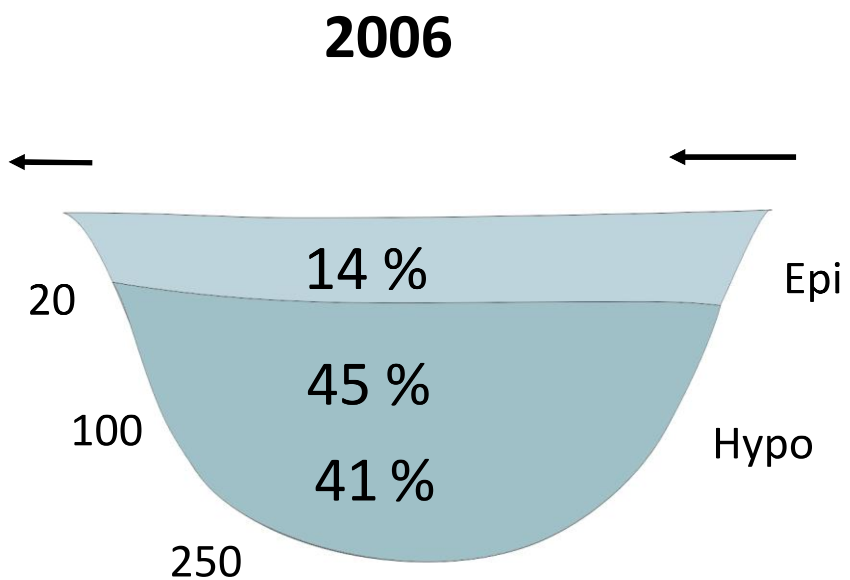

Loss by sedimentation:

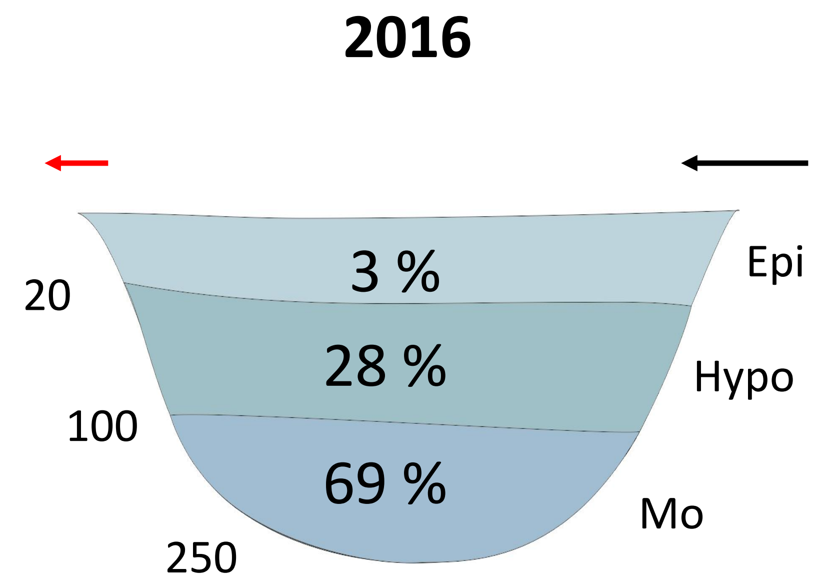
**4.5 mg P m$^{-2}$ d$^{-1}$**

**Meromixis increases the trap function of the lake due to lower P output**

**Nizzoli et al. (in prep)*

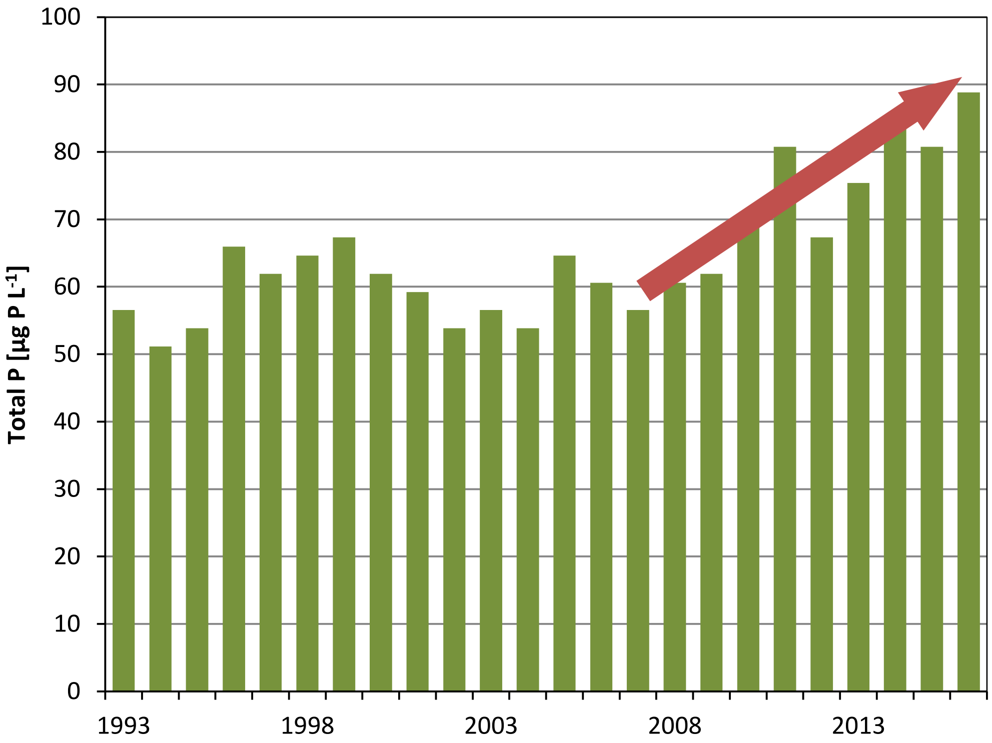
# Relative distribution of P in the water




**Meromixis changes the P distribution in the lake water and reduces P in the euphotic zone**

# Long term P devolopment

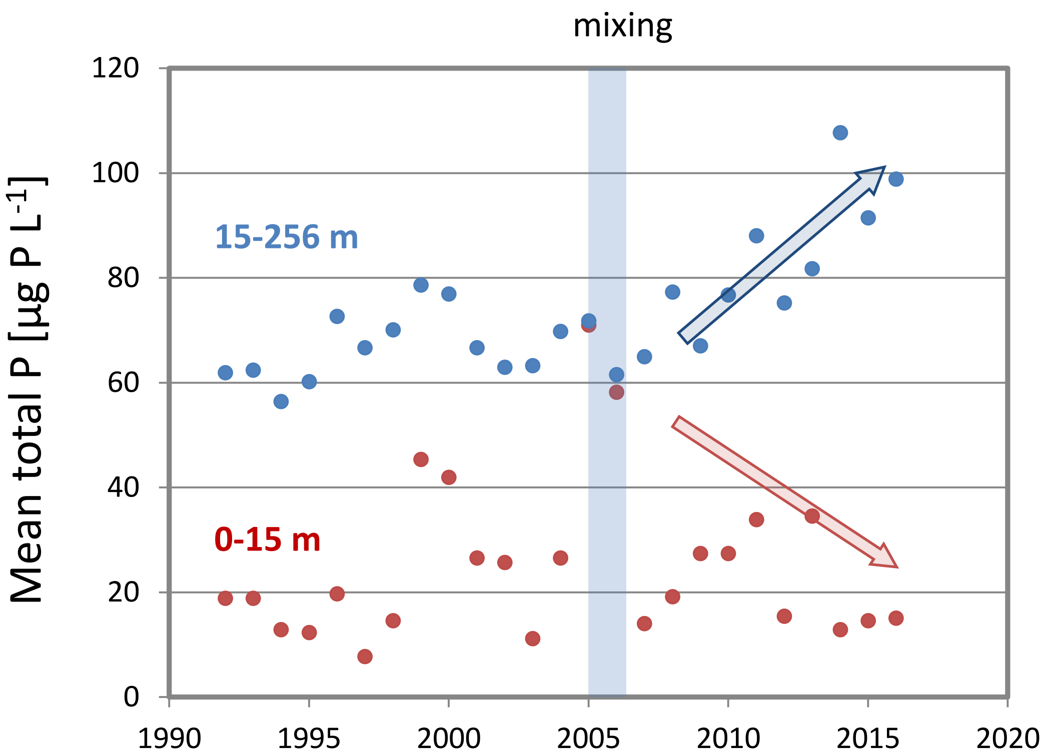



*redrawn from Rogora et al. (2018)*

*Rogora et al. (2018): Climatic effects on vertical mixing and deep-water Oxygen content in the subalpin lakes in Italy. Hydrobiologia*

**Meromixis increases average P in the water body due to P accumulation in the deep water**

# Long term P devolopment

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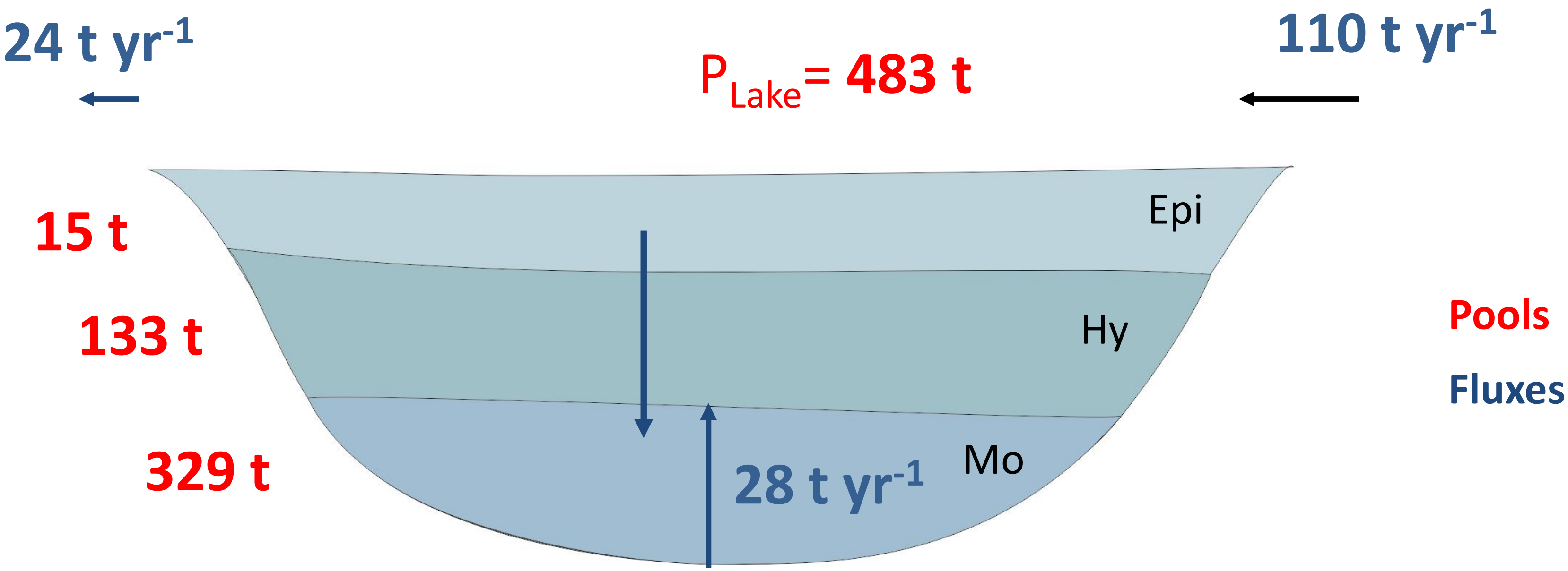
**Meromixis increases average P in the water body due to P accumulation in the deep water**

# P pools in the lake




*Redox controlled P:*
**30.2 t**

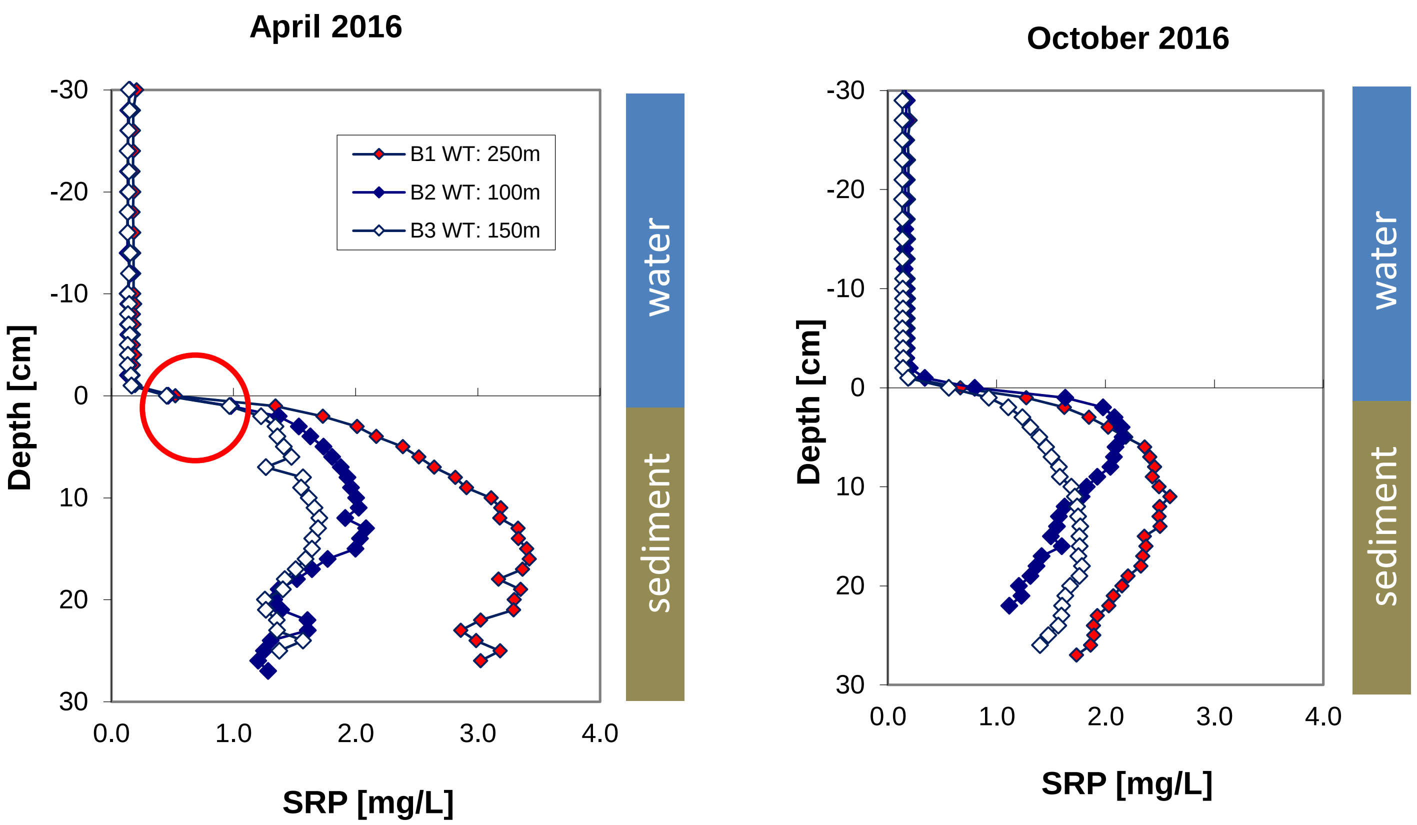
*Potentially mobile P:*
**41.2 t**

*IGB data 2016*

**Sedimentary P pools are of low importances compared to the pools in the water and the P input**

# Determination of P release (I)

## SRP gradients between sediment and water

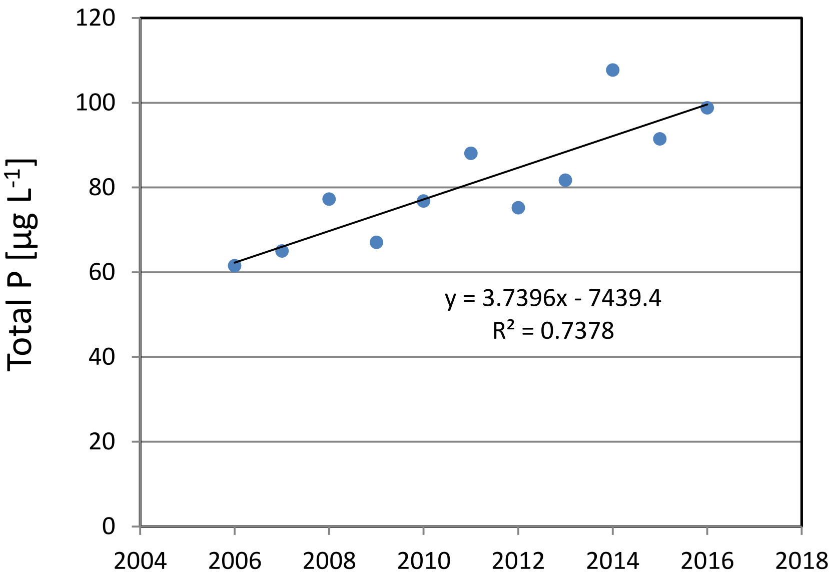



**Phosphorus release rates ranged between 1.26 and 3.02 mg P $m^{-2}$ $d^{-1}$**

**Mean value 2.1 mg P $m^{-2}$ $d^{-1}$**

# Determination of P release (II)

## Hypolimnetic/monomolimnetic P accumulation




*Data from Rogora et al. (2018)*

**2006-2016**

263 t P increase in the depth 15-256 m

= 26,3 t per year

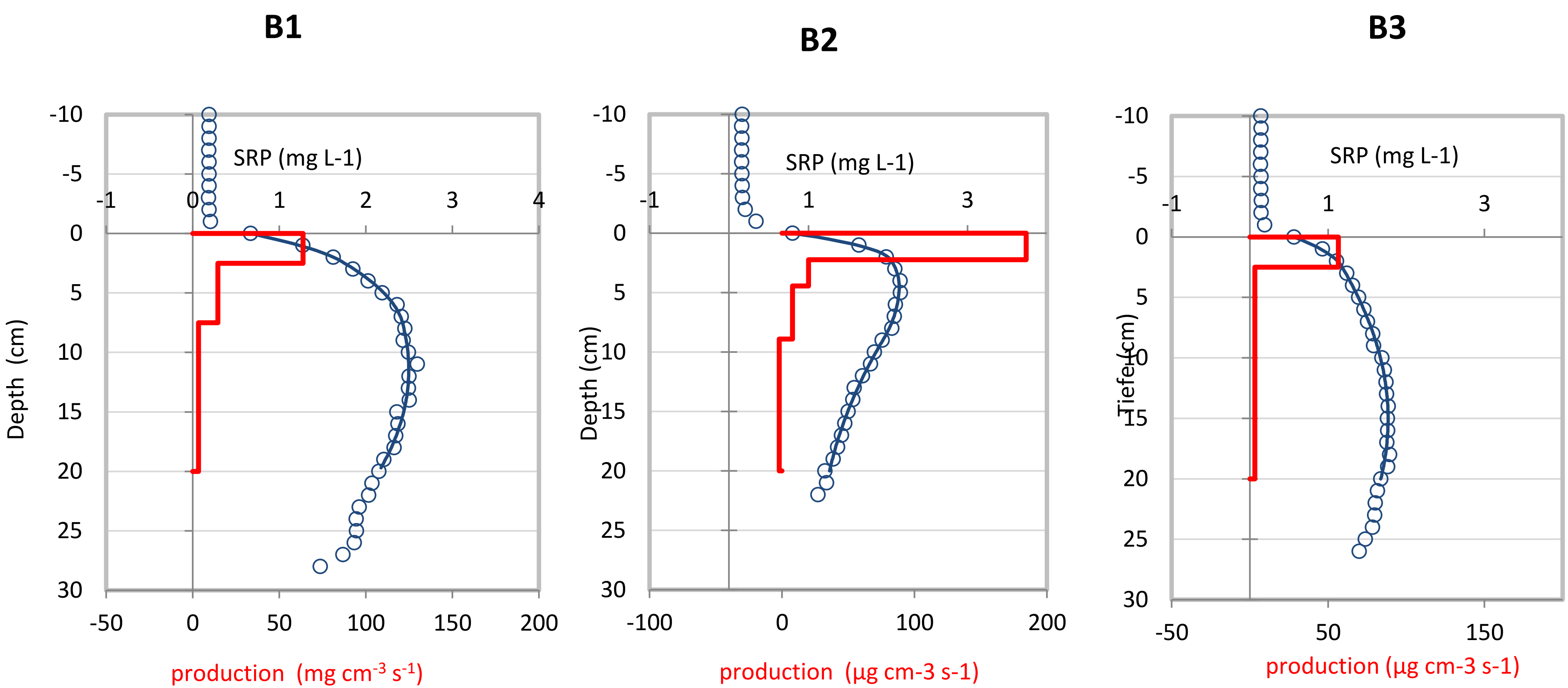
P increase is mainly taken place below 100 m

TP is mainly SRP in deeper layers

**P release rates determined by using the SRP gradients are realistic.**

# Phosphorus diagenesis

## Porewater profiles




*Profile V 1.0 Berg et al (1998): L&O 43*

**P release takes place mainly at the sediment surface**

# Phosphorus diagenesis

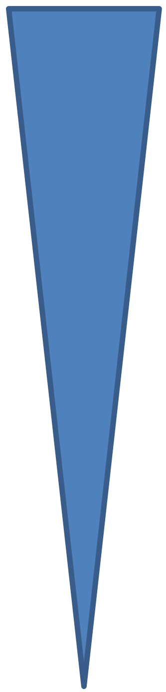
## Particulate P

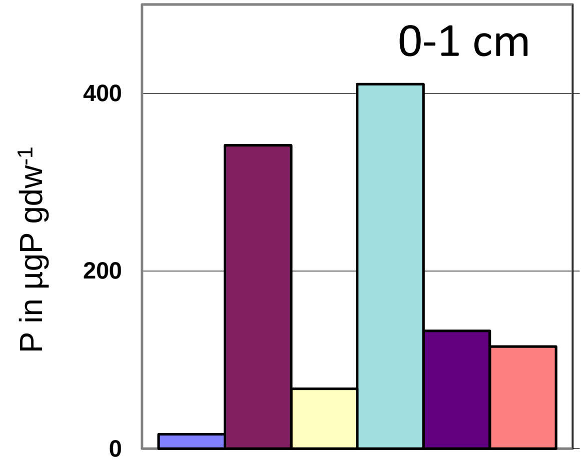
P content mg g dw$^{-1}$

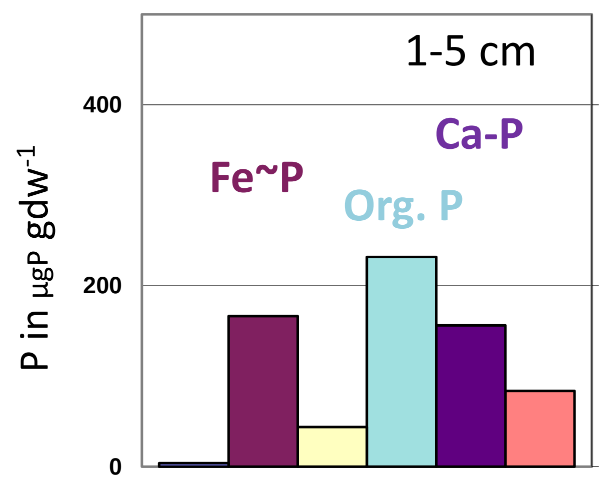
Settling seston — 1.95

Sediment Surface (0-1 cm) — 1.06

Sediment below surface (1-5 cm) — 0.73



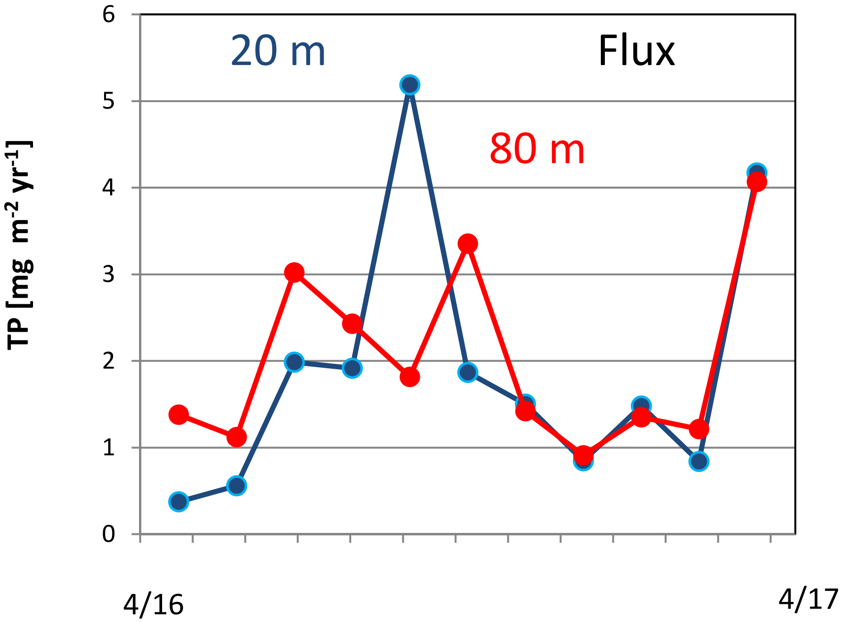



**P release takes place mainly at the sediment surface**

**Most of settled P is released to the water**

# P sedimentation vs. P release



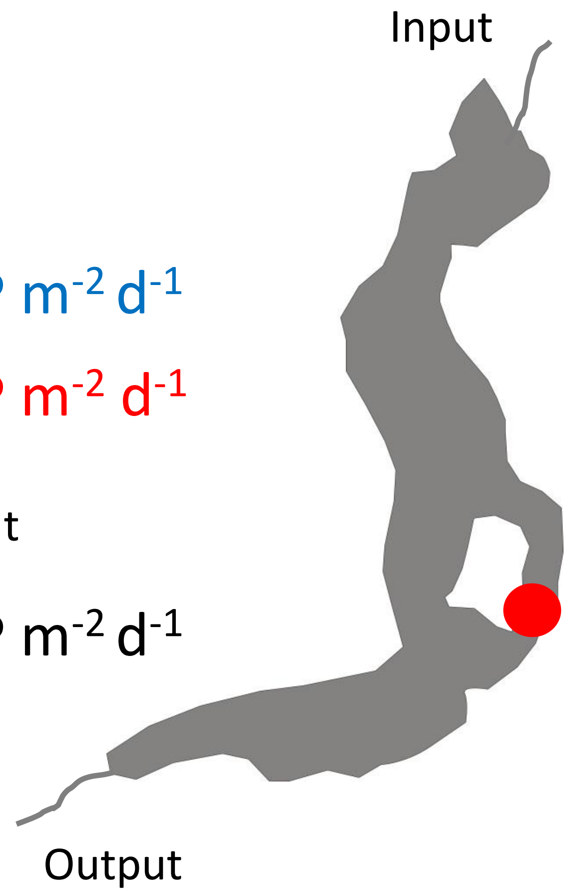

Traps

1.88 mg P $m^{-2}$ $d^{-1}$

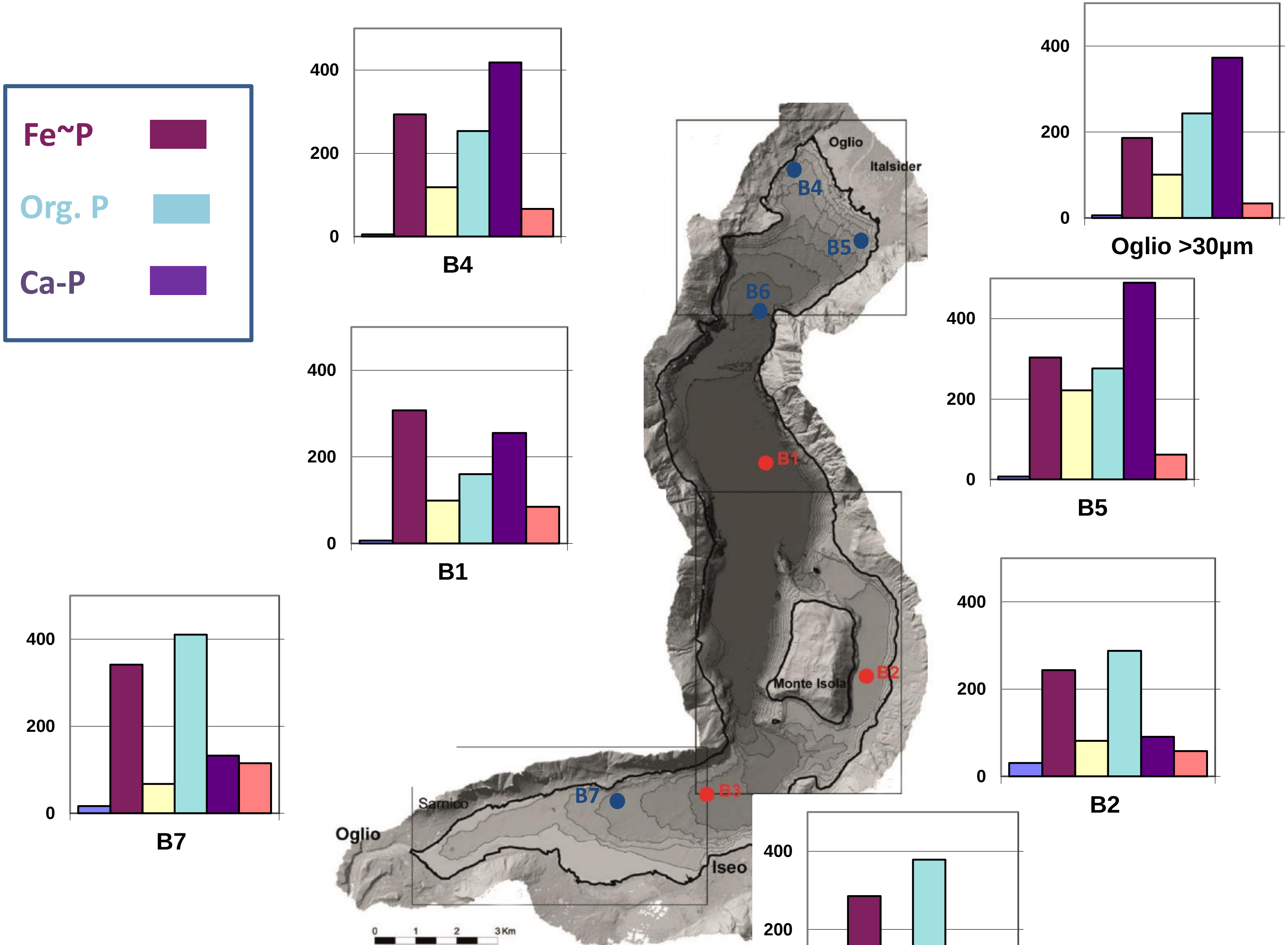
2.01 mg P $m^{-2}$ $d^{-1}$

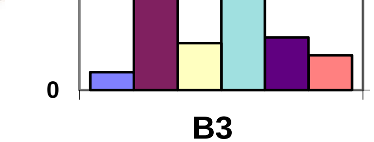
Input-Output

4.47 mg P $m^{-2}$ $d^{-1}$



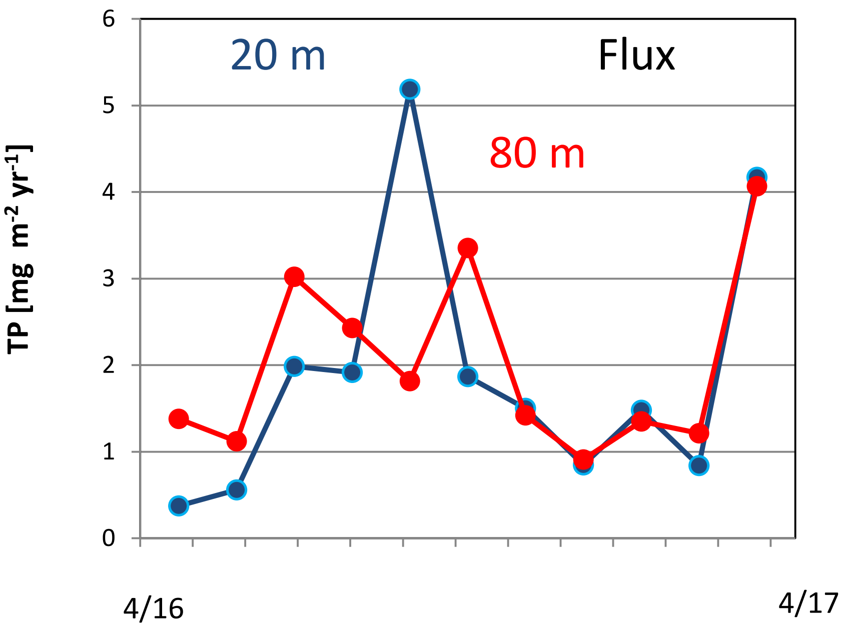

**Different P sedimentation (and P burial) along the N-S transect**




P forms at the sediment surface (0-1 cm)
in µg P $g^{-1}$ dw

# P sedimentation vs. P release

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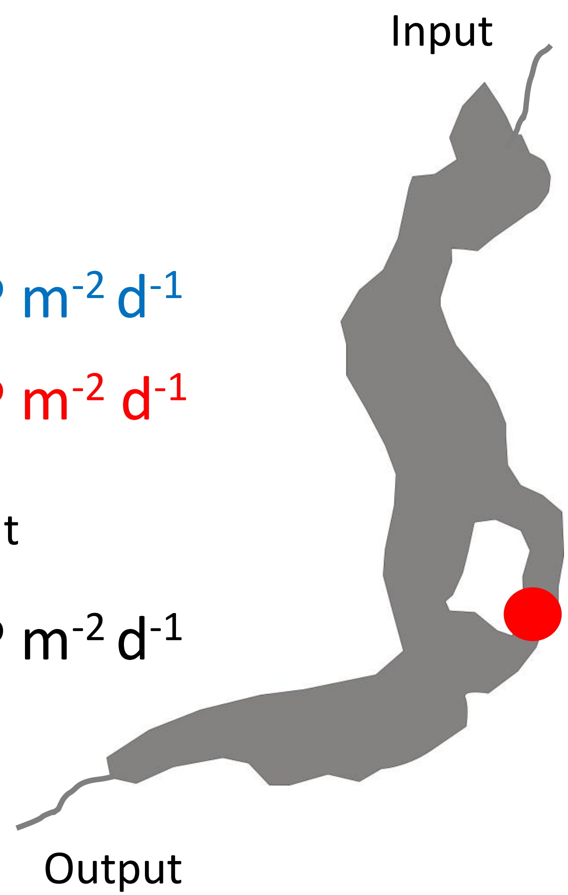
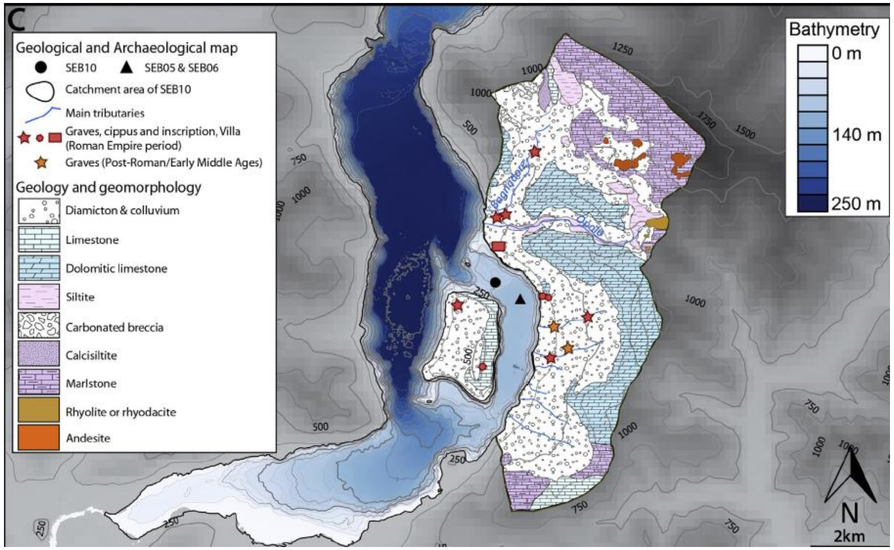
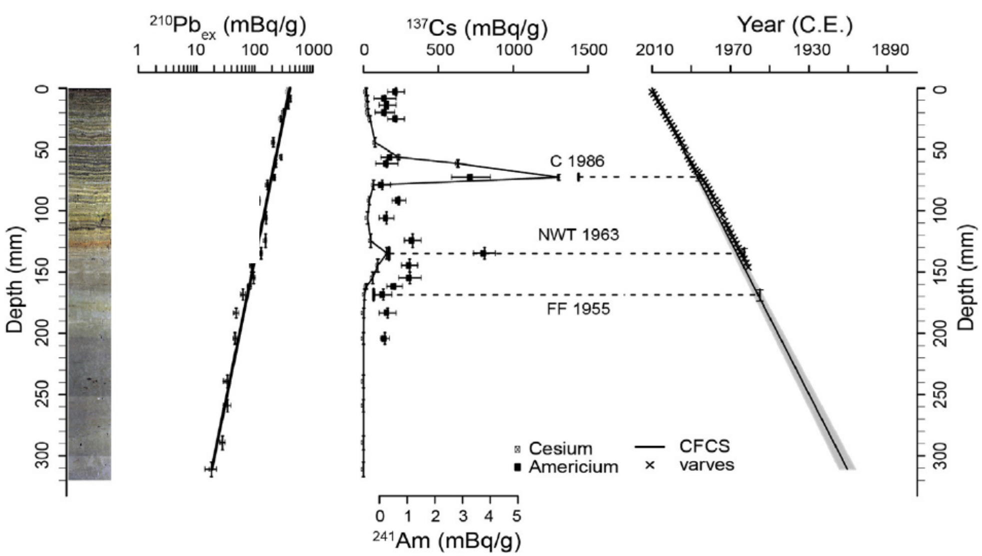



P release 2.11 mg P $m^{-2}$ $d^{-1}$

**P sedimentation rates measured by trap is similar to P release rate.**
**No P burial in the sediment?**

# P retention (burial) in the sediment




265 g m$^{-2}$ yr$^{-1}$

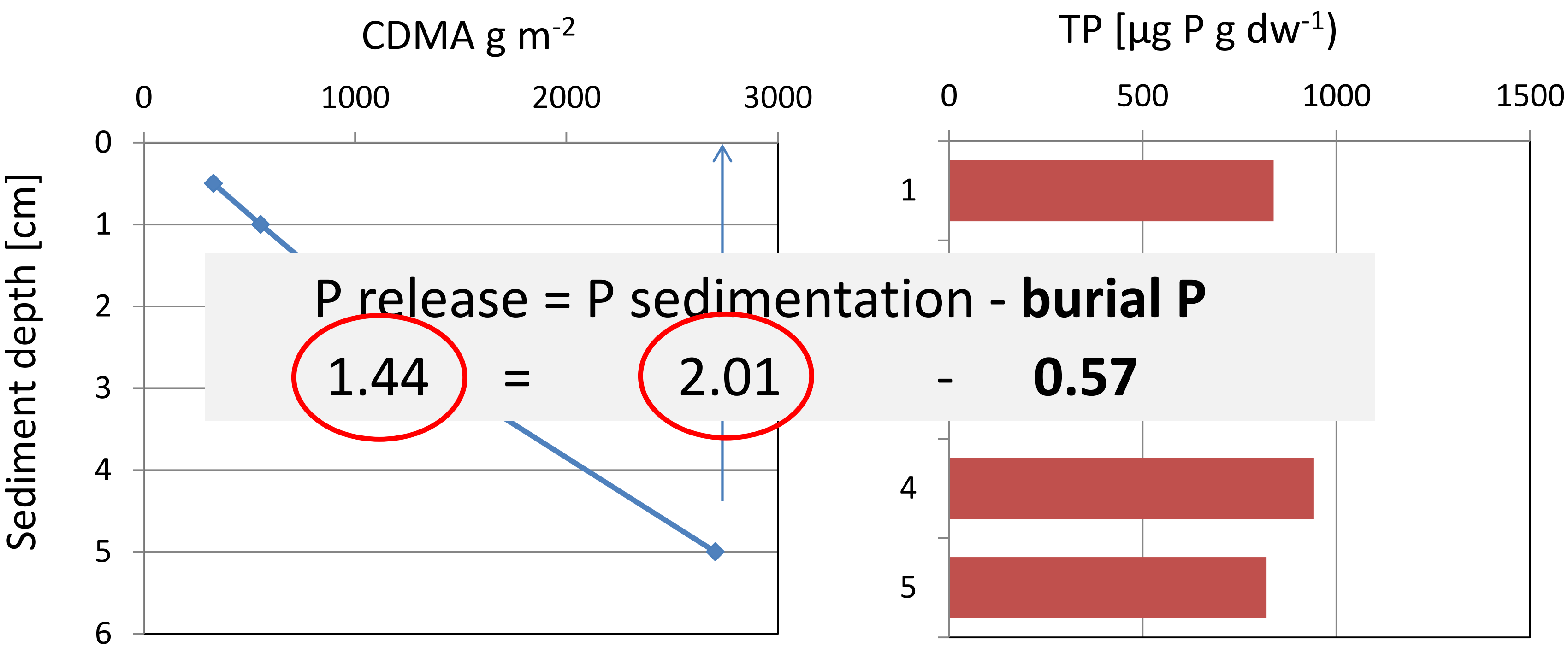
Trap material (80 m)

375 g m$^{-2}$ yr$^{-1}$

*Rapuc et al. (2019)*

# P retention (burial) in the sediment

## Sediment B2




P release = P sedimentation - **burial P**

1.44 = 2.01 - **0.57**

Trap rate: 375 g $m^{-2}$ $yr^{-1}$

5 cm = 7.2 years

Permanent P (in 5 cm): 1509 mg P $m^{-2}$

Burial P : 209 mg P $m^{-2}$ = 0.57 mg P m-2 d-1

**27% of settled P is buried in the sediment (B2)**

**Monimolimnion is of higher importance as P sink than the sediments**

# Short summary

Meromixis increases the total P in the lake

Oxic/anoxic conditions are of low importance for P release

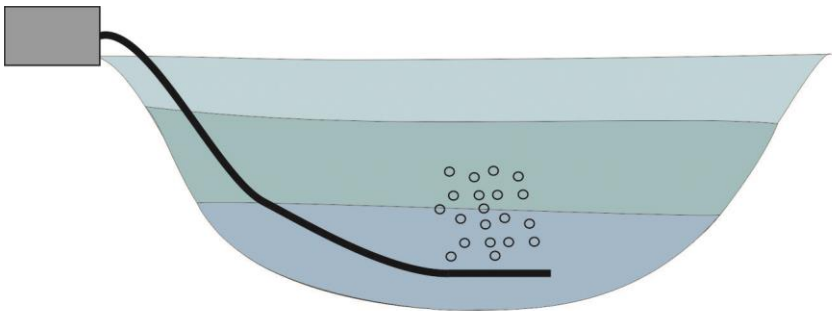
Low P pool in the sediment
Fast P release after sedimentation

Monimolimnion is a more important P sink than sediment.

Discontinuous circulation leads to pulsative nutrient supply
P in monimolimnion is a „time bomb“

# Management options (I)

**Aeration/oxygenation**

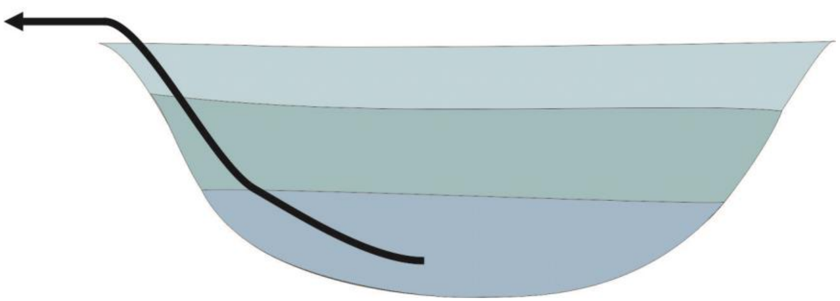


Low impact on P in the lake

Inrease of oxic habitat

Costs: very high

**Deep water withdrawal**



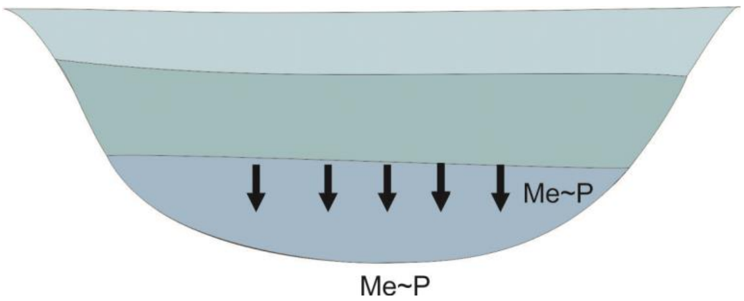

Strong impact on P in the lake by increasing P output

Preventive measure

Costs: moderate

# Management options (II)

**Monimolimnetic P precipitation**

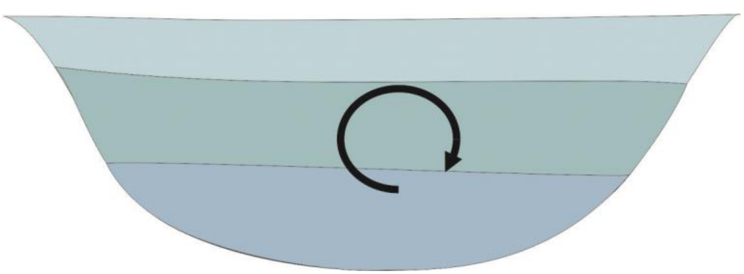



Strong impact on P in the lake by chemical P inactivation

Preventive measure

Costs: very high

**Artifical circulation/destratfication**



Support of natural circulation

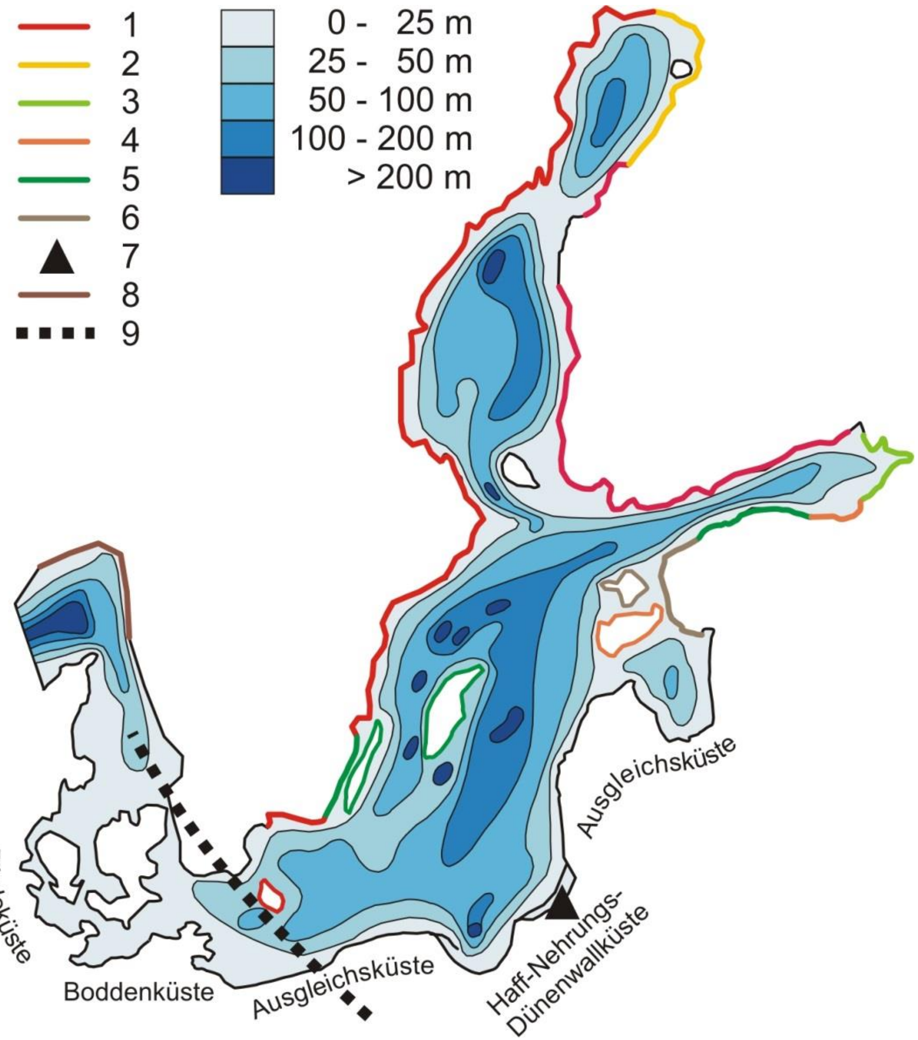
Oxygen supply

Increase P output

Higher P in the euphotic zone

Costs: very high

# Large scale ecological engineering (Geo-Engineering)




## Baltic Sea

373.000 km$^2$

Irregular salt water inflows

Stable stratification due to sea salt

50.000 km$^2$ of the deep bottoms are now anoxic

Accumulation of P in the deep water

# Large scale ecological engineering (Geo-Engineering)

AMBIO 2015, 44:42–54
DOI 10.1007/s13280-014-0524-9

REPORT

## An Experiment with Forced Oxygenation of the Deep of the Anoxic By Fjord, Western Sweden

Anders Stigebrandt, Bengt Liljebladh, Loreto de Brabandere, Michael Forth, Åke Granmo, Per Hall, Jonatan Hammar, Daniel Hansson, Mikhail Kononets, Marina Magnusson, Fredrik Norén, Lars Rahm, Alexander H. Treusch, Lena Viktorsson

Received: 10 November 2013/ Revised: 22 March 2014/ Accepted: 28 Ma

**Abstract** In a 2.5-year-long environmental engineering experiment in the By Fjord, surface water was pumped into the deepwater where the frequency of deepwater renewals increased by a factor of 10. During the experiment, the deepwater became long-term oxic, and nitrate became the dominating dissolved inorganic nitrogen component. The amount of phosphate in the water column decreased by a factor of 5 due to the increase in flushing and reduction in the leakage of phosphate from the sediments when the sediment surface became oxidized. Oxygenation of the sediments did not increase the leakage of toxic metals and organic pollutants. The bacterial community was the first to show changes after the oxygenation, with aerobic bacteria also thriving in the deepwater. The earlier azoic deepwater bottom sediments were colonized by animals. No structural difference between the phytoplankton communities in the By Fjord and the adjacent Havsten Fjord, with oxygenated deepwater, could be detected during the experiment.

AMBIO 2013, 42:587–595
DOI 10.1007/s13280-012-0356-4

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THE ROYAL SWEDISH ACADEMY OF SCIENCES

REPORT

## Improving Oxygen Conditions in the Deeper Parts of Bornholm Sea by Pumped Injection of Winter Water

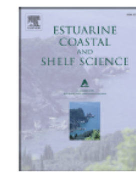
Anders Stigebrandt, Ola Kalén

**I would like to warn against such interventions!**

Contents lists available at ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss



ELSEVIER

## Inactivated phosphorus by added aluminum in Baltic Sea sediment

CrossMark

Emil Rydin

*Erkenlaboratory, Dep. of Ecology and Genetics, Uppsala University, Norra Malmavägen 45, SE 761 73 Norrtälje, Sweden*

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ABSTRACT

Decreased phosphorus (P) retention in aquatic sediments during hypoxic periods results in increased P recycling to the water column. To revert to less productive conditions in the enclosed bays of the Baltic Sea archipelago, increased sediment P burial capacity is needed. Aluminum (Al) addition is considered to be a cost-effective lake restoration method, as it improves sediment P burial capacity. However, little is known about its ability to permanently bind P in brackish systems. In summer 2000, Al sulfate granules were added to a hypoxic bottom area in the Östhammar bay, Sweden. Sediment core samples from the area were collected 10 years later. A peak in Al and P was detected at 20 cm sediment depth, reflecting the added Al and P trapped to it. Only part of the added Al was recovered, but the recovered Al (8 g Al/$m^2$) trapped P at a ratio of 5:1 (molar). Chemical fractionation showed that P extracted as "Al–P" constituted 55% of the trapped P, indicating that Al added also trapped P extracted as other P forms.

# Thanks to the IGB team

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