Fish of the Upper Mekong:

Biodiversity, Resources and Conservation

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The Sustainable Mekong Research Network

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SUMMARY

This report is focused on conservation and development of fish stocks and the commercial infrastructure surrounding them in the Mekong River basin area.
At this time the group focused on this task, the Mekong River Commission (MRC), has provided data that indicates that fish stocks are already suffering a decline in the area due to several factors. Although this information is not conclusive due to the limited availability of data on the status of fish stocks and habitats in the upper area of the Mekong River Basin in China, there are still indications that fish stocks are already being damaged and will continue to be unless changes are made.

The major factors damaging the fish in this area are:

Depletion of fish stocks

- Due to improvements in the methods and technologies of catching and farming fish, more fish are being caught.

- General increase in demand of fish due to a recent influx of people to this area.

- Increase in river traffic affecting the behaviour of fish as well as damaging the population due to direct contact or indirectly by affecting their behaviour and environment.

All of these factors contribute greatly to over-fishing as more and more people are fishing in this area and those migrants who are not involved in aquaculture are still serving to increase fish market demand.

Changes to the environment that affect the ecosystem and migratory routes

- Introduction of exotic species that can have negative effects on the eco balance of the area.

- Damming that has large impacts on the surrounding area, destroying spawning sites, blocking the river to upstream migration and filtering the water so less debris continues downstream. It also slows the flow speed that smaller fish and fingerlings are reliant on.

- Industrial and agricultural changes to the area that cause pollution, cause sedimentation and deforestation of areas surrounding the rivers.

These changes bring into question the sustainability of the ecosystems from which the fish stocks of the Mekong are derived.

The proposed methods of conservation involve encouraging development to help in the conservation of fish and the habitats they rely on. They also involve the education of local people affected by these methods and encouraging their active participation in conservation.

- Establishing protected areas in sites of great ecological importance.

- Programs aimed at re-stocking depleted fish stocks in lakes, banning fishing of key areas during spawning seasons and combining aquaculture and fisheries.

- Increase awareness and knowledge of the effects of developing river areas in a non-ecologically friendly manner. And also increasing the knowledge of how to and the positive effects of farming and developing aquaculture in a sustainable and ecologically friendly manner.

These programs, already active in some areas, will provide long term sustainable fish stocks that can be fished responsibly and continue to provide for the needs of the local peoples, while at the same time not negatively affecting the biodiversity of the area or fish population and health.

1. Background

In densely populated areas, multiple users compete for water resources. Human activities upstream can degrade the habitat and amenity value of downstream sections and inevitably have negative effects on the biodiversity, especially on fish. Fortunately, the custom of Tibetan nationality respects fish as totem, which directly results in the limited disturbance of fish in the Mekong headwater where Tibetans live on both sides of the river. The harsh environmental conditions create distinctive biodiversity conditions in this area but also restrict the amount of research on the area, except a published 599 pages monograph ‘The fishes of the Qinghai-Xizang Plateau’ written by Pro. Wu Yunfei in 1991 after 30-years of working experience, and ‘Fishes in Yunnan’ by Pro. Chu Xinluo written in1990. With the economic development and resource exploitation, more immigrants move to the remote region and the gap between fish utilization and conservation of the fish stock gradually widens. The actual facts regarding biodiversity and resources in the Upper Mekong are still unconfirmed and inconclusive. The Chinese portion of the Mekong contributes about 50% of the sediment load and 20% of the discharge at the mouth of the river. As an important river, rich in biodiversity in the world, published scientific research papers on Mekong are few, based on the search results from ISI Web of Science. Effective conservation of all migratory fish in the Mekong is beyond the scope of the national legislative frameworks and will require coordinated actions among the countries within the river basin. The Mekong River Commission is an intergovernmental body with ministerial-level representation and has carried out many research programs and published reports on them. But MRC is worried that China is not included. The insufficient research on fish in the Upper Mekong and the lack of information sharing of scientific research productions make the effective management and sustainable utilization difficult. So investigations and researches on fish in the Mekong, especially in the Upper Mekong areas are inconclusive.

2. PROJECT OBJECTIVES

Goal and purpose

Fishing is the main economic support in the Mekong watershed. People through the watershed depend on the fish for food and livelihood. Many of the fish migrate long distances, even form Tonle Sap to the Upper Mekong (also named as Lancang River in China),e.g. *Pangasius*. Human activities, e.g. over-fishing, water pollution, hydroelectric projects, can adversely impact fish biodiversity and fish resources through changes to the habitat. This research will give us a better understanding of the fish in the Upper Mekong, and its contribution to the countries in the lower Mekong basin. The results will also give scientific countermeasures for conservation, reasonable utilization, effective management and sustainable development, and if possible, would be a good example of trans-boundary cooperation.

3. OUTPUTS

3.1 Description of the Study Area

The Lancang—Mekong River originates from the Tanggula Mountain on the Qinghai-Tibet Plateau. It belongs to the Pacific Water System, and is called the Lancang (the Upper Mekong) within China, and then the Mekong after it leaves China (He and Tang, 2000). From the headwaters to the estuary, the Lancang-Mekong River flows through a variety of landscapes, as well as through multiple social, economic and political areas.

A river can be divided into different parts based on topography, geology and successive hydrodynamic characteristics. The Upper Mekong is divided into: The Source, The Upper-Reach, The Middle-Reach and The Lower-Reach, which are described below. (Ding and Liu, 1993):

The Source: this 564.4km stretch of the river from the headwaters to Changdu has the steepest gradient of the watershed.

The Upper-Reach: this narrow section from Changdu to Gongguoqiao, developed along a fault line, and includes many small tributaries.

The Middle-reach: within this section from Gongguoqiao to Jinglinqiao, the river flows from The Qinghai-Tibet Plateau onto The Yunnan-Guizhou Plateau, and is characterized by deep gorges and fragmentary habitats.

The Lower-reach: from Jinglinqiao to Nanla, this 355 kilometre section of the river is wide, with a 253 meter elevation change and an average altitude of 1500~2000 meters.

The specific geographic conditions of the Upper Mekong Watershed means the region is home to specialized flora and fauna, with many of the species found only in the Yunnan Province. The fish species in this region vary greatly between the Upper to the Lower Reaches, with the transition of fishes being affected by a variety of factors including water temperature. The cold waters of the Upper Reach are home to fewer fish species than the warmer waters of the Lower Reach that contain many more species.

3.2 Output 1:
Fish Assemblage in the Upper Mekong

Activities to achieve this output

Visit institutes, museums and universities;

Visit the local government;

Visit the markets;

Visit local fishermen;

Collected the information from all the ways mentioned above (including species photos, papers, official materials, scientists and local fisherman's knowledge);

Sampling fish specimen;

Sampling and visit routes;

1. Kunming—Xining—Yushu—Xining—Kunming;
2. Kunming—Dali—Lanping—Weixi—Manwan—Dachaoshan—Lincang—Yunxian—Puer—Jinhong—Menglun—Mengla—Kunming

Materials available;

Cheng, 1958; Zhang, 1962; Chu, 1987; Chu and Zhou, 1989; Chu and Chen, 1989, 1990; Wu and Wu, 1991; Chen and He, 1992; Chen et al., 1994; He and Chen, 1994; Zhu, 1989, 1995; Zhou and Cui, 1996; Chen, 1998; Chu et al., 1998, Li et al., 1998; Yue and Chen, 1998; Chen, 1999; Yue, 2000; The College of Life Sciences and Chemistry of Yunnan University, Manwan Hydropower Station of Yunnan Province, 2000; MRC, 2003; Chen et al., 2003; Kong et al., 2007.

Nelson, 2006.

Yunnan Statistics Bureau, 1989-2005.

Methodology applied to achieve this output

Representative spots along the Upper Mekong are selected for fish investigation and collection. Several fishing methods (hook, gill net, drift net, trap, etc.) and market trade are conducted seasonally. All samplings are preserved in 95%

ethanol or 10% formalin immediately just after recording the basic biological characters (including body colour, length, and weight, etc.).

Fish are later sorted in the lab and then identified. Samples are anatomized and the stomachs are extracted to deduce the feeding habitats.

Achievements

The fish of the Upper Mekong include 6 orders, 21 families, 86 genera and 162 species. Cypriniformes was the dominant fish order, comprising 72.22% of the total species number, followed by Siluriformes at 16.67%, Cyprinnodontiformes at 1.85%, Synbranchiformes 0.62%, Perciformes 8.02% and Tetraodontiformes 0.62% (Fig. 1).

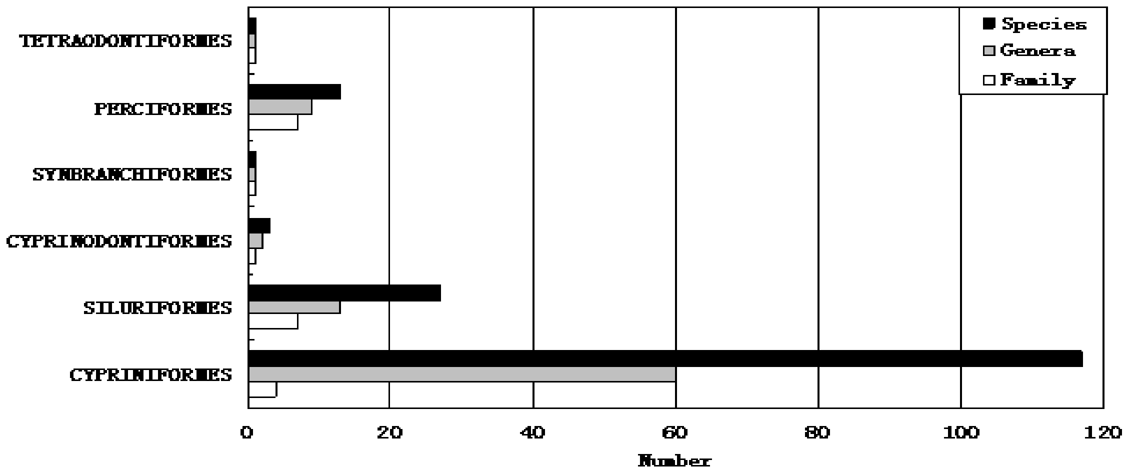


Fig.1 Numbers of each taxonomic unit in fishes of the Upper Mekong

In the headwater 11 species were recorded, in the upper reach there were 22 species, whilst 44 species were recorded in the middle reach, and 142 species were recorded in the lower reach. Erhai Lake, an affiliated lake of the Upper Mekong, contained 9 species of Cyprinidae, and 8 of them were only found in this lake (Fig.2).

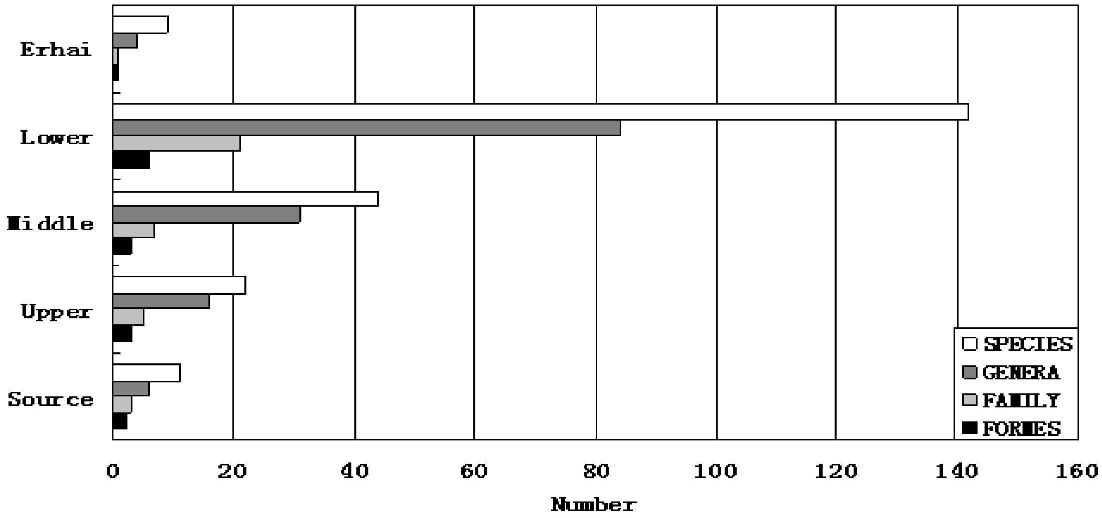


Fig.2 Fishes in different parts of the Upper Mekong

Fish in the Upper Mekong can be grouped by a number of classifications, including: distribution according to water temperature, distribution in different water column and feeding preference. These groupings are outlined as:

According to water temperature:

1) Cold water species; 2) Cold temperature species; 3) Warm temperature species; 4) Warm water species

According to water column:

1) Pelagic fish; 2) Sub-bottom fish; 3) Demersal fish; 4) Lentic species.

According to feeding preference:

1) Algivore; 2) Planktivore; 3) Aquatic insectivore; 4) Piscivore; 5) Detritivore; 6) Invertebrate feeder.

5 environmental factors including mainstream length, watershed area, average discharge, water depth, mean gradient of the Upper Mekong mainstream and tributaries as Yangbi, Weiyuan, Xiaohei, Buyuan and Nanla were used to describe the relationship between environment and fish species number/ endemic species number (Table1).

Table 1 Characters and fish numbers in the Upper Mekong and its tributaries

River	The Upper Mekong	Yangbi River	Weiyuan River	Xiaohei River	Buyuan River	Nanla River
Species number	162	26	40	31	60	54
Endemic species number	51	13	12	10	21	18
Length (Km)	2129	334.4	290.4	175.3	282.4	172
Basin area ($\times 10^4$ Km^2)	16.48	1.197	0.8821	0.5776	.7393	.4531
Average discharge (m^3/S)	2140	155	193.4	121	185	48
Water depth (mm)	450.2	527	476	529	421	539
Gradient ($\times 10^{-3}$)	2.12	4.2	5.86	10.8	4.41	4.39

The river physiological characters were from He and Tang, 2000.

The results showed that there was significantly positive correlation between fish species number/ endemic fish species number and mainstream length/ watershed area/ average discharge. When the considered fish species number in per km mainstream length or per watershed area, it was not remarkably affected by environmental factors except a negative relationship between fish species number and mean altitude (Table 2).

Table 2 Relationship between fish number with river characters using regression analysis

Item X	Y	Optimal regression equation	R^2	Sig.
Endemic species number	Species number	y = 0.29x + 3.47	0.998	P< 0.01
Species number	Length (Km)	y = 0.14x – 12.11	0.928	P< 0.01
	Basin area ($\times10^4$ Km^2)	y = 9.05x + 29.43	0.994	P< 0.01
	Average discharge (m^3/S)	y = 0.05x + 35.68	0.998	P< 0.01
Endemic species number	Length (Km)	y = 0.04x-0.56	0.944	P< 0.01
	Basin area ($\times10^4$ Km^2)	y =2.65x +12.00	0.997	P< 0.01
	Average discharge (m^3/S)	y = 0.01x +13.92	0.996	P< 0.01
species number per km length	Water depth (mm)	_____	___	P> 0.05
	Gradient ($\times10^{-3}$)	_____	___	P> 0.05
species number in per 10^4 Km^2 area	Water depth (mm)	_____	___	P> 0.05
	Gradient ($\times10^{-3}$)	_____	___	P> 0.05

3.3 Output 2:
Representative Migrating Fish and Their Biological Characters

Achievements

Buyuan River as a spawning site for spawning of migratory fish

Buyuan River and the Nanla River are tributaries of the Upper Mekong near the borderline, and have large discharge and high water temperature. Buyuan River originates from Puer County, it flows through Jiangchen County, Jinghong County, Mengla County, and comes into The Upper Mekong at the foot of Apilubeng Mountain in Gongbing village. It is 370 km long, with a catchment area of 7575 km^2, yearly average runoff depth 764 mm and yearly average runoff volume of 57.89×10^{8}m3 (Fig.3).

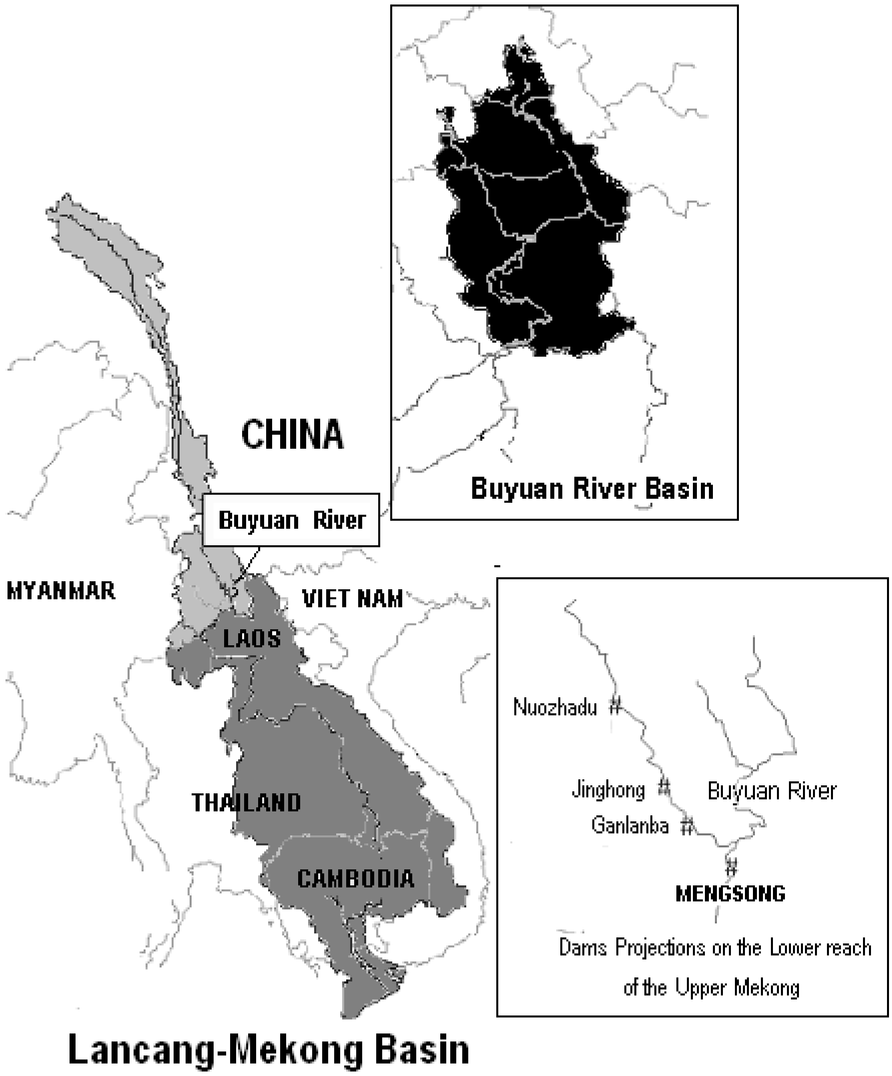


Fig.3 Sketch of the Lancang-Mekong Basin. The light-gray is the Lancang Watershed (in China), and the heavy-gray means the Lower Mekong Basin. The insert on the up-right is the sketch of Buyuan River Basin, the black is the Xishuangbanna district, through which the Buyuan River flows into the Mekong mainstream. Another one in the down-right is the sketch of dams on Mekong mainstream in the part 'Lower reach of the Upper Mekong'. The Mengsong dam site lies behind the juncture of Buyuan River and mainstream according to the plan.

The juncture of Buyuan River and mainstream, characterized by large seepage gradient, a strong current and a complicated microhabitat, is the best place for migratory fishes from the Lower Mekong to forage and spawn. In flood season, normally the variation of water temperature caused by dams operation will hamper migratory fish to finish their reproduction. Furthermore, the average flow velocity can weaken stimulation on migratory fishes in reproductive stage. This will push those fish to find new migration patterns. When these problems unfortunately happen, fish with high breeding ability, short reproductive period and strong adaptability will obtain a new mode of reproduction, while the rest will suffer much from environmental transformation, and may even become extinct if they can't find a fitting new habitat.

Representative economic species

Wallago attu

Nocturnally active, predominantly carnivorous fish are typically found in deep, slow-flowing rivers, lakes and also in reservoirs, are particularly common in large rivers and on The Lower Mekong floodplain. They easily adapt to habitat changes. It is an important commercial species caught with seines, gill-nets, and hooks and sold at market while still fresh. It feeds on other fish, large crustaceans, and occasionally on small branches and roots.

The Wallago attu shows longitudinal as well as lateral migration patterns and migrates to smaller streams, canals and to the floodplain at some stage during the flood season, while during the dry season it lives in deep pools. The migration seems to have the dual purpose of spawning and, especially at the time where smaller fishes are migrating, pursuing food. It spawns in floodplain areas throughout the flood season. Eggs are reported to be present in the abdomen of the species from March to October, with most fishers reporting May-July, and it spawns from May to October with peak activity from July to September. The spawning takes place in flooded areas where the eggs attach to the substrate and hatch within three days.

Mystus wyckioides

It is a carnivorous species, which occurs in large upland and lowland rivers with irregular beds. It is an important food fish, which is caught with hooks, nets and traps, and marketed fresh for its high commercial value. It feeds on shrimp, fish, crabs, insects, earthworms and snails.

Freshwater habitats, demersal, carnivorous.

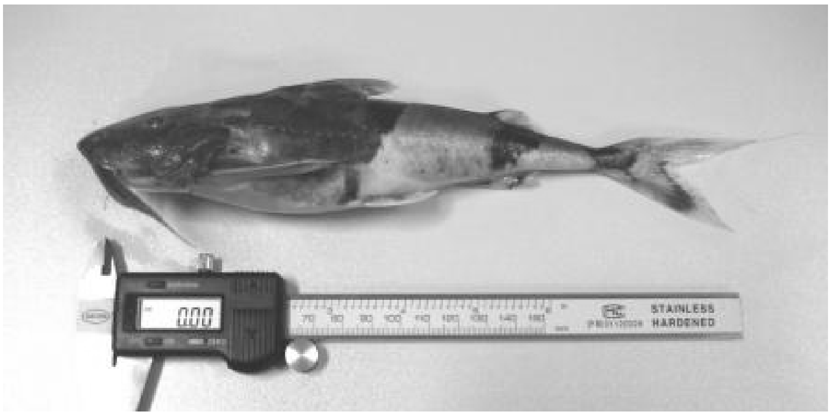
It is, at least locally, a migratory fish showing longitudinal as well as lateral migrations. It has been found to migrate upstream from July-September, and also enters inundated areas. Migratory activity is mainly concentrated in early to the mid June and again towards the end of the month.

Bagarius yarrelli

It is a nocturnal carnivore known to dwell in the rapids and rocky pools of large and medium-sized rivers in The Lower Mekong Basin. It is an important food fish caught with various gears, and occasionally seen in markets.

It feeds on small fishes, frogs, shrimps, insects, worms, detritus, and it also scavenges.

It is a black fish species showing longitudinal migration patterns, inhabiting rapids and rocky pools during the dry season and during floods .



Migration systems

According to a MRC technical report, three migratory systems were confirmed besides a minor but an important one ‘the Sekong-Sesan-Srepok system’ between mainstream and three tributaries (Rainboth, 1996; Baran, 2006). The three mainstream systems are not separated, but sometimes connect each other. Because of the lack of data on the fish of the Upper Mekong, the first system was ended at China border. As Buyuan River, and possibly Nanla River, was considered an important spawning area for some up- swimming migratory species (yang et al., 2007) such as Pangasius, Wallago attu, Mystus wyckioides etc, this migratory system should be extended to the Upper Mekong at Jinghong Dam.

In the Upper Mekong, there must be at least one whole mainstream migratory system from Jinghong to Xiaowan (Fig.4).

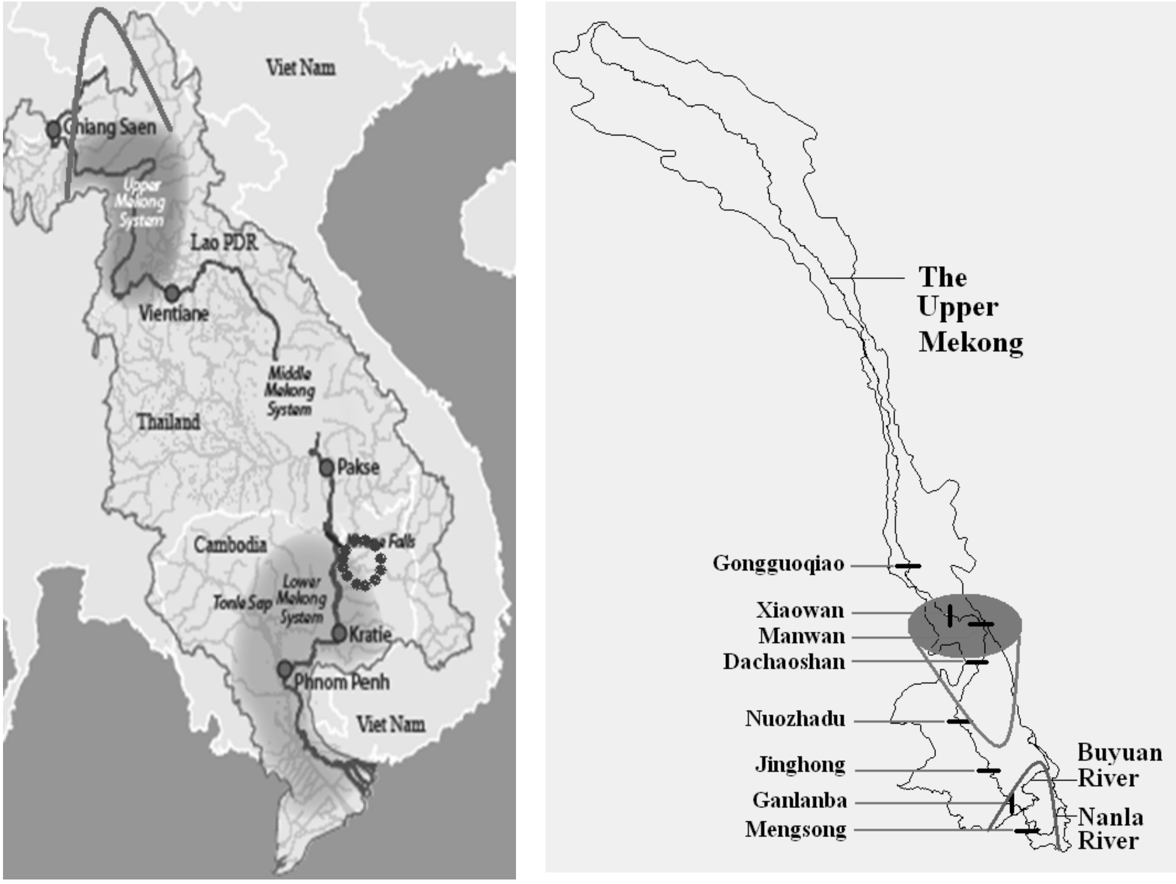


Fig.4 Migratory systems in the Mekong Basin. The left one shows three mainstream (Upper, Middle and Lower) and a tributary migratory (Sekong-Sesan-Srepok) systems in the Lower Mekong Basin. The right one shows migratory system in the Upper Mekong. The grey circle is a main migratory system in the Upper Mekong, and probably extends to Jinghong. The upper migratory system from Vientiane to Jinghong is a transboundary one.

Environmental factors and migratory fishes in Buyuan River

Based on the fish species men collected from Buyuan River in Mar. –Jun. 2006 and the corresponding water quality and hydrological data, relationship between environmental factors and migratory species in number was analyzed using ANN (artificial neural network). Totally 8 migratory species were collected at that period, as *Platytropius sinensis*, Tor tor sinensis, Bagarius yarrelli, Bagarius bagarius, Sikukia gudgeri, Mastacembelus armatus, Barbodes pierrei, Mystus wyckioides.

The result showed mean water depth (MWD) accounted for the most with the statistical weight value 0.0318. The following factors were maximum water level (MaxWL), minimum water depth (MinWD) and dissolved oxygen (O) in turn (Fig.5).

This indicated that in the spawning period, enough water volume is necessary for migratory fishes to complete their reproductive actions.

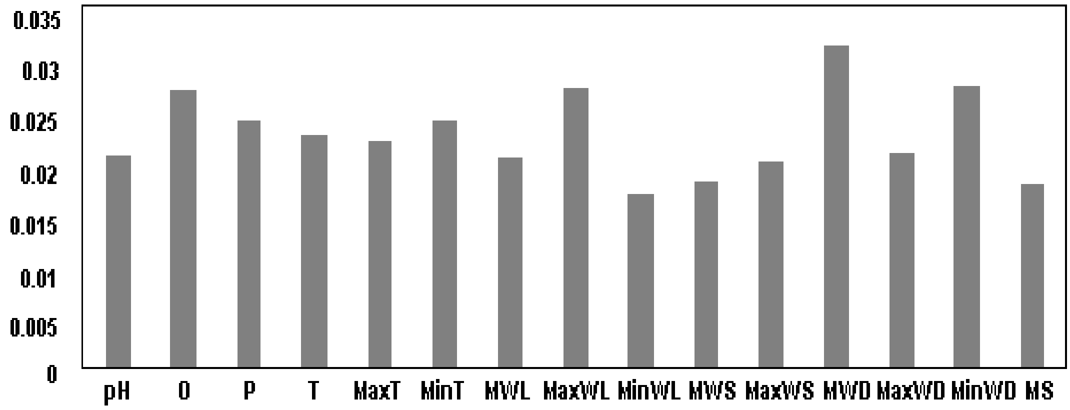


Fig. 5 Statistical weight values accounted for the fish biodiversity of all environmental factors.
(pH, O-dissloved oxygen(mg/L), P-total phosphorus(mg/L), T-water temperature( ), MaxT-maximum water temperature( ), MinT-minimum water temperature( ), MWL-mean water level(m), MaxWL-maxmum water level(m), MinWL-minimum water level(m), MWS-mean water speed(m/s), MaxWS-maxmum water speed(m/s), MWD-mean water depth(m), MaxWD-maxmum water depth(m), MinWD-minimum water depth(m), MS-mean sediment(kg/m^3))

Data on water quality, hydrological factors and fish collection numbers in March 2007 were used to test the prediction of this network, and the result showed an effective validity (Fig.6).

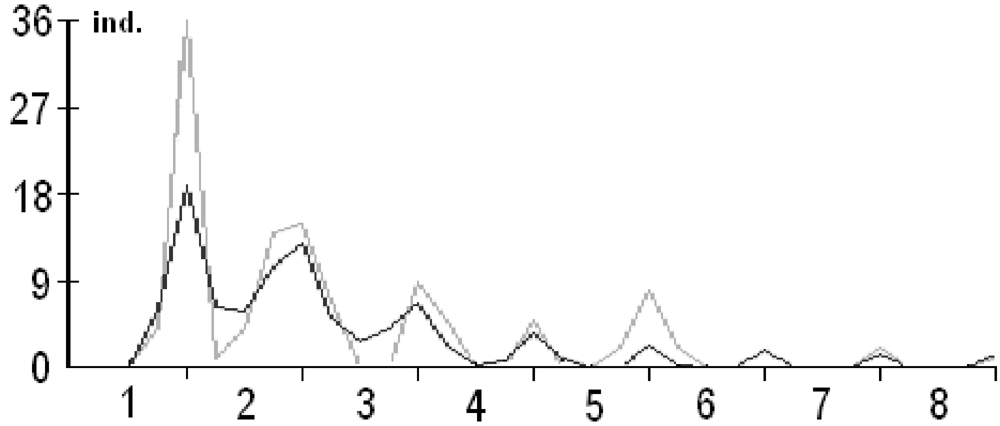


Fig. 6 Validation of ANN prediction on migratory fishes in number in Buyuan River in spawning period. The grey line was the predictive value, and the black line was the actual value in number of each fish species. A total of 8 species were analyzed.
(1 Platytropius sinensis, 2 Tor tor sinensis, 3 Bagarius yarrelli, 4 Bagarius bagarius, 5 Sikukia gudgeri, 6 Mastacembelus armatus, 7 Barbodes pierrei, 8 Mystus wyckioides）

Analysis of the effects of environmental factors on migratory fishes weight, mean sediment (MS) ranked first, following by mean water depth (MWD), water temperature (T), maximum water temperature (MaxT) and minimum water level (MinWL) (Fig.7).

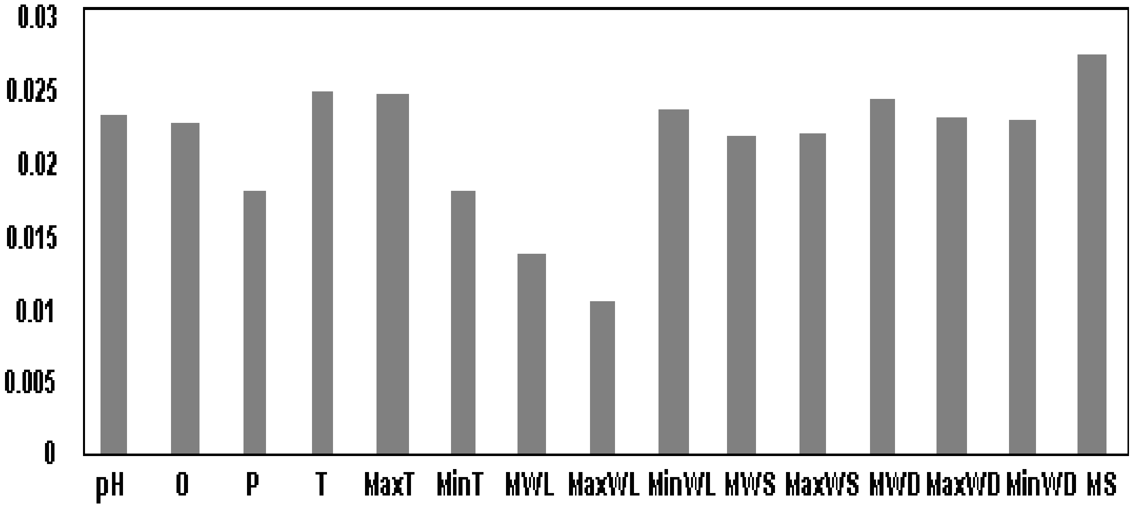


Fig.7 Statistical weight values accounted for the fish in weight of all environmental factors.

Data on water quality, hydrological factors and fish collection in weight for March 2007 were used to test the prediction of this network, and the result showed an effective validity (Fig.8).

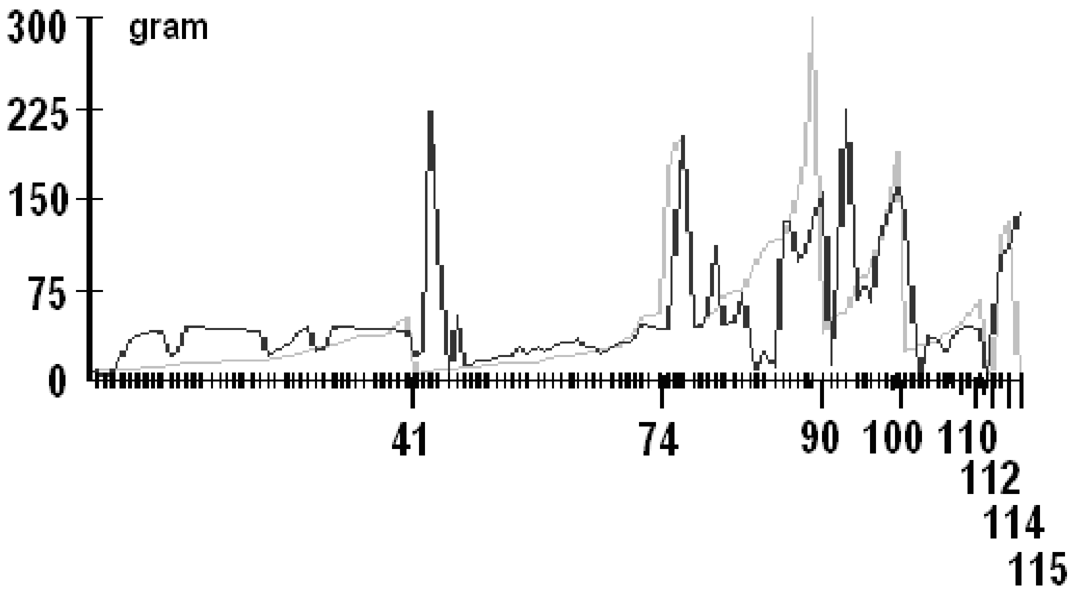


Fig.8 Validation of ANN prediction on migratory fishes weight in Buyuan River in spawning period. The grey line was the predictive value, and the black line was the actual value in number of each fish species. A total of 8 species were analyzed.

(1-41 Platytropius sinensis, 42-74 Tor tor sinensis, 75-90 Bagarius yarrelli, 91-100 Bagarius bagarius, 101-110 Sikukia gudgeri, 111-112 Mastacembelus armatus, 113-114 Barbodes pierrei, 115 Mystus wyckioides）

3.4 Output 3:

Fisheries in the Upper Mekong

Activities to achieve this output

Visit the local government (fishery monitoring station, propagation station, bureau of agriculture).

Visit the markets and fishermen.

Methodology applied to achieve this output

Collect the fisheries information (aquaculture, fishing) to understand the contribution by the fish in Upper Mekong to the whole watershed.

Achievements

Fisheries

In the headwater, the native people regard fish as 'totem', and fishing here has no statistic data. Annual fishing production (only in Yunnan province) decreased from 1995-1997 and then started to steadily increase, with production peaking at 10,000 t in 2004. The sharp increase in production after 1998 may be a result of an improvement in fishing technology and a rise in the number of fishers. The aquaculture production increased more than three-fold, from 17,000t in 1995 to 50,000 t in 2004 (Fig.9).

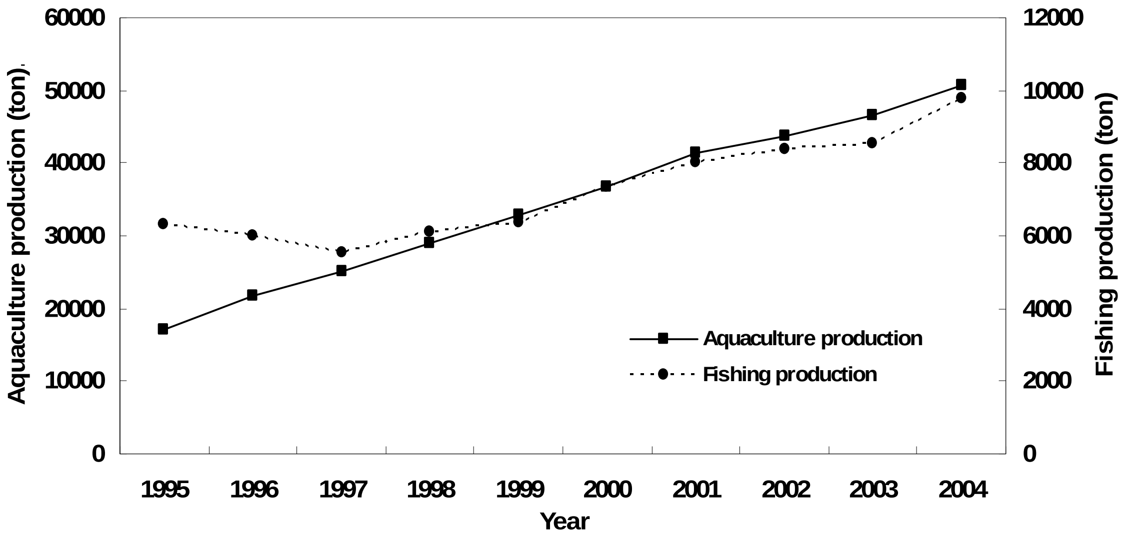


Fig.9 The aquaculture production and fishing production in the Upper Mekong basin from 1995 to 2004. Both showed increasing tendencies, especially in aquaculture production which increased by about 3 times

This increasing aquaculture production can be attributed to an increasing area of aquaculture and an increased production per aquaculture unit (Fig.10), due to an improvement in technology, increased government support and an increased demand for farmed fish.

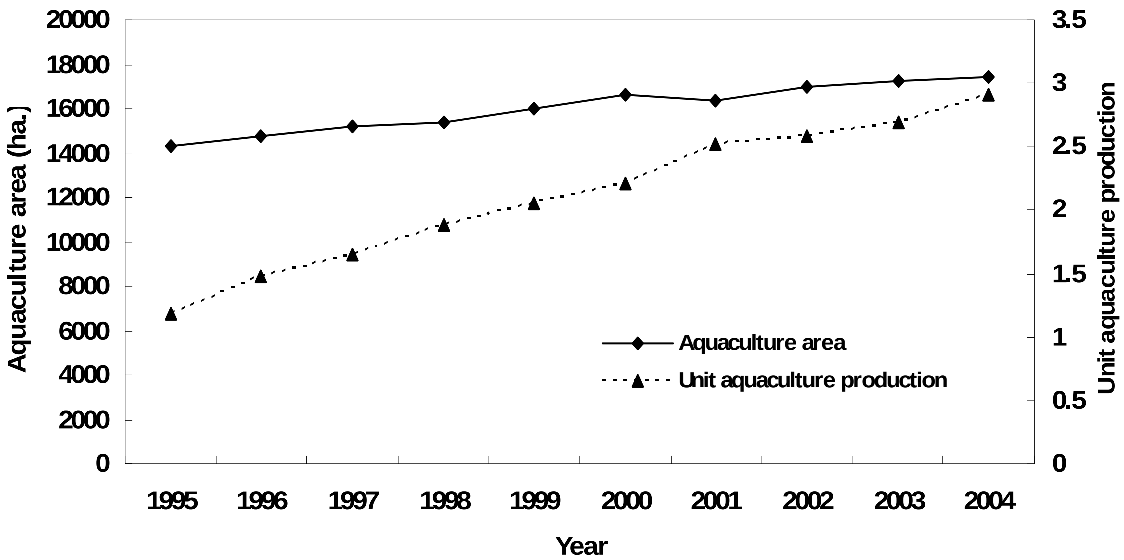


Fig.10 The aquaculture area and unit aquaculture production in the Upper Mekong Basin from 1995 to 2004. During the ten years, the aquaculture area increased because of the encouragement from the government. The unit aquaculture production sharply increased by the improvements of technique.

Fisheries catch and environmental factors

According to the fisheries data from “Yunnan Statistical Yearbook” (1989－2005) and relative hydrological data, the relationship between environmental factors and fishing amount were tested. The aquaculture amount was eliminated from fisheries. The results showed air temperature (AT) was the dominant factor, then precipitation (AP), then maximum water temperature (MaxWT) and minimum water speed (MinWS) (Fig.11). This phenomenon seemed not to be closely correlative with natural fisheries but the suitable fishing conditions. The ANN model got a higher validation (Fig.12).

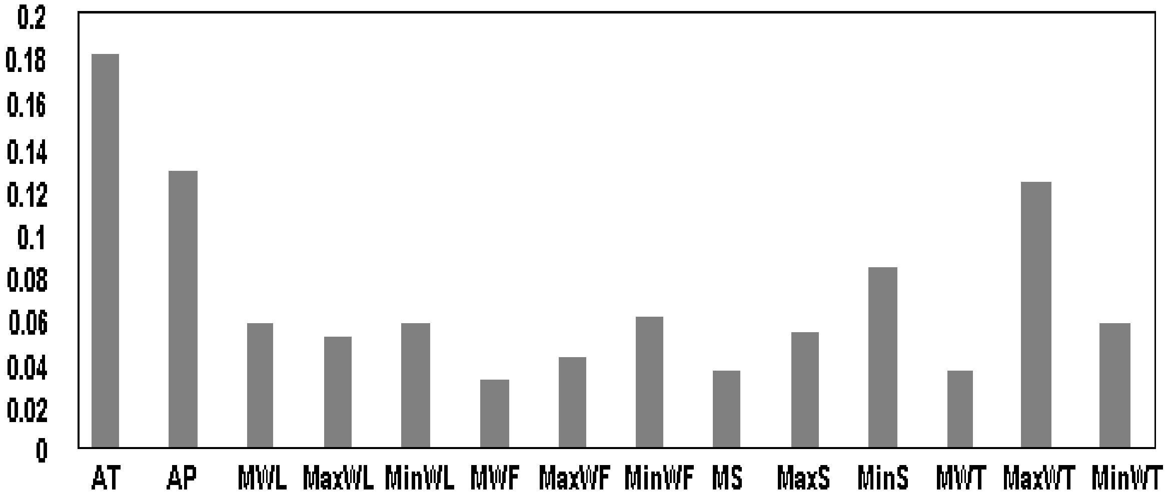


Fig. 11 Statistical weight values accounted for the fisheries (without aquaculture) of all environmental factors.

(AT-atmosphere temperature( )，AP-precipitation(mm)，MWL-mean water level(m)，MaxWL-maximum water level(m)，MinWL-minimun water level(m)，MWF-mean water flow(m^3/s)，MaxWF-maximum water flow(m^3/s)，MinWF-minimum water flow(m^3/s)，MS-mean sediment(kg/m^3，MaxS-maximum sediment(kg/m^3) ， MinS-minimum sediment(kg/m^3) ， MaxWT-maximum water temperature( )，MWT-mean water temperature( )，MinWT-minimum water temperature( ))

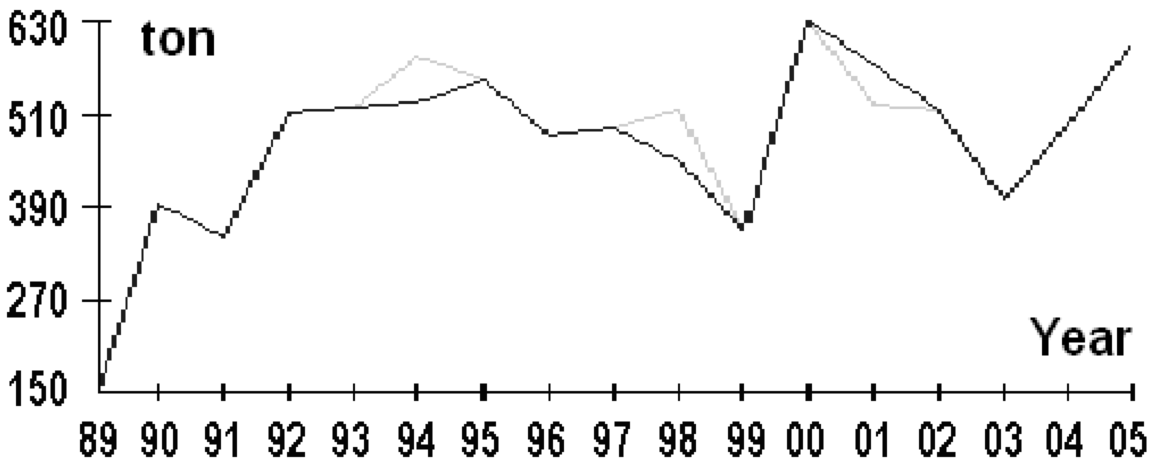


Fig.12 This figure showed the relationship between predictive values and actual values from 1989-2005. The grey line was predictive value, and the black one was actual values. The figure showed a high validity of this ANN model. Using ANN to predict the fisheries in 2006, the predictive value was 624 ton, 67 ton lower than actual value. The relative error was 9.7%, which meant the ANN model can effectively predict the fisheries.

3.5 Output 4:

Suggestion on Threats and Conservation

Threats

In the Upper Mekong River basin, changes in fish diversity and community structure are mainly due to human-induced disturbance, including: dam construction (Rosenberg et al., 1997; Dudgeon, 2000; Nilsson et al., 2005; He et al., 2006), over fishing, exotic species introductions (Xie et al., 2001; Dudgeon and Smith, 2006), as well as water pollution and eutrophication (Xie and Chen, 1999), sedimentation (Fu et al., 2008), deforestation and land erosion (Robert, 2001).

Dam construction

Dam construction divides the mainstream into several huge reservoirs leading to fish habitat fragmentation (Dynesis and Nilsson, 1994). With an ever increasing population and energy consumption the trend in Asia has been towards a greater number of large hydro-power dams being planned and constructed. In the Upper Mekong eight cascade dams have been planned across the mainstream. The dams are at various stages of development and construction with Manwan and Dachashan Dams already in operation from 1993 and 2001 respectively. Xiaowan dam is planned as the tallest dam in the world with dam height more than 300 meters to be completed by 2010; it is predicted to have a great impact on hydrology and the biotic conditions of the river downstream of the dam. Mengsong Dam which is planned to cross the Mekong below the junctures of two major tributaries, Buyuan River and Nanla River, will block migratory fish from reaching these rivers. Furthermore, dams will simplify the physical structure of natural waterways with loss of shallow banks, and heterogeneous habitats such as pools and rapids. This will result in endangerment of fish species and the decline of fish fingerlings dependent on the free flow.

Over-fishing

Historically, fishing was undertaken to satisfy the subsistence need for protein. With the commercialisation of fishing, people fish more and more for money. Over-fishing is considered the biggest threat to the fisheries in the Lower Mekong basin (Department of Fisheries, 1999). In the Upper Mekong, especially in the headwater, local people seldom fish for they regard fish as 'totem' and the working conditions for the fishers are considered dangerous. In the course of economic development and resources exploitation, more and more people migrate to the area and disturb the former natural environment and ecosystem. Though aquaculture was greatly encouraged, it still couldn't support the demand for fish, which resulted in the decreasing of natural fisheries. At the same time, the introduction of exotic species also occupied the habitat of native species and changed the former fish fauna.

Increased fishing pressure can largely be attributed to more fishers using more efficient and more readily available fishing gear. As fishing pressure increases, large predatory species are "fished-down" first, initially allowing a greater survival of their prey. Once these smaller fish have also begun to be caught, however, the total catch increases but so also does the percentage of small species within the catch.

Pollution

The Upper Mekong basin possesses lots of mineral resources and places of natural beauty. The exploitation of these resources brought many kinds of pollution and affected water quality, air quality and land erosion. Bijiang, a big branch of the Upper Mekong, has been greatly polluted with high contents of Hg, Pb etc. Few fish can be found now in this tributary, where there were many fishes before. Similar development also appeared in other river branches.

Exotic species introduction

The differentiation of endemic species in the Upper Mekong is remarkable. The fish fauna here is special because of a long-term geographic isolation and ecological isolation caused by the great difference of altitude between them (Ye et al., 2003; Guo and Cui, 2003). The special ecological environments cause the differentiation of species, with each fish having formed its own species morph. Now however, some new species introduced for economic reasons such as silver fish Neosalanx taihuensis (Huang, 2003) gradually dominating the local area, thereby altering species composition and structure of the area. In Xishuangbanna, the commercial consumption was mostly the introduced Tilapia mossambica. The remarkable decline in native species caught indicates that fish fauna is negatively affected by this introduced fish.

Sedimentation, deforestation and land erosion

Sedimentation accumulates and lines the bottom of the river channel, thus resulting in the loss of valuable fish habitats and rest spaces. Moreover, sedimentation can affect the clarity of the water. Deforestation and land erosion also destroyed or degraded river and riparian habitats. Loss of habitat from drainage and the shrinkage of lake area have contributed to declines of fish and aquatic biodiversity, but declines have not been quantitatively evaluated.

Conservation

Conserve Fish biodiversity

The current conservation policies for freshwater fish biodiversity in China mainly focus on the endangered fish and economic fish (Fu et al., 2003; Park et al., 2003). Commercial fishing of endangered fish is banned. In recent years, with Gyrinocheilus aymonieri as a flagship species has also helped to increase public and government awareness of aquatic biodiversity, with this increased awareness resulting in the creation of a natural reserve in Xishuangbanna for this fish. Also, reforestation of farmland also benefits fishes.

Conserve fisheries

Measures were implemented to restore fish communities including restocking economically important fish species in lakes; banning fishing in spawning season, and combining fisheries with aquaculture. The artificial propagation of Wallago attu, Mystus wyckioides is in researching by researchers in the Yunnan Fisheries institute. About 20000 larvae and some juveniles of the Wallago attu obtained by artificial propagation have been restocked into the river in 2004.

Setup Natural Reservations

To support the sustainable production and utilization of the whole ecosystem, not only the fish species but also the whole ecosystem should be paid attention to. Nature reserves are protected areas that are characterized by the availability of living creatures such as plants, animals and fish or considered natural phenomena of cultural, scientific, touristic or aesthetic significance. Nature reserves aim at safeguarding natural resources, maintaining healthy environmental processes and conserving inherent biological diversity of species activate within the ecosystem. Considering the importance of Buyuan River as an important spawning ground and possessing high biodiversity, it is suggested to be the best place for establishing a protected area to compensate the loss of natural resources caused by land usage, fishing, pollution, dams and navigation etc. The protected area should contain an artificial propagation station, a fish reserve, a local peoples' training centre, and some branches of this organization was also encouraged at each dam site.

4. DISSEMINATION AND ANTICIPATED IMPACT

Dam construction

China has a great plan for exploiting the plentiful water resources in western China. In total 14 cascade dams were planned on the Upper Mekong mainstream. The fact that hydropower projects can do harm to fish and other aquatic animals has been proven by many studies. Cascade dams will cause more harmful effects by separating river into several huge reservoirs. After the Manwan Dam, fish fauna characterized by species enjoying rapid current was substituted by slow water species, with the loss of desermal species.

Mainstream migratory system: In wet season, increasing water level stimulates long-distance migratory species swim upstream from The Lower Mekong. After reproduction, these fishes feed intensively and returning back downstream to flatter waters. If dams are built in their activity space, fish can't successfully complete their life cycle.

Mainstream-tributary migratory system: Fish, especially many medium and small sized fish move upstream for a short distance to find some gravel-bed brooks to feed and spawn. Most of those fish gestate adhesive eggs which stick to gravel, roots and floating debris. If dams obstruct the juncture of tributaries to the mainstream, the fish biodiversity and the fisheries resources will also inevitably decline.

After the dams are completed, the water way for migratory or other activities would be obstructed. The mainstream migratory system would disappear and this forces fish to have to change their reproductive route from mainstream into tributary. This means the dam construction would impact the long-distance mainstream migratory fish more than the short-distance mainstream-tributary fish. According to the plan, Mengsong Dam site lies on the mainstream near the border and will block the upstream fish from the lower reach in spawning period, which will result in significant impacts on fisheries and biodiversity.

In addition, dams shrink the habitats and inhibit reproduction, which put the recovery and growth of fish population at a disadvantage.

Navigation

China and the countries in the Lower Mekong basin signed the agreement on navigation from Jinghong to Thailand, in order to develop the water transportation and economy. Unlike dams, navigation would smooth the river bottom by removing islands, reefs and other roadblocks. Many fish always choose the reef and islands as their shelters and spawning grounds. When the navigation works, fish would lose their important habitats. Moreover, the shipping will also cause disturbance to fish by propeller and swirling etc.

5. CONCLUSIONS ON PROJECT ACHIEVEMENTS

Freshwater fish in the Upper Mekong basin richly contribute to world-wide fish diversity. The Upper Mekong also possesses multiple spawning habitats for migratory fish from the Lower Mekong, thus contributing to one of the largest inland fisheries in the world. The demands of economic development, human activities, especially dam construction and over fishing have temporally and structurally affected fish species composition. This change in species composition will likely have further impacts on the decline of biodiversity and fisheries. Unfortunately the losses are accompanied by the invasion of exotic fishes. As the threat to fish and fisheries in the Upper Mekong have become serious, the conservation has become urgent and is mostly focused on protecting fish biodiversity in the upper reach and the spawning habitats of migratory fish in the lower reach. Some hotspots, such as spawning areas for up-stream migratory fish (e.g. Buyuan River and Nanla River), should be identified and designated as natural reserves. The knowledge of the biology of key species and the technique of artificial propagation and restocking should be improved to recover and maintain native fish communities in the basin. Moreover, data sharing and collaboration between academic institutions and governmental agencies, between China and other countries in the Lower Mekong basin are particularly essential for the effectiveness of fish conservation.

APPENDICES

1. Literature review report

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2. List of Fish in the Upper Mekong

CYPRINIFORMES

Gyrinocheilidae

Gyrinocheilus aymonieri

Cyprinidae

Danioninae

Barilius caudiocellatus

Barilius pulchellus

Raiamas guttatus

Danio menlaensis

Danio chrysotaeniatus

Danio myersi

Gymndanio strigatas

Opsariichthys bidens

Rasbora myersi

Rasbora atridorsalis

Culterinae

Hemiculterella leucisculus

Hemiculterella macrolepis

Macrochirichthys macrochirius

Paralaubuca barroni

Megalobrama anblycephala

Acheilognathinae

Acheilognathus barbatulus

Rhodeus spinalis

Rhodeus ocellatus

Rhodeus sinensis

Barbinae

Cyclocheilichthys repasson

Acrossocheilus krempfi

Barbodes vernayi

Barbodes huangchuchieni

Barbodes parva

Barbodes pierrei

Barbodes carinatus

Barbodes gonionotus

Barbodes daliensis

Barbodes exigua

Cosmochilus cardinalis

Cosmochilus nanlaensis

Hampala macrolepidota

Luciocyprinus striolatus
Mystacoleucus lepturus
Mystacoleucus marginatus
Percocypris pingi retrodorslis
Sikukia flavicaudata
Sikukia longibarbata
Sikukia stejnegeri
Tor brevifilis brevifilis
Tor douronensis
Tor laterivittatus
Tor polylepis
Tor sinensis
Onychostoma gerlachi
Scaphiodonichthys acanthopterus
Puntius semifasciolatus
Puntius ticto

Labeoninae

Cirrhinus molitorella
Crossocheilus reticulatus
Garra pingi pingi
Garra orientalis
Garra microfrontis
Garra taeniata
Henicorhynchus lineatus
Labeo yunnanensis
Labiobarbus lineatus
Lobocheilus melanotaenia
Placocheilus cryptonemus
Sinilabeo laticeps
Sinilabeo zhui
Sinilabeo cirrhinoides

Gobioninae

Hemibarbus maculatus
Pseudorasbora parva
Abbottina rivularis

Schizothoracinae

Schizopygopsis anteroventris
Ptychobarbus kaznakovi
Schizothorax lissolabiatus
Schizothorax lantsangensis
Schizothorax griseus
Schizothorax yunnanensis

Schizothorax talensis

Gymnocypris potanini potanini

Leuciscinae

Mylopharynodon piceus

Ctenopharyngodon idellus

Hypophthalmichthyinae

Hypophthalmichthys molitrix

Aristichthys nobilis

Cyprininae

Carassius auratus auratus

Cyprinus carpio

Cyprinus carpio barbatus

Cyprinus carpio chilla

Cyprinus carpio megalophthalmus

Cyprinus carpio longipectoralis

Cyprinus carpio daliensis

Puntioplites proctozysron

Puntioplites waandersi

Gobiobotinae

Gobiobotia longibarba yuanjiangensis

Cobitidae

Nemacheilinae

Nemacheilus schultzi

Nemacheilus shuangjiangensis

Paracobitis anguillioides

Schistura conirostris

Schistura bucculenta

Schistura fasciolatus

Schistura latifasciata

Schistura vinciguerrae

Schistura meridionalis

Schistura thai

Schistura bannaensis

Schistura heterognathas

Triplophysa leptosoma

Triplophysa microps

Triplophysa stoliczkae

Tripliphysa kungessana

Triplophysa stenura

Botiinae

Botia beauforti

Botia nigrolineata

Botia yunnanensis

Cobitinae

Acanthopsis choirorhyrchos

Acanthopsoides gracilis

Lepidocephalus octocirrhus

Misgurnus anguillicaudatus

Homalopteridae

Gastromyzoninae

Vanmanenia tetraloba

Homalopterinae

Balitora tchangi

Balitora elongata

Balitora pengi

Balitora lancangjiangensis

Balitoropsis yunnanensis

SILURIFORMES

Siluridae

Hemisilurus heterorhynchus

Kryptopterus bleekeri

Kryptopterus moorei

Wallago attu

Clariidae

Clarias fuscus

Schilbidae

Platytropius longianlis

Platytropius sinensis

Pangasidae

Pangasius beani

Pangasius micronemus

Pangasius nasutus

Pangasius sanitwangsei

Akysidae

Akysis brachybarbatus

Akysis sinensis

Bagridae

Mystus wyckioides

Sisoridae

Bagarius bagarius

Bagarius yarrelli

Glyptothorax deqinensis

Glyptothorax lampris

Glyptothorax laosensis

Glyptothorax macromaculatus
Glyptothorax zanaensis
Oreoglanis delacouri
Oreoglanis jingdongensis
Pareuchiloglanis kamengensis
Pareuchiloglanis myzostoma
Pareuchiloglanis gracilicaudata
Pseudecheneis sulcatus

CYPRINODONTIFORMES

Oryziatidae

Oryzias latipes sinensis
Oryzias minutillus

Poeciliidae

Gambusia affinis

SYNBRANCHIFORMES

Synbranchidae

Monopterus albus

PERCIFORMES

Anabantidae

Anabas testudineus

Belontiidae

Macropodus opercularis
Trichogaster trichopterus

Channidae

Channa gachua
Channa siamensis
Channa striata

Eleotridae

Hypseleotris swinhonis

Cichlidae

Oreochromis niloticus
Tilapia mossambicus

Gobiidae

Ctenogobius giurinus
Ctenogobius brunneus
Ctenogobius cliffordpopei

Mastacembelidae

Mastacembelus armatus

TETRAODONTIFORMES

Tetraodontidae

Monotremus leiurus