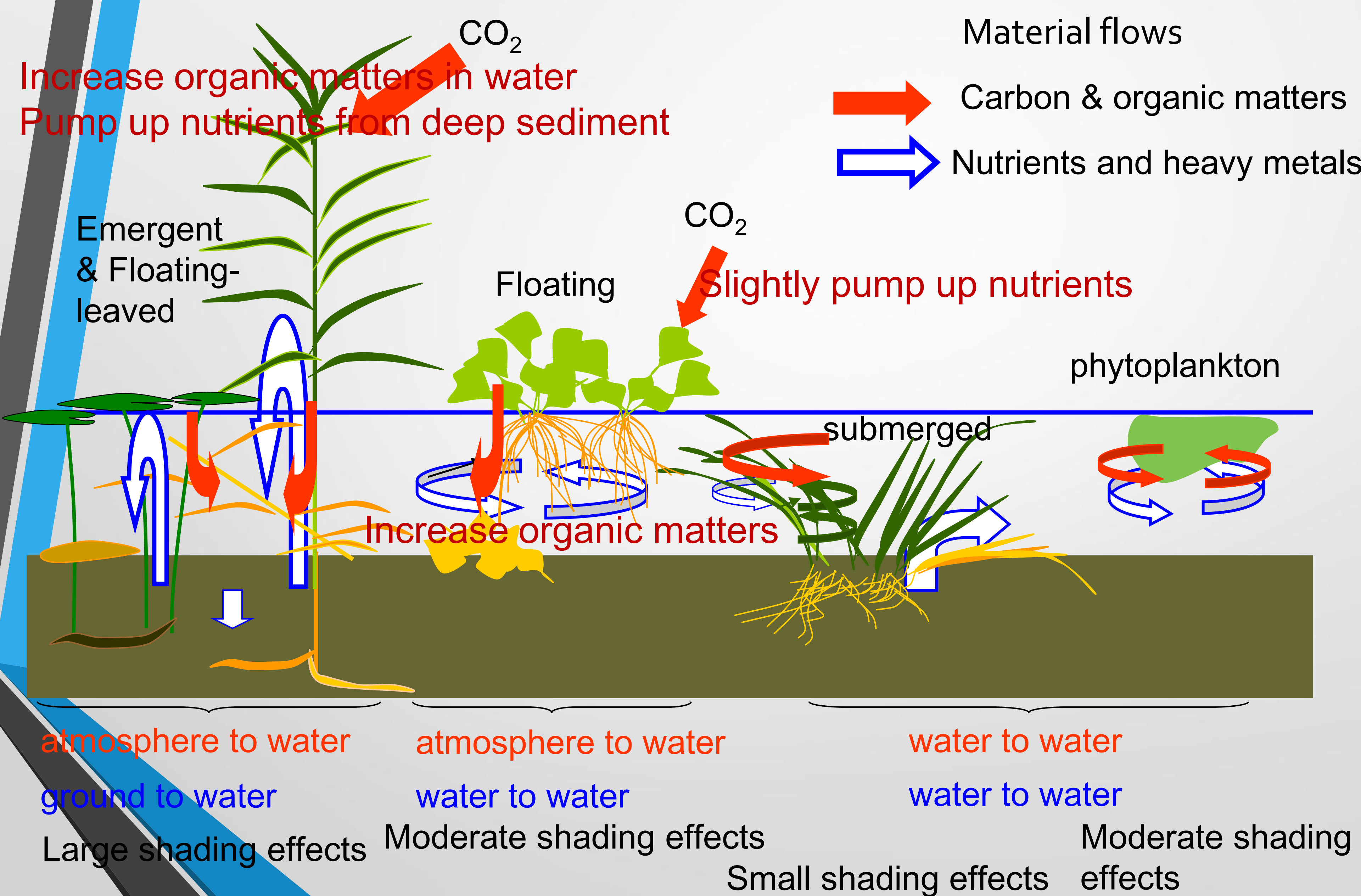
Use of Aquatic Plants in Urban Drainage Wetlands - What kind of aquatic plants are good both for drainage and phytoremediation? =

Takashi Asaeda
and
Md Harun Rashid
Department of Environmental Science
Saitama University
255 Shimo-okubo, Sakura, Saitama 338-8570 Japan

Aquatic plants are useful for urban wetlands system. But….

Different types of phytoremediation by aquatic plants in wetlands

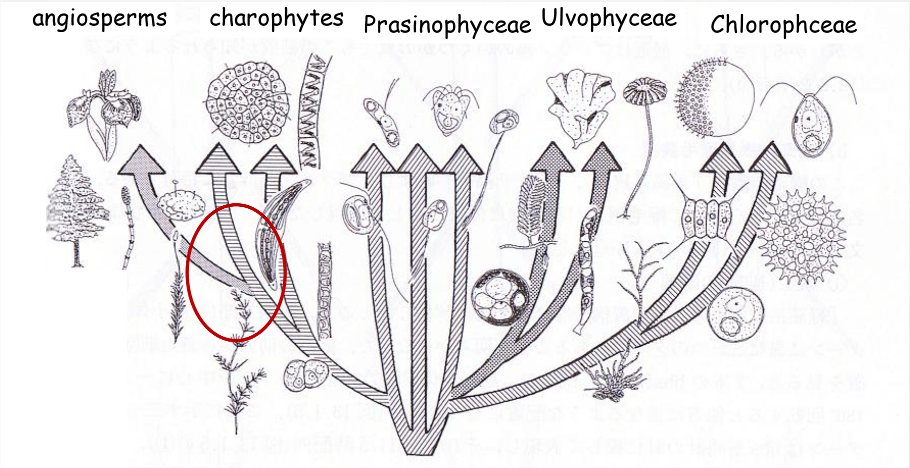
Sources of carbon dioxide and elements for the growth



Removal of heavy metals and phosphorus
- A magnificent property of charophytes-

What are charophytes?

In plant systematics, charophytes are located between angiosperms and algae



Charophytes (*Chara braunii*) growing in the treatment wetland

Ecological significance of Charophytes

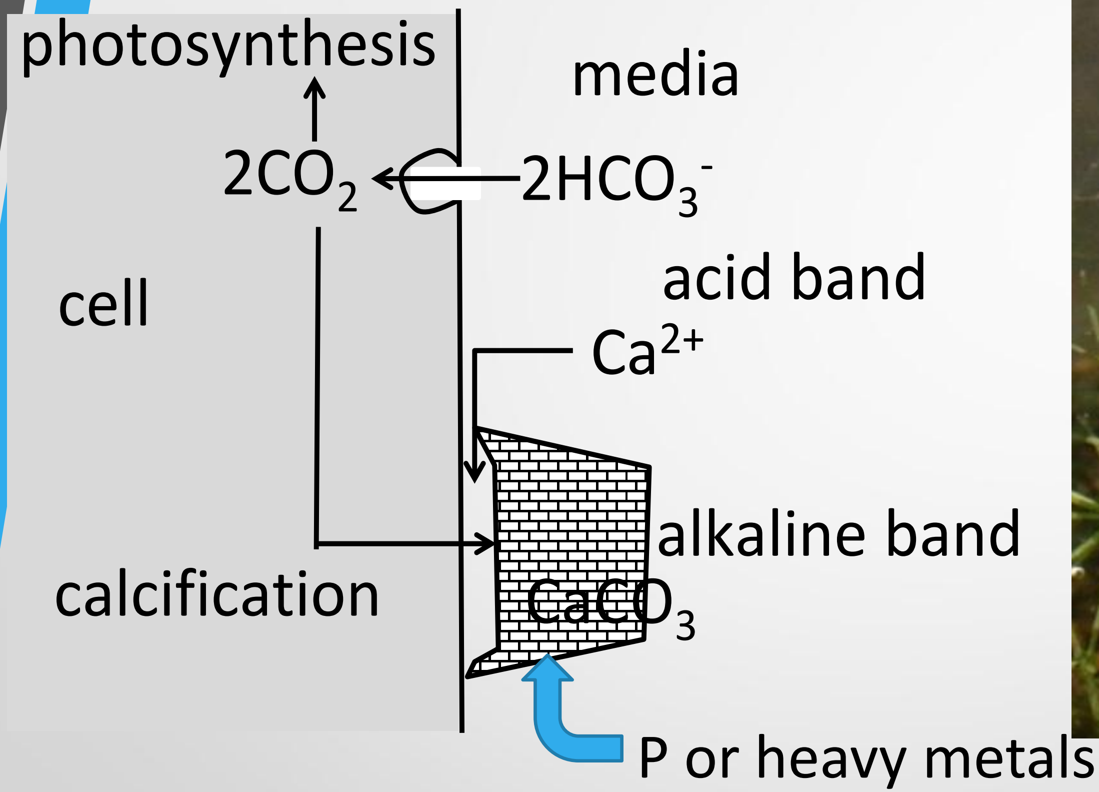
- Charophytes provide habitats for various organisms and increase their biomass.

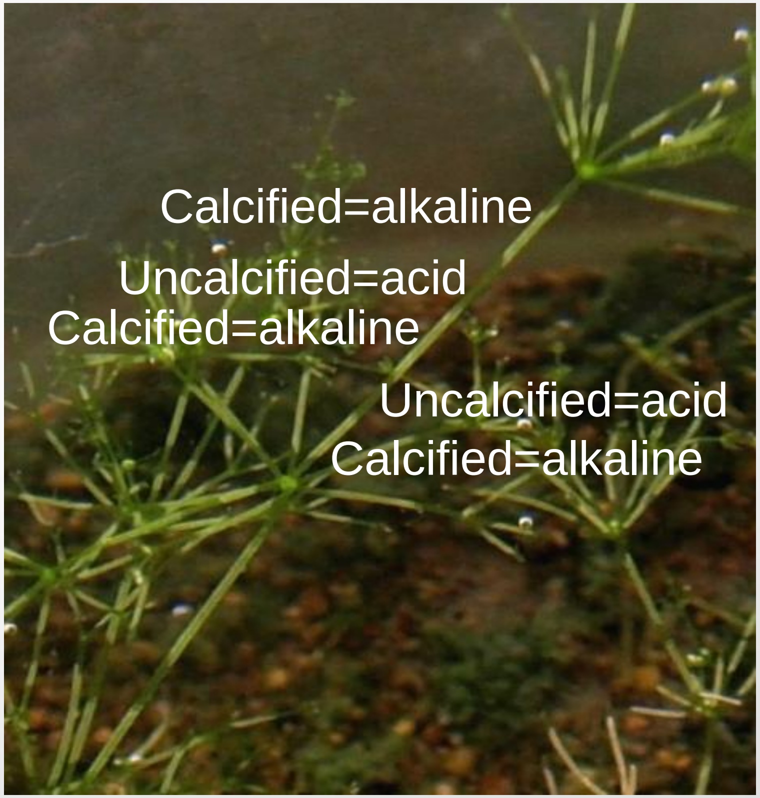
  ex. zooplankton grazes

  phytoplankton

- Charophytes prevent bed materials to be re-suspended.

Effective for removal of phosphorus and heavy metals





Charophytes produce calcium carbonate crust and trap phosphorus and heavy metals with Ca^{2+} in water.

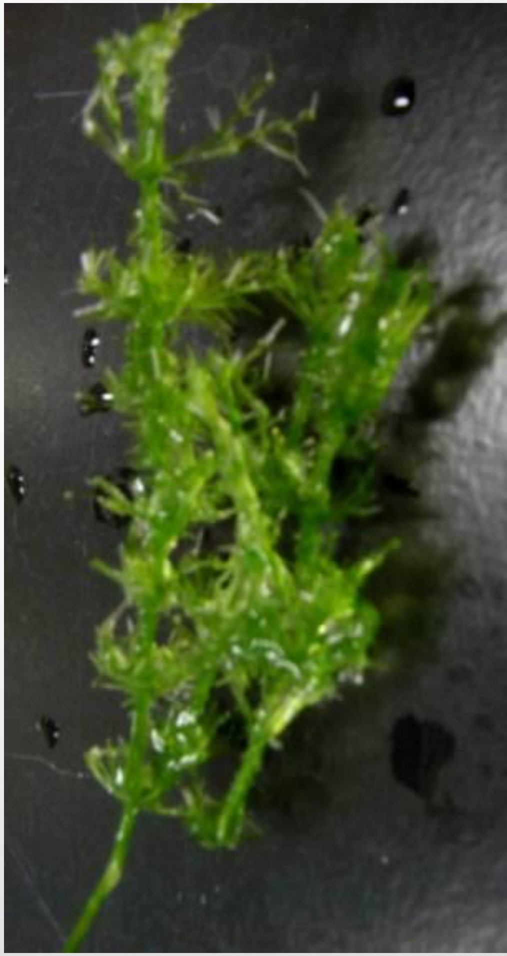
Highly tolerant against heavy metals

Cd in media :0.001 mg/L

Total Cd in plant: 0.3 mg/kg dry weight basis (d.w.), BCF (bio-concentration factor) : 300

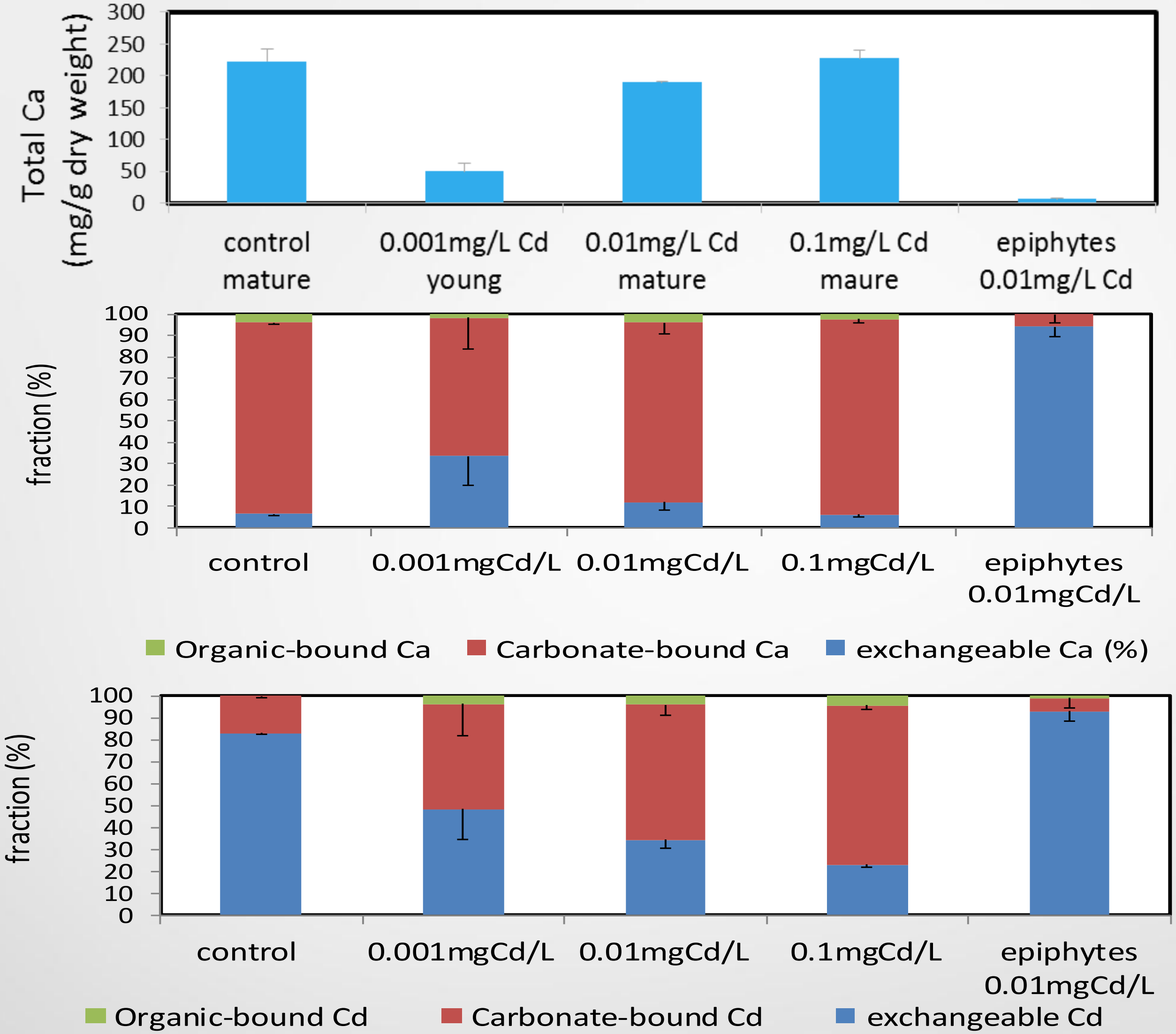
Cd: 0.01 mg/L

Total Cd: 125-134 mg/kg d.w.
BCF: 12500 - 13400



Cd: 0.1 mg/L

Total Cd: 734 mg/kg d.w.
BCF: 7340



- Large amount of cadmium is carbonate-bound.
- Carbonate-bound cadmiun is not released at decomposition of plants and therefore is stably accumulated in the sediment.
- Biomass of charohytes is relatively small. Good for drainage system.

(Siong & Asaeda, *J Hazardous Materials*, 167, 2009)

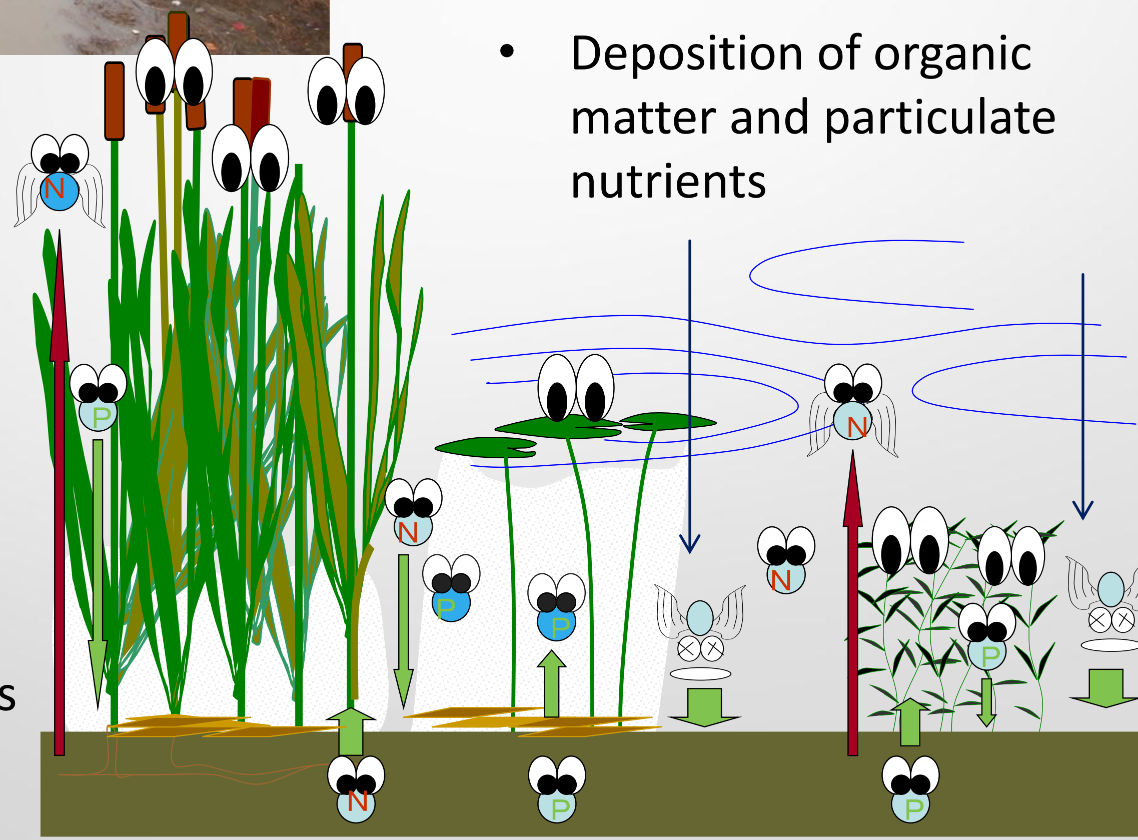
Removal of nutrients and organic matters
- Acceleration of floating matter particles settling-

Plant community traps particles suspended in water, and purifies.

Trapped sediments in plant community

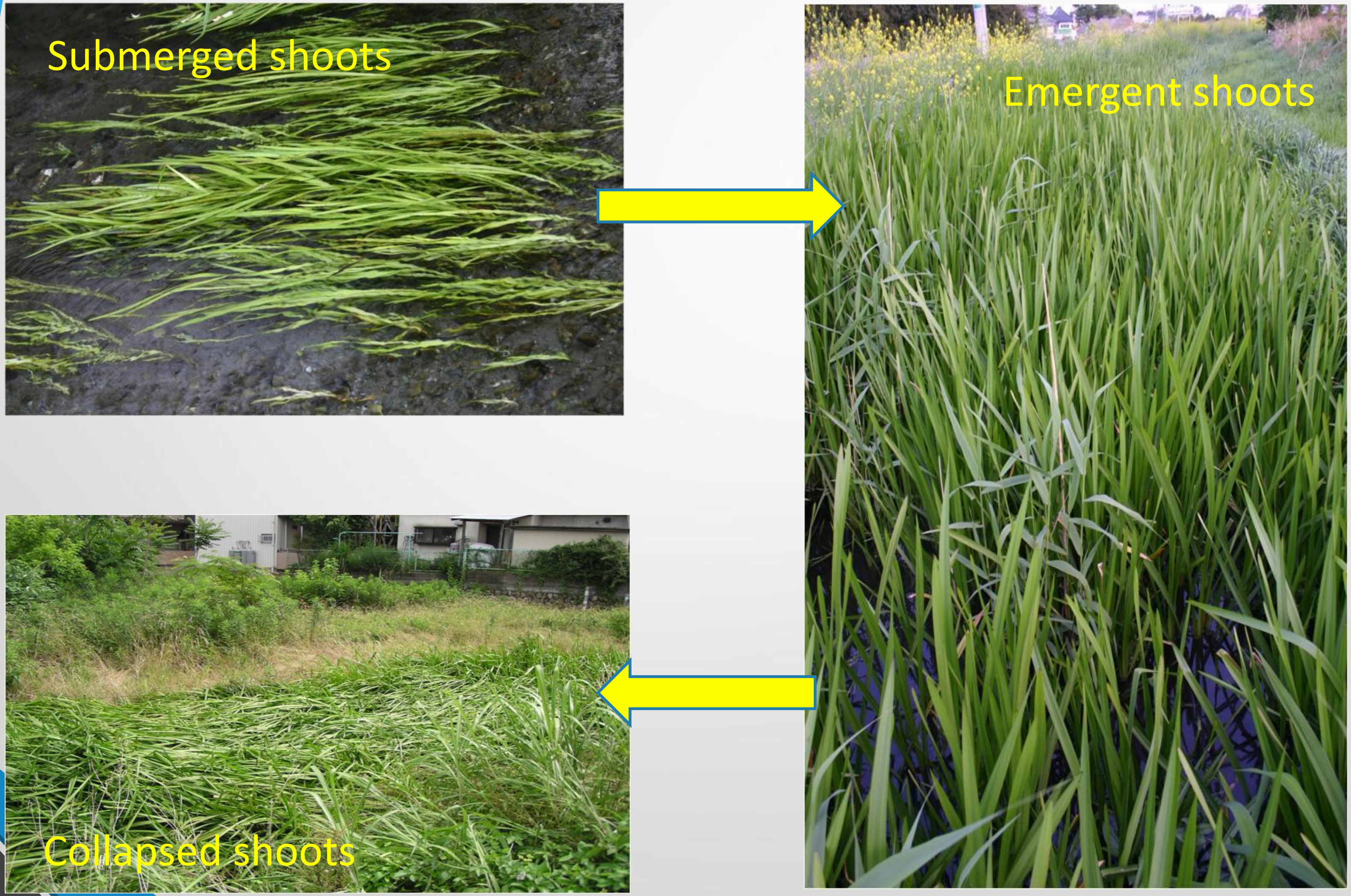
- Deposition of organic matter and particulate nutrients

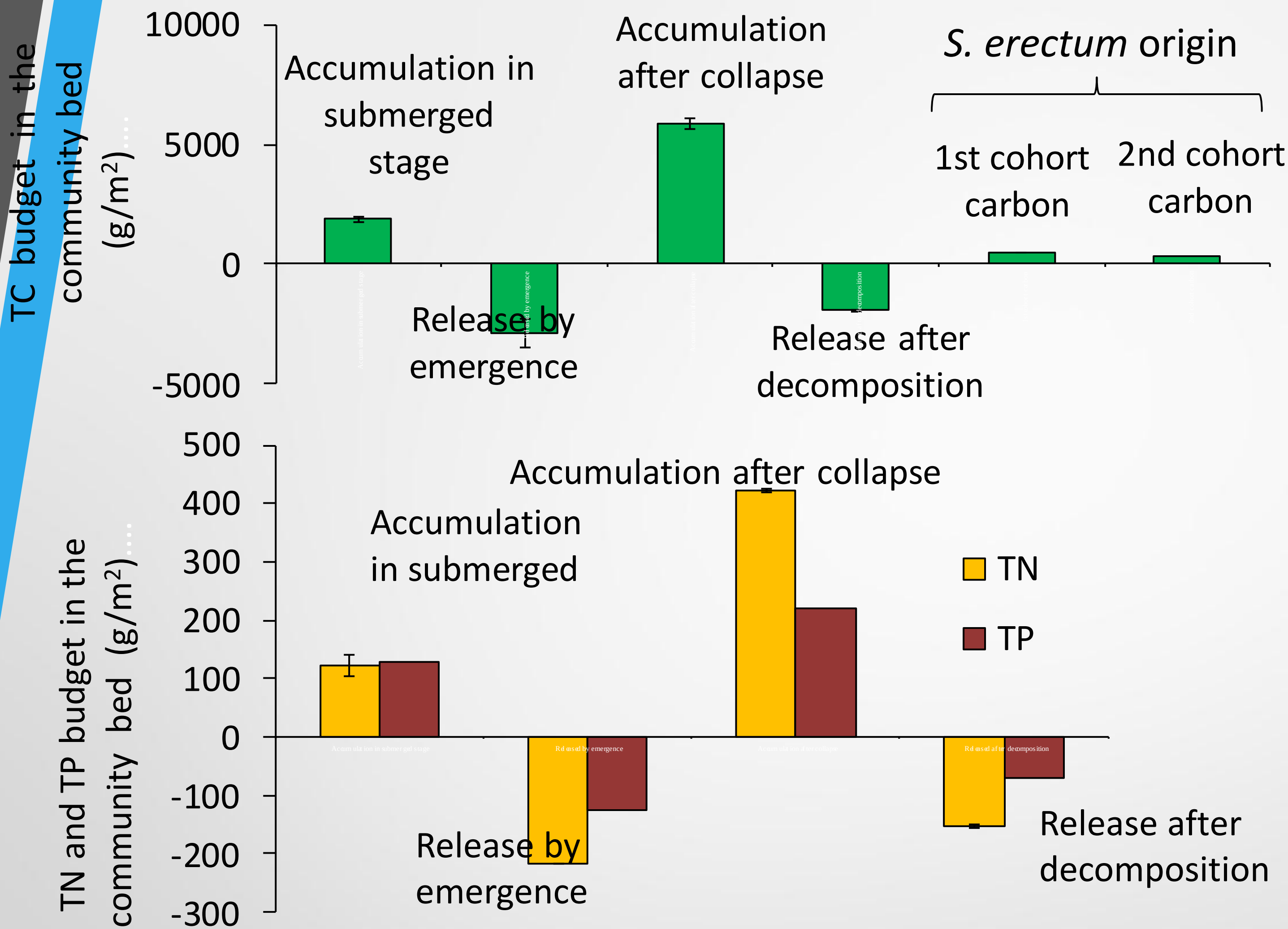
- Acceleration of nitrification and de-nitrification
- Transport oxygen into the sediment
- Provide habitats for organisms which consume organic matters and phytoplankton



Which type of aquatic plants are more efficient to trap floating matters, emergent or submerged?

Life cycle of *Sparganium erectum*





Carbon and nutrients are deposited when shoots are submerged and collapsed, while are washed away when shoots emerge or collapsed shoots are decomposed.

Organic matter and nutrient are more efficiently trapped in submerged stage (plants) rather than emergent stage (plants).

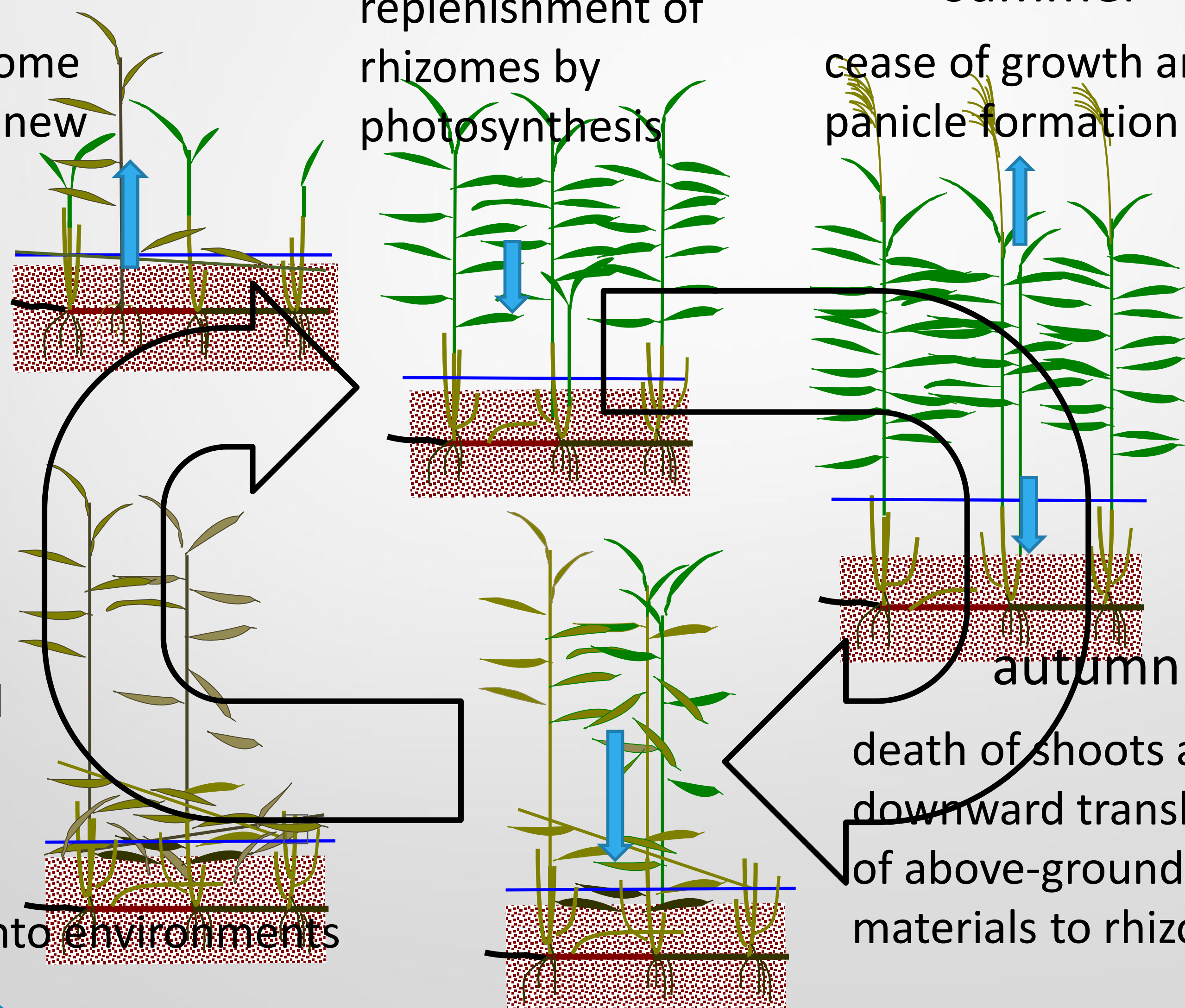
Biomass is small with submerged plants.

(Asaeda et al., *River Res. Appl.*, 27, 2010)

Quantitative prediction method
- Application of numerical models -

Life cycle of perennial plants

: material flows



spring to early summer

shoot growth and replenishment of rhizomes by photosynthesis

spring

translocation rhizome materials to form new shoots

summer

cease of growth and panicle formation

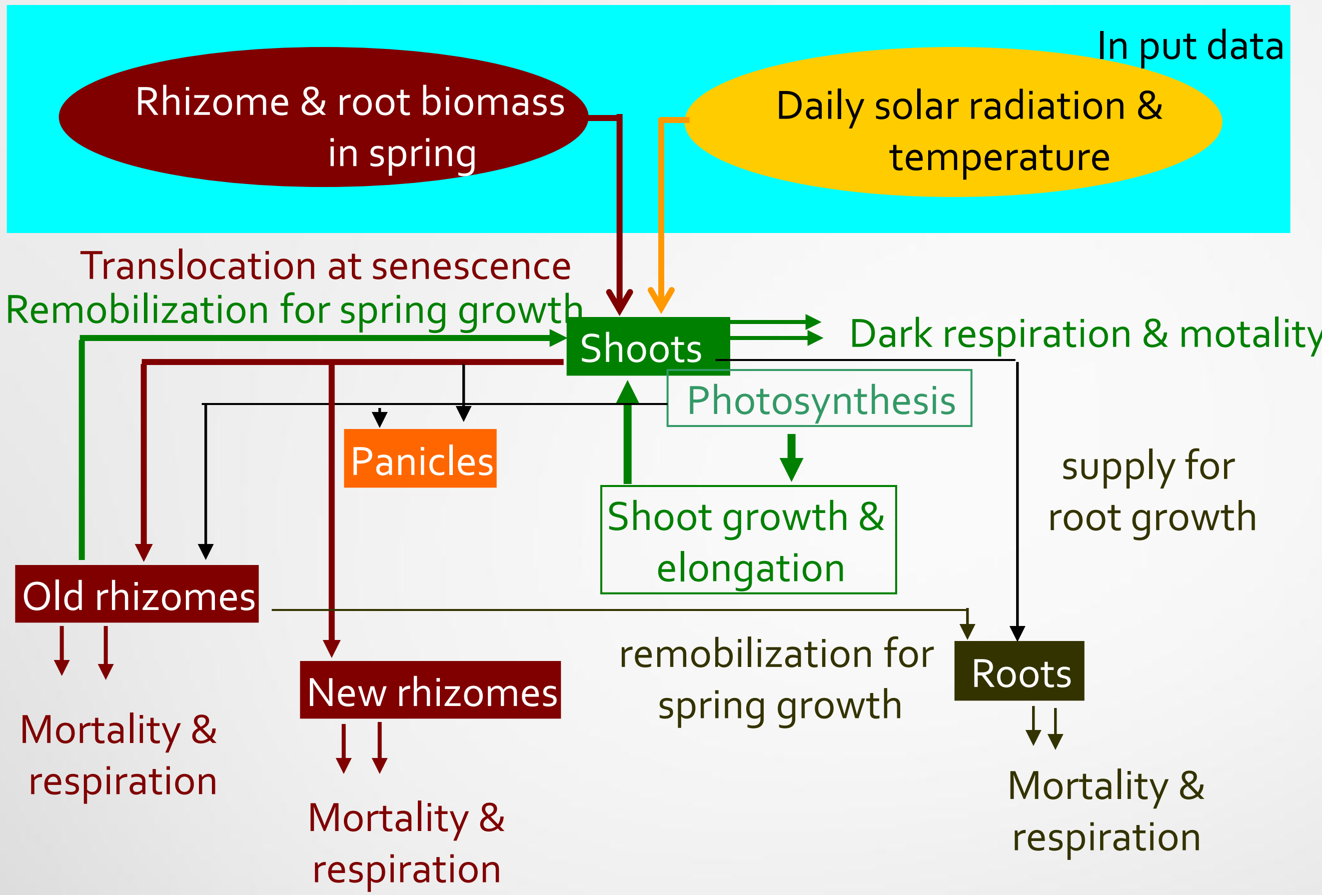
winter

Standing dead, and collapsed and decomposing shoots

nutrient release into environments

autumn

death of shoots and downward translocation of above-ground materials to rhizomes



f(environment)

shoots $\frac{d}{dt}$ [biomass] = [photosynthetic production] - [respiration loss] - [mortality loss] - [translocation]

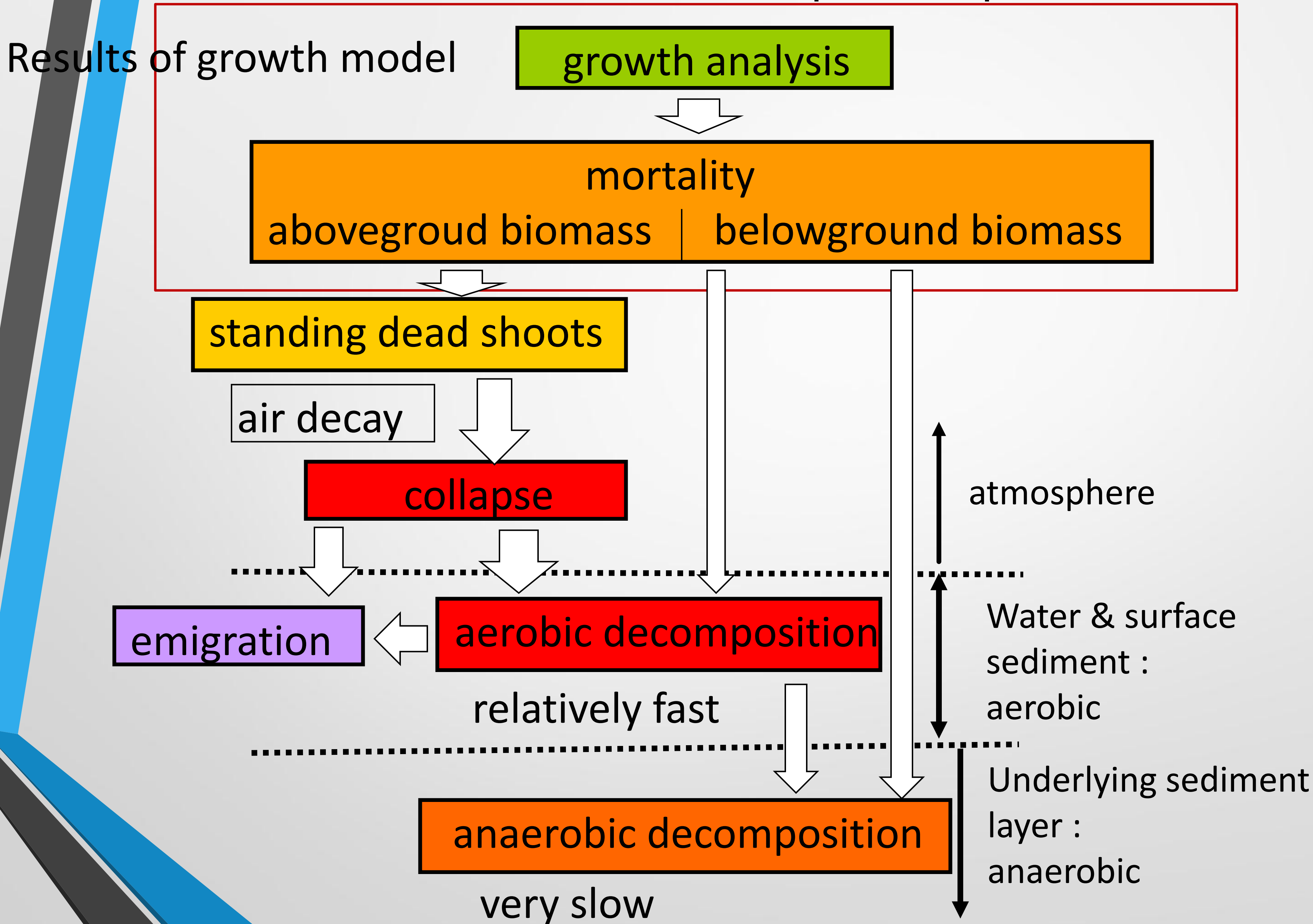
f(light, temp, biomass) f(temp, biomass)

other organs $\frac{d}{dt}$ [biomass] = [translocation] - [respiration loss] - [mortality loss]

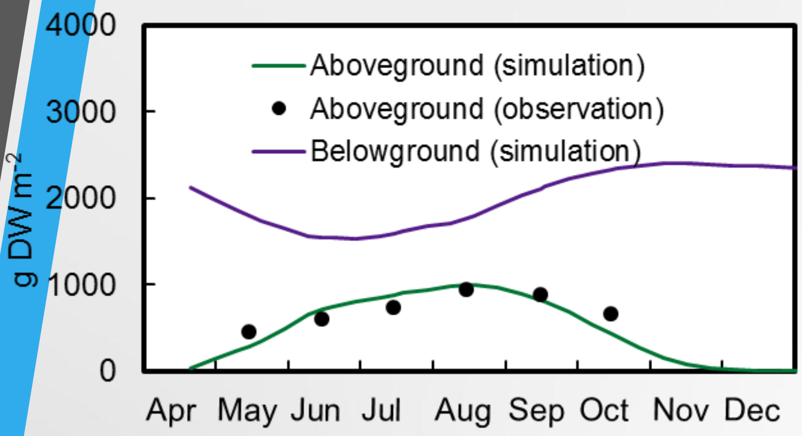
Starting with initial rhizome biomass at daily or weekly time-step

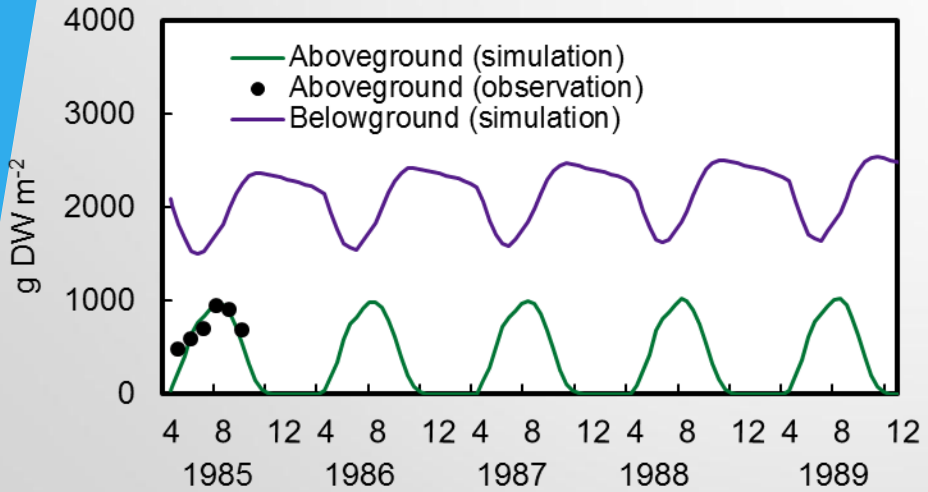
(Asaeda & Karunaratne, *Aquatic Botany*, 67, 2000)

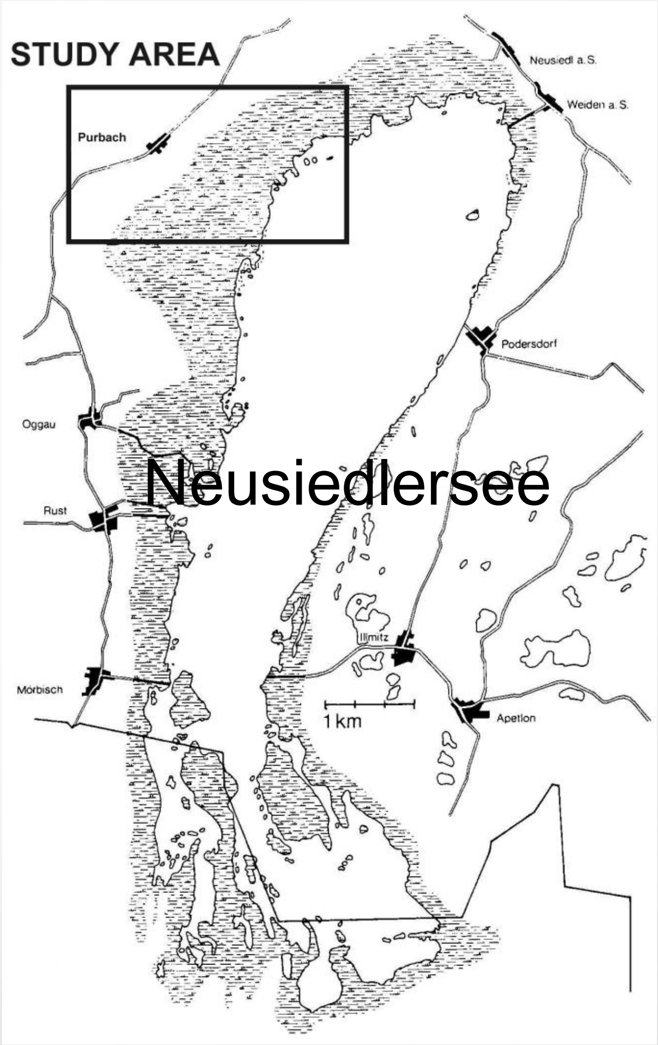
Procedures to estimate decomposition process



(Asaeda et al. , *Aquatic Botany*, 73, 2002)



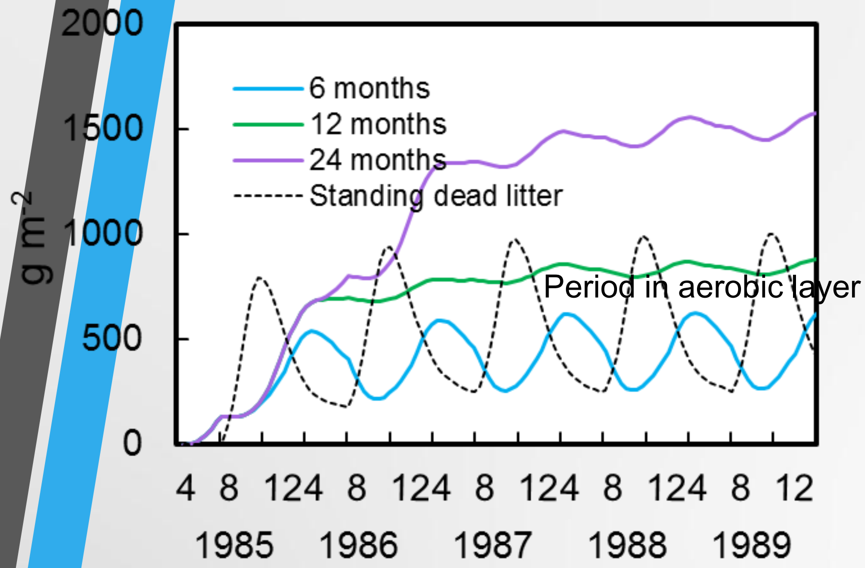


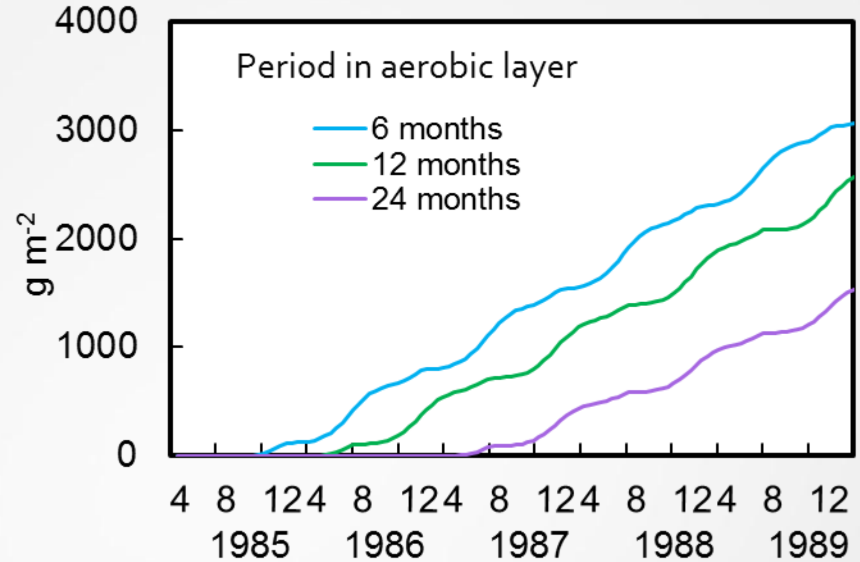


Simulated Above and Belowground Biomass in Comparison with Observations

observed data: the average of 1981 & 1982 at #3 in Neusiedlersee (Sieghardt,1987)

simulation: started with observed belowground biomass in June

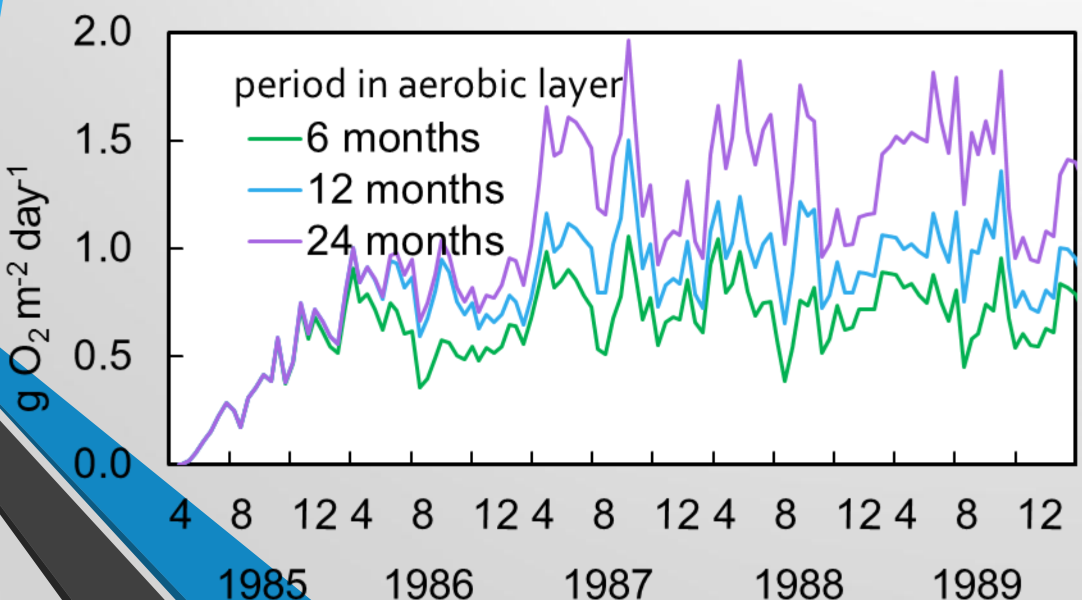




The amount of carbon in the aerobic layer and water : oscillates following shoot mortality and decomposition rate

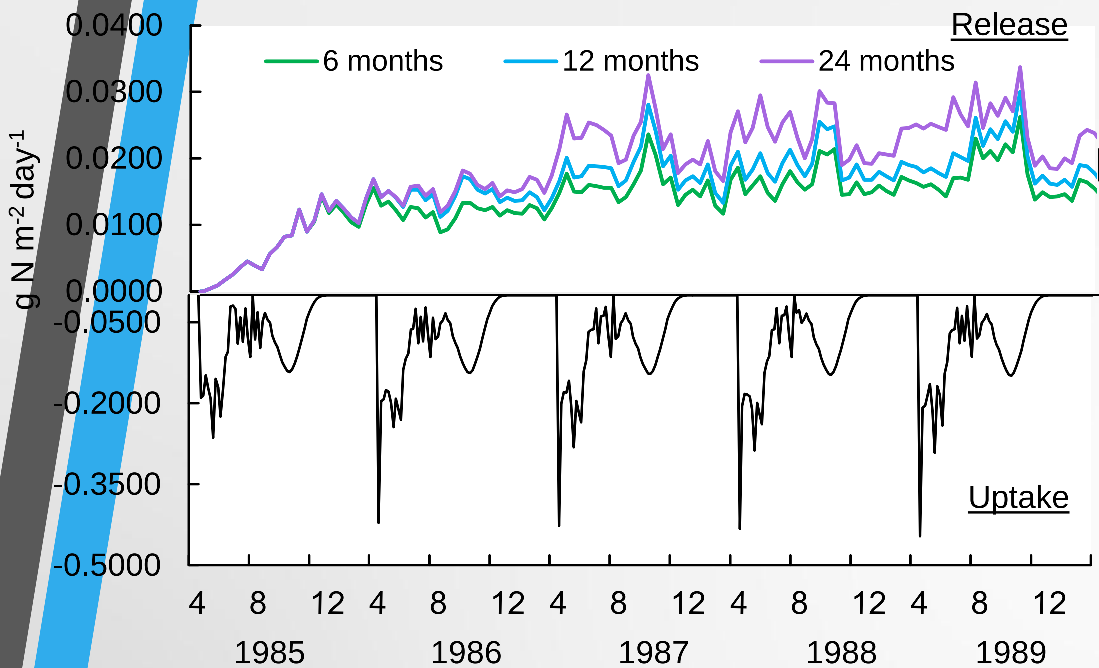
The amount of carbon accumulated in the anaerobic layer: gradually increases due to low decomposition rate

Nutrients are steadily trapped in the substrate



Oxygen consumption rate : highly fluctuates due to temperature

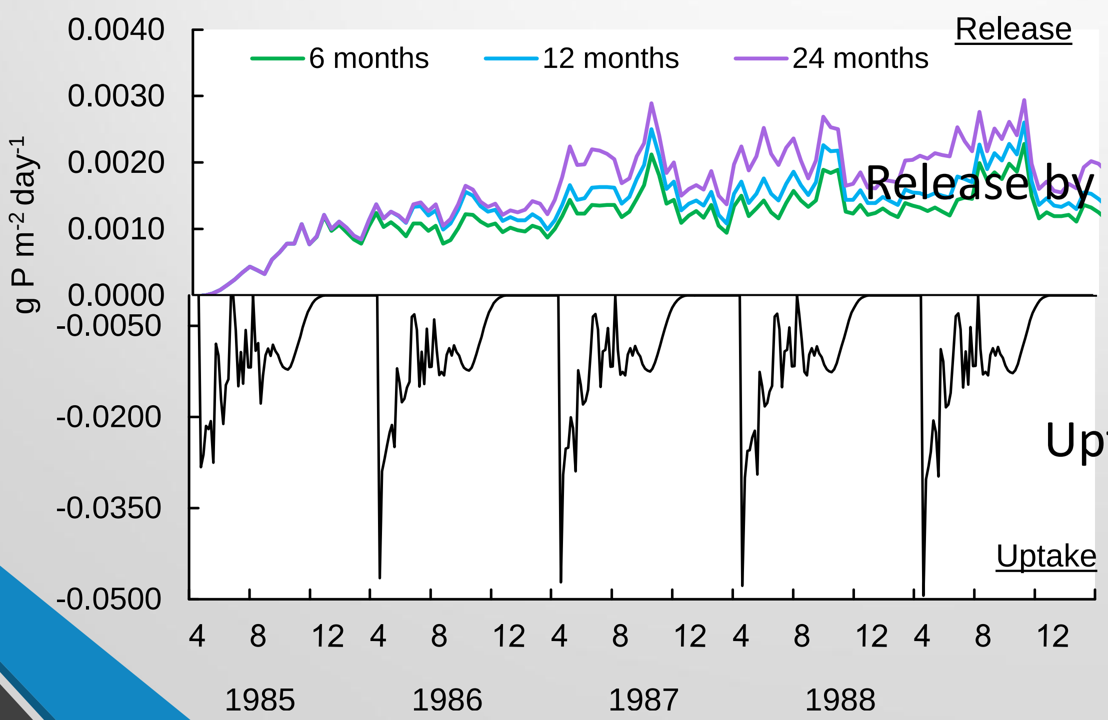
Nitrogen budget



Release by decomposition

Uptake by plants

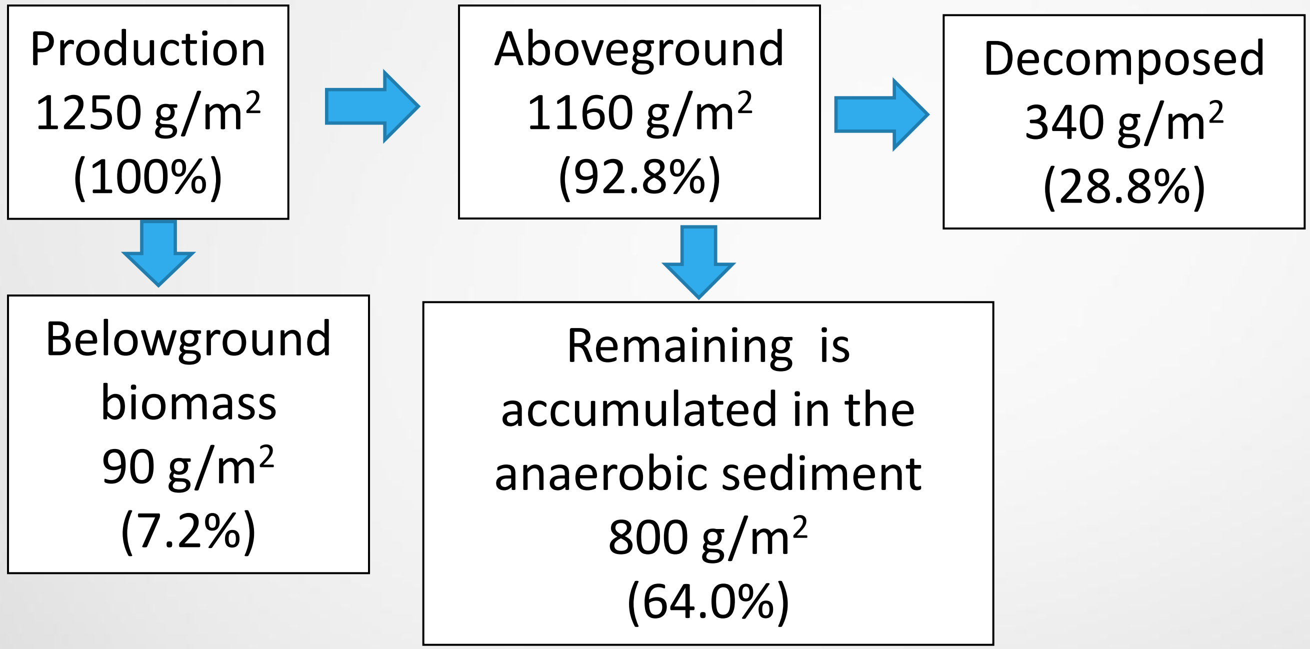
Phosphorus budget



Release by decomposition

Uptake by plants

Annual Biomass Budget of the Reed Stands in Neusiedlersee (#3 point)

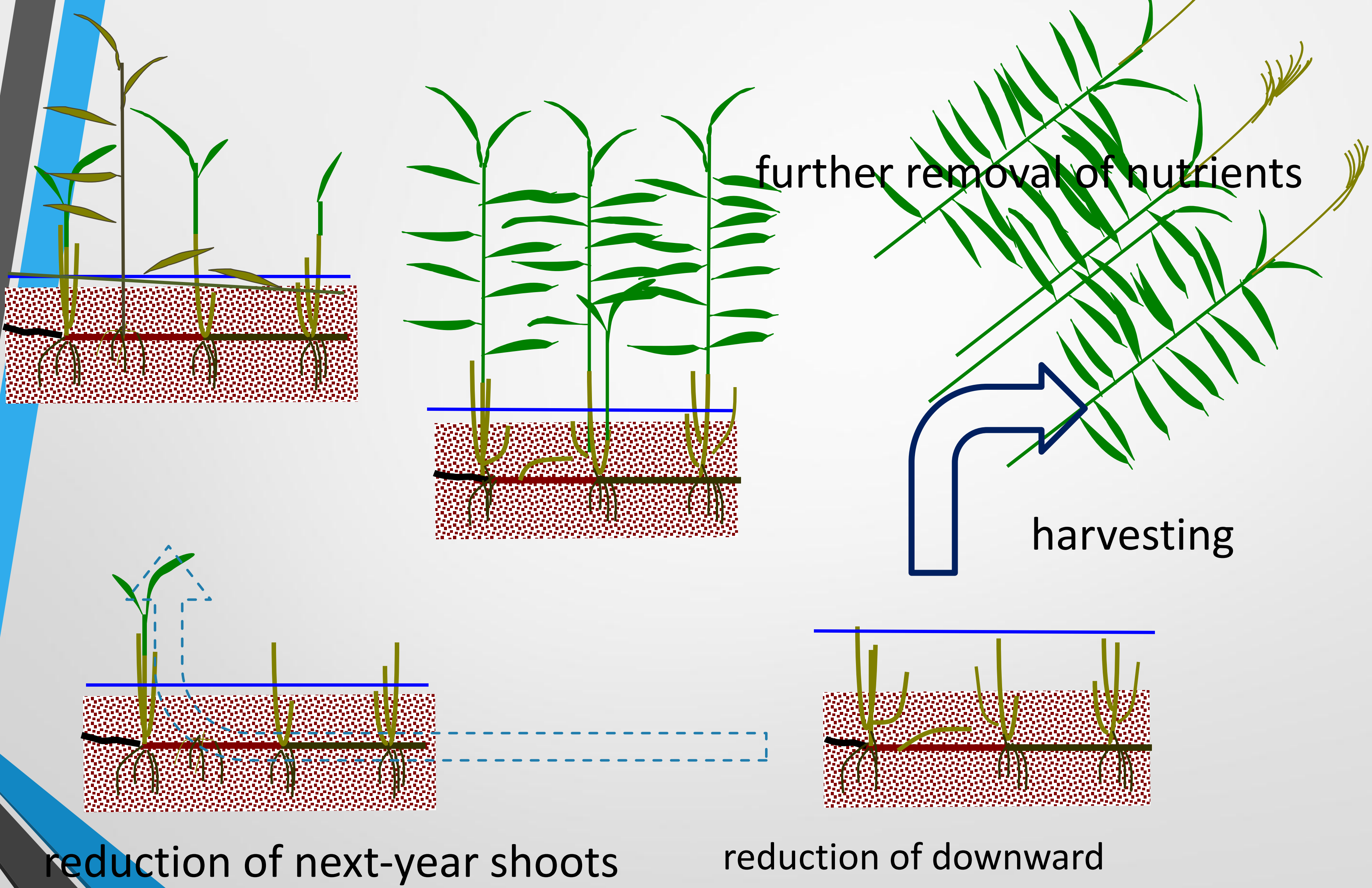


Two thirds of produced materials (absorbed nutrients) are accumulated in the anaerobic substrate.

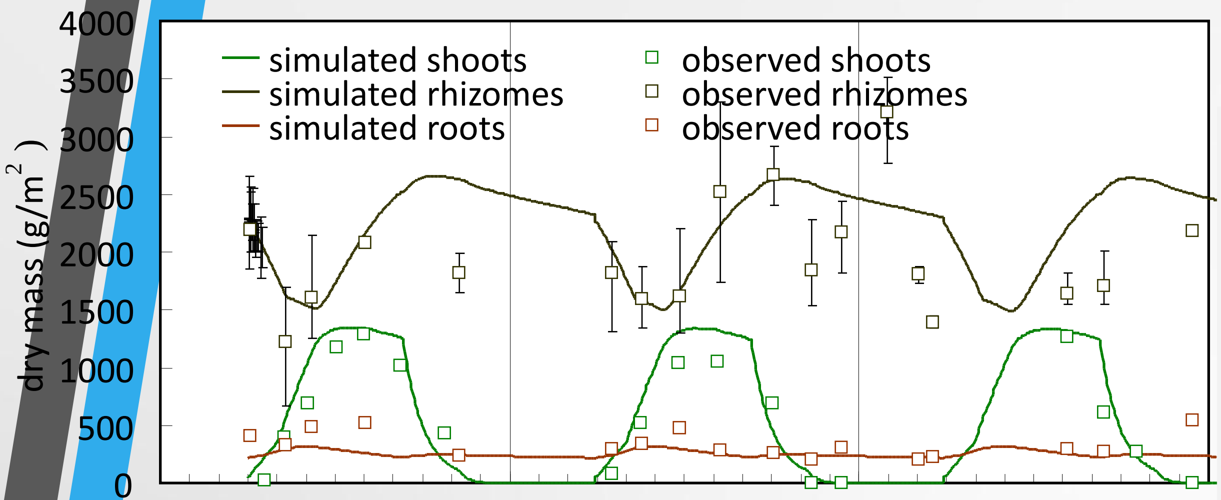
Two thirds of nutrients are removed from water even without harvesting. Wetlands becomes shallower

(Asaeda et al. , *Aquatic Botany*, 73, 2002)

Application to the harvesting management

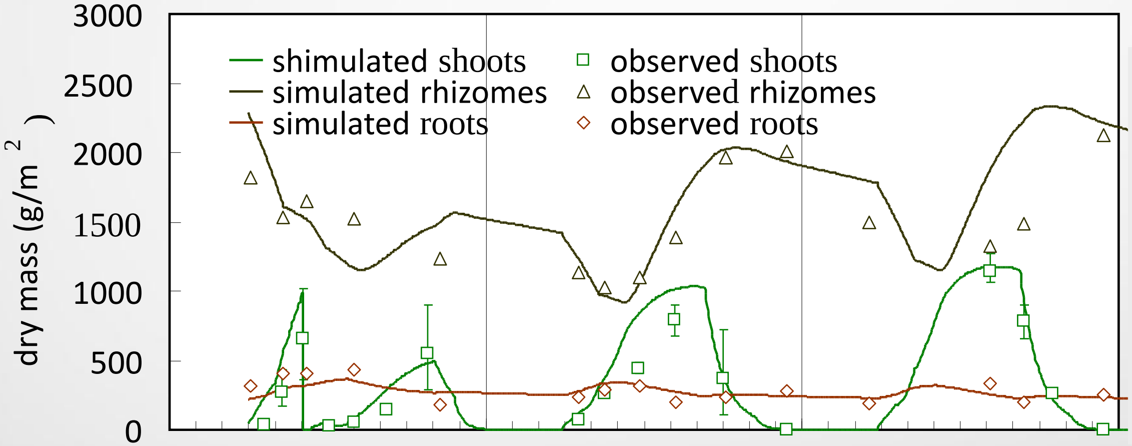


Validation of the model for 2001- 2003 observation

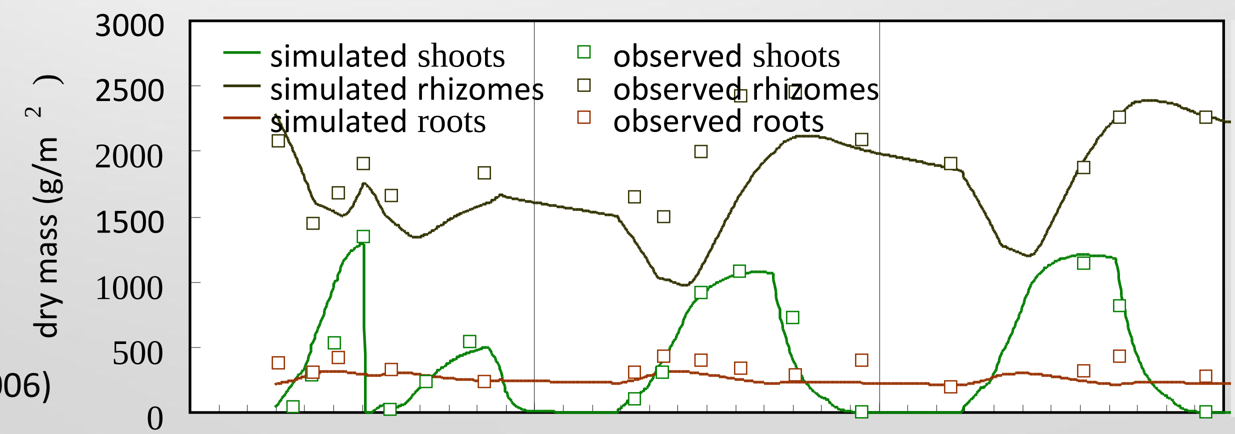


unharvest

June harvest

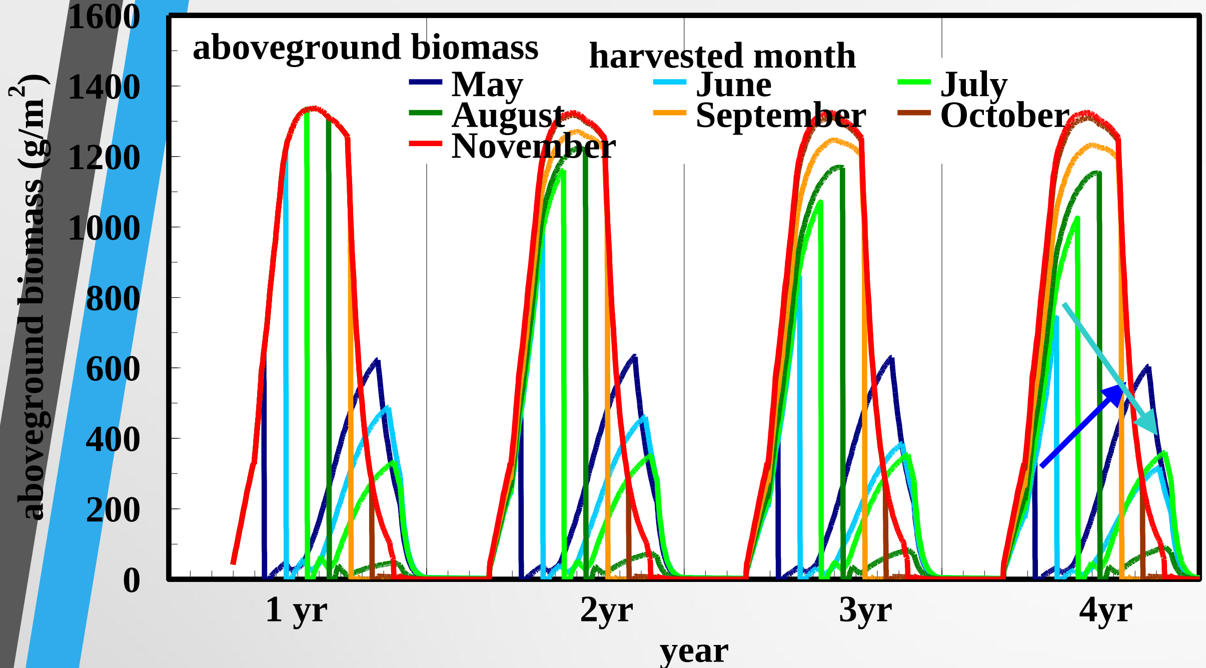


July harvest

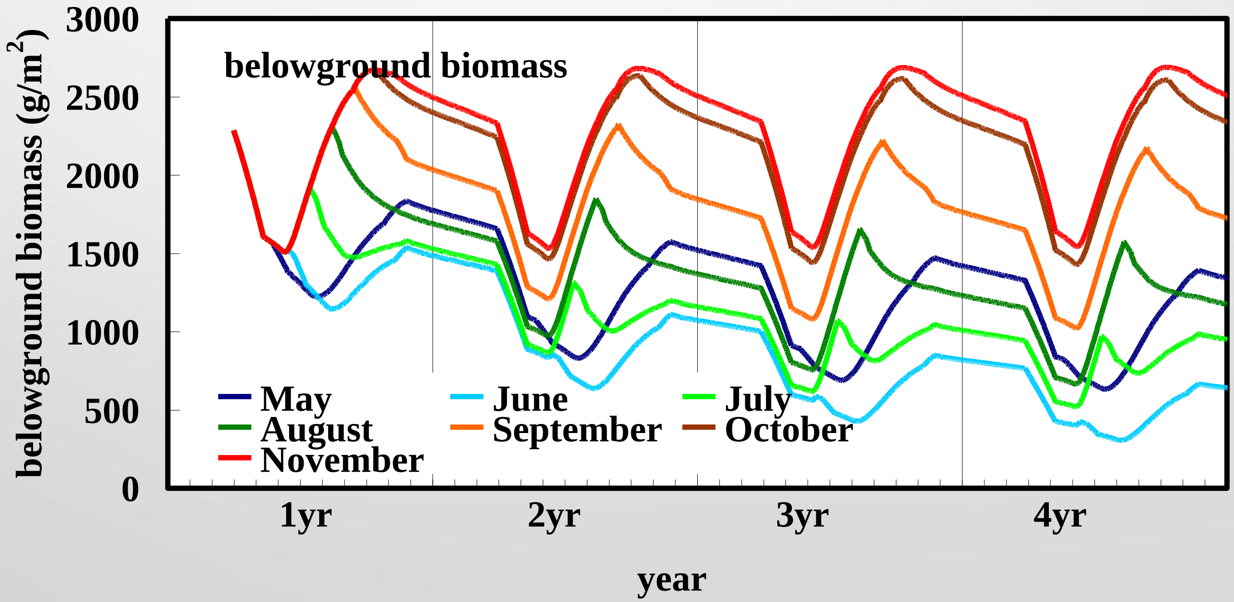


(Asaeda et al. , *Hydrobiologia*, 553, 2006)

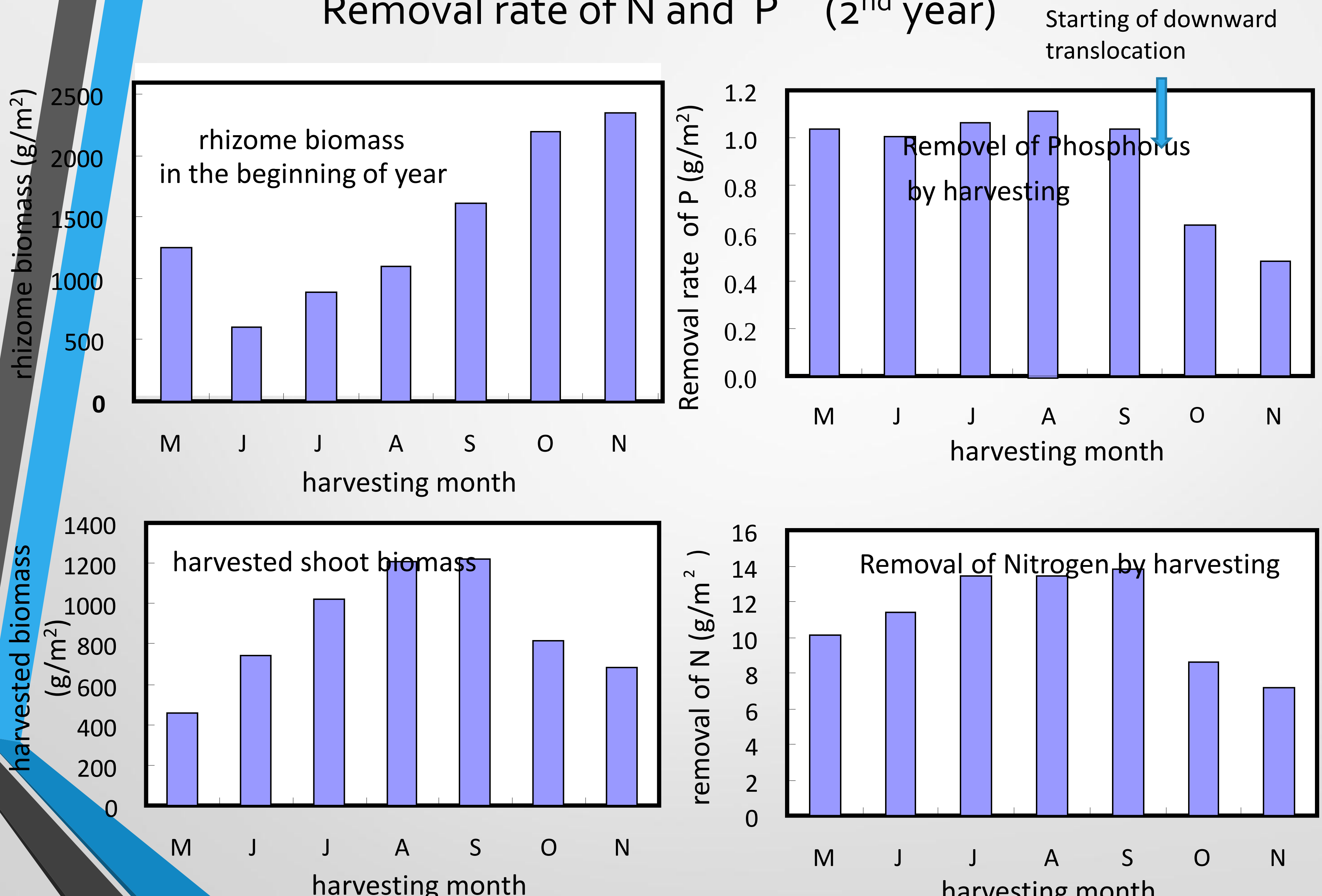
Effect of annual harvesting at different month on the succeeding year biomass



- A large secondary shoots form if harvested too early.
- August harvesting causes the highest reduction of shoots. Good for drainage.
- June harvesting causes the highest reduction of rhizomes.



Removal rate of N and P (2nd year)



For the high removable of nutrients harvesting must be before downward translocation at the senescence

Concluding remarks

- Aquatic plants have magnificent properties to purify waters in various ways.

- Charophytes trap heavy metals and phosphorus in water by the formation of calcium-carbonate crust. Biomass is relatively small, available for drainage system.

- Aquatic plant community accelerates deposition of floating organic matters and nutrients. Among the aquatic plants, submerged plants have higher efficiency and are low in biomass.

- Numerical models can simulate the behaviors of aquatic plants with sufficient accuracy and are available for the planning of aquatic plant management.

Thank you

Ecohydraulics symposium in 2018 is in Tokyo!

asaeda@mail.saitama-u.ac.jp

One year frequent cutting
(in the case of *Typha angus*tifolia)