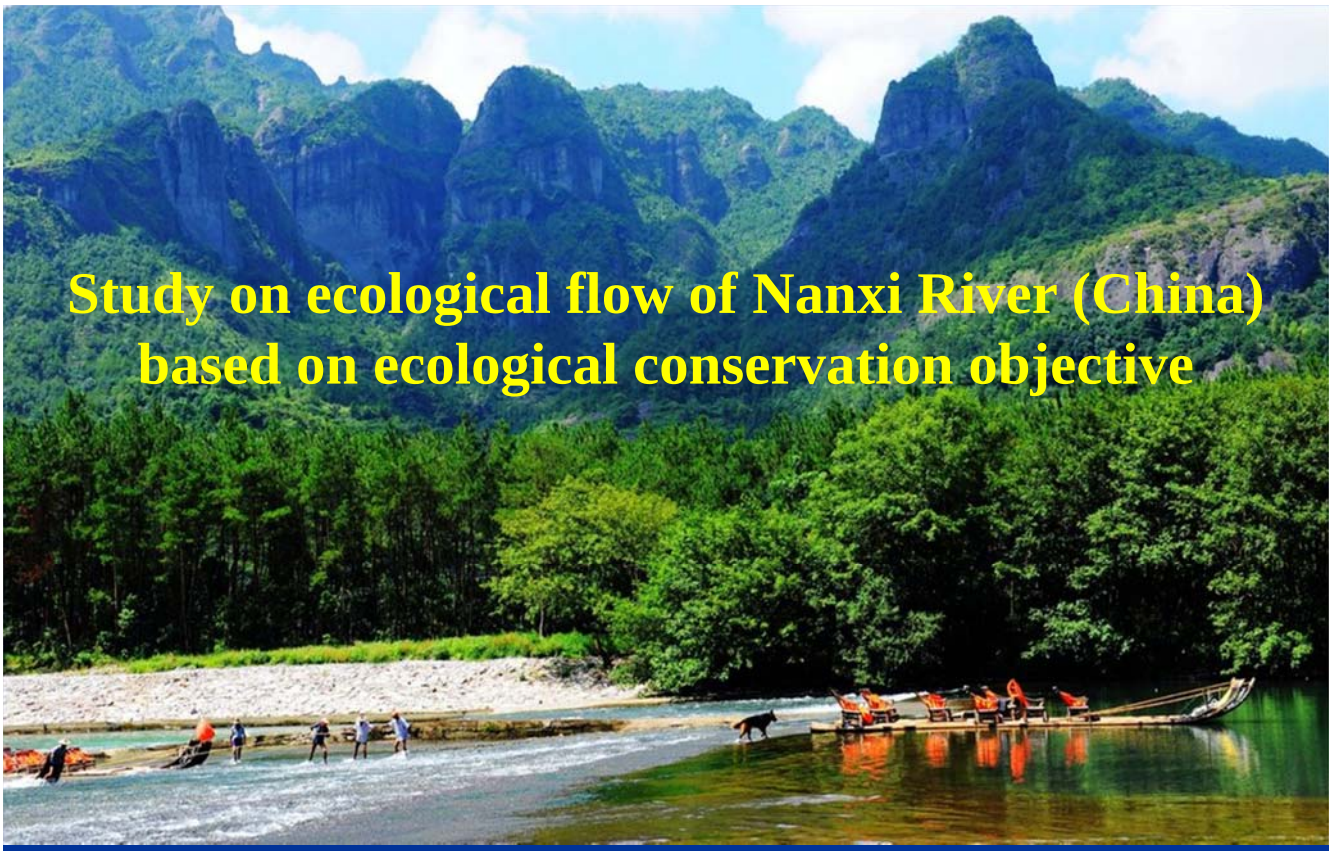

Study on ecological flow of Nanxi River (China) based on ecological conservation objective

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October 29, 2014

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1. Introduction

1. Introduction

➢The study area is located at the north bank of the lower reaches of Oujiang River, Southeast Zhejiang Province, Eastern China. The Nanxi river basin consist of hilly and mountainous areas, the land is high in the northwest and descends to the southeast.

➢The valleys are shaped like tree branches, forming many waterfalls, pools and rapids; the basin area is 2436 km^2 and the length of mainstream is 142 km.

➢Many famous landscapes are located in the upper and middle reaches of Nanxi River, characterized by “beautiful river, peculiar rocks, many waterfalls, thick forests and ancient villages”.

➢There are as many as 475 landscapes, including 274 cultural landscapes and 201 natural landscapes.

Alternant distribution of deep pools and shoals

Integration of natural and cultural landscapes

2 Aquatic ecosystem protection objective

➢The basin offers suitable habitats for fishes, shrimps, shellfishes, crabs and so on, because of the warm weather, four distinct seasons, moist air, various landforms and good water quality.

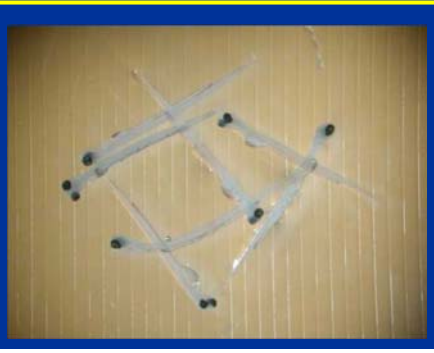
➢There are 60 species of fishes, 10 species of crustaceans and 8 species of shellfishes and several migration fishes such as ayu, eel, anguilla marmorata, river crab and weever.

- ✓ The juvenile eel migrate from the sea to freshwater for growth in spring; adult eel migrate to the sea in fall (from August to September).
- ✓ The anguilla marmorata lives in the river cave from March to July, and migrates to the sea to reproduce from October to November.
- ✓ The river crab migrates to the river mouth to spawn in fall; from March to May (next year), the juvenile river crab hatches and migrates upstream along the river and grows up in the freshwater.
- ✓ The weever is one of the most important species of mariculture.
- ✓ The ayu has been listed in the “Redbook of endangered animals in China”. The habitat conditions of ayu varies during lifespan, and its requirement for environmental conditions is obviously higher than the other fishes.

The ayu is selected as the objective of aquatic ecosystem protection.




- The ayu feeds on algae, crustaceans, insects, sponges, and worms; belongs to the catadromous migration fish.
- The adults ascend from coastal waters into the lower reaches of rivers to spawn in the spring.
- The larvae descend to the sea immediately on hatching and winter there before returning to fresh water again in the spring. Most but not all individuals die after their first spawning. In reference to its typical one-year lifespan, it is also written as ”year-fish“.
- Ayu is an edible fish, mostly consumed in East Asia
- There is no specified threshold value for **hydraulic conditions** such as water depth and velocity of spawning sites. In general, the velocity is considered as less than 1.0 m/s, the water depth is around 10 cm in the shallow area or more than 1.0 m in the deep area.


Life cycle of ayu in study area

Spatial and temporal distribution for spawning, overwintering and fattening of ayu in Nanxi River

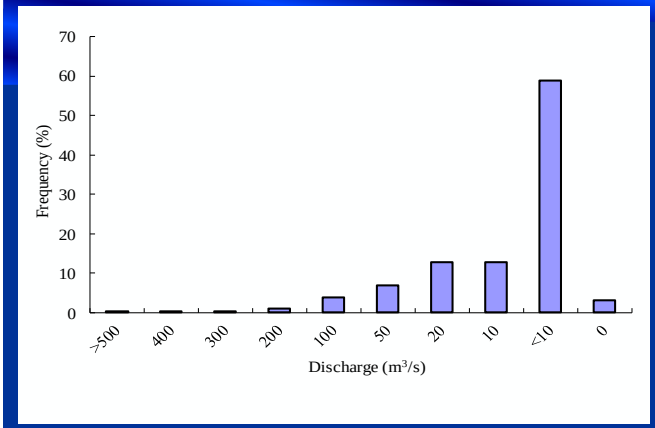
The Nanxi River Ayu has been renowned since the Qing Dynasty.
The ayu is endangered in the late 1990s.
The protection of propagation and releasing has been tried since 2001.
The protection and management has been strengthened since 2007.

Time	Life stage	Length (cm)	Feeding habit	Velocity (m/s)	Water depth (m)	Habitat river reach
Mar-May	Migration period (Junevile)	2 - 3	Cladocera and copepod	<1	0.1 - 1	River mouth - Xikou station
Jun-Apr	Fattening period (Grown-up)	20	Benthic algas		0.6 - 1.2	Gumiaokou station - Xikou station
Sep-Oct	Spawning period (Spaw)	20 - 30	Omnivore		0.6 - 1.2	Shuangxikou station – Xiangshan station
Nov-Dec	Catadeomous migration period (Prelarva)	-	Cladocera and copepod		-	Spawning site – River mouth
Jan-Feb	Grown-up period (Junevile)	2 - 3	Cladocera and copepod		-	Sea

Habitat environment requirement of ayu in its various life stages

3 Hydrologic regime of Nanxi River during migration periods

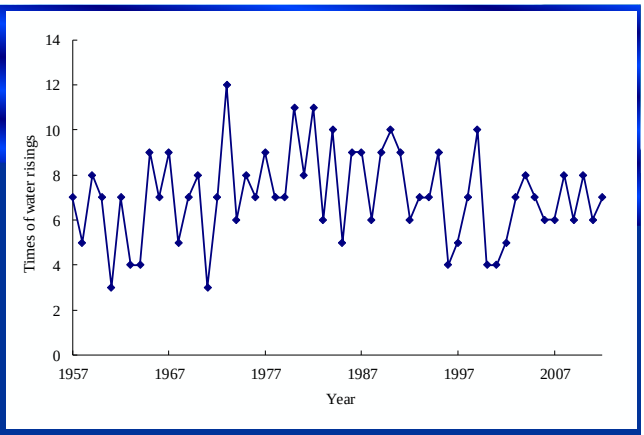
➢Migration period (March - May)



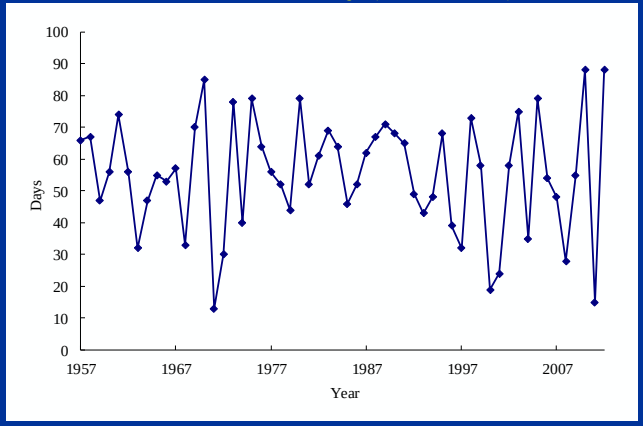
Frequency fluctuation of flow discharges at the Shizhu station from March to May

➢The annual average discharge is higher than 30 m^3/s during migration period, with frequent fluctuations. There are about 60% days of period with discharge value lower than 10 m^3/s.

➢The rise of water level occur at least 3 times during migration period. There are more than 13 days with discharges exceed 20 m^3/s.

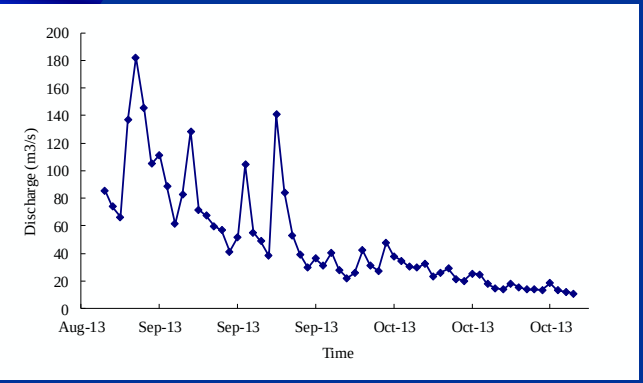


The numbers of rise of water level at shizhu station from March to May (1957-2012)

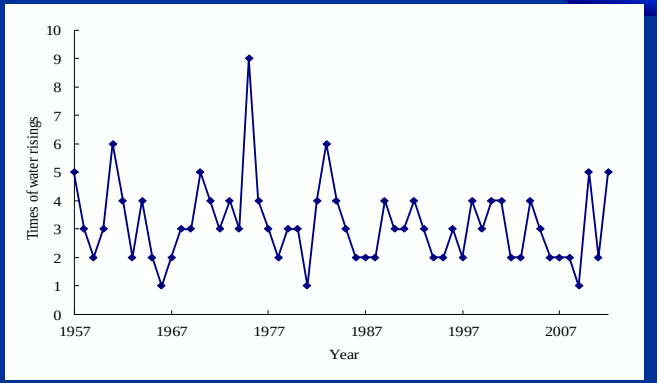


Number of days when flow discharges exceed 20 m^3/s at the Shizhu station (1957-2012)

➢Spawning period (September - October)



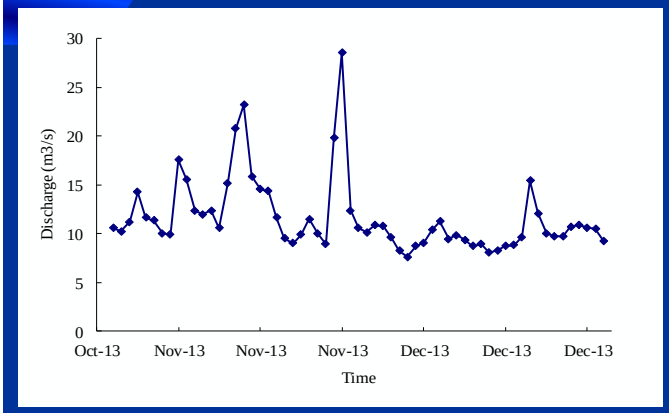
Daily average flow hydrograph of Shizhu station from September to October



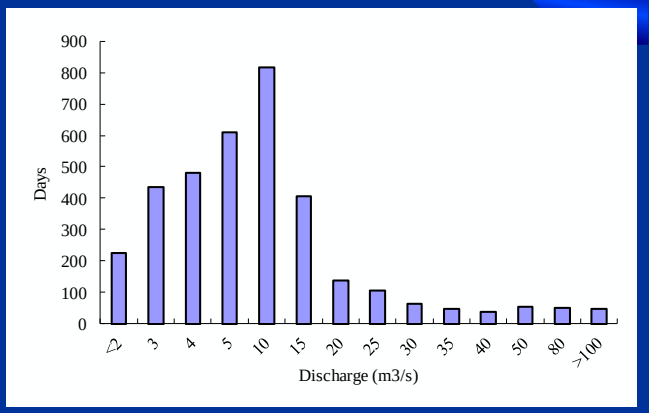
Number of rise of water level at Shizhu station from September to October

➢There are 2-4 times water level risings (at least 1 time) during the spawning period in most years, usually occurred in September. And there is no water raising occurred in Oct during last 23 years based on 56 years` hydrologic data.

➢Catadromous migration period (November - December)



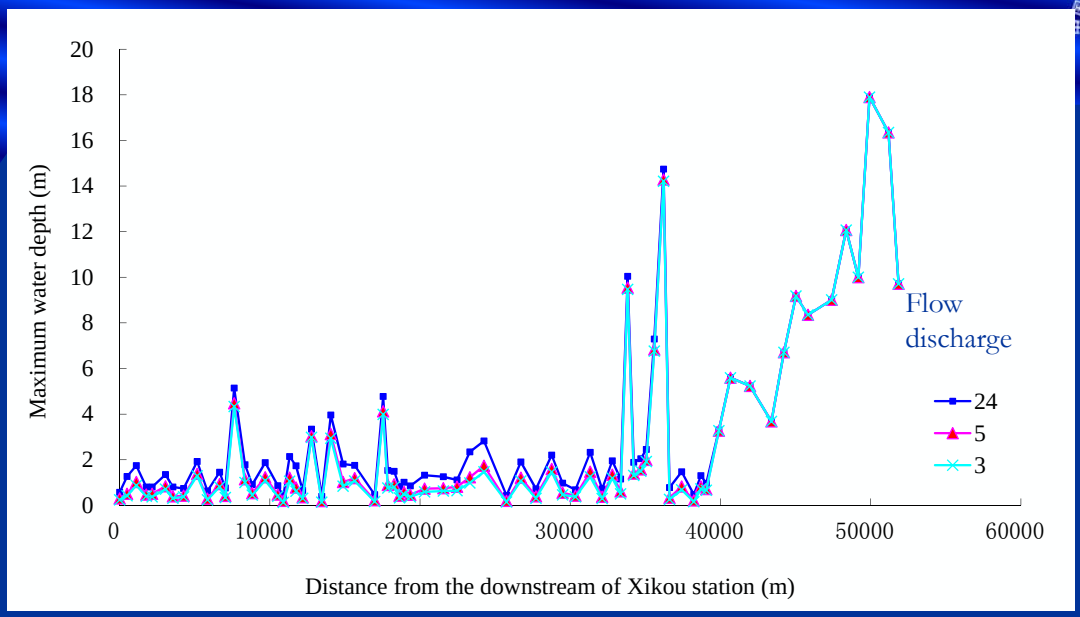
Daily average flow values at Shizhu station from November to December



The Numbers of days of various average flows occurred at Shizhu station from November to December

➢There are several raising of water level occur during the juvenile ayu migrations. There are 70% of days with discharge lower than 10 m^3/s during Catadromous period ; and there are 50% of days with discharge lower than 5 m^3/s. The water level rising occur 2-3 times with discharge exceed 10 m^3/s in the migration period.

4 Ecological habitat requirement of ayu



The maximum water depth of the Nanxi River

➢The reaches of Nanxi River are characterized by alternant distribution of water pools and shoals. The distance between a deep pool and a shoal is generally 1-2 m. This kinds of river morphology provide shelters for fishes, even low-flow period from June to September.

➢Using 1-D model to compute the ecological habitat parameters along the Nanxi River on the basis of various flows of Xikou station.

Ecological habitat parameters of Nanxi River

Flows of Xikou station (m^3/s)	3	5	7	11	18
Maximum water depth at the shallowest location (m)	0.13	0.18	0.21	0.26	0.33
Cross section percentage (>0.2 cm)	93%	96%	100	100	100
Average water depth of 95% river reaches (m)	0.11	0.14	0.17	0.20	0.24
Average velocity of 95% river reaches (m/s)	0.02	0.03	0.04	0.06	0.08
Average width of 95% river reaches (m)	11.9	14.6	16.5	20.2	22.7
Average area of 95% cross sections (m^2)	2.3	3.5	4.5	6.4	9.4
River reach percentage of rapids area (%)	30	33	36	38	44
Number of deep pools	1	1	1	1	2

➢According to records, the ayu is 4.5 - 6.8 cm long (average length is 4.7 cm) when release around the upper and lower reaches around Shizhu station; in early May, the ayu is 7 cm long; in early June, the ayu is 23 cm long; the ayu is 4 - 20 cm long during anadromous period from March to May; the ayu is 20 - 30 cm long during catadromous period from September to October.

Analysis from perspective of unblocked ayu migration routes

➢The ayu is 4 - 20 cm long during anadromous period from March to May, and 20 - 30 cm long during the catadromous period from September to October.

➢When the discharge is 5-7 m^3/s from March to May, the deepest shallowest water depth along the river reaches is 2 times of the ayu`s length.

➢The ayu grow up from September to October, and when the discharge is exceed 18 m^3/s the deepest shallowest water depth along the river reaches is 1- 2 times of the ayu length.

➢The juvenile migrate to the lower reaches and the coastal area from November to December. The water risings occur 1-2 times during the catadromous period, with discharge of 10 - 20 m^3/s.

5 Ecological flows of river reaches for ecology protection

Comparison of ecological flows of Nanxi River using Tennant, Time Series (90%) and Wetted Perimeter methods (m^3/s)

Month	Cross section of Xikou			Cross section of Shizhu		
	Tennant Method (30%)	Time Series Method (90%)	Wetted Perimeter Method	Tennant Method (30%)	Time Series Method (90%)	Wetted Perimeter Method
1	6.1	1.06	7	13.8	2.22	13
2	6.1	2.29		13.8	4.76	
3	6.1	6.29		13.8	11.83	
4	10.2	5.92		22.9	13.4	
5	10.2	5.95		22.9	13.62	
6	10.2	15.59		22.9	26.56	
7	10.2	7.35		22.9	14.21	
8	10.2	5.49		22.9	11.93	
9	10.2	6.33		22.9	16.04	
10	6.1	2.69		13.8	5.58	
11	6.1	1.26		13.8	3.07	
12	6.1	0.87		13.8	2.09	

Ecological flow of ayu

Ecological flows of control stations of Nanxi River for ecology protection (m^3/s)

Cross section	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Xikou	3.5	4.0	5.9	7.2	7.5	13.6	9.4	8.4	8.2	6.4	5.6	5.5
Shizhu	4.7	6.5	11.5	14.6	15.1	24.6	16.3	14.8	17.9	9.3	7.5	6.7


Thank you
for your attention!