ON THE WAY TO QUANTIFY THE VALUE OF SELF-PURIFICATION CAPACITY OF STREAMS AS AN ECOSYSTEM SERVICE

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ECOLAB Ecologie fonctionnelle et environnement

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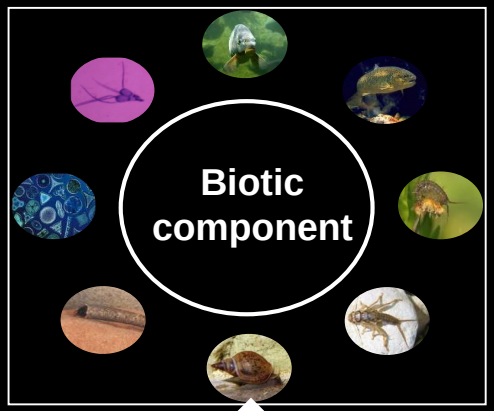
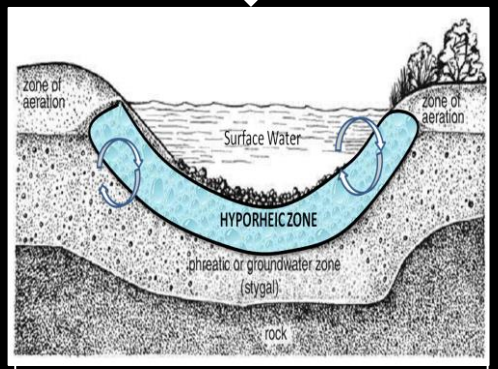
Main questions

- How many nutrients are removed by the self-purification service in streams at the reach scale ?
- Who are the ecosystem service providers of this water regulation service ?
- How is this biodiversity involved in this natural service?
- How to value this purification service?

Ecosystem → **Ecological functions** → **Ecosystem services**



Promote ⇕ **Shape**



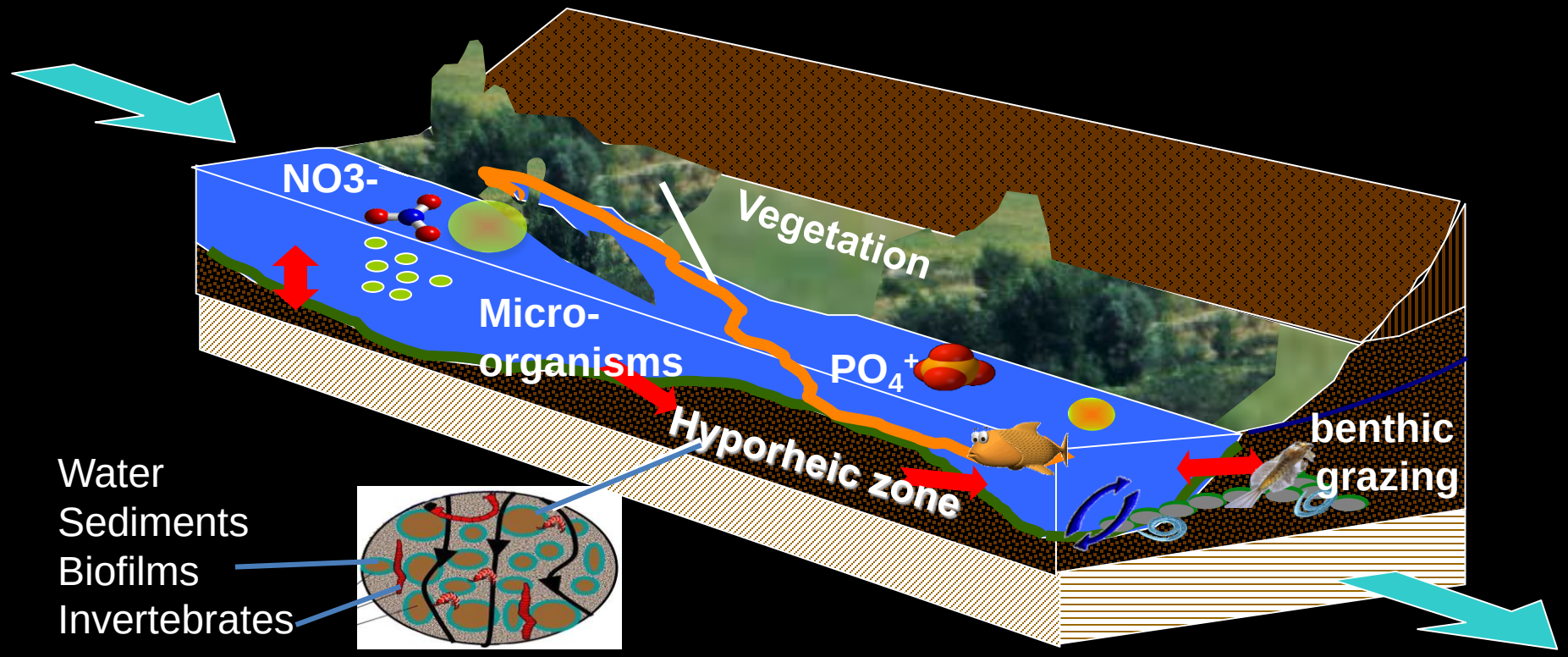
Abiotic component

Integrative of biotic and abiotic component and their interactions

Self-purification capacity

- **Nutrients retention**

➢ Where is water self-purification process

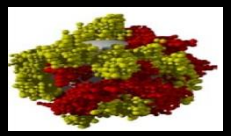


➢ Who are the purification providers

Invertebrates

Grazing and Gardening →

Bacterial community



→ **Purification capacity (NH4,NO3,PO4)**

?

Millennium Ecosystem Assessment (2005)

How to value this natural service

Nutrients retention measurement

↓

Replacement method

↓

Waste water treatment plants

↓

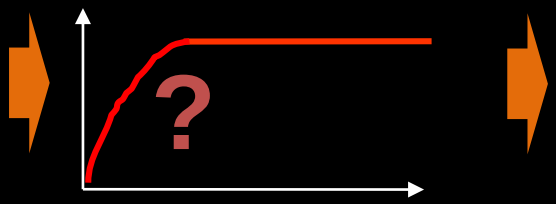
€ or $

The VALUE of an ES =

Benefits - Cost

Identify the required biodiversity of invertebrates

Purification service



Invertebrate biodiversity

Insurance Hypothesis (Loreau et al. 2001)

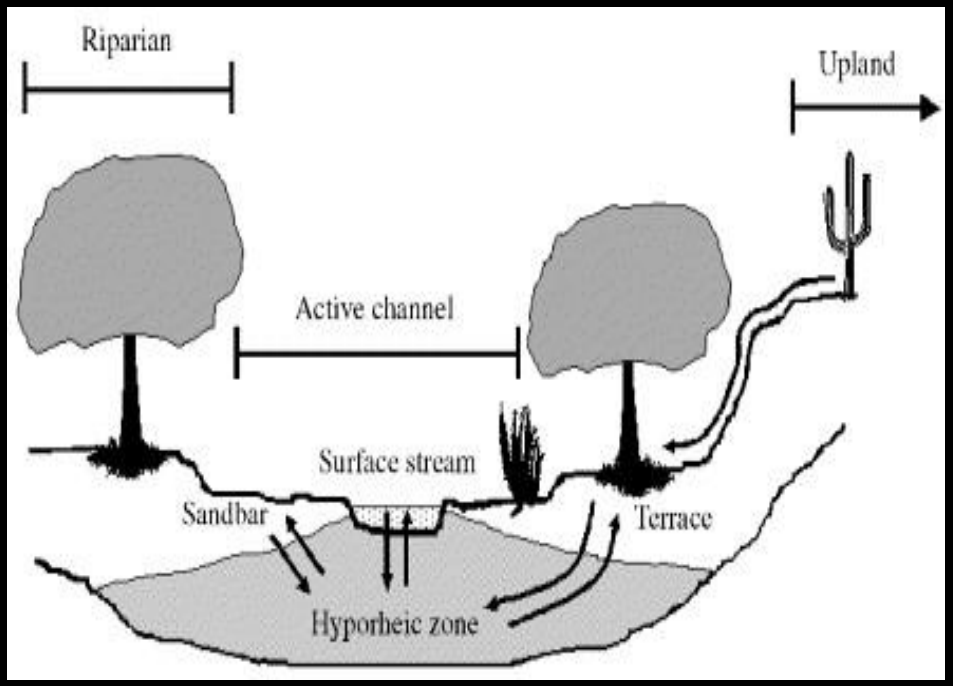
Costs of conservation/ restoration project in providing these biodiversity in its ecosystem

Study of biodiversity-function relationship

E.g. of self-purification service values

N.S.V = Natural Service Value = B-C

- B = Benefit of nutrient and other pollutants retention
- C: = Costs of restoration



◆ **HIGH RETENTION**
A river with a good status of conversation

◆ **LOW RETENTION**
A river with a poor status of conversation

Case study: On quantifying the value of self-purification service in The STREAMES Project (11 streams in Europe)

Aposelemis (Crete)
Demnitzer Muehlenfliess (Germany)
Erpe (Germany)
Fosso Bagnatore (Italy)
Kleine Erlauf (Austria)
Lézat (France)
Montégut (France)
Gurri (Catalonia, ES)
Tordera (Catalonia, ES)
Ribeira de Grândola (Portugal)
Yargon (Israel)

Benefits evaluation

Step1: In field retention rates quantification [a]

- **Enrichment techniques** (e.g. slug addition)
- Net nutrient value

Step 2: Replacement method [b]

- Wetlands
- Agriculture
- **Waste water treatment plants**

Step 3: Prices of 1KG nutrients removal

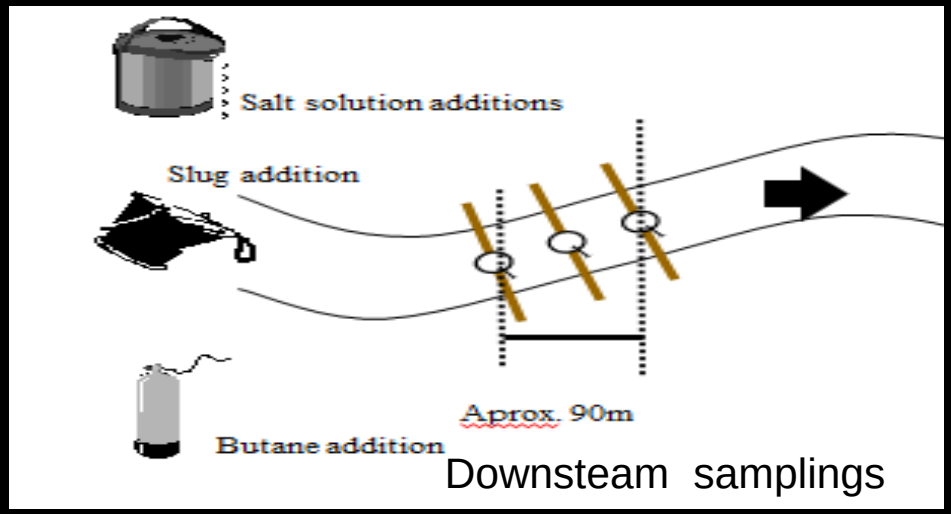
Benefits

a: Niyogi et al. 2010
b: Gren et al. 1995

Benefits

Nutrients retention capacity measurements (reach scale)

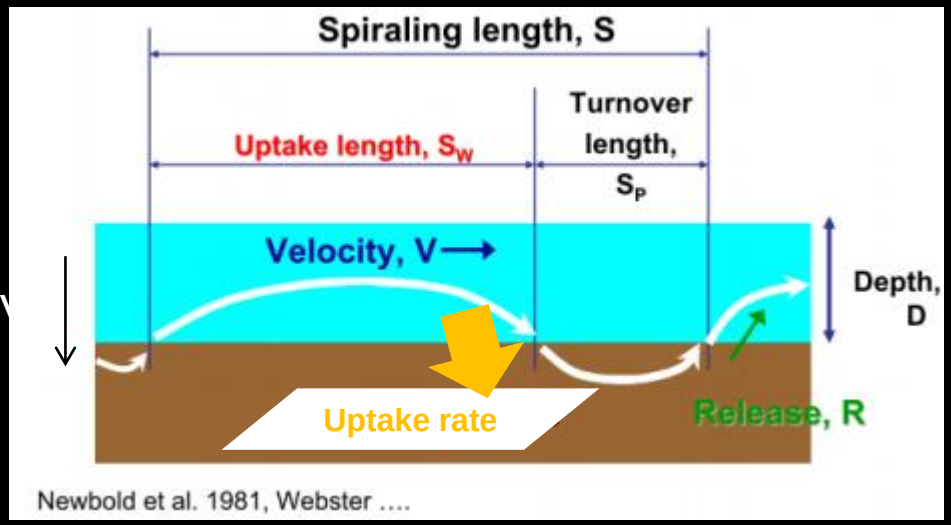
- **Field works**



Morphological transects

Experimental reach (every 30m) Samplings sites

- **Uptake rate(U) represented purification capacity: UNH4,UNO3,UPO4**



$$U = \frac{C_b \bullet d \bullet v}{S_w} \bullet 60$$

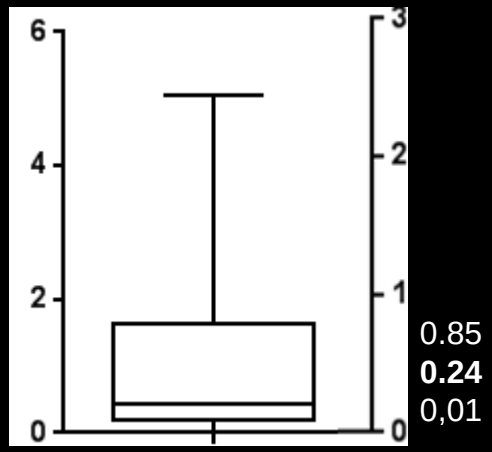
(mg N/m2/min)

U: uptake rate per area of an inorganic nutrient under ambient conditions

Benefits

Results 1: Benefits evaluation

Uptake rate (mg N/m²/min) **U'ptake rate (kg N/m²/year)**



Median (box) and whisker(min to max)

How much kg of nitrate reduction by purification capacity

Dimension of third-order river reach: 100 m length and 4 m wet perimeter

Wastewater treatment Plant

100 kg N /year/100m river reach **X** **i.e. 9 EUROS per KG TN**

= 900 € per year/100m reach

Costs evaluation

Costs

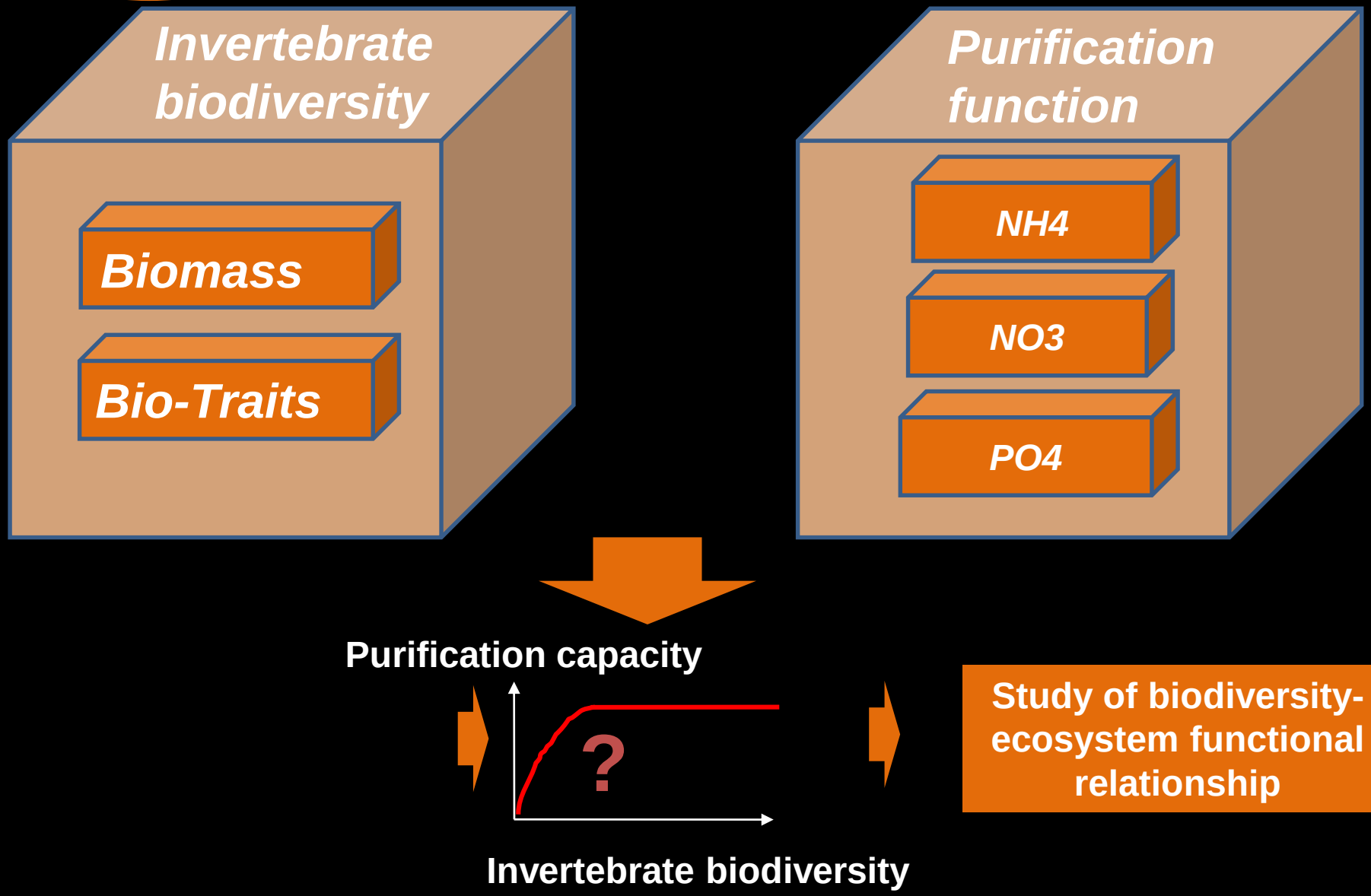
What is the price of ecosystem that is providing this natural service?

How much biodiversity of invertebrates is necessary to provide this purification service?

- **Identify the required community /biodiversity of invertebrates for purification service**
- **Biodiversity - Ecosystem Function relationship research (BEF)**

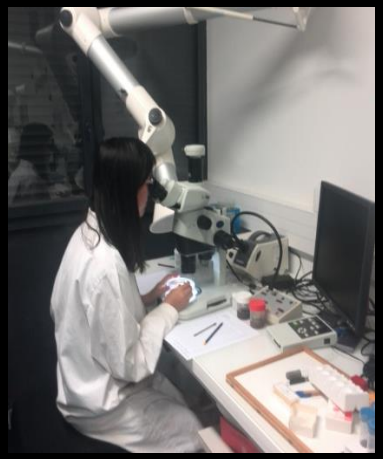
Costs

Identify the required community/biodiversity of invertebrates for purification service



Costs

Biodiversity-Ecosystem Function relationship research (BEF)



Invertebrate identification

（Tachet et al., 2000）

Taxonomic groups

Functional Groups: Biotraits (e.g. food, size, life cycle, etc…)

Functional diversity index

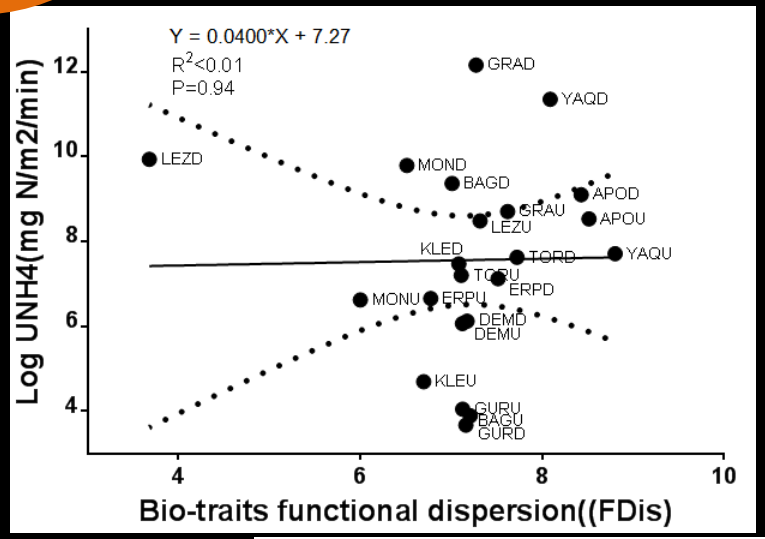
Levels of information integrity

Costs

Result 1 : Relationship between functional diversity and retention (n=22)

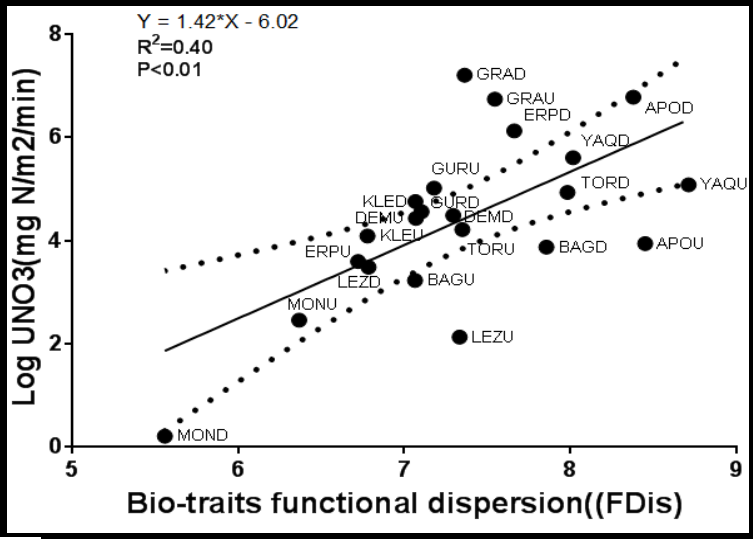
UNH4

X



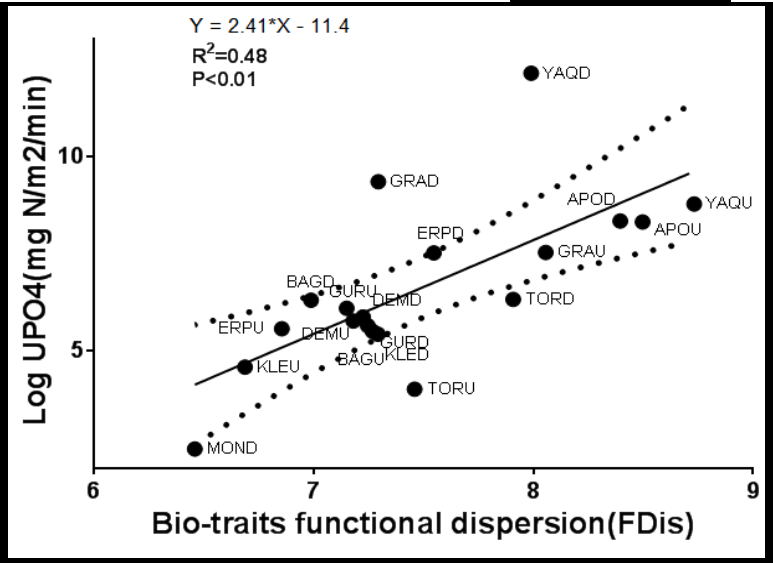
UPO4

OK!



UNO3

OK!



When biodiversity index decreases of one unit, how much nutrient retention is lost ?

Invertebrates'biodiversity is positively related in purification capacity of NO3 and PO4

Costs

Result 2: Invertebrate community traits selection

Fuzzy code correspond analysis of 11 Bio-traits

Projected inertia (%):

Ax1	Ax2	Ax3	Ax4	Ax5
11.067	**8.293**	7.408	7.229	5.375

Cumulative projected inertia (%):

Ax1	Ax1:2	Ax1:3	Ax1:4	Ax1:5
11.07	**19.36**	26.77	34.00	39.37

The account of each trait in the total variability of the invertebrate community

	RS1	RS2
Resistance forms	0.06	0.03
Locomotion and substrate relation	0.06	0.25
Dispersal	0.06	0.06
Aquatic stages	0.07	0.02
Respiration	0.07	0.5
Cycle_Y	0.19	0.12
Life cycle duration	0.23	0.03
Maximum size	0.28	0.15
Reproduction	0.33	0.28
Food	0.47	0.06
Feeding habits	**0.52**	**0.27**

The functional trait that varies the most is feeding habits of invertebrates between sites and times

Costs

Result 3 : What are the functional feeding groups that contribute to retention (U)

Dependent variable	Independent variable	Estimate	P	Independent (%)
Uptake rate of NH4(n=72)	Deposit feeders	0.56	<0.01	18.60
	Scrapers	-0.80	<0.01	19.7
	Filter feeders	-0.32	0.02	11.40
	Piercers	-0.47	<0.01	30.00
	Predators	0.90	<0.01	21.60
Uptake rate of NO3(n=64)	Deposit feeders	0.76	<0.01	33.10
	Shredders	-0.23	0.1	7.8
	Scrapers	0.29	0.11	23.30
	Filter feeders	0.15	0.15	18.10
	Others	-0.32	0.03	17.80
Uptake rate of PO4(n=67)	Deposit feeders	0.58	<0.01	53.80
	Shredders	0.39	0.03	11.40
	Filter feeders	-0.23	0.02	5.10
	Piercers	-0.43	<0.01	30.00

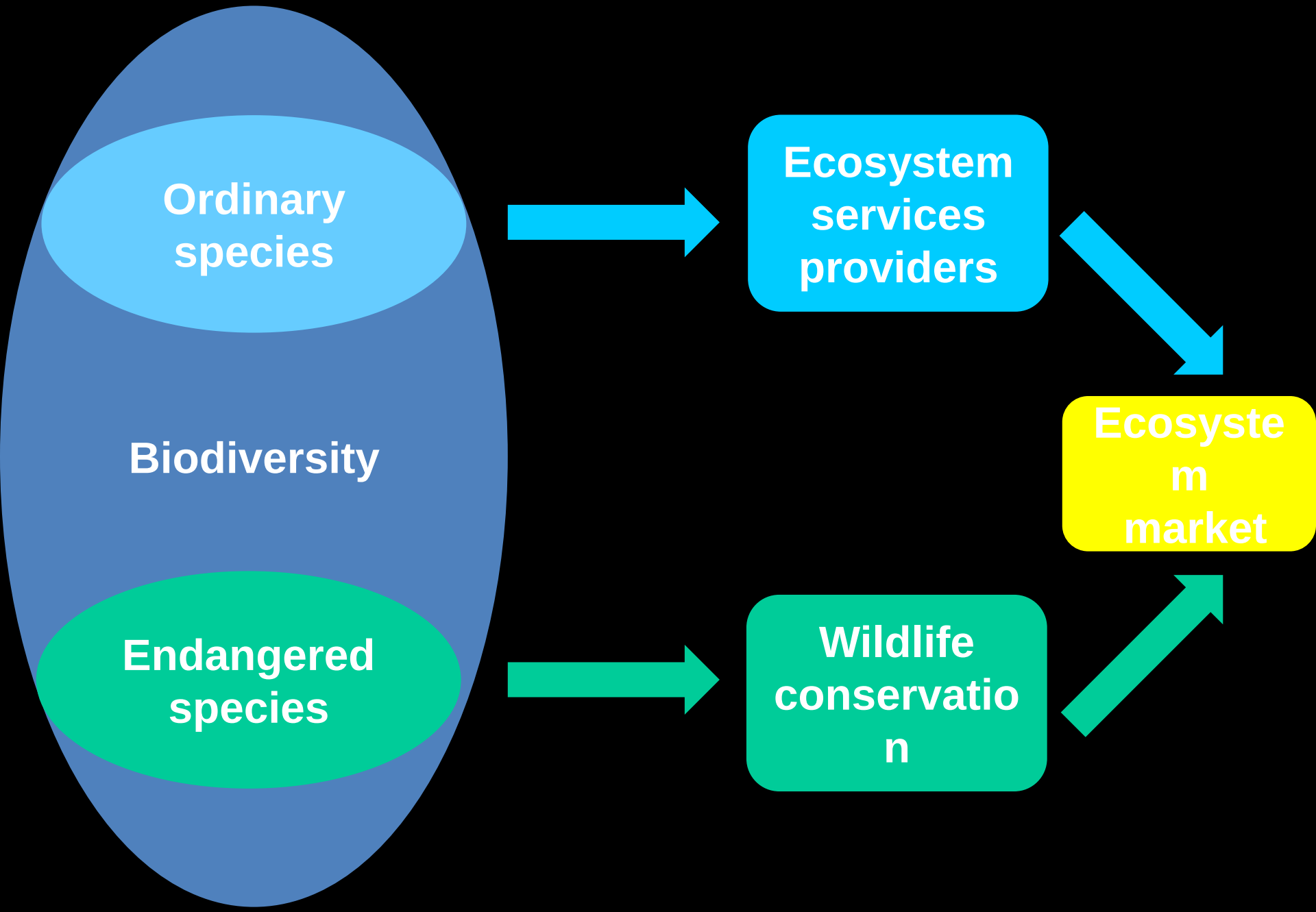
Deposit Feeders that live in the sediments are the most contributors to retention capacity. Predators, scrapers and shredders may also participate depending on nutrients.

- The invertebrate organisms that live in the river bed are the ecosystem services providers.

- This biodiversity is not only useful for bio-indication purpose !

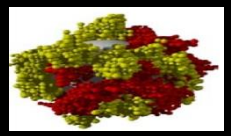
- In order to conserve the purification service in streams, we need to conserve the sediments as invertebrates biodiversity habitats

- This community makes part of the ordinary biodiversity in aquatic ecosystem


Ordinary species
Biodiversity
Endangered species
Ecosystem services providers
Wildlife conservation
Ecosystem market

Costs

The different communities of the streams ecosystem that are involved in purification



Microbial community

Invertebrates community

Plants community

Purification service providers

What is the price of this biodiversity ?

We know how much biodiversity is required, now we want to know how much it costs to maintain it ?

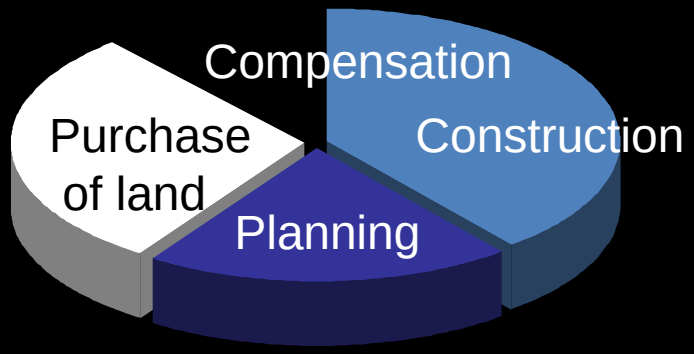
Costs

Costs evaluation

- **Conservation costs**

Price of maintaining biodiversity

- **Restoration costs**

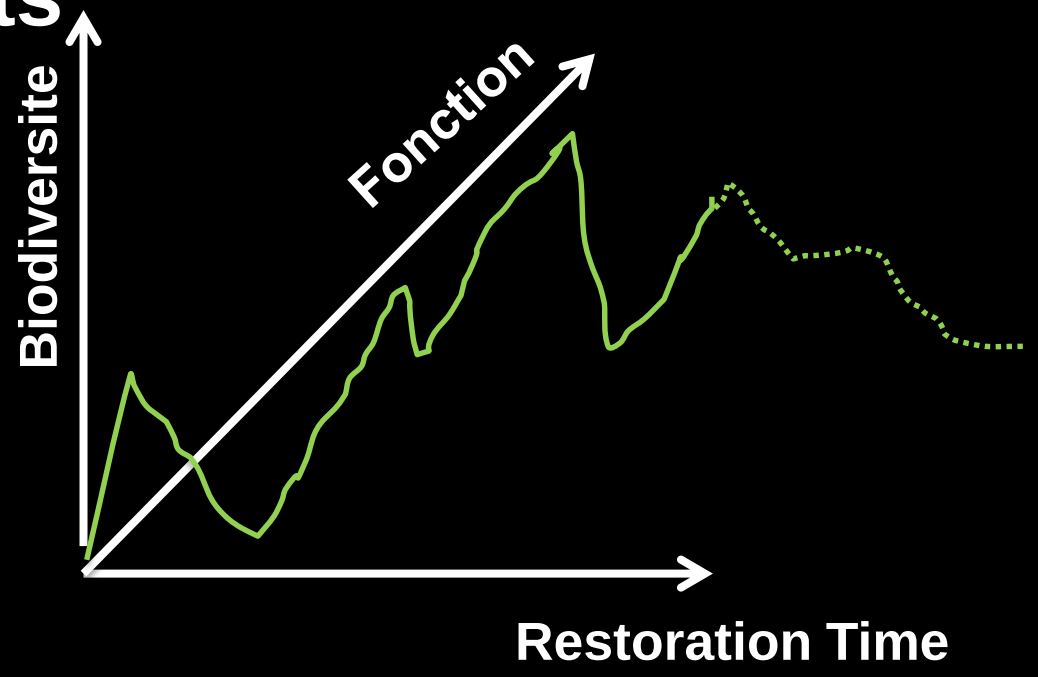


Price of engineering to recover ecosystem with related biodiversity

+

Price of maintaining biodiversity

- **Restoration costs**



The success of restoration should be the recovery of :

- Habitats
- Water quality
- Biodiversity
- Ecosystem function

- Water self-purification service is an **in-stream** process (and also riparian process)

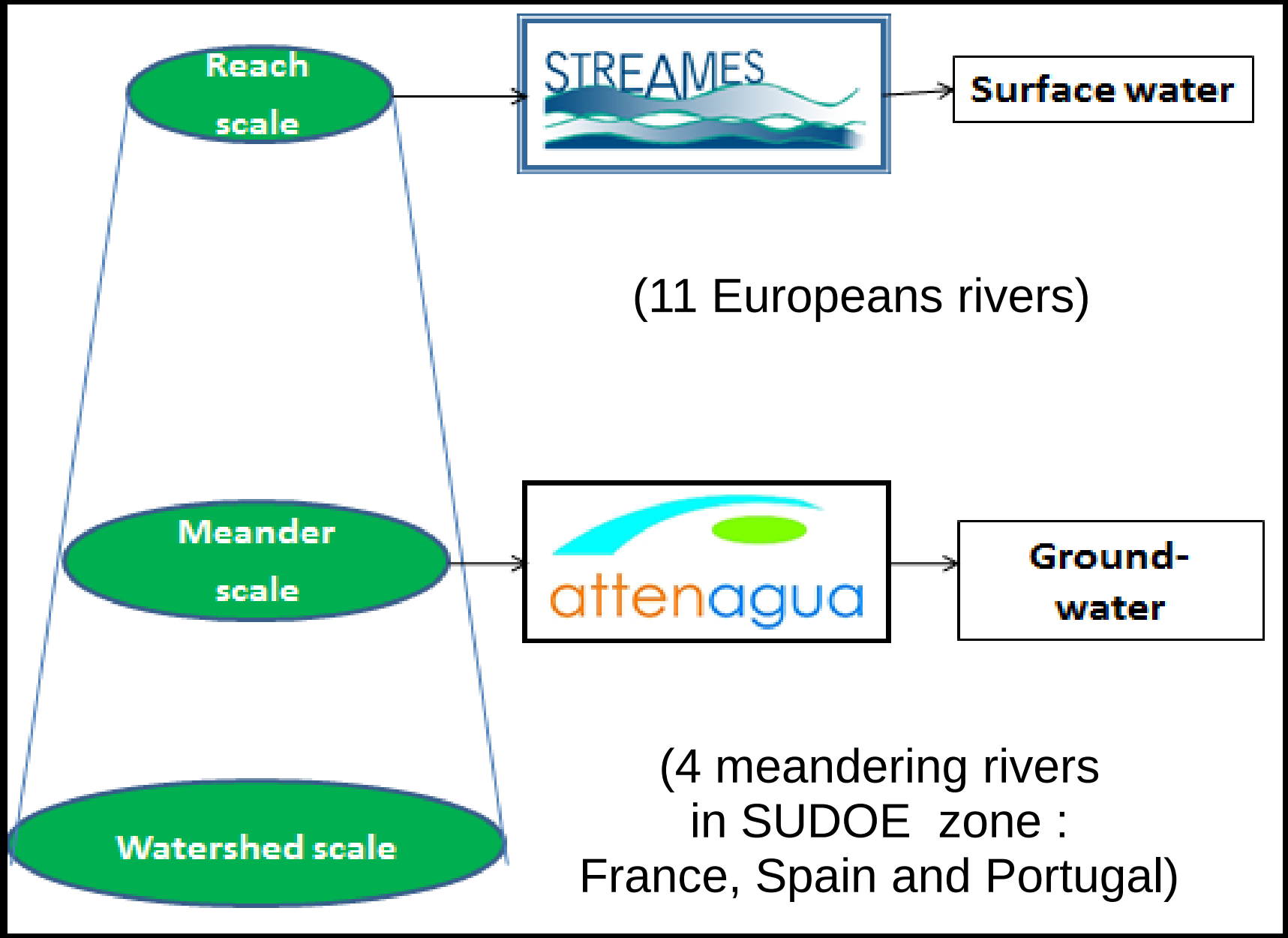
- The estimation of the success of managements or restoration projects may be not only recovery of water quality but also ecosystem functions, as well as related biodiversity

Expectation

- Data set with simultaneous function and biodiversity measurements
- Conservation/Restoration project costs
- Economists cooperation for benefit-cost model applying in self - purification value estimation

Thank you for your attention and suggestion!

PROJECTS supporting :
Evidence of biodiversity-ecosystem function relationship



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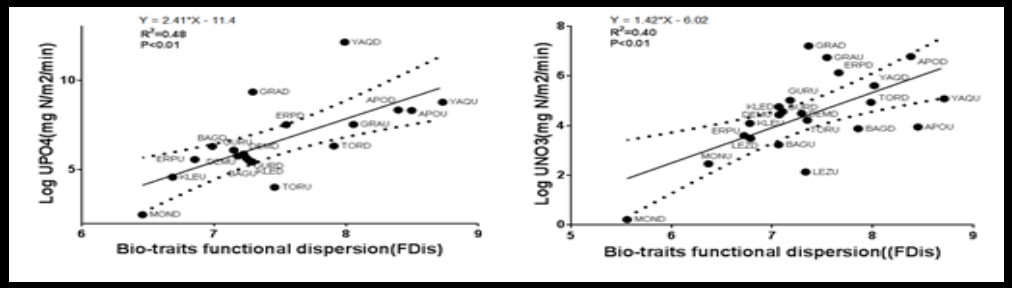
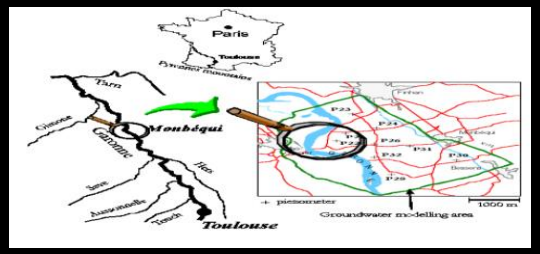
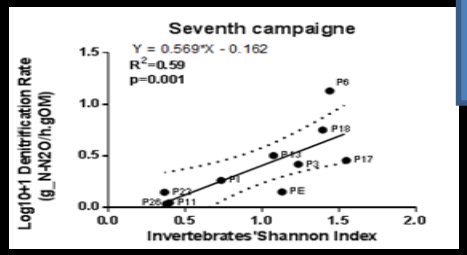


The most suitable diversity index to reflect relationship with retention capacity was functional dispersion of 11 biotraits.(i.e. feeding habits). Both $NO3^-$ and $PO4^-$ retentions are positively correlated to this functional diversity index of invertebrate community.





Significant positive relationship between invertebrates diversity and denitrification rate/microbial community was found in autumn campaign, during a long period of hydrological stability and low discharge. This period with relative stable environmental conditions may be regarded as a “hot moment” to examine biodiversity-ecosystem function relationship .

- Biodiversity is involved in water self-purification (e.g. U) both in surface water and groundwater.
- It is necessary to take into account it in ecosystem services values estimation.

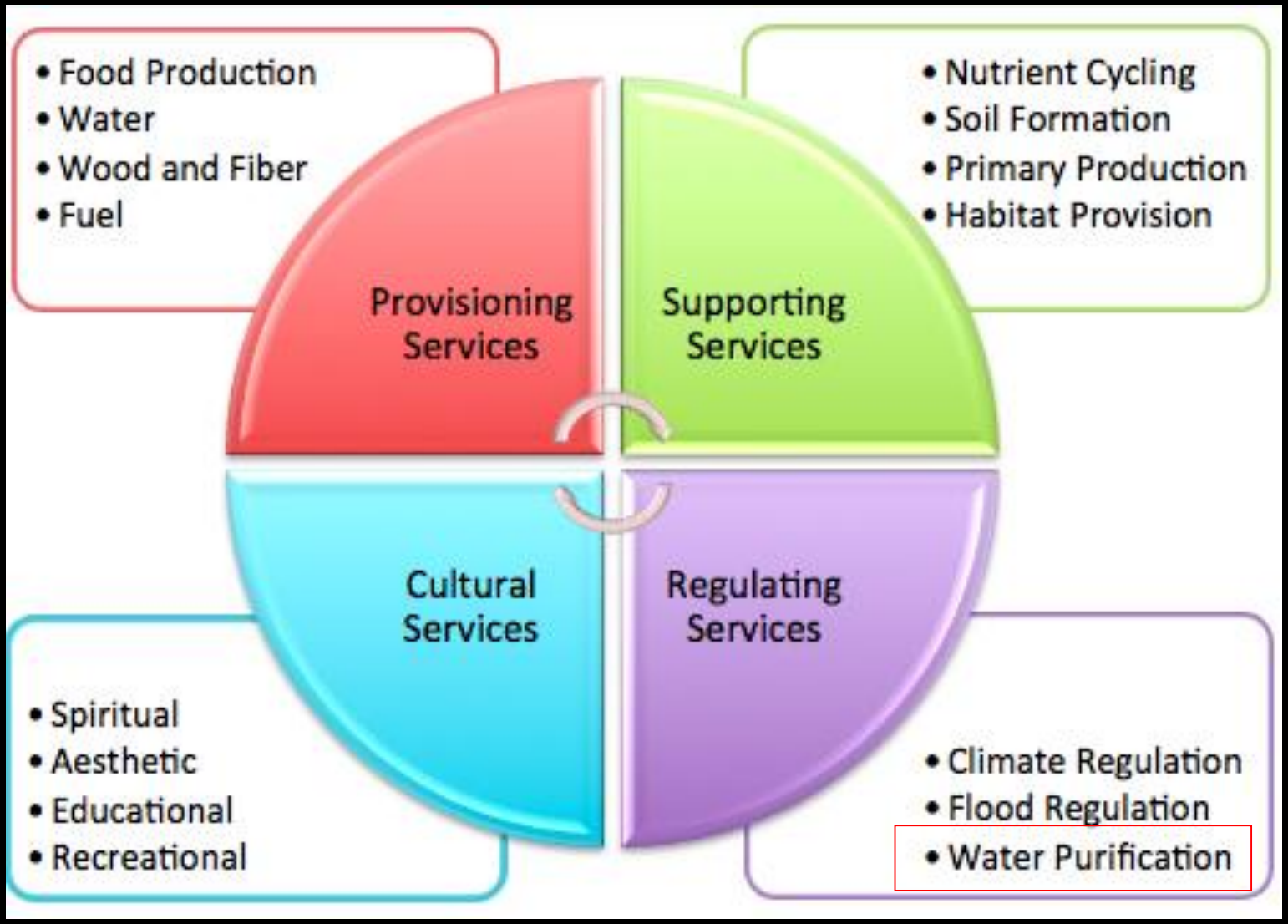
Partial least squares regression (PLS): Denitrification rate ~INV+ENV (4 campaigns ; n=44)

Independent variables:	Estimate	Pr(>|t|)
Invertebrates Shannon	**0.17**	7.86e-05 ***
O2	-0.24	1.22e-09 ***
Temperature	-0.13	0.04 *
NH4	0.17	0.01 *
DOC	0.18	0.01 *
NO3	-0.2	4.22e-07 ***
PEST.CON	-0.12	0.03*

TRAINING: % variance explained by 1 comps
X 41.65% Y1 64.48%

Environmental parameters are significantly related to denitrification

Ecosystem services



Millennium Ecosystem Assessment (2005)

Costs

2

How bio-traits related to nutrients retention ?

		Estimate	P		Estimate	P		Estimate	P
	(Intercept)	23.06	0	(Intercept)	0.69	0.78	(Intercept)	-24.14	0.00
Maximum potential size	X<0.25	0.99	0.17	X<0.25	1.78	0.00	X<0.25	2.02	0.01
	X0.25~0.5	3.26	0	X0.25~0.5	0.63	0.22	X0.25~0.5	3.24	0.00
	X0.5~1	-3.28	0.01	X0.5~1	2.49	0.02	X0.5~1	-1.55	0.13
	X2~4	2.35	0	X2~4	1.23	0.00	X2~4	1.80	0.00
of circle per year	X>1	1.18	0.23	X>1	-0.70	0.39	X>1	10.01	0.00
Aquatic stages	egg	2.88	0.04	egg	5.22	0.00	egg	1.57	0.11
	lar	1.71	0.36	lar	-2.06	0.20	lar	14.67	0.00
	nym	-3.36	0	nym	-1.83	0.00	nym	-1.24	0.11
							ad	1.91	0.01
Reproduction	ov	-2.04	0	ov	0.34	0.24			
	efr	0.88	0.1	efr	0.40	0.24			
	ec	-1.62	0	ec	-3.02	0.00			
	cfx	-1.52	0.12	cfx	2.69	0.00	ec	-0.92	0.02
	cfr	2.5	0	cfr	1.73	0.01	cfx	5.59	0.00
				cv	0.30	0.05	cfr	3.98	0.00
	ct	-0.62	0.04	ct	0.35	0.10	cv	1.08	0.00
	asx	2.58	0	asx	-4.19	0.00	asx	-2.09	0.10
Dispersal	aqp	-7.18	0	aqp	-5.93	0.00	aqa	-18.65	0.00
	aqa	-11.43	0				aep	-0.87	0.08
	aep	-2.52	0				aea	-4.34	0.00
	aea	-3.33	0						
Resistance forms				egst	0.78	0.04	egst	-0.29	0.35
				cdes	-1.38	0.01	coc	0.51	0.27
	coc	-3.71	0	dia	-3.62	0.00	cdes	0.97	0.02
							dia	-3.94	0.00
				no	-1.77	0.25	no	1.80	0.15
Respiration	gi	3.01	0				teg	-7.93	0.00
	plst	-1.9	0	teg	-3.12	0.12	gi	1.07	0.06
	spiracle	1.03	0.01	spi	-1.04	0.00	plst	-2.36	0.00
							spiracle	-0.75	0.00
Locomotion and substrate relation	fli	0.61	0.25				fli	-0.65	0.17
	sswim	-1.58	0	sswim	-0.87	0.00	fswim	-2.77	0.00
	fswim	2.37	0.01	fswim	-0.88	0.24	craw	-1.20	0.32
	craw	-1.67	0.33	bur	-1.42	0.04	bur	-2.12	0.00
	bur	-1.88	0	tat	-1.50	0.01	int	-4.67	0.00
	int	-3.9	0.02	pat	-6.86	0.00	tat	-3.26	0.00
	pat	0.99	0.35				pat	-3.78	0.00
Food	mic	-0.98	0.09	det	1.32	0.33	mic	-1.78	0.01
	dp	2.71	0	dp	3.18	0.00	det	-3.22	0.01
	lmic	1.52	0.32	lmic	10.30	0.00	dp	1.76	0.00
	lmac	4.4	0	lmac	-2.21	0.00	lmic	4.53	0.00
	da	0.76	0.08	da	1.19	0.00	lmac	1.56	0.06
	lmici	2.98	0	lmaci	-2.71	0.00	da	-0.79	0.02
	lmaci	3.79	0	ver	-0.49	0.03	lmici	-2.55	0.00
	ver	-1.1	0						
Feeding habits				ab	6.27	0.00	ab	3.41	0.03
	depf	5.96	0	depf	2.66	0.00	depf	3.91	0.00
	shr	-2.46	0	shr	1.25	0.02			
	[redacted]	-0.8	0.02	scr	-4.46	0.00	scr	-1.84	0.04
	pier	-1.92	0.05	filt	-0.67	0.09	pier	-0.32	0.02
	pred	1.11	0.05	pier	0.78	0.00	pred	-0.64	0.21
	par			pred	4.75	0.00	par	-2.61	0.00

Most efficient bio traits of the community for retention have been identified(like maximal size,reproducton)

Costs

Step 1: Biodiversity-ecosystem function relationship research(BEF)

2

How eco-traits related to nutrients retention ?

UNH4

		Estimate	P
Transversal distribution	(Intercept)	56.58	0
	rc	3.9	0
	bc	14.45	0
	po	-3.99	0.02
	tw	-1.6	0.17
	lak	9.27	0
	gw	0.49	0.12
Longitudinal distribution	cr	-9.05	0
	metr	-11.66	0
	mett	-13.08	0
Altitude	lowl	-19.76	0
	pil	-11.29	0
Biogeographic regions	Pyr	3.6	0.06
	Alps	22.88	0
	Vosge	21.12	0
	lowlo	31.06	0
Substrate (preferendum)	fl	-3.79	0
	sand	-10.78	0
	silt	4.71	0
	miph	-1	0.07
	org	-8.51	0
Current velocity	null	9.88	0
	fast	5.62	0
Trophic status	oli	9.75	0
	meso	12.47	0
Salinity	fw	-64.07	0
Temperature	cold	9.28	0
	warm	-3.48	0
	eury	12.37	0.02
Saprobity	xen	-7.07	0
	b.mesos	-22.39	0
	a.mesos	-9.05	0
pH	X4~4.5	-2.81	0.05
	X4.5~5	13.05	0
	X5.5~6	19.58	0

UNO3

		Estimate	P
Transversal distribution	(Intercept)	-23.54	0.01
	rc	-5.14	0.00
	bc	9.07	0.02
	po	8.63	0.00
	mar	-7.92	0.00
	lak	-6.56	0.00
	gw	-0.26	0.32
Longitudinal distribution	cr	-11.43	0.00
	epr	16.58	0.00
	hypor	6.49	0.05
	ept	-35.56	0.00
	mett	5.54	0.04
	est	-3.75	0.00
Altitude	lowl	28.20	0.00
	pil	-2.60	0.27
	al	-2.77	0.03
Biogeographic regions	Alps	-32.39	0.00
	Vosge	-19.87	0.00
	lowlo	15.39	0.01
	lowlm	10.40	0.00
Substrate (preferendum)	gra	-6.87	0.01
	maphs	5.75	0.02
	miph	6.90	0.00
	twig	4.00	0.00
	mud	4.46	0.01
Current velocity	null	-6.32	0.00
	medi	10.39	0.00
	fast	4.93	0.00
Trophic status	oli	4.25	0.08
	meso	27.20	0.00
	eutr	5.18	0.11
Salinity	fw	-19.17	0.09
Temperature	cold	5.70	0.01
	warm	4.50	0.00
	eury	5.74	0.19
Saprobity	xen	-3.31	0.06
	olis	-11.45	0.00
	b.mesos	-15.23	0.01
	a.mesos	-17.24	0.00
	polys	-1.69	0.04
pH	X4	2.39	0.09
	X4.4.5	5.40	0.01
	X5.5.5	-31.95	0.00
	X5.5.6	44.11	0.00

UPO4

		Estimate	P
Transversal distribution	(Intercept)	-17.64	0.17
	po	-3.60	0.13
	mar	-1.62	0.31
	tw	-1.72	0.31
	lak	7.51	0.01
	gw	-0.35	0.22
Longitudinal distribution	cr	-14.28	0.00
	epr	14.12	0.00
	metr	-20.65	0.00
	hypor	-11.32	0.00
	ept	13.48	0.00
	mett	-17.01	0.00
	est	3.78	0.00
	our	-13.66	0.00
Altitude	pil	2.25	0.16
	Pyr	-6.38	0.24
Biogeographic regions	Alps	6.56	0.30
	Vosge	-7.69	0.03
	lowlo	18.56	0.00
	lowlm	-6.11	0.03
Substrate (preferendum)	fl	-7.36	0.00
	sand	-6.15	0.00
	twig	-0.86	0.31
	org	-5.51	0.01
	mud	2.81	0.10
Current velocity	null	-4.21	0.20
	slow	4.79	0.38
	medi	-5.84	0.02
	fast	8.76	0.00
Trophic status	eutr	-2.34	0.38
Salinity	fw	10.07	0.33
	bw	13.70	0.00
Temperature	cold	-3.76	0.08
	warm	-6.34	0.00
	eury	-11.19	0.04
Saprobity	xen	-2.59	0.07
	b.mesos	-12.07	0.03
	a.mesos	6.04	0.04
	polys	0.74	0.30
pH	X4~4.5	-7.44	0.00
	X4.5~5	26.85	0.00
	X5.5~5	9.71	0.11
	X5.5~6	17.32	0.04
	X>6	12.64	0.02

Most efficient bio traits catorgery to retention have been identified(like current velocity and ph preference)

What is Ecosystem services

1.What is self-purification service?

2.How to quantify it?

-3 projects with nutrients retention measurements?

-invertebrate diversity

-Evidence of biodiversity ecosystem function relationship

3.Where we get in this service valuation

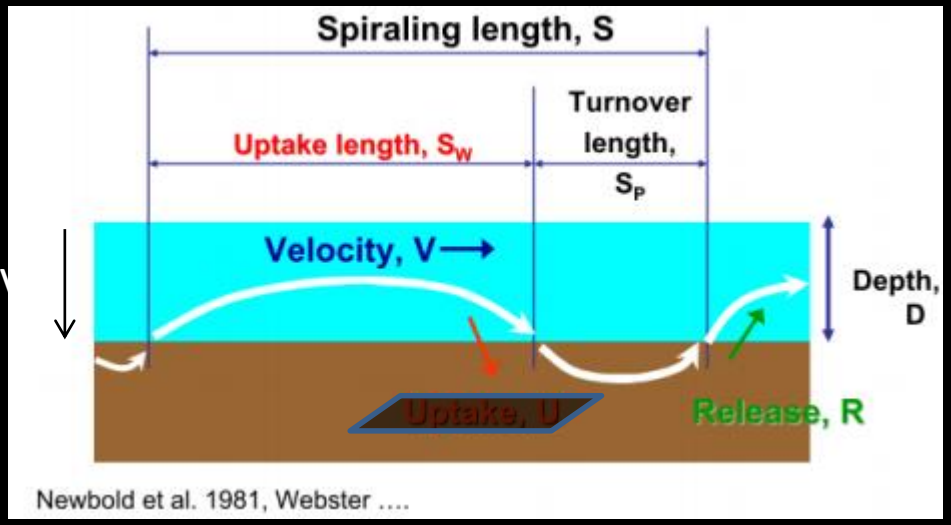
-benefites-costs replacement method

-data

Looking for more restoration data

Looking for economists cooperation

2.Retention parameter selection



Sw: average distance traveled by a nutrient molecule in inorganic phase prior to uptake

Vf :vertical velocity of nutrient molecules through the water column towards the benthos

U:areal uptake rate of an inorganic nutrient into the benthos under ambient conditions

1 Mass transfer velocity

(m/s)

2 Gross nutrient uptake rate

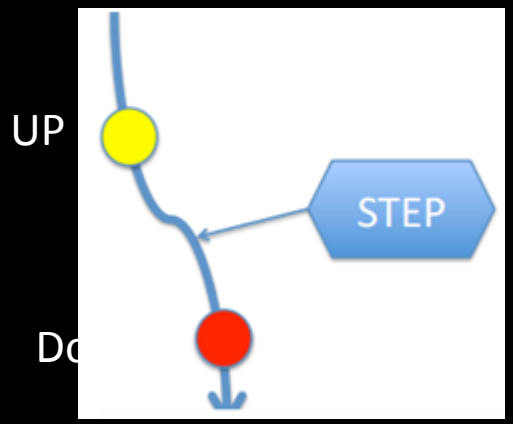
(mg N/m2/min)

2.Which is the most suitable retention parameter

Site,Reach effects (Anova analysis)

Factor	VFNH4	UNH4
Site	***	***
Reach		***
Factor	VFNO3	UNO3
Site	***	***
Reach		**
Factor	VFPO4	UPO4
Site	***	***
Reach		**

* p<0.05 significant difference



VF

Site effect/ no reach effect

Group Site

N=11

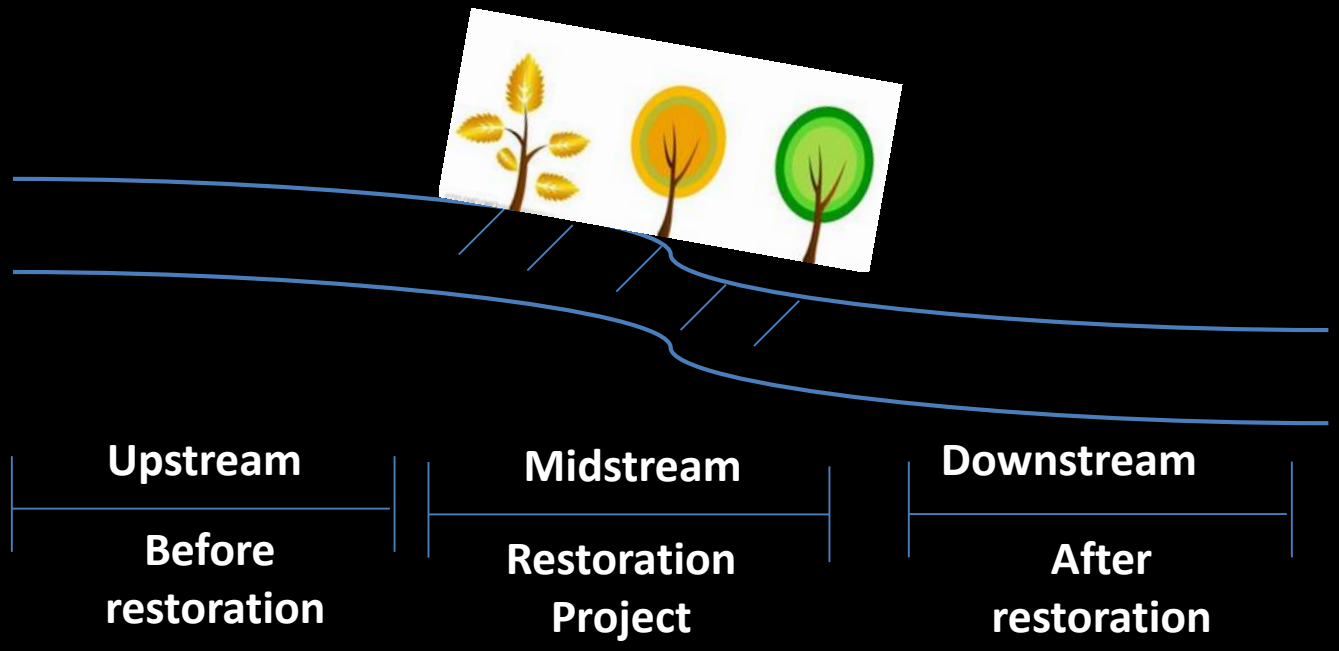
U

Site effect and reach effect

Group Reach

N=22

Results from both VF and U


Upstream
Before restoration
Midstream
Restoration Project
Downstream
After restoration

Costs

Results 2: Costs evaluation

Step 1: Biodiversity-ecosystem function relationship research(BEF)

Identify the required community/biodiversity of invertebrates for purification service

Invertebrate

Density/ Biomass

1 Taxonomic/ functional diversity index

2 Bio/Eco traits Composition

3 Traits selection

4 Feeding habits

?

Retention Capacity

U

NH4

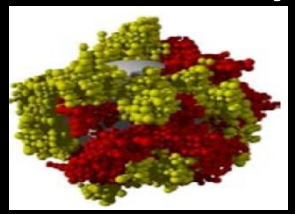
NO3

PO4

Who is self-purification service provider

Service	Ecosystem service providers/ trophic level	Functional units	Spatial scale	Potential to apply
Purification of water	Vegetation, soil and aquatic micro-organisms, aquatic invertebrates	Populations, species, functional groups, communities, habitats	Local–regional	Medium to high*

Quantify how invertebrates biodiversity is involved in supporting the purification capacity?(BEF research)



Biodiversity of Invertebrates
- Taxonomic
- Functional

Grazing and Gardening

Bacterial community

+

+

water Purification functions

?

NH4

NO3

PO4

Millennium Ecosystem Assessment (2005)