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Evaluation of the ecosystem values of aquatic wildlife reserves: a case of Chinese Sturgeon Natural Reserve in Yichang reaches of the Yangtze river

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Summary

Chinese Sturgeon Natural Reserve (CSNR) is a typical river ecosystem in the middle of the Yangtze River. An evaluation system of the river ecosystem services of CSNR was established using the so-called 'Market Price Approach', 'Expense Payment Method', 'Contingent Valuation Method', 'Substituted Value Method', 'Cost Analysis Method' and 'Opportunity Cost Method'. The results showed that the total values of the ecosystem goods and services of the natural reserve amount to an estimated 73.57 million USD. The use-values and non use-values were 72.5 and 27.5%, respectively. The direct use values, including fisheries, water supplies and others, reach a total of about 24.23 million USD; On the other hand, the indirect use values, which include endangered species, purification costs and degradation losses, have been estimated at cost levels of approximately 29.12 million USD, indicating with 39.6% its important role of the total value. Meanwhile the non-use values of CSNR in the Yichang Reaches of the Yangtze River were assessed by a contingent valuation method (CVM) and the willingness to pay (WTP), The study shows that the annual non-use values of CSNR is up to 20.22 million USD, of which its existence values is in the range of 8.59 million USD, its bequest values 8.03 million USD, and the option values around 3.6 million USD. This preliminary analysis indicates that this natural reserve represents a special hydro-ecosystem in China with the sturgeon as target species, which is highly valued. The value of endangered aquatic species is up to 25.2% of the total, which places much emphasis on aquatic species. Investment in scientific research and management is presently quite low, amounting to only 0.7% of the total; this fact incidates that research work should be given more concern and support. Limited by the data availability, data processing capacity and time given, result of this initial investigation only represents part of CSNR's assessable value, however, considering the reality that lots of water resource and hydropower projects are now on the way, this valuation will still be helpful to inform the public with the importance of protecting endangered aquatic wildlife and such special hydro-ecosystem.

Introduction

Mankind benefits from a multitude of resources and processes that are supplied by natural ecosystems. Collectively, these benefits are known as ecosystem services, which include supply services such as food and water; regulating factors that influence services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on a global scale (de Groot et al., 2002). George Marsh may be the person who firstly documented the ecosystem services in 1864 (Ouyang et al., 1999). About a century later, the recent dramatic biodiversity loss reminded scientists worldwide again for potential threats to ecosystem and humans (Ehrilich and Ehrlich, 1981; Schulze and Mooney, 1993; Walker and Steffen, 1996; Costanza et al., 1997).

In early studies, the relationship between biodiversity and ecosystem services has been of central concern to ecologists. Odum (1953) had hypothesized that the biodiversity would benefit for enhancing the productivity and stability of the ecological communities. During the 1990s, most studies focused on providing evidence for the relationship between biodiversity and ecosystem functions (Naeem et al., 1995; Tilman et al., 1996, 1997; Lawton, 1998), which is still debated in recent studies (Pfisterer and Schmind, 2002). One reason that ecosystem services have always been ignored by the public at large and governmental agencies is the fact that the values of ecosystem services could hardly be embodied with monetary value. Costanza et al. (1997) systematically calculated average global values of ecosystem services across the 17 distinct types of services and 16 biomes to US$ 16–54 trillion every year, with an estimated average of US$ 33 trillion per year. Such study is still influential today for highlighting the significance of ecosystem services and have created greater awareness among scientists, especially ecologists and economists, who have devoted time and effort to determine the connotations and the evaluation methods of ecosystem services (Seidl and Moraes, 2000).

Historically, Chinese Sturgeon *Acipenser sinensis* was mainly distributed along the continental shelf waters of East Asia and its river systems. Currently, it can be mainly found in China, primarily in the Yangtze River. As a large anadromous species, Chinese sturgeon would migrate more than 2000 km to the upper Yangtze River for spawning, while after the construction of the Gezhouba dam in 1981, its migration route was blocked and its resource was dramatically decreased. Fortunately, a new spawning ground was formed downstream the Gezhouba dam and a 80 km stretch from the Gezhouba dam to the Lujiahe ford in the Yangtze river were protected by the local government Yichang city, Hubei Province as Chinese sturgeon nature reserve (CSNR) in 1996 (Fig. 1).

The CSNR is located in the center of China (Longitude 111°16′∼111°36′, latitude 30°16′∼30°44′), occupying nearly 8000 hectares. It is a typical sub-tropical climate are and Is annual average air and water temperatures 14–18°C, 18.1°C, with a runoff value of $4510*10^8$ m^3, respectively. Along the 80 km river stretch of CSNR exist an estimated total

Fig. 1. Location of CSNR (Chinese Sturgeon Nature reserve)

population of $159.75*10^4$ residents belonging to four districts and two local cities. As a typical river ecosystem, the CSNR is rich in its flora and fauna including 115 fish species, 32 zooplankton species, 60 phytoplankton species, 40 zoobenthos species and others. Except for the Chinese sturgeon, Chinese paddlefish (*Psephurus gladius*), River Sturgeon (*Acipenser dabryanus*), Chinese sucker (*Mxocyprinus asiaticus*), and four of the famous Chinese carps are also the main conservation target species within the CSNR[1].

With the development of the Chinese economy in recent years, the CSNR's priority was ignored and subsequent disturbances occurred, caused by the increase in human activities such as navigation and underwater constructions. Ecosystem valuation is a widely used tool in determining the impact of human activities on an environmental system, by assigning an economic value to an ecosystem function or its ecosystem services. In this paper, our objective attempts to provide an example on how the total value of ecosystem services of an area such as the aquatic wildlife reserve (CSNR) can be assessed, in an attempt to visualize the benefits that can be gained when considering a sustainable development by properly focused conservation and management measures within the CSNR.

Materials and methods

The study is based on characteristics of the Chinese Sturgeon Natural Reserve (CSNR), as identified in the studies by He, (2005), Xu and Peng, (2003) and de Groot et al. (2002) to which we frequently refer. An evaluating system of the total economic values of the river ecosystem of CSNR was established (Table 1). The total value of the ecosystem service of the CSNR is categorized into three types: direct use values which are attributed to direct utilisation of ecosystem services; indirect use values which are attributed to secondary utilisation of existing ecosystem services, through positive externalities that ecosystems provide; and finally, Non-use values which are attributed to values on ecosystem services where there are no market prices but ideal and societal values are obvious.

Results

Direct value of CSNR

Value of fishery products. According to the statistical data from the Yichang Fishery Administration Department and Fishing Port Superintendence Agencies, in recent years the overall fishery catch in the CSNR stretch of the river is around 200 tonnes annually, among which *Coreius guichenoti, Coreius heterodon* and members of the Gobioninae account for about 40% of the total while *Leiocassis longirostris* and *Silurus asotus* account for about 30% and the four most important Chinese carps are accounting for only 20% while the rest are other fish species[1]. Based on the average price of certain fishery products of the year and the exchange rate of 7.9 Yuan to 1 dollar (Chinese Price Information Network, accessed on 8 October 2010), the value of all fishery products in CSNR section can be presently estimated to account for about 1.62 million USD (Table 2).

Value of the shipping industry. According to official statistics, the number of waterway passengers was 1.55 million person-trips in the first half year of 2005 (Yichang Tourism, 2005) and the annual transport capacity of Yichang Port Group was 0.2 million tonnes (Yichang Port Group, 2007). Average price for inland waterway goods transportation is 0.06 Yuan per tonne-km and passenger transportation price is 0.24 Yuan per passenger-km (Wang et al., 2004). Based on the data above, the direct value of passenger transport is about 59.52 million Yuan and waterway goods valuation is about 0.96 million Yuan. Therefore, total direct value of shipping industry in CSNR is 60.48 million Yuan (7.66 million USD). Certainly, this does not account for the spin-off benefits and values of the transported goods themselves on the gross economy nor the labor value of workers transported to and from business locations.

Value of water resources. There are up to 65 thousand hectares farmland and 131.7 thousand hectares woodland depending on the water resource in the CSNR. In this case, Market Price Approach was adopted to calculate the value of the water source for agriculture. The mean volume of water used for farmland irrigation is 424 m^3 per Mu (Xinhua Net, 2007) and the price of water resource is 0.035 Yuan per m^3 (average price for water in agriculture in 2002). We can conclude that the total value of the water resource utilized in agriculture in the area is about 43.785 million Yuan (about 5.54 million USD).

Recreational value. Using Costanza's et al. (1997, 2007) criteria of recreational value of rivers, which is estimated with 230 US \$ ha^{-1} yr^{-1}, we concluded that the recreational value of the 8000 hectares' of the CSNR area could be tentatively assessed by a first approximation by assigning an overall amount of 1.84 million USD. Certainly a site-specific study will have to verify this generalized ballpark figure which may be much higher for a number of specialized services.

[1]Yangtze River Fisheries Research Institute, Chinese Academy of Fishery Science Comprehensive investigation report of Chinese Sturgeon Natural Reserve in Yichang reaches of the Yangtze River, 2006.

Table 1
The index system of values of Chinese Sturgeon Natural Reserve (CSNR) ecosystem services

Index	Classification of ecosystem services function	Evaluation methods	Calculation formulas
Direct use value	Fishery products Shipping industry Water resources	Market value method Market value method Market value method	Vm = $\sum$Qn*Pn, In the formula, Vm is the value of products provided by the ecosystem every year; Qn is annual output of the n products; Pn is the unit price of the n products
	Recreation	Substituted value method	Using Costanza's critieria of river ecosystem recreational value calculate this value
	Scuebce support	Expense payment method	Vt = Pt + Mt, In the formula, Vt is the annual value of scientific research service; Pt is the annual scientific research funds; Mt is the annual management funds
	Culture	Substituted value method	Using Costanza's average value of wetlands cultural calculate this value
Indirect use value	Aquatic wildlife	Cost analysis method	Ve = $\sum$Vn*Nn, In the formula, Ve is annual protection value of endangered rare species; Va is the protection value of the n endangered rare species, Na is the number of the n endangered rare species
	Sediment transport	Opportunity cost method	Vq = Qq*R*Pq, In the formula, Vq is the annual sediment transport value; Qq is the annual sediment transport value of Yangtze river R is the sediment transport rate of CSNR; Pq is the cost of channel cleanup
	Degradation and purification	Substituted value method	Vd = Qd*Md, In the formula, Vd is the degradation and purification ecosystem service value; Qd Costanza's average value of rivers criterion; Md is the area of Nature Reserve
	Biodiversity and habitat	Substituted value method	Vh = Ph*Mh, In the formula, Vh is the habitat protection value of CSNR regions; Ph Costanza's average value of wetland habitat criterion; Mh is the area of Nature Reserve
Non-use values	Existence values Bequest values Option values	Contingent valuation method (CVM)	Vn = Mn*N*P, In the formula, Vh is the Nature Reserve Existence values or Bequest values or Option values; Mn is the median of willingness to pay; N is the number of the Nature Reserve; P is the proportion of the motives behind willingness to pay for chosing Existence values orBequest values or Option values

Table 2
Value of main commercial fishes in CSNR

	Fish species (systematic categories)				
Category	*Coreius guichenoti*, *Coreius heterodon* and Gobioninae family fishes	*Leiocassis longirostris* and *Silurus asotus*	Four famous Chinese carps	Other fishes species	Total amount
Fishing production (tones)	80	60	40	20	200
Price (Yuan / tonne)	15 000	180 000	10 000	20 000	
Value (million Yuan)	1.2	10.8	0.4	0.4	12.8

Fish species were categorized by the market price.

Science support value. Annually the fee donated by provincial and municipal government for rescuing the by-catch or injured Chinese sturgeon in CSNR is presently at a level of 1.5 million Yuan per year*. The annual costs in support funds for the researches carried out on the spawning ground and in the CSNR is about 2.6 million Yuan per year. To sum up, the value of scientific research on CSNR is 4.1 million Yuan, which is equivalent to about 0.52 million USD.

Culture value. Based on the Costanza's criteria on the culture value of wetland which is given with 881 US $ ha^{-1} yr^{-1} (Costanza et al., 1997), we concluded in a tentative approximation that the culture value of 8000 hectares' CSNR amounts to 7.05 million USD.

Indirect value of CSNR

Value of aquatic wildlife. Chinese Sturgeon and Chinese Sucker were listed as class I and class II national protected wildlife animals, respectively. According to relevant laws and regulations, it is illegal to trade national protection species and derived products. Therefore, there is not legal price for their commercial trading. While the policy stipulated a compensation fee for catching the fish for scientific research and education: a juvenile Chinese sturgeon and a adult Chinese sturgeon is 5000 and 50000 Yuan, respectively; a juvenile Chinese sucker and a adult Chinese sucker represents a value of 100 Yuan and 5000 Yuan, respectively. The policy also stipulated that the Value of class I protected species set at a level equal to eight times of the compensation fee assigned for it while and the value of class II protected species would equal six times the assigned compensation fee (He, 2005). Therefore, juveniles and adults of Chinese sturgeon, as well as juveniles and adults of Chinese sucker would be valued at 40 000, 400 000, 600, and 30 000 Yuan, respectively.

Value of Chinese Sturgeon. Because Chinese sturgeon larvae from natural reproduction and juveniles from releasing programmes will soon leave the CSNR stretch, only the broodstocks were considered in calculating the value of Chinese sturgeon in this area. Wei (2003) used the Petersen method meliorated by Bailey and Chapman to estimate extent of the Chinese Sturgeon stock. The results showed that the annual size of the broodstock resources ranged between 292 and 473 individuals (average 363) in the CSNR area during the period between 1996 and 2001 (Wei, 2003). Therefore, it was concluded that the values of adult Chinese Sturgeon is 400 000 Yuan $\times$ 363 = 1.452 (Billion Yuan).

Value of Chinese sucker

Spawning ground of Chinese sucker also has been documented from 1985 to 1992 in the CSNR. Near 200 adults of Chinese sucker could be caught in Yichang section every year from 1981 to 1995, however, only about 10 adults and 1000 juveniles were caught in this area[1]. Therefore, the value of Chinese sucker is estimated with 30 000 Yuan $\times$ 10 + 600 Yuan $\times$ 1000 = 0.9 million Yuan. The total values of the aquatic wildlife is estimated with about 1.46 billion yuan, which is about 18.5 million USD.

Sediment transport value. The Yangtze River with its length of about 6211 miles transfers 4.86×10^8 tonnes sediment every year (Zhao et al., 2003). In view of the portion of CSNR to the whole river, the CSNR is responsible for 1.29% of total sediment transportation. Taking 3.62 Yuan / tone as channel cleanup cost (Wang, 1994; Wang et al., 2004), the value of sediment transport in CSNR is 22.695 million Yuan (about 2.87 million USD).

Value of degradation and purification. Using Costanza's criteria of recreational value of rivers, which is 665 US $\$ha^{-1}$ yr^{-1}, we concluded that the recreational value of the 8000 hectares' CSNR could be tentatively assessed by a first approximation with all amount of 5.32 million USD.

Value of maintaining biodiversity and habitat. The CSNR is not only a gene bank for aquatic wildlife, but also ground for them to inhabit, reproduce, migrate and over-winter. Calculated by Costanza et al.'s (1997) wetland criterion which is 304 US $\$ha^{-1}$ yr^{-1}, this value of 8000 hectares' CSNR reaches 2.43 million USD every year.

It should be noticed that, as the sole spawning ground for Chinese Sturgeon, the CSNR is so cardinal to the reproduction and existence of this specie that any damage to it may cause Chinese Sturgeon's extinction. According to former studies, this spawning ground has developed gradually from 1981 to 2003. An adverse slope with particular length and inclination is the most important part in riverbed topography which causes the formation of three function sections of Chinese Sturgeon's spawning ground: fertilization, spawning and incubating section. This slope is 1568 m long with 2.0% grade inclination, so it will be 11.06 million cubic meters' project if we take half of the width of the river bed (450 m) into account. Eliminating the reconstruction project for the fertilization and spawning sections, but maintaining the construction of a same spawning ground will need 165.9 million Yuan at a conservative price 15 Yuan m^{-3}. Though it is not the best method for reckoning the CSNR's existing value, it can be used as first reference value in estimating the CSNR's conservation value.

Non-use values of CSNR. The non-use value of Chinese Sturgeon Natural Reserve (CSNR) in the Yichang Reaches of Yangtze River was evaluated by a contingent valuation method (CVM) and the willingness to pay (WTP). Total 172 feedback questionnaires with the residents along the CSNR showed that the non-use value of CSNR is up to 159.75 million Yuan (20.22 million USD) per year, with the existence value, the heritage value and the option value is 8.59, 8.03 and 3.6 million USD per year, respectively. The WTP of surveyed respondents was significantly correlated ($P < 0.01$) with their occupation, educational level, income, as well as their acquaintance with the CSNR and less correlated with their gender and age. Among the respondents' characteristics, the value of WTP was obviously determined by their familiarity with the CSNR and their incomes ($P < 0.01$), which indicated that the respondents will pay more for the conservation of CSNR when they are more familiary with the CSNR. The study also found that the income level still restricted people's participation to protection project. According to the investigation, 67% of the fisherman whose income directly come from the CSNR considered the construction of the CSNR had impair their benefits, while 60% of them still supported the construction of the CSNR for their awareness of the goals of the conservation.

Total values of the CSNR

The total economic values of the river ecosystem of CSNR included use-values and non use-values. These use-values principally evaluated both the direct and indirect use-values of the river ecosystem of CSNR. The results indicated that the annual total economic values of CSNR is about 73.57 million USD (Table 3), of which the use-values and non use-values were72.5 and 27.5%, respectively.

Discussion

Ecosystems maintain the earth life support system, providing not only environmental conditions that mankind depends on for existence, but also offering great direct and indirect values that provide services to the quality of human lifes. Costanza et al. (1997) calculated average global values of ecosystem service with an estimated US$ 16–54 trillion (average US$ 33 trillion) every year. This is an order of magnitude higher than anyone could have imagined. In 2000, the total annual value of ecosystem goods and service to Nhecllandia region of the Brailian Pantanal was evaluated more than US$ 15.5 billion, or US$ 5 million per resident by A. F. Seidl et al., an annual per hectare value of approximately half of Costanza et al.'s (1997) calculations. According to the calculation, the annual total economic values of CSNR was 73.57 million USD Which was not only far inferior to calculation by Costanza et al. (1997) and (Seidl and Moraes, 2000) A. F. Seidl et al., but also far lower than that of actual value of river ecosystem of CSNR. However, the total annual value can reflect to some extent the great ecological economic value of the CSNR.

The total value of the nature reserve ecosystem products and services is estimated in the order of 73.57 million USD each year, of which the use values and the non-use values represent 53.35 and 20.22 million USD (Table 3), accounting for 72.5 and 27.5% of the total values. These data demonstrate that the value of the ecosystem service is mainly embodied as the indirect use values, which are about 39.6% of the total values, indicating that the ecosystem services value of the CSNR is not in the traditional production of materials as we initially imagined.

This study is the first attempt to assess the value of rare species – Chinese sturgeon and Chinese sucker of the nature reserve by calculating the protection cost, which indicates that rare species are the highest, 25.2% of the total values, far higher than the value of others. Rare species protection was classified as one of the maintenance value of biological diversity and calculating the value of biodiversity through rare species protection fees is feasible, It is different from economic values of Danube Floodplains estimate by Gren et al. (1995).The total annual value of the entire actual area of Danube floodplains corresponds to EUR 650 million per year, and approximately one-half of the total value was accounted for as a nutrient sink (Gren et al., 1995). Certainly, this is different from the value of wetland lake ecosystem, for example, Pan et al., (2002) assessed the lake ecosystem value mainly by storage and water supply, and Cui (2004) assessed such lake ecosystem mainly by their value providing degradation capacity for pollutants. The results also demonstrated the great value of protected areas when incorporating the protection of rare aquatic animals and their habitats. The indirect ecosystem service values of this river provided to humans is far greater than the benefits obtained from the physical products extracted directly from such systems.

In people's traditional values, direct material extraction and production should be the primary service function of an ecosystem, while the value of other ecosystem services have largely been ignored. We have to recognize that the values for direct material products of this section of the river was lower and the value of fishery products accounted only for 2.2% of the total values, indicating that the direct value of aquatic products supply of protected areas is relatively low. The fishery production function has been weakening and fish species, numbers and overall biodiversity decreased noticeably. This must also be seen, however, in the context of a larger picture, while incorporating these functions into an analysis on regional biodiversity scale where net primary productivity serves the total value of ecosystem service functions with benefits from the value of biodiversity, which may making the value of the entire river ecosystem services relatively low (Costanza et al., 2007).

Due to restrictions of shipping data acquisition, the shipping value of protected areas is only 10.4%, but the actual value of this ratio will be much higher, not even considering the spin-off value of this industry in destinations outside the study area itself. The protected area is located at the so-called 'gold arteries' of the Yangtze River, and therefore the Government will be inclined to make full use of its advantages to develop the shipping capacities. However, the development of shipping will contribute to the loss of the other values when looking at the total value of the entire ecosystem service of the protected areas, which also suggests that economic development and protection of rare species are in conflict when just accounting for the direct values of various human usages. How to coordinate local economic development with biodiversity conservation of protected areas is a main problem between the management of protected areas and conservation biology experts in the future.

The research investment in the protection accounts only for 0.7% of the total values, which does not match the high conservation value of the protected areas. Therefore, the

Table 3
Value composition estimated by various methodologies for ecosystem goods and services of the Chinese Sturgeon Natural Reserve

Classification	Ecosystem services categories	Value (million dollars)	Proportion (%) of total value	Total (million dollars)	Proportion (%) of total value
Direct use values	Fishery products	1.62	2.20	24.23	32.93
	Shipping industry	7.66	10.41		
	Water resources	5.54	7.53		
	Recreation	1.84	2.50		
	Science support	0.52	0.71		
	Culture	7.05	9.58		
Indirect use values	Aquatic wildlife	18.5	25.15	29.12	39.58
	Sediment transport	2.87	3.90		
	Degradation and purification	5.32	7.23		
	Biodiversity and habitat	2.43	3.30		
Non-use values	Existence values	8.59	11.68	20.22	27.48
	Bequest values	8.03	10.91		
	Option values	3.6	4.89		
Total values				73.57	

respective Governmental Authorities should increase their funding for management and research within protected area, supporting more rigorously the protection of rare species, while maintaining biodiversity and ecosystems stability.

Non-use value accounted in this study for 27.5% of the ecosystem products and the total service value of the protected area, of which existence of value is the main reflection in value, which indicates protection of Chinese Sturgeon and other rare species in protected areas is necessary. This knowledge and insight is recognized by the general public and has been identified through surveys. These survey data are all obtained in the form of interviews with a high survey response rate and all persons originated from urban counties along the coast of the protection area. They are considered as representative. The interview survey, subjects to certain conditions to a relatively small sample size, considered quota of different age groups, occupation, education level and low income groups. The statistics of WTP is distributed uneven, so the use of the median value was considered more reasonable. In addition, in the case of CVM evaluation, non-use values of protected areas were not fixed values, causing some bias errors in the analytical results due to many uncertainties and unavoidable errors. However, the effective CVM method was still used by the scholars to assess non-use value of protected areas and although it can be considered a rough value it reflects the trends toward environmental goods and services while also providing some basis for the considerations of planers and managers.

Ecosystems are the basis for human survival and development. Although the data collection and the current assessment methods have their shortcomings and are affected by subjective factors in the evaluation process, the estimation of river ecosystems values has its merits eventhough it is not to come to exact values for each of the ecosystem service values within the protected areas. These preliminary assessments, however, can inform people and government officials to realize the importance of protected areas and identify their core values aggregated from each ecosystem component and the ratio between them. It can be seen from this study, the main conservation value of protected areas is reflected by the protection of Chinese Sturgeon and other rare species, requiring specific habitat protection and restauration efforts. At present, the protected section of the river is the only spawning section of Chinese Sturgeon after the finalizing of the Gezhouba Dam, which plays an irreplaceable role to prevent extinction of the species, preservation of biodiversity and genetic conservation.

Conclusions

This initial study on the CSNR ecosystem goods and services was undertaken using locally derived data and the investigation of YFI research reports as basic approximation of values directly derived from the area. The annual economic values of the river ecosystem of CSNR was assessed with 73.57 million USD per year. This is a conservative figure, as the wider impact of these services to downstream economies have not been considered. The highest value was assigned to the rare protected animals (Chinese sturgeon, Chinese sucker), accounting for 18.5 million USD and 25.2% of the total values. The reasons why the annual value of ecosystem services were low were analyzed, mainly because of the limitations of this subjected data presently available. Due to the incomplete and unilateral data collection, so far the annual value of ecosystem services calculated have to be considered as being at the lower end of the true value. Another reason is that decreasing abundance of fish species caused also the decline of biological diversity, thus this had led to the actually reduced value from some of the river ecosystem services. These 'losses' should actually be added and need to be regained through appropriate management measures. Further studies are needed to fully assess the full ecosystem values which may be much higher, need to be maintained or – where lost – should be restored.

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