ISEO: **I**mproving the lake **S**tatus from **E**utrophy towards **O**ligotrophy

University of Parma

Nutrient loads, factors affecting
their availability and response of submerged vegetation

Main activities

WP1:

to estimate N and P potential loads of the different anthropic activities in the watershed

to quantify nutrients (P, N and Si) loads to lake Iseo, evaluate how their magnitude and bioavailability are affected by hydrological conditions

to check (and improve) the accuracy of P determination by the *in situ* auto analyzer

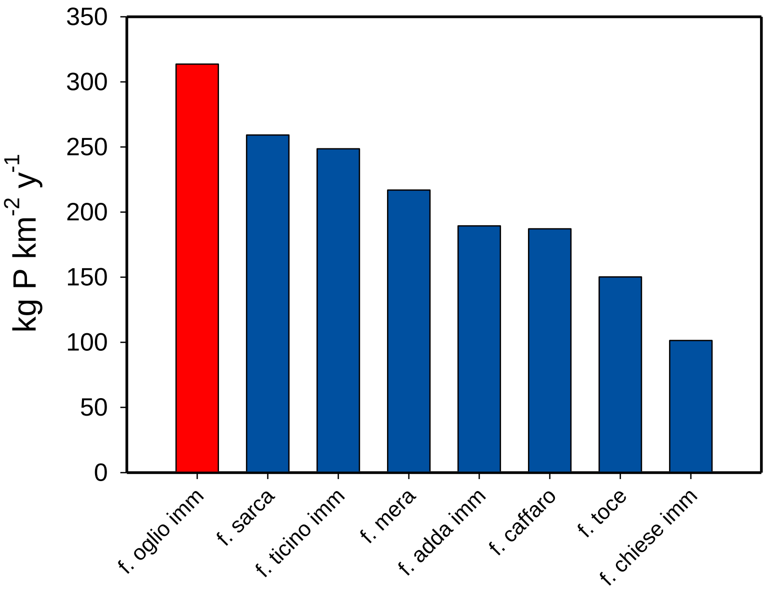
WP2:

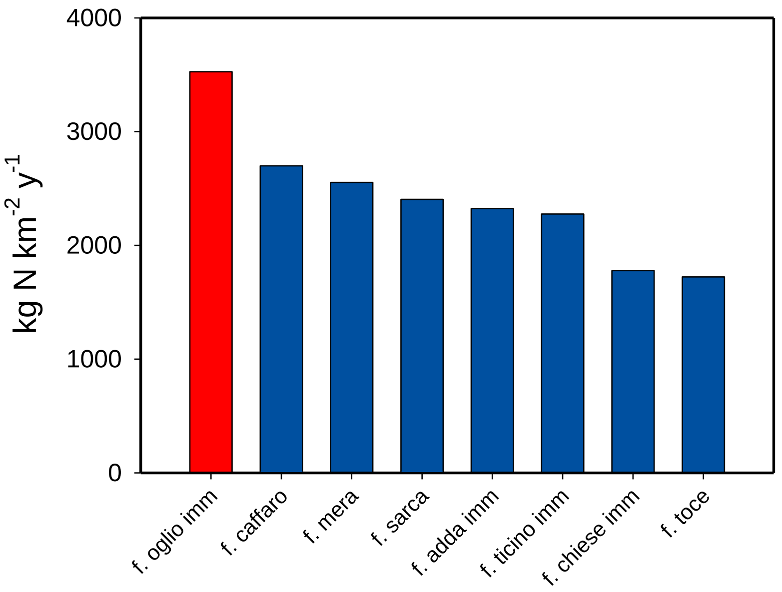
to quantify nutrients (P, N and Si) concentrations in waters discharged by sewer overflows

to evaluate the functioning of the littoral areas as a buffer of the external nutrients loads

to map the extension and composition of submerged macrophytes meadows and their nutrients content and how they change in relation to external pressures

Net anthropogenic P and N input to watersheds: a comparison





Net anthropogenic phosphorus input = **562 t P y^{-1}**, (areal load of 314 kg P km^{-2} y^{-1})

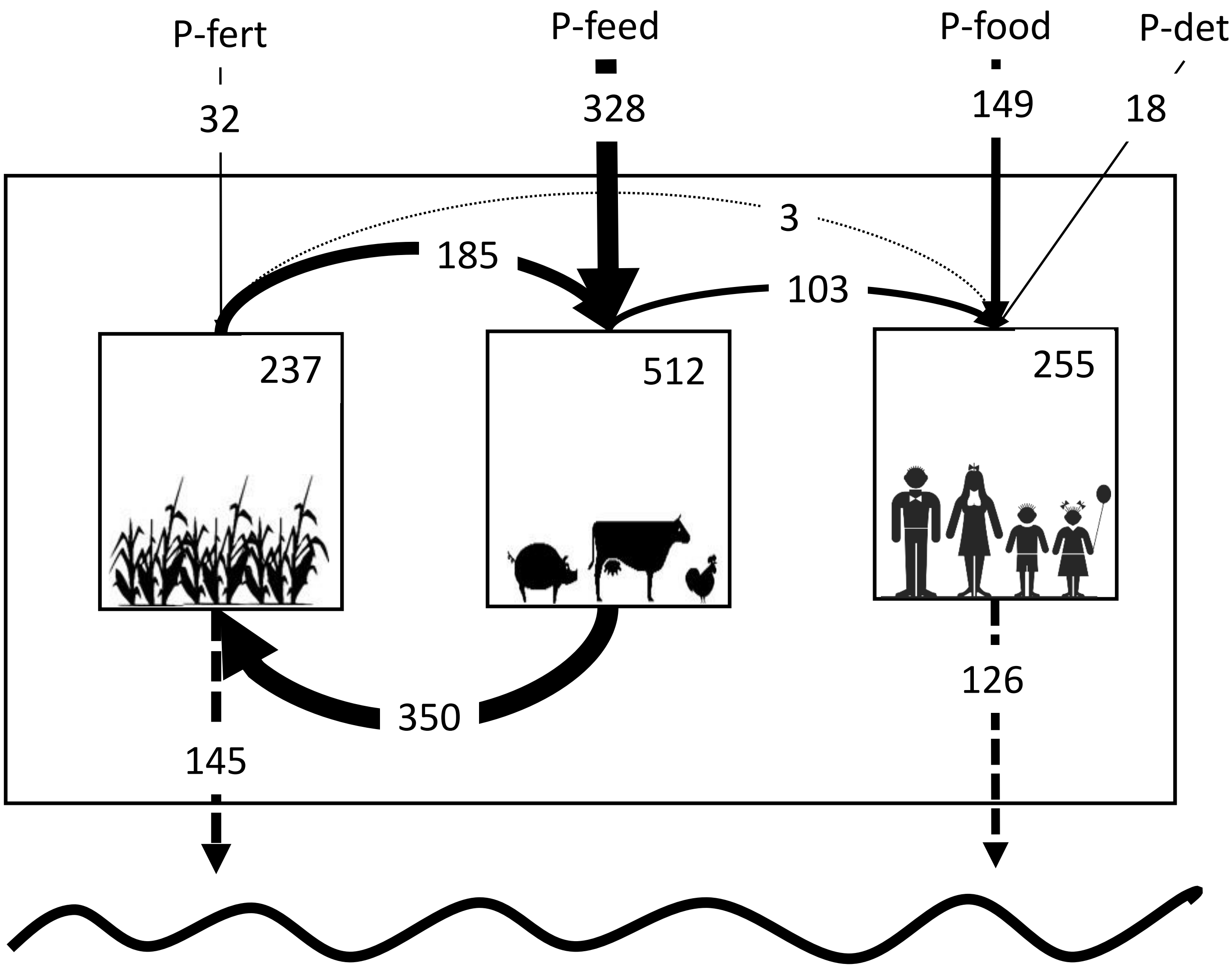
average Po river watershed: 800 kg N km^{-2} y^{-1}

Net anthropogenic nitrogen input = **6325 t N y^{-1}** (areal load of 3526 kg N km^{-2} y^{-1})

average Po river watershed: 8000 kg N km^{-2} y^{-1}

all fluxes are tons/y

input = **562 t P y^{-1}**



Main activities

WP1:
to estimate N and P potential loads of the different anthropic activities in the watershed

to quantify nutrients (P, N and Si) loads to lake Iseo, evaluate how their magnitude and bioavailability are affected by hydrological conditions

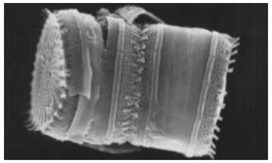
to check (and improve) the accuracy of P determination by the *in situ* auto analyzer

WP2:
to quantify nutrients (P, N and Si) concentrations in waters discharged by sewer overflows

to evaluate the functioning of the littoral areas as a buffer of the external nutrients loads

to map the extension and composition of submerged macrophytes meadows and their nutrients content and how they change in relation to external pressures

Why Silica



- essential element for many aquatic primary producers;
- control on communities composition;
- changes in Si availability in relation to P and N can trigger harmful algal blooms;
- Si transport has been largely considered a geochemical process, mainly regulated by chemical weathering and hydrology;

- lakes are biogeochemical reactors;
- relatively little is known about Si biogeochemistry in lakes;
- little is known about the role of the littoral zone on Si cycling.

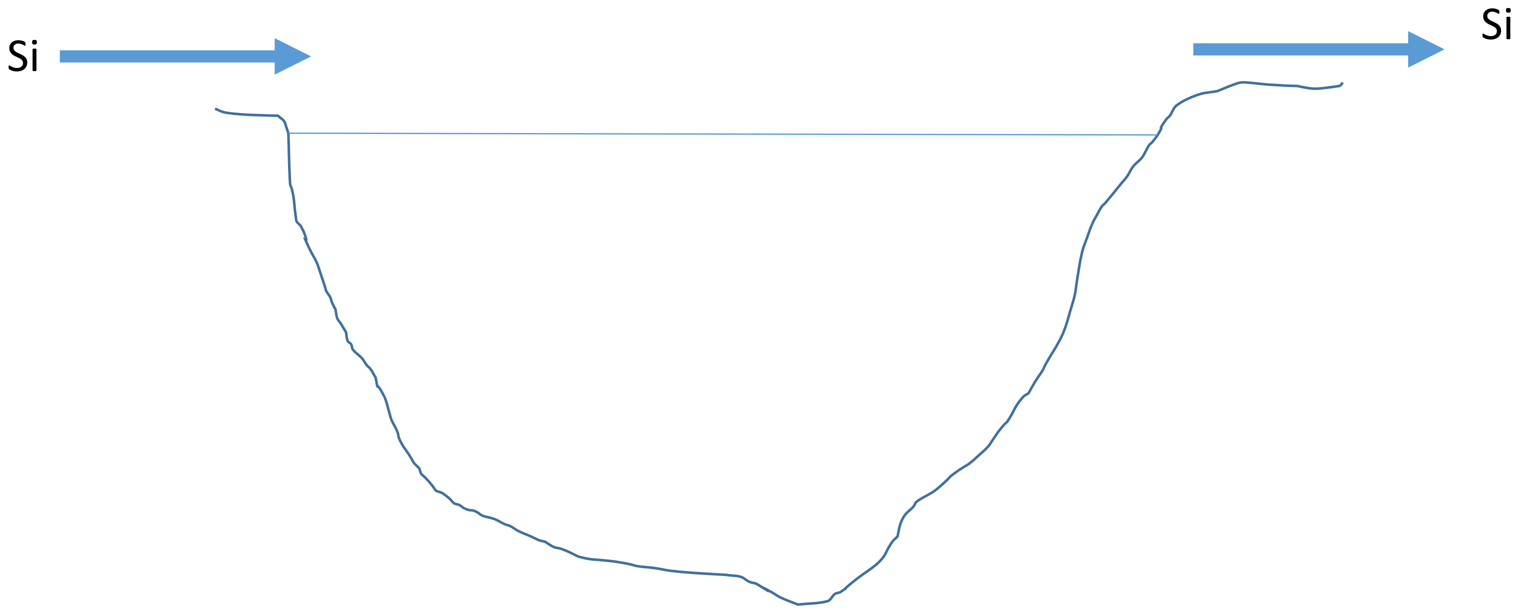
AIMS

to analyse factors controlling silica transport and retention. More specifically:

AIMS

to analyse factors controlling silica transport and retention. More specifically:

to quantify the amount and composition of incoming silica loads to the lake and Si lake retention

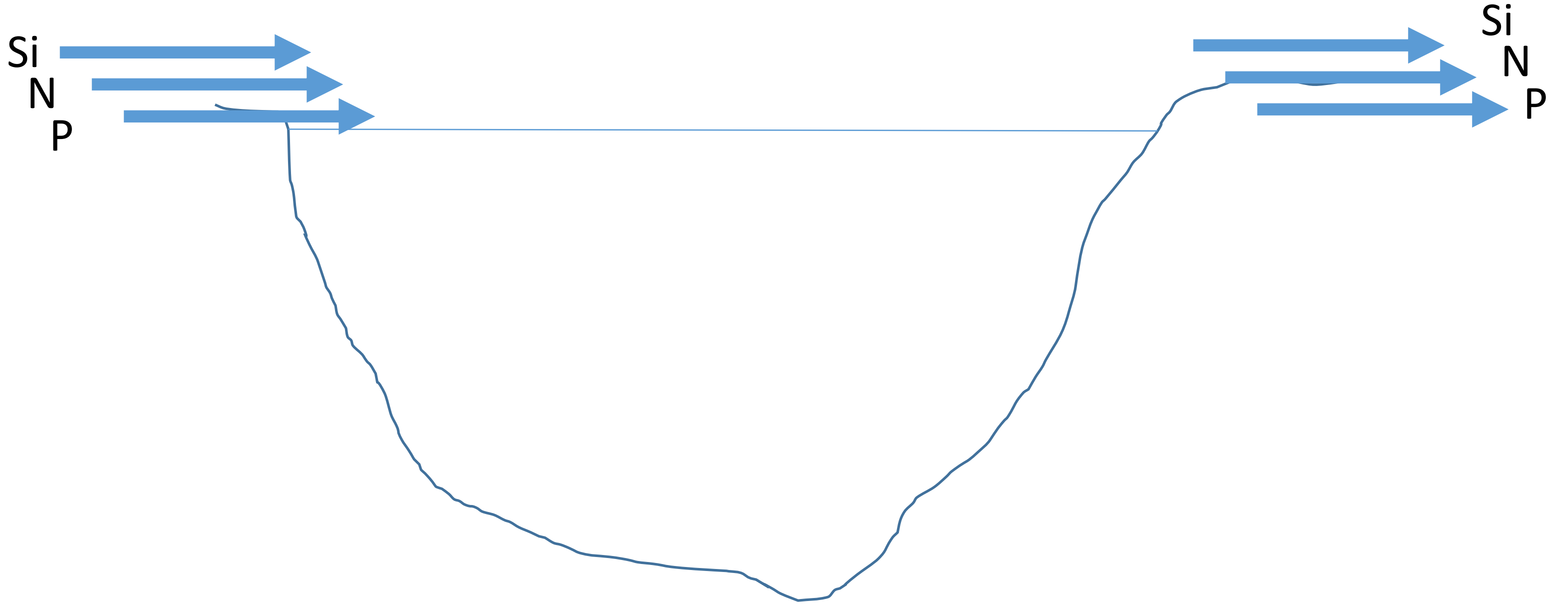


AIMS

to analyse factors controlling silica transport and retention. More specifically:

to quantify the amount and composition of incoming silica loads to the lake and Si lake retention

to evaluate how the lake influence nutrient ratios (N:P:Si) along the hydrographic network

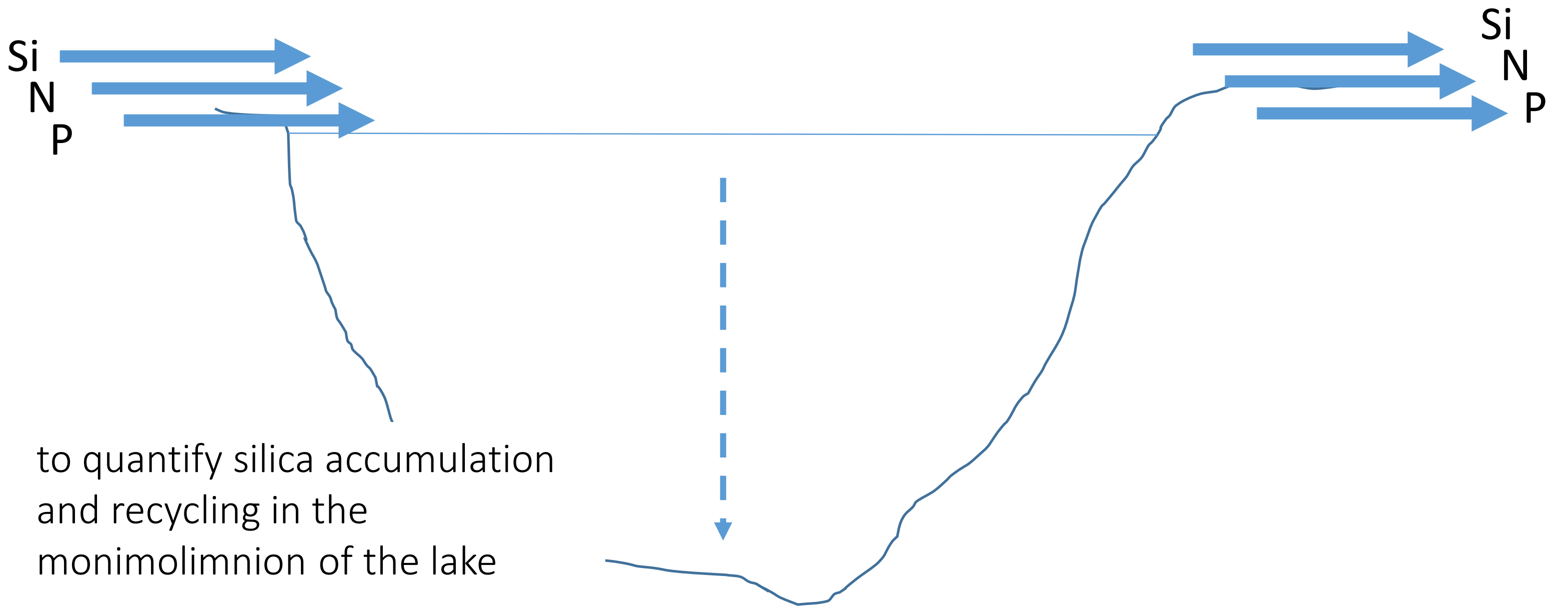


AIMS

to analyse factors controlling silica transport and retention. More specifically:

to quantify the amount and composition of incoming silica loads to the lake and Si lake retention

to evaluate how the lake influence nutrient ratios (N:P:Si) along the hydrographic network



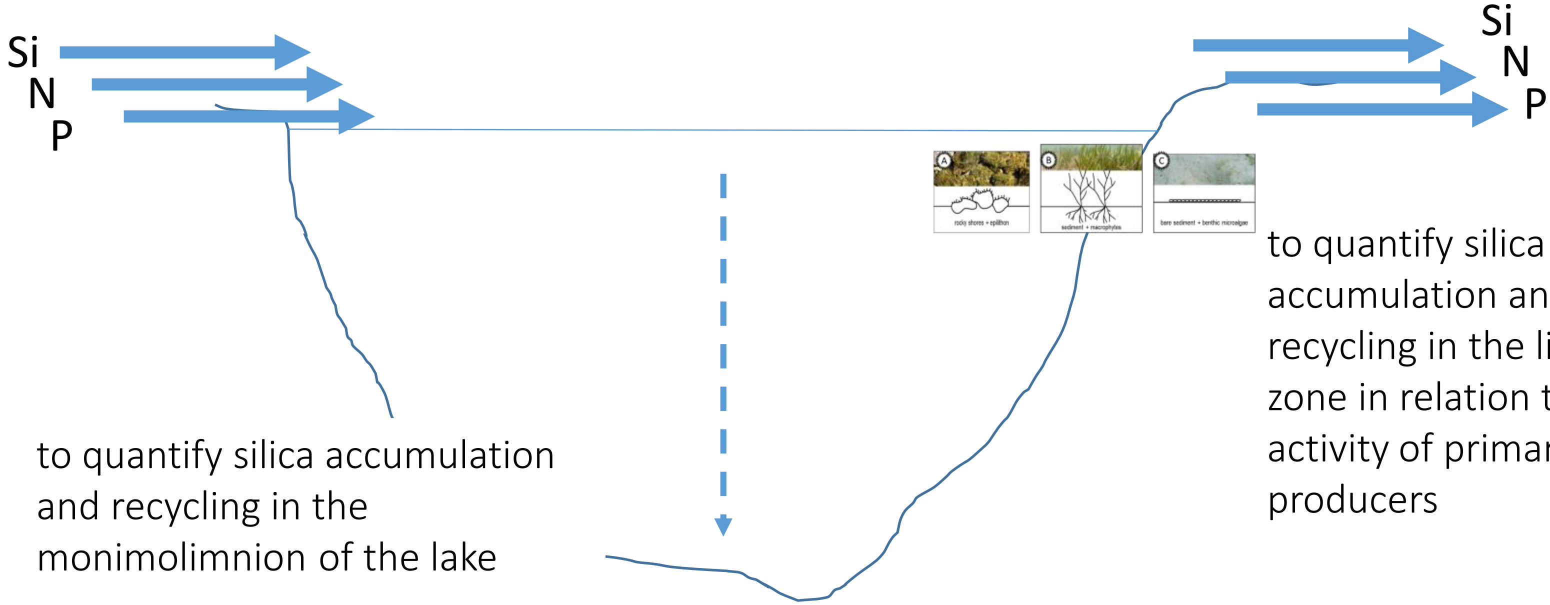
to quantify silica accumulation and recycling in the monimolimnion of the lake

AIMS

to analyse factors controlling silica transport and retention. More specifically:

to quantify the amount and composition of incoming silica loads to the lake and Si lake retention

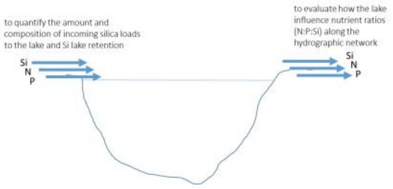
to evaluate how the lake influence nutrient ratios (N:P:Si) along the hydrographic network



to quantify silica accumulation and recycling in the littoral zone in relation to the activity of primary producers

to quantify silica accumulation and recycling in the monimolimnion of the lake

MATERIAL AND METHODS



estimation of nutrients load:

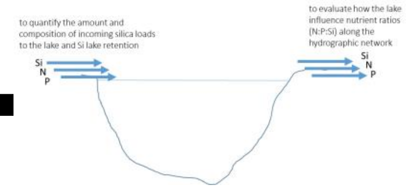
Water samples were collected in three site: two main inlets and the outlet.

Dissolved parameters: dissolved silica (DSi), soluble reactive phosphorus (SRP) and dissolved inorganic nitrogen (DIN = NH_4^+ + NO_3^-), dissolved organic phosphorus and nitrogen.
Suspended material: amorphous silica (ASi), particulate phosphorus (PP) and particulate nitrogen (PN).

Loads calculated using as the product of the discharge weighted mean concentration by the mean annual discharge of the 3 years

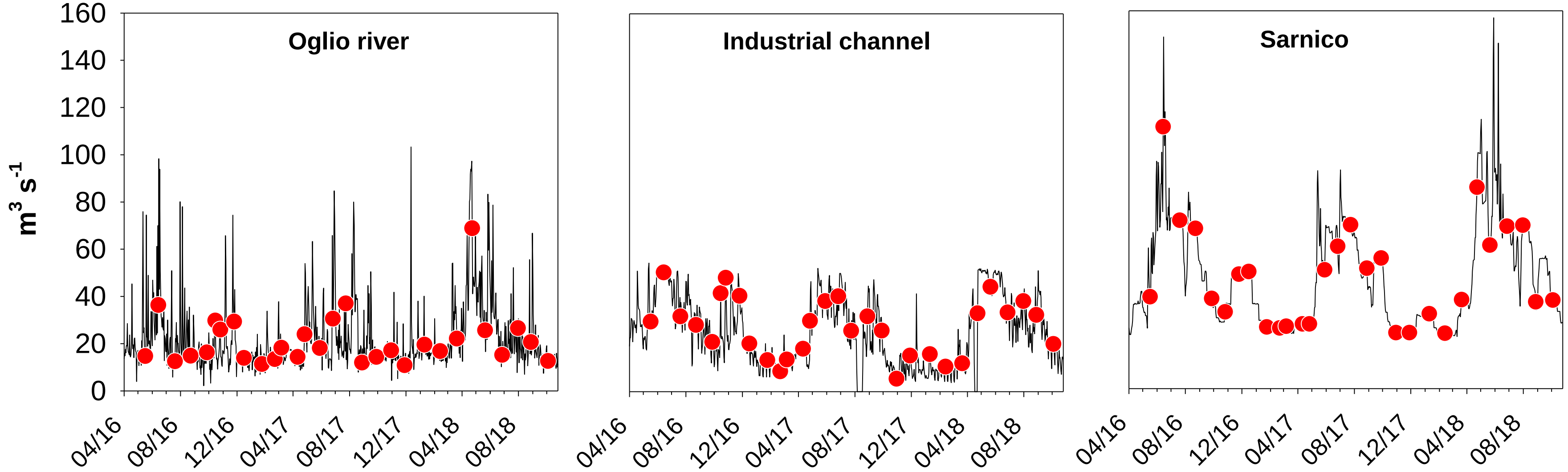
$$L = \frac{\sum(Qi * Ci)}{\sum Qi} * \overline{Q_{tot}} * k$$

MATERIAL AND METHODS



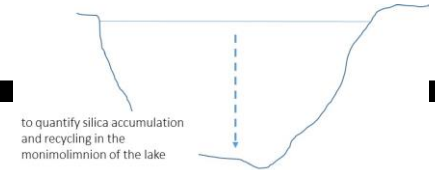
Lake Inlet

Lake Outlet



A total of 30 water samples were collected at each station from April 2016 to Novembre 2018

MATERIAL AND METHODS

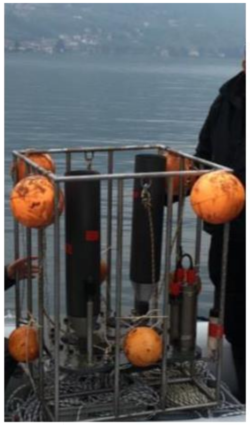


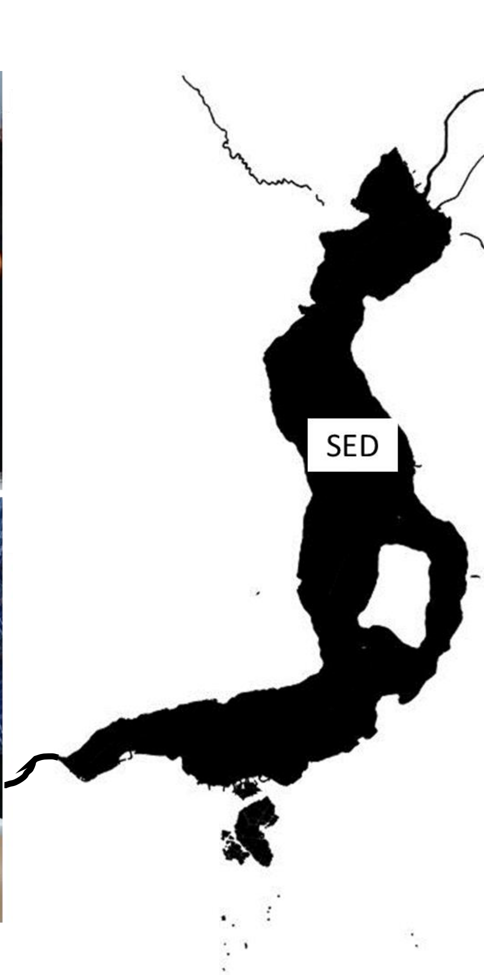
Silica sedimentation rates and release from deep sediments:

Quantification of silica *sedimentation rates* analyzing (ASi) in the particulate material collected with the sedimentation traps (thanks Michael)

Intact *sediment cores* were collected at the deeper layer (250 m c.a.) and incubated for flux measurement. (many thanks Michael)

Quantification of silica in porewater (DSi), and sediment (ASi).





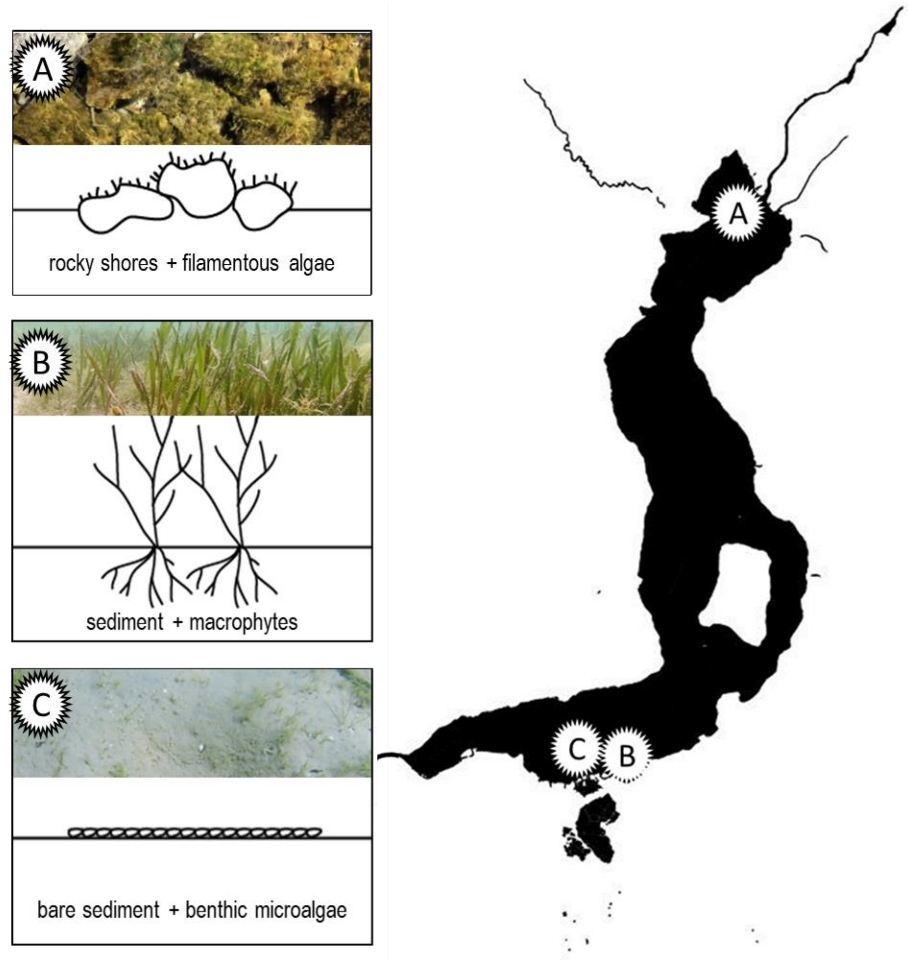
MATERIAL AND METHODS

nutrients accumulation and recycling in the littoral zone:

Three different *littoral habitats* (depth < 5m, rocky with epilithon, sediments with microalgae and with macrophytes) were sampled in 3 dates from May to September 2017.

Intact *sediment cores or rocky substrates* were collected and incubated.

Quantification of *Si fluxes* under light/dark cycles. Silica pools: in water (DSi), primary producers biomass and surficial sediment (BSi).



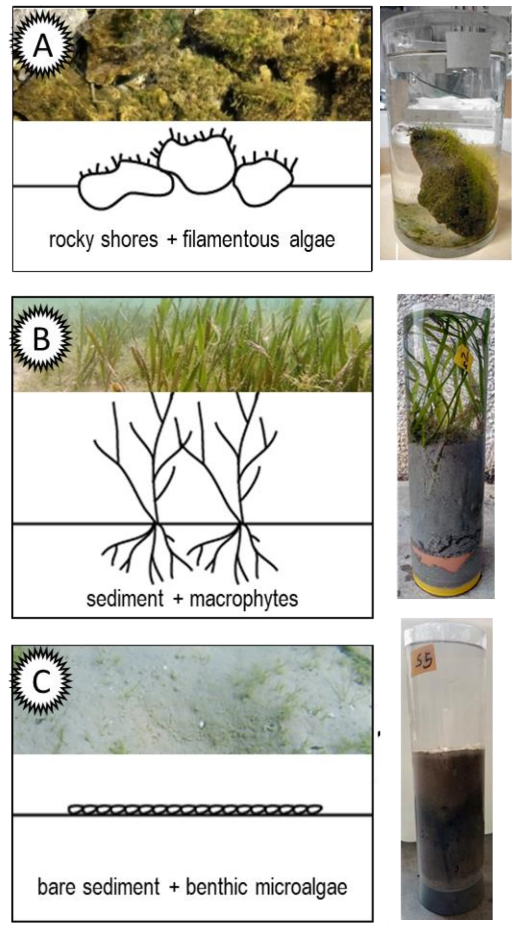
MATERIAL AND METHODS

nutrients accumulation and recycling in the littoral zone:

Three different *littoral habitats* (depth < 5m, rocky with epilithon, sediments with microalgae and with macrophytes) were sampled in 3 dates from May to September 2017.

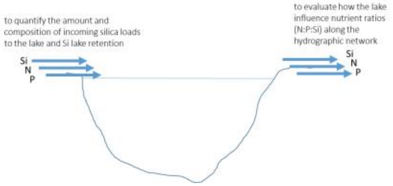
Intact *sediment cores or rocky substrates* were collected and incubated.

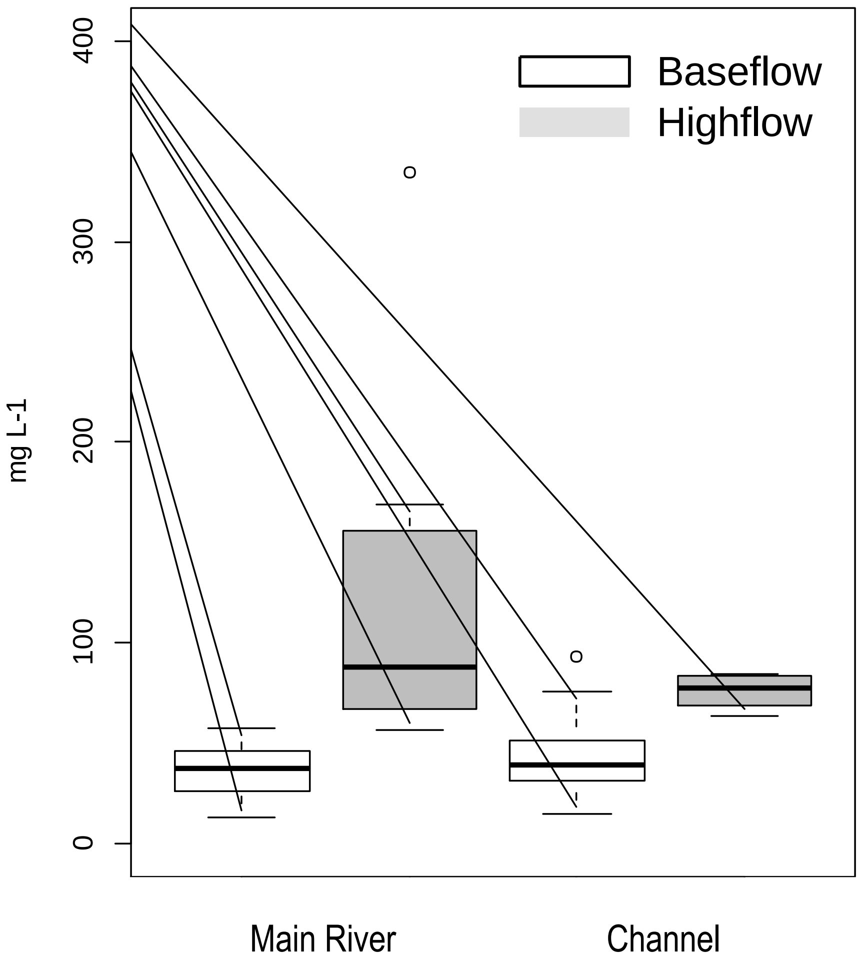
Quantification of *Si fluxes* under light/dark cycles. Silica pools: in water (DSi), primary producers biomass and surficial sediment (BSi).



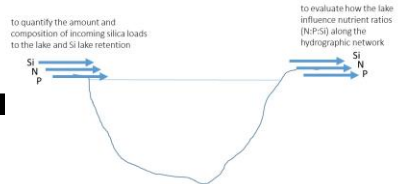
$$F = \frac{(C_f - C_0)V}{A * T}$$

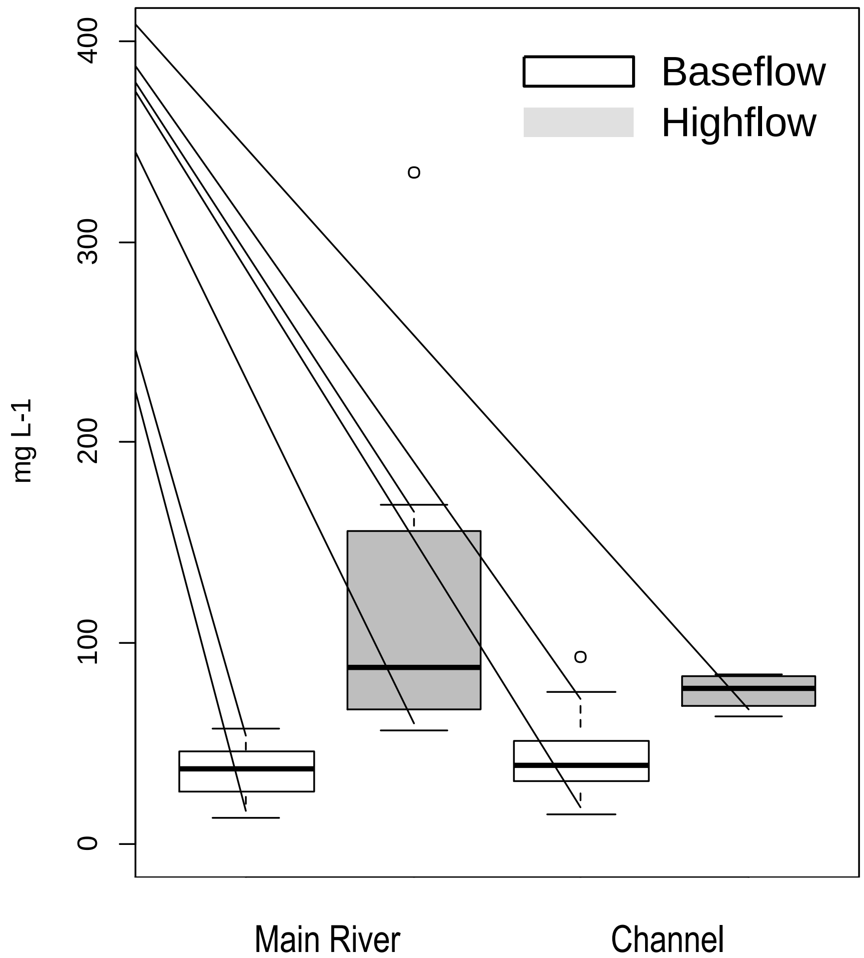
Si external loads

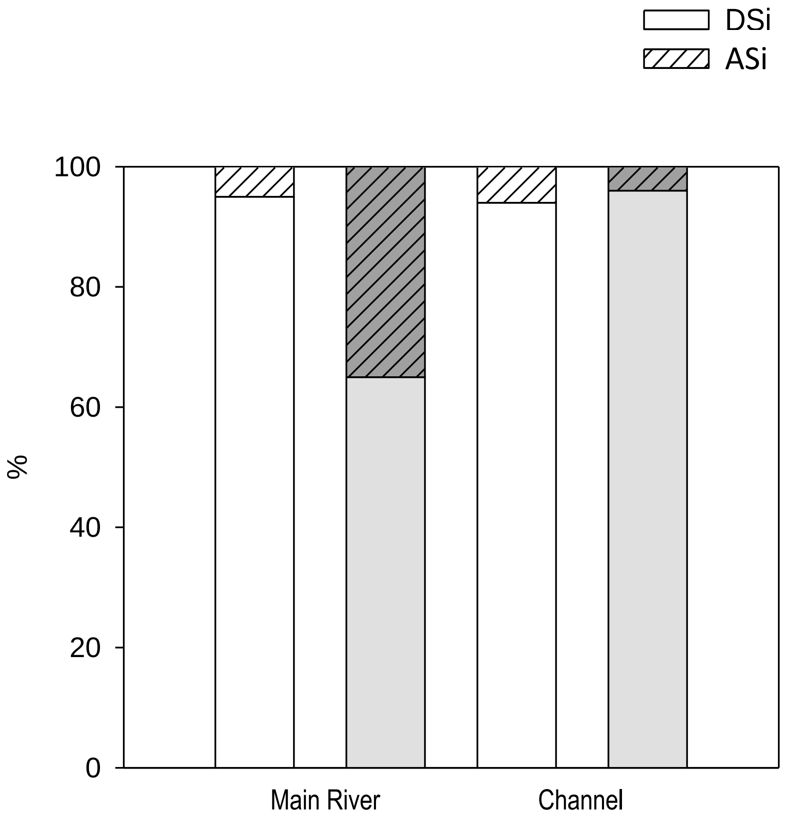




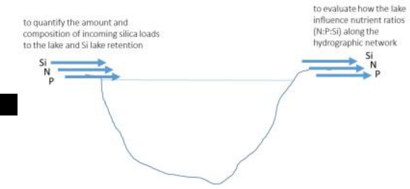
RESULTS
Si external loads

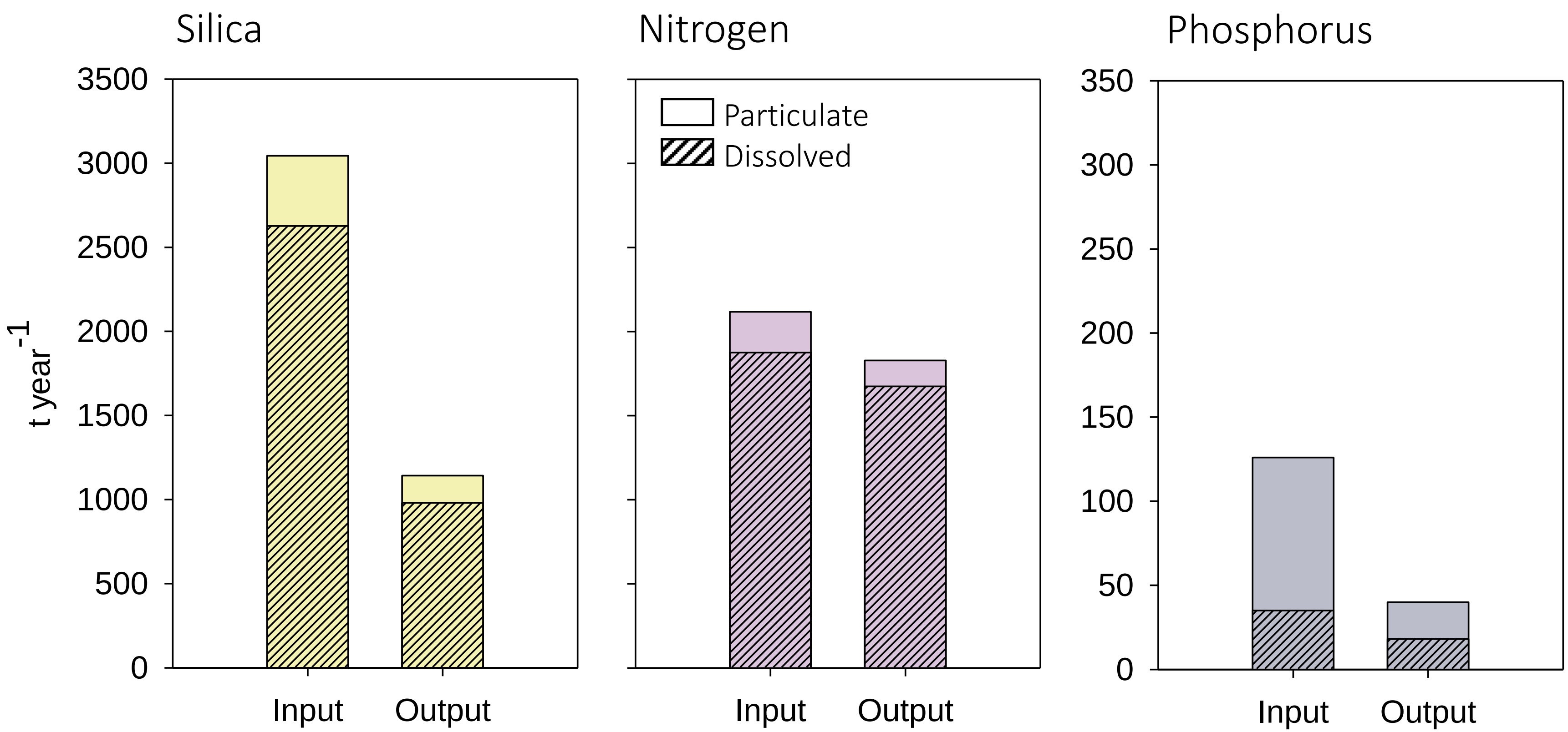






Si, N and P loads and retention

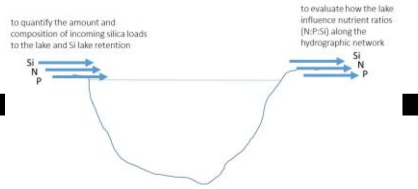


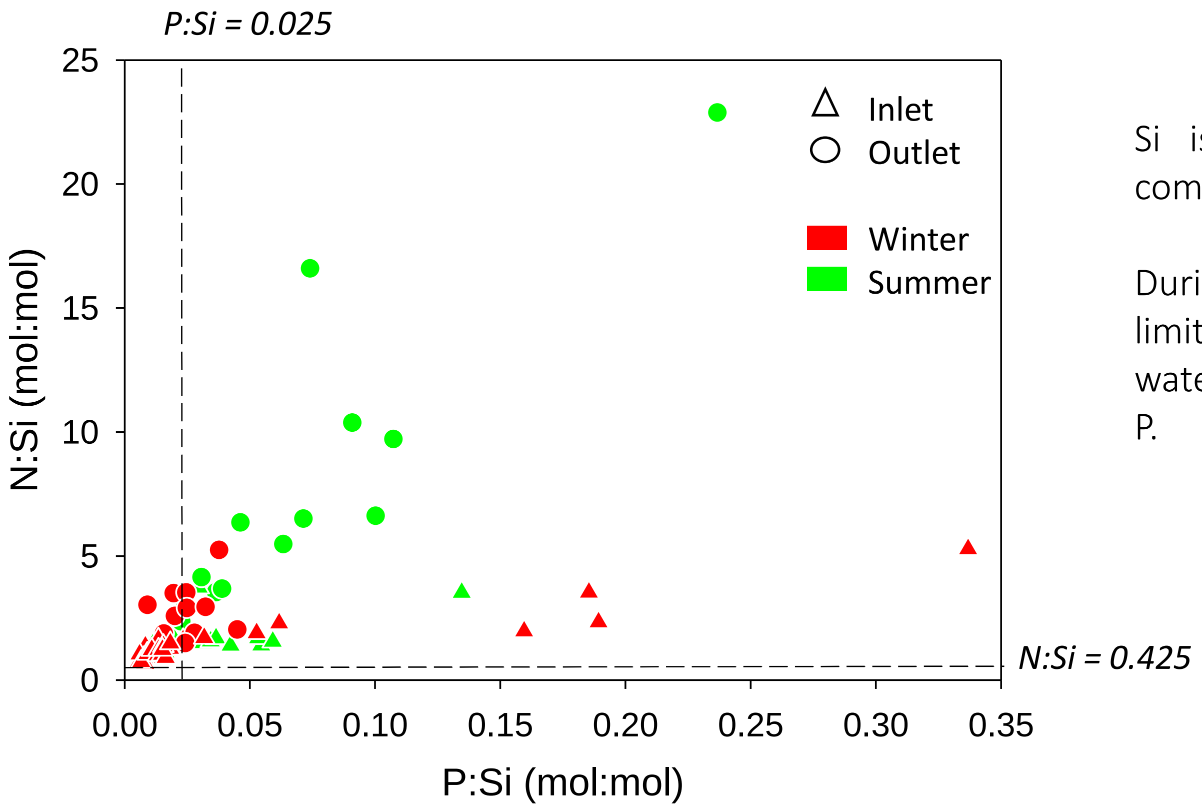


annual retention (%)	annual retention (%)	annual retention (%)
63%	14%	68%

Data from January 2016 to December 2018

Influence of lake biogeochemical processes on Si, P and N ratios

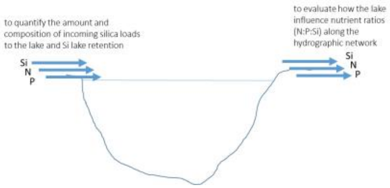


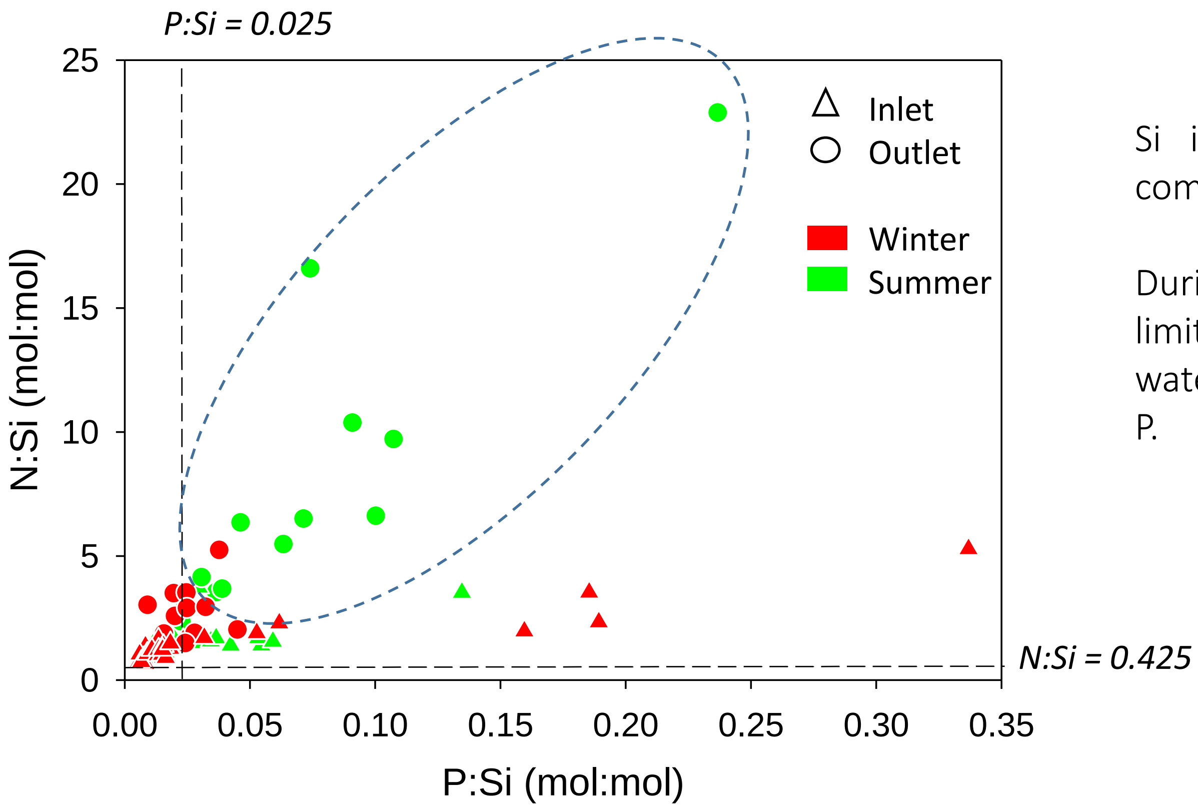


Si is always in limited supply compared to N.

During the summer period Si limitation increases in outflowing waters compared to both N and P.

Influence of lake biogeochemical processes on Si, P and N ratios

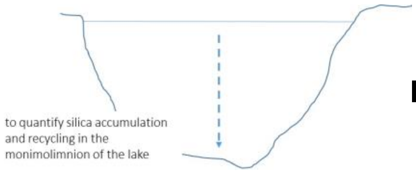


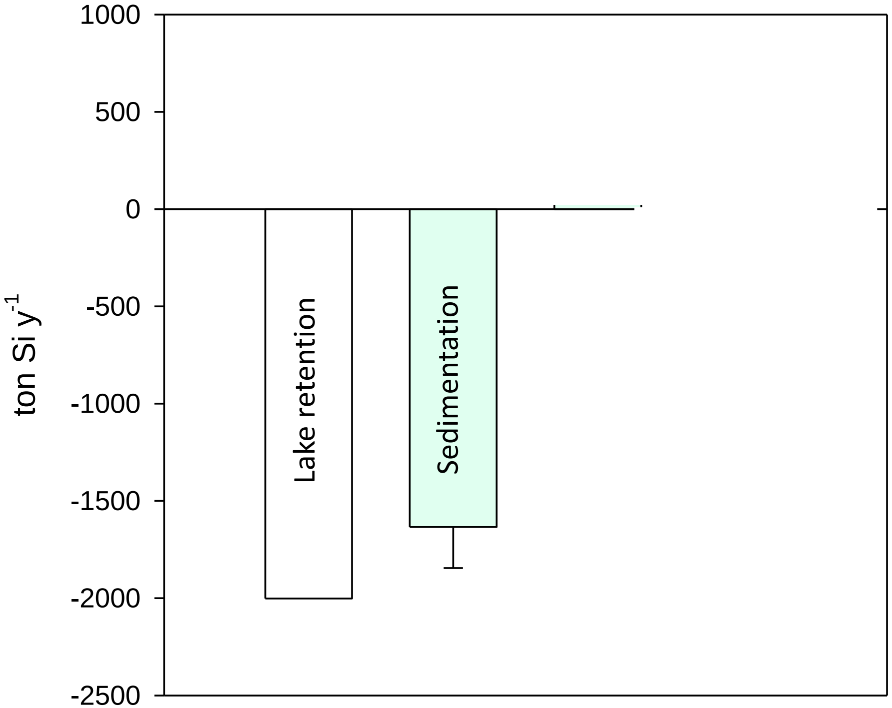


Si is always in limited supply compared to N.

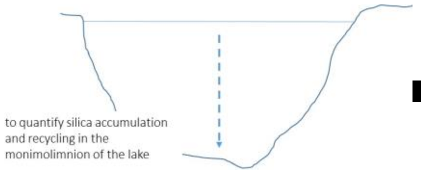
During the summer period Si limitation increases in outflowing waters compared to both N and P.

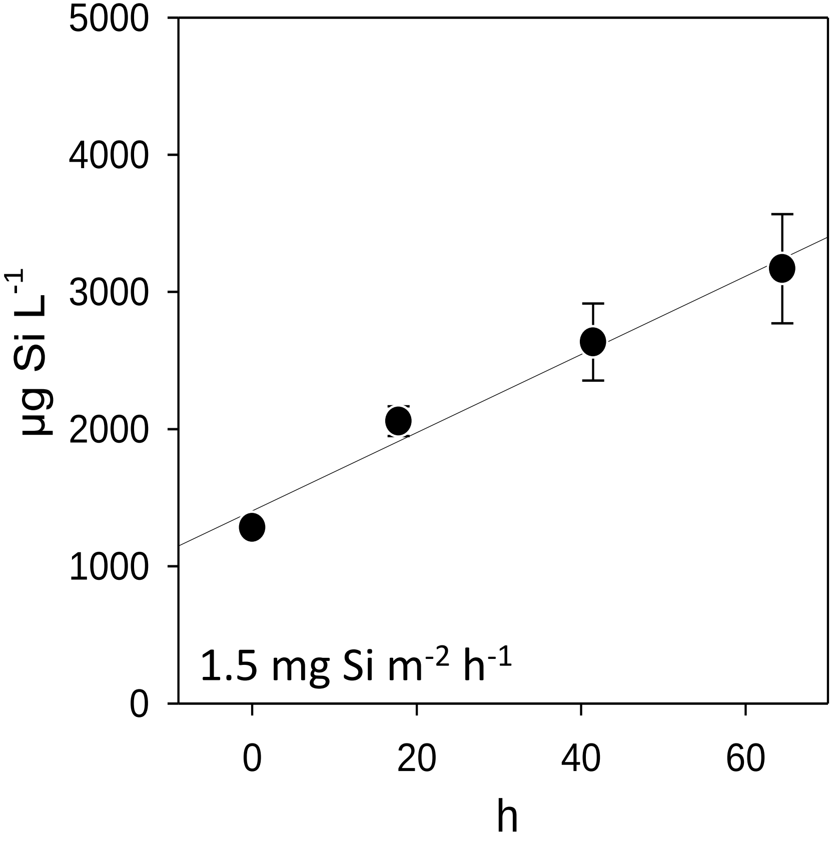
where does the retained Si go?

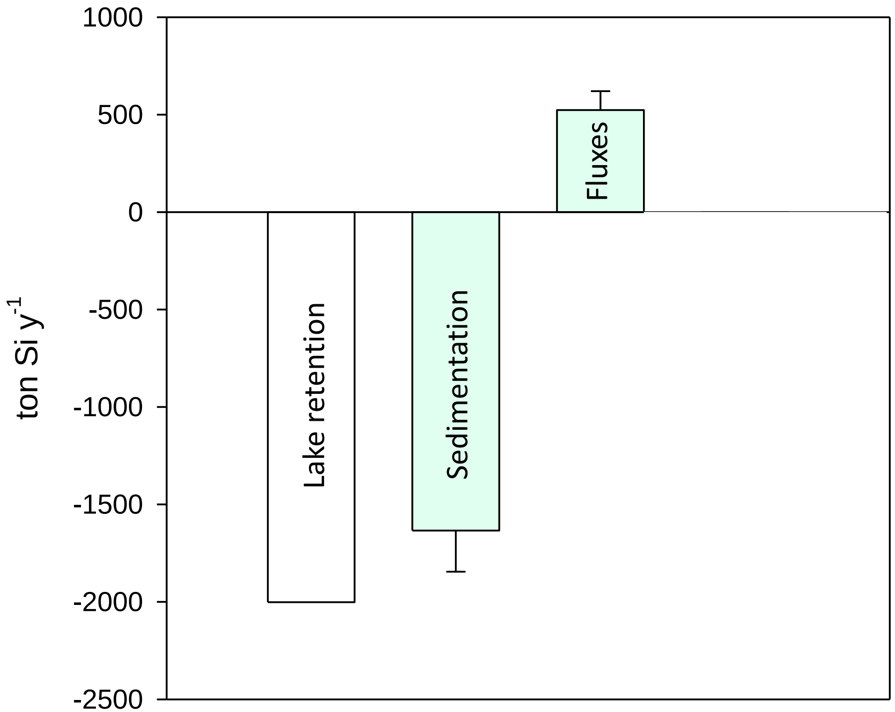




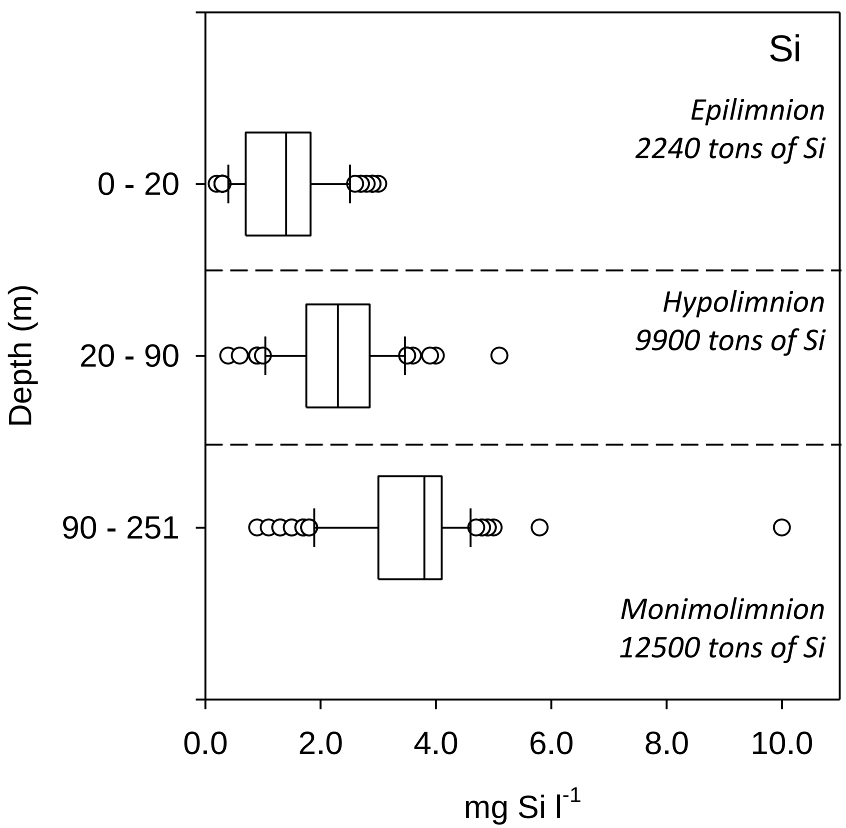
Si recycling in the monimolimnion

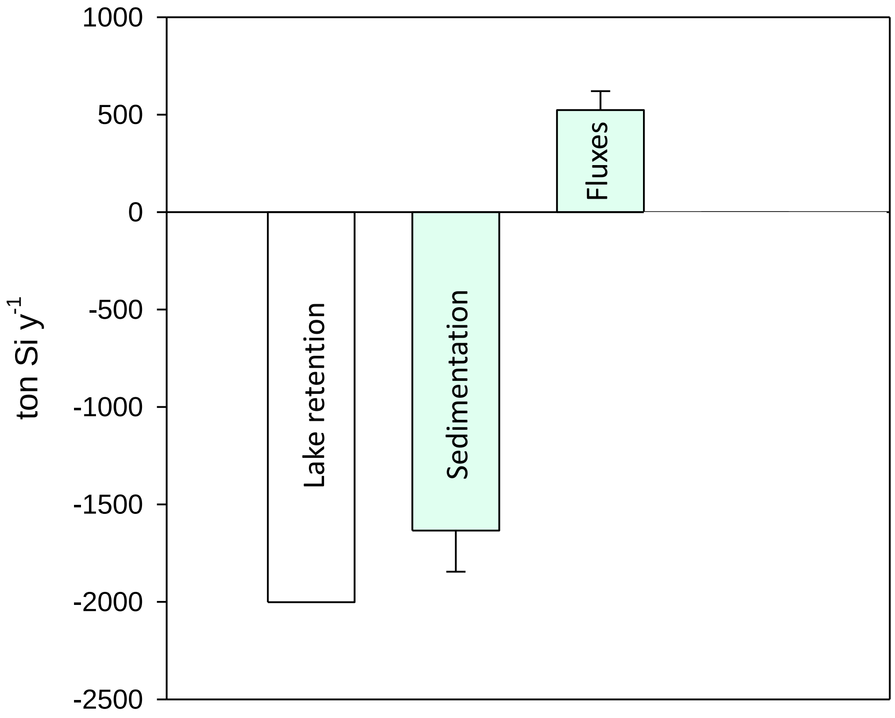






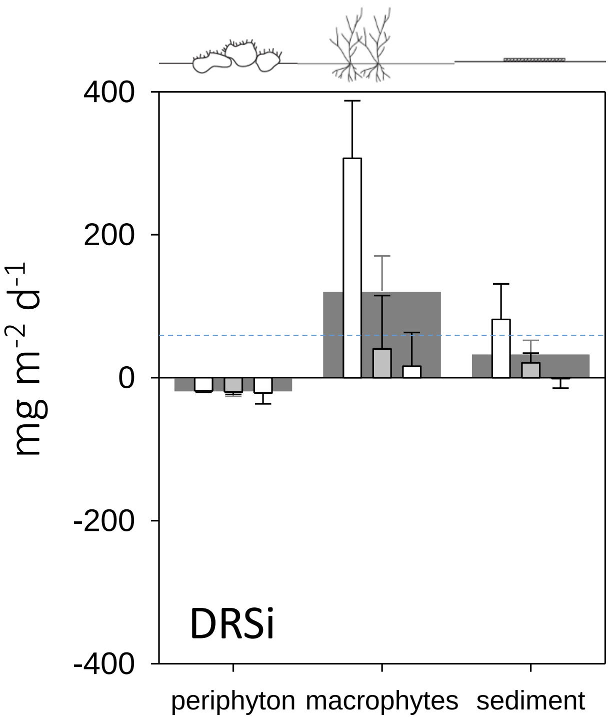
Si accumulation in the monimolimnion

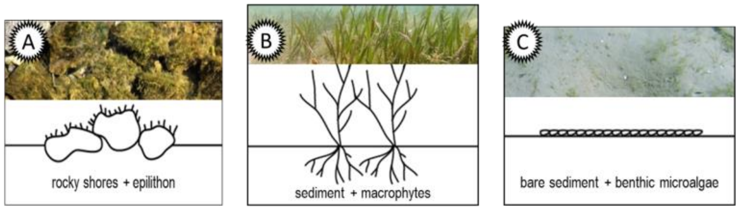




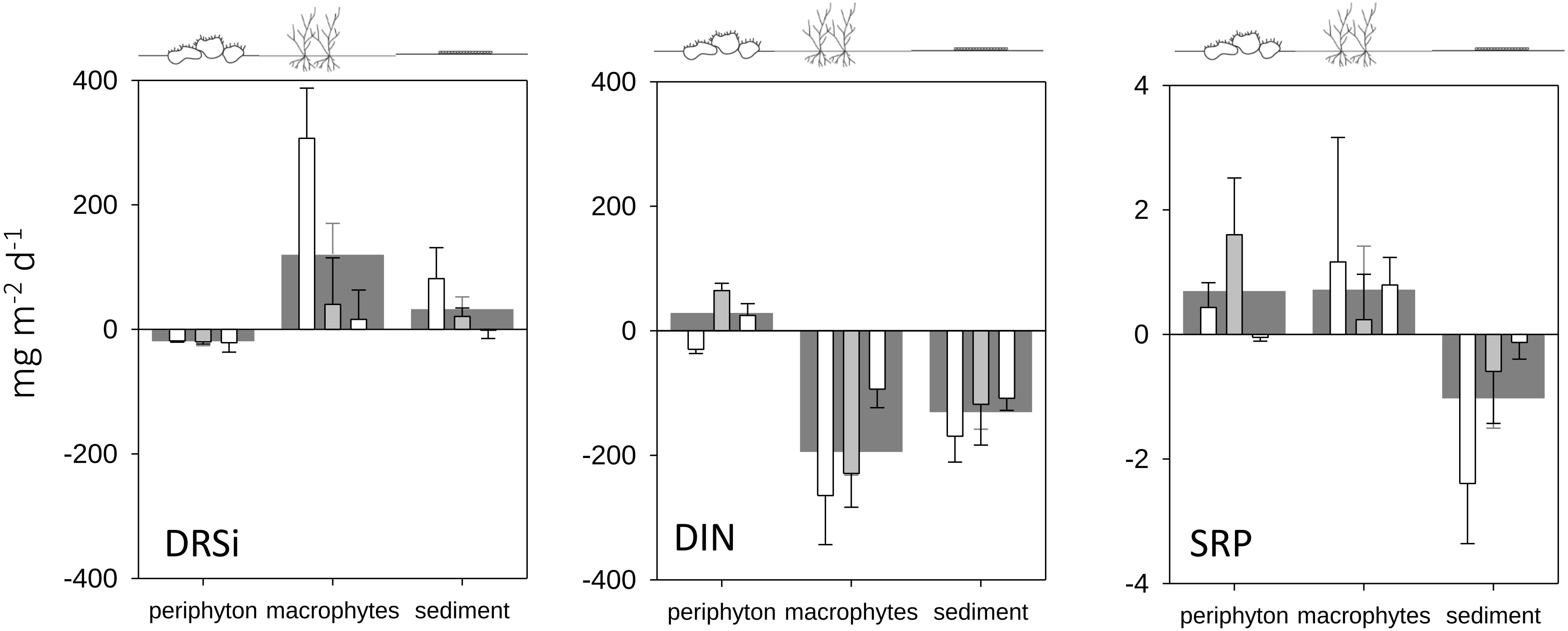
ARPA: 2009 - 2016

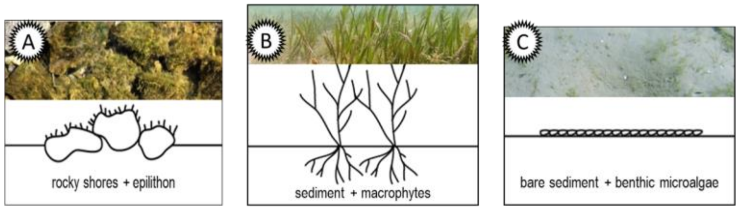
Si fluxes in the littoral zone



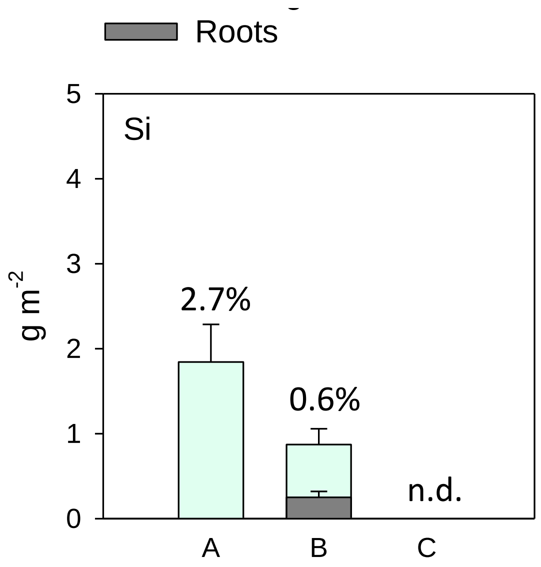


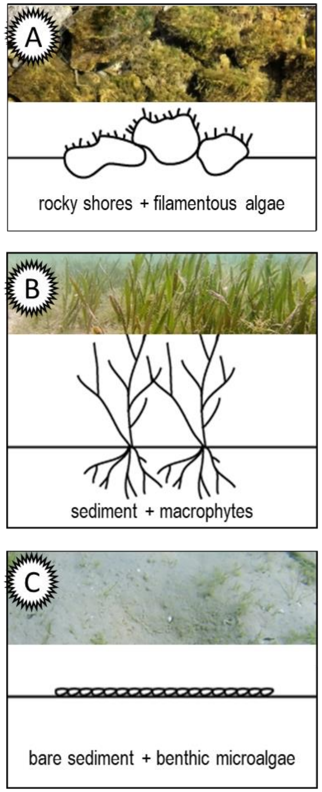
Si, N and P fluxes in the littoral zone





Silica contents in primary producers of littoral zone

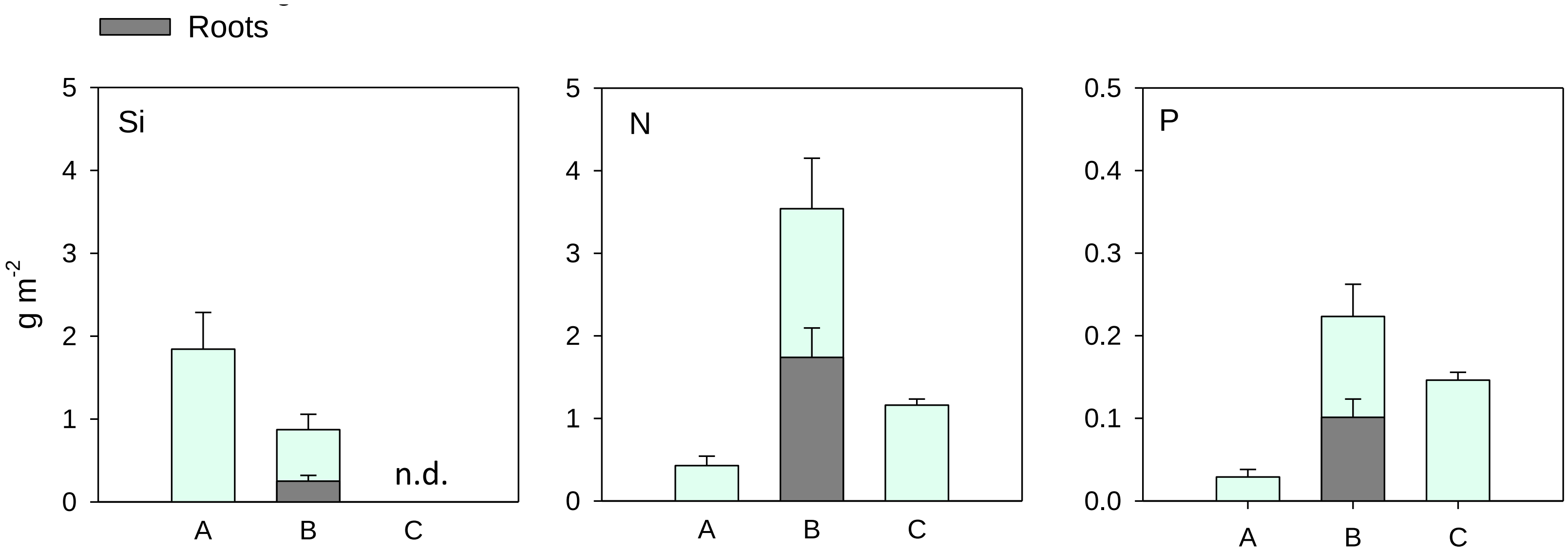




0.05 - 1.0% in *Egeria densa*
0.05 - 0.9% in *Nuphar lutea*
2.4 - 4.6% in *Cladophora glomerata + diatoms*

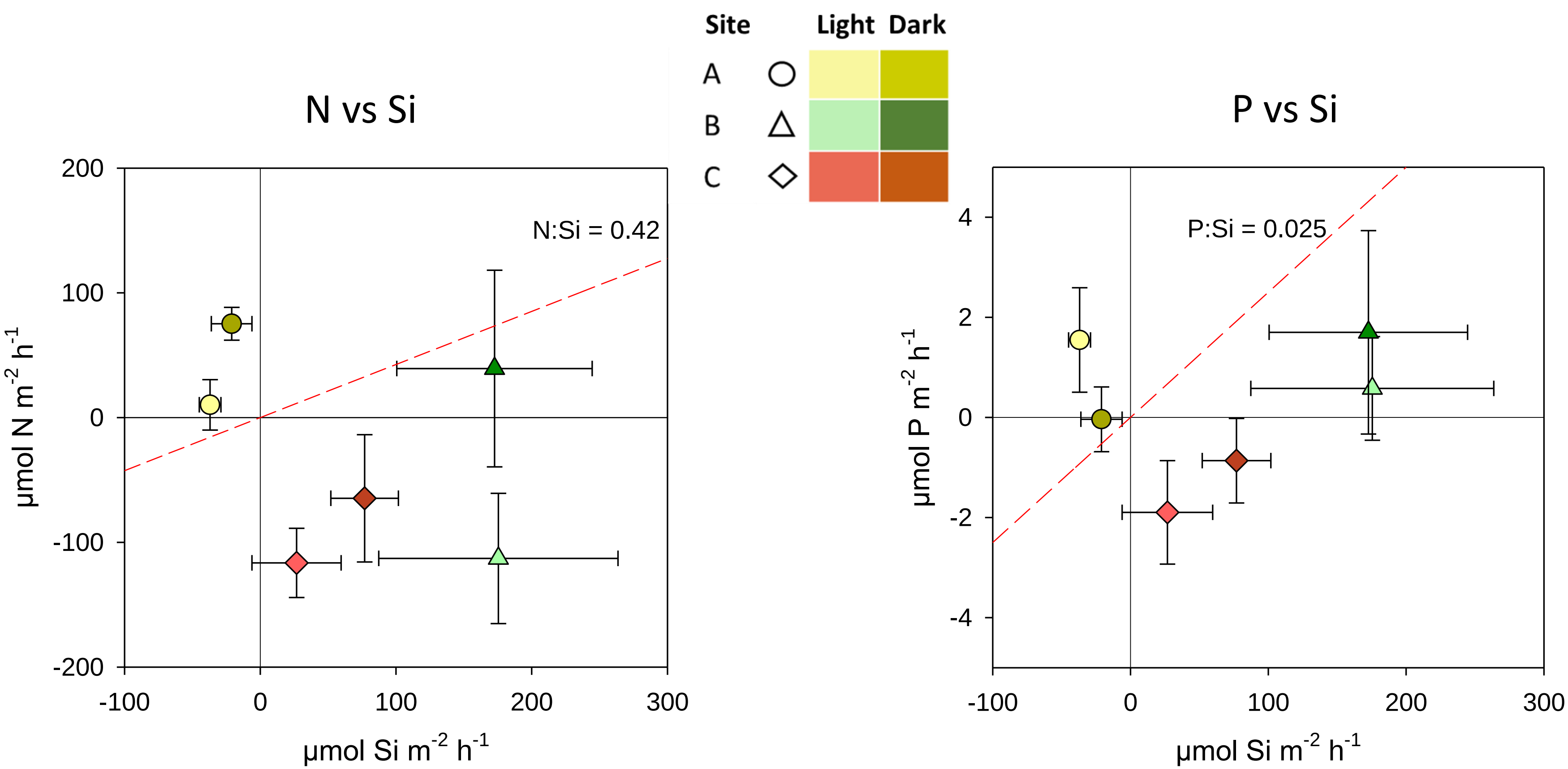
(Malkin et al., 2009; Shoelynk et al., 2012; Shoenlynk & Struyf., 2016)

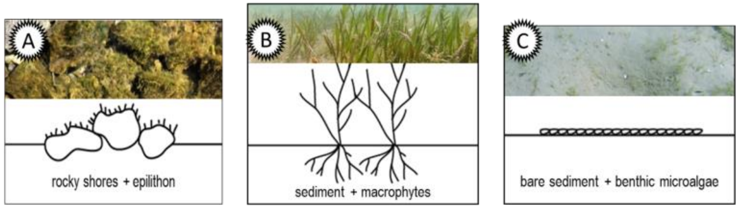
Nutrients content and stoichiometry in primary producers



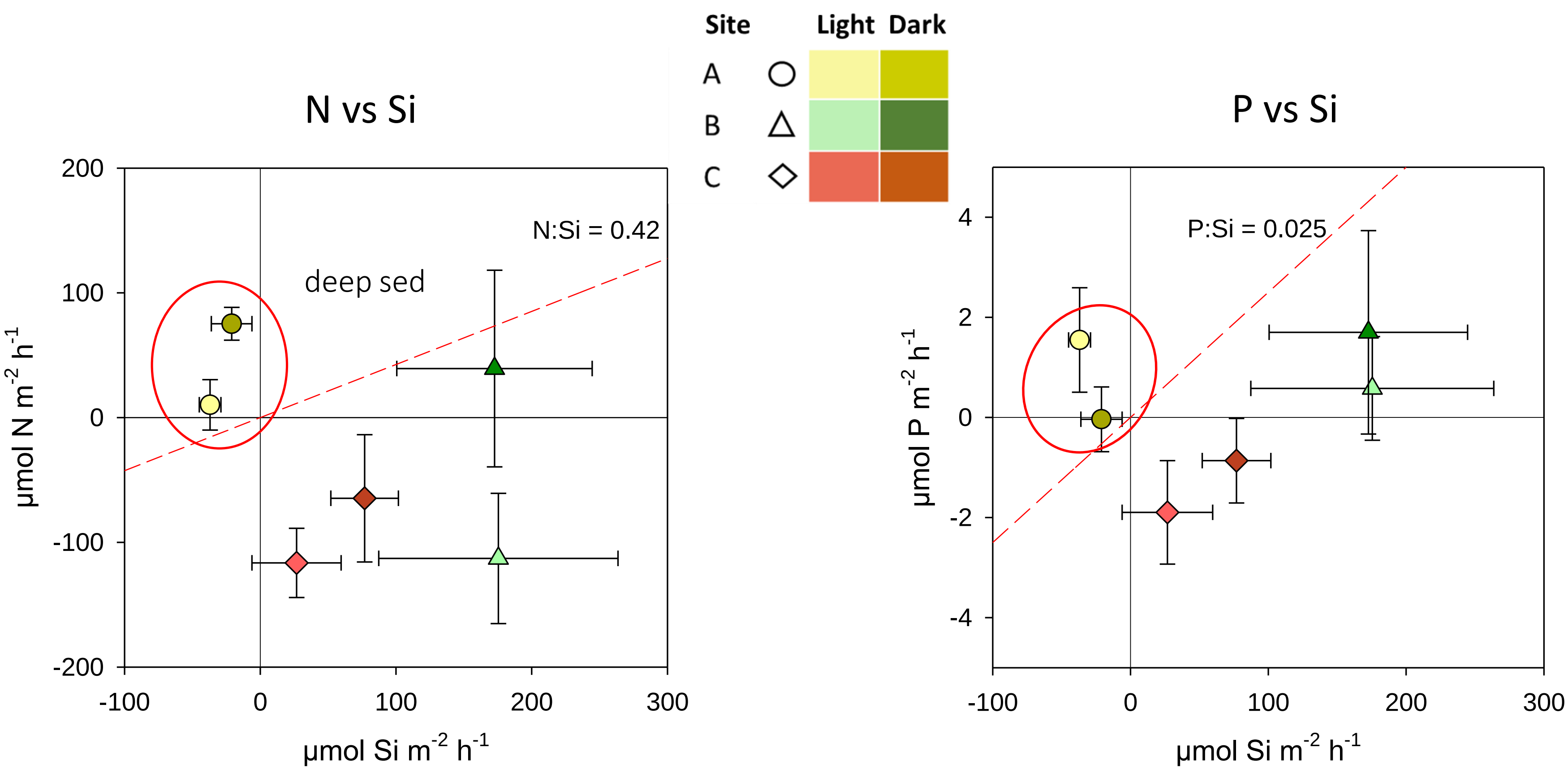
Site	N:Si	P:Si
A filamentous algae	0.45 (± 0.11)	0.01 (± 0.01)
B aboveground	6.71 (± 2.56)	0.21 (± 0.12)
B roots	12.22 (± 5.93)	0.31 (± 0.11)

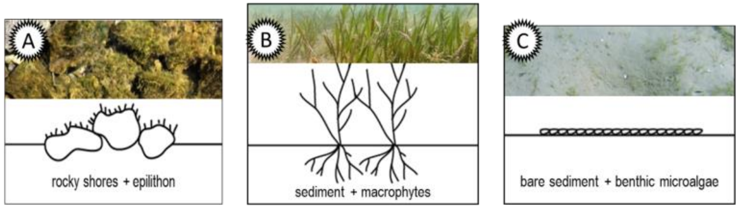
Flux stoichiometry





Flux stoichiometry





Concluding remarks

Lake Iseo is a net and efficient sink of Si (2000 tons Si y^{-1}) and phosphorous (86 tons P y^{-1}). Efficient Si retention influences nutrients proportions along the hydrographic network especially during the summer period, resulting in an increase of N:Si and P:Si molar ratio in the Oglio river.

The retained Si is mainly deposited to the lake bottom (1634 tons Si y^{-1}) and the Si released from the same sediments (523 tons Si y^{-1}) is trapped into the monimolimnion.

On average the littoral zone is a net source of Si to the water column during the summer season. This is an important function as Si recycling is a source to phytoplankton.

However littoral primary producers influence differently water-sediment Si fluxes. The littoral zone with sediment is a net Si source to the water column (sites VS = 364±119 ton Si y^{-1} and BS = 111±45 ton Si y^{-1}) while rocky shores are a net Si sink (-59±15 ton Si y^{-1}).

1 first level degree thesis, Natural and environmental Sciences
Ferrari Alessandro, Water quality in the Oglio river flowing into the Iseo Lake.

2 second level degree thesis
Ceccon Silvia, Origin and transfer of phosphorus and nitrogen loadings in the Lake Iseo watershed.

Cristini Domiziana, Evaluation of nitrogen and phosphorus loads and benthic metabolism in the littoral zone of Lake Iseo.

1 PhD thesis in Ecology
Scibona Alessandro Influence of hydrology and primary producers activity on silica biogeochemistry in shallow aquatic environments

Congresses

Nizzoli D, Scibona A, Bolpagni R, Longhi D, Cristini D, Viaroli P. Silica dynamics in a subalpine lake: from external loads to in lake processes. XXVIII Convegno Nazionale della Società Italiana di Ecologia Cagliari 12-14 settembre 2018.

Scibona A., Nizzoli D., Cristini D., Longhi D., Bolpagni R., Viaroli P. Silica regulation and nutrients stoichiometry in a subalpine lake: from external loads to in lake processes. XXIV Congresso AIOL. Bologna 5-7 giugno 2019

In preparation

Scibona A., Nizzoli D., Cristini D., Bolpagni R., Viaroli P. Influence of different primary producers on silica tranformations and nutrients stoichiometry in a subalpine lake (lake Iseo). Waters

Scibona A., Nizzoli D., Hupfner M., Pilotti M., Viaroli P. Silica load and nutrient stoichiometry in a meromitic lake (lake Iseo, italy). Biogeochemistry

N and P loads to lake Iseo

	DRSi	BSi	Tsi	TP	SRP	TDP	PP	TN	NH4	NO3	TDN	PN
Canal	1399	78	1477	41	11	14	29	885	32	652	825	59
Oglio	1227	340	1568	85	17	22	62	1232	72	859	1050	174
Input	**2626**	**418**	**3044**	**126**	**28**	**35**	**91**	**2117**	**104**	**1510**	**1875**	**233**
Output	980	162	1142	40	8	18	22	1828	94	1095	1674	153
Retention	1646	256	1902	86	20	17	69	289	10	415	201	80
%	63	61	62	68	71	49	76	14	10	27	11	34