Problems and researches on eco-hydraulics and eco-sedimentation

Zhao-Yin Wang

Professor, Tsinghua University

Vice President of IAHR

Chairman, Advisory council of UNESCO International Research and Training Center on Erosion and Sedimentation

Chief editor, International Journal of Sediment Research

The main contents are in the following paper:

Wang Zhao-Yin, Lee J. H.W. and Xu Mengzhen, 2013, eco-hydraulic and eco-sedimentation studies in China, Journal of Hydraulic Research, No.1. 2013

search

Contents

1. Ecological problems and Indicate species

Eco-hydraulics and eco-sedimentation

- Eco-hydraulics is the relations between the aquatic organisms and hydraulic conditions of stream flow.
- Eco-sedimentation is the relations between the aquatic organisms and sediment transportation and fluvial process.
- Eco-hydraulics and eco-sedimentation are growing points of interdisciplinary studies.

Problems and approaches

- Dam construction, pollution, exotic species, fragmentation of habitats, and river bed incision have impaired or disturbed the stream ecology.
- Using indicator species the stream ecology can be quantitatively studied and restoration measures are proposed and assessed.

Indicator Species

Indicator species are a group of species whose characteristics are used as an index of environmental conditions of interest.

Good indicator species should be in the top or the middle on the food chain and have high stability and a narrow tolerance to stresses.

Most ecological assessment of rivers are done with Benthic invertebrates and Fish as indicator species.

Mayfly (**collectors),** Dragonfly (**predator**), Cadisfly (**shredders)**

黄鳍鲷
Sparus latus Houttuyn

七丝鲚
*Coilia grayi*洄游鱼类

大眼鳜
Siniperca kneri

Taxa Richness and Abundance

Richness S - The most important characteristic of biodiversity is richness

S = total number of species, genus or families in the the sample

Abundance N – The total number of animal individuals per area for all species from one sampling site

Bio-community index is defined as:

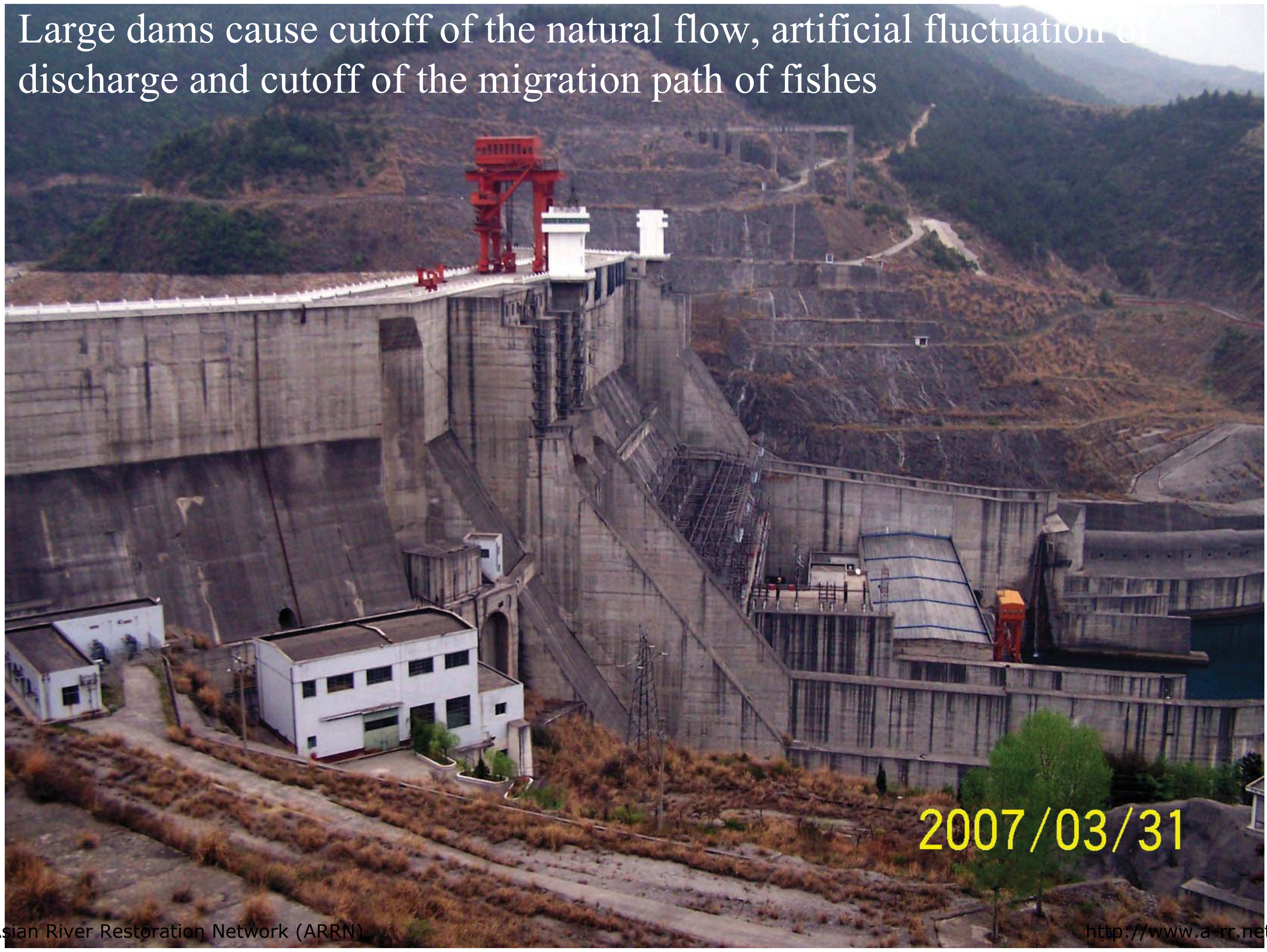
$$B = -\ln N \sum_{i=1}^{S} \frac{n_i}{N} \ln(\frac{n_i}{N})$$

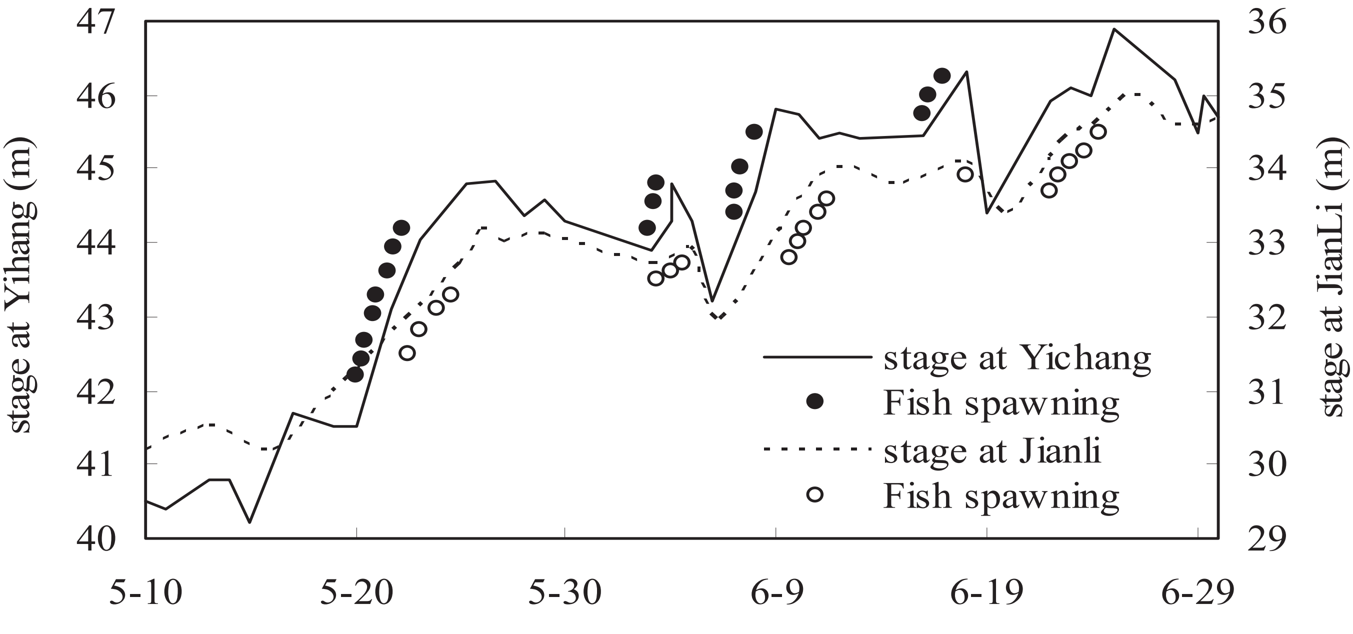
ni is the number of individual animal of *i*-th species

2. Eco-hydraulics

2.1 Ecological impacts of damming and Habitat Modeling

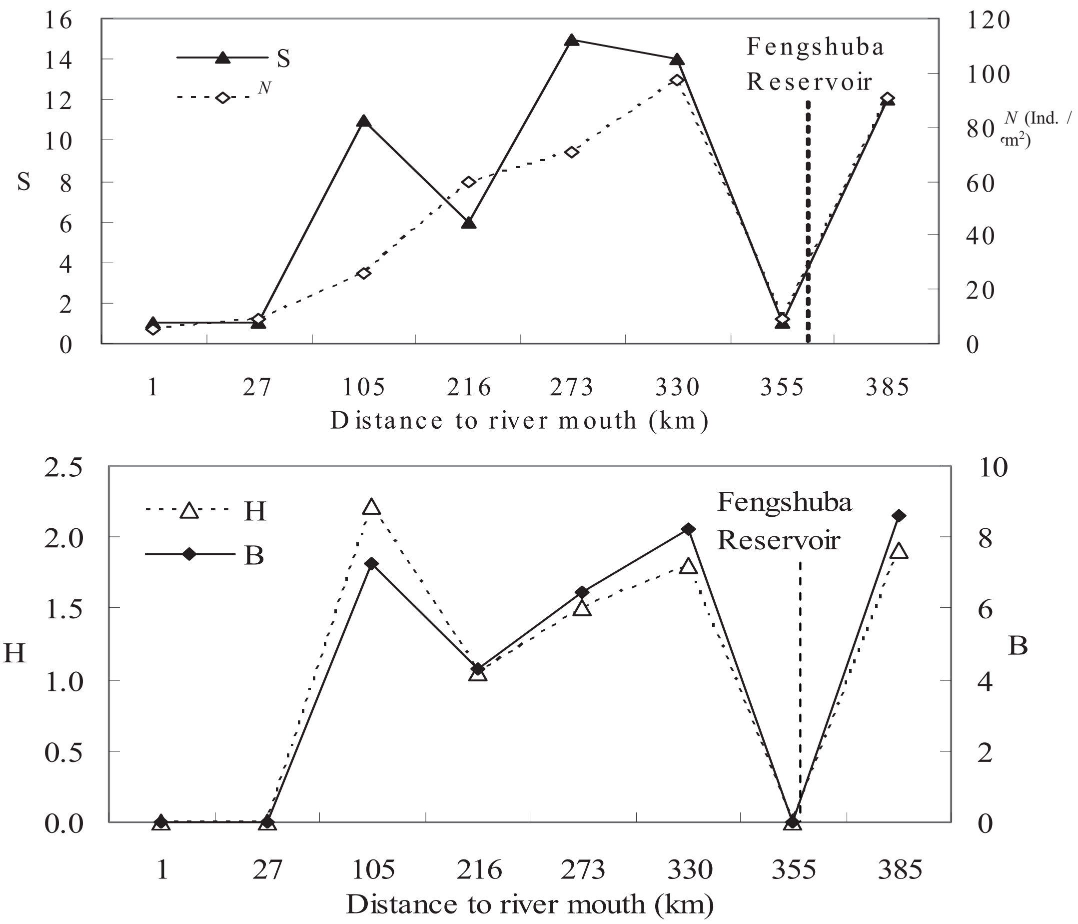
Large dams cause cutoff of the natural flow, artificial fluctuation of discharge and cutoff of the migration path of fishes



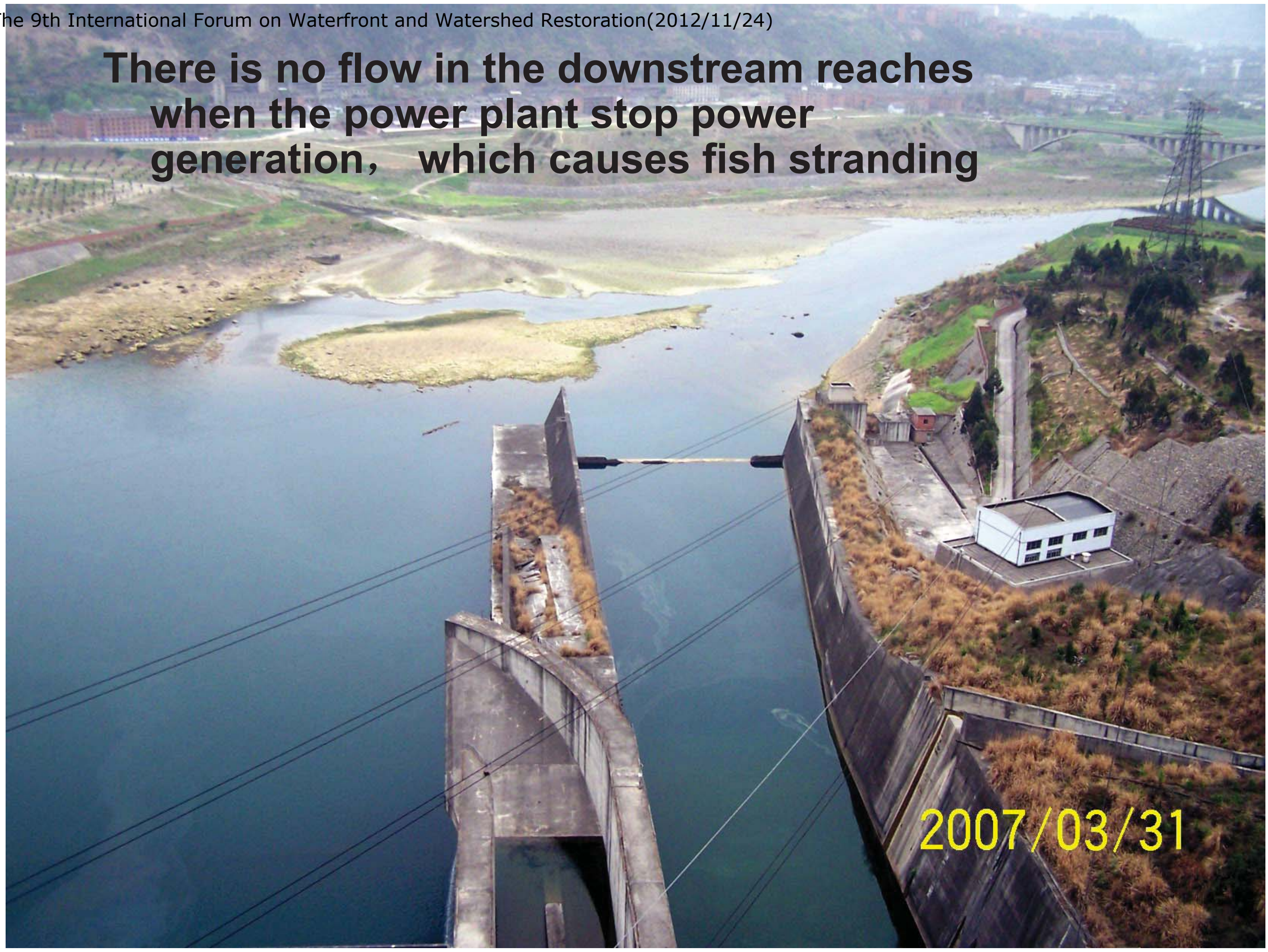


Stage variation at Yichang and Jianli under natural conditions and the spawning time of chinese carps. The TGP dam has reduced the flux of fry by 98% by changing the flood stage

The Fengshuba dam causes daily fluctuation of discharge and impact the ecosystem in the downstream reaches



Richness S and abundance N, and the bio-community index, *B,* as functions of distance to the river mouth

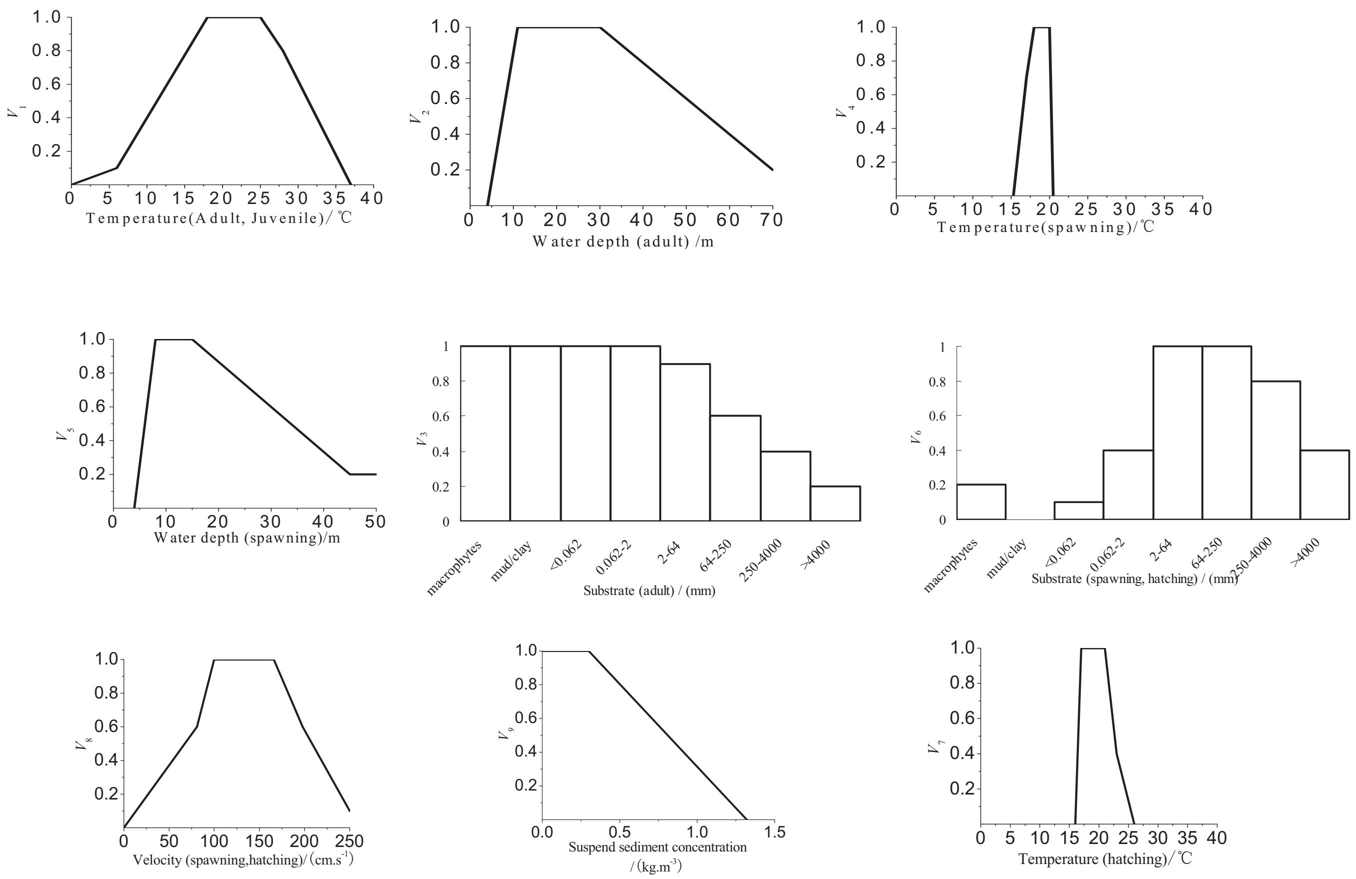


Suitability Indices

- Suitability indices are the core for habitat modeling.
- Life cycle of the Chinese sturgeon in the Yangtze River mainly comprises spawning, hatching and growth of juvenile sturgeon.
- Brood fish seek suitable spawning sites; fertilized eggs adhere to stone and hatch about 120-150 h.

Ten aquatic eco-factors are selected for the modeling :

1) Water temperatures for adults and juveniles (*V*1, ° C);
2) Water depth for adults (*V*2, m);
3) Substrate for adults (*V*3);
4) Water temperature for spawning (*V*4, ° C);
5) Water depth for spawning (*V*5, m);
6) Substrate for spawning and hatching (*V*6);
7) Water temperature during hatching (*V*7, ° C);
8) Flow velocity during spawning (*V*8, m/s);
9) Suspended sediment concentration during spawning (*V*9, mg/l); and
10) The amount of eggs-predating fishes in the studied year in comparison to a standard year (*V*10).



Suitability Index curves for habitat of Chinese sturgeon

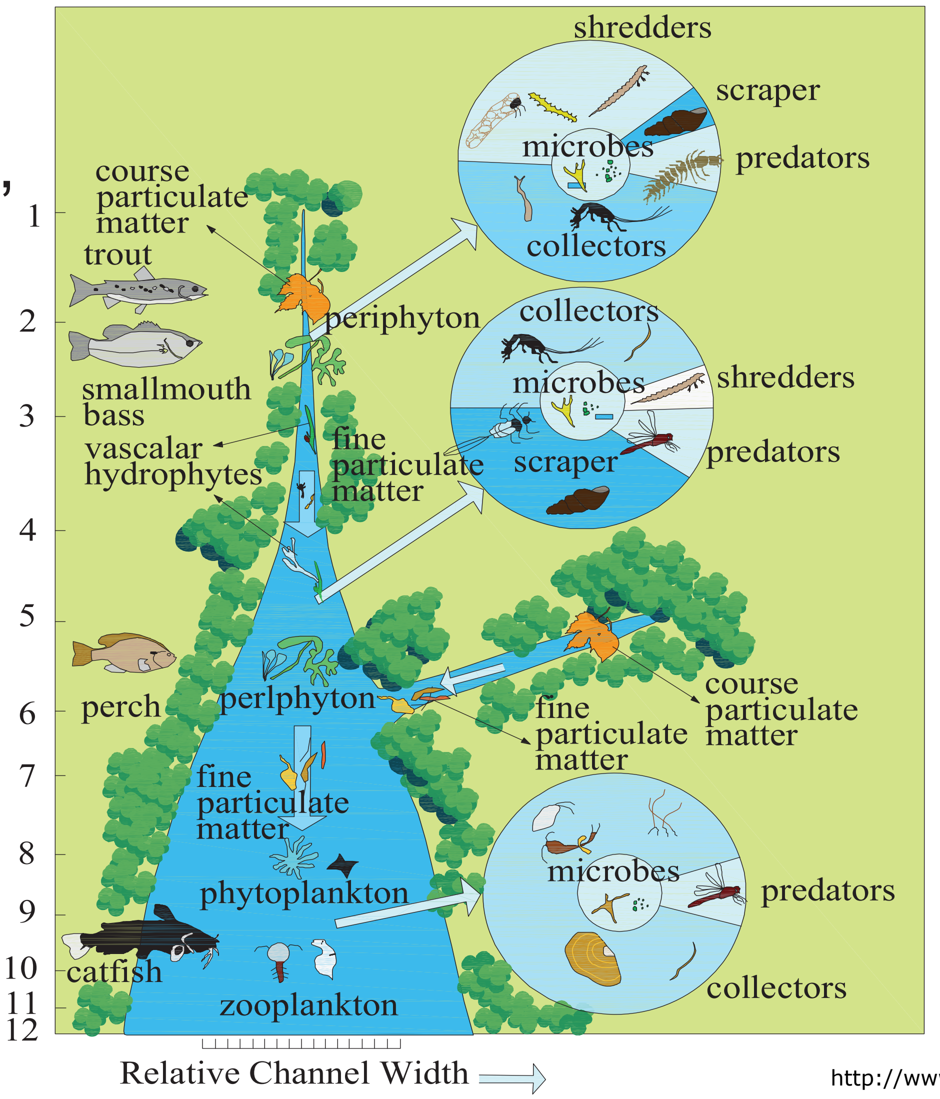
- Habitat Suitability Index:
- $$HSI = \min(C_{Ad}, C_{Sp}, C_{Ha})$$
- $$C_{Ad} = \min(V_1, V_2, V_3)$$
-
- *C*Sp represents the suitability for spawning
- $$C_{Sp} = \min(V_4, V_5, V_6)$$
- *C*-Ha represents the suitability for hatching
- $$C_{Ha} = V_{10} \bullet \min(V_6, V_7, V_8, V_9)$$
-
- The habitat suitability ranges from unsuitable (0) to optimal habitat suitability (1).

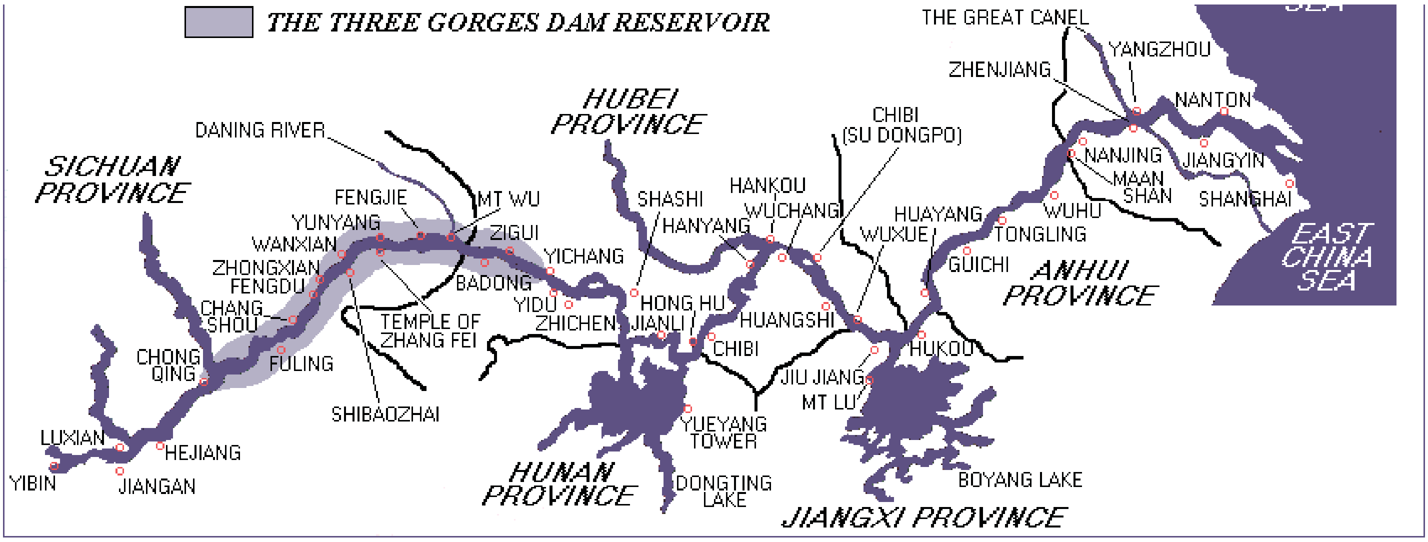
Restoration method

- Simulation results indicated that the operation of the TGP reservoir has reduced the space and time elements of the river with high habitat suitability index (*HIS*=1).
- The habitat suitability might partly be restored if the operation scheme were adjusted to mimic the natural flow regiem.

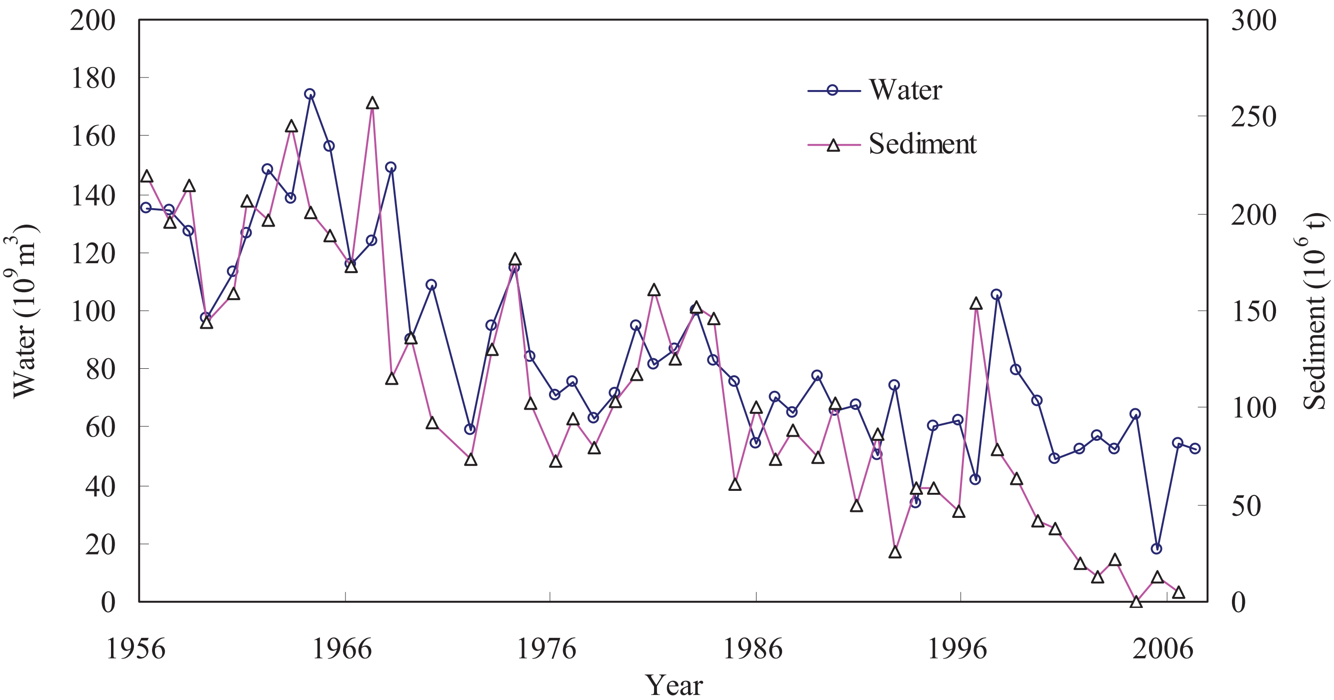
2.2 Habitat Connectivity and Fragmentation

Connectivity = flux of water, nutrients, sediment and organisms between different parts of the river and riparian waters

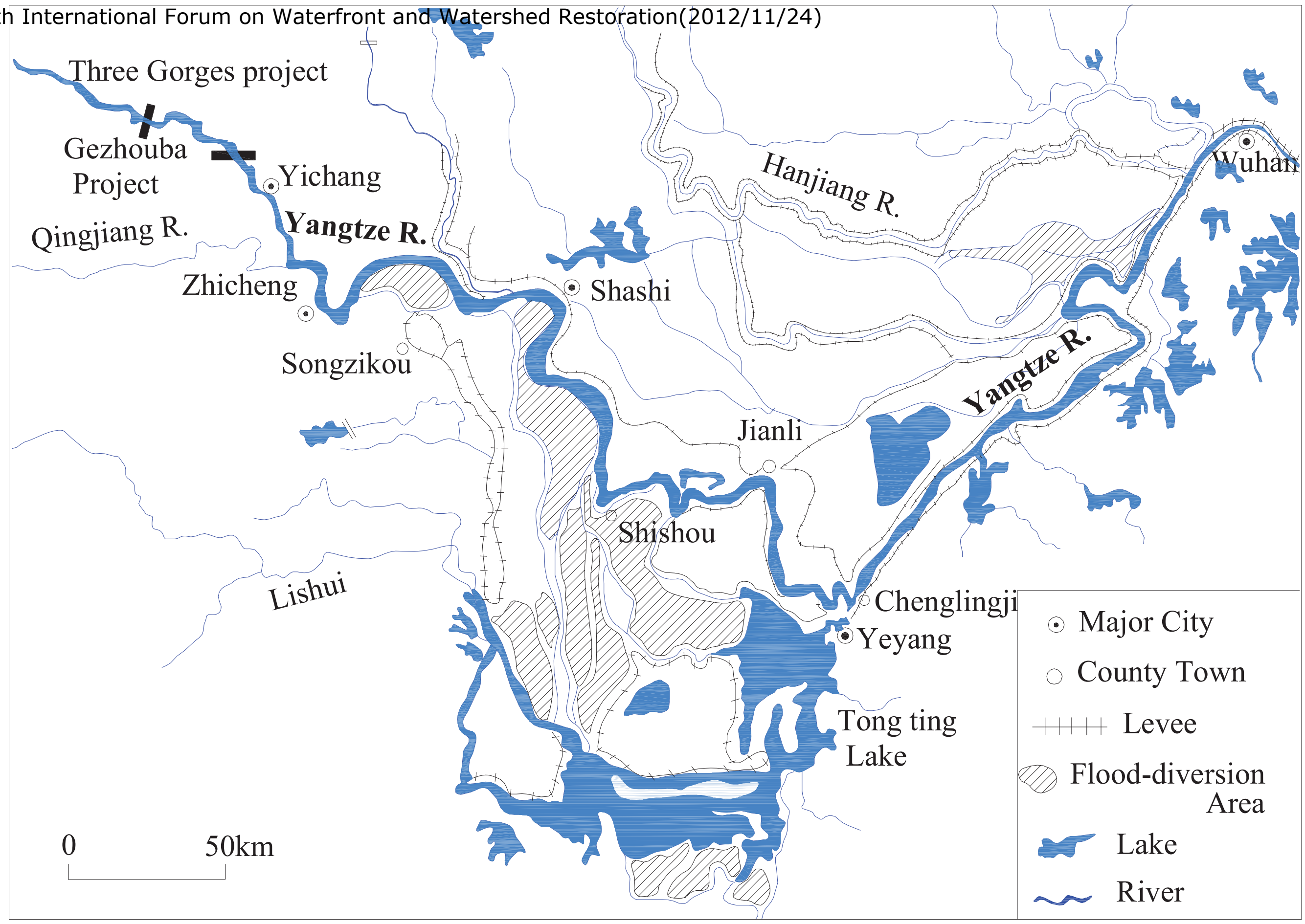




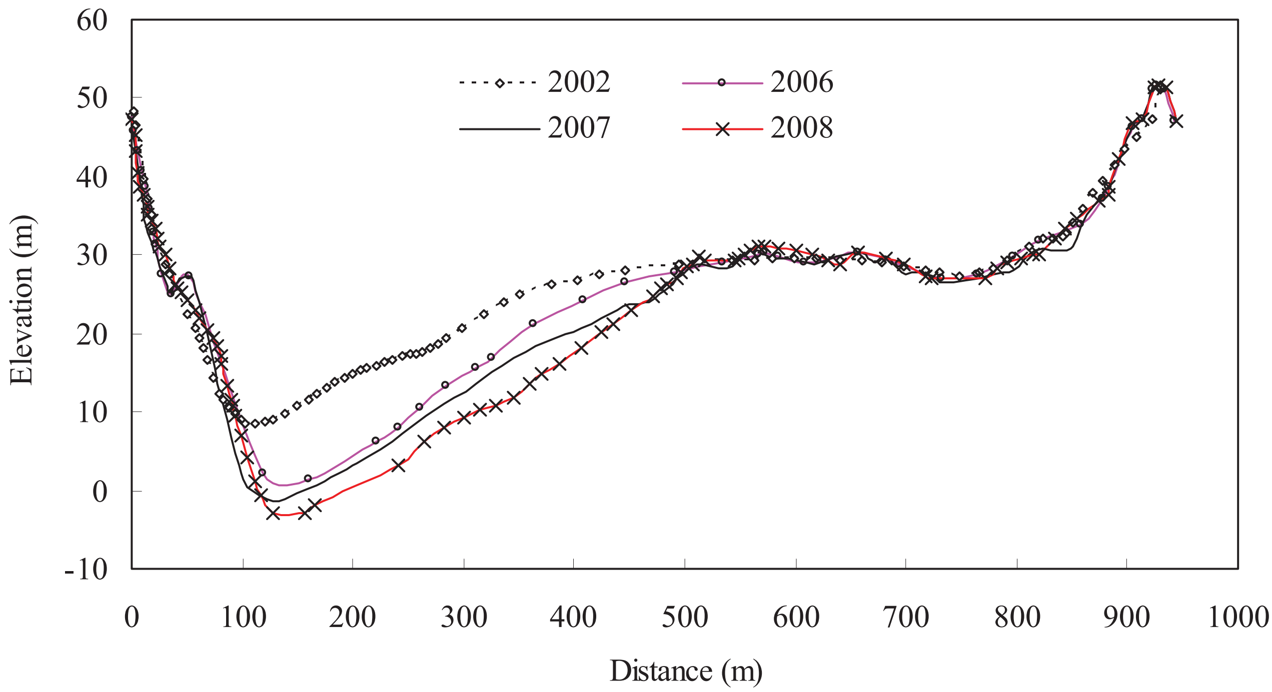
Connection of the Tongting and Poyang lakes with the Yangtze River



Annual amount of water and sediment diverted from the Yangtze River into Tongting Lake has been reducing and so the connectivity of the lake with the river



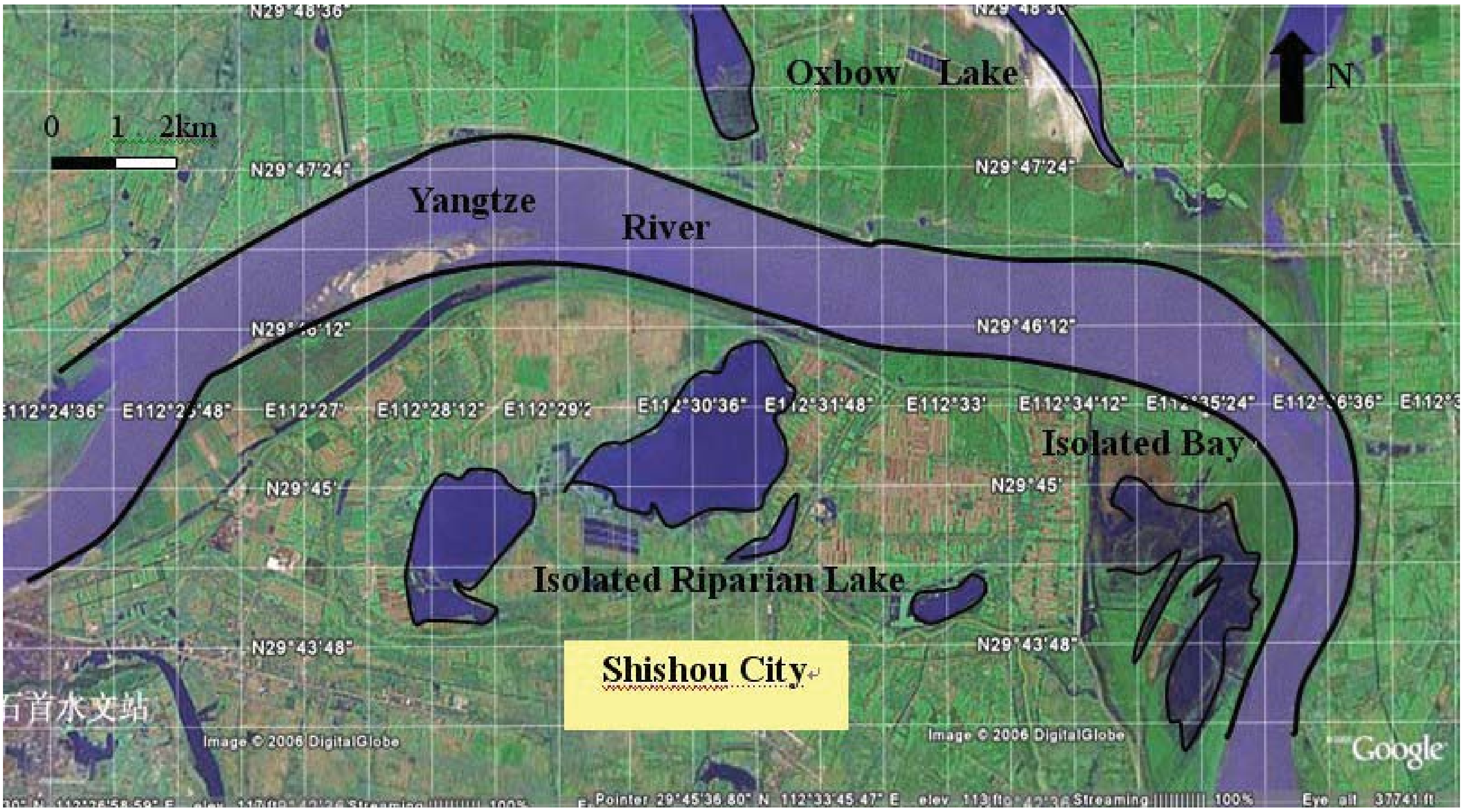
The connectivity between the Tongting lake and the Yangtze River has been greatly reduced by the TGP reservoir



Measured bed cross sections of the middle Yangtze River at 88 km downstream from the Three Gorges Dam (The bed has been incised down by 10 m due to scour of clear water released from the dam).

Fragmentation of habitat

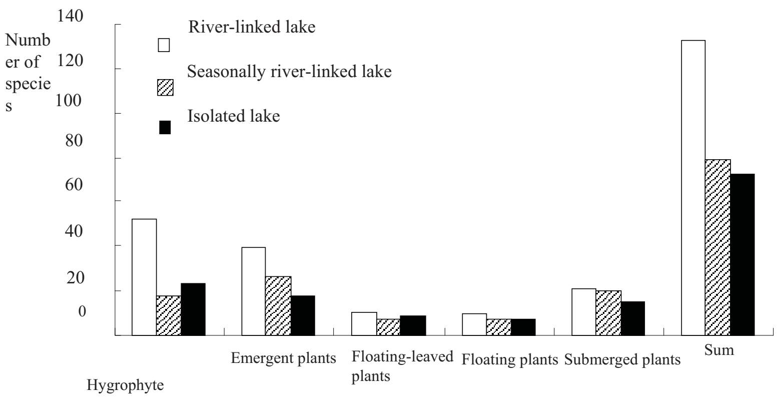
- Riveruses result in the fragmentation and isolation of habitats.
- In the middle and lower Yangtze River, numerous riparian lakes with different sizes lakes connected with the Yangtze River and formed a huge habitat in the past. Humans cut the connection for flood defense and aquatic farming, thus fragmented the habitat.
- The fragmentation of habitat has resulted in deterioration of ecology and extinction off some species.

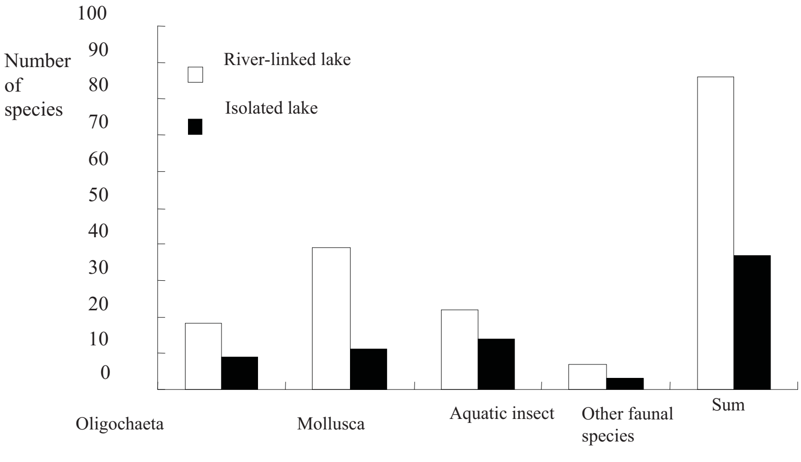


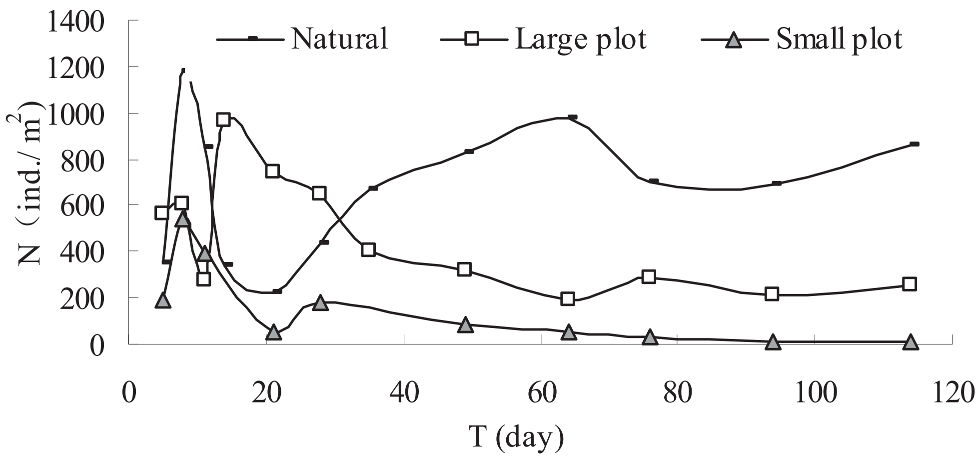
Isolation of riparian lakes in the Yangtze River basin results in fragmentation of habitat

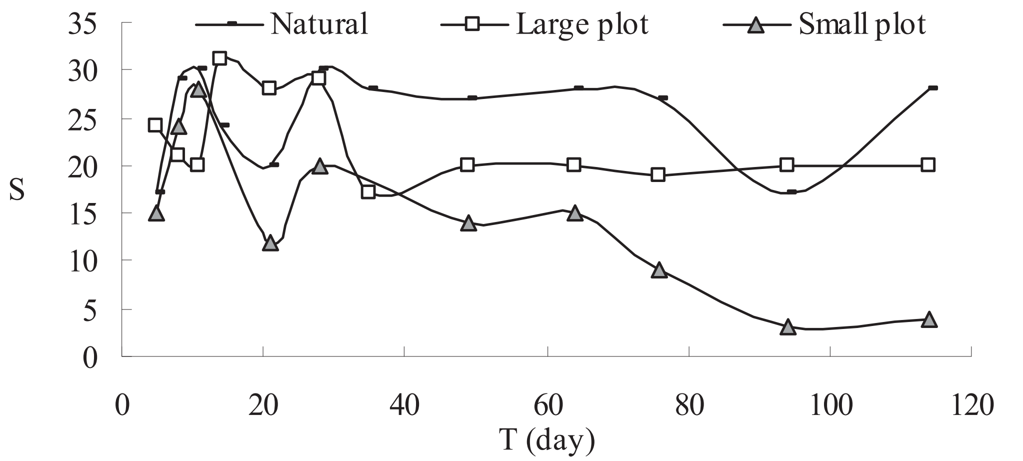
Fankou lock separating the Liangzi lake and the Yangtze river

Comparison Of biodiversity between River-linked lakes and isolated lakes in the Yangtze River baisn

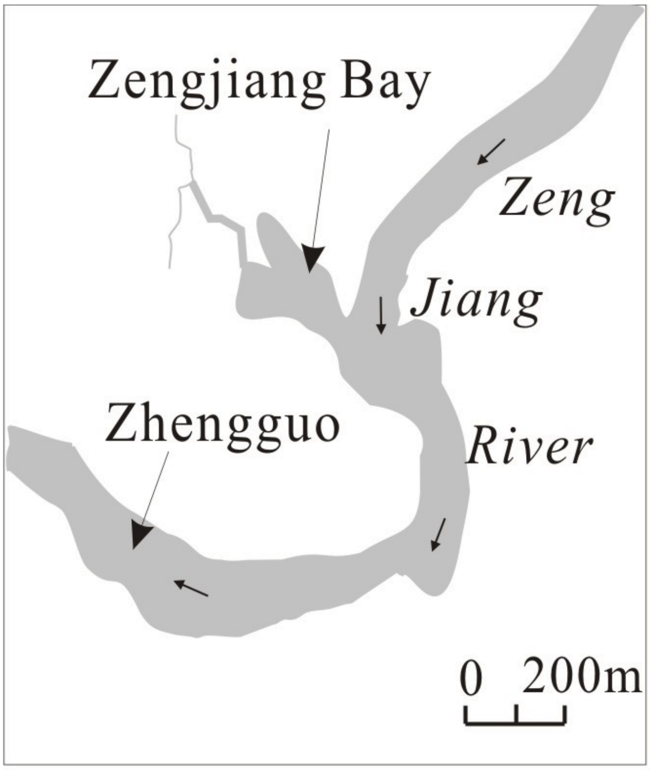


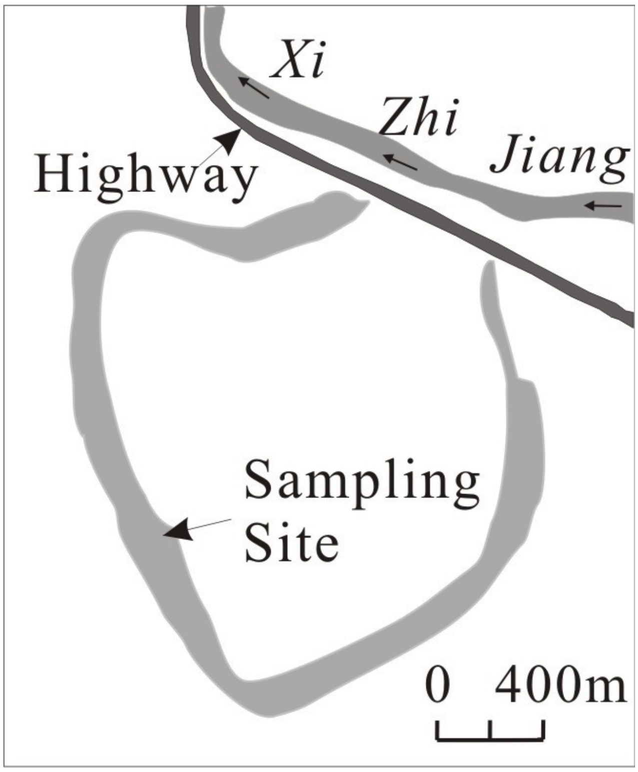






各隔离区生物密度与物种丰度随时间的变化





Location and shape of Zengjiang Bay 31species and Xizhijiang Oxbow Lake 7 species

Comparison of species in the Zengjiang bay and neighboring channel bed

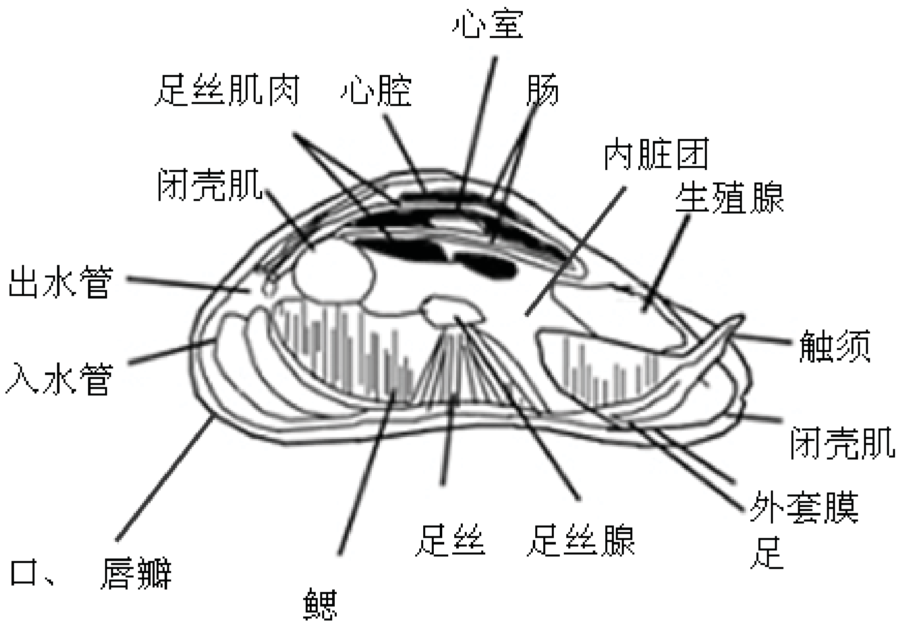
- ***Zengjiang Bay* – *31 families***
- *Corbiculidae C.fluminea (113); Chironomidae (four species 44); Elmidae， Stenelmis (25); Ceratopogonidae Bezzia (25); Corixidae (21); Limnodrilus(23); Semisulcospira (20); Libellulidae (14); Ephemeridae (11); Bellamya B.Purificata (8); Macromiidae (6); Bellamya Sp1 (5); Branchiura (4); Coenagrionidae Pseudagrion (4); Gomphidae, Trigomphus (3); Ampullariidae (2); Psephenidae (2); Hydrophilidae Hydrobius (2); Tabanidae (2); Lepidoptera (1); Acariformes (1); Gomphidae, Sinictinogomphus (1)； Palaemonidae (1); Tricladida (1); Baetidae(1); Heptageniidae (1); Parafossarulus(1); Elmidae, Sp1.(1)*
- **Zhengguo** – 0 species

2.3 Hydraulic control of exotic species

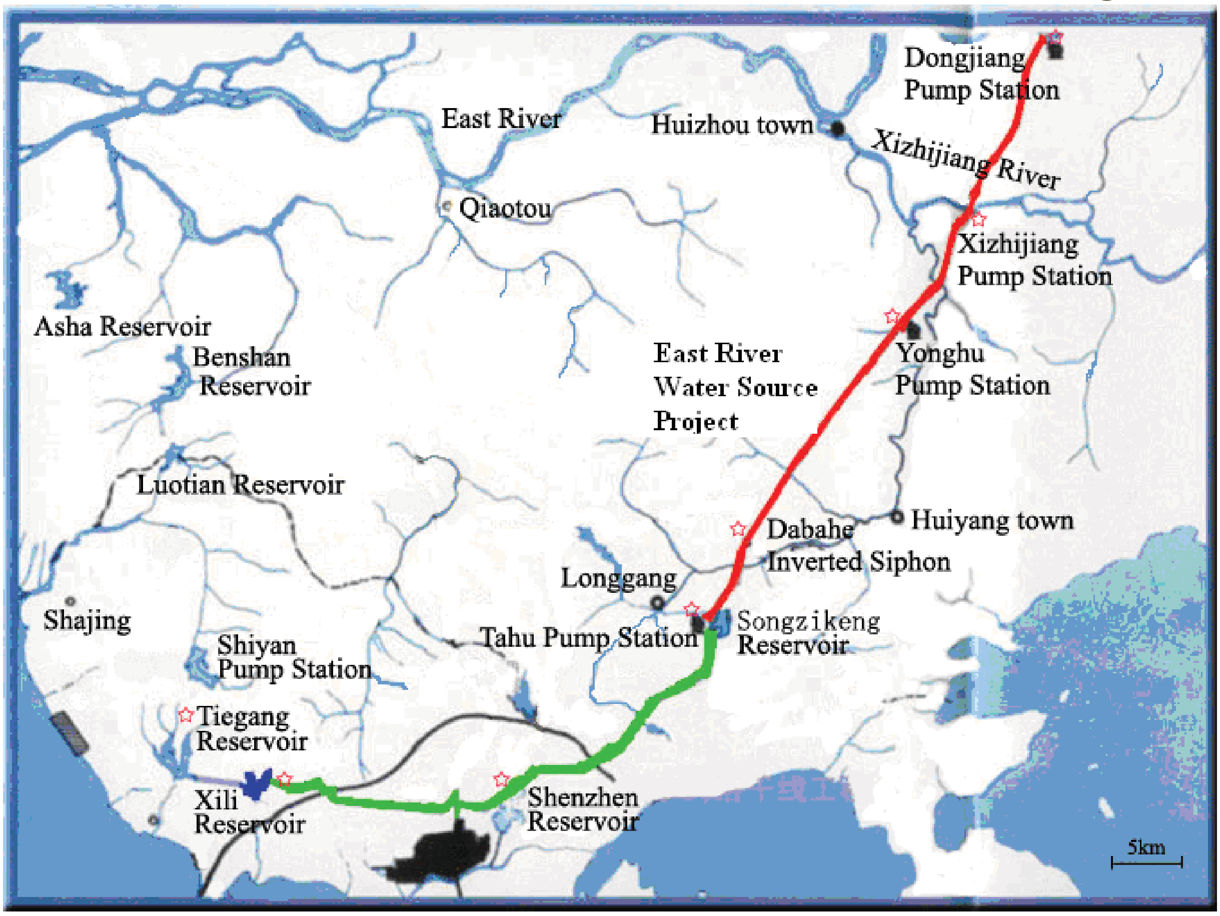
Golden mussel were found in many rivers in south China

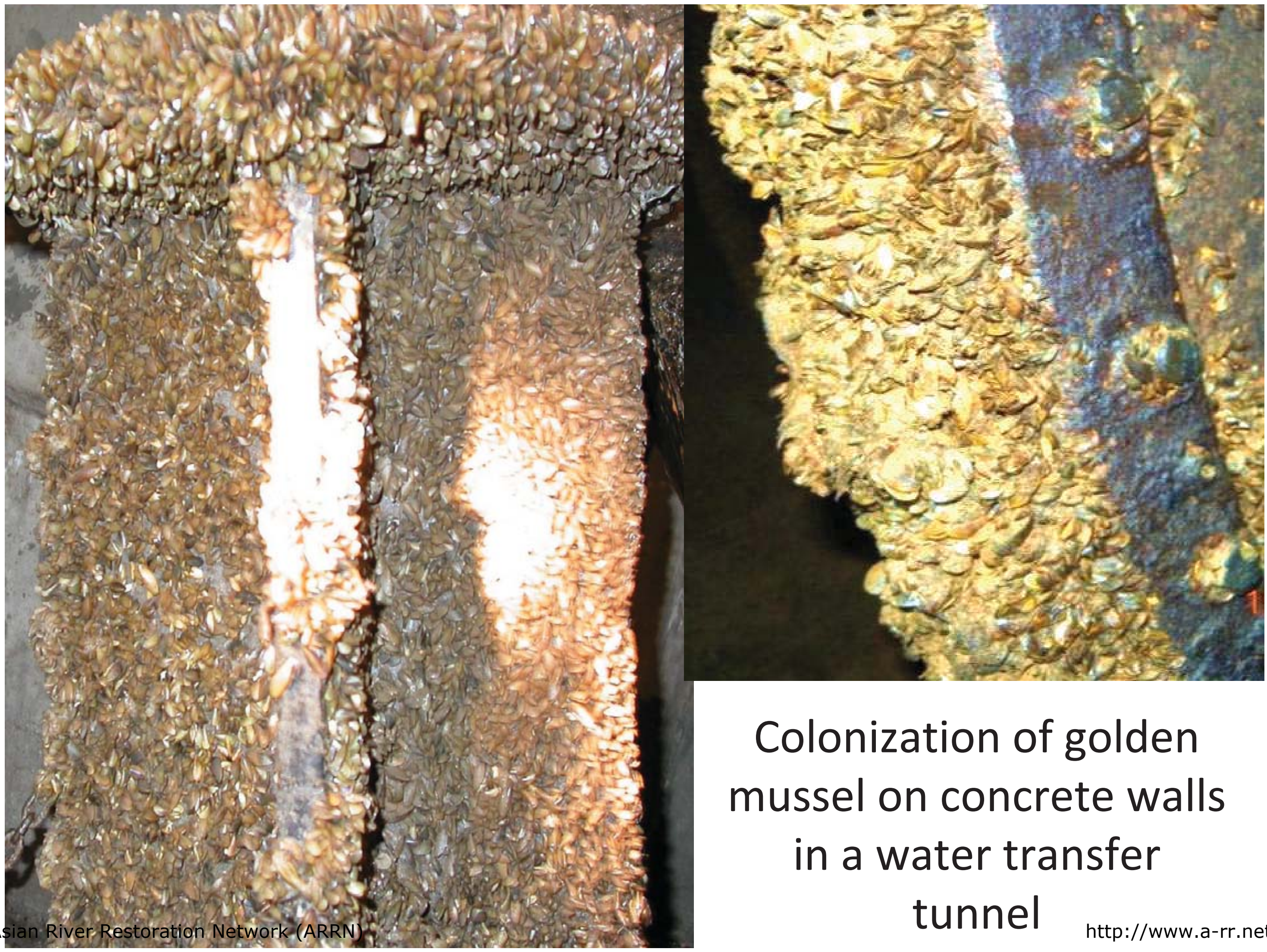
Golden mussel

- Golden mussel (*Limnoperna fortunei*) is an invasive filter species.
- Golden mussels have byssus threads, which allow them to attach onto solid walls.
- Dense attachment of golden mussels in water transfer tunnels and pipelines results in bio-fouling.
- This causes damage to tunnel walls, and along with dead mussels decay harms the water quality



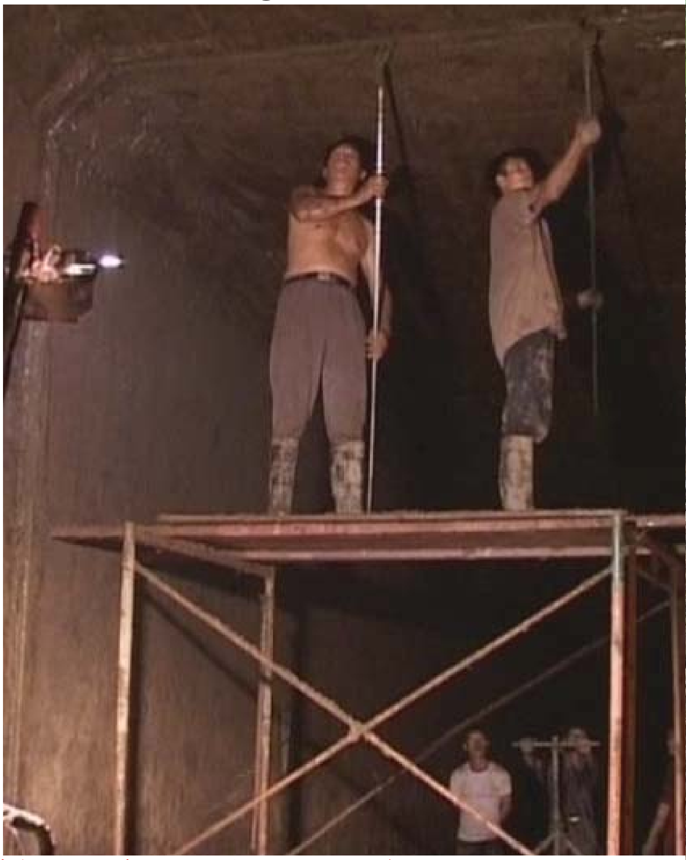
Golden mussel invaded into a 100 km long water transfer tunnel from the East River to Shenzhen and HongKong





Colonization of golden mussel on concrete walls in a water transfer tunnel

Removing the attached golden mussel from water transfer tunnels by labors

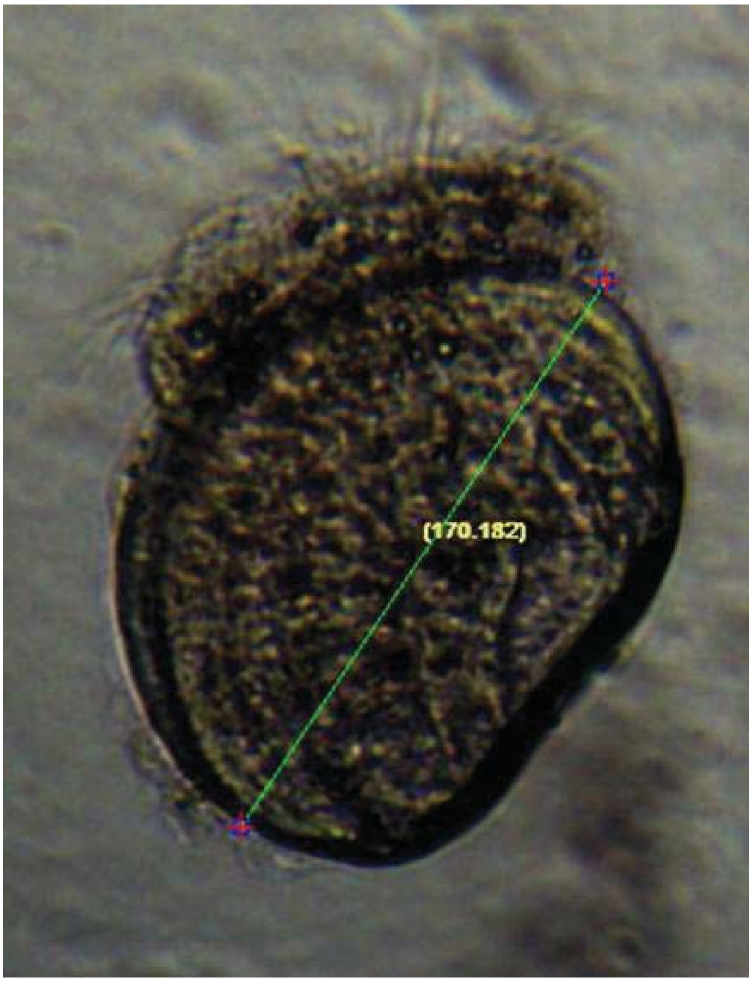


箱涵壁面贻贝刮除

Sample once per week from the river to find golden mussel larvae

D-larva of golden mussel

Larva pediveliger

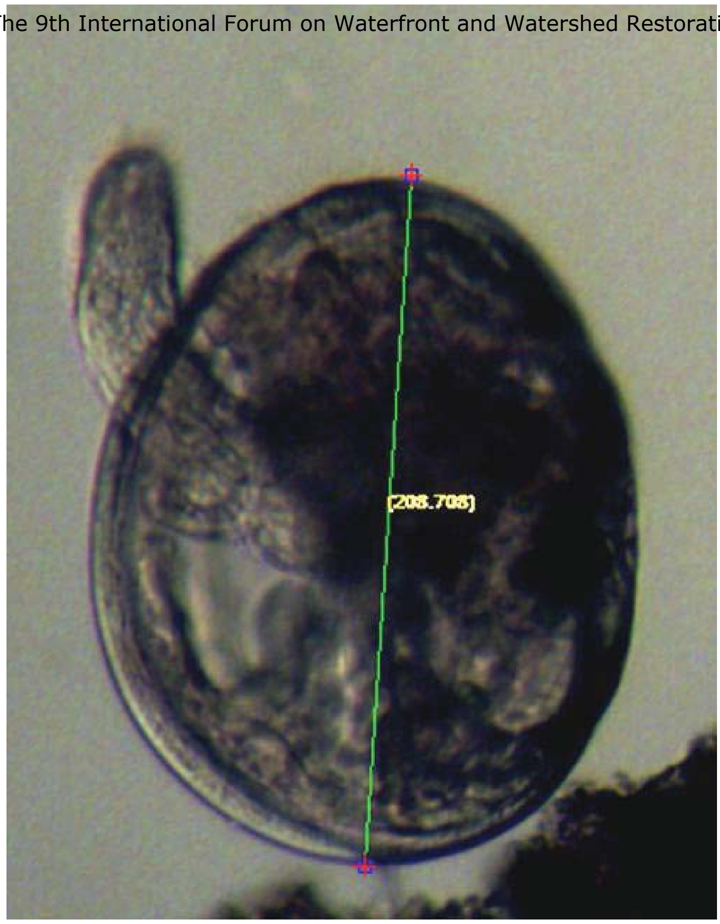


前期壳顶幼虫

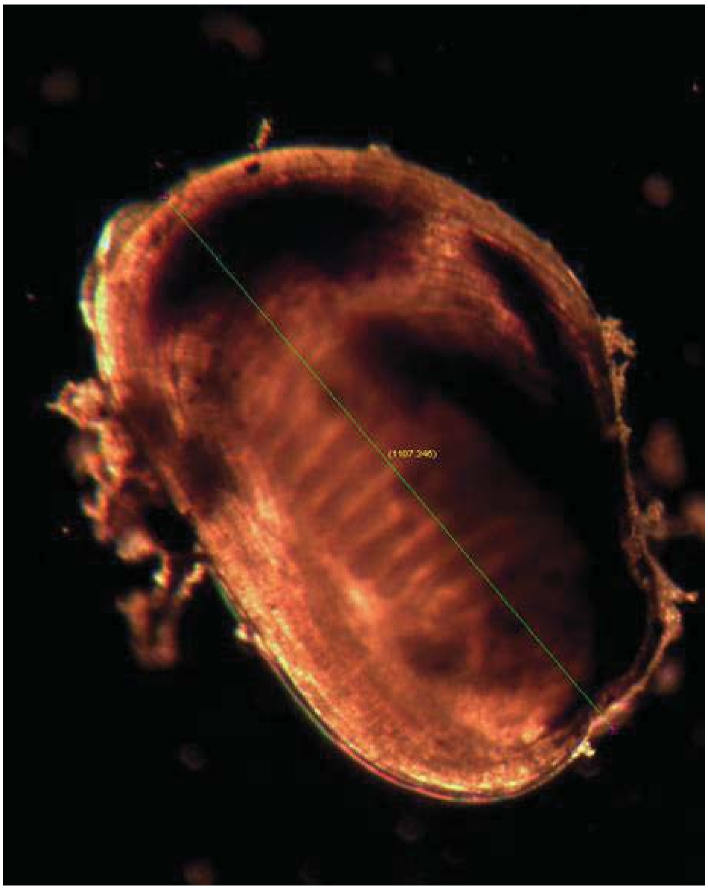
L=180μm

后期壳顶幼虫

L=190μm



Juvenile

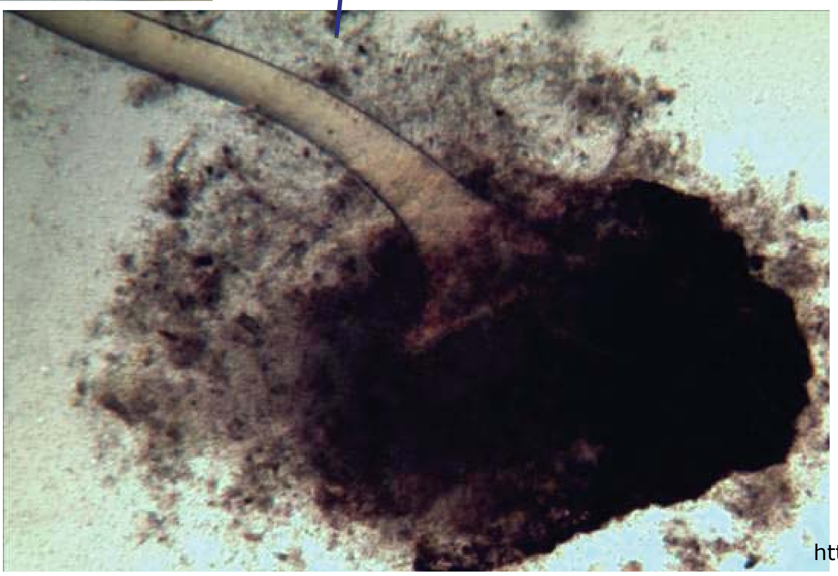


Plantigrade

Attachment of golden mussel

足丝

Byssus



Tsinghua University Experimental Station on the Xizhijiang River

Experimental flume for ecological studies

Attachment experiment in river ： Attachment materials were put in mousetrap cages

Attachment of golden mussel on the solid materials after 5 months-favor bamboo and a textile

铁丝笼

玻片

瓷片

布条

90% of the larvae attached on the bamboo and textile frames before the water flows into the tunnel

High frequency turbulence killed the residual golden mussel larvae before flowing into the tunnel

3. Eco-Sedimentation

3.1 Hyporheic zone

1. "Hyporheic zone" is defined as a layer of substrate on the riverbed in which benthic animals normally live, grow, feed, and reproduce.
2. Many problems about hyporheic zone need to be studied: thickness of the zone and control factors, species composition of different depths of the zone, and relations between the benthic animals in different layers of the zone.

Sample Tools

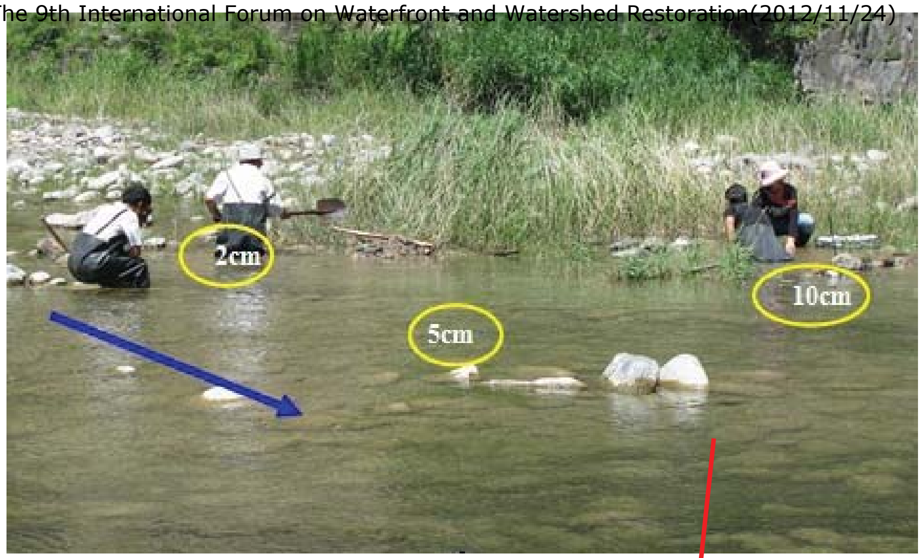
- Modified Surber net - used at S1
- Multilevel colonization samplers - used at S2-4
- Pipe corer - used at S5-8

Pipe corer

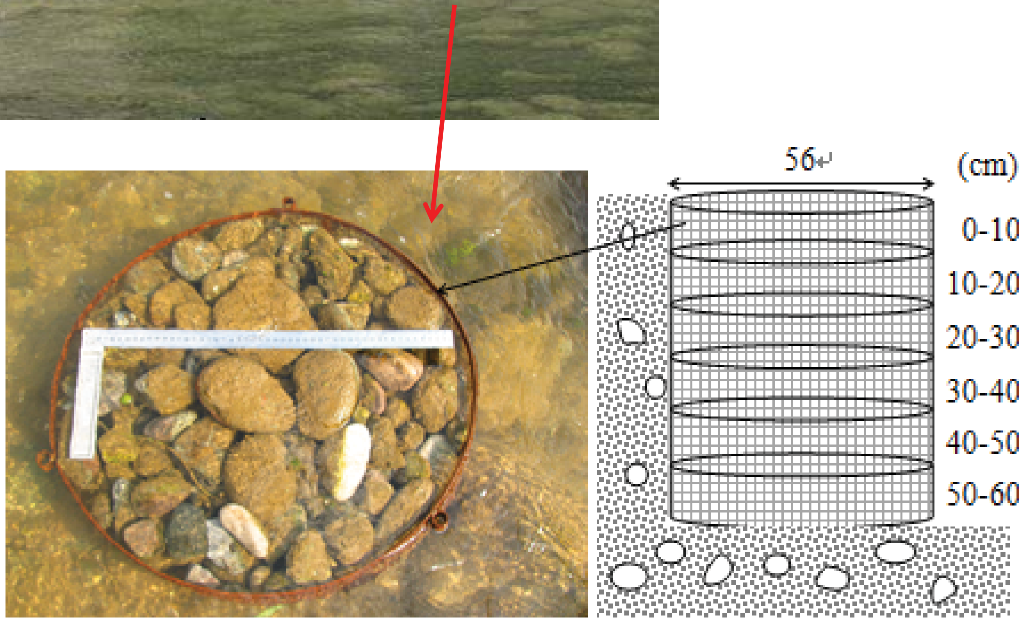
Modified surber net

Multilevel colonization samplers

Colonization experiment Each layer 10cm, 6-8 layers， colonization time 4 weeks, 6 weeks and 8 weeks



Experiment site



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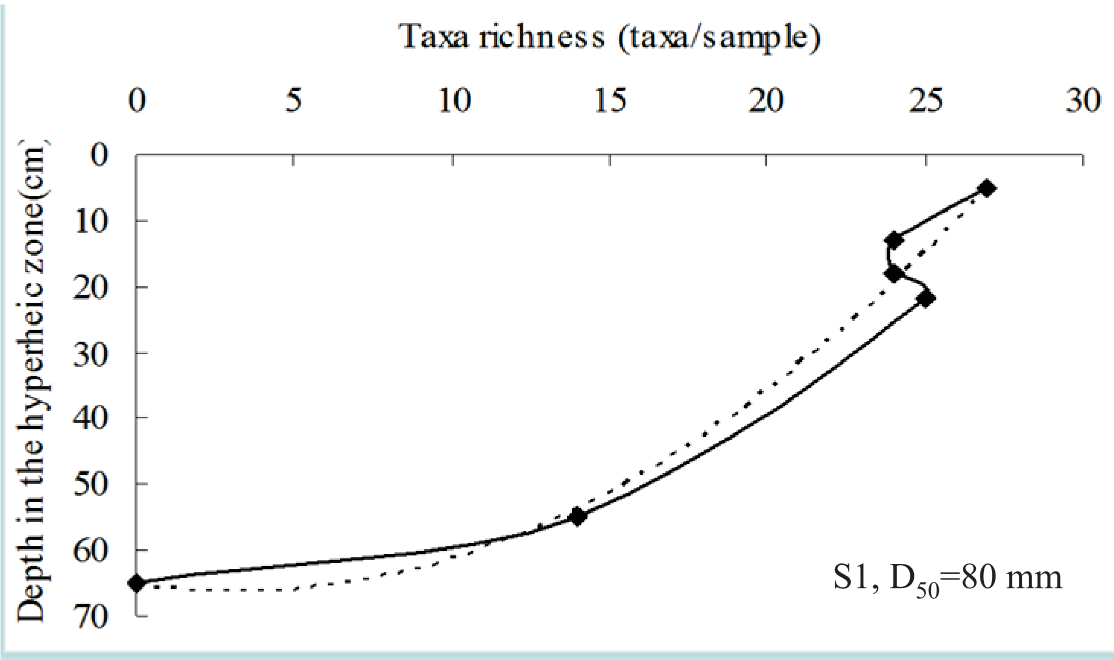
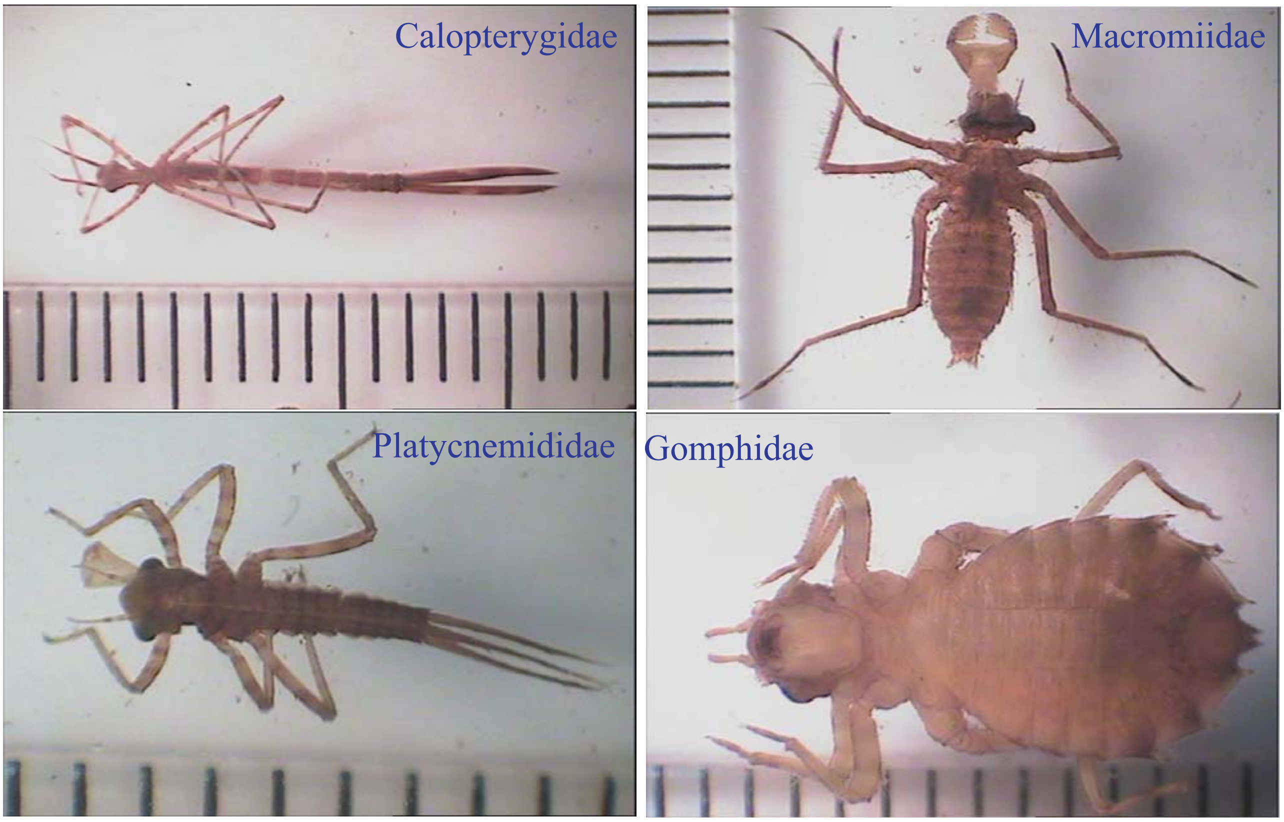
taxa richness as a function of bed depth



- At S1: Taxa richness **decreases from 27 to 0** from bed surface to bed depth of 65 cm in hyporheic zone.

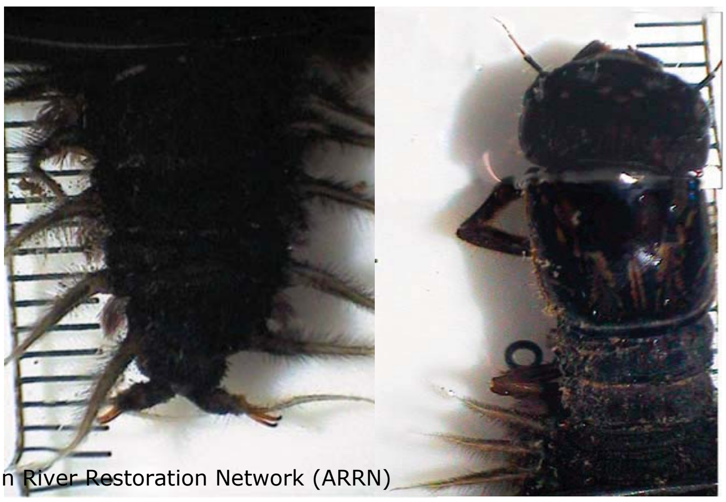
➢Odonata prefers the top hyporheic zone

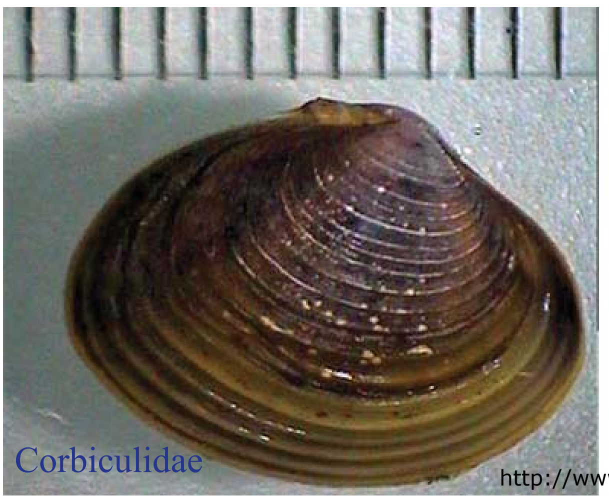


➢Dytiscidae, Haliplidae, Atyidae, live only in shallow layers of hyporheic zone

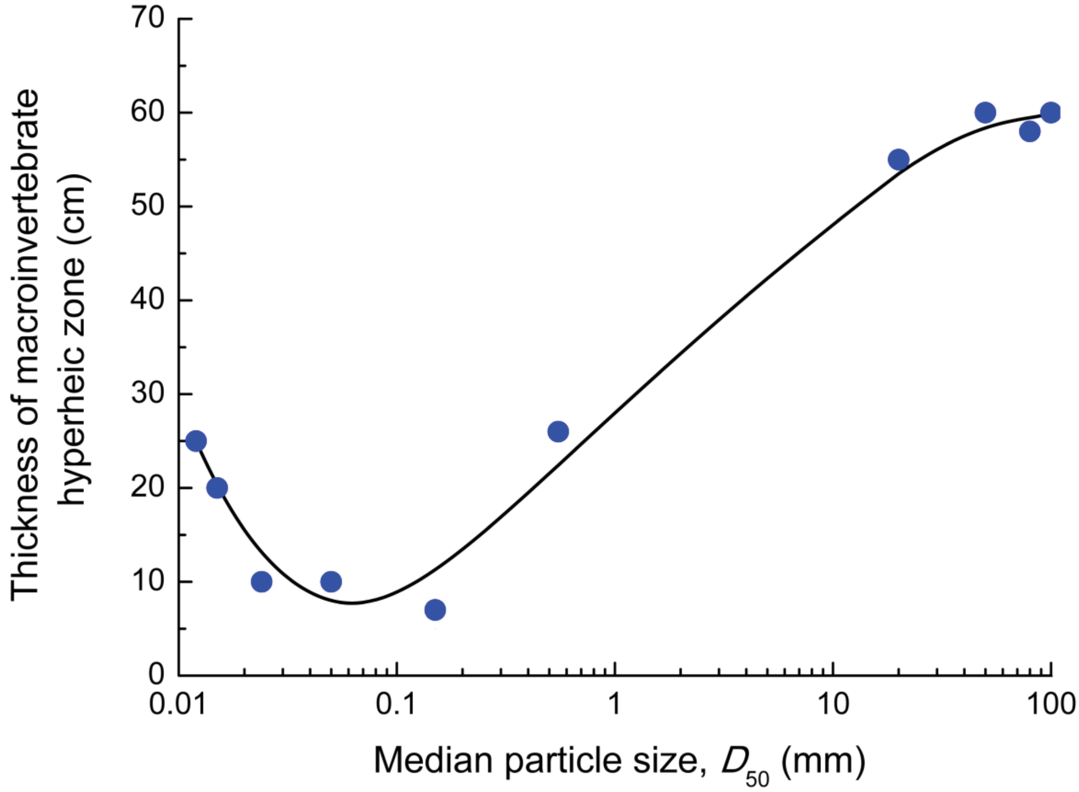
- Gastropoda prefers the moderate depth of the hyporheic zone

- Corydalidae, Naucoridae, and Corbiculidae, inhabit in deep layers of hyporheic zone.





Thickness of hyporheic zone



3.2 Habitat stability and diversity

Habitat Stability is the most important for stream ecology

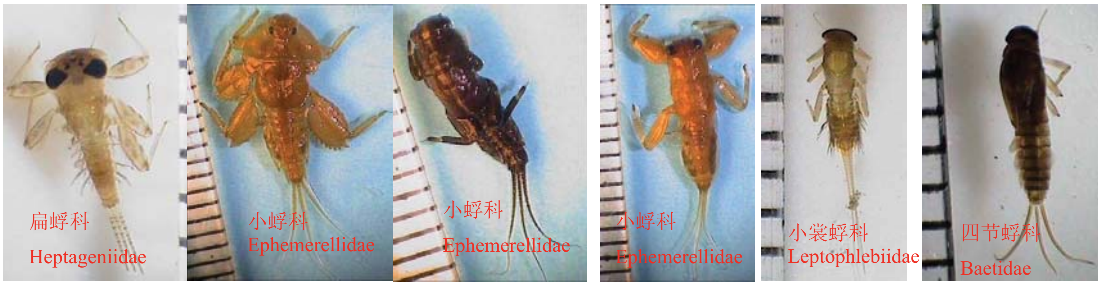
- Analyzing 300 samples from about 60 rivers concluded that
- Stability of aquatic habitat is the most important for stream ecology

The Baihe River is stable and has high biodiversity

Streams with stable bed have the best aquatic ecology

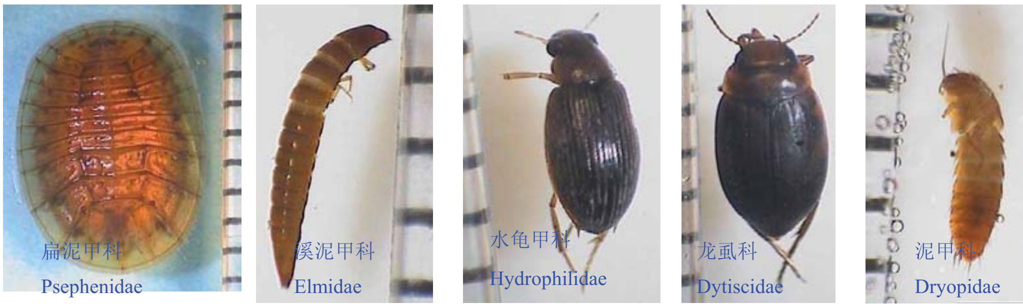
- 襀翅目 Plecoptera

- 蜉蝣目 Ephemeridae

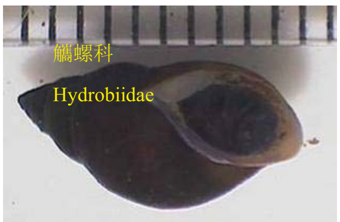


- 毛翅目 Trichoptera

- 鞘翅目 Plecoptera

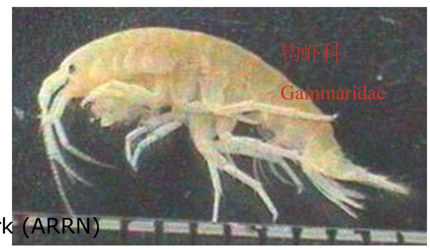


- 腹足纲 Gastropoda



- 双翅目 Diptera

- 端足目 Amphipoda

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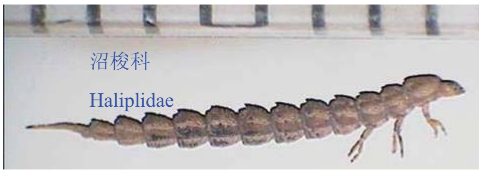
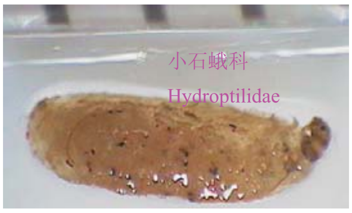
Incised streams have less species

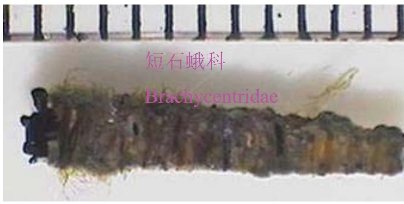
- 鞘翅目
Plecoptera



- 蜉蝣目
Ephemeridae

- 毛翅目
Trichoptera





- 双翅目
Diptera

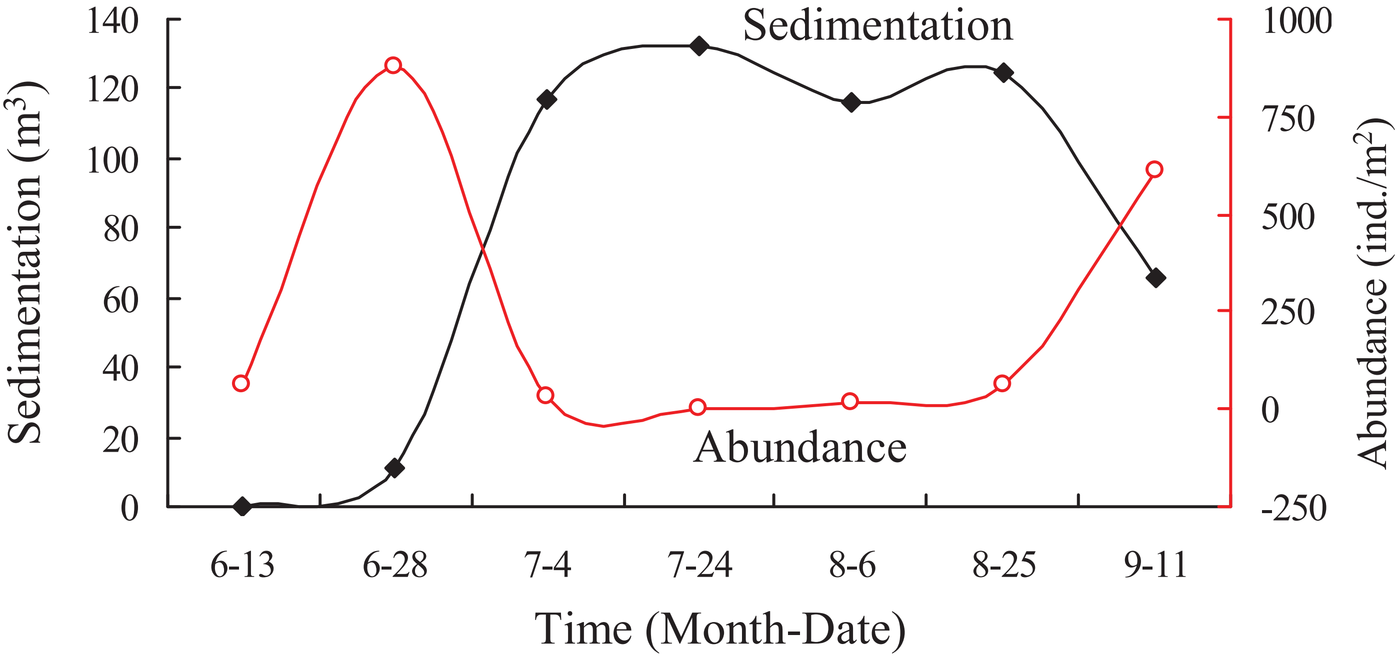
Aggradating streams have even less species

- 蜻蜓目
Odonata

- 蜉蝣目
Ephemeridae

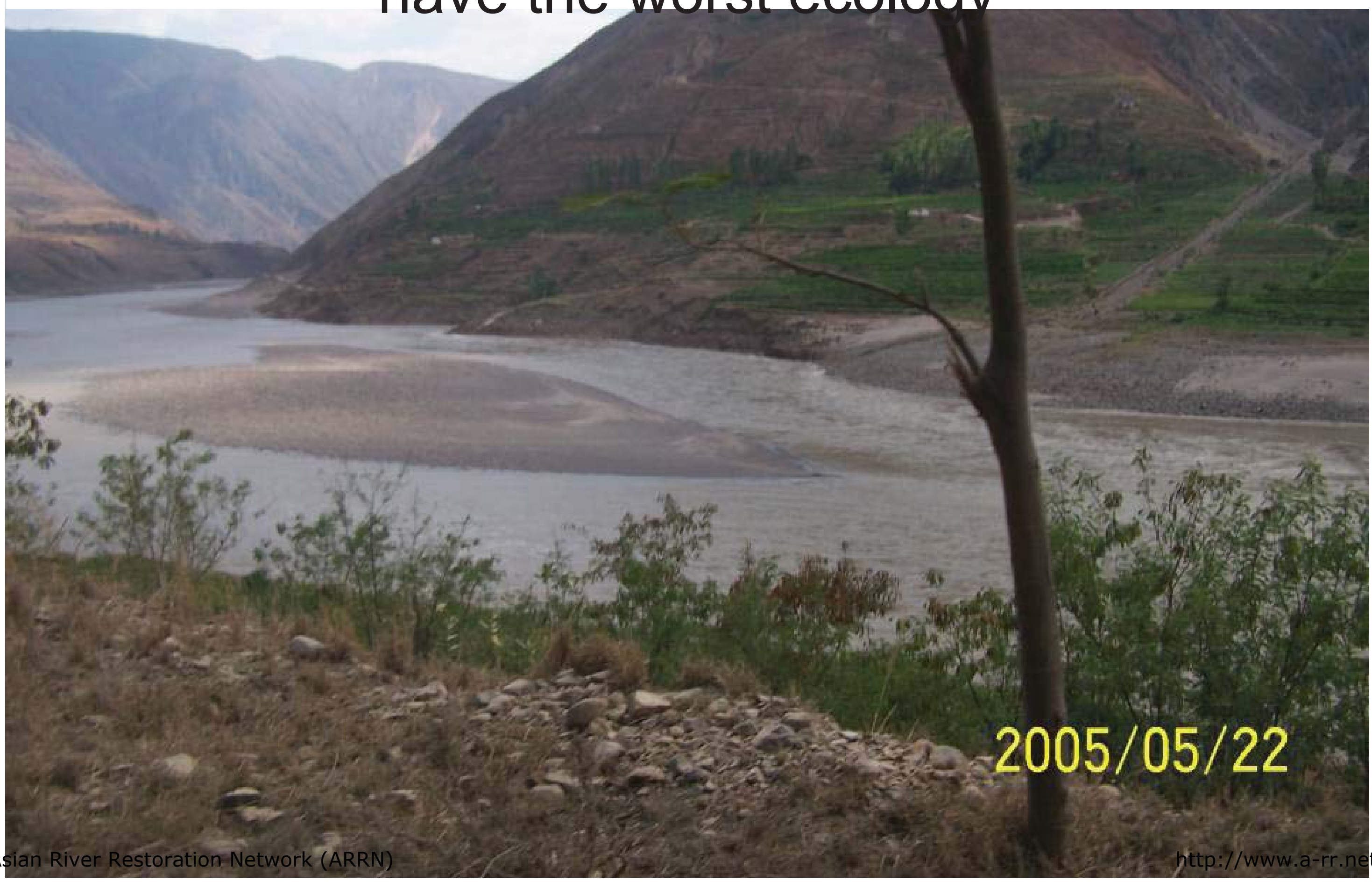
- 双翅目
Diptera

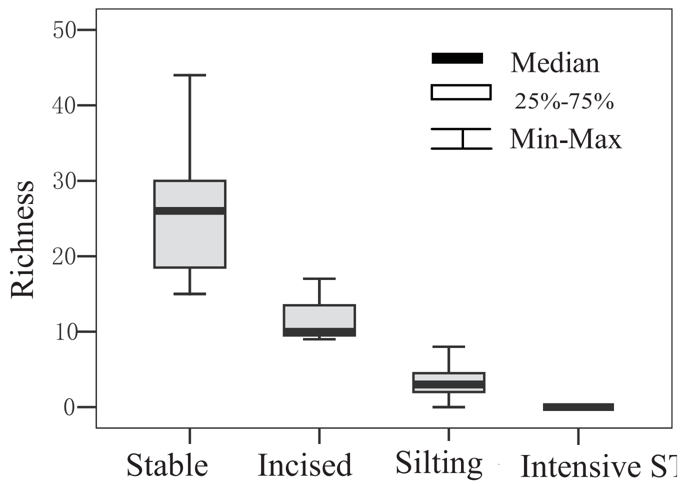
- 鞘翅目
Plecoptera

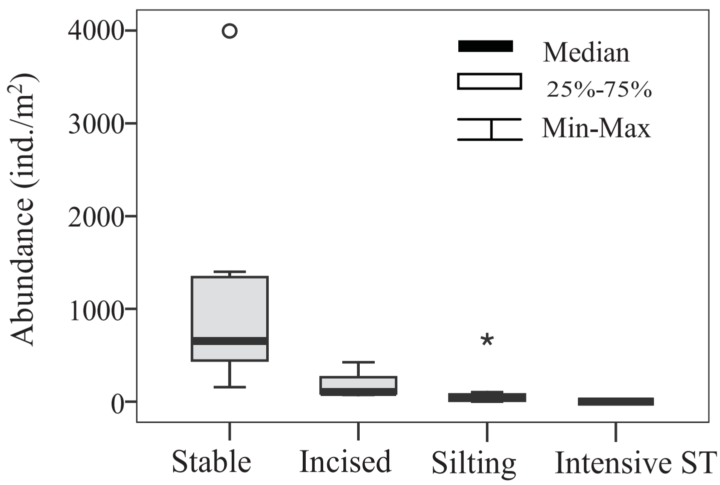


Abundance of macroinvertebrates per area as a function of sediment deposition volume

Streams with intensive sediment transportation have the worst ecology







(a) Relation of species richness of macro-invertebrates and status of the fluvial process of rivers; and (b) Relation of abundance of macroinvertebrates per area with status of the fluvial proces

Habitat Diversity

Habitat has a carrying capacity to support wildlife populations, which depends on the habitat diversity.Habitat diversity, H_D, is given by

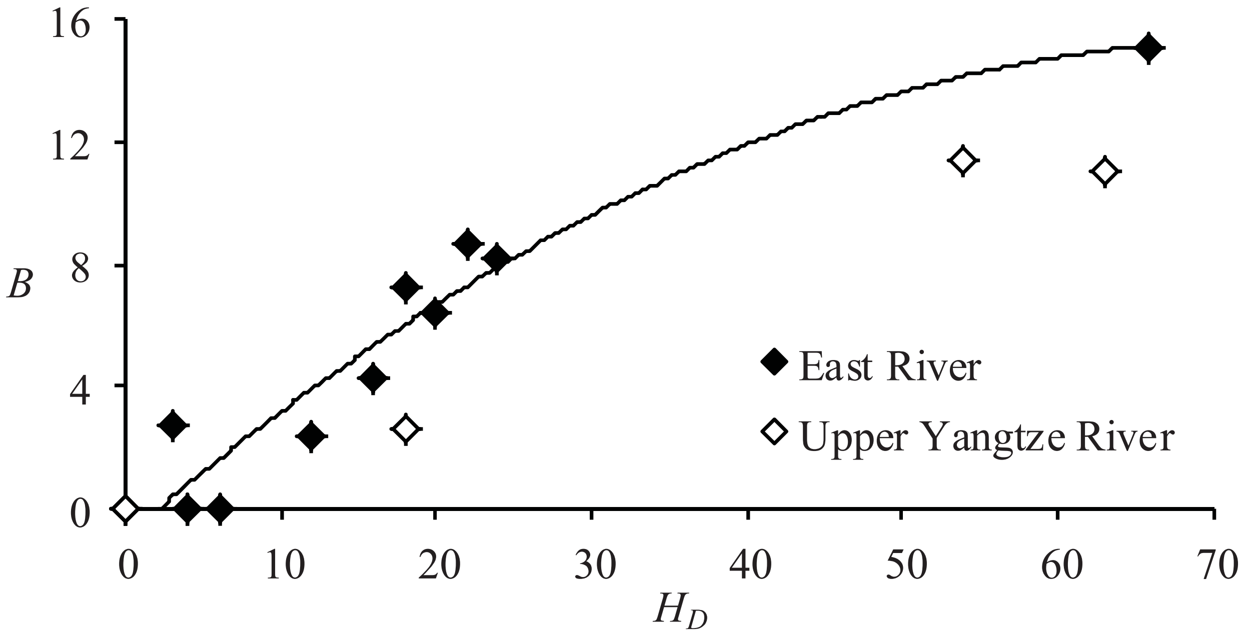
$$H_D = N_h N_v \sum_i \alpha_i$$

Nh water depth diversity; Nv velocity diversity and Sigma alpha is the substrate diversity

Values of velocity, depth and substrate diversity

α

Velocity diversity	High+mid+low velocities	High+mid Velocities	High+low velocities	Mid+low velocities	High velocity	Mid velocity	Low velocity
N_v	3	2	2	2	1	1	1
Depth diversity	Deep+mid+ Shallow waters	Deep+mid waters	Deep+shallow waters	Mid+shallow waters	Deep water	Mid-water	Shallow water
N_h	3	2	2	2	1	1	1
Substrate	Cobbles (D＞200 mm)	Aquatic grass	Gravel (2-200 mm)	Fluid mud (D<0.02mm)	Silt (0.02 ~0.2 mm)	Sand(0.2~2 mm)	Unstable bed
α	6	5	4	3	2	1	0

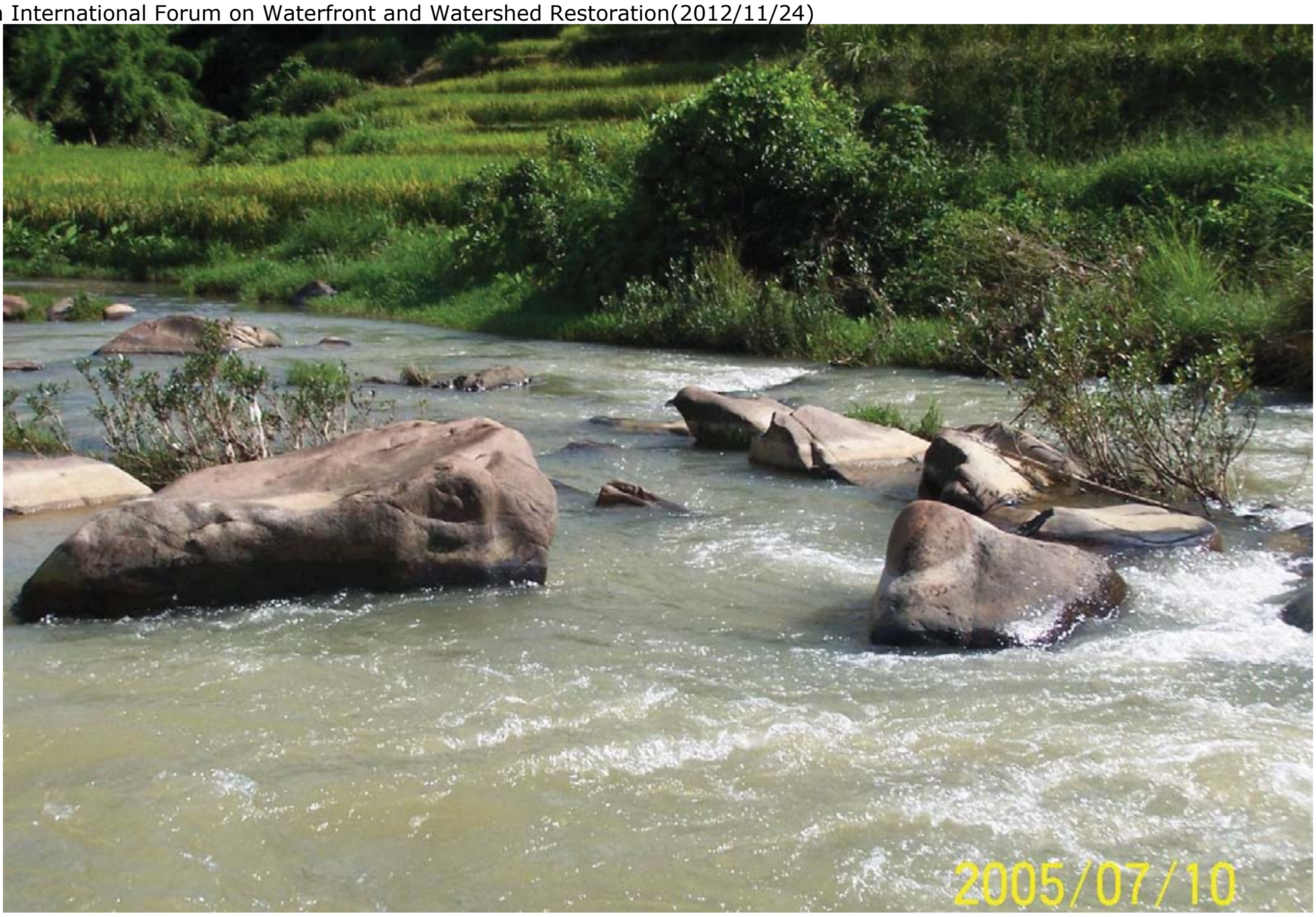


Relation between habitat diversity, *HD*, and bio-community index, *B* for the East and Yangtze rivers

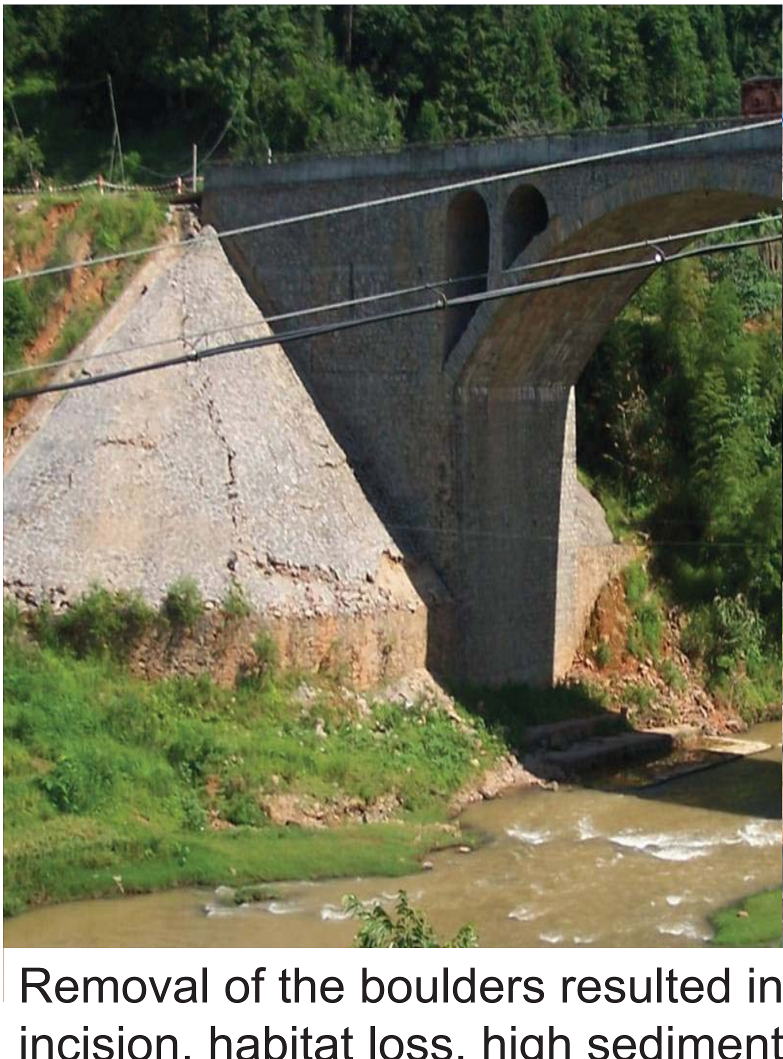
3.3 Ecological restoration

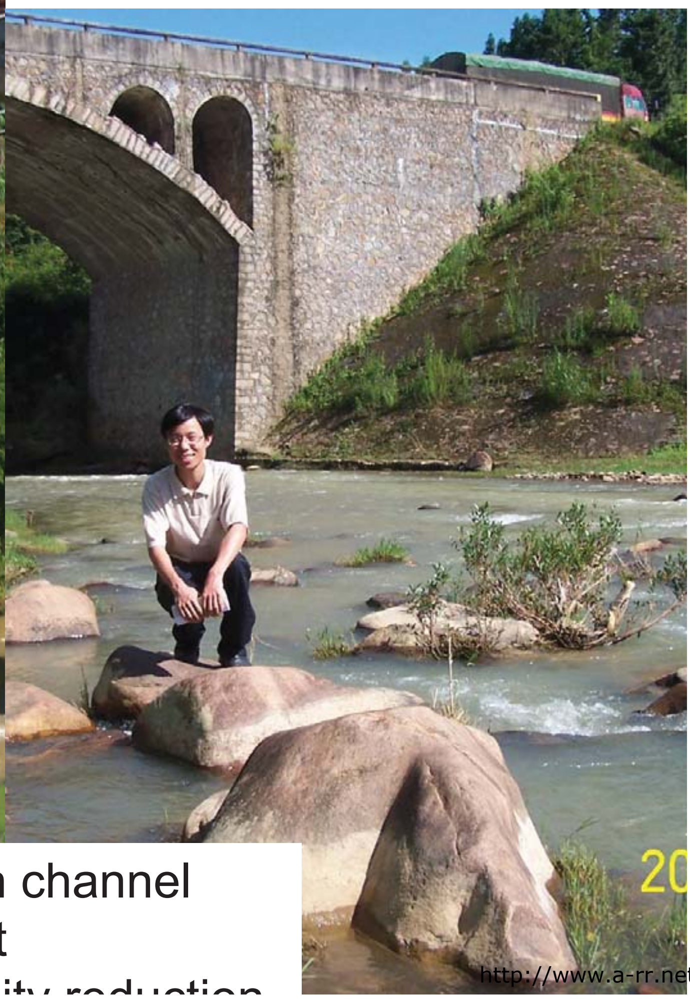
Stabilized banks with stones provide stable habitats for flora and faunal communities

Stabilization of landslide dams created high habitat diversity and increased the biodiversity



Large boulders in stream create high resistance and high habitat stability, which make the stream high bio-diversity





Removal of the boulders resulted in channel incision, habitat loss, high sediment concentration and 40% of biodiversity reduction

Replacing the substrate with cobbles and gravel increased biodiversity

Field experiments by replacing the substrate with gravel and stones

Artificial Covers and fish attractors

- Reforested banks provide covers and multiple habitats for different fish species.
- Artificial cover device made of wood plates and bundles of logs have been used for creation of multiple habitats.
- Fish attractors made from the branches of trees were reported to be more successful in attracting fish.
- Artificial fish reefs (sunk ships) in the Yellow sea and Bohai sea have increased fish harvest.

Reforested banks provide covers and multiple habitats for different fish species.

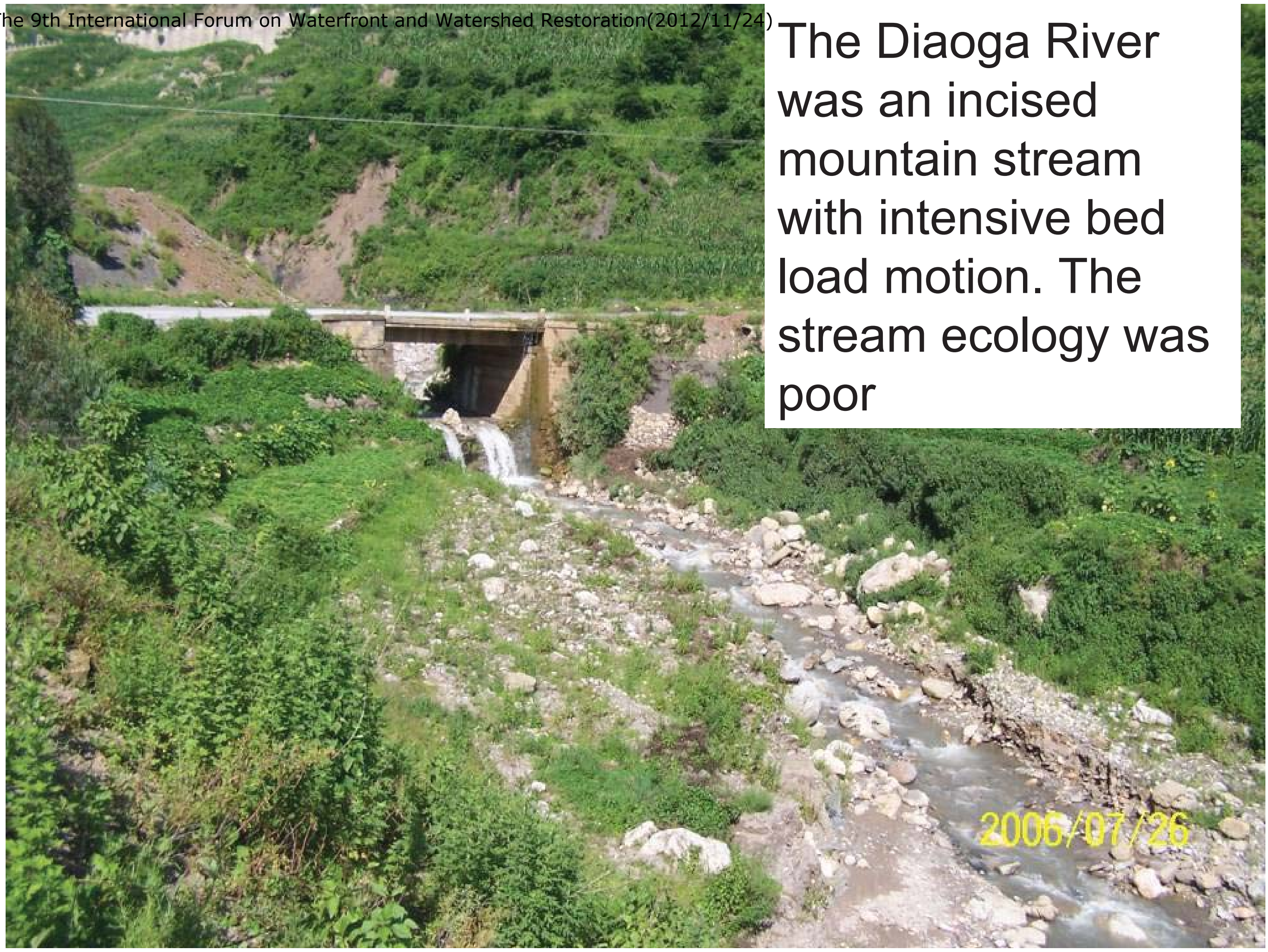
Artificial cover device made of wood plates and bundles of logs have been used for creation of multiple habitats

Riparian trees and wood logs provide shade and shelter for aquatic wildlife and attract many fish

- Artificial fish reefs (sunk ships) in the Yellow sea and Bohai sea have increased fish harvest.

Artificial step-pools for stabilization of habitat and ecological improvement

- The Diaoga River in south China was an incised stream with occasionally debris flows. The ecology was poor.
- Artificial step-pools, mimicking natural step-pools, were used for incision control, debris flow control, and stabilization of habitat.
- The stream bed was stabilized and the taxa richness and abundance of benthic invertebrates were greatly enhanced after the step-pools.



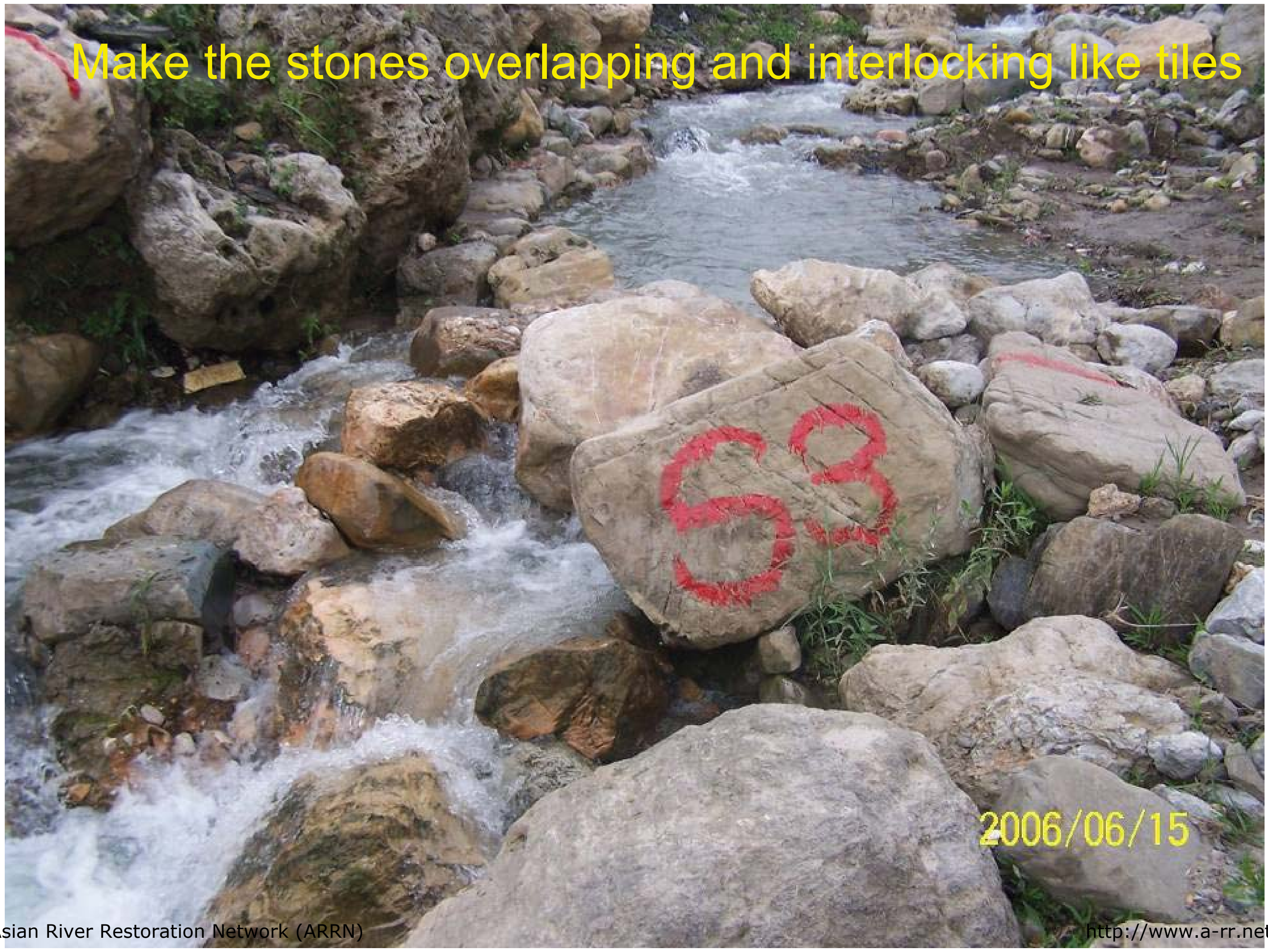
The Diaoga River was an incised mountain stream with intensive bed load motion. The stream ecology was poor

Intensive bed load motion limited the benthic communities

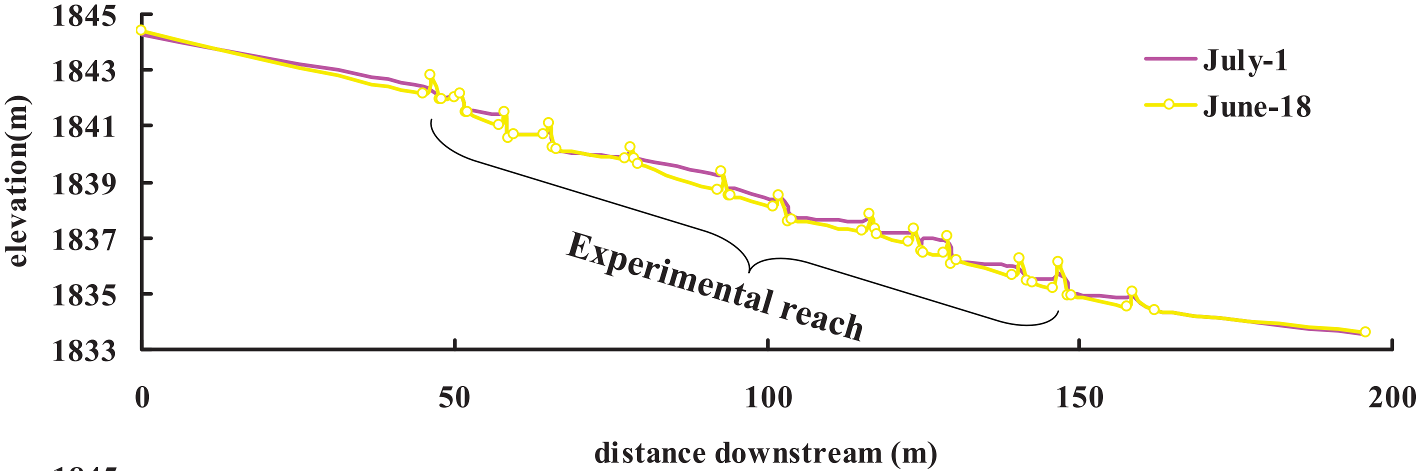

2006/10/25
Debris flows occurred occasionally

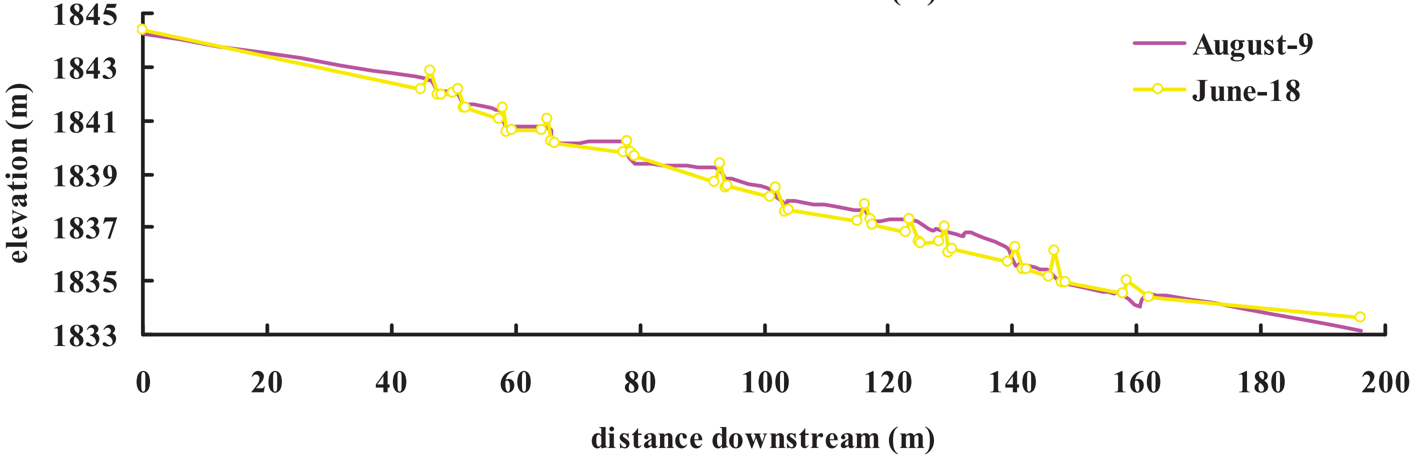

Macro-benthic invertebrate sampling in the Diaoga Ravine
2006/06/13


S8
S4
2006/06/15

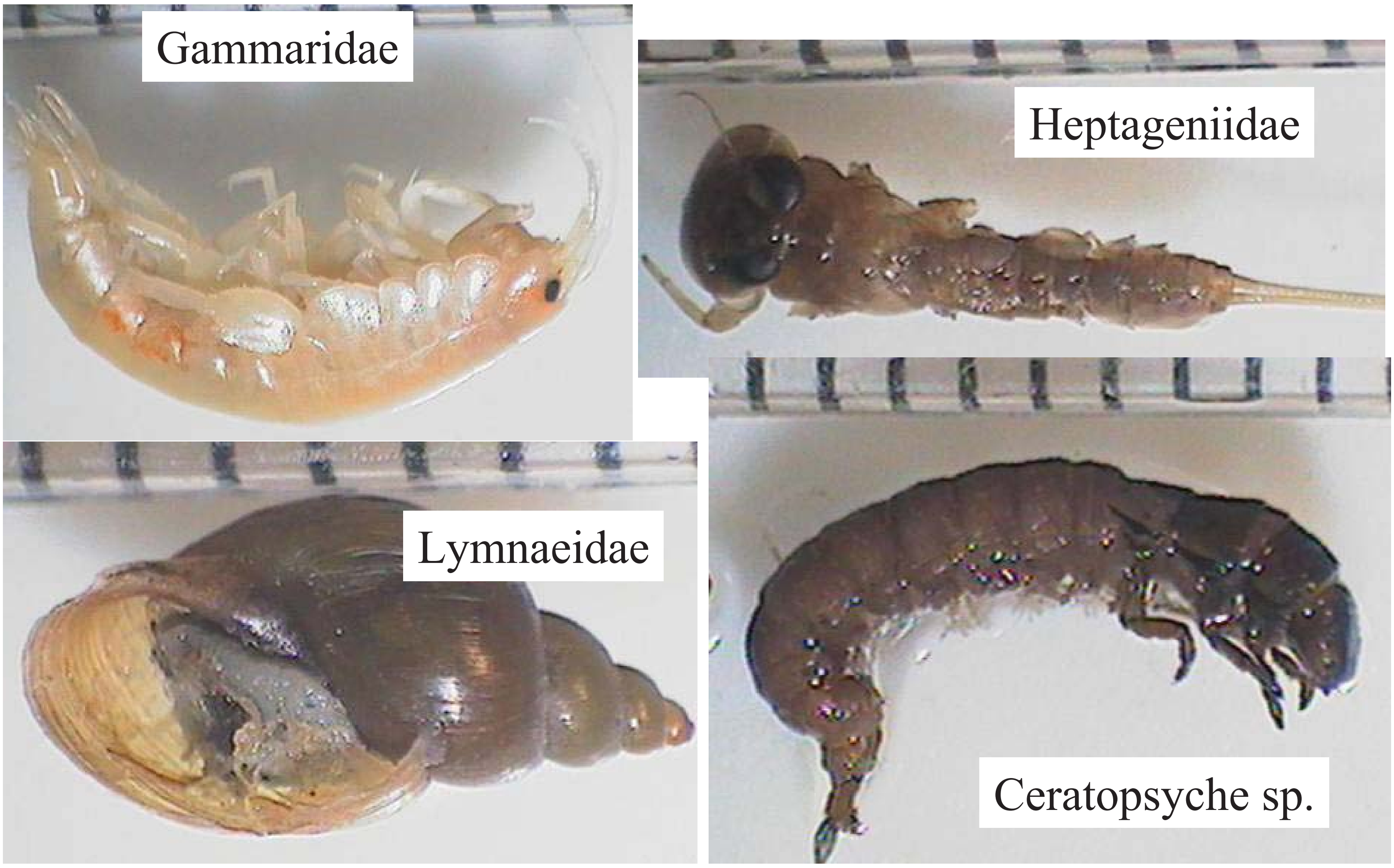

Make the stones overlapping and interlocking like tiles
S3
2006/06/15

Variation of longitudinal profile of experimental reach



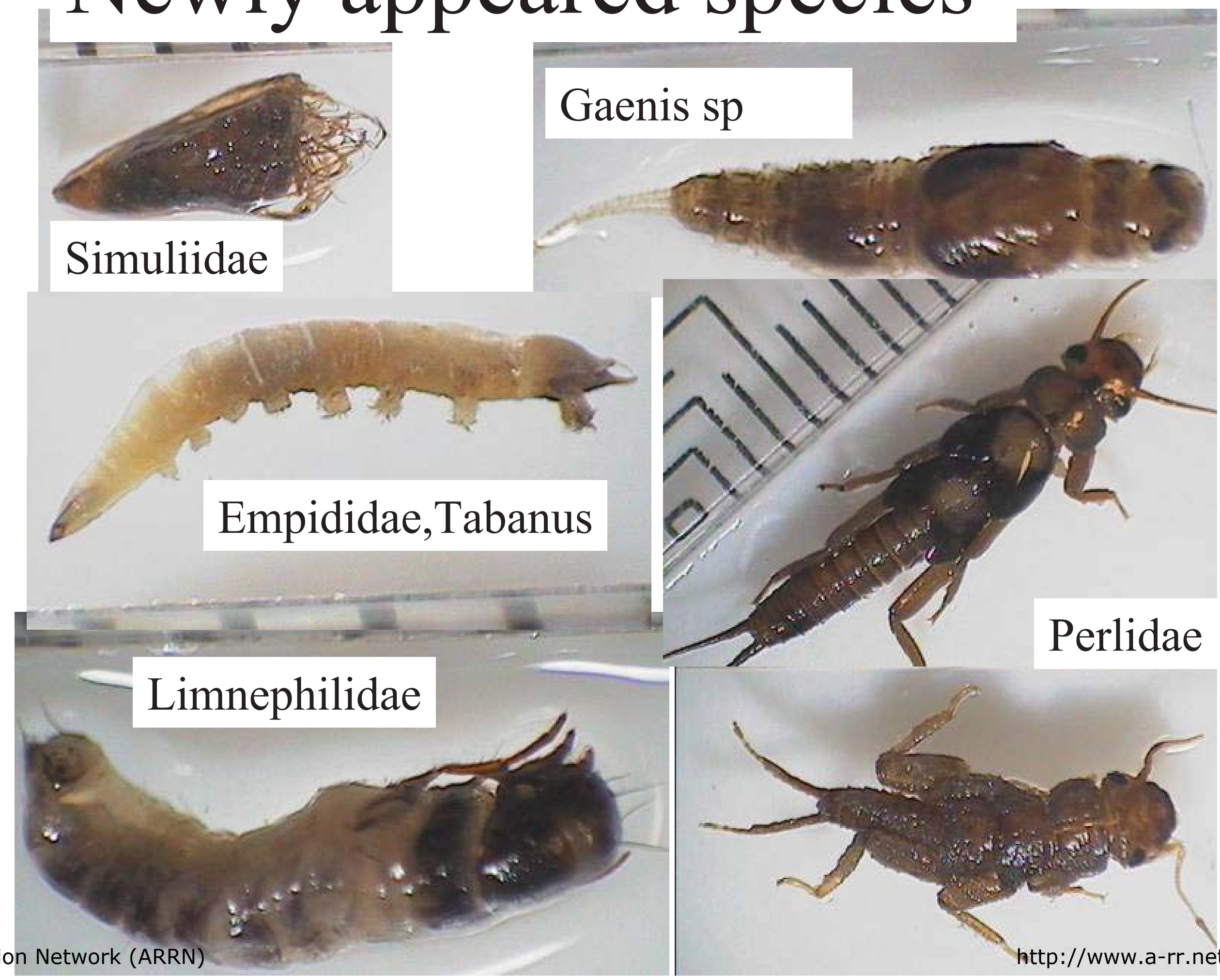


Main species before the artificial step-pools



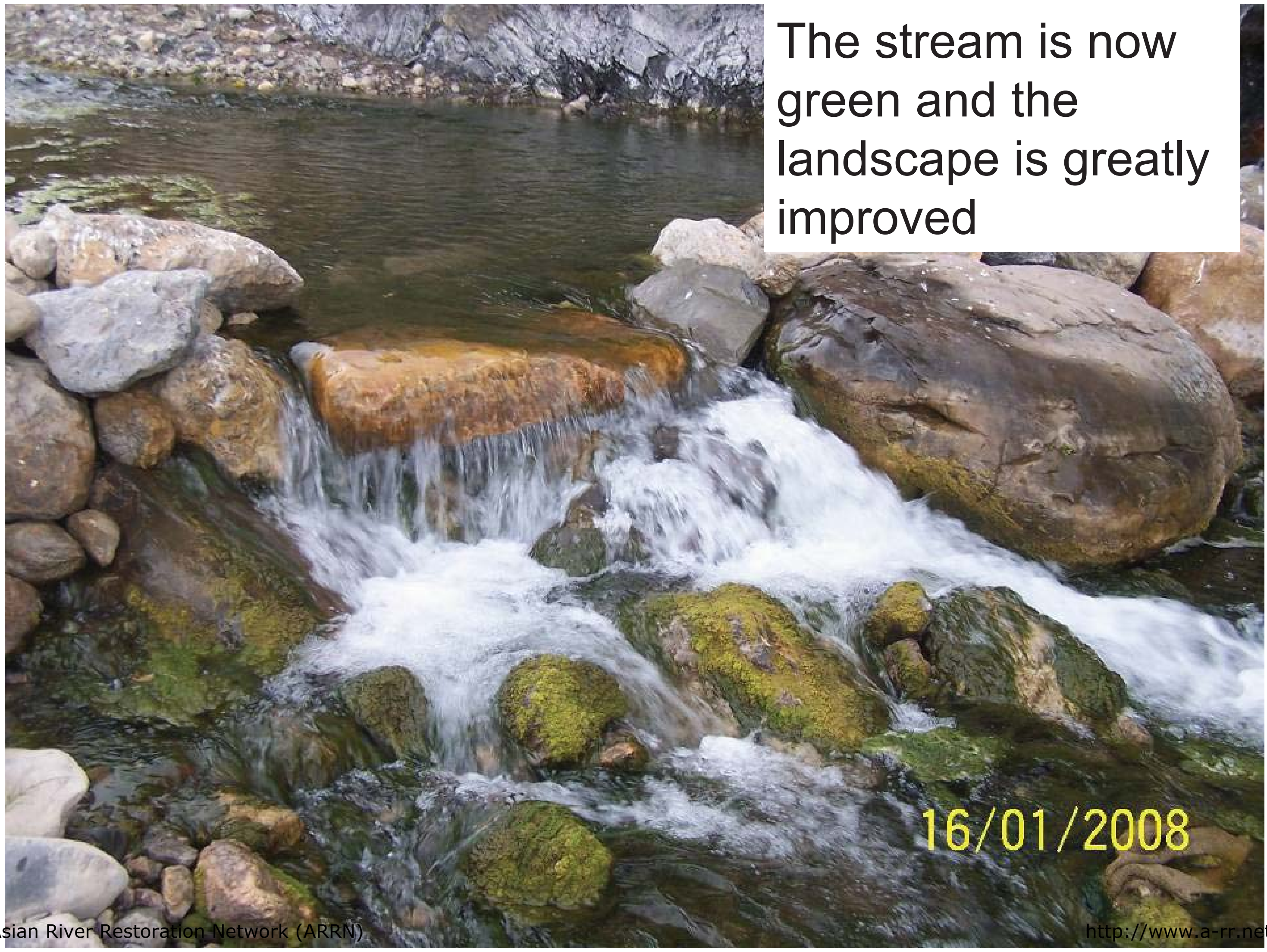
Newly appeared species

With Step-Pools



variation of taxa richness and diversity before and after artificial step-pool system

	Sampling date	Taxa richness	Number density (ind/m^2)	Dominant species (number density of the individual invertebrate per m^2)
Natural channel	13-Jun	17	61.5	Hydropsychidae (17); Baetidae (9); Haliplidae, Haliplus sp (7)
With artificial step-pools	28-Jun	39	881.5	Baetidae (492); Simuliidae (150); Tipulidae, Antocha (65)
	11-Sep	28	612.8	Baetidae, Baetis (330); Baetidae, Baetiella sp. (70); Chironomidae sp1 (57); Chironomidae sp2 (48)



4. Conclusions

- Stream eco-system is closely related to the water flow and sediment transportation, because the main ecological conditions for almost all species in the stream are dependent on the flow discharge and sediment transportation.
- The habitat suitability index was obviously reduced after the impoundment of the Three Gorges Dam. Optimization of the operation scheme of the dam may mitigate the impact.
- Dense attachment of golden mussels in water transfer tunnels and pipelines results in bio-fouling. Bamboo and a textile were used and attracted most of the larvae to attach before the water flows into the tunnel. Moreover, the residual larvae were killed by high intensity and high frequency turbulence.

Conclusions

- Biodiversity is proportional to habitat diversity. The taxa richness and abundance are high in stable streams, lower in incised and silting streams, but the lowest in streams with intensive sediment transportation.
- The benthic macro-invertebrates live in a bed layer of a thickness of 5-60 cm depending on the composition of the bed materials. Different species prefer different bed depth.
- Impaired stream ecology can be restored by increasing the habitat connectivity, stabilizing the stream bed and banks, creating cover and fish attractors, managing substrate, and constructing step-pools for creation of multiple and stable habitats.

Thank you

Questions are welcome