HighARCS Highland Aquatic Resources Conservation and Sustainable Development

www.higharcs.org

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Summary

This report is the deliverable 3.1. for Work Package 3 of the HighARCS project. It comprises of five separate stand alone reports that present the freshwater ecosystem service and biodiversity values at the five sites that have been selected for the HighARCS project. The primary aim of these reports is not to provide recommendations for the conservation or sustainable use, but to present the information required by the Integrated Action Plans on the biodiversity and ecosystem service values at the sites. This information will be integrated along with the information provided by the Work Package 4 *Report on livelihoods dependent on highland aquatic resources derived ecosystem services* and Work Package 5 *Report on institutions, policy and conflict* to help formulate the necessary actions and indicators to ensure the conservation and sustainable use of the highland aquatic resources at the five sites.

Each research for each report has followed the guidance on biodiversity and ecosystem service valuations provided by the IUCN Integrated Wetland Assessment Toolkit along with expertise from across the HighARCS project partners and are therefore all similar in layout and content. However there are differences with the methodologies used and types of data collected due to each sites unique social and environmental situation and issues and the capacity of the teams undertaking the research. Each report presents site and catchment maps, allowing the results to be placed into a geographic context as understanding the linkages up and down stream will be an important factor in the formulation of the IAP. They also report the freshwater biodiversity present at the site and their utilization and livelihood value along with their conservation status. The relevant policy and legal frameworks that cover freshwater biodiversity, its use and conservation is also been summarized. The threats to freshwater biodiversity and ecosystem services are identified, discussed and mapped. Lastly in each report the freshwater ecosystem services are identified, discussed and valued (through stakeholder prioritization, and for the China site an economic valuation) and the areas generating the service and receiving (or benefiting) are also mapped.

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Freshwater ecosystem services and biodiversity values of the Beijiang River, China.

Freshwater ecosystem services and biodiversity values of the Beijiang River, China

Work Package 3 report:

Highland Aquatic Resources Conservation and Sustainable Development (HighARCS)

South China Agricultural University
Luo Shiming, Cai Kunzheng
Zhao Huihong, Cui Ke, Gan Lian, Fu Jinghua
Zhuang Xueying, Tong Xiaoli
Zhang Jia'en, Ye Yanqong, Li Huashou, He Hongzhi

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Acknowledgments

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We would like to thank Dr Fraser Sugden from University of Stirling, Scotland who worked with SCAU during the summer of 2010, and 2011 primarily for WP4, but he also helped us in WP3 to investigate the habitat situation in the three sampling villages and to finish the habitat mapping. Also graduate student Ms. Li Yun (李韵) who spent a lot of time mapping ecosystem services and ecosystem costs. We would like to thank local government officers, company leaders, farmers and fishers who joined our research and help us a lot during our research.

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1. Introduction

1.1. About this report

This report is a deliverable for an EC funded project called 'Highland Aquatic Resources Conservation and Sustainable use' (HighARCS - www.higharcs.org). This project is using an integrated approach of biodiversity, livelihoods, and policy framework surveys (following the IUCN Integrated Wetland Assessment Toolkit Springate-Baginsky *et al.* 2009) to value five wetland sites across Asia, and develop action plans to ensure aquatic resources are conserved and used sustainably. Here we present the findings of research taken to identify and value biodiversity and ecosystem services at one of these sites; three fishing villages along the Beijiang River, Guangdong Province, China. This report will be used alongside two others (one on livelihoods and one on policy and management) to formulate an Integrated Action Plan (IAP) to address sustainable use of aquatic resources at the site.

For this report the aquatic biodiversity at the three fishing villages has been identified through literature reviews, IUCN Red List assessments and field surveys. A participatory rural assessment method was adopted to identify the prioritisation of different ecosystem services and costs by different stakeholders. A total economic valuation of the ecosystem services provided by the Beijiang River has also been calculated using existing data. The policy and management framework that influences biodiversity and the provision of ecosystem services is also reviewed and discussed. The information in this report (WP3) together with the research results on the livelihoods of the fishers in the fishing villages (WP4) and the policy and management analysis (WP5) will provide a solid foundation for the integrated action plan (IAP).

1.2. Background

The Pearl River watershed is the third largest river in China. It is situated in southern China and extends from 21°31'N to 26°49'N and from 102°14'E to 115°53'E (Figure 1). The major tributaries of the Pearl River are the Xijiang River (West River), Beijiang River (North River), and the Dongjiang River (East River). After they merge together, they form the main stem of the Pearl River, which runs into the Pearl River Delta and to the South China Sea (Figure 2). The Beijiang River (North River), where the HighARCS project sites (fishing villages) are situated is the second largest sub-catchment in the Pearl River system and one of the most important rivers in Guangdong Province. The Beijiang River has been chosen as HighARCS project site is because of the highland areas within the catchment and the presence of fishing communities who depend heavily on aquatic resources.

Most of the Beijiang River watershed is mountainous or hilly and covered with evergreen vegetation typically a broad leaf seasonal forest containing high levels of biodiversity in a subtropical monsoon region. Due to the high rainfall in the region and steep topography, there are a lot of streams and rivers with high potential for power generation. Because of the rapid economic development in the region, especially mining and heavy industry activity, damming of rivers, pollution and habitat disturbance have become major threats to aquatic resources.

For detailed information on the Beijiang River site (natural environment, livelihood strategies etc. see the WP1 report ‘HighARCS situation analysis report – China site’ SCAU 2010 available at www.higharcs.org).

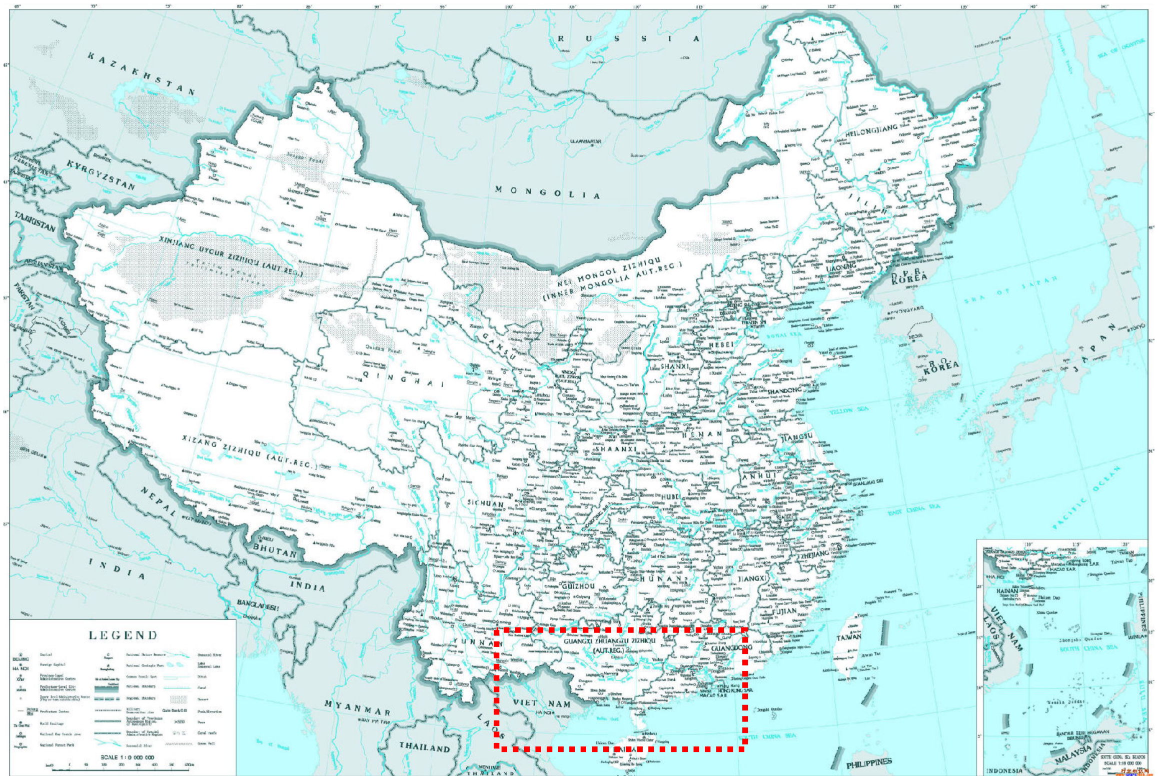

Figure1. The Pearl River watershed is within the red box (and is enlarged in Figure 2.)

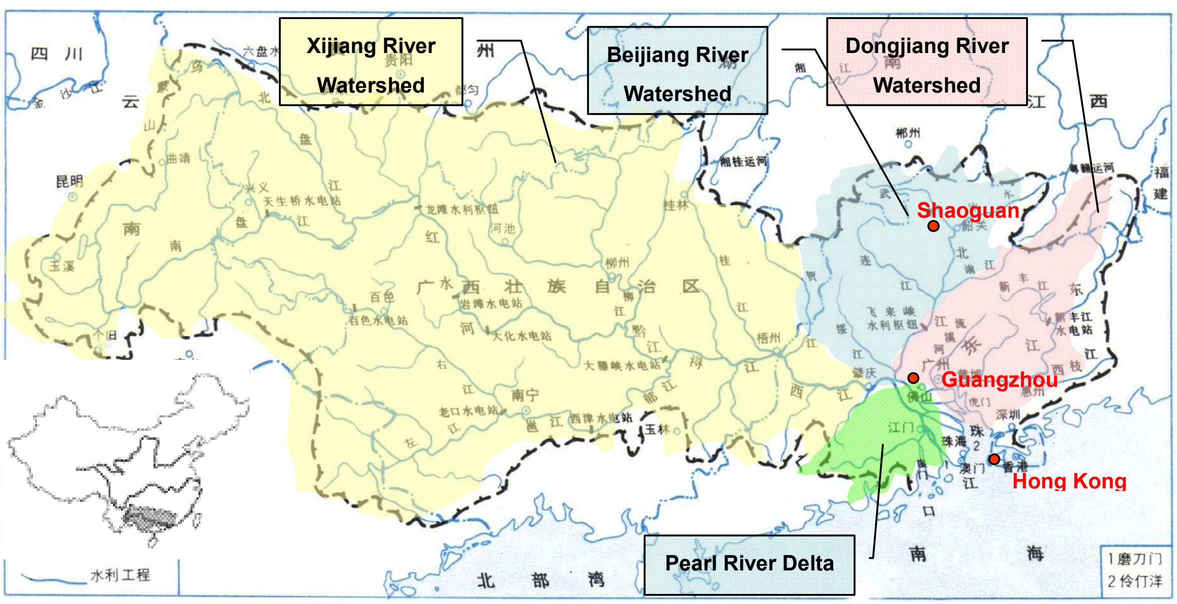

Figure 2. Position of Beijiang River (blue) in the Pearl River watershed

2. Site maps

The maps of the sites are important as they allow the results of this Work Package to be put into a geographic context. They will not only allow detailed information to be presented in an easy to understand format, but they will also be key in developing the IAP and identifying any potential indicators and monitoring plans. The maps of the field sites below were produced by initially digitizing satellite imagery using ESRI ArcInfo Geographic Information Software (GIS) by Dr. Fraser Sugden of Stirling University, and IUCN, whereas the catchment maps have been digitised by SCAU staff. Then through a mapping workshop held on 23-24 August, 2011 at the South China Agricultural University, Guangzhou, China the maps were reviewed, edited and land classifications were confirmed by SCAU staff based on their knowledge and field observations taken while at the site.

The Pearl River watershed (Figure 1) is found in the southern part of China draining into the South China Sea, and is China's third longest river. Figure 2 shows the three major branches of the Pearl River and the Pearl River Delta. The largest sub-catchment is the Xijiang (West River), which covers most of Guangxi Province and stretches into Yunnan, Guizhou and parts of northern Viet Nam. The Dongjiang (East River) and Beijiang (North River) are almost entirely found within Guangdong Province.

Figure 3 shows the upper Beijiang River where the three fishing villages are located. Two villages Lishi (24o 52'53.48''N, 113o 32'20.10"E) and Zhoutian (24o 58'57.77"N, 113o 51'36.75") are upstream of Shaoguan City on the Wujiang and Zhenjiang rivers respectively, and Kengkou village (24o 32'2.13"N, 113o 35'26.63"E) is downstream of Shaoguan on the Beijiang River after the Wujiang - Zhenjiang confluence. The major land cover within the Beijiang River watershed is forest, with farmland mainly found along the river valleys and flood plains. Some of the sensitive regions for biodiversity have been protected as national forests, natural reserves, or reserves for aquatic resources.

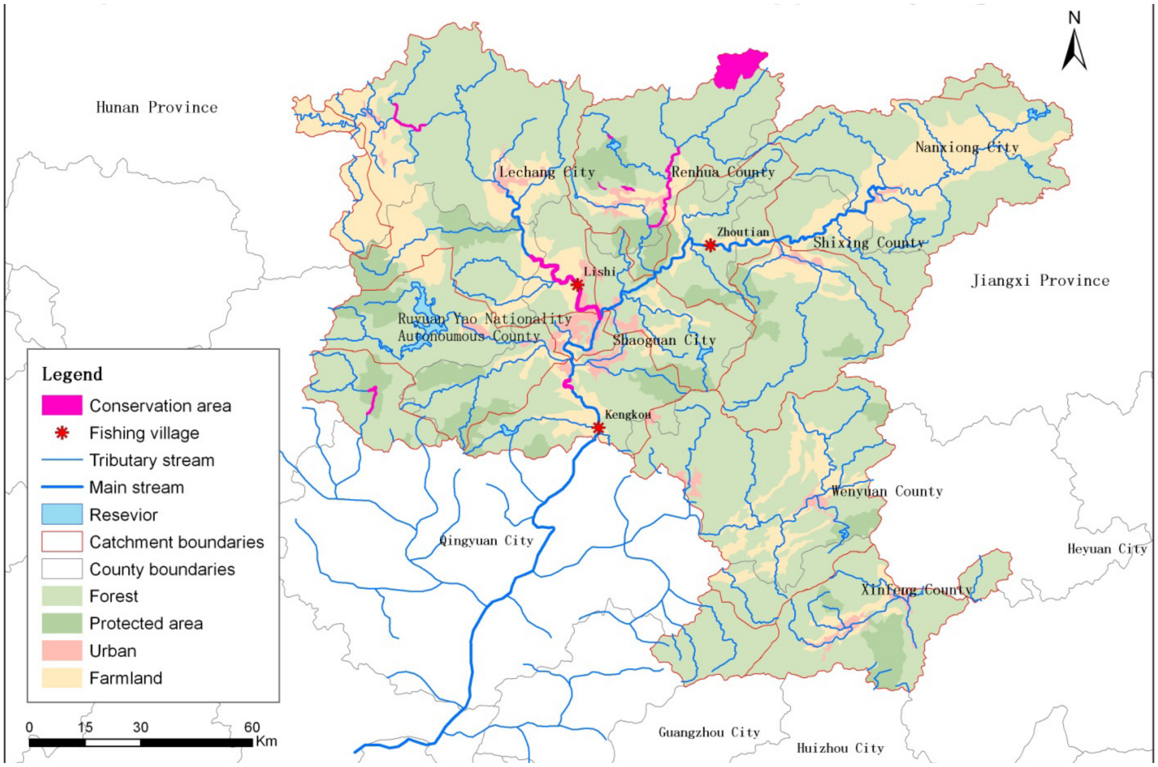

Figure 3. The major habitats in Beijiang River Watershed in Shaoguan

Figure 4 (top map) shows a detailed land cover classification map of the area that surrounds Zhoutian fishing village. The village is relatively far from built up areas and is surrounded mostly by agricultural land and forest. However, the village is situated just downstream of an active sand mine and a hydropower dam. Figure 5 (left) shows the land cover around Kengkou fishing village which is predominantly forest and plantations with little agricultural land. The village is situated downstream of a dam, sand mine and industrial areas. Also as the site is downstream of Shaoguan City, the river contains higher levels of pollution than the other sites. Figure 6 (top) shows the land cover around Lishi Fishing village. Lishi is very close to urban areas with Shaoguan city just downstream of the village and Lishi town is upstream. There are large areas of agricultural land on the opposite side of the river and is a dam downstream near Shaoguan City suburbs. Water is often pumped out from the river for agricultural irrigation and for urban usage which is released back into the river as waste water. Figures 4 (bottom map), 5 (right) and 6 (bottom) also show the locations of the field sites that relate to the different taxonomic groups that have been surveyed (see section 3 Biodiversity within the Beijiang River).

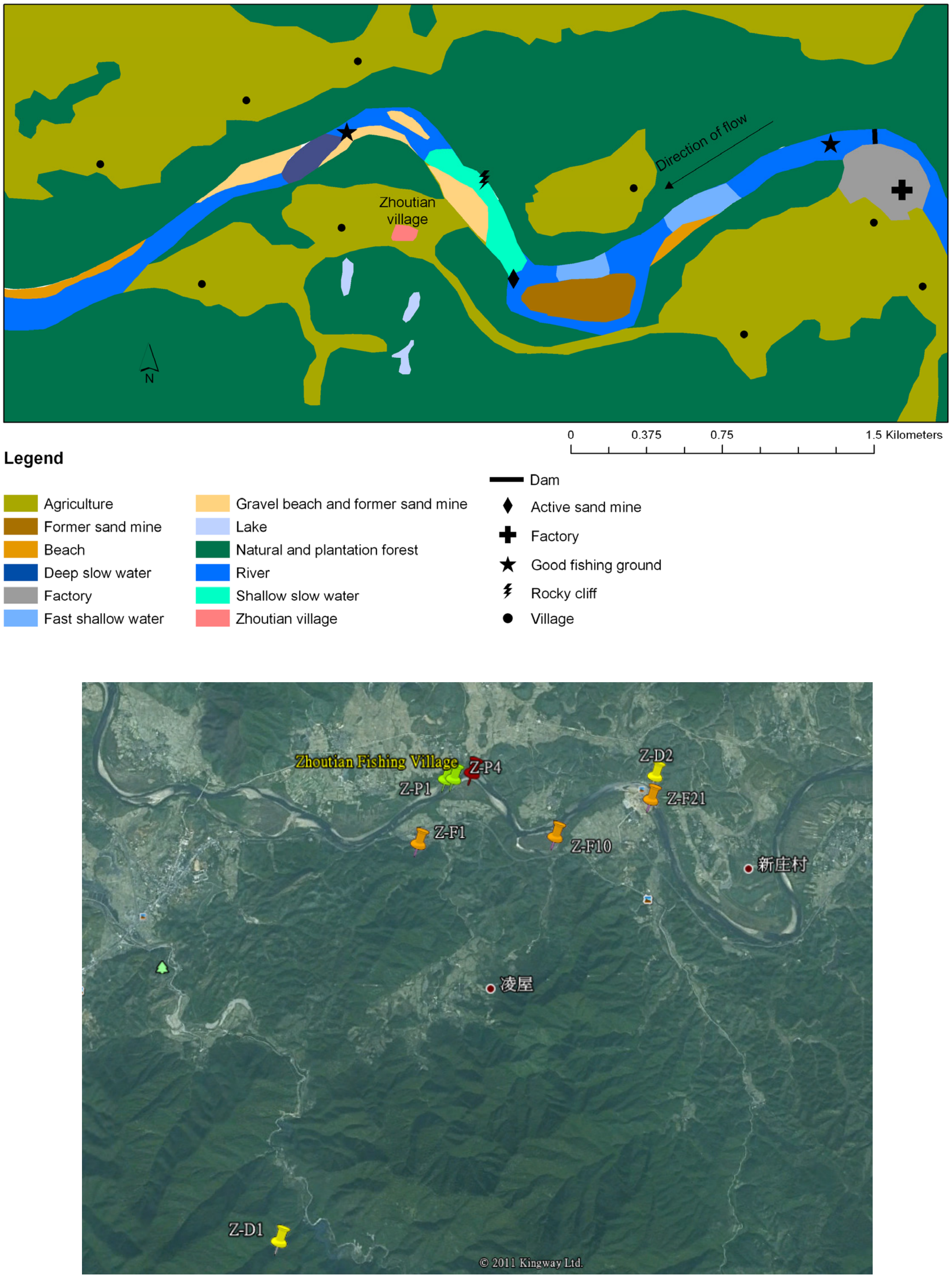

Figure 4. The site map of Zhoutian Fishing village (above) and the sampling sites for aquatic species (below)

In the lower map, the orange pins denote the sampling points for fish, yellow pins for dragonflies, green pins for aquatic plant species. Codes e.g. **Z-P4** mean **Z** for **Z**houtian fishing village, **P** is for aquatic **P**lants, and **4** is the sampling point number **4**. A full list of the sampling points can be found in Annex I.

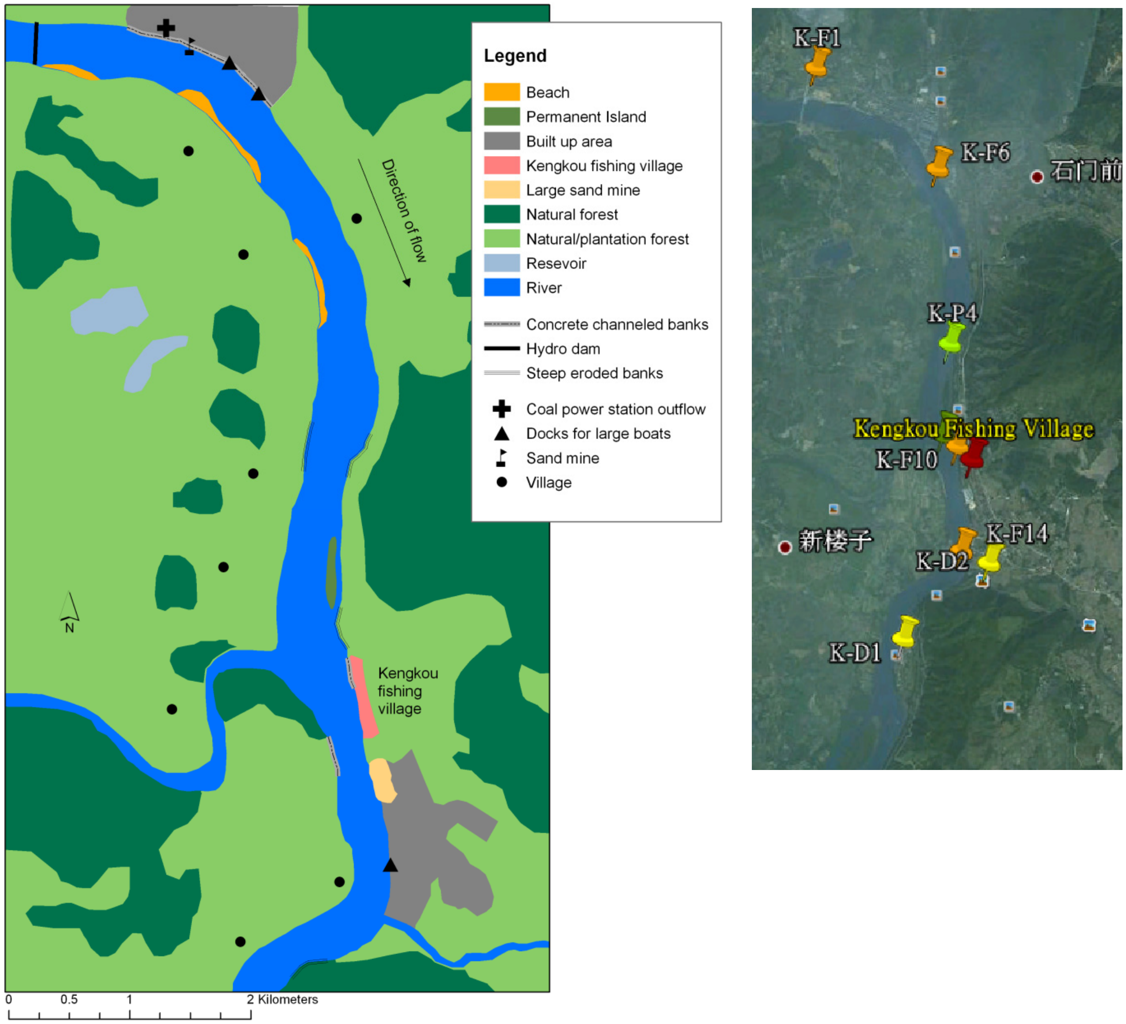

Figure 5. The site map of Kengkou fishing village (left) and the sampling sites for aquatic species (right)

In the right map, the orange pins denote the sampling points for fish, yellow pins for dragonflies, green pins for aquatic plant species. Codes e.g. **K-F10** mean **K** for **K**engkou fishing village, **F** is for aquatic **P**lants, and **10** is the sampling point number **10**. A full list of the sampling points can be found in Annex I.

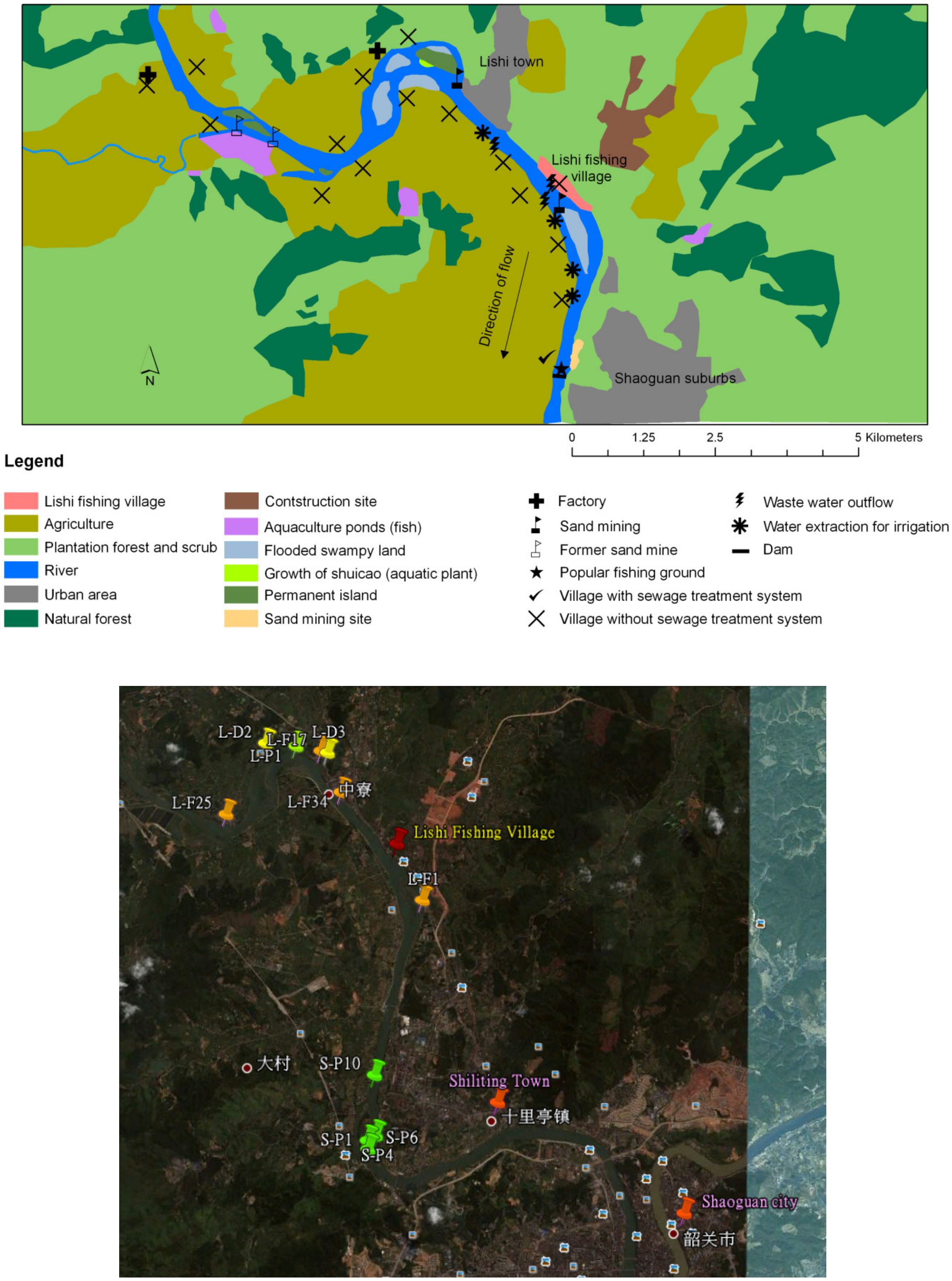

Figure 6. The site map of Lishi fishing village (left) and the sampling sites for aquatic species (right)

In the right map, the orange pins denote the sampling points for fish, yellow pins for dragonflies, green pins for aquatic plant species. Codes e.g. **L-D3** mean **L** for **L**ishi fishing village, **D** is for **D**ragonflies, and **3** is the sampling point number **3**. A full list of the sampling points can be found in Annex I.

3. Biodiversity within the Beijiang River

To inform the Integrated Action Plan (IAP) we need to know what aquatic species are present in the Beijiang River particularly at the 3 fishing villages, which species contribute to local livelihoods and what their conservation status are. Literature reviews, IUCN Red List assessments, field surveys, market investigation and household visits were undertaken to identify the aquatic species present within the three fishing villages along the Beijiang River.

3.1. Chosen taxonomic groups

The taxonomic groups chosen to be included in these analyses are fishes, molluscs, aquatic plants and dragonflies (odonates). Some fish and mollusc species are very important for the livelihood of fishers providing food and income, and molluscs, bivalves in particular (being sedentary filter feeders), odonates (rely on water for their juvenile life stage) and some aquatic plants are very sensitive to habitat quality and pollution. By identifying the presence and status of these species we will be able to recommend management actions to secure sustainable use and livelihoods and monitor environmental quality at the sites. This work will also allow us to identify any species that may not be important for livelihoods, but are of conservation concern, again allowing for suitable recommendations to be made in the IAPs.

3.2. Conservation status of biodiversity - IUCN Red List assessments

There are several methods of determining species conservation status and the most commonly used tool is the IUCN Red List Categories and Criteria (IUCN 2001), which allows consistency in approach across different taxonomic groups. It helps in determining the relative risk of extinction at a global scale and provides the basis for understanding if a species is Extinct, threatened (Critically Endangered, Endangered or Vulnerable), Near Threatened, of Least Concern, or lacking sufficient basic data for assessment (Data Deficient) (see Figure 7). The IUCN Red List of Threatened Species™ publishes the results of the global assessments (www.iucnredlist.org). The IUCN Red List also provides basic information on species taxonomy, distributions, habitat and ecology, threats, population trends, use and trade, livelihood information, ecosystem services provided, and research and conservation priorities.

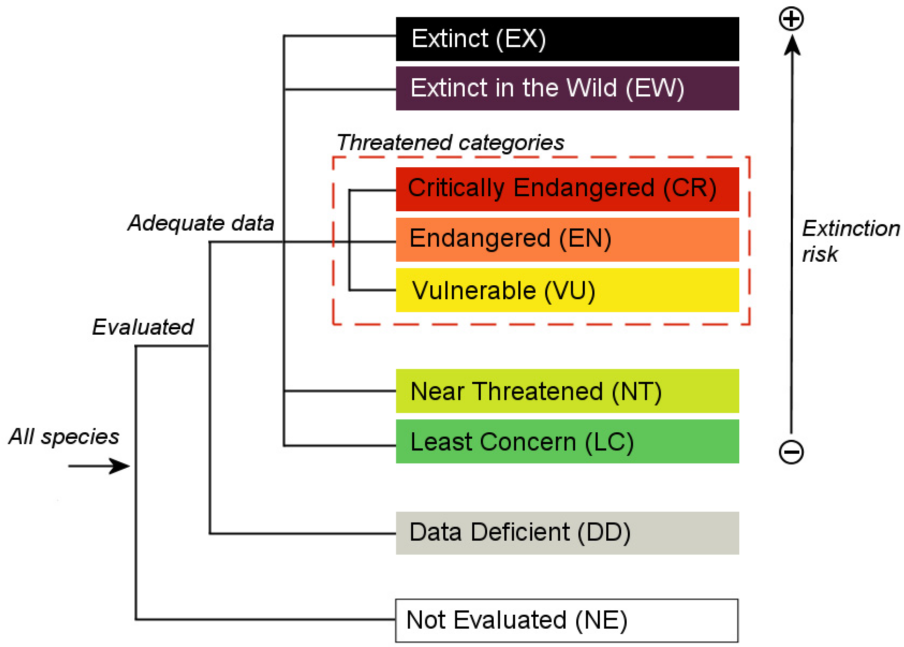

Figure 7. IUCN Red List Categories

Biodiversity experts from the HighARCS project partners, including from SCAU, were trained at a workshop (06-09 June 2009, Kolkata, India) in the use of the IUCN Species Information Service (SIS – the Red List species database), application of the IUCN Red List Categories and Criteria (IUCN 2001) (see Annex II for a summary of the IUCN Red List Criteria), and Geographic Information Systems (GIS) for digitally mapping species distributions. Following the training workshop, experts collated native species lists of freshwater fishes, dragonflies and damselflies (odonates), freshwater molluscs and aquatic plants for the Pearl River catchment (Figure 2), and input within the SIS, all available information on each species. The required data fields (with standard classification schemes) within SIS are species taxonomy, distribution, habitat and ecology, threats, population trends, use and trade, and research and conservation priorities, Red List Category and rationale. Data gaps were filled and corrections made to the data from another overlapping IUCN project (Freshwater biodiversity assessment of Indo-Burma) which is funded by the Critical Ecosystem Partnership Fund (www.cepf.org). These species were then reviewed at a second workshop (17-22 January 2011, Vientiane, Lao P.D.R.) and via email communications with other species experts after the workshop. The IUCN Indo-Burma project is due to be published in March 2012.

While these species will not all found at the fishing villages, it will allow the actions proposed through the IAP to take into consideration any globally threatened species within the wider catchment if necessary. It will also allow for all the species identified at the site, to be put into a global conservation context. For example a species may be stable and numerous at the site with no known threats and perceived locally as not being of conservation concern, but at a global scale the species may be threatened to impacts elsewhere within the species range, this would make the population at the site of high conservation concern. Alternatively, global conservation status is not the only aspect to identify important species at the site. A species may be of Least Concern globally but may be undergoing severe declines at the site and may also be of economic and livelihood concern and would therefore potentially qualify as a species to be incorporated into the IAP.

The resulting dataset allows 238 fish species, 62 molluscs and 207 odonates, and 233 aquatic plants species to be identified as present in the Pearl River wider catchment as shown in Figure 2. A list of these species with their IUCN Red List Category can be found in Annex III. An extract of the globally threatened species from the Pearl River catchment can be found in Table 1. There are 2 Extinct (both fishes), 12 Critically Endangered, 9 Endangered, and 6 Vulnerable species (4 odonates, 20 fishes, 2 plants and 1 mollusc).

Table 1. Globally threatened (those listed as Critically Endangered, Endangered and Vulnerable) and Extinct species found within the Pearl River catchment.

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Order	Family	Binomial	IUCN Red List Category
Dragonflies & damselflies			
Odonata	Aeshnidae	*Cephalaeschna dinghuensis*	CR
Odonata	Gomphidae	*Gomphidia kelloggi*	EN
Odonata	Macromiidae	*Macromia katae*	VU
Odonata	Megapodagrionidae	*Philosina alba*	VU
Fishes			
Acipenseriformes	Acipenseridae	*Acipenser sinensis*	CR
Cypriniformes	Balitoridae	*Yunnanilus pleurotaenia*	VU
Cypriniformes	Cobitidae	*Paralepidocephalus yui*	EN
Cypriniformes	Cyprinidae	*Anabarilius andersoni*	CR
Cypriniformes	Cyprinidae	*Anabarilius liui yiliangensis*	EN*
Cypriniformes	Cyprinidae	*Anabarilius macrolepis*	EX
Cypriniformes	Cyprinidae	*Anabarilius qiluensis*	CR
Cypriniformes	Cyprinidae	*Anabarilius yangzonensis*	CR
Cypriniformes	Cyprinidae	*Bangana decorus*	CR
Cypriniformes	Cyprinidae	*Cyprinus chilia*	EN
Cypriniformes	Cyprinidae	*Cyprinus fuxianensis*	CR
Cypriniformes	Cyprinidae	*Cyprinus ilishaestomus*	CR
Cypriniformes	Cyprinidae	*Cyprinus yilongensis*	EX
Cypriniformes	Cyprinidae	*Cyprinus yunnanensis*	CR
Cypriniformes	Cyprinidae	*Parasinilabeo assimilis*	VU
Cypriniformes	Cyprinidae	*Poropuntius chonglingchungi*	CR

	Order	Family	Binomial	IUCN Red List Category
	Cypriniformes	Cyprinidae	*Pseudohemiculter dispar*	VU
	Cypriniformes	Cyprinidae	*Ptychidio jordani*	CR
	Cypriniformes	Cyprinidae	*Sinocyclocheilus tingi*	EN
	Cypriniformes	Cyprinidae	*Sinocyclocheilus yangzongensis*	CR
	Cypriniformes	Cyprinidae	*Tor yunnanensis*	EN
	Siluriformes	Cranoglanididae	*Cranoglanis bouderius*	VU
Molluscs				
	Architaenioglossa	Viviparidae	*Margarya mansuyi*	EN
Plants				
	Alismatales	Alismataceae	*Sagittaria lichuanensis*	EN
	Hydrocharitales	Hydrocharitaceae	*Ottelia acuminata*	EN*

Of these, only five species, all of them fish, are found within the Beijiang catchment. *Cranoglanis bouderius* (VU) is recorded from China in the Zhu Jiang River where it is distributed in Beijiang River at Yingde south of Shaoguan City, in the Xijiang River from Wuzhou to Longzhou, Liucheng and Zhaoping, at Funing County in Yunnan and at Anlong in Guizhou Province. The species was once common, but has declined drastically in the last twenty years, due to overfishing and increasing levels of pollution and habitat loss. *Parasinilabeo assimilis* (VU) is recorded from the Xijiang tributaries, Beijiang tributaries, and also from the Xiangjiang (a tributary of the Yangtze River). It is estimated that due to the impact of dams, overfishing, and pollution in recent years the species range has drastically reduced with recent surveys in Guangxi, Guangdong and other provinces not recording the species. *Bangana decorus* (CR) is known from Yunnan, Guangdong, and Guangxi Provinces in China. Dams impact the Beijiang, disrupting the species migration, and pollution from agriculture impacts all rivers. Recent surveys (2005-2009) in the Beijiang found only 10-20 specimens per year, and the population is estimated to have declined by 80% in 15 years (three generations). *Acipenser sinensis* (CR), the Chinese sturgeon is now extirpated from the Pearl River, and currently only occurs in the middle and lower reaches of the Yangtze river and close to shore in the Yellow and East China Sea, there is just one remaining spawning ground (a 4 km stretch of river), which is situated below the Gezhouba dam. The species has historically been overfished, its migrations have been blocked by dams and it is impacted by water pollution across its range. *Pseudohemiculter dispar* (VU) is usually found in the area to the south of Chang Jiang (Yangtze) River in China and is also known from the Mekong and Nam Ma basins in Lao PDR, central and northern Viet Nam. The species is impacted by high levels of pollution and major hydrological changes within the range of this species, in particular in the Mekong and Yangtze river basins and its population is suspected to have declined by more than 30% in the past 10 years.

The vast majority of the threatened species in the Pearl River catchment (17 fishes and 1 mollusc) are found far from the HighARCS project sites and are endemic to lakes in the very upper Xijiang catchment in Yunnan. *Cyprinus yilongensis* and *Anabarilius macrolepis* are now both extinct but were endemic to Yilong Lake are considered to have gone extinct when Yilong Lake dried up as a result of water abstraction for agriculture in 1981. Five species are assessed as Critically Endangered ‘Possibly

Extinct'. *Anabarilius qiluensis, Cyprinus ilishaestomus* and *Cyprinus yunnanensis* which are all endemic to Qilu Lake and haven't been recorded in fisheries since the late 1970's early 1980's, it is thought that the introduction of non-native fishes in the 1960s caused their declines and possible extinction. *Anabarilius yangzonensis* (CR Possibly Extinct) is only recorded from Yangzong Lake. Recent surveys in 2008 did not find any specimens of the fish and it is suspected that the population has crashed as a result of pollution, as well as introduced fish species, and overexploitation. *Poropuntius chonglingchungi* (CR Possibly Extinct) is only known from Fuxian Lake and has been impacted by introduced species, the loss of spawning grounds (through the construction of aquaculture ponds and tourism development) and overfishing and has not been collected in surveys since the 1980s. The other threatened species from these lakes are the cyprinids; *Anabarilius andersoni* (CR), *Cyprinus chilia* (EN), *Cyprinus fuxianensis* (CR), *Sinocyclocheilus tingi* (EN), *Sinocyclocheilus yangzongensis* (CR) and *Tor yunnanensis* (EN) the loaches (Balitoridae and Cobitidae); *Yunnanilus pleurotaenia* (VU) and *Paralepidocephalus yui* (EN) and the mollusc (gastropod) *Margarya mansuyi* (EN). All these species are being impacted by pollution, introduced species (usually to improve fish catches), and overharvesting.

The four threatened odonate species are all found around the Pearl River delta and Hong Kong, where their terrestrial habitats have been lost due to development and their aquatic habitats polluted. The two threatened plant species may be found within the Beijiang catchment but specific locality data could not be found. *Sagittaria lichuanensis* (EN) is no longer found in Guangdong Province, and it is thought that the species now only occurs in small patches of swamps in Fujian, Jiangxi, Hubei, and Guizhou. The species has been impacted by overgrazing and agricultural chemical pollution. *Ottelia acuminata* (EN*) is widespread in southern China but has seen a significant decline in population (particularly in Yunnan) due to pollution.

3.3. Fishes

3.3.1. Literature review

The first step of undertaking a species survey was to undertake a comprehensive literature review to try and identify what species may have been recorded at the sites. Through the review of sixty one publications (see below), 119 species of fishes have identified as being previously recorded in the Pearl River system (Table 2). This is different to the figure generated through the Red List assessments (237 fish species) as the Red List assessments also use expert opinion and unpublished data to help generate species distributions.

All the globally threatened species identified through the literature survey are discussed above in section 3.2, apart from *Cyprinus barbatus* (from Erhai Lake, Yunnan) and *Yunnanilus nigromaculatus* (Dianchi Lake and Yangling Lake, Yunnan) as according to the Red List assessments are not found within the Pearl River Catchment. Out of the 118 species identified, only five species have been evaluated for the Chinese national Red List. Only two of these are not listed as threatened by IUCN *Atrilinea roulei* and *Siniperca roulei*. *Atrilinea roulei* (black striped minnow) is assessed as 'Rare' in the China National Red List and Least Concern by IUCN. It is endemic to China, known from the Qiantang Jiang (River) in Zhejiang Province, Guangxi (present in Tayaoshan nature reserve, and Shiwandashan) and Anhui Province, China. The China national Red List states the species population is extremely small and has been impacted by deforestation and soil erosion and destructive fishing methods but the IUCN

Red List states that the species may be naturally rare. *Siniperca roulei* (slender mandarin) is listed as VU on the China national Red List and Data Deficient by IUCN. The species population has declined mostly due to overfishing but also pollution. The IUCN DD listing states that it may qualify for a threatened category if further information on the level of exploitation and threat from habitat degradation becomes available, meaning more data is required to be able identify the threatened category. Forty of the 119 species have been identified through the literature review to have a declining population within the Pearl River catchment, and only three of these species have no economic or livelihood importance. *Anguilla marmorata* (marbled eel) is an economically important species that has seen a sharp decline within the Pear River. It has suffered primarily to dams and weirs blocking its migratory route from the ocean to the middle and upper stretches of the river where its spawning grounds are located. Only one species *Hypseleotris compressocephalus*, has a population that is increasing. The remaining 77 species have an unknown population trend.

The literature review also identifies that many species are important for livelihoods, either through providing food, income or used as medicine. Only 14 species (11% of all the species identified) have been identified as having no value. Species used as food (either commercial or local use) is the dominant use with 95 species (80%) being harvested for this purpose, and 12 species (10%) are utilised for the aquarium trade.

Table 2. Fish species identified from the Pearl River based on literature surveys.

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Species binomial	National Red List status	IUCN Red List	Economic or livelihood value	Population trend in catchment	Source
Acantopsis arenae	Not Evaluated	DD	None.	Unknown	Zheng 1989
Acheilognathus taenianalis	Not Evaluated	LC	None.	Unknown	Zheng 1989
Acrossocheilus beijiangensis	Not Evaluated	LC	Ornamental fish and a food fish.	Decline	Chen, X., J.-H. Pan, Z. Liu and D. Liang. 1991.
Acrossocheilus labiatus	Not Evaluated	NA	Ornamental fish and a food fish.	Unknown	Shen, S.C. (ed.). 1993
Acrossocheilus parallens	Not Evaluated	LC	Ornamental fish and a food fish.	Unknown	Chen, X., 1991
Acrossocheilus rendahli	Not Evaluated	NT	Ornamental fish and a food fish.	Unknown	Chen, X., 1991
Acrossocheilus wenchowensis	Not Evaluated	DD*	Ornamental fish and a food fish.	Unknown	Chen, X., 1991
Anabarilius liui ssp. Yiliangensis	Not Evaluated	EN*	Food fish.	Decline	Luo, Y. And Chen, Y. 1998.
Anabarilius macrolepis	Not Evaluated	EX	Food fish.	Considered to have gone extinct in the	Luo, Y. And Chen, Y. 1998.

Species binomial	National Red List status	IUCN Red List	Economic or livelihood value	Population trend in catchment	Source
				1970s	
Anabarilius maculatus	Not Evaluated	DD	Food fish.	Unknown	Zhou, W. And Cui, G.-H. 1992
Anabarilius qiluensis	Not Evaluated	CR	Food fish.	The species has not been recorded since the 1980's	Zhou, W. And Cui, G.-H. 1992
Anabarilius yangzonensis	Not Evaluated	CR	Food fish.	Considered to be almost extinct	Zhou, W. And Cui, G.-H. 1992
Anguilla marmorata	Not Evaluated	LC	Commercial fisheries.	Sharp declines	Shiao *et al.* 2003
Atrilinea roulei	Rare	LC	Food fish.	Unknown	Liu, K. And W. Zhou. 2009
Balitora longibarbata	Not Evaluated	LC	None.	Possibly a naturally scarce population	Chen, Y. And Tang, W. 2000
Bangana decorus	Not Evaluated	CR	Food fish.	Declined	Liu, K. And W. Zhou. 2009
Bangana wui	Not Evaluated	DD	Food fish.	Unknown	Zhang, E., Yue, P. And Chen, J. 2000
Beaufortia cyclica	Not Evaluated	LC	None	Unknown	Chen, Y. And Tang, W. 2000
Beaufortia kweichowensis ssp. Gracilicauda	Not Evaluated	NA	Food fish.	Unknown	Zheng, C.-Y. 1991
Beaufortia kweichowensis ssp. Kweichowensis	Not Evaluated	NA	Food fish.	Unknown	Zheng, C.-Y. 1991
Beaufortia pingi	Not Evaluated	LC	None	Unknown	Chen, Y. And Tang, W. 2000
Beaufortia polylepis	Not Evaluated	LC	Food	Unknown	Chen, Y. And W. Tang. 2000
Cranoglanis bouderius	Not Evaluated	VU	Food fish.	Decline	Zheng, C. 1989
Culter recurviceps	Not Evaluated	LC	Food fish.	Decline	Zheng, C. 1989
Cyprinus barbatus	Not Evaluated	CR	Previously important in fisheries	Possibly Extinct	Luo, Y. And Yue, P. 2000
Cyprinus chilia	Not Evaluated	EN	Commercial and local fisheries	Endange-red	Yang, J.-X. 1991

Species binomial	**National Red List status**	**IUCN Red List**	**Economic or livelihood value**	**Population trend in catchment**	**Source**
Cyprinus ilishaestomus	Endangered	CR	Commercial fisheries.	Possibly Extinct	Wang, S. 1998
Cyprinus longzhouensis	Not Evaluated	DD	Food fish.	Decline	Zhang, W. 1998
Cyprinus multitaeniata	Not Evaluated	NT	Commercial fisheries.	Near Threaten-ed	Huang, H.C. 1987
Cyprinus yilongensis	Extinct	EX	Food fish.	Extinct	Xiawuping. 1963
Cyprinus yunnanensis	Endangered	CR	Commercial fisheries.	Possibly Extinct	Zhou Wei. 1990
Discogobio tetrabarbatus	Not Evaluated	LC	Food fish.	Unknown	Cui, G.-H., W. Zhou and J.-H. Lan. 1993.
Discogobio yunnanensis	Not Evaluated	LC	Food fish.	Unknown	Zheng, L. And W. Zhou. 2008
Distoechodon tumirostris	Not Evaluated	LC	Food fish.	Unknown	Shen, S.C. (ed.). 1993
Formosania tinkhami	Not Evaluated	LC	Food fish.	Unknown	Zheng, C.-Y. 1991
Garra orientalis	Not Evaluated	LC	Food fish.	Unknown	Huang, H.C. 1987
Garra yiliangensis	Not Evaluated	DD	Food fish.	Possibly Extinct	CHU XIN-LUO CUI GUI-HUA. 1987
Glossogobius olivaceus	Not Evaluated	LC	Commercial fisheries.	Decline	Thi, N. N. And Quan, N. V. 2006
Glyptothorax fokiensis	Not Evaluated	LC	Food fish.	Decline	Zhengciyin. 1989
Glyptothorax pallozonus	Not Evaluated	NT	Ornamental fish.	Near Threaten-ed	Zhengciyin. 1989
Gnathopogon taeniellus	Not Evaluated	DD	None.	Unknown	Yue, P. 1998
Gobiobotia longibarba	Not Evaluated	DD*	Food fish.	Unknown	ZHANG E; LIU Huan-zhang. 1995
Gobiobotia tungi	Not Evaluated	NT	Food fish.	Near Threaten-ed	Y.Y. Chen.1998
Hemibagrus macropterus	Not Evaluated	LC	Commercial and local fisheries	Unknown	Nelson, J.S. 1994
Hemibarbus longirostris	Not Evaluated	NT	Commercial fisheries.	Decline	Matsuura, K. And T. Yoshino. 1984
Hemiculter lucidus	Not	LC	Commercial fisheries.	Unknown	Bogutskaya,

Species binomial	National Red List status	IUCN Red List	Economic or livelihood value	Population trend in catchment	Source
	Evaluated				N.G. and Naseka, A.M. 1996
Hemiculter tchangi	Not Evaluated	DD	Minor commercial fisheries.	Unknown	Luo, Y. And Y. Chen. 1998
Hemiculterella sauvagei	Not Evaluated	LC	Minor commercial fisheries.	Unknown	Lu, K. 1991
Hemimyzon macroptera	Not Evaluated	LC	Food fish.	Unknown	Zhengciyin. 1989
Huigobio chenhsienensis	Not Evaluated	LC	Minor commercial and local fisheries	Unknown	Yue, P. 1998
Hypophthalmichthys molitrix	Not Evaluated	NT	Food fish.	Decline	Skelton, P.H. 1993
Hypseleotris compressocephalus	Not Evaluated	LC	None.	Increase	Zhengciyin. 1989
Leptobotia guilinensis	Not Evaluated	LC	Food fish.	Unknown	Zhu, S.-Q. 1995
Leptobotia pellegrini	Not Evaluated	LC	Food fish.	Unknown	Ye, G. 1991
Liniparhomaloptera disparis ssp. disparis	Not Evaluated	NA	Food fish.	Unknown	Zhengciyin. 1989
Megalobrama amblycephala	Not Evaluated	LC	Food fish.	Unknown	Zhu, S.-Q. 1995
Micronemacheilus pulcher	Not Evaluated	LC	Ornamental species.	Unknown	Zhengciyin. 1989
Microphysogobio chinssuensis	Not Evaluated	LC	Food fish.	Unknown	Zhu, S.-Q. 1995
Microphysogobio fukiensis	Not Evaluated	LC	Food fish.	Unknown	Jin, X. 1991
Microphysogobio kiatingensis	Not Evaluated	LC	Food fish.	Unknown	Jin, X. 1991
Microphysogobio tafangensis	Not Evaluated	LC	Ornamental fish and a food fish.	Unknown	Yue, P. 1998
Microphysogobio tungtingensis	Not Evaluated	NT	None	Decline	Zhang, T. And Li, Z. 2007
Neosalanx tangkahkeii	Not Evaluated	LC	Commercial and local fisheries	Unknown	Froese, R. And Pauly, D. 2010
Odontobutis obscura	Not Evaluated	Introduced	Commercial and local fisheries.	Unknown	Shao, K.-T. And Lim, P.L. 1991
Onychostoma barbatum	Not Evaluated	DD	Minor commercial fisheries.	Decline	Shan, X., Lin, R., Yue, P. And Chu, X. 2000
Onychostoma rarum	Not	DD	Used in local fisheries	Decline	Shan, X., Lin,

Species binomial	National Red List status	IUCN Red List	Economic or livelihood value	Population trend in catchment	Source
	Evaluated				R., Yue, P. And Chu, X. 2000
Parabotia banarescui	Not Evaluated	DD	Food fish.	Unknown	Zhu, S.-Q. 1995
Parabotia lijiangensis	Not Evaluated	DD	Ornamental fish and a food fish.	Unknown	Zhu, S.-Q. 1995
Parabotia maculosa	Not Evaluated	LC	Food fish.	Unknown	Zhengciyin. 1989
Paracobitis variegatus ssp. variegatus	Not Evaluated	NA	Food fish.	Unknown	Wu, Y. And Wu, C. 1992
Paralepidocephalus yui	Not Evaluated	EN	Food fish.	Decline	Zhengciyin. 1989
Paranemachilus genilepis	Not Evaluated	DD	Ornamental fish.	Unknown	Zhengciyin. 1989
Parasinilabeo assimilis	Not Evaluated	VU	Commercial and local fisheries.	Decline	Kottelat, M. And E. Zhang. 2003
Pareuchiloglanis longicauda	Not Evaluated	LC	Food fish.	Unknown	Chu xin luo. 1999
Pelteobagrus argentivittatus	Not Evaluated	LC	Commercial and local fisheries.	Unknown	IUCN. 2010
Percocypris pingi	Not Evaluated	NT	Commercial fisheries and aquaculture.	Decline	Wu, Y. And C. Wu. 1992
Platysmacheilus exiguus	Not Evaluated	LC	Minor commercial and local fisheries	Unknown	Jin, X. 1991
Poropuntius chonglingchungi	Not Evaluated	CR	Minor commercial and local fisheries	Possibly Extinct	Zhang, E. And F. Fang. 2005
Pseudobagrus albomarginatus	Not Evaluated	DD*	Food fish.	Unknown	IUCN. 2010
Pseudobagrus ondon	Not Evaluated	LC	Food fish.	Unknown	IUCN. 2010
Pseudogastromyzon changtingensis ssp. changtingensis	Not Evaluated	NA	Food fish.	Unknown	Zhang, E., Yue, P. And Chen, J. 2000
Pseudogastromyzon fangi	Not Evaluated	LC	Food fish.	Unknown	Zheng, C. 1989
Pseudogastromyzon myersi	Not Evaluated	LC	None.	Unknown	Zheng, C. 1989
Pseudogobio vaillanti	Not Evaluated	LC	Commercial and local fisheries.	Unknown	Zhengciyin. 1989
Pseudogyrinocheilus prochilus	Not Evaluated	LC	Food fish.	Unknown	Zhengciyin. 1989
Pseudolaubuca engraulis	Not Evaluated	LC	Food fish.	Unknown	Y.Y. Chen, X.L. Chu, Y.L. Luo,

Species binomial	National Red List status	IUCN Red List	Economic or livelihood value	Population trend in catchment	Source
					Y.R. Chen, H.Z. Liu, M.G. He et al. 1998
Pseudorasbora elongata	Not Evaluated	LC	Minor ornamental fish	Unknown	Yue P.-Q. And Chen Y.-Y
Pterocryptis anomala	Not Evaluated	LC	Food fish.	Unknown	HEOK HEE NG and BOSCO P.-L. CHAN. 2005
Ptychidio jordani	Not Evaluated	CR	Food fish.	Endanger	Zhengciyin. 1989
Ptychidio macrops	Not Evaluated	DD	Food fish.	Unknown	Zhengciyin. 1989
Rectoris luxiensis	Not Evaluated	DD	Food fish.	Unknown	Zhengciyin. 1989
Rhodeus fangi	Not Evaluated	LC	Ornamental fish and livestock fodder.	Unknown	Zhengciyin. 1989
Rhodeus lighti	Not Evaluated	LC	Unknown.	Unknown	Y.Y. Chen, X.L. Chu, Y.L. Luo, Y.R. Chen, H.Z. Liu, M.G. He et al. 1998
Rhodeus sinensis	Not Evaluated	LC	Livestock fodder.	Unknown	Zhengciyin. 1989
Sarcocheilichthys kiangsiensis	Not Evaluated	DD*	None.	Unknown	Zhengciyin. 1989
Sarcocheilichthys parvus	Not Evaluated	LC	Potential ornamental fish.	Unknown	Zhengciyin. 1989
Sarcocheilichthys sinensis	Not Evaluated	LC	Commercial fisheries.	Decline	Zhengciyin. 1989
Schizothorax wangchiachii	Not Evaluated	NT	Food fish.	Unknown	Huang, H.C. 1987
Silurus meridionalis	Not Evaluated	LC	Aquaculture fish.	Unknown	Xie xiao jun. 1996
Sinibotia zebra	Not Evaluated	DD	Food fish.	Unknown	Kottelat, M. 2004
Sinibrama macrops	Not Evaluated	LC	Common commercial fisheries.	Decline	Zhengciyin. 1989
Siniperca fortis	Not Evaluated	DD	Food fish.	Unknown	Zhengciyin. 1989
Siniperca obscura	Not Evaluated	LC	Food fish.	Unknown	Zhengciyin. 1989
Siniperca roulei	Vulnerable	DD	Ornamental fish and food fish.	Decline	Zhengciyin. 1989

Species binomial	**National Red List status**	**IUCN Red List**	**Economic or livelihood value**	**Population trend in catchment**	**Source**
Siniperca undulata	Not Evaluated	NT	A highly prized commercial fish.	Unknown	Yue P.-Q. And Chen Y.-Y. 1998
Sinocyclocheilus guilinensis	Not Evaluated	NA	None.	Unknown	Yahui Zhao. 2009
Sinocyclocheilus tingi	Not Evaluated	EN	Food fish.	Decline	Xiong fei. 2006
Sinocyclocheilus yangzongensis	Not Evaluated	CR	Food fish.	Decline	Gao Li Cun. 1980
Sinogastromyzon sichangensis	Not Evaluated	LC	Commercial and local fisheries.	Unknown	Zheng, C. 1989
Sinogastromyzon szechuanensis	Not Evaluated	LC	Food fish.	Unknown	Zhengciyin. 1989
Sinogastromyzon wui	Not Evaluated	LC	Food fish.	Unknown	Zheng, C. 1989
Squalidus wolterstorffi	Not Evaluated	LC	Food fish.	Unknown	Hwang, H.C., Chen, I.Y. and Yueh, P.C. 1988
Tachysurus fulvidraco	Not Evaluated	LC	Important food fish, aquaculture.	Unknown	Zheng, b. And d. Dai 1999
Takifugu orbimaculatus	Not Evaluated	LC	Medicinal use.	Decline	Zhengciyin. 1989
Tor yunnanensis	Not Evaluated	EN	None.	Possibly extinct	Xiong fei. 2006
Vanmanenia pingchowensis	Not Evaluated	LC	Food fish.	Unknown	Zhengciyin. 1989
Onychostoma barbatulum	Not Evaluated	DD	Food fish.	Decline	Zhengciyin. 1989
Yaoshanicus arcus	Not Evaluated	LC	None.	Unknown	Zhengciyin. 1989
Yunnanilus nigromaculatus	Not Evaluated	EN	None .	Possibly extinct	Zheng, C. 1989

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3.3.2. Field survey methods

The information provided by the literature is not at a high enough resolution to allow us to identify the species at the three fishing villages and some of the information is out of date as the environmental conditions at the sites have changed significantly in recent years. Therefore we undertook a field survey, market survey and interviewed fishermen to identify what species are found at the sites.

Market surveys

Small local markets situated near the three sampling fishing villages (Lishi, Kengkou and Zhoutian) were visited 6 times in total, in 2009 and 2010. At each market the fish stall holders were surveyed and species were identified. Information on the location the species were harvested from, who the fishers are, catch trends (according to the stall holder) were noted, and the value of different fish species were recorded. Photographs of fishes were taken.

Field surveys

In August 2010, fishers were accompanied to their fishing sites and their catches and location (using a GPS) on where species were caught was recorded. The methods used by the fishers were:

Nets: Gillnets are versatile, low cost, and easy to operate. The size of the nets used was usually 1.5 meters high and 60-80 meters long (Figure 8).

Other methods: Traps come in a wide range of sizes and designs including net-trap (Figure 8), small ‘basket traps’ and ‘fence traps’ which direct the fish into baskets.

The locations of fish field surveys in the three fishing villages are shown in Figures 4, 5 and 6.

Figure 8. Nets (left) and net-trap (right) for fishing in Beijiang River, China

3.3.3. Field survey results

Distribution of fish resources along river

The richness of fish resources of each fishing ground of the three villages were differentiated into 3 types: low, normal or rich fish resources. Usually fish resources were rich behind the dams of hydropower stations with deep water, and poor in front of the dams or in certain sections of the river with shallow water (the areas of rich fish resources are noted in the site maps in Figures 4, 5 and 6).

Fish species composition

A total of 26 species of freshwater fishes, belonging to 23 genera, 7 families and 3 orders were found in the 3 fishing villages, 3 of which are non native species (Table 3 and 4). Among them, there are 20 species of cypriniformes, making up 76.9% of the total, 4 species of perciformes, or 15.4% of the total, 2 species of siluriformes, or 7.7% of the total (Table 4, Figures 9). Further information regarding the species economic importance, habitat, IUCN Red List status and population trends is provided in Table 5. Figure 10 shows some of the fish species photographed during the fish surveys.

Table 3. The proportion of species belonging to each order

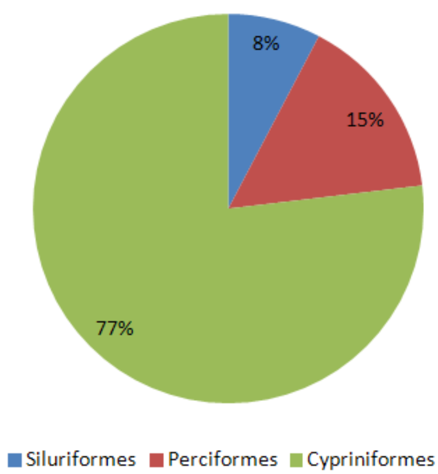
Order	Family	Genus	Species	Percentage
Siluriformes	2	2	2	7.7%
Perciformes	3	3	4	15.4%
Cypriniformes	2	18	20	76.9%
total	7	23	26	100.0%

Table 4. Fish species from the survey in the 3 fishing villages and their higher taxonomy

Species	Family	Order	Location
Micronoemacheilus pulcher	Balitoridae	Cypriniformes	Zhoutian
Schistura fasciolata	Balitoridae	Cypriniformes	Zhoutian
Schistura incerta	Balitoridae	Cypriniformes	Lishi
Sinibotia robusta	Cobitidae	Cypriniformes	Lishi

Species	Family	Order	Location
Sinibotia pulchra	Cobitidae	Cypriniformes	Lishi
Cobitis sinensis	Cobitidae	Cypriniformes	Lishi, Zhoutian
Misgurnus anguillicaudatus	Cobitidae	Cypriniformes	Lishi, Zhoutian, Kengkou
Metzia formosae	Cyprinidae	Cypriniformes	Lishi
Pseudohemiculter dispar	Cyprinidae	Cypriniformes	Lishi, Zhoutian, Kengkou
Toxabramis houdemeri	Cyprinidae	Cypriniformes	Lishi, Zhoutian, Kengkou
Sarcocheilichthys parvus	Cyprinidae	Cypriniformes	Lishi, Zhoutian, Kengkou
Pseudogobio vaillanti	Cyprinidae	Cypriniformes	Lishi, Zhoutian, Kengkou
Abbottina rivularis	Cyprinidae	Cypriniformes	Lishi, Zhoutian, Kengkou
Microphysogobio fukiensis	Cyprinidae	Cypriniformes	Lishi
Saurogobio dabryi	Cyprinidae	Cypriniformes	Lishi, Zhoutian, Kengkou
Rhodeus lighti	Cyprinidae	Cypriniformes	Lishi, Zhoutian, Kengkou
Acheilognathus tonkinensis	Cyprinidae	Cypriniformes	Lishi, Zhoutian, Kengkou
Puntius semifasciolatus	Cyprinidae	Cypriniformes	Lishi, Zhoutian, Kengkou
Cyprinus carpio carpio	Cyprinidae	Cypriniformes	Lishi, Zhoutian, Kengkou
Carassius auratus auratus	Cyprinidae	Cypriniformes	Lishi, Zhoutian, Kengkou
Pterocryptis cochinchinensis	Siluridae	Siluriformes	Lishi, Zhoutian, Kengkou
Tachysurus fulvidraco	Bagridae	Siluriformes	Lishi, Zhoutian, Kengkou
Rhinogobius giurinus	Gobiidae	Perciformes	Lishi, Zhoutian, Kengkou
Macropodus opercularis	Osphronemidae	Perciformes	Lishi, Zhoutian, Kengkou
*Macrognathus aculeatus**	Mastacembelidae	Perciformes	Lishi
Mastacembelus armatus	Mastacembelidae	Perciformes	Lishi, Zhoutian, Kengkou

**Macrognathus aculeatus* – this record is probably misnamed as due to taxonomic revision this species is now only found in Indonesia.



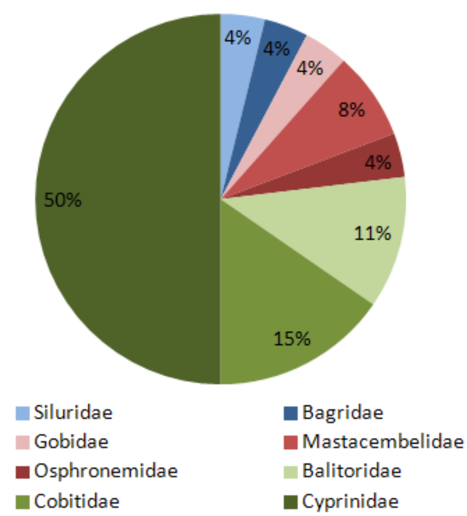


Figure 9. Proportion of species identified at the 3 fishing villages belonging to different orders (left) and families (right)

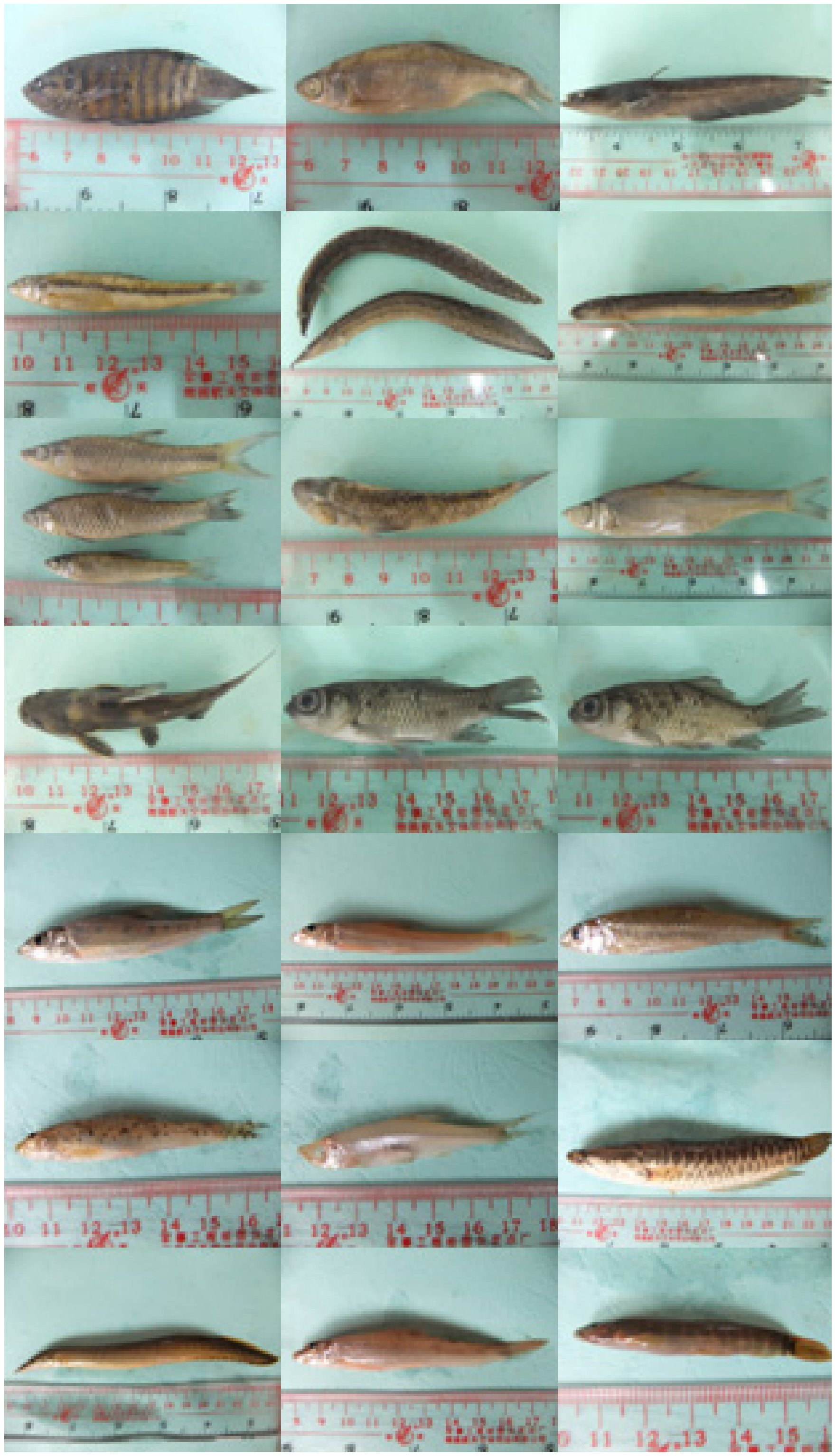


Figure 10. Photos of some of the fish specimens from Beijiang River

Table 5. Fish species identified from the three fishing villages through field and market surveys

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Species binomial	National Red List status	IUCN Red List	Economic importance	Population trends at the site	Habitat/sample site recorded from
Micronemacheilus pulcher	Not Evaluated	LC	None	Unknown	Streams on sand and gravel bottom.
Schistura fasciolata	Not Evaluated	DD	None	Unknown	Rapid current streams.
Schistura incerta	Not Evaluated	DD*	None	Unknown	Streams on the bottom.
Sinibotia robusta	Not Evaluated	DD	Commercial fisheries	Unknown	Inhabit in bottom parts of clear flowing water with sandy bottoms.
Sinibotia pulchra	Not Evaluated	DD*	None	Unknown	Inhabit in bottom parts of streams and main rivers in clear, moderately or slowly flowing water with some aquatic plants.
Cobitis sinensis	Not Evaluated	LC*	Subsistence fisheries	Unknown	Benthopelagic
Misgurnus anguillicaudatus	Not Evaluated	LC*	Commercial fisheries	It is a common but declining species in Beijiang River.	Found in rivers, lakes and ponds.
Metzia formosae	Vulnerable	LC	None	Unknown	Clear, still or slow moving waters of small rivers
Pseudohemiculter dispar	Not Evaluated	VU	Important commercial fisheries	It is a common but declining species in Beijiang River.	Benthopelagic
Toxabramis houdemeri	Not Evaluated	LC	None	Unknown	Benthopelagic
Sarcocheilichthys parvus	Not Evaluated	LC	None	Unknown	Bottom parts of clear flowing water with gravel bottoms.
Pseudogobio vaillanti	Not Evaluated	LC	Commercial fisheries	Unknown	Benthopelagic
Abbottina rivularis	Not Evaluated	Not Evaluate d	Important commercial fisheries	Increasing	Inhabits shallow zones of lentic rivers and lakes with sandy or muddy bottoms.
Microphysogobio fukiensis	Not Evaluated	LC	None	Unknown	Benthopelagic

Species binomial	National Red List status	IUCN Red List	Economic importance	Population trends at the site	Habitat/sample site recorded from
Saurogobio dabryi	Not Evaluated	LC*	Low economic value	Unknown	Benthopelagic
Rhodeus lighti	Not Evaluated	LC	None	Unknown	Bottom parts of streams and main rivers.
Acheilognathus tonkinensis	Not Evaluated	DD	Likely to be found in local fisheries	Unknown	Inhabits bottom parts of streams and main rivers in clear, moderately or slowly flowing water with some aquatic plants.
Puntius semifasciolatus	Not Evaluated	DD*	None	Unknown	Benthopelagic
Cyprinus carpio	Not Evaluated	Introduced	Important commercial fisheries	Increasing	Inhabit warm, deep, slow-flowing and still waters
Carassius auratus	Not Evaluated	LC	Important commercial fisheries	Increasing	Benthopelagic
Pterocryptis cochinchinensis	Not Evaluated	LC	Commercial fisheries	Unknown	Benthopelagic
Tachysurus fulvidraco	Not Evaluated	LC	Commercial fisheries	Unknown	Benthopelagic
Rhinogobius giurinus	Not Evaluated	LC	Subsistence fisheries	Unknown	Inhabits bottom parts of streams and main rivers in clear flowing water with sandy or gravel bottoms.
Macropodus opercularis	Not Evaluated	LC	None	Unknown	Found in streams, paddy fields and ditches.
*Macrognathus aculeatus**	Not Evaluated	NA	Commercial fisheries and aquarium trade	Unknown	Benthopelagic
Mastacembelus armatus	Not Evaluated	LC	Commercial fisheries and aquarium trade	Unknown	Benthopelagic
Channa maculata	Not Evaluated	LC	Commercial fisheries	Unknown	The species inhabits silty and weedy bottoms of still water or slow-running river with lots of caves and aquatic vegetation to hide.

**Macrognathus aculeatus* – this record is probably a different species as due to taxonomic revision this species is now only found in Indonesia.

Of the species identified at the sites, only *Pseudohemiculter dispar* is globally threatened (discussed in section 3.2), and *Metzia formosae* is nationally threatened. *Metzia formosae* is a widespread species known from southeast Asia in southern China, Lao P.D.R. and Viet Nam and it is thought that the species may be impacted by pollution and dams. The majority of the species population trends at the site are unknown, but two species are known to be declining *Pseudohemiculter dispar* and *Misgurnus anguillicaudatus*. Three species have populations that are currently increasing at the sites *Abbottina rivularis*, *Carassius auratus* and the introduced *Cyprinus carpio*. Over half of the species have value to livelihoods, either through subsistence fisheries (4 species) or through commercial fisheries (12 species), 11 species have no direct livelihood value.

It is important to note that for the species where the populations trends are 'unknown', it should not be assumed that they are stable or increasing. Historically, the fish resources in Beijiang River were very rich with harvests reaching 8,000 tons annually in the 1950's. The species captured included eel (*Anguilla japonica*), grass carp (*Ctenopharyngodon idella*), black Chinese roach (*Mylopharyngodon piceus*), mud carp (*Cirrhinus molitorella*), triangular bream (*Megalobrama terminalis*), eastern barbell (*Squaliobarbus curriculus*), *Spinibarbus hollandi*, spotted long barbell catfish (*Hemibagrus guttatus*), and some local rare species, such as *Sinilabeo decorus*, *Sinilabeo discognathoides*, *Ptychidio jordani*, *Tor (Folifer) brevifilis*. However, fish resources have been decreasing, and the annual fishing production has not been more than 2,000 tons since 2000. Most of the fish species captured were of the low valued species such as *Saurogobio dabryi*. The traditionally high value economic species such as *Pseudohemiculter dispar* and *Misgurnus anguillicaudatus* are decreasing. The only species that are known to be increasing at the site are the non-native species *Cyprinus carpio* and the native *Carassius auratus*. Although the total aquatic production was continuously increasing since 1970, but the percentage from river fishing are decreasing. Species of conservation concern such as the Asian giant soft-shell turtle (*Pelochely bibroni*), marbled eel (*Anguilla marmorata*), hilsa herring (*Macrura reevesii* Richardson), wattle-necked soft-shell turtle (*Palea steindachneri*), *Luciobrama macrocephalus* (Lacépède, 1803) are very rare in north river today (Le, 1998).

3.4. Molluscs

3.4.1. Literature review

There is limited information available on the mollusc fauna of the Beijiang River. Only two publications have been identified, and are listed below. Through these publications 40 species of freshwater molluscs have been identified to occur in the Pearl River (Table 6). All of the species identified are globally assessed on the IUCN Red List as Least Concern or Data Deficient. However two species both gastropods, are classed as threatened on the Chinese national Red List, *Bellamya limnophila* (EN) and *Cipangopaludina ampulliformis* (VU). *Bellamya limnophila* is endemic to China and recorded from the lakes in Yunnan province and the eastern provinces and is threatened by water pollution, overharvesting and destructive fishing methods. IUCN classify this species as DD as the assessors question the validity of this species as a distinct species and state it needs taxonomic revision. *Cipangopaludina ampulliformis* is found in southern and eastern China and central Viet Nam, it has a small and fragmented population in China that is slowly declining due to overharvesting and water pollution (Sung and Yan 2005). Only four species have no direct livelihood value, with the vast majority providing either food for humans or livestock, medicine or are even used for art and jewellery purposes (buttons or pearls).

Table 6. Mollusc species identified from Pearl River based on literature surveys.

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient. NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Species binomial	Common name	National Red List status	IUCN Red List	Economic importance	Population trends at the site/wider catchment	Source
Pila tischbeini	none	Not evaluated	NA	Food species.	Unkown	Yueying L. et al., 1979
Assiminea lutea	none	Not evaluated	LC*	None	Unkown	Yueying L. et al., 1979
Corbicula nitens	clam	Not evaluated	DD*	Used for food, animal feed and traditional Chinese medicine	Unkown	Yueying L. et al., 1979
Alocinma longicornis	Angle bean snail, B snail	Not evaluated	LC*	Used for animal feed	Unkown	Yueying L. et al., 1979
Parafossarulus striatulus	None	Not evaluated	LC*	Used for animal feed	Unkown	Yueying L. et al., 1979
Stenothyra glabra	None	Not evaluated	LC	Used for animal feed	Unkown	Yueying L. et al., 1979
Radix plicatula	Lymnaea, mark snail	Not evaluated	LC*	Used for animal feed	Unkown	Yueying L. et al., 1979
Limnoperna lacustris	none	Not evaluated	LC*	Important for local livelihoods (for food and animal feed)	Unkown	Yueying L. et al., 1979
Gyraulus chinensis	none	Not evaluated	LC	Used for feed	Unkown	Yueying L. et al., 1979
Tricula gregoriana	Ge's Tricula aperta	Not evaluated	DD*	None	Unkown	Yueying L. et al., 1979
Semisulcospira cancellata	none	Not evaluated	LC*	Used for animal feed	Unkown	Yueying L. et al., 1979
Acuticosta chinensis	clam	Not evaluated	LC	Used as raw material for making buttons and art ware, and also as animal feed	Unkown	Yueying L. et al., 1979
Acuticosta lanceolata	Banana clam	Not evaluated	NA	Some importance for local livelihoods (buttons, art ware and animal feed)	Unkown	Yueying L. et al., 1979
Acuticosta ovata	none	Not evaluated	LC	Used for buttons, art ware and animal	Unkown	Yueying L. et al., 1979

Species binomial	Common name	National Red List status	IUCN Red List	Economic importance	Population trends at the site/wider catchment	Source
				feed		
Anodonta fluminea	clam	Not evaluated	NA	Use for food, animal feed and traditional Chinese medicine	Unkown	Yueying L. et al., 1979
Anodonta globosula	Food clam	Not evaluated	NA	Little economic use	Unkown	Yueying L. et al., 1979
Cuneopsis capitata	Old duck lips	Not evaluated	LC	Use for food, animal feed and traditional Chinese medicine	Unkown	Yueying L. et al., 1979
Cuneopsis celtiformis	none	Not evaluated	LC	Use for food, animal feed and traditional Chinese medicine	Unkown	Yueying L. et al., 1979
Cuneopsis heudei	Lair thief, cone clam	Not evaluated	LC	Use for food, animal feed and traditional Chinese medicine	Unkown	Yueying L. et al., 1979
Cuneopsis pisciculus	Ox horn	Not evaluated	LC	Use for food, animal feed and traditional Chinese medicine	Unkown	Yueying L. et al., 1979
Hyriopsis cumingii	Trigonioides	Not evaluated	LC	Commercial use for producing freshwater pearls, and used for food, animal feed, buttons and art ware	Declining in the catchment	Yueying L. et al., 1979
Lamprotula caveata	none	Not evaluated	LC	Use for buttons and art ware	Unkown	Yueying L. et al., 1979
Lamprotula fibrosa	Old wozi	Not evaluated	LC	Important use buttons and art ware	Unkown	Yueying L. et al., 1979
Lamprotula leai	Pig ears clam	Not evaluated	LC	Important use buttons and art ware	Declining in the catchment	Yueying L. et al., 1979
Lamprotula mansuyi	Buddha ears clam, White jade clam	Not evaluated	NA	Use for food, animal feed, buttons and traditional Chinese medicine	Declining in the catchment	Yueying L. et al., 1979
Lamprotula tientsinensis	White jade clam	Not evaluated	DD	Important use for buttons and art	Unkown	Yueying L. et al., 1979

Species binomial	Common name	National Red List status	IUCN Red List	Economic importance	Population trends at the site/wider catchment	Source
				ware		
Lamprotula zonata	none	Not evaluated	DD	Use for buttons and art ware	Unkown	Yueying L. et al., 1979
Lanceolaria gladiola	Salt note, Long clam	Not evaluated	LC	Used for food, animal feed and buttons	Unkown	Yueying L. et al., 1979
Lanceolaria triformis	Salt note	Not evaluated	DD	Used for food, animal feed and buttons	Unkown	Yueying L. et al., 1979
Lepidodesma languilati	Green shell clam	Not evaluated	DD	Used for food and animal feed	Unkown	Yueying L. et al., 1979
Schistodesmus lampreyanus	Gold and silver bread， lake clam	Not evaluated	LC	Used for food, animal feed, buttons and traditional Chinese medicine	Unkown	Yueying L. et al., 1979
Schistodesmus spinosus	Gold and silver bread	Not evaluated	LC	Little economic use	Unkown	Yueying L. et al., 1979
Angulyagra polyzonata	none	LC	LC	Used for food and animal feed	Distribute widely	Yueying L. et al., 1979
Bellamya aeruginosa	stone clam	LC	LC*	Used for food and animal feed	Distribute widely	Yueying L. et al., 1979
Bellamya limnophila	snail	EN	DD	Used for food	Population is small	Wangsong et al., 2004
Bellamya purificata	snail	LC	LC	Used for food, animal feed and traditional Chinese medicine	Distribute widely	Yueying L. et al., 1979
Bellamya quadrata	snail, stone clam	LC	LC	Important use for food, animal feed and traditional Chinese medicine	Distribute widely	Yueying L. et al., 1979
Cipangopaludina ampulliformis	field clam	VU	LC	Very important use for food and animal feed	The population is small	Yueying L. et al., 1979, Wangsong et al., 2004
Cipangopaludina cathayensis	snail	LC	LC	Very important use for food and animal feed	Distribute widely	Yueying L. et al., 1979
Cipangopaludina chinensis	snail	LC	LC	Important use for food, animal feed and traditional Chinese medicine	Distribute widely	Yueying L. et al., 1979

Reference used for molluscs literature review:

1. Yueying, L., Wenzhen, Z., Yuexian, W. and Enyi, W. 1979. Economic animal fauna of China (Freshwater molluscs) [M]. Beijing. Science Press.
2. Sung, W and Yan, X. 2005. China Species Red List. Volume 3 Invertebrates. Biodiversity Working Group of China Council for International Cooperation on Environment and Development. Higer Education Press.

3.4.2. Field survey methods

A field species survey along with fishermen interviews were undertaken as the information provided by the literature was not at a high enough resolution to allow us to identify the species at the three fishing villages, also the information could be out of date as the environmental conditions at the site have changed significantly in recent years.

The mollusc field surveys were carried out in August 2010 and the locations were the same as for the fish surveys (see Figures 4, 5 and 6). The sampling methods used were as follows.
1 - Hand-sampling - This is only feasible in the shallow margins or bank of rivers.
2 - Using a hand-net (triangle net see Figure 11) - Used in shallow and easily accessible water.
3 - Fishing nets - Fishermen often catch molluscs along with fish using fish nets.

Figure 11. Hand-net (triangle net) used for sampling molluscs

3.4.3. Field survey results

Eight species of freshwater mollusc were recorded at the three fishing villages, one of which is a non-native introduced species (Table 7). All of the species are either Least Concern or Data Deficient according to their global IUCN Red List status, but one species *Cipangopaludina ampulliformis* is classed as Vulnerable by the Chinese national Red List (discussed in 3.4.1.). All the species have some form of livelihood value as all are harvested either for animal feed or human use as medicine or food.

Table 7. Molluscs species from the three sites in Beijiang River through field surveys.

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Species binomial	Common name *(local name)*	National Red List status	IUCN Red List	Economic importance	Population trends at the site	Habitat/sample site recorded from
Corbicula fluminea	Gold clam, yellow clam	Not Evaluated	LC	Important as food, animal feed, and traditional Chinese medicine. It can also be used for calcined lime CaO	Unknown	Lishi, Kengkou and Zhoutian.
Semisulcospira libertina	Chuan quan snail	Not Evaluated	LC	Used for animal feed	Common	Lishi, Kengkou and Zhoutian.
Melanoides tuberculatus	Chuan quan snail	Not Evaluated	LC	Used for animal feed	Unknown	Lishi
Semisulcospira sp.	None	Not Evaluated	DD	Used for animal feed	Unknown	Lishi, Kengkou and Zhoutian.
Cipangopaludina chinensis	snail	LC	LC	Important use for food, animal feed and traditional Chinese medicine	Distributed widely	Lishi, Kengkou and Zhoutian.
Cipangopaludina ampulliformis	field snail	VU	DD	Very important use for food and animal feed	Small population and sensitive to declines in habitat quality	Lishi, Kengkou and Zhoutian.
Angulyagra polyzonata	none	LC	LC	Used for food and animal feed	Distributed widely	Lishi
Ampullaria gigas	Fu Shou snail	Not Evaluated	Introduced species	Used for animal feed	Common	Lishi, Kengkou and Zhoutian.

Indicator species

Benthic organisms (such as molluscs) are valuable bio-indicators for water quality, especially for the quality of water and sediment. For example, *Cipangopaludina chinensis* is very sensitive to polluted water, and *Semisulcospira libertina* is very sensitive to even slightly polluted water (Deng *et al*. 2007). Since a lot of *Semisulcospira libertina* can be caught from the three sampling sites, it indicates that the water and sediment of the investigated water was not seriously polluted at present. Both these species can be used as indicators to monitor water quality through regular field surveys.

Threats to molluscs

There are very few surveys on mollusc resources in the Beijiang in recent years. Through interviews with fishermen, the number of species and numbers individuals has been found reducing gradually. The main reasons are as follows: (1) The habitats of many mollusc species have been destroyed by dams and dredging etc; (2) Water pollution is increasing with pyrite, and oil; (3) Major floods, the last in 2006, which bring large levels of sand and sediment which cover the molluscs and their habitats (4) Over-harvesting, also there is no artificial breeding or stocking; (5) The invasion of the introduced *Ampullariua gigas* (native specie of Amazon River basin, and introduced into China in 1981). A large number of apple snail (*Ampullarius gigas*) was found in the water surveyed. Due to its rapid growth, amphibious nature, strong reproduction ability and adaptability, it has spread and formed populations in most parts of south China, and now threatens biodiversity and ecosystems where it is found (Yang et al, 2010). Therefore, some preventive and control measures should be taken, again without having a negative impact to the native mollusc fauna.

Economic significance and human disease control

Some large molluscs such as *Corbicula fluminea, Cipangopaludina chinensis* and *Cipangopaludina ampulliformis* provide good prospects for market development. For example, *Corbicula fluminea* has great aquaculture development prospects (nutritious and popular). It can be processed into dry clam or even processed in to canned product (Deng and Tang, 2007). However, of the 8 species of mollusc listed in Table 8, most of them are an intermediate host of human and livestock parasites (Liu *et al.,* 1979; Li *et al.,* 2009). It is important that the prevention and control of parasites (or the molluscs) is undertaken without harming the sustainable utilisation of the mollusc species.

3.5. Decapods (shrimps and crabs)

In addition to the groups that were specifically targeted for surveys, shrimps and crabs deserve a brief discussion as they are popular species caught by fishermen. Common species caught are *Procambarus clarkii* (Louisiana crayfish**)**, *Macrobranchium nipponense* (Giant Freshwater Prawn) and *Eriocheir sinensis* (Chinese mitten crab). However, *Procambarus clarkii* is an invasive alien species native to south-eastern United States, and holds a competitive advantage over native species and may damage the native ecology.

3.6. Aquatic plants

Aquatic plants are essential elements in aquatic ecosystems. They play an important role in food chains, energy flow, and the ecological succession of the aquatic ecosystems. Many species are also sensitive to pollution from urbanization and industrialization. Therefore, the aquatic plants have been chosen to be surveyed at the sites. The information obtained can reveal the potential impact of the economic development and urbanization on the aquatic resources in the Pearl River.

3.6.1. Literature review

According to Yu *et al.* (1998) there are 2 Extinct, 16 Endangered, 31 Vulnerable, 22 Rare and 44 Uncertain species of aquatic plants in China. Through reviewing the published literature and national and regional botanical monographs, a total of 233 aquatic plants were recorded in the Pearl River region – these are the species that had their IUCN Red List assessments undertaken (see section 3.2 and Annex III). For Guangdong Province, 101 vascular aquatic plant species have been identified, 8 are submerged plants, 16 are emergent, and 5 are floating and 72 are classed as wetland (surviving in wet or water logged ground) (Table 8) (Yan 1989).

Table 8. Aquatic plants and their growth form present in Guangdong Province (Yan 1989).

	Submerged plants	Floating plants	Emergent plants	Wetland plant
Families	20	7	37	111
Genera	5	3	13	22
Species	8	5	16	72

There was very little information available on the aquatic plants of the Beijiang River. Based on literature available, only 17 aquatic plant species from 5 families and 11 genera have been identified as present in the Beijiang River, this is likely to be a large underestimate of the true number. Hydrocharitaceae and Potamogetonaceae have the most species present, the former having 6 genera and 8 species while the latter has 2 genera and 5 species (Table 9). Most aquatic plant species recorded in Beijiang River are widespread and categorized as Least Concern in the IUCN list.

Table 9. Aquatic plant species identified from Beijiang River based on literature surveys.

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient. The categories CR, EN and VU are classed as the 'threatened' categories.

Species binomial	National Red List status	IUCN Red List	Economic importance	Population trends at the site/wider catchment	Source
Blyxa aubertii	Not in the list	LC	unknown	No information	Ye *et al.* 2006
Blyxa octandra	Not in the list	LC	unknown	No information	Ye *et al.* 2006
Ceratophyllum demersum	Not in the list	LC	Ornamental plant; used for ecological restoration	No information	Ye *et al.* 2006
Hydrilla verticillata	Not in the list	LC	Fodder for fish and water purifying	No information	Ye *et al.* 2006
Myriophyllum spicatum	Not in the list	LC	Ornamental plant	No information	Ye *et al.* 2006
Myriophyllum verticillatum	Not in the list	Introduced	Ornamental plant	No information	Ye *et al.* 2006
Najas marina	Not in the list	LC	Fodder for fish	No information	Ye *et al.* 2006
Nechamandra alternifolia	Not in the list	LC	unknown	No information	Ye *et al.* 2006
Ottelia alismoises(*O. dioecia*)	Not in the list	LC	Chinese medicine	No information	Ye *et al.* 2006

Species binomial	National Red List status	IUCN Red List	Economic importance	Population trends at the site/wider catchment	Source
Potamogeton crispus	Not in the list	LC	Fodder for fish	No information	Ye *et al.* 2006
Potamogeton distinctus	Not in the list	LC	Fodder for fish	No information	Wu *et al.* 1992
Potamogeton pusillus	Not in the list	LC	Fodder for fish	No information	Ye *et al.* 2006
Potamogeton wrightii (*Potamogeton malaianus*)	Not in the list	LC	Fodder for fish	No information	Ye *et al.* 2006
Stuckenia pectinata (Potamogeton pectinatus)	Not in the list	LC	unknown	No information	Yan 1989; Ye *et al.* 2006
Utricularia aurea	Not in the list	LC	Ornamental plant	No information	Ye *et al.* 2006
Vallisneria denseserrulata	Not in the list	NA	Fodder for fish	No information	Yan 1989; Ye *et al.* 2006
Vallisneria natans	Not in the list	LC	Fodder for fish	No information	Ye *et al.* 2006

The references used in the aquatic plant review are listed below.

1 - Bao, B., Clemants, S.E., Thomas, B. 2003. In Wu Zhengyi. Flora of China. Vol. 9. Beijing: Science Press. 415-429

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3.6.2. Field survey methods

The aquatic plant surveys were conducted at the three sites within the Beijiang River watershed between 2009 and 2010 (see Figure 4, 5 and 6 for survey site locations). Line-transects were used to estimate the species composition and distribution of the submerged plant communities. A quadrat with an area of 1m X 1m was set up at a distance of 2m. In each quadrat, water depth, species composition, coverage, and heights of the submerged plants were recorded.

At Lishi the field surveys were undertaken between July and December in 2010. The submerged plant communities are located in the middle of the river covering an area of about 1,000 m^2 at a depth of about 1-2m (see Figures 12 and 13). At Kengkou Fishing Village the surveys were conducted in October 2009 and September 2010 and no submerged plant community was observed, but some specimens of floating plants were found in the water near the banks (invasive water hyacinth) (Figures 14). The third site Rujiang River near the town of Rucheng, was surveyed in October 2009. The river banks have been paved with concrete (Figure 15) and the water is clear and clean and the depth is 2-3.5m. The most common submerged plant identified was *Potamogeton wrightii* (Figure 16).

Figure 12. The river section along Lishi fishing village that is wide and deep

Figure 13. Aquatic plants found near Lishi fishing village.

Figure 14. River section along Kengkou Fishing Village with water hyacinth

Figure 15. Rujiang river section along Rucheng, which is clear and clean

Figure 16. *Potamogeton wrightii* in the Rujiang river section along Rucheng

3.6.3. Field survey results

A total of 11 species belonging to 4 families and 6 genera of submerged vascular plant species were found in our study sites, including 5 species of Potamogetonaceae and 4 species of Hydrocharitaceae (Table 10, Figure 17). Rujiang and Lishi had 9 and 8 species recorded respectively, 5 species were recorded in Kengkou and only 1 species in Zhoutian. Only one species, *Vallisneria natans*, was found in all four sites. *Hydrilla verticillata*, *Myriophyllum spicatum*, and *Potamogeton wrightii* were seen in all sites apart from Zhoutian. *Ceratophyllum demersum* and *Potamogeton crispus* were each found in two sites. *Potamogeton maackianus*, *P. pusillus*, and 2 species of Najas were all confined to one site, Lishi.

Table 10. Submerged plant species identified from site Beijiang through field surveys.

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not Assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

S1：Lishi；S2：Kengkou；S3：Zhoutian；S4：Rujiang.

Species binomial	National Red List status	IUCN Red List	Economic importance	Population trends at the site	Habitat/sample site recorded from	Habitat/sample site recorded from			
						S1	S2	S3	S4
Ceratophyllum demersum	Not assessed	LC	Ornamental plant for home decoration, used for ecological restoration	Declining due to habitat degradation. Rare or locally common.	Shallow areas with water depth between 0.3-2 m.	+	-	-	+
Hydrilla verticillata	Not assessed	LC	Used for raising pond fish and water purifying	Locally common, but declining due to habitat degradation	Intermediate areas between muddy and sandy sediments with water depth between 0.2-1.2 m.	+++	++	-	+
Myriophyllum spicatum	Not assessed	NA	Ornamental plant for home decoration and wetland planting in parks; fodder for raising livestock; used as medicinal plant and water purifying	Locally common, but declining due to habitat degradation	Shallow areas with water depth between 0.3-2.8 m.	+	+	-	+
Najas marina	Not assessed	LC	Used as fodder for fish ponds	Declining due to habitat degradation. Rare or locally	Only found in the shallow sediment river sections with	+++	-	-	-

Species binomial	**National Red List**	**IUCN Red List**	**Economic importance**	**Population trends at the site**	**Habitat/sample site recorded**	**Habitat/sample site recorded from**			
				common.	water depth between 0.3-1 m.				
Najas minor	Not assessed	LC	Used as fodder for fish ponds	A rare species declining due to habitat degradation	Growing in the habitats same to *Najas marina.*	++	-	-	-
Potamogeton crispus	Not assessed	NA	Used for water purifying	A rare species declining due to habitat degradation	Shallow or deep river sections with water depth between 0.2-1.8 m.	-	+	-	+
Potamogeton distinctus	Not assessed	LC	Used as fodder for livestock and as a fertilizer	A rare species declining due to habitat degradation	Shallow muddy beds near river banks with water depth between 0.3-1.3 m.	-	-	-	+
Potamogeton maackianus	Not assessed	LC	Used as fodder for livestock and as a fertilizer	A rare species declining due to habitat degradation	Central river sections with water depth between1-2.3 m.	-	-	-	++
Potamogeton pusillus	Not assessed	NA	Used as fodder for livestock and as a fertilizer	A rare species declining due to habitat degradation	Shallow muddy beds near river banks with water depth between 0.2-1.2 m.	-	-	-	++
Potamogeton wrightii	Not assessed	LC	Used as fodder for fish ponds and livestock, as a medicine, and for water purifying	Locally common, but declining due to habitat degradation	Muddy or sandy river sections with water depth between 0.2-3 m. Adapted to varied water flows.	++	++	-	+++

Species binomial	National Red List	IUCN Red List	Economic importance	Population trends at the site	Habitat/sample site recorded	Habitat/sample site recorded from			
Vallisneria natans	Not assessed	LC	Used as fodder for fish ponds; used for fertilizer and medicine; also used as raw materials of biogas, and as a food.	Declining due to habitat degradation. Rare or locally common.	Shallow muddy areas with water depth between 0.3-1 m.	+++	+++	++	+


a


b


c


d


e


f


g


h

i

j

a: *Potamogeton wrightii*; b. *P. crispus*; c. *Najas marina*; d. *N. graminea*; e. *Ceratophyllum demersum*; f. *Hydrilla verticillata*; g. *Myriophyllum verticillata*; h. *Vallisneria natans*; i. *Potamogeton pusillus*; j. *Chara* sp.

Figure 17. Photos of aquatic plant species collected from the three sites in the Beijiang River

3.6.4. Indicator species

Most aquatic plants in the sites are globally widespread and adaptive plants, all assessed as Least Concern. However, their distributions in our research sites are uneven. This implies that they are sensitive to the environment and have specific habitat needs. Some species could be used as indicators for water pollution and changes in natural flow regimes. For example, *Vallisneria natans* prefers muddy river beds (also found by You *et al.* 1994), *Potamogeton wrightii* is more likely found on sandy beds, while *Hydrilla verticillata* was commonly found in the intermediate areas between muddy and sandy sites. *Hydrilla verticillata* and *Vallisneria natans* are potential indicator species for long-term monitoring (see f. and h. in Figure 17) as they are found at all three sites though the populations were generally small and sparsely distributed, they are key food for fish and crabs (Xiong and Yao 2000, Lin *et al.* 2005) and therefore have great impacts on aquaculture success. Currently, the information on their ecological and phonological characteristics is still lacking and the impact of the local environment on their population development needs to be further studied.

3.6.5. Threats to aquatic plants at the sites

Based on our field surveys and discussions with the locals at the fishing villages, aquatic plant communities in Beijiang River have drastically declined in the past few decades. The major threats to aquatic plants in Lishi, Zhoutian and Kengkou are the dams (hydropower stations), sand mining, and industrial pollution. The dams have altered the water level and water flow regime of the river which has greatly affected the growth and distributions of the aquatic plants. Frequent and severe sand mining has also destroyed river bed habitats and added large amounts of sand in to the water impacting and covering submerged plants. Water pollution from industrial sources and domestic, have also threatened aquatic plants. In Rujiang, which has the highest species richness, the major threats to aquatic plants are the regular cutting for fodder and the artificially draining of wetlands. Rujiang has the best because water quality, then Lishi and Zhoutian, with the worst being Kengkou. The number of species at these sites partly reflects this difference in water quality, with Rujiang having 9 species, Lishi 8, Kengkou 5 and Zhoutian 1.

3.7. Odonata (dragonflies and damselflies)

Guangdong Province has been regarded as one of biodiversity hotspots for Odonata in China (Wilson and Xu 2007, 2008) but the overwhelming majority of the information comes from headwater streams at remote mountain areas in Guangdong Province. Like other Chinese large rivers, the Odonata fauna in the Beijiang River is poorly known. Not being a popular species, for most local people, all Odonata species are regarded as one name, i.e. 'Qingting' (means dragonfly). Therefore a literature survey was not possible and a field survey was necessary to identify the Odonata fauna in the Beijiang River.

3.7.1. Field survey methods

Odonata surveys were conducted at three sites in the Beijiang River on the 28 and 29 October 2010 (see Figures 4, 5 and 6). The survey methods included observation of species on the wing and while resting using binoculars, netting to capture adults and kick sampling in streams and other aquatic habitats for sampling for larvae.

Lishi Site (Figure 6): Location near Lishi Town, Shaoguan. Three sites were investigated along the Wujiang River, a main tributary of the Beijiang River at altitudes between 63-72m. Site L-D1 (24.8766N, 113.5447E) has deep water near a highway and can be navigated by ferry and ships (Figures 19 and 20). Site L-D2 (24.9012N, 113.5103E) is located on a river bend at a pool where the current is very slow (Figures 21 and 22). Site L-D3 (24.8993N, 113.5236E) is located at a dredging sand site where dredging vessels and fishing boats can be found (Figures 23 and 24).

Zhoutian Site (Figure 4): Location near Zhoutian Town, Shaoguan. Two sites were surveyed along the Zhenjiang River, a main tributary of the Beijiang River at altitudes between 69-78m. Site Z-D1 (24.9267N, 113.8356E) the habitat is damaged by dredging sand (Figures 25 and 26) and site Z-D2 (24.9820N, 113.8846E) is located downstream of a hydropower station at a riffle area near the confluence the Zhenjiang River with a small stream (Figures 27, 28 and 29).

Kengkou Site (Figure 5): Location near Dakengkou Town, Shaoguan. Two sites were sampled along Wushi-Kengkou reach in the Beijiang River. This section is difficult to survey the river bank because it is separated by a railway system between the road and river bank. Site K-D1 (24.5099N, 113.5808E) is located near a village where the river width is about 250 m (Figures 30 and 31). Site K-D2 (24.5200N, 113.5933E) is located by a small tributary of the Beijiang River (Figure 32).

Figure 19. Site 1 in Lishi (Wujiang River)

Figure 20. Site 2 in Lishi (Wujiang River)

Figure 21. Site 2 in Lishi (Wujiang River)

Figure 22. Electric fishing at Site 2 in Lishi

Figure 23. Dragonflies survey at site 3 in Lishi

Figure 24. Dredging sand vessels at site 3 in Lishi

Figure 25. Dredging sand site at site 1 in Zhoutian (Zhenjiang River)

Figure 26. Dredging sand at site 1 in Zhoutian (Zhenjiang River)

Figure 27. Upriver of Site 2 in Zhoutian at a hydropower station (Zhenjiang River)

Figure 28. Downriver of Site 2 in Zhoutian


Figure 29. Kick sampling for larvae at Site 2 in Zhoutian (Zhenjiang River)


Figure 30. Site 1 in Kengkou (Beijiang River)


Figure 31. Site 1 in Kengkou (Beijiang River)


Figure 32. Site 2 of Kengkou (tributary of Beijiang River)

3.7.2. Field survey results

Twenty five Odonata species were identified during the survey (Table 11). All the species are very common and widely distributed in all kinds of freshwater habitat, although their population trends at the sites are not known. All species are assessed as Least Concern on the IUCN Red List. Their photos are shown in Figure 33. Lishi had 23 species recorded, Zhoutian 11 and Kengkou only 1 species. Of all the species recorded only two species were not found in Lishi *Matrona basilaris* and *Onychothemis testacea*, both of which are only found in Zhoutian. The only species found in Kengkou, *Orthetrum sabinam*, is also found in the two other sites.

Table 11. Odonata species identified from Beijiang River through field surveys

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Species binomial	National Red List status	IUCN Red List	Economic importance	Population trends at the site	Habitat/sample site recorded from		
					Lishi	KengKou	Zhoutian
Anax parthenope julis	NA	LC	No direct importance	unclear	site 1 site 2		site 2
Epophthalmia elegans	NA	LC	No direct importance	unclear	site 2		
Ictinogomphus	NA	LC	No direct	unclear	site 2		

Species binomial	**National Red List status**	**IUCN Red List**	**Economic importance**	**Population trends at the site**	**Habitat/sample site recorded from**		
pertinax			importance				
Brachythemis contaminata	NA	LC	No direct importance	unclear	site 2 site 3		
Orthetrum pruinosum neglectum	NA	LC	No direct importance	unclear	site 2		Site 2
Orthetrum sabina sabina	NA	LC	No direct importance	unclear	site 2	Site 2	
Orthetrum glaucum	NA	LC	No direct importance	unclear	site 2		Site 2
Sympetrum darwinianum Selys	NA	LC	No direct importance	unclear	site 2		
Sympetrum eroticum ardens	NA	LC	No direct importance	unclear	site 2		Site 2
Sympetrum risi risi Bartenev	NA	NA	No direct importance	unclear	site 2		
Tholymis tillarga	NA	LC	No direct importance	unclear	site 2		
Tramea virginia Rambur	NA	LC	No direct importance	unclear	site 2		
Trithemis aurora	NA	LC	No direct importance	unclear	site 2 site 3		Site 2
Libellago lineata	NA	LC	No direct importance	unclear	site 2 site 3		
Copera marginipes	NA	LC	No direct importance	unclear	site 2		Site 2
Ceriagrion auranticum ryukyuanum Asahina	NA	LC	No direct importance	unclear	site 2 site 3		Site 2
Ischnura senegalensis	NA	LC	No direct importance	unclear	site 2		
Pseudagrion pruinosum fraseri Schmidt	NA	LC	No direct importance	unclear	site 2		
Pseudagrion rubriceps rubriceps Selys	NA	LC	No direct importance	unclear	site 2		
Pseudagrion spencei Fraser	NA	LC	No direct importance	unclear	site 2 site 3		
Prodasineura autumnalis	NA	LC	No direct importance	unclear	site 2		
Crocothemis servilia servilia	NA	LC	No direct importance	unclear	Site 3		Site 1 Site 2

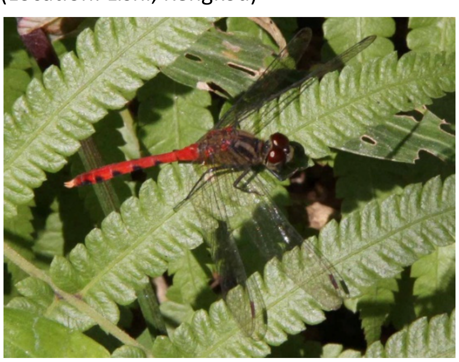
Species binomial	National Red List status	IUCN Red List	Economic importance	Population trends at the site	Habitat/sample site recorded from		
Pantala flavescens	NA	LC	No direct importance	unclear	Site 3		Site 2
Matrona basilaris Selys	NA	LC	No direct importance	unclear			Site 2
Onychothemis testacea *tonkinensis* Martin	NA	LC	No direct importance	unclear			Site 2

Ictinogomphus pertinax (Hagen in Selys, 1854) (Location: Lishi)

Sympetrum darwinianum Selys, 1883 (Location: Lishi)

Orthetrum sabina sabina (Drury, 1770) (Location: Lishi, Kengkou)

Orthetrum pruinosum neglectum (Rambur, 1842) (Location: Lishi, Zhoutian)



Sympetrum eroticum ardens (McLachlan, 1854) (Location: Lishi, Zhoutian)

Sympetrum risi risi Bartenev, 1914 (Location: Lishi)

Matrona basilaris
(Location: Zhoutian)

Pseudagrion rubriceps rubriceps Selys, 1876
(Location: Lishi)

Neurobasis chinensis(Location: Lishi)

Pseudagrion spencei Fraser, 1922 (Location: Lishi)

Figure 33 Photos of some Odonata species found during the field surveys (All photos by Tong Xiaoli)

3.7.3. Indicator species

Dragonflies (Odonata) have been widely used as indicators of environmental quality in freshwater ecosystems (Samways 1993, Chovanec and Waringer 2001). They live in a wide range of aquatic habitats, are easy to record and identify at the species level, and they respond clearly to environmental variation. However, there is debate over which is the best, adult or larvae, as the suitable stage to monitor as the indicator. Adults may not respond well to changes in water quality due to being predominantly aerial, their mobility might also limit their value in indicating local habitat quality because adults can occur at sites where they do not breed (Corbet 1993). Odonata larvae are more directly dependent on the aquatic environment, and have the added advantage of occurring over a more prolonged period than adults (Corbet 1993; Osborn and Samways 1996). Even though none of the species have been identified as being particularly habitat specific, the number of species declined in polluted areas. Kengkou for example is the most polluted of the sites (it receives water after the river has flowed through Shaoguan City) has only one odonate species recorded. Also in recent years, SCAU Odonata team have studied the dragonfly larvae taxonomy in southern China (Zhang & Tong, 2009a, 2009b, 2010; Zhang et al., 2010a, 2010b). Therefore the SCAU team have the capacity to use dragonfly larvae as indicators to assess the change of aquatic environment in the Beijiang River.

3.8. Inclusion of data in online databases

Data collated through this research will be included in two online species databases; the IUCN Red List (www.iucnredlist.org) and Fishbase (www.fishbase.org).

Through Work Package 1 of this project the fish, odontata, molluscs and selected aquatic plant species of the Beijiang River basin were assessed against the IUCN Red List categories and criteria and have been published on the Red List website (see section 3.2). Information on the species identified through this workpackage such as new information on species distributions, threats but in particular their utilisation by humans will be added to their Red List assessment and published online with the next IUCN Red List update in 2012. If the information provided is significant it may require the species to be reassessed, changing the species Red List Category.

The information on the fish species utilisation will also be added to the Fishbase online database, under the 'Human Uses' tag. For example, the species will be tagged as being 'Fisheries: minor commercial' or 'aquarium: potential'.

4. Threat surveys

The major threats to aquatic biodiversity and ecosystem services in Beijiang River come from (1) water pollution caused by waste water from industry and urban areas, (2) sand mining activity along the river which destroys the habitat of aquatic species, and (3) dams of hydropower stations which cut off natural flow of the river and block the migration route of many fish species.

4.1. Water pollution

Due to the rapid economic development and population growth in Guangdong, large amount of waste water is generated each year (Table 12). Although great effort has been made to reduce waste water and to increase waste water treatment capacity, the water in the Beijiang River becomes polluted as it flows through big cities like Shaoguan (Figure 34). This impacts biodiversity as can be seen through the field surveys as only one dragonfly species was sampled in Kengkou Fishing Village, which is just downstream of Shaoguan City. Whereas the number of dragonfly species in Lishi was 23 and 11 in Zhoutian, both of which are upstream of Shaoguan which is the major source of water pollution in the Beijiang river.

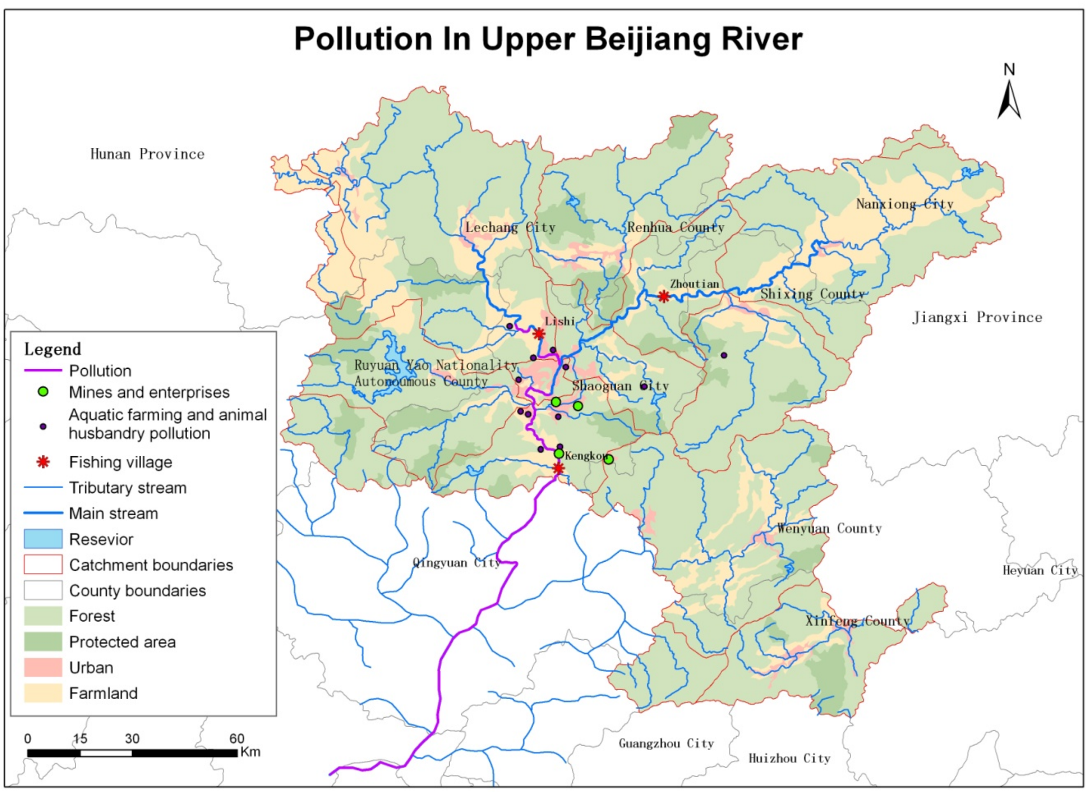


Figure 34. Water pollution along the Beijiang River

Table 12 Waste discharge into the Beijiang River during 1980s to 2008

(Committee for Annals of Shaoguan, Guangdong Province, 2001)

	Total wastewater (10000 t)	Industrial wastewater rate (%)	Domestic sewage rate (%)	Total COD (t)	Industrial COD rate (%)	Domestic sewage COD rate (%)
1980s	12080	71.7	28.3	-	-	-
2004	21678	68.1	31.9	-	-	-
2005	22056	68.7	31.3	2.89	28.8	71.2
2006	19197	64.1	35.9	2.78	26.8	73.2
2007	18527	57.9	42.1	2.99	30.7	69.3
2008	18530	54.4	45.6	2.89	27.5	72.6

4.2. Sand mining

Due to large amounts of construction work such as high ways, buildings, and factories the demand for sand as a building material has rapidly increased. Large scale sand mining operations have appeared in many sections of the Beijiang River (Figures 35 and 36). This mining activity not only destroys the habitat of aquatic species, but also impacts many of the aquatic ecosystem services provided by the river (Table 13).

Figure 35. Sand mining in Beijiang River

Table 13. The effects of the sand mining on the river ecosystem services

Effects	Service functions	Index
Positive effects	Sand supply	Annual sand quarrying
Negative effects	Agricultural output	Sand-pile occupancy on the river banks
	Environment purification	Collapse of the river banks
	Nutrient cycling	Collapse of the river banks
	Water storage and supply	River bed sinking, water level drops
	Inland navigation	River bed sinking, gradient changes
	Flood control	Embankment damage, part of river bed deteriorated
	Soil conservation	Soil erosion
	Water purification	Water environment capacity
	Soil and sand transfer	Accumulation of sediment of the reservoirs
	Biodiversity maintain	Effects on the area of habitats and fish species

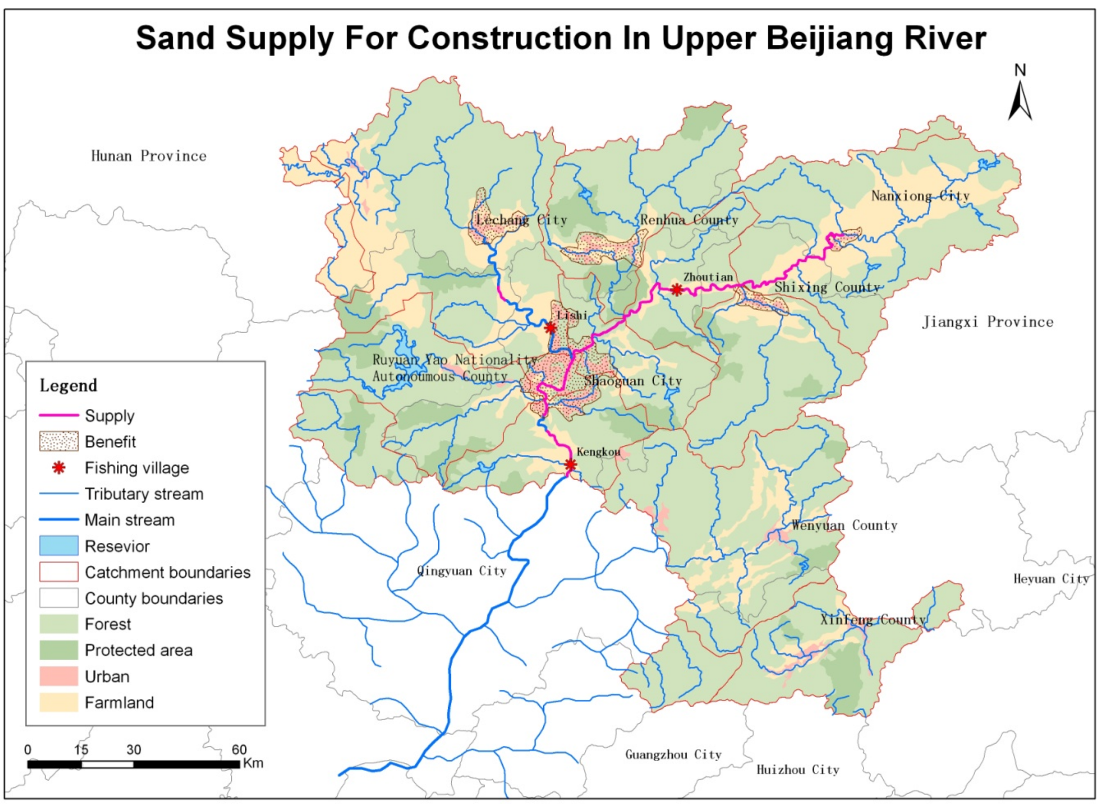


Figure 36. Sand mining sites along the Beijiang river and the areas 'benefiting' from the sand for construction

4.3. Hydropower dams

There are 485 dams in Shaoguan city, out of which 454 dams are small, 27 dams are medium sized and 4 dams are large scale (Figures 37 and 38). Figure 39 shows that the numbers of dams have been increasing over the past 20 years, particularly in the 1990s, which declined after 2000 only to significantly increase again after 2007. Most of the increase is due to the construction of small dams. The storage capacity of reservoirs has also increased, particularly in recent years (Figure 40). The construction of the dams and reservoirs have increased the water supply capacity and flooding control capacity but they have had a detrimental impact on the fisheries resources of the river. The local fishermen complain that the amount of fish has significantly decreased due to the change of the water flow and the blocking of fish migration routes (Table 14).

Figure 37. Hydropower dam (large scale) across the Beijiang River

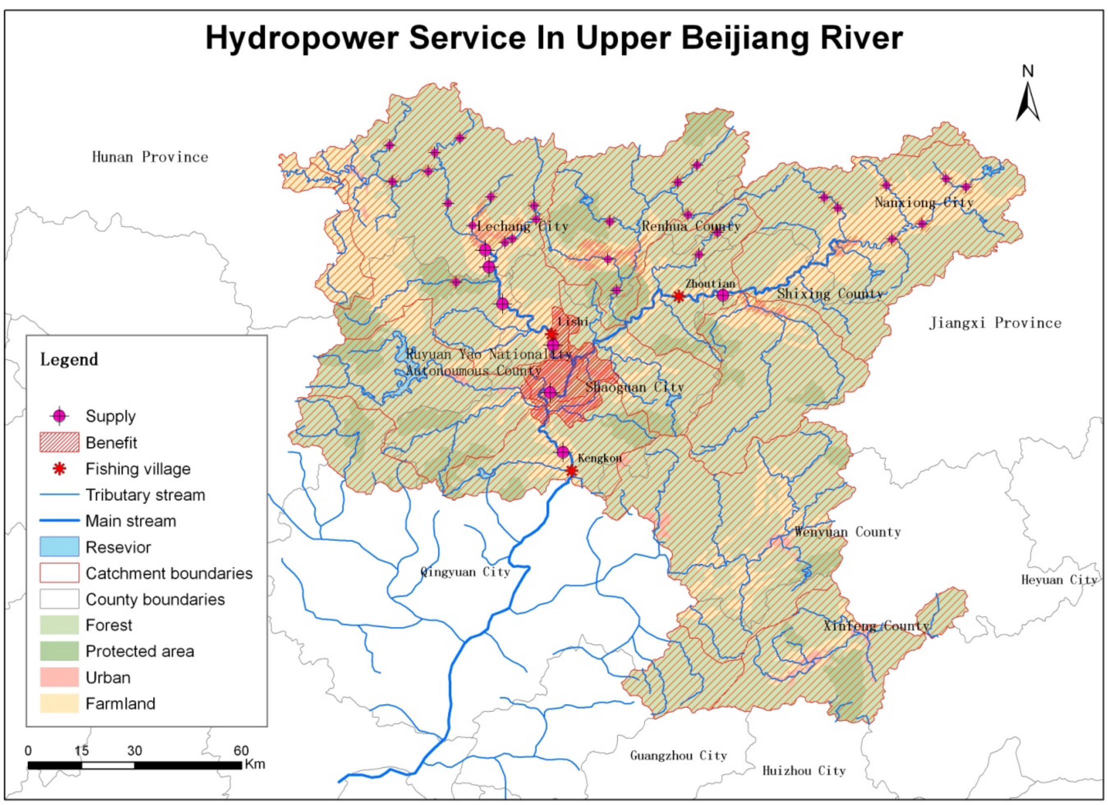


Figure 38. The distribution of dams in Beijiang River and the areas benefiting from the power produced

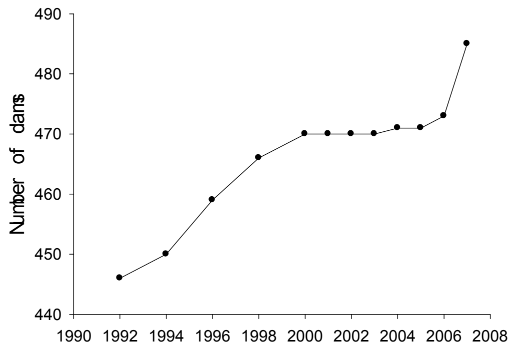


Figure 39. Number of dams over the years in Shaoguan City (Guangdong Bureau of Statistics 2002-2009)

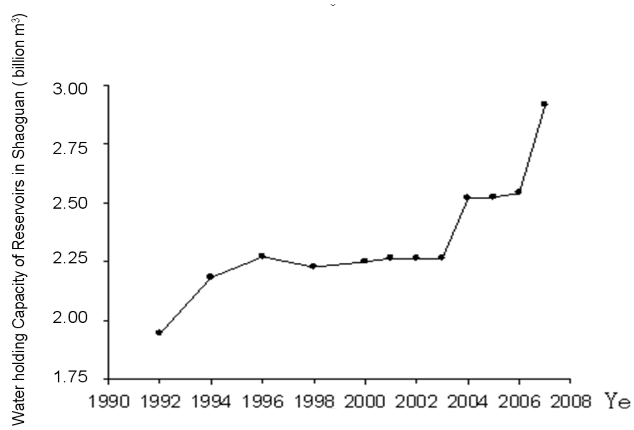


Figure 40. Storage capacity of the reservoirs in Shaoguan City (Guangdong Bureau of Statistics 2002-2009)

Table 14 The effects of dams on the river ecosystem services

Effects	Service functions	Index
Positive effects	Water supply	Adjusted storage capacity
	Hydropower	Annual generating capacity
	Inland navigation	Increase of transport
	Aquiculture output	Fish culture
	Flooding control	Country and field protection area
	Recreation and cultural	Tourism carrying capacity
Negative effects	Agricultural output	Inundated agricultural output, forests and grass biomass
	Environmental purification	Net primary productivity of inundated forests and grass
	Nutrient cycling	Net primary productivity of inundated forests and grass
	Aquiculture output	Fish capture
	Soil conservation	Soil erosion
	Water purification	Water environment capacity
	Soil and sand transfer	Accumulation of sediment of the dams
	Biodiversity maintain	Effects on the area of the habitats, fish species and migration

5. Ecosystem services

Ecosystem services are the conditions and processes through which natural ecosystems and the biodiversity that make them sustain and fulfil human life (Daily 1997). They provide many goods, such as food, timber, fuel, natural fibber, and many pharmaceuticals, industrial products, and their precursors. The American ecologists (Costanza *et al.* 1997) called the products and services provided by ecosystems as “ecosystem services” and divided it into 17 different types. We have divided ecosystem services into 4 major types; provisioning, regulating, cultural and supporting services (Figure 41) (following the Millennium Ecosystem Assessment (MEA) as shown in Springate-Baginski *et al.* 2009). The value derived from these ecosystem services can be categorised as direct use values (from provisioning services), indirect use values (from supporting and regulating services) and existence values (from cultural services) and option values can come from all types of services. Different types of services need different assessment methods (Figure 42).

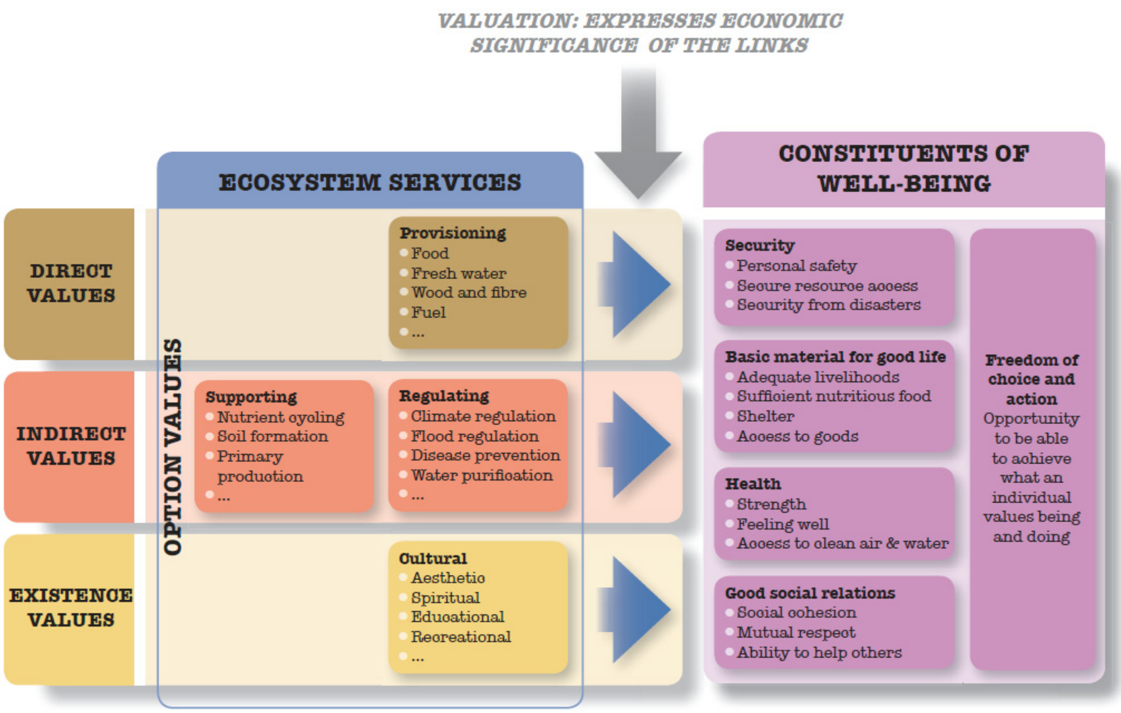


Figure 41. Types of ecosystem services and how they relate to human well-being (adapted from MEA Springate-Baginski *et al.* 2009)

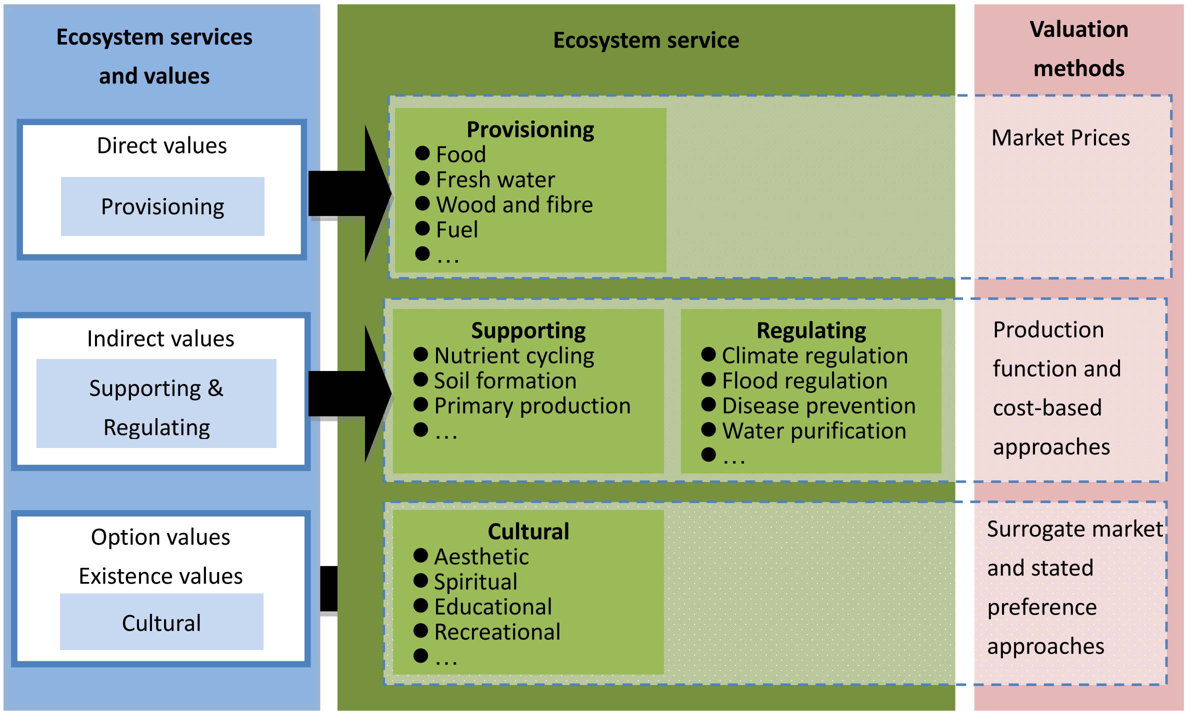


Figure 42. Ecosystem values, services and evaluation methods

5.1. Types of ecosystem services provided by the Beijiang River watershed

5.1.1. Provisioning services

In the upper Beijiang River, the ecosystem products mainly include wood from the forest ecosystem, fishes for food, industrial water supply, domestic water supply, sand supply for building, hydropower supply, and transportation across the river, reservoirs and lakes; and grain products from irrigated farmland. Provisioning services can often be valued by the price they are sold for known as the market value method.

(1) Wood

In recent years, many trees have been planted within the Beijiang catchment, increasing forest cover to 1.162 million ha (1.433 million ha used for forestry) by 2008. The standing forest stock was 65.235 million m^3, with the biomass of forest being 73.666 million tons, including 46.91 million tons of commercial forest biomass and 26.755 million tons of non-commercial forest biomass. (Shaoguan Bureau of Forest 2009)

(2) Aquatic products

In 2007, the aquaculture production of Shaoguan City was 60,395 tons, including 59,612 tons of fish, 393 tons of shellfish, and 202 tons of shrimps and crabs (Table 15). In 2007, the total aquaculture production value was 431.87 million Yuan (~40 million Euros in 2007). It was 3.93% of the total agricultural output value.

Table 15. The aquaculture output of Shaoguan City in 2007

(Statistical Bureau of Shaoguan, 2008)

	Yield (tons)
Total aquaculture output	**60395**
1. Fish	**59612**
(1) High value fish	**18420**
Channa argus	166
Siniperca chuatsi	130
Micropterus salmoides	526
Piaractus brachypomus	2009
Oreochromis niloticus	5118
Carassius auratus	3809
(2) Other fish	**41192**
Ctenopharyngodon idella	14781
Hypophthalmichthys nobilis	9194
Hypophthalmichthys molitrix	10126
Cyprinus carpio	4853
2. Shellfish	**393**
3. Shrimps and crabs	**202**

In spring, a typical amount of catch per day by a small fishing boat operated by two people is 15 kg of common carp (*Cyprinus carpio*) (at 5 Yuan/kg), or 0.25 kg of yellow horn fish (*Pelteobagrus fulvidraco*) (18 Yuan/kg). In April to September, 2 kg of shrimp (14 Yuan/kg) can be captured per day. According to our research in the three villages, a third of the fishermen's families are completely reliant upon fishing for their income. About one fifth of fishing families partly rely on fishing and partly on income from working outside or from children working outside. For example, in Lishi Fishing Village, there are 11 families that totally rely upon fishing, and 3 families that totally rely on income from working outside the village, 2 families are totally dependant on the support from their children working outside, and the income of the remaining 7 households are 50-90% from fishing, 10-50% from other sources.

(3) Water for productive use

Water for productive use includes agricultural water supply and industrial water supply. For agricultural irrigation, there are 1,567,200 hectares of cultivated land and 1,433,000 hectares of forest land in Shaoguan City in 2008. Most of the agricultural irrigation is provided by the water stored in dams or reservoirs while some is provided directly by the springs from the forest. Industrial water supply is very important for many companies in Shaoguan City, including the Shaoguan Iron Steel Group Limited Company of Guangdong Province, Shaoguan Smelter, Dabaoshan Mining Limited Company of Guangdong, etc. The industrial water consumption was 5.49×10^6 tons in 2008 (Shaoguan Bureau of Forest, 2009).

(4) Domestic Water Supply

The urban and rural domestic water is mostly supplied by the large reservoirs such as the Nanshui reservoir in Ru Yuan County. Some of the rural domestic water is supplied directly from the river and underground water (wells).

(5) Sand Supply for Construction

The main sand digging activity to provide construction sand, takes place in the river beds of the major streams. An example is the Water Management Bureau of Shaoguan who have allowed a 5.3 km section of the river near Zhoutian Village to opened for sand mining at a quota of 0.35 million cubic metres per year. It also permitted a 4.6 km river section near Lishi village for sand mining and the quota was 25 million cubic meters per year. The depth for sand mining usually reaches 1-1.3 m on average. (Sources: Contract between Shaoguan local government and sand mining company)

(6) Hydropower Supply

The Beijiang River is abundant in its hydropower resources, with a theoretical potential of 1,744,900 kW (kilowatt) (Committee for Annals of Shaoguan 2009). The annual hydropower generated can reach 55.8 billion kWh (Kilowatt hours). By the end of 2008, there were 485 reservoirs in Shaoguan, including 4 large, 29 medium and 454 small scale dams and 1989 small scale hydropower stations. The total installed capacity of power generation reaches 1,519,200 kW and the power generated in 2008 was 45.56 billion kWh (Annual Report of Shaoguan, 2009). All the hydropower supplies are incorporated into the national electricity network and supply to domestic, commercial and industrial usage.

(7) River Transportation

Shaoguan water transportation channels include rivers such as Beijiang, Wujiang, Zhenjiang, Wengjiang, Xinfengjiang, and the Longguihe. The Beijiang River can be accessed by hundred tonnage ships between Shaoguan and Guangzhou (a port city in the Pear River Delta). In 2008, there were 698 km of water transportation channel in Shaoguan and the shipping capacity reached 15 million tons, with the actual port throughput reaching 200 million tons (Committee for Annals of Shaoguan, 2009). The 184 km long Shaoguan-Qingyuan river channel is wide enough for cargo ship transportation (Guangdong Shaoguan city ecological civilization construction planning, 2008) and on October 14, 2008, the container shipping voyage from Beijiang Xingang Port, Shaoguan to Hong Kong was officially opened. It diversified the channels for importation and exportation from the mountainous area of north Guangdong (see http://www.yicang.com/html/news/view/awv).

(8) Food products

Shaoguan is suited to agricultural production in owing to its warm and humid subtropical climate resources. The arable land area per capita in Shaoguan is the largest in Guangdong Province and it relies heavily upon irrigation from the water stored in reservoirs. In recent years, the infrastructure in agricultural and rural areas has been improved and agricultural output value has increased. The seven major agricultural products in the region are vegetables, rice, livestock, fish, fruit, bamboo, and tobacco. Many rice, livestock and fish are well known for their quality and have high market values. In 2009, the grain growing area was 1,567,266 ha with a total production of 9,010,000 tons. The growing area of high-quality rice was 564,933 ha with a total production of 3,894,000 tons. The production of meat was 148,000 tons which included 117,000 tons of pork and 66,000 tons of fish.

5.1.2. Regulating services

Regulating services include climate regulation, water regulation, water purification, soil conservancy, natural disaster/flood control, etc. and they usually can not be valued directly by market prices (as is the case also for cultural and supporting services). In this case, other methods must be adopted for evaluation. The following methods can be used for the evaluation of regulating ecosystem services:

- Replacement cost method: If an ecosystem service is not provided by nature, the cost which must be used to generate this service artificially is called a replacement cost. For example, the value of water storage capacity of forest can be estimated by the cost of building a reservoir with similar capacity.
- Shadow price method: Values of some services can be estimated by the value given for a change in an ecosystem services. The value changed can be estimated indirectly by the price which visitor agree to pay, e.g. the pollution treatment cost which society has to pay, or the price increase of land property etc.

(1) Forest ecosystem's regulating services

In 2008 the land area used for forestry was 1.433 million ha. This area provided annual carbon dioxide absorption of 106 million tons, released 78 million tons of oxygen, stored 56 million tons of carbon and provided 2.16 billion tons of fresh water downstream (Shaoguan Bureau of Forest, 2008). According to the ecological service assessment methods which include the replacement cost method, and shadow price method, the value of forest ecosystem service was 8.4737 billion RMB Yuan. This includes 2.3675 billion Yuan of forestry carbon assimilation, 2.5528 billion Yuan of forestry oxygen releasing, 1.998 billion Yuan of forest water saving and flood control, 300 million Yuan for cleaning atmosphere, 0.3855 billion Yuan of forest soil erosion control, and 0.1375 billion Yuan for wildlife protection benefit (Shaoguan Bureau of Forest, 2008).

(2) River ecosystem's regulating services

Shaoguan City covers many different sub-catchments of the Beijiang River, including the Mojiang, Jinjiang, Wujiang, Nanshui, and Wenjiang all of which are larger than 1,000 km^2. The river ecosystem regulating services, as shown in Table 16, includes: flooding control; water resource storage; environmental purification; providing wildlife habitat; and CO_2 fixation (Xiao *et al.* 2006, 2008; Wang 2006).

Table 16. Regulation services provided by river ecosystem

Regulating service	Description
Flooding control	Vegetation along the river ecosystem, floodplains and downstream wetlands, swamps, etc. with water storage capacity, can reduce flood peaks, delay flood flows and reduce the economic losses caused by floods.
Regulation of soil, sand and nutrients transferred through river ecosystem	River transportation of sediment allows nutrients to be passed downstream, including carbon, nitrogen, phosphorus and others, and is one of the world's most important biogeochemical cycles.
Water resource storage	Floodplains, wetlands and marshes accumulate and store large amounts of water. In the dry season they supplement the supply of water and can improve regional stability of water supply.
Water purification and climate regulation	Wetlands and their biodiversity help water purification (e.g. through the absorption of nitrogen and phosphorous) and help regulate local climate (by absorbing heat in the day and releasing heat at night).
Providing wildlife habitat	The river ecosystem provides important breeding, migration and nursery habitats for birds, mammals, fish, invertebrates, amphibians, plankton and aquatic plants.

5.1.3. Supporting services

Supporting services provided by the Beijiang river includes soil development and nutrient cycling. Soil is an important part of national wealth and is formed through a slow process taking thousands of years (Ou Yang Zhi Yun 2000). Freshwater systems support soil development through the transfer of sediment and soil particles to wetlands, swamps and river estuaries creating new land, and during floods by depositing sediment to flood plains (which are often used as agricultural land during the dry season).

Freshwaters also play a key role in nutrient storage and cycling for example soil organic matter balance, and nitrogen, phosphorus, potassium, carbon and sulphur cycling. It is estimated that soil carbon storage is 118 times larger than all plant carbon storage while soil nitrogen storage is 19 times larger than plants nitrogen storage (Schlesinger 1991). The organisms within freshwater systems supply, store and absorb nutrients and promote the exchange of nutrients between living organisms and their environment.

5.1.4. Cultural services

Cultural services include the spiritual enjoyment, inspiration, entertainment, recreational opportunities, aesthetic and educational values. In the Beijiang basin, sightseeing, fishing, boating and swimming are the major cultural services provided. The natural tourism resources of Shaoguan City are mainly geological features, forest waterfalls, rivers and valleys, lakes and hot springs. There are 10 forest parks, (including 3 state forest parks, 2 provincial forest parks, 5 county forest parks) and 22 nature reserves (including 3 state nature reserves, 12 provincial nature reserves, and 2 county nature reserves).

5.2. Ecosystem costs

In the "Integrated Wetland Assessment Toolkit" published by IUCN (Springate-Baginski *et al.* 2009), the costs of ecosystem services are defined into four categories (Figure 43): **Management costs**: the direct physical expenditures on the equipment, infrastructure and human resources required to manage wetlands; **Opportunity costs**: alternative uses of time, land, money or other resources required for wetland conservation which could have generated income and profits had they been used or allocated elsewhere; **Costs to other activities**: damage and interference to human and economic activities caused by wetlands resources and species, including human and livestock disease and injury, crop pests and sources of competition over resources.

5.2.1. Management cost

In Beijiang River, the management costs include waste water treatment and pollution control, maintenance of river channels (such as river dike construction, channel clearance, floating garbage collection), biodiversity protection, fishery management, and reforestation and water conservation.

5.2.2. Opportunity cost

The opportunity costs in the Beijiang River include the cost for losing the opportunity to develop heavy industry and chemical industry because of the water quality requirements, and the opportunity to develop more wood harvesting forest and fruit orchard in hilly areas because of the water and soil erosion controls.

5.2.3 Costs for other activities

The other costs that can be identified include the transmission of water born diseases such as schistosomiasis, and the damage caused by flooding during the rainy season.

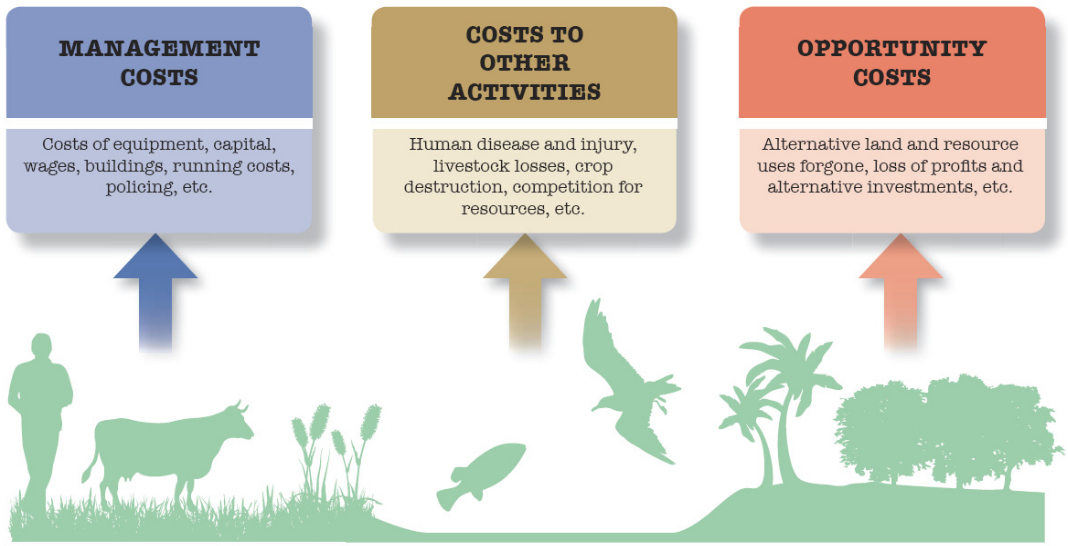


Figure 43. The total economic cost of an ecosystem (Springate-Baginski *et al.* 2009)

5.3. Ecosystem prioritisation

A participatory assessment to identify the priority ecosystem services and costs of the Beijiang River, according to different stakeholders has been undertaken. This will provide the relevant information for the integrated action planning process to help ensure that these services are given full recognition by all stakeholders, and also allow potential indictors to be developed that can be used to monitor any actions proposed through the IAP.

5.3.1. Methods

Referring to Springate-Baginski *et al.* (2009) Table 17 was designed to question different stakeholder groups to identify their prioritisation of the identified ecosystem services and costs provided by the Beijiang River.

On May 21, 2010, an evaluation meeting was held in the meeting room of Shaoguan City Government where the evaluation table and methodology was presented to government officers (morning meeting), and leaders from enterprises (afternoon meeting). After a short discussion, each individual filled in their own form with or without their name on it although a mark on each table was used to identify the type of stakeholder. On May 22, and July 2, 2010, three teams visited the different fishing villages and farming villages to conduct the same surveys with fishermen and farmers.

Table 17. Evaluation Sheet for Ecosystem Service and Cost of Beijiang River

Affiliation____________Location____________Date____________No.________

Draw a circle 'o' in the cell where you think the level of importance is right. The bigger the number, the more important it is. You can add other items at the end of the table (no. 24/12).

Ecosystem services		5	4	3	2	1
Provisioning	1 irrigation					
	2 daily water use					
	3 industrial water supply					
	4 aquatic products					
	5 sand for construction					
	6 transportation					
	7 hydro-electricity					
	8 game fishing					
	9 boating					
	10 tourism					
	11 swimming					
Regulating and supporting	12 air humidity					
	13 stable air temperature					
	14 clean environment					
	15 reduce flooding					
	16 delete pollution					
	17 reduce diseases					
	18 biodiversity					
	19 residential value					
Cultural	20 beautiful environment					
	21 spiritual home					
	22 education					
	23 research					
	24					
Ecosystem Cost		5	4	3	2	1
Cost for other reasons	-1flooding					
	-2 drought					
	-3 transmit diseases					
	-4 carrying pollutants					
Management cost	-5 dike building					
	-6 river bed clearance					
	-7 fishing management					
	-8 planting tree					
	-9 river pollution control					
	-10 water hyacinth					
	-11 picking up river garbage					
	-12					

One hundred and eight people participated in the investigation. Among them 15 from government offices including the Bureau of Agriculture, the Bureau of Water Management, the Bureau of Forestry, the Bureau of Environmental Protection, the Bureau of Industry and Commerce, the Bureau of Aquatic Product, the Department of Development and Reform, the Department of Security, Research Institute of Aquatic Products, Secretary of City Government, City Hospital, and Xihe Township Government. Fourteen came from enterprises including sand mining, river transportation, agricultural, steel and iron manufacturing, mining, hydropower station, hotel and food. There were 62 fishers who came from the three site villages of this project (Kengkou, Lishi and Zhoutian), and Shangping fishing village and 17 farmers from near by villages (Kengkou village in Kengkou, Qunlai village in Lishi, and Pingfu village in Zhoutian). In total, there were 29 women, 71 men and 8 who did not record their sex. All 28 women, except one, were from fishing or farming villages. Software SPSS was used for data statistic analysis.

5.3.2. Result and analysis

5.3.2.1. The general result of variation analysis

In order to understand if true differences exited within the data collected, the statistical method for ANalysis Of VAriation (ANOVA) using SPSS was applied. The results of an ANOVA (Table 18) show that there are significant differences existing among different ecosystem services or costs, between the different stakeholders, and between the different sex groups. However, further analysis shows that there are no significant different between men and women because the significant difference was caused by the group without sex record (Table 19). Therefore further analysis is focused on the difference between the different stakeholders and different ecosystem services/costs.

Table 18. Result of Univariate Analysis of Variance for ecosystem services provided by Beijiang River, China

Tests of Between-Subjects Effects Dependent Variable: evaluation value

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	37739.983(a)	204	185.000	88.334	.000
ecosystem services	727.631	33	22.049	10.528	.000
types of stakeholder	481.071	3	160.357	76.567	.000
Sex group	251.110	2	125.555	59.950	.000
ecosystem services X types of stakeholder	552.443	99	5.580	2.664	.000
ecosystem services X sex group	172.562	66	2.615	1.248	.086
Error	7261.017	3467	2.094		
Total	45001.000	3671			

a R Squared = .839 (Adjusted R Squared = .829)

Table 19. Duncan's multi-range analysis result for sex group effects

Sex group	Average score	Duncan's Multi-range test result
Men	3.126	b
Women	3.144	b
No sex record	2.669	a

5.3.2.2. Differences between different ecosystem services and costs

The most important ecosystem services ranked included aquatic products; daily water supply, reducing flooding, hydro-power supply and deletion of pollutants by Beijiang River (services in red in Table 20). For this group, the average importance achieved is more than 3.61 (in our 1-5 point system). These services impact almost everyone (from all the stakeholder groups) living within the Beijiang River area.

Table 20. Analysis of the results given for ecosystem services and costs

	Service Item	Average	SD	Duncan's multi-range test*								
Ecosystem Service provided by Beijiang River	11 swimming	1.71	1.22	a								
	9 boating	2.06	1.36	a								
	8 game fishing	2.07	1.37	a								
	10 tourism	2.08	1.28	a								
	6 transportation	2.56	1.38		b							
	23 research	2.58	1.55		b	c						
	1 irrigation	2.87	1.77		b	c	d					
	12 air humidity	2.94	1.56		b	c	d	e				
	20 beautiful environment	2.98	1.54		b	c	d	e				
	3 industrial water supply	2.99	1.63		b	c	d	e				
	13 stable air temperature	3.00	1.5		b	c	d	e				
	19 residential value	3.03	1.63		b	c	d	e				
	18 biodiversity	3.04	1.48			c	d	e				
	5 sand for construction	3.16	1.57				d	e	f	g		
	22 education	3.32	1.58					e	f	g	h	
	17 reduce diseases	3.34	1.58					e	f	g	h	
	14 clean environment	3.53	1.54						f	g	h	i
	21 spiritual home	3.55	1.34						f	g	h	i
	16 delete pollution	3.61	1.55							g	h	i
	7 hydro-electricity	3.62	1.48							g	h	i
	15 reduce flooding	3.71	1.58								h	i
	2 daily water use	3.77	1.74								h	i
	4 aquatic products	3.98	1.34									i
Ecosystem cost caused by Beijiang River	-2 drought	2.15	1.55	a								
	-3 transmit diseases	2.75	1.61		b	c	d					
	-10 water hyacinth	2.88	1.66		b	c	d	e				
	-8 planting tree	3.09	1.63				d	e	f			
	-11 picking up river garbage	3.21	1.67				d	e	f	g		
	-7 fishing management	3.24	1.56					e	f	g		
	-4 pollutant diffusion	3.52	1.49						f	g	h	i
	-6 river bed clearance	3.6	1.49							g	h	i
	-5 dike building	3.62	1.52							g	h	i
	-9 river pollution control	3.83	1.57									i
	-1flooding	3.86	1.73									i

* Factors with the same character did not significantly different within 5% significant level; they can be assigned to the same group. The numbers in front of the service items are the same as in table 15. Negative number indicates ecosystem cost.

The second most important 'group' of ecosystem services (an average score of 3.16-3.55 points) include the spiritual function, clean environment provided, reduction of diseases, educational function, and sand production for construction (services in orange in Table 20). The third most important 'group' of ecosystem services (2.56-3.04 points) ranked by the stakeholders include biodiversity, scientific research, stable air temperature and humidity, industrial and agricultural water supply, beautiful environment, residential value, and river transportation (services in yellow in Table 20). The least important 'group' of ecosystem services (1.71-2.08 points) ranked by the stakeholders includes tourism, fishing for sport, boating for sport and swimming. Although tourism is developing very quickly, the number of people benefiting from these services is still very limited.

The most important ecosystem costs ranked by the stakeholders include the damage caused by flooding and pollution, the expenditure used in waste water treatment; dike building and dredging of river bed for transportation (ecosystem costs in red in Table 20). These costs are very relevant to the most important category of ecosystem services (the stakeholders considered that the reduction of flooding and pollution are very important ecosystem services) as they considered that the money spent in waste water treatment, dike building and dredging is very important. The second most important 'group' of ecosystem costs include expenditure used for fishing management, picking up river garbage, and tree planting (costs in orange in Table 20). The third most important 'group' of ecosystem costs include the expenditure induced by diseases spreading along rivers and the picking of water hyacinth, an invasive species that grows very quickly in rivers and lakes (costs in yellow in Table 20). The least important 'group' of ecosystem costs include the loss caused by drought such as crop failure and lack of drinking water supply. Many people recognize that the river itself is not the reason of drought costs (costs in white in Table 20).

5.3.2.3. The differences between different stakeholder groups

There is no significant difference in the prioritisation made by men and women. This is likely due to the equal status of men and women in their daily life in this region. They often work together and share their life together without significant sexual work separation.

The higher the average ranking given by a stakeholder group, the more important they considered the ecosystem services provided by freshwater. The average ranking value for ecosystem services is in this order: government officers (3.54) > leaders of enterprises (3.42)> farmers (3.28) > fishers (2.87) (Table 21, line 1). Surprisingly the fishers have the lowest average, even though they rely the most directly upon the services provided by the river. This may be due to the concept of ecosystem services being quite abstract and that some groups of fishers and farmers needed more explanation, whereas the government officers and leaders of enterprises are usually more educated. The slide explanation for government officers and leaders of enterprises in a meeting room was more easily understood than oral explanation by different researchers for farmers and fishers in their houses.

Fishermen score aquatic products highly (Table 21, item 4), but surprisingly flooding is given a comparatively low score (Table 21, item 15). Government officers and leaders of enterprises give more priority to daily water supply than farmers and fishermen, the reason may be that many farmers and fishermen rely on well water rather than tap water from reservoirs (Table 21, item 2). The function for clean [aquatic] environment was considered less important by farmers than by the other stakeholders, possibly a result of farmers activity being confined on land (Table 21, item 14).

Table 21. The influence of Stakeholder to the evaluation of ecosystem services

	Average score for the evaluation of the importance				Result of Duncan's multi-range test*			
Stakeholders Ecosystem service/cost	Gov.officer	Leaders of enterprise	Farmer	Fisher	Gov. officer	Leaders of enterprise	Farmer	Fisher
Average	**3.54**	**3.42**	**3.28**	**2.87**	**c**	**cb**	**b**	**a**
10 tourism	2.80	2.64	2.29	1.73	b	b	ab	a
6 transportation	2.87	3.50	2.59	2.27	ab	b	a	a
20 beautiful environment	3.80	3.71	3.41	2.50	b	b	ab	a
3 industrial water supply	4.00	4.14	2.35	2.66	b	b	a	a
-11 picking up river garbage	3.47	4.07	3.47	2.89	ab	b	ab	a
1 irrigation	4.40	4.71	3.70	1.85	bc	c	b	a
12 air humidity	3.60	3.42	3.53	2.50	b	ab	b	a
13 stable air temperature	3.53	3.71	3.35	2.61	ab	b	ab	a
18 biodiversity	4.13	3.57	3.17	2.61	c	bc	ab	a
-1 flooding	5.00	5.00	4.47	3.16	b	b	b	a
15 flooding control	4.60	4.21	4.21	3.24	b	ab	b	a
2 daily water supply	4.93	5.00	4.05	3.13	b	b	ab	a
-8 tree planting	4.06	3.78	4.12	2.42	b	b	b	a
14 clean environment	4.40	4.07	2.95	4.41	b	b	a	b
-4 pollutant diffusion	3.80	2.35	3.41	3.74	b	a	b	bc
4 aquatic products	3.80	3.21	3.53	4.32	b	a	ab	b
-2 drought	1.53	1.00	2.65	2.41	ab	a	c	bc

* Factors with the same character did not significantly different within 5% significant level; they can be assigned to the same group. The numbers in front of the service items are the same as in table 17. Negative number indicates ecosystem cost.

For the lowest ranking 'group' of services, the value given from government officers and leaders of enterprises is significantly higher than from fishers and farmers, possibly as these groups may have more opportunity to enjoy these services due to their better financial situation. The leaders of enterprise gave significantly lower values than the other stakeholders on pollutant diffusion by the river (Table 21, item 4), possibly as many companies are releasing pollutants in to the river and they are not directly affected by the polluted river. Whereas, fishers gave a significant lower value to tree planting than other groups. This may be due to the fact that only a very few activities of fishers link directly to the forest up in the hill and mountain, like firewood collecting if flooding did not carry enough wood downstream for them.

Fishers gave lower value to many ecosystem services and costs, but they did score the clean environment (Table 21, no. 14), water pollution (Table 21, no. -4), aquatic production (Table 21 no. 4), and drought disaster (Table 21, no. -2) very highly. Although leaders of enterprises gave high scores for many ecosystem services and costs, they scored pollutant diffusion, aquatic products and drought relatively low. This may be a reason for the conflict of interest among different stakeholders, which could be solved by improving education and awareness of ecosystem services and how different groups rely upon them. Leaders of enterprises need a greater understanding of the importance of the river to the livelihoods of fishers and the serious impacts of water pollution. Government policy should help fishers to overcome the loss caused by pollution and other economic activities. For example, an ecological compensation fund could be set up and collected from industrial companies that damage ecosystem services. More financial support should be channelled to help the conservation and sustainable use of aquatic species, to improve the housing and employment opportunities for fishermen, and to recover ecosystem structure such as reforestation, soil erosion control and pollution treatment.

5.4. Ecosystem service maps

The following maps (Figure 48- Figure 56) present spatial information on the ecosystem services provided at a watershed scale and show the areas generating the services and the areas receiving (or benefiting) from the services.

Water supply depends upon the forested areas in the upper catchment to capture and store the water and then supply it through the rivers and ground water throughout the year. The areas benefiting from this water supply are the agricultural areas for irrigation (Figure 44), urban areas for domestic water supply (Figure 45) and the industrial areas where it is used in industrial process (Figure 46). Any damage to the forested areas within this catchment would negatively impact the water supply by degrading quality (increased sediment) and reducing quantity in dry periods (by increasing runoff and reducing the amount of water stored in the ground water) and also increase flooding risk (by increasing flash floods).

Aquatic products (fishes, plants, molluscs, shrimps etc.) are generated primarily from the rivers and reservoirs within the catchment as this is their primary habitat (Figure 47). However this service also relies upon the upper catchment to provide the water in the correct quantity and quality to sustain their life cycles. In addition the rivers and catchments downstream are also generating this ecosystem service (historically in this case) as many migratory species require suitable conditions and free passage downstream to the ocean. Unfortunately due to damming and pollution many migratory species that once provided ‘aquatic products’ (e.g. *Anguilla marmorata* the marbled eel) are no longer found in the upper catchment. The aquatic products are harvested from the rivers and reservoirs but the benefits spread further than just the fishing villages as they are consumed by people across the region, especially in those cities and towns with high population density. Degradation to the water quality or continued loss of habitat for the species that provide this service will not only impact the livelihoods of those that harvest the species but also those who consume the products.

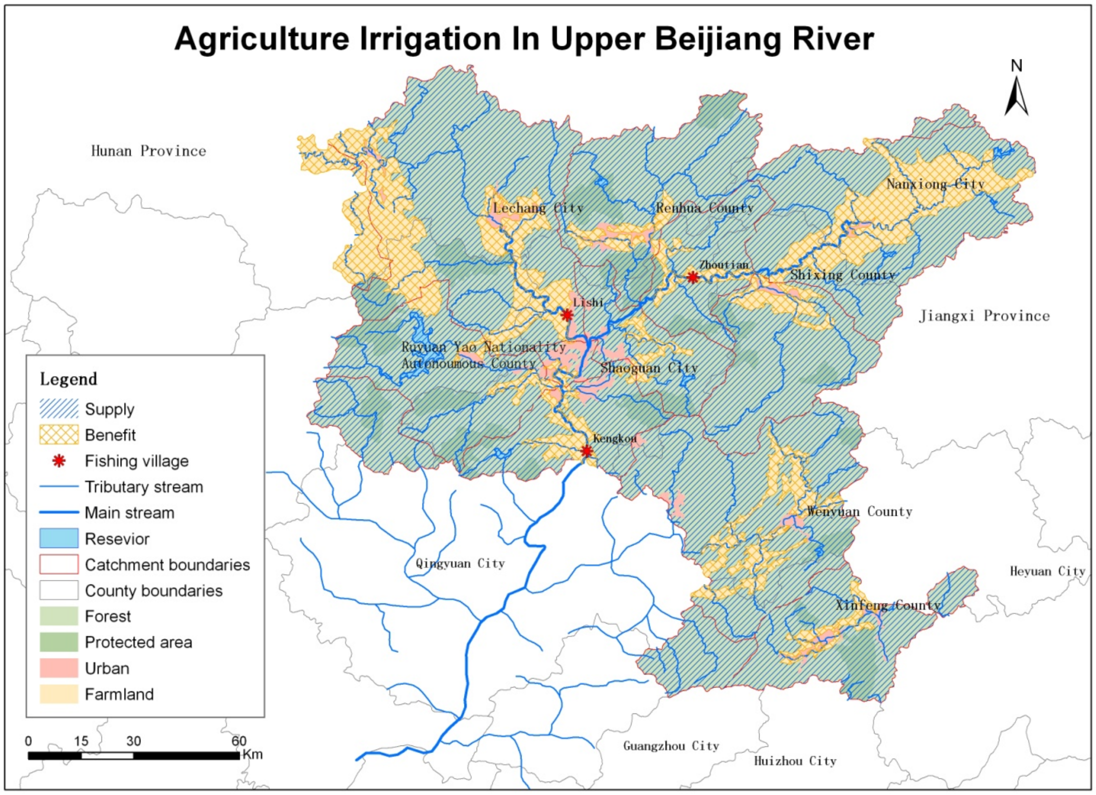


Figure 44. Water provision for irrigation of agricultural areas

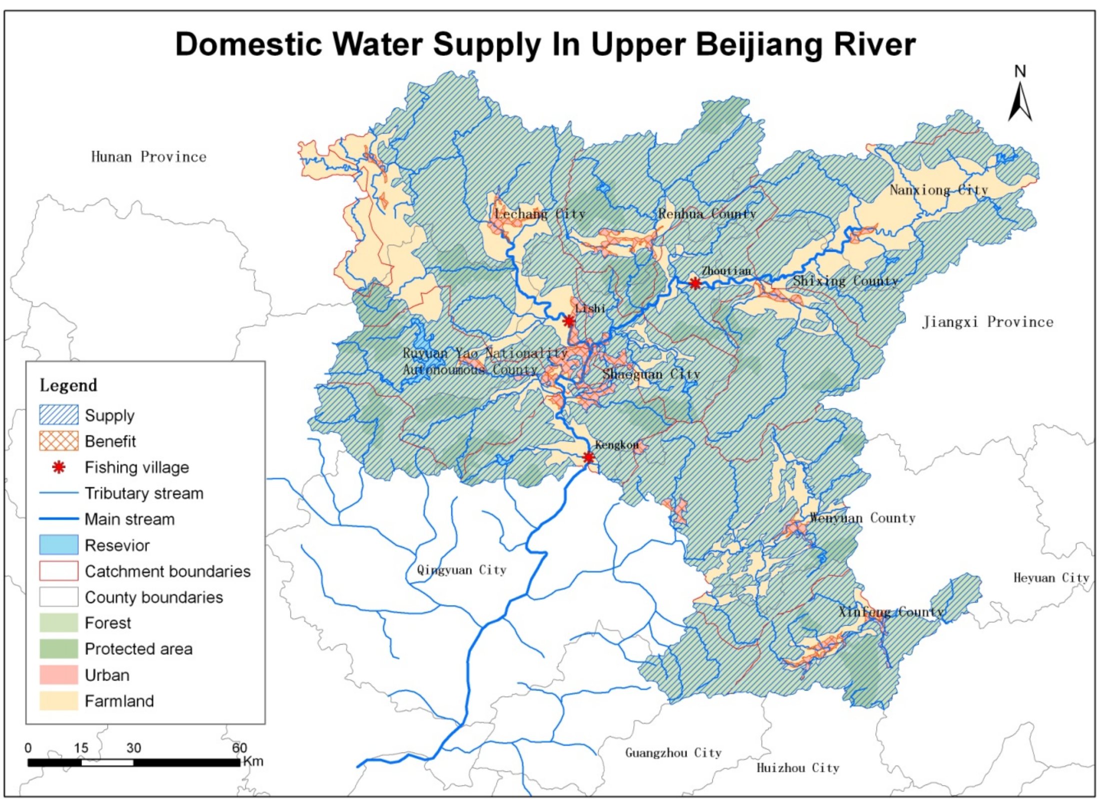


Figure 45. Water provision for domestic water supply

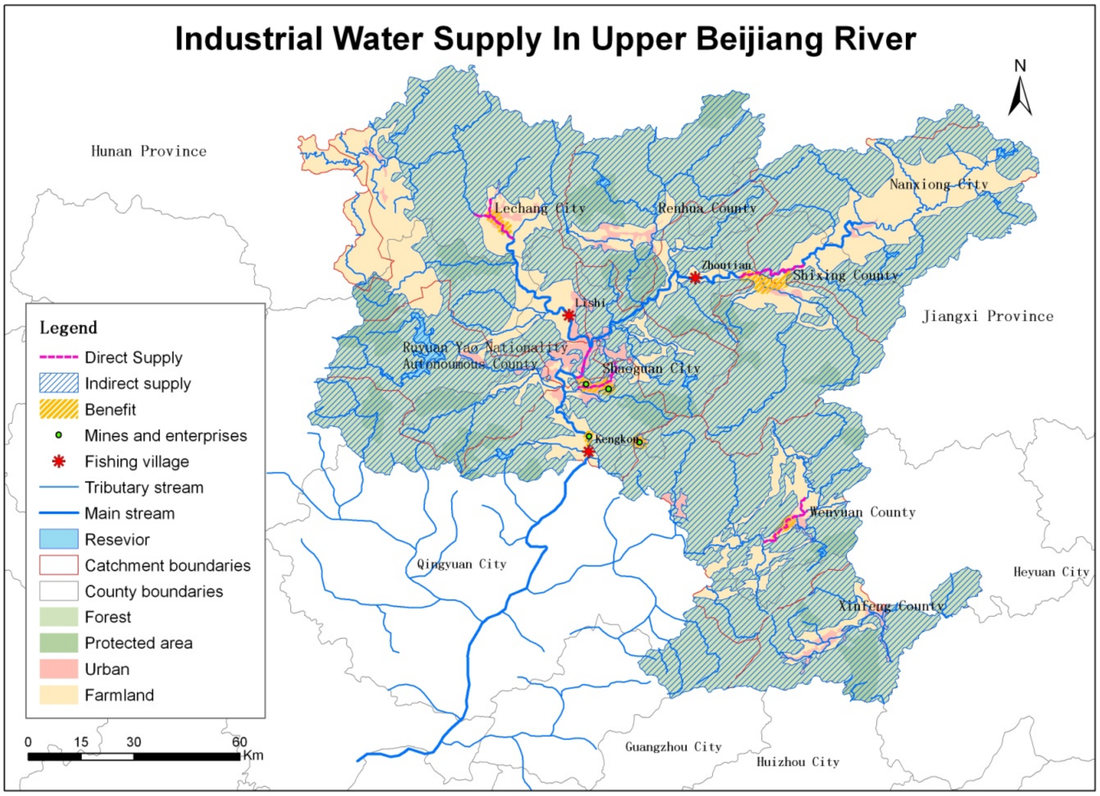


Figure 46. Water provision for industrial water supply

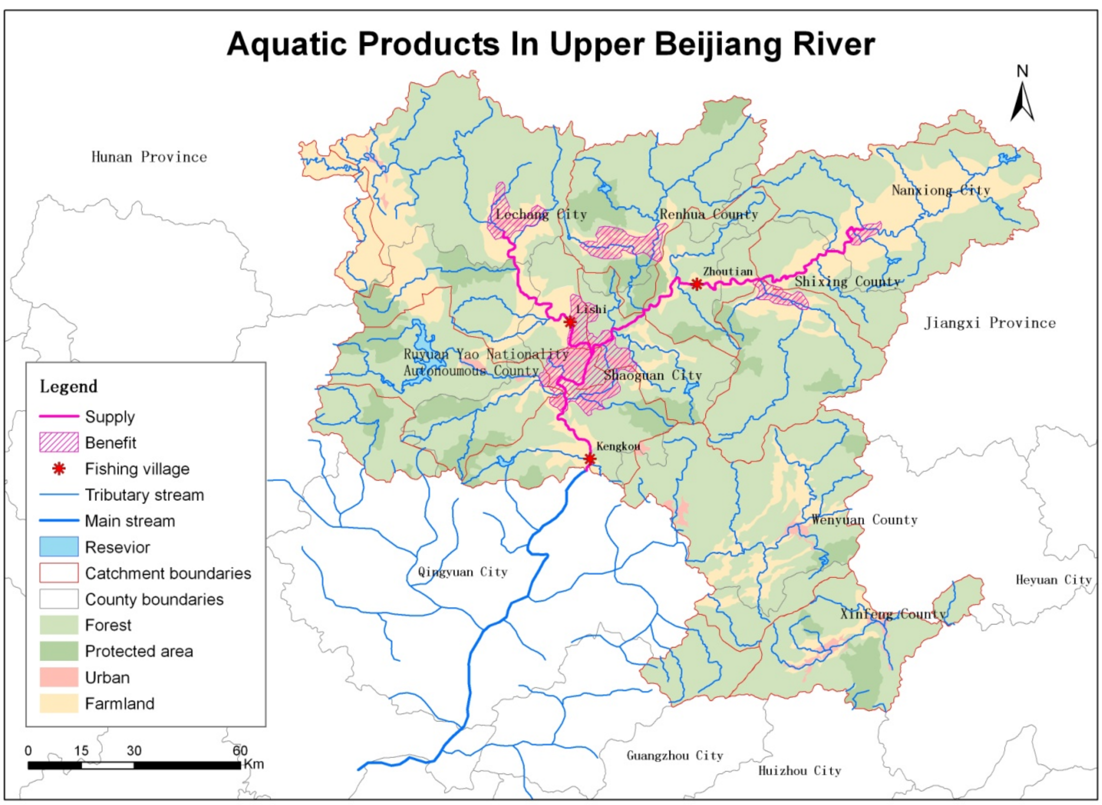


Figure 47. Provision of aquatic products

River transportation is no longer as important today as it once as dam construction within the river has limited the available transportation routes. However the river still provides a cheap and accessible way to transport goods up and down the river, and the areas that benefit from this are the major urban areas that are connected by the river (Figure 48).

Sand lying in the river bed is a major resource for the construction industry across the catchment (Figure 49). The sand is 'generated' by the erosion of material from the bed and banks of rivers and transported down the river until the flow is not strong enough to carry the particles, where it deposits the particles (sand) to the river bed. However, this process takes place over many hundreds of years to produce the sand beds that are being mined and it is not a service that can be renewed quickly. Therefore this is not a 'renewable' ecosystem service in the conventional time frame, and harvesting of the sand now reduces the value of the service in the future. The sand that is mined is transported to major cities and towns where it is used as construction material.

There are over 500 power stations along streams and major rivers in the watershed which are generating power to industrial and urban area areas in the region (areas benefiting from this service) (Figure 50). This service depends upon the supply of water, which is provided by the whole upper catchment.

Tourism not only benefits the tourists themselves but also the local people and businesses that generate an income in providing services for the tourists. Within the catchment there are many beautiful forest parks, natural reserves and historical sites in the region (areas generating the services of tourism) which are attracting more and more visitors from the region and outside the region (Figure 51).

Key recreation activities within the catchment are angling, boating and swimming that take place in the major sections of the Beijiang River and benefit the many people living and working in the cities and towns (Figure 52). This service is generated by many different areas, from the wider catchment that generates water provision (quantity and quality) to allow swimming and boating and the provision of biodiversity to provide fish for angling.

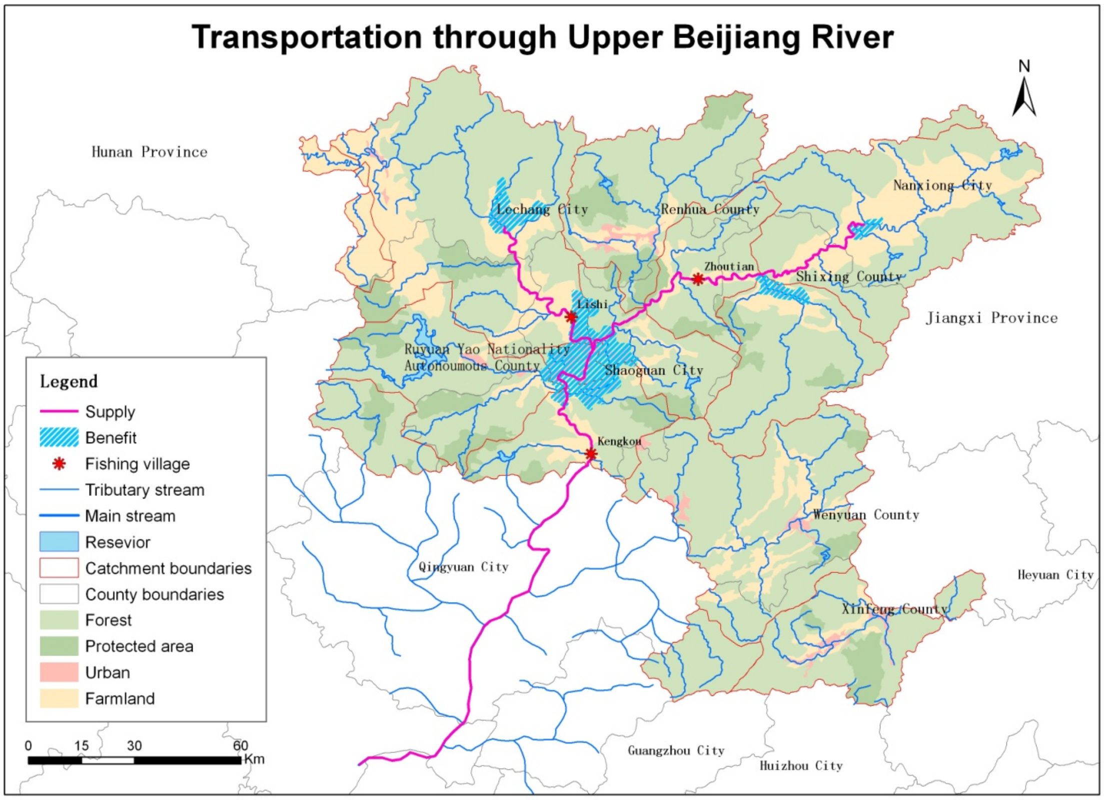


Figure 48. River transportation

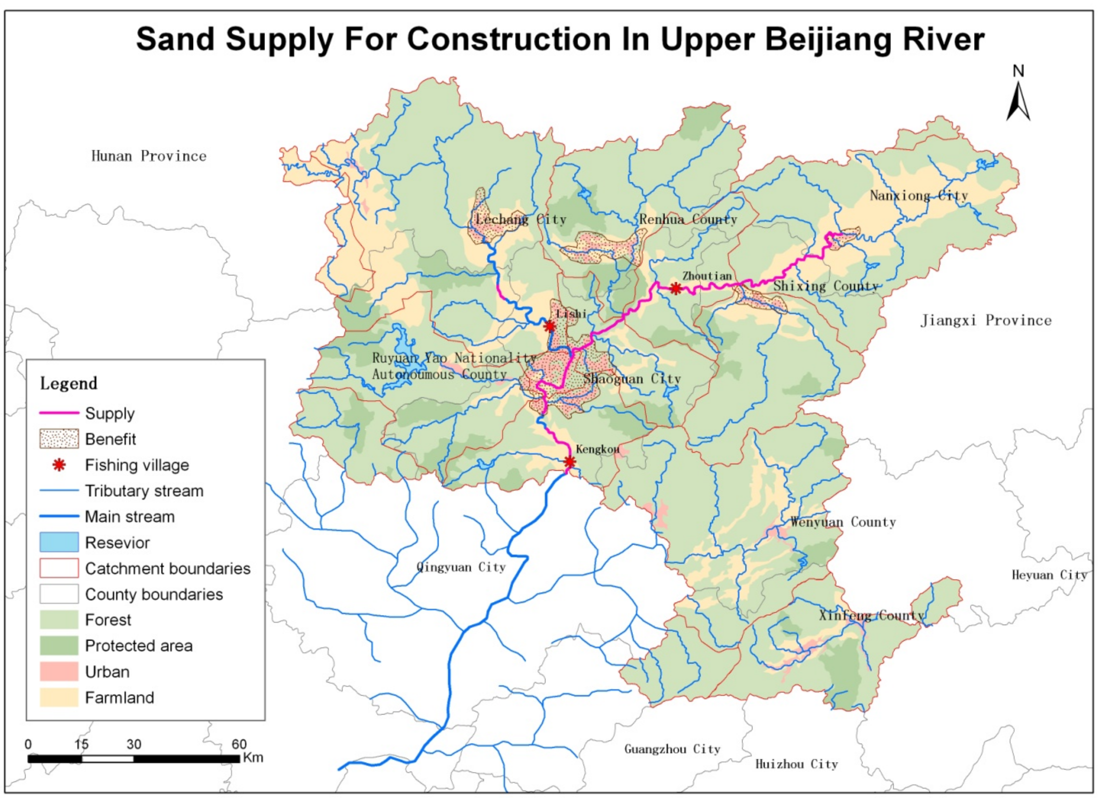


Figure 49. Sand supply

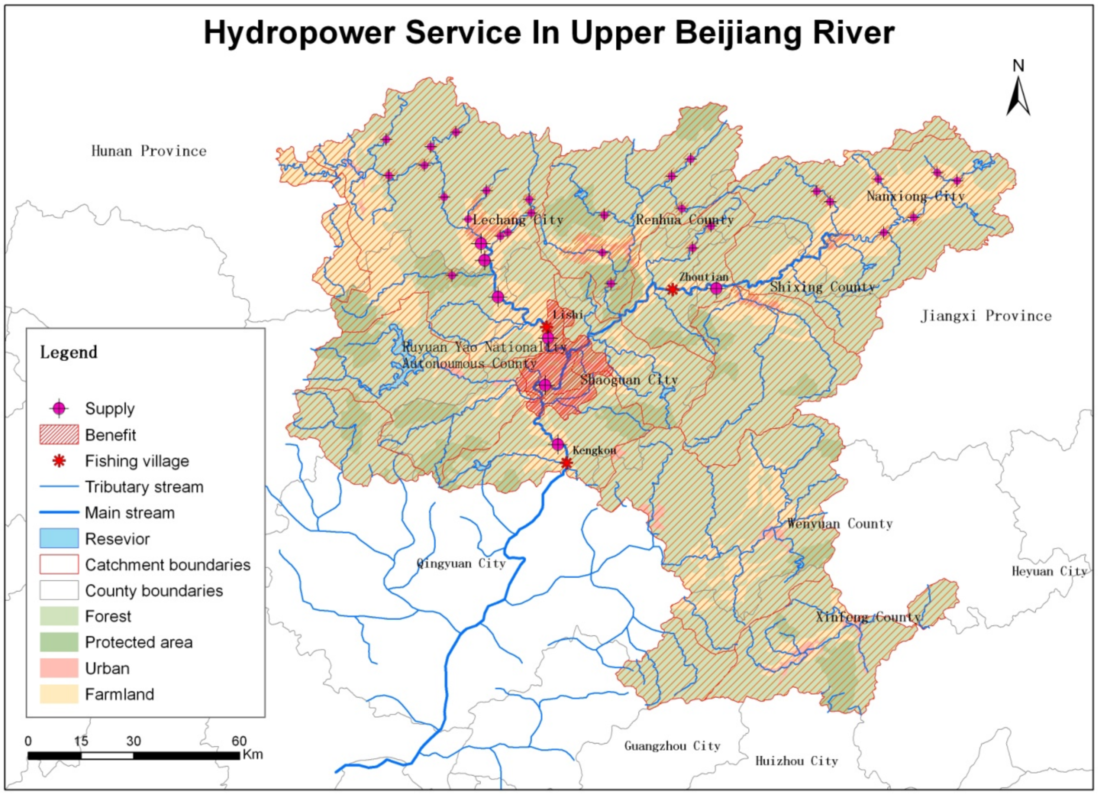


Figure 50. Hydropower supply

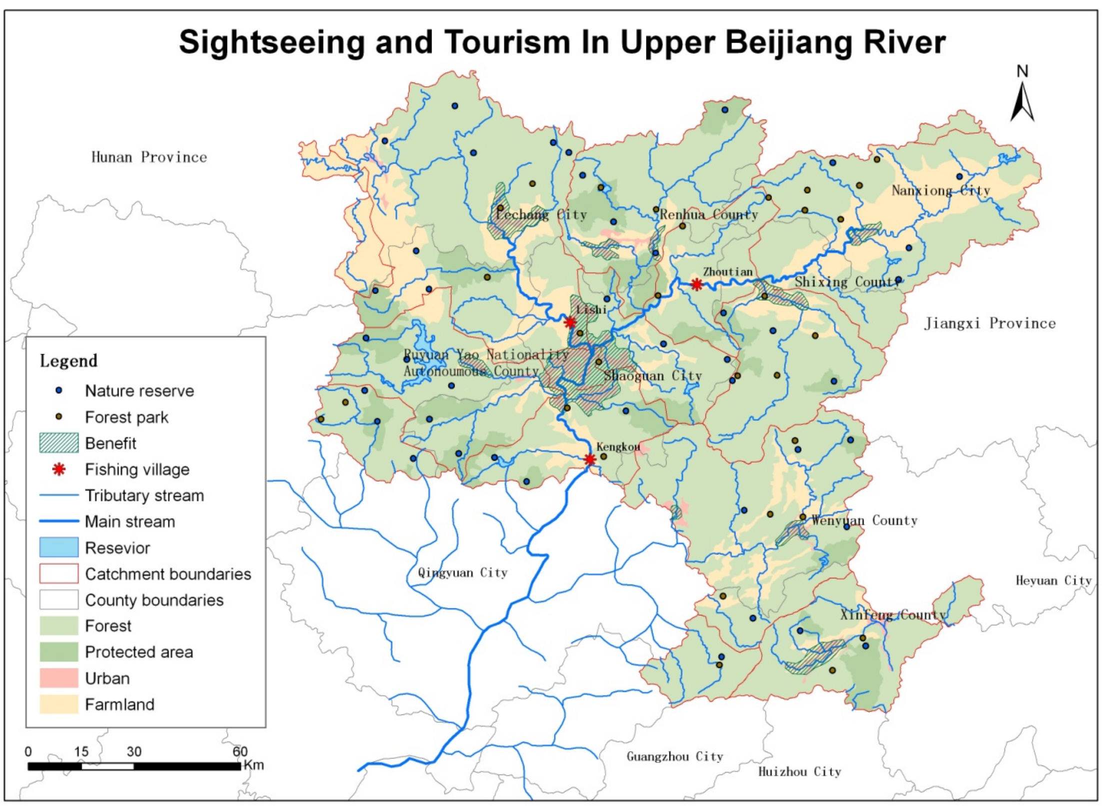


Figure 51. Sightseeing and tourism

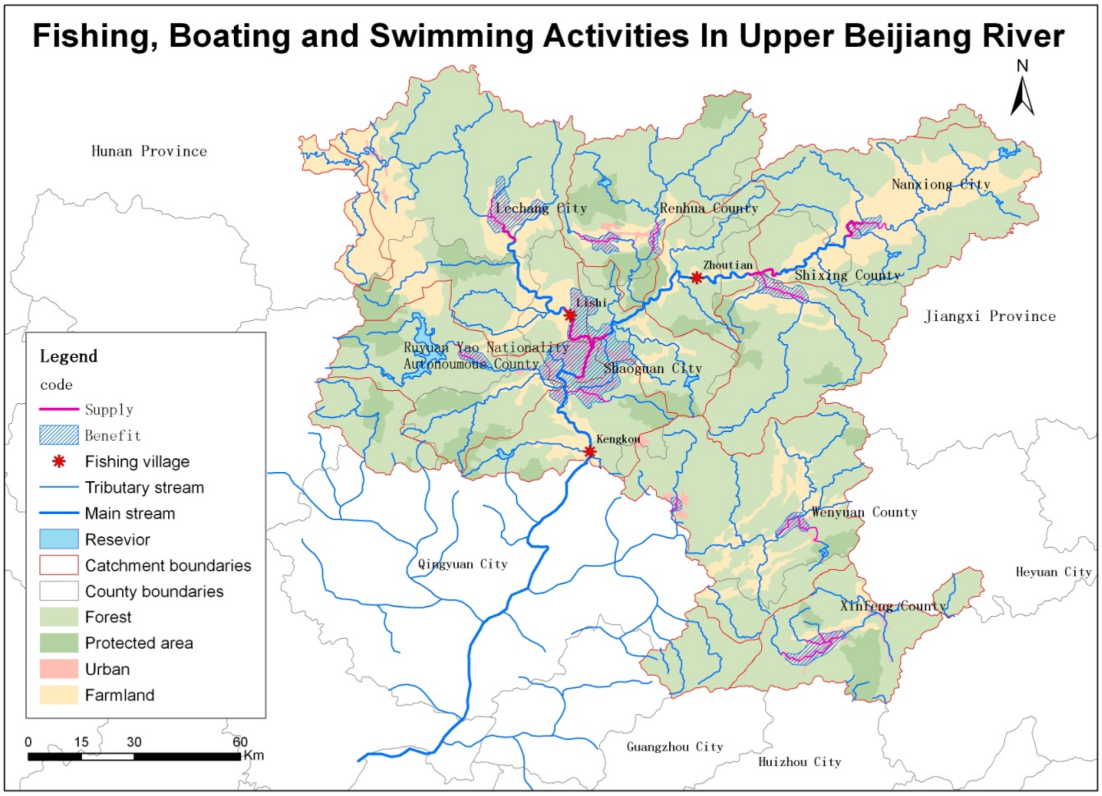


Figure 52. Leisure activities including fishing, boating and swimming

5.5. Economic valuation of ecosystem services

According to Xie Gaodi's improvement on Costanza's ecosystem valuation study (Xie *et al.,* 2003); there is an equation which is more suitable for the calculation of China's ecosystem service value:

$$ESV = \sum_{i=1}^{n} VC_i \times A_i$$

Where:

ESV = the total ecosystem service value (Yuan) in the research area.

VC_i = the unit value of ecosystem service provided by the ith type of land use pattern (yuan/hm^2).

A_i = the total area of the ith type of land use pattern.

n = the number of land use patterns.

For example, woodland can provide 3,097 Yuan service each hm2 (square hectometre = 1 hectare or 0.01km^2) for gas regulation (see Table 23), therefore 1.3879 million hm^2 woodland (see Table 22) provides 4,298.4 million Yuan of gas regulation service (see Tables 22 and 23).

Here:

$VC_i = VC_{(woodland\ gas\ regulation)}$ = 3097 Yuan,

Ai=$A_{(woodland)}$ = 1.3879 million hm^2,

Therefore: VC_i X A_i = 3096.8 (Yuan/hm^2) X 1.3879 (million hm^2) = 4298.4 (million Yuan)

The value of ecosystem services provided by Beijiang River watershed in Shaoguan City is calculated according to Shaoguan land use data in 2007 (Table 22). The value of $\boldsymbol{VC_i}$ is adopted from Xie Gaodi's research on Chinese land ecosystem services (Xie *et al.* 2003). The calculated results are in Table 23, and show that ecosystem services in Shaoguan provided are valued at 29,801.45 million Yuan.

Woodland is by far the greatest contributor being valued at 27,385.23 million Yuan, followed by cropland (1517.75 million Yuan) and water bodies (1471.26 million Yuan). Woodland provides more economic value than every other land type for every service apart from food production, where cropland has the highest value. Water bodies may have a lower value than woodland or cropland, but they cover a significantly smaller land area. If the total value for each land type is divided by the area that they cover to give a million Yuan per hm^2 value, water bodies are the most valuable with cropland valued at 0.0062 million Yuan per hm2, woodland 0.0197, grassland 0.0065, water bodies 0.0411 and unused land 0.0001.

Table 22. Land use cover in Shaoguan City in 2007 (unit: hm^2)

Type of land use	cropland	Woodland	Grassland	Water surface	Land for construction	Unused land
Area	242986.67	1387926.67	2460.00	35813.33	70440.00	89413.33

Table 23. Ecosystem service values in Shaoguan City for 2007 (unit: million Yuan)

Ecosystem service	Cropland	Woodland	Grassland	Water body	Unused land	Total
Gas regulation	107.50	4298.41	1.74	0.00	0.00	4407.65
Climate regulation	1913.52	3315.90	19.59	145.76	0.00	3523.78
Water conservation	129.00	3929.91	1.74	645.83	2.37	4708.86
Soil formation	313.91	4789.60	4.24	0.32	1.58	5109.65
Water treatment	352.62	1608.88	2.85	576.11	0.79	2541.26
Biodiversity conservation	152.64	4003.61	2.37	78.91	2.75	4240.29
Food production	215.02	122.83	0.65	3.17	0.79	342.46
Raw materials	21.50	3193.06	0.11	0.32	0.00	3214.99
Recreation	2.14	1571.97	0.09	137.53	0.79	1712.51
Total value	**1517.75**	**27385.23**	**16.09**	**1471.26**	**9.15**	**29801.45**
Total value per hm^2	**0.0062**	**0.0197**	**0.0065**	**0.0411**	**0.0001**	**0.0162**

5.6. Economic cost of maintaining ecosystem services in the Beijiang River

The economic cost of maintaining the ecosystem services of the Beijiang River has been calculated by using different methods including expert consultation, social-economic data sources and participation techniques as suggested by the IUCN toolkit. All statistical data in this section are provided by the Shaoguan Bureau of Environment Protection according to different internal reports.

5.6.1. Management costs

Management costs are the cost of equipment, capital, wages, buildings and running costs etc. required to manage the system.

5.6.1.1. Costs of water pollution control

Major water pollution sources along the Beijiang River include agricultural, household sewage and industrial discharge. The costs of water pollution control include the costs for water quality and quantity monitoring; soil erosion control; the construction and maintenance of wastewater treatment plants and pipe network for collecting sewage water; construction of biogas tanks, cropland ditch networks, wastewater filtration wetlands, and rural domestic sewage and animal husbandry wastewater treatment facilities. The cost includes infrastructure construction, maintenance and human resources used for pollution control. The total direct cost of water pollution control is 670 million Yuan during the period 2006-2010 (Table 24).

5.6.1.2. Cost of river channel maintenance

During the period 2006-2010 the cost for river dike protection was 2,000 million Yuan RMB, and the construction of flood control reservoirs was 3,680 million Yuan RMB (Table 24). For the same period river bed dredging cost about 400 million Yuan RMB (sand mining can also be regarded as a dredging process, which is very active in the Beijiang River and the income gained from selling the sand is 800 million Yuan RMB during the period 2006-2010). The costs of collecting and transporting river garbage and water hyacinth are about 200,000 RMB every year (but it can bring 100,000 Yuan RMB back per year by selling wood collected from the river). Costs of treating industrial solid waste, hazardous waste, and clinical waste came to 247.2 million Yuan RMB during the period 2006-2010.

Table 24. Project costs for the protection and improvement of water quality in Shaoguan City 2006-2010.
(Provided by Environmental Protection Agency of Shaoguan City)

NO.	Name of Projects	Investment (million)
1	The second wastewater treatment plants of Shaoguan city (50000t/d)	101.8
2	Wastewater treatment plants of Wengyuan County (15000t/d)	53.44
3	Wastewater treatment plants of Ruyuan County (15000t/d)	53.44
4	Wastewater treatment plants of Renhua County (10000t/d)	36.4
5	Wastewater treatment plants of Lechang City (10000t/d)	36.4
6	Wastewater treatment plants of Nanxiong City (15000t/d)	46.46
7	Wastewater treatment plants of Qujiang District (the second phase, 20000t/d)	61.95
8	Wastewater treatment plants of Lechang City (the second phase, 20000t/d)	61.95
9	Wastewater treatment plants of 16 centre towns	103.5
10	Pollutant intercepting network construction	330
11	Hualazhai refuse landfill of Shaoguan City (755 t/d)	222
12	Refuse landfill of Shaoguan urban district (800 t/d)	200
13	Refuse landfill of Ruyuan County (60 t/d)	19
14	Refuse landfill of Shixing County (60 t/d)	19
15	Refuse landfill of Renhua County (50 t/d)	16
16	Refuse landfill of Wengyuan County (70 t/d)	21.5
17	Refuse landfill of Xiongfeng County (90 t/d)	27
18	Refuse landfill of Lechang County (210 t/d)	50
19	Refuse landfill of Nanxiong City (120 t/d)	30
20	Industrial solid waste disposal centre of Shaoguan City (500 t/d)	60
21	North Guangdong hazardous waste disposal centre of (the first phase, 30 t/d)	180

NO.	Name of Projects	Investment (million)
22	Clinical waste disposal centre of Shaoguan City (10t/d)	7.2
23	River dredging of Wujiang River	200
24	River dredging of Zhenjiang Rive	200
25	Soil erosion management of Zhenjiang River drainage basin	16.593
26	Water pollution of Dabaoshan mine	100
27	Construction of public welfare forest	1700
28	Conservation of water and soil	4.35
29	Construction of nature reserve	200
30	Construction of “green channel”	384
31	Projects for technological ability construction of environmental management	19.63
Total investment		**4,561.613**

5.6.1.3. Cost for biodiversity protection

In order to protect aquatic species and fish resources, nine conservation areas have been established. Cost of fish species protection and proliferation is about 3 million Yuan RMB every year.

5.6.1.4. Cost for fisheries management

The Fisheries Administration Team of Shaoguan City is in charge of fisheries management which includes the supervision of fishing activity and the setting up, management and monitoring of natural reserves. The cost of fisheries administration is about 3 million Yuan RMB per year.

5.6.1.5. Cost of reforestation and water conservation

One example of a reforestation project is the reforestation of the hilly areas of Shaoguan highway system, costing 384 million Yuan RMB during 2006-2010. It included a reforestation project for an area of 2,133 ha along both sides of the highway. In 2009, reforestation project in both sides of Beijing-Zhuhai Expressway was also completed. There were 918.5 km2 of soil erosion areas in Shaoguan City in 2006-2009, and 209.6 km2 have been treated by biological (re-vegetation) and engineering (sand dam, contour terrace, and drainage channel) methods. The investment for this work was about 171 million Yuan for the period 2001-2005. During the period 2006-2010, the level of investment increased up to 2,100 million Yuan (Table 25).

Table 25. Project costs for increasing technological ability for environmental management in Shaoguan during the period 2006-2010.
(provided by Environmental Protection Agency of Shaoguan City)

NO.	Name of Projects	Investment (million)
1	Emergency monitoring system for environmental safety	2.8
2	Monitoring information network for city and county	2
3	Automatic monitoring station in drinking water source	2.2
4	Environmental monitoring centre station of Shaoguan City	1.7
5	Personal training for information management	2.1
6	Personal training for implementation and education of environmental law and related legislation system	1
7	Personal training and hardware purchasing for monitoring	7.83
	Total investment	**19.63**

5.6.2. Opportunity costs

An opportunity cost is alternative uses that are forgone, the loss of potential profits and alternative investment caused by maintaining an ecosystem service, i.e. preventing it being used to provide another service. The cost can be estimated by the alternative use which is sacrificed.

5.6.2.1. Industrial development and water quality

For maintaining the water quality of the Beijiang River, the development of certain heavily polluting industries is not allowed. The local government has turned down many proposals for the establishment of chemical or other heavy industry. The economic loss will be large but is hard to estimate.

5.6.2.2. Industrial development and biological conservation

Some industrial projects in the Beijiang River watershed have had to change design or location due to conservation purposes. For example, the Wu River Bridge project for the GuangLe freeway had to change location to cross the river, so to avoid a nature reserve in the Beijiang River. It also had to pay a compensation fee of 90 million Yuan to fund artificial reproduction of fish projects and 75 million Yuan for ecological monitoring.

5.6.3. Cost for other reasons

5.6.3.1. Water borne diseases

River water can transmit water borne diseases, such as schistosomiasis. The cost of projects that to try control water bourn diseases in Shaoguan City is estimated to be about 200 thousand Yuan each year.

5.6.3.2. Flooding

Although much work has been undertaken to control flooding in the Beijiang River, flooding still occasionally happens. For example, in 2006 a typhoon caused a large flood that caused 2.6 billion Yuan in damage. In order to prepare for flooding, the expenditure for material purchase and personal training is 3.65 million Yuan each year in Shaoguan City.

6. Policy relating to biodiversity and ecosystem services

Local government has made great efforts to solve the problems facing the freshwater systems and their ecosystem services and biodiversity.

6.1. Development strategy of Shaoguan

The development strategy for Shaoguan City has been defined by the provincial government as an important ecological buffering zone, tourist development region and an important transportation channel. The coordination between the development of the regions economy and protection of ecology are emphasized. For example, high quality food production methods with lower levels of chemical fertilizer and pesticides are encouraged. Industry with modern technology, low energy consumption and low pollution are also emphasized. Nature conservation and ecological tourism can be coordinated. Shaoguan is a popular tourist destination as it is one of the oldest places of civilization in southern China, with the Maba people living in the area 130,000 years ago. There are many tourist attractions such as Nanhua Temple, with more than 1,000 years of history, which was founded by Huineng, the Sixth Patriarch of Zen Buddhism, and Danxia Mountain and Nanling national forest parks and Guangdong Grand Canyon are tourist hot spots.

6.2. Protected areas in Shaoguan

6.2.1. Forests

Forested areas have been continuously increasing since 2005 (Figure 53), and now covers 78% of the total land area of Shaoguan (Figure 54) (Guangdong Bureau of Statistics 2002-2009).

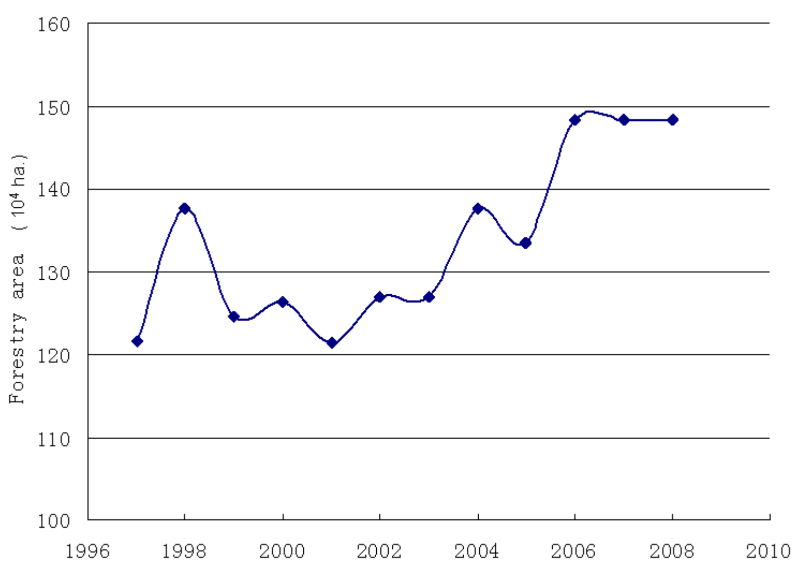


Figure 53. Forested area in Shaoguan (Guangdong Bureau of Statistics 2002-2009)

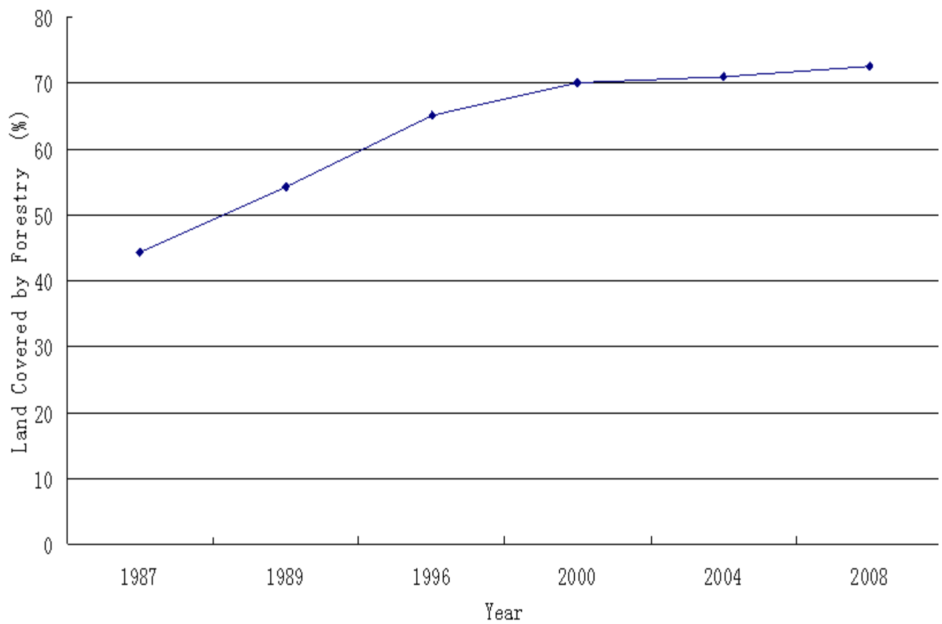


Figure 54. Land covered by forest in Shaoguan (Sources: http://number.cnki.net/)

Since 1999, all forests are classified as either commercial forest or ecological forest based on their major functions. In 2008 in Shaoguan, 31.54% of forest land was designated as ecological forest. Based on the Management and Compensation Regulation of Guangdong Ecological Forest (issued in 1999), all the ecological forests are not allowed to be cut and the owners obtain compensation from the Government. The compensation fees have increased from 37.5 Yuan/hm2 in 1999 to 180 Yuan/hm2 in 2009. There are 22 nature reserves in Shaoguan City, which cover a total area of 25.3 × 106 ha. Of these, 3 are national, 13 are provincial, and 6 are city level. There are also 11 Forest Parks, covering a total area of 5.3 × 104 hm2. Among these, 3 are national, 2 are provincial, and 6 are county level. The forest disturbances caused by fire and wood cutting has decreased dramatically since 1985, however, the impacts caused by the building of hydropower stations (deforestation) still exist.

6.2.2. Aquatic resource conservation zones

In order to protect native aquatic species and fish resources, the "Fisheries Law of the People's Republic of China" (1986) and "Protection Law of Wildlife" (1988) were passed. Under these pieces of legislation nine conservation areas with an area more than 3,780 ha have been set up in order to protect biodiversity in Shaoguan. The protected species include Asian giant soft-shell turtle (*Pelochelys cantorii* or *Amyda sincnsis* an Endangered species), marbled eel (*Anguilla marmorata)*, and wattle-necked soft-shell turtle (*Palea steindachneri* an Endangered species) (Table 26). At the same time, destructive fishing methods such as explosives, poison or electricity have been prohibited and the fishermen require a fishing licence to catch fish, which they receive from Shaoguan Fisheries Administration Team. There are 180 families with Fishing License at present. Fish fry releasing (all of native species) has been strengthened in the past decade (see section 6.5.2.).

Table 26. Aquatic conservation areas in Shaoguan
(Institute of Aquaculture of Shaoguan City, 1991)

Name of conservation area	Objective	Area protected
Shaoguan Beijiang endemic and rare fish Provincial conversation area	High quality and rare fish resources	From Guitou bridge in Wujiang River to Haiguan Island, 2820 ha.
Huangmaoxia endemic and rare fish conversation area	High quality and rare fish resources	From Madongji to Baisha Tangkou in Beijiang river, 160 ha.
Wujiang aquatic resources conservation area	Fresh Aquatic fish resources (*Semilabeo notabilis*)	*Semilabeo notabilis* Spawning area in Luojiadu, Wujiang river, 400 ha
Wattle-necked soft-shell turtle conversation area in Ruyuan	Wattle-necked soft-shell turtle	400 ha
Sixi River aquatic animals conversation area	Aquatic animals	Sixi River
Chishijin aquatic animals conversation area	Aquatic animals	Chishijin
Hongshan aquatic animals conversation area	Aquatic animals	Hongshan
Wangshishan Salamander conversation	Giant salamander	Wangshishan
Jinjiang fish biodiversity conversation area	Fish	Jinjiang river

6.3. Waste water and pollution control in Shaoguan

Shaoguan, as a less developed part of Guangdong Province, has been designated as an important ecological buffering zone and faces the sharp conflict between environmental protection and economic development. This conflict is clearly evident within freshwater systems. In China, through the Environmental Quality Standard for Surface Water bodies (GB3838-2002) (including rivers, lakes and reservoirs) are divided into 5 classes (or functions) based on its purpose of use and protection target (see below) and the water quality needs to pass standards for each category (class I/II is regarded 'good', III/IV 'moderate' and V/V+, 'poor').

Type I - refers to the water quality for National Preserved Areas,
Type II - refers to water quality for drinking water and important fish species,
Type III - refers to water quality for dinking water, swimming and fishing,
Type IV - refers to water suitable for industrial water resources, and
Type V - refers to agricultural water resources.

To protect water resources and improve the water quality of the Beijiang River, water quality goals for 2010 were set up through the Zhujiang River Valley Pollution Remediation Project. These goals included: that 80% of the surface water in the Beijiang River should reach the national water quality standards according to its purpose of use; 80% of the total volume of water that is 'handed over' to the next city must be able to reach the required standard; 95% of the water discharged from industry will be treated and should reach the required standard; and 60% of domestic wastewater should be treated and should the required standard (Government of Shaoguan City 2003).

According to monitoring data under the Environmental Quality Standard for Surface Water bodies, water quality in 2008 was 'good' in the upper reaches of Beijiang River (Shaoguan section) and the total 'pass rate' of water quality in major rivers and lakes is 93.50%. One hundred percent of water quality samples in the four Class II zones in Shaoguan City passed the standard, 97.2% of water samples in the six Class III zones reached the required standard, 83.3% of water samples in the three Class IV zones reached the required standard. The major pollutants of the Class III and IV zones was *E. coli* Water quality of the Wujiang River, Nanshui River, Jingjiang River, Mojiang River, Wengjiang River, Beijiang River (Shaoguan section), and Xinfengjiang River were good, with a 100% pass rate (Bureau of Environment Protection of Shaoguan, 2009).

6.3.1. Closure of polluting industries

The local government (Shaoguan City) has closed polluting small steel factories that have up to 83 thousand tones of productivity, iron factories with up to 30 thousand tones of productivity and cement factories with up to 88 thousand tones of productivity within the past five years. They have also reduced the amount of pulp and paper sludge, grain industries, dyeing factories and electroplating industries.

6.3.2. Waste water treatment measures

In recent years in Shaoguan enforcement of waste water treatment measures for major industries has been strengthened and there has been more investment in the infrastructure for environmental protection. The percentage of industrial waste water discharge that has reached the required standard is fluctuating around 80% (Figure 55). In 2008, 8,915,000 tons of industrial solid wastes were produced in Shaoguan city, but 80% of this was recycled (Figure 56).

Seven domestic wastewater treatment plants (WWTP) have been established since 2007 with the total treatment capacity reaching 140,000 tons per day, and 23.3 km of waste pipes have been laid (Bureau of Environment Protection of Shaoguan, 2009). The total domestic wastewater treatment capability of Shaoguan now has reached 260,000 tons per day. With an investment of 0.12 billion RMB the first phase (600 t per day) of the Hualazhai sanitary landfill for domestic waste has been built and put into use (Bureau of Environment Protection of Shaoguan, 2009).

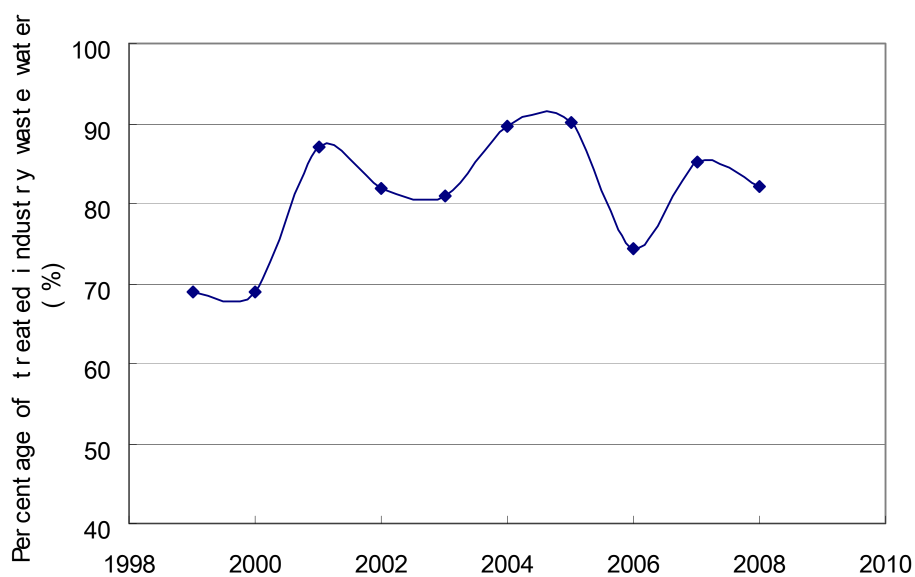


Figure 55. Percentage of industrial waste water discharged which reached the standard in Shaoguan

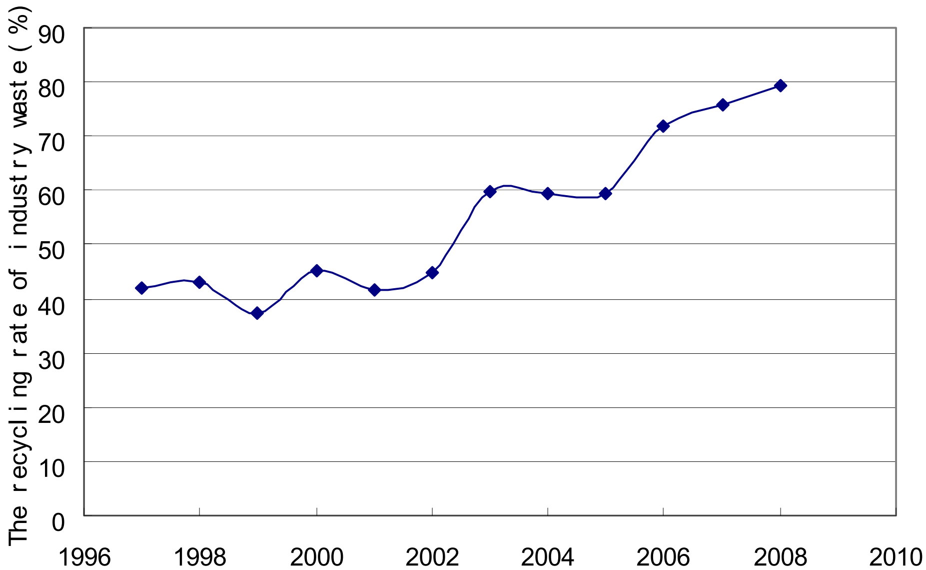


Figure 56. The recycling rate of industrial solid waste in Shaoguan

6.4. Environmental protection in rural areas

Major rural pollution sources of the Beijiang River include animal husbandry, overuse of pesticides and fertilizers, and household sewage discharge. Strategies for water quality improvement in agricultural areas include: 1) Reinforcing the environmental management of livestock farms by building biogas tanks and collecting and recycling animal excrement. 2) Developing eco-agriculture and extend biogas application - there have been 175,000 biogas pools established up to 2010 reducing COD (Chemical Oxygen Demand) by 6,566 t per year 3) Reinforcing the management of agricultural chemicals by the extension of optimum fertilizer application methods and more accurate forecasting for the outbreak of crop pests. The level of pesticide and fertilizer application will be reduced and bio-fertilizer, organic fertilizer, bio-pesticides, green feed and green feed additives will be encouraged (Government of Shaoguan City, 2003).

6.5. Conservation of aquatic resources

6.5.1. Research and monitoring of aquatic resources

Since the mid 1990s the Shaoguan Fishery Monitoring Team (local government) has monitored the daily fishing activity along the Beijiang River and recorded the amount and size of fish caught and their price at the market. The total aquatic production has continuously increased since 1970, however the percentage of this from river fish has decreased (Figure 57). Species of conservation concern such as the Asian giant soft-shell turtle, marbled eel, hilsa herring, wattle-necked soft-shell turtle and *Luciobrama macrocephalus* are now very rare in the Beijiang River. Nine conversation areas with area more than 3,780 ha have been set up in order to protect the biodiversity in Shaoguan.

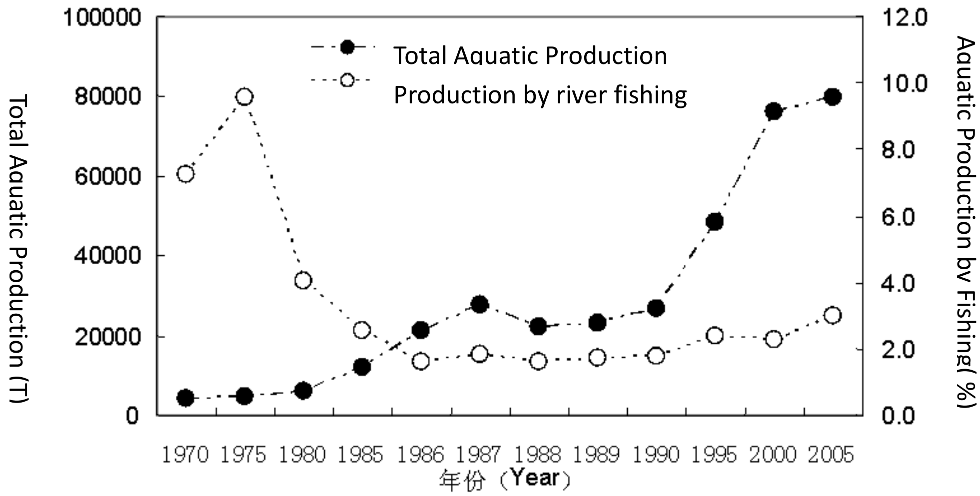


Figure 57. Aquatic production of fish in Shaoguan

6.5.2. Fish breeding and release of fry

Since 2006, the principle of “government guide and public participation” for releasing fish fry back to Beijiang River has been implemented. Native species of captive bred fish, shrimp, crab and shellfish are released into the river at different sites along the Beijiang. On average, five million fish are released every year to the river with 60% being purchased by the public. Ten to 20 thousand people have so far taken part by visiting the fish releasing sites and paying to release fish in to the river (Figure 58 and 59).

Figure 58. The opening of the Shaoguan Association of Animal Releasing Culture in 2009
(Source: http://www.gdyzhj.gov.cn)

Figure 59. Local people releasing fish fry in to the Beijiang River (Source: http://www.gdyzhj.gov.cn)

6.5.3. Net-cage fishing in conservation and protected areas

In order to protect water quality, aquatic resources and rare species, the local government has banned net-cages from protected areas and reservoirs and issued compensation for the fisherman's loss of livelihood (Figure 60).

Figure 60. Fish farmers removing net-cages from Nanshui reservoir which is a source of drinking water (Source: http://www.gdyzhj.gov.cn)

6.5.4. Management of sand mining

Efforts to monitor the bidding and operational activity of sand mining companies has been strengthened by coordinating activities of different law enforcement agencies such as Bureau of Environment Protection, Bureau of Water Management, and Bureau of Land Resources. In 2008 the Department of Water Conservancy of Guangdong issued a bulletin to prohibit sand mining in some major watercourses of the Pearl River. This new regulation is important for improving the management of sand mining in Beijiang River (Yang *et al.* 2009).

6.5.5. Development plans for ecology and resources protection

Various development plans have been published including the Ecological Agriculture in Shaoguan (2008-2015), Fishing in Shaoguan (2008-2015-2020) and Water Management Monitoring Agency (2008-2010). Also, legal infringement cases in large-and-medium reservoirs have been investigated and people have been charged. In 2000 and 2004, the People's Congress of Shaoguan put forward proposals for setting up economic compensation systems for the negative impacts on aquatic resources and livelihoods caused by the construction of dams and hydropower stations.

7. Conclusions and recommendations

Within the three sampling sites in the Beijiang River, 26 fish species, 8 mollusc species, 11 aquatic plant species, and 25 odonate species have been identified. One species, the fish *Pseudohemiculter dispar* has been identified as globally threatened, and two species the fish *Metzia formosae* and the mollusc (gastropod) *Cipangopaludina ampulliformis* are nationally threatened. The traditionally high value economic species such as *Pseudohemiculter dispar* and *Misgurnus anguillicaudatus* are decreasing, and many others are suspected to be declining also based on the general decline in fishery catch. Some species such as the marbled eel (*Anguilla marmorata*) once an important fishery species at the sites has now almost disappeared due to dams blocking the species migration route. All the molluscs and plants the majority of the fishes that were identified through the site species surveys were of livelihood importance to the communities at the sites. Their uses varied widely from providing income (selling as food) to providing fodder for livestock, medicinal use and to produce biogas. Many species have also been identified at the sites that can act as indicators for environmental quality (in particular molluscs and plants) and status of fisheries.

The Beijiang river provides many ecosystem services to the communities at the fishing villages (such as food, water etc) but also to the people of Shaoguan (including power, sand for construction, water for industry). Through the ecosystem service prioritisation exercise undertaken with the different stakeholders, the provisioning services of aquatic products, water provision and electricity, along with the regulating service of flood control and pollution removal were the highest valued services by all the stakeholders. There were differences among the stakeholder groups, but it was felt that the fishermen and farmers did not understand the concept of ecosystem services as well as government officers and company leaders. Also both government officers and company leaders need to understand the importance of aquatic products and other services to the fishermen and farmers, and the damage caused to ecosystem services by polluted waste water. More education and awareness building is needed for all stakeholder groups.

The total economic value of the ecosystem services provided by the Beijiang river and its watershed is estimated at 29.8 billion Yuan in 2007 (~3.4 billion (as in thousand million) Euros in 2007). This is the equivalent of 61.4% of the GDP of Shaoguan City in the same year. The major provisional services provided include wood, aquatic products, clean water, sand, hydropower, agricultural food and transportation channel. Regulating services, such as flood regulation are also very important. Cultural services are becoming more valuable as there is a development in tourism, recreation, education and research. Ecosystem service costs spent on management are calculated to be 1.41 billion Yuan each year which is less than 5% of the ecosystem services value. Among all ecosystem service costs, the management costs are by far the biggest, as there has been costly investment in to the construction and maintenance of dikes, deepening river beds, protection of biodiversity, fishery management, reforestation projects, and soil and water conservation projects.

The major threats to the sites aquatic resources and ecosystem services are water pollution (mostly from urban and industrial sources in Shaoguan City), sand mining and hydropower dams. In order to protect these ecosystem services, the government of Shaoguan have taken many actions including the closing of many polluting industries and have refused to allow the development of environmentally harmful businesses. These opportunity costs may need to be compensated for in the future.

In order to achieve the sustainable use of aquatic resources, many stakeholders in Shaoguan have taken action, in particular:

- Regional strategic development plans have been made;
- Nature preservation zones for forest and aquatic organisms have been set up;
- Water pollution control has been strengthened;
- Regulation of sand mining in the river has been strengthened,
- Fishing activities are under continuous monitoring by a government agency;
- Breeding and releasing of fish fry in to Beijiang River have put into action for many years.
- A ‘no fishing season’ in the Pearl River began to be implemented from April 1, to June 1, each year from 2011. Although it will be good for the recovery of some aquatic species, it will be a challenge for the monitoring force.

All these measures need to continue, but they need to be strengthened if they are to be successful in the future. For example we recommend that the below actions need to be considered:

- Shaoguan is considered an important ecological buffering zone, however, ecological compensation mechanisms need to be considered to improve the relatively poor economic situation of the area.
- Preservation zones for aquatic organisms have been set up, but sand dredging and fishing activities have not been prevented and therefore better management and enforcement is needed.
- More preservation zones need to be considered in the near future, in particular to aid in the conservation of globally, nationally locally threatened species and species that are declining and are of direct livelihood value.
- Although regulation and monitoring of water pollution have been improved, not all waste water from industry and residential regions is treated. Sections of the river are still polluted due to the waste water from iron ore mining activities. Fertilizer and pesticide used in agriculture sectors need to be reduced and more environmentally friendly methods for agricultural production needs to be developed. Waste water treatment capacity still needs to be expanded.
- Destructive fishing methods such as electricity and poison are still used illegally by some people to kill fish in river. More education and monitoring activities need to be developed.
- There are only 10 locations for releasing fish fry. Releasing points should be expanded. Only common low price species are raised and released at present. More locally rare species and economically high value fish fry should be raised and released. This will depend upon the financial resources available, but these could be strengthened by gathering money from resources tax from various industries.
- The sections of river bed destroyed by dredging should be restored by the replanting of aquatic plant species, particularly those that are important for fish, shrimp, turtles, crabs and snails.
- Compensation for the fisher’s loss of income and food from the new “no fishing season” needs to be developed.

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Annex I. Locations of species survey sites

Fishes and molluscs

Site		Longitude	Latitude	Habitats
Zhoutian	1	113.852800	24.973600	fast flowing channel
	2	113.854500	24.974600	fast flowing channel
	3	113.855900	24.975700	fast flowing channel
	4	113.861100	24.978300	fast flowing channel
	5	113.862300	24.979500	deep slow channel
	6	113.864000	24.980600	deep slow channel
	7	113.867500	24.979600	deep slow channel
	8	113.869000	24.978200	shallow slow channel
	9	113.870600	24.976400	shallow slow channel
	10	113.871100	24.974500	shallow slow channel
	11	113.872000	24.971900	shallow slow channel
	12	113.874100	24.971400	shallow slow channel
	13	113.877000	24.974800	shallow slow channel
	14	113.873200	24.973700	shallow slow channel
	15	113.877000	24.974100	fast flowing channel
	16	113.876000	24.974300	fast flowing channel
	17	113.878700	24.976000	fast shallow channel
	18	113.879400	24.976300	fast shallow channel
	19	113.879900	24.976800	fast shallow channel
	20	113.881400	24.977900	fast flowing channel
	21	113.884000	24.979100	fast flowing channel
Lishi	1	113.544300	24.870490	near village
	2	113.544740	24.872610	near village
	3	113.545080	24.870900	about 2m deep water
	4	113.543300	24.868170	about 2m deep water
	5	113.541600	24.862120	about 2m deep water
	6	113.541040	24.860120	about 2m deep water
	7	113.539980	24.855460	about 2m deep water
	8	113.542510	24.867780	around sand mining
	9	113.541470	24.871420	deep water
	10	113.539650	24.875420	deep water
	11	113.537520	24.880100	deep water
	12	113.534100	24.886100	deep water
	13	113.531650	24.888050	15m deep water
	14	113.527900	24.892400	near waste water outlet
	15	113.523850	24.895620	deep water
	16	113.523150	24.897000	deep water

Site		Longitude	Latitude	Habitats
	17	113.522200	24.899640	forest area
	18	113.517500	24.901540	about 2m deep water
	19	113.514060	24.903300	about 2m deep water
	20	113.510300	24.899790	around small island
	21	113.508800	24.896540	about 2m deep water
	22	113.508960	24.899120	about 2m deep water
	23	113.506700	24.887940	about 2m deep water
	24	113.505090	24.886950	about 2m deep water
	25	113.502450	24.887160	about 2m deep water
	26	113.496380	24.890000	about 2m deep water
	27	113.488310	24.892230	about 2m deep water
	28	113.484500	24.894600	about 2 to 5m deep water
	29	113.503750	24.885270	about 2 to 5m deep water
	30	113.510580	24.890630	about 2 to 5m deep water
	31	113.513250	24.893700	about 2 to 5m deep water
	32	113.513650	24.899330	about 2 to 5m deep water
	33	113.519450	24.899480	near dam, deep water
	34	113.526670	24.891510	near dam, deep water
Kengkou	1	113.566700	24.588200	close to Mengli dam, Shallow water, fast flow
	2	113.566900	24.586200	close to bamboo dike
	3	113.569300	24.586600	close to bamboo dike
	4	113.580600	24.583300	close to Shaoguan Power Plant
	5	113.582300	24.583000	close to the dock of power plant for coal loading
	6	113.585300	24.574000	major fishing section with slow water flow
	7	113.589700	24.558100	major fishing section
	8	113.588600	24.549600	close to the sandy island with bamboo
	9	113.588400	24.546500	close to the collapse dike
	10	113.588600	24.535700	close to the fishing village
	11	113.590000	24.533200	close to the discharge channel for iron ore washing water
	12	113.590300	24.531400	close to the sand pile
	13	113.590000	24.524700	deep water section, close to dike with very few plants
	14	113.589200	24.521600	deep water section

Aquatic plants

Site	Longitude	Latitude	Habitat

Site			Longitude	Latitude	Habitat
Rujiang	Site 1-1	1	113.268465	24.777209	Shallow Water about 0.5m
	Site 1-2	2	113.273431	24.775246	Shallow Water about 0.5m
	Site 1-3	3	113.268777	24.777669	Shallow Water about 0.5m
	Site 1-4	4	113.273506	24.776069	Shallow Water about 0.5m
	Site 2-1	5	113.259591	24.787760	Shallow Water about 0.5m
	Site 2-1	6	113.259167	24.781782	Shallow Water about 0.5m
	Site 2-2	7	113.259890	24.787795	Shallow Water about 0.5m
	Site 2-3	8	113.259765	24.781861	Shallow Water about 0.5m
Shiliting	Site 1-1	1	113.533849	24.825033	water about 1 m
	Site 1-2	2	113.535397	24.826220	
	Site 1-3	3	113.533991	24.824842	
	Site 1-4	4	113.535458	24.826044	
	Site 2-1	5	113.532253	24.825433	water about 1 m
	Site 2-2	6	113.534047	24.823427	
	Site 2-3	7	113.533467	24.824453	
	Site 2-4	8	113.532943	24.825483	
	Site 3-1	9	113.534821	24.825412	water about 1 m
	Site 3-2	10	113.535012	24.837218	
	Site 3-3	11	113.535151	24.835384	
	Site 3-4	12	113.535296	24.837414	
Lishi	1		113.516875	24.900571	Shallow water, about0.5 m
	2		113.517882	24.901803	Deep water, about0.8 m
	3		113.520586	24.899256	Deep water, about0.8 m
	4		113.521366	24.899971	Deep water, about0.8 m
Zhoutian	1		113.856369	24.981652	about 1 m
	2		113.856497	24.981393	about 0.8 m
	3		113.857287	24.982114	about 1 m
	4		113.857419	24.981720	about 0.7 m
Kekou	1		113.586422	24.537251	water about 1 m
	2		113.588091	24.537184	water about 0.8 m
	3		113.581520	24.549053	water about 1 m
	4		113.587354	24.549665	water about 0.8 m

Odonata

Site		Longitude	Latitude	Habitat
Lishi	1	113.544700	24.876600	River bank
	2	113.510300	24.901200	Permanent pool

	3	113.523600	24.899300	River bank near sand mining
Zhoutian	1	113.835600	24.926700	Temporary pool in sand mining near river
	2	113.884600	24.982000	The confluence downstream of a hydropower dam and a small stream
Kengkou	1	113.580800	24.509900	River bank near a village
	2	113.593300	24.520000	Permanent pool at a tributary of the Beijiang River

Annex II. Summary of the IUCN Red List criteria

Summary of the five criteria (A–E) used to evaluate if a taxon belongs in a threatened category (Critically Endangered, Endangered or Vulnerable).

Use any of the criteria A–E	Critically Endangered	Endangered	Vulnerable
A. Population reduction	Declines measured over the longer of 10 years or 3 generations		
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%
A1. Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND have ceased, based on and specifying any of the following: (a) direct observation (b) an index of abundance appropriate to the taxon (c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality (d) actual or potential levels of exploitation (e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.			
A2. Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible, based on (a) to (e) under A1.			
A3. Population reduction projected or suspected to be met in the future (up to a maximum of 100 years) based on (b) to (e) under A1.			
A4. An observed, estimated, inferred, projected or suspected population reduction (up to a maximum of 100 years) where the time period must include both the past and the future, and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible, based on (a) to (e) under A1.			
B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)			
B1. Extent of occurrence (EOO)	< 100 km²	< 5,000 km²	< 20,000 km²
B2. Area of occupancy (AOO)	< 10 km²	< 500 km²	< 2,000 km²
AND at least 2 of the following:			
(a) Severely fragmented, OR Number of locations	= 1	≤ 5	≤ 10
(b) Continuing decline in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals.			
(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals.			
C. Small population size and decline			
Number of mature individuals	< 250	< 2,500	< 10,000
AND either C1 or C2:			
C1. An estimated continuing decline of at least: (up to a max. of 100 years in future)	25% in 3 years or 1 generation	20% in 5 years or 2 generations	10% in 10 years or 3 generations
C2. A continuing decline AND (a) and/or (b):			
(a i) Number of mature individuals in each subpopulation:	< 50	< 250	< 1,000
or			
(a ii) % individuals in one subpopulation =	90–100%	95–100%	100%
(b) Extreme fluctuations in the number of mature individuals.			
D. Very small or restricted population			
Either:			
Number of mature individuals	< 50	< 250	**D1.** < 1,000
			AND/OR
	Restricted area of occupancy		**D2.** typically: AOO < 20 km² or number of locations ≤ 5
E. Quantitative Analysis			
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations (100 years max.)	≥ 20% in 20 years or 5 generations (100 years max.)	≥ 10% in 100 years

Annex III. Species lists from the Pearl River

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Fishes

Order	Family	Binomial	IUCN Red List Category
Acipenseriformes	Acipenseridae	*Acipenser sinensis*	CR
Anguilliformes	Anguillidae	*Anguilla marmorata*	LC*
Beloniformes	Adrianichthyidae	*Oryzias sinensis*	LC
Cypriniformes	Balitoridae	*Balitora longibarbata*	LC
Cypriniformes	Balitoridae	*Beaufortia cyclica*	LC
Cypriniformes	Balitoridae	*Beaufortia pingi*	LC
Cypriniformes	Balitoridae	*Beaufortia polylepis*	LC
Cypriniformes	Balitoridae	*Erromyzon sinensis*	DD
Cypriniformes	Balitoridae	*Formosania tinkhami*	LC
Cypriniformes	Balitoridae	*Hemimyzon macroptera*	LC
Cypriniformes	Balitoridae	*Liniparhomaloptera disparis*	DD
Cypriniformes	Balitoridae	*Micronemacheilus pulcher*	LC
Cypriniformes	Balitoridae	*Oreonectes platycephalus*	DD
Cypriniformes	Balitoridae	*Paranemachilus genilepis*	DD
Cypriniformes	Balitoridae	*Protomyzon pachychilus*	LC
Cypriniformes	Balitoridae	*Pseudogastromyzon changtingensis changtingensis*	DD*
Cypriniformes	Balitoridae	*Pseudogastromyzon fangi*	LC
Cypriniformes	Balitoridae	*Pseudogastromyzon myersi*	LC
Cypriniformes	Balitoridae	*Schistura fasciolata*	DD
Cypriniformes	Balitoridae	*Schistura hingi*	LC
Cypriniformes	Balitoridae	*Schistura incerta*	DD*
Cypriniformes	Balitoridae	*Sinogastromyzon sichangensis*	LC
Cypriniformes	Balitoridae	*Sinogastromyzon szechuanensis*	LC
Cypriniformes	Balitoridae	*Sinogastromyzon wui*	LC
Cypriniformes	Balitoridae	*Sinohomaloptera kwangsiensis*	LC*
Cypriniformes	Balitoridae	*Vanmanenia pingchowensis*	LC
Cypriniformes	Balitoridae	*Yunnanilus pleurotaenia*	VU
Cypriniformes	Cobitidae	*Acantopsis arenae*	DD
Cypriniformes	Cobitidae	*Cobitis sinensis*	LC*
Cypriniformes	Cobitidae	*Leptobotia guilinensis*	LC
Cypriniformes	Cobitidae	*Leptobotia pellegrini*	LC
Cypriniformes	Cobitidae	*Misgurnus anguillicaudatus*	LC*

Order	Family	Binomial	IUCN Red List Category
Cypriniformes	Cobitidae	*Parabotia banarescui*	DD
Cypriniformes	Cobitidae	*Parabotia fasciata*	LC
Cypriniformes	Cobitidae	*Parabotia lijiangensis*	DD
Cypriniformes	Cobitidae	*Parabotia maculosa*	LC
Cypriniformes	Cobitidae	*Paralepidocephalus yui*	EN
Cypriniformes	Cobitidae	*Sinibotia pulchra*	DD*
Cypriniformes	Cobitidae	*Sinibotia robusta*	DD
Cypriniformes	Cobitidae	*Sinibotia superciliaris*	DD
Cypriniformes	Cobitidae	*Sinibotia zebra*	DD
Cypriniformes	Cyprinidae	*Acheilognathus barbatulus*	LC
Cypriniformes	Cyprinidae	*Acheilognathus chankaensis*	LC*
Cypriniformes	Cyprinidae	*Acheilognathus macropterus*	DD
Cypriniformes	Cyprinidae	*Acheilognathus meridianus*	DD
Cypriniformes	Cyprinidae	*Acheilognathus taenianalis*	LC
Cypriniformes	Cyprinidae	*Acheilognathus tonkinensis*	DD
Cypriniformes	Cyprinidae	*Acrossocheilus beijiangensis*	LC
Cypriniformes	Cyprinidae	*Acrossocheilus clivosius*	DD
Cypriniformes	Cyprinidae	*Acrossocheilus hemispinus*	LC
Cypriniformes	Cyprinidae	*Acrossocheilus iridescens*	DD
Cypriniformes	Cyprinidae	*Acrossocheilus parallens*	LC
Cypriniformes	Cyprinidae	*Acrossocheilus rendahli*	NT
Cypriniformes	Cyprinidae	*Acrossocheilus wenchowensis*	DD*
Cypriniformes	Cyprinidae	*Acrossocheilus yunnanensis*	LC
Cypriniformes	Cyprinidae	*Anabarilius andersoni*	CR
Cypriniformes	Cyprinidae	*Anabarilius liui yiliangensis*	EN*
Cypriniformes	Cyprinidae	*Anabarilius macrolepis*	EX
Cypriniformes	Cyprinidae	*Anabarilius maculatus*	DD
Cypriniformes	Cyprinidae	*Anabarilius qiluensis*	CR
Cypriniformes	Cyprinidae	*Anabarilius transmontanus*	DD
Cypriniformes	Cyprinidae	*Anabarilius yangzonensis*	CR
Cypriniformes	Cyprinidae	*Aphyocypris chinensis*	LC
Cypriniformes	Cyprinidae	*Atrilinea roulei*	LC
Cypriniformes	Cyprinidae	*Bangana decorus*	CR
Cypriniformes	Cyprinidae	*Bangana wui*	DD
Cypriniformes	Cyprinidae	*Bangana yunnanensis*	DD
Cypriniformes	Cyprinidae	*Carassioides acuminatus*	LC
Cypriniformes	Cyprinidae	*Carassius auratus*	LC
Cypriniformes	Cyprinidae	*Chanodichthys dabryi*	LC
Cypriniformes	Cyprinidae	*Chanodichthys erythropterus*	LC*
Cypriniformes	Cyprinidae	*Cirrhinus molitorella*	NT
Cypriniformes	Cyprinidae	*Cirrhinus mrigala*	LC

Order	Family	Binomial	IUCN Red List Category
Cypriniformes	Cyprinidae	*Ctenopharyngodon idella*	LC
Cypriniformes	Cyprinidae	*Culter recurviceps*	LC
Cypriniformes	Cyprinidae	*Cyprinus chilia*	EN
Cypriniformes	Cyprinidae	*Cyprinus fuxianensis*	CR
Cypriniformes	Cyprinidae	*Cyprinus ilishaestomus*	CR
Cypriniformes	Cyprinidae	*Cyprinus longzhouensis*	DD
Cypriniformes	Cyprinidae	*Cyprinus multitaeniata*	NT
Cypriniformes	Cyprinidae	*Cyprinus rubrofuscus*	LC
Cypriniformes	Cyprinidae	*Cyprinus yilongensis*	EX
Cypriniformes	Cyprinidae	*Cyprinus yunnanensis*	CR
Cypriniformes	Cyprinidae	*Discogobio tetrabarbatus*	LC
Cypriniformes	Cyprinidae	*Discogobio yunnanensis*	LC
Cypriniformes	Cyprinidae	*Distoechodon tumirostris*	LC
Cypriniformes	Cyprinidae	*Elopichthys bambusa*	DD
Cypriniformes	Cyprinidae	*Garra imberba*	DD
Cypriniformes	Cyprinidae	*Garra orientalis*	LC
Cypriniformes	Cyprinidae	*Garra yiliangensis*	DD
Cypriniformes	Cyprinidae	*Gnathopogon taeniellus*	DD
Cypriniformes	Cyprinidae	*Gobiobotia kolleri*	DD
Cypriniformes	Cyprinidae	*Gobiobotia longibarba*	DD*
Cypriniformes	Cyprinidae	*Gobiobotia meridionalis*	DD
Cypriniformes	Cyprinidae	*Gobiobotia tungi*	DD
Cypriniformes	Cyprinidae	*Hemibarbus longirostris*	LC
Cypriniformes	Cyprinidae	*Hemibarbus macracanthus*	DD*
Cypriniformes	Cyprinidae	*Hemibarbus medius*	DD
Cypriniformes	Cyprinidae	*Hemibarbus umbrifer*	LC
Cypriniformes	Cyprinidae	*Hemiculter leucisculus*	LC
Cypriniformes	Cyprinidae	*Hemiculter tchangi*	DD
Cypriniformes	Cyprinidae	*Hemiculterella sauvagei*	LC
Cypriniformes	Cyprinidae	*Huigobio chenhsienensis*	LC
Cypriniformes	Cyprinidae	*Hypophthalmichthys molitrix*	NT
Cypriniformes	Cyprinidae	*Hypophthalmichthys nobilis*	DD
Cypriniformes	Cyprinidae	*Labeo rohita*	LC
Cypriniformes	Cyprinidae	*Luciobrama macrocephalus*	DD
Cypriniformes	Cyprinidae	*Luciocyprinus langsoni*	None
Cypriniformes	Cyprinidae	*Megalobrama amblycephala*	LC
Cypriniformes	Cyprinidae	*Megalobrama terminalis*	LC
Cypriniformes	Cyprinidae	*Metzia formosae*	LC
Cypriniformes	Cyprinidae	*Metzia lineata*	LC
Cypriniformes	Cyprinidae	*Microphysogobio chinssuensis*	LC
Cypriniformes	Cyprinidae	*Microphysogobio fukiensis*	LC

Order	Family	Binomial	IUCN Red List Category
Cypriniformes	Cyprinidae	*Microphysogobio kachekensis*	LC
Cypriniformes	Cyprinidae	*Microphysogobio kiatingensis*	LC
Cypriniformes	Cyprinidae	*Microphysogobio labeoides*	DD*
Cypriniformes	Cyprinidae	*Microphysogobio tafangensis*	LC
Cypriniformes	Cyprinidae	*Microphysogobio tungtingensis*	NT
Cypriniformes	Cyprinidae	*Mylopharyngodon piceus*	DD
Cypriniformes	Cyprinidae	*Ochetobius elongatus*	DD*
Cypriniformes	Cyprinidae	*Onychostoma barbatulum*	DD
Cypriniformes	Cyprinidae	*Onychostoma barbatum*	DD
Cypriniformes	Cyprinidae	*Onychostoma gerlachi*	NT
Cypriniformes	Cyprinidae	*Onychostoma lini*	DD*
Cypriniformes	Cyprinidae	*Onychostoma ovale*	DD
Cypriniformes	Cyprinidae	*Onychostoma rarum*	DD
Cypriniformes	Cyprinidae	*Onychostoma simum*	DD
Cypriniformes	Cyprinidae	*Opsariichthys bidens*	DD*
Cypriniformes	Cyprinidae	*Osteochilus salsburyi*	LC
Cypriniformes	Cyprinidae	*Parasinilabeo assimilis*	VU
Cypriniformes	Cyprinidae	*Parator zonatus*	DD*
Cypriniformes	Cyprinidae	*Parazacco spilurus*	DD
Cypriniformes	Cyprinidae	*Percocypris pingi*	NT
Cypriniformes	Cyprinidae	*Platysmacheilus exiguus*	LC
Cypriniformes	Cyprinidae	*Poropuntius chonglingchungi*	CR
Cypriniformes	Cyprinidae	*Procypris mera*	DD
Cypriniformes	Cyprinidae	*Pseudogobio guilinensis*	DD
Cypriniformes	Cyprinidae	*Pseudogobio vaillanti*	LC
Cypriniformes	Cyprinidae	*Pseudogyrinocheilus prochilus*	LC
Cypriniformes	Cyprinidae	*Pseudohemiculter dispar*	VU
Cypriniformes	Cyprinidae	*Pseudohemiculter hainanensis*	LC
Cypriniformes	Cyprinidae	*Pseudolaubuca engraulis*	LC
Cypriniformes	Cyprinidae	*Pseudolaubuca sinensis*	LC
Cypriniformes	Cyprinidae	*Pseudorasbora elongata*	LC
Cypriniformes	Cyprinidae	*Pseudorasbora parva*	LC
Cypriniformes	Cyprinidae	*Ptychidio jordani*	CR
Cypriniformes	Cyprinidae	*Ptychidio macrops*	DD
Cypriniformes	Cyprinidae	*Puntius semifasciolatus*	DD*
Cypriniformes	Cyprinidae	*Rasbora steineri*	LC
Cypriniformes	Cyprinidae	*Rectoris luxiensis*	DD
Cypriniformes	Cyprinidae	*Rectoris posehensis*	DD*
Cypriniformes	Cyprinidae	*Rhodeus fangi*	LC
Cypriniformes	Cyprinidae	*Rhodeus lighti*	LC
Cypriniformes	Cyprinidae	*Rhodeus ocellatus*	DD

Order	Family	Binomial	IUCN Red List Category
Cypriniformes	Cyprinidae	*Rhodeus sinensis*	LC
Cypriniformes	Cyprinidae	*Sarcocheilichthys kiangsiensis*	DD*
Cypriniformes	Cyprinidae	*Sarcocheilichthys nigripinnis*	LC*
Cypriniformes	Cyprinidae	*Sarcocheilichthys parvus*	LC
Cypriniformes	Cyprinidae	*Sarcocheilichthys sinensis*	LC
Cypriniformes	Cyprinidae	*Saurogobio dabryi*	LC*
Cypriniformes	Cyprinidae	*Schizothorax griseus*	LC
Cypriniformes	Cyprinidae	*Schizothorax lissolabiatus*	LC
Cypriniformes	Cyprinidae	*Schizothorax wangchiachii*	NT
Cypriniformes	Cyprinidae	*Schizothorax yunnanensis*	DD
Cypriniformes	Cyprinidae	*Semilabeo notabilis*	DD
Cypriniformes	Cyprinidae	*Semilabeo obscurus*	LC
Cypriniformes	Cyprinidae	*Sinibrama macrops*	LC
Cypriniformes	Cyprinidae	*Sinibrama melrosei*	DD*
Cypriniformes	Cyprinidae	*Sinocyclocheilus tingi*	EN
Cypriniformes	Cyprinidae	*Sinocyclocheilus yangzongensis*	CR
Cypriniformes	Cyprinidae	*Spinibarbus denticulatus*	LC
Cypriniformes	Cyprinidae	*Spinibarbus hollandi*	DD*
Cypriniformes	Cyprinidae	*Squalidus argentatus*	DD
Cypriniformes	Cyprinidae	*Squalidus wolterstorffi*	LC
Cypriniformes	Cyprinidae	*Squaliobarbus curriculus*	DD
Cypriniformes	Cyprinidae	*Tanichthys albonubes*	DD
Cypriniformes	Cyprinidae	*Tor brevifilis*	DD*
Cypriniformes	Cyprinidae	*Tor yunnanensis*	EN
Cypriniformes	Cyprinidae	*Toxabramis hoffmanni*	DD
Cypriniformes	Cyprinidae	*Toxabramis houdemeri*	LC
Cypriniformes	Cyprinidae	*Xenocypris davidi*	LC*
Cypriniformes	Cyprinidae	*Xenocypris macrolepis*	LC*
Cypriniformes	Cyprinidae	*Yaoshanicus arcus*	LC
Cypriniformes	Cyprinidae	*Zacco platypus*	DD*
Osmeriformes	Salangidae	*Neosalanx tangkahkeii*	LC
Osmeriformes	Salangidae	*Salanx chinensis*	DD
Osmeriformes	Salangidae	*Salanx cuvieri*	DD
Perciformes	Anabantidae	*Anabas testudineus*	DD
Perciformes	Channidae	*Channa asiatica*	LC*
Perciformes	Channidae	*Channa gachua*	LC
Perciformes	Channidae	*Channa maculata*	LC
Perciformes	Eleotridae	*Eleotris fusca*	LC
Perciformes	Eleotridae	*Eleotris oxycephala*	LC
Perciformes	Eleotridae	*Hypseleotris compressocephalus*	LC
Perciformes	Eleotridae	*Micropercops cinctus*	LC*

Order	Family	Binomial	IUCN Red List Category
Perciformes	Gobiidae	*Glossogobius giuris*	LC
Perciformes	Gobiidae	*Glossogobius olivaceus*	LC
Perciformes	Gobiidae	*Rhinogobius brunneus*	DD
Perciformes	Gobiidae	*Rhinogobius giurinus*	LC
Perciformes	Gobiidae	*Rhinogobius leavelli*	LC
Perciformes	Labridae	*Pseudolabrus crassilabris*	DD*
Perciformes	Odontobutidae	*Sineleotris chalmersi*	LC
Perciformes	Osphronemidae	*Macropodus opercularis*	LC
Perciformes	Percichthyidae	*Coreoperca whiteheadi*	LC
Perciformes	Percichthyidae	*Siniperca fortis*	DD
Perciformes	Percichthyidae	*Siniperca kneri*	DD
Perciformes	Percichthyidae	*Siniperca obscura*	LC
Perciformes	Percichthyidae	*Siniperca roulei*	DD
Perciformes	Percichthyidae	*Siniperca scherzeri*	DD
Perciformes	Percichthyidae	*Siniperca undulata*	NT
Siluriformes	Amblycipitidae	*Xiurenbagrus xiurenensis*	DD
Siluriformes	Bagridae	*Hemibagrus guttatus*	DD*
Siluriformes	Bagridae	*Hemibagrus macropterus*	LC
Siluriformes	Bagridae	*Pelteobagrus argentivittatus*	LC
Siluriformes	Bagridae	*Pelteobagrus intermedius*	LC*
Siluriformes	Bagridae	*Pseudobagrus albomarginatus*	DD*
Siluriformes	Bagridae	*Pseudobagrus gracilis*	DD*
Siluriformes	Bagridae	*Pseudobagrus ondon*	LC
Siluriformes	Bagridae	*Pseudobagrus vachellii*	DD*
Siluriformes	Bagridae	*Pseudobagrus virgatus*	DD*
Siluriformes	Bagridae	*Tachysurus adiposalis*	LC
Siluriformes	Bagridae	*Tachysurus fulvidraco*	LC
Siluriformes	Clariidae	*Clarias fuscus*	LC*
Siluriformes	Clariidae	*Clarias macrocephalus*	NT
Siluriformes	Cranoglanididae	*Cranoglanis bouderius*	VU
Siluriformes	Siluridae	*Pterocryptis anomala*	LC
Siluriformes	Siluridae	*Pterocryptis cochinchinensis*	LC
Siluriformes	Siluridae	*Silurus asotus*	LC
Siluriformes	Siluridae	*Silurus meridionalis*	LC
Siluriformes	Sisoridae	*Glyptothorax fokiensis*	LC
Siluriformes	Sisoridae	*Glyptothorax pallozonus*	DD
Siluriformes	Sisoridae	*Parachiloglanis hodgarti*	LC
Siluriformes	Sisoridae	*Pareuchiloglanis longicauda*	LC
Synbranchiformes	Mastacembelidae	*Mastacembelus armatus*	LC
Synbranchiformes	Mastacembelidae	*Sinobdella sinensis*	LC
Synbranchiformes	Synbranchidae	*Monopterus albus*	LC

Order	Family	Binomial	IUCN Red List Category
Tetraodontiformes	Tetraodontidae	*Takifugu orbimaculatus*	LC

Molluscs

Class	Order	Family	Binomial	IUCN Red List Category
Bivalvia	Mytiloida	Mytilidae	*Limnoperna lacustris*	LC*
Bivalvia	Unionoida	Unionidae	*Acuticosta chinensis*	LC
Bivalvia	Unionoida	Unionidae	*Acuticosta ovata*	LC
Bivalvia	Unionoida	Unionidae	*Cristaria plicata*	DD
Bivalvia	Unionoida	Unionidae	*Cuneopsis celtiformis*	LC
Bivalvia	Unionoida	Unionidae	*Cuneopsis heudei*	LC
Bivalvia	Unionoida	Unionidae	*Cuneopsis pisciculus*	LC
Bivalvia	Unionoida	Unionidae	*Hyriopsis cumingii*	LC
Bivalvia	Unionoida	Unionidae	*Lamprotula bazini*	DD
Bivalvia	Unionoida	Unionidae	*Lamprotula caveata*	LC
Bivalvia	Unionoida	Unionidae	*Lamprotula fibrosa*	LC
Bivalvia	Unionoida	Unionidae	*Lamprotula leai*	LC
Bivalvia	Unionoida	Unionidae	*Lamprotula tientsinensis*	DD
Bivalvia	Unionoida	Unionidae	*Lamprotula zonata*	DD
Bivalvia	Unionoida	Unionidae	*Lanceolaria gladiola*	LC
Bivalvia	Unionoida	Unionidae	*Lanceolaria grayana*	LC
Bivalvia	Unionoida	Unionidae	*Lanceolaria triformis*	DD
Bivalvia	Unionoida	Unionidae	*Lepidodesma languilati*	DD
Bivalvia	Unionoida	Unionidae	*Schistodesmus lampreyanus*	LC
Bivalvia	Unionoida	Unionidae	*Schistodesmus spinosus*	LC
Bivalvia	Unionoida	Unionidae	*Unio douglasiae*	LC
Bivalvia	Veneroida	Corbiculidae	*Corbicula fluminea*	LC
Bivalvia	Veneroida	Corbiculidae	*Corbicula nitens*	DD*
Gastropoda	Allogastropoda	Bullinidae	*Indoplanorbis exustus*	LC
Gastropoda	Architaenioglossa	Ampullariidae	*Pila polita*	LC
Gastropoda	Architaenioglossa	Viviparidae	*Angulyagra polyzonata*	LC
Gastropoda	Architaenioglossa	Viviparidae	*Bellamya aeruginosa*	LC*
Gastropoda	Architaenioglossa	Viviparidae	*Bellamya limnophila*	DD
Gastropoda	Architaenioglossa	Viviparidae	*Bellamya quadrata*	LC
Gastropoda	Architaenioglossa	Viviparidae	*Cipangopaludina ampulliformis*	LC
Gastropoda	Architaenioglossa	Viviparidae	*Cipangopaludina cathayensis*	LC
Gastropoda	Architaenioglossa	Viviparidae	*Cipangopaludina chinensis*	LC
Gastropoda	Architaenioglossa	Viviparidae	*Margarya mansuyi*	EN
Gastropoda	Hygrophila	Lymnaeidae	*Galba pervia*	LC

Class	Order	Family	Binomial	IUCN Red List Category
Gastropoda	Hygrophila	Lymnaeidae	*Lymnaea stagnalis*	LC
Gastropoda	Hygrophila	Lymnaeidae	*Radix auricularia*	LC
Gastropoda	Hygrophila	Lymnaeidae	*Radix plicatula*	LC*
Gastropoda	Hygrophila	Lymnaeidae	*Radix swinhoei*	LC
Gastropoda	Hygrophila	Planorbidae	*Gyraulus convexiusculus*	LC
Gastropoda	Hygrophila	Planorbidae	*Hippeutis umbilicalis*	LC
Gastropoda	Hygrophila	Planorbidae	*Polypylis hemisphaerula*	LC
Gastropoda	Littorinimorpha	Assimineidae	*Assiminea latericea*	LC
Gastropoda	Littorinimorpha	Assimineidae	*Assiminea lutea*	LC*
Gastropoda	Littorinimorpha	Bithyniidae	*Bithynia fuchsiana*	LC
Gastropoda	Littorinimorpha	Bithyniidae	*Bithynia misella*	LC
Gastropoda	Littorinimorpha	Bithyniidae	*Parafossarulus eximius*	LC*
Gastropoda	Littorinimorpha	Bithyniidae	*Parafossarulus sinensis*	LC*
Gastropoda	Littorinimorpha	Bithyniidae	*Parafossarulus striatulus*	LC*
Gastropoda	Littorinimorpha	Hydrobiidae	*Alocinma longicornis*	LC*
Gastropoda	Littorinimorpha	Pomatiopsidae	*Oncomelania hupensis*	LC
Gastropoda	Littorinimorpha	Pomatiopsidae	*Tricula cristella*	DD*
Gastropoda	Littorinimorpha	Pomatiopsidae	*Tricula gregoriana*	DD*
Gastropoda	Littorinimorpha	Pomatiopsidae	*Tricula humida*	DD*
Gastropoda	Littorinimorpha	Stenothyridae	*Stenothyra glabra*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Melanoides tuberculatus*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Semisulcospira cancellata*	LC*
Gastropoda	Sorbeoconcha	Thiaridae	*Semisulcospira libertina*	LC*
Gastropoda	Sorbeoconcha	Thiaridae	*Tarebia granifera*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Thiara riqueti*	LC
Gastropoda	Hygrophila	Planorbidae	*Gyraulus chinensis*	LC
Bivalvia	Unionoida	Unionidae	*Cuneopsis capitata*	LC
Gastropoda	Architaenioglossa	Viviparidae	*Bellamya purificata*	LC

Odonata

Family	Binomial	IUCN Red List Category
Aeshnidae	*Anaciaeschna jaspidea*	LC
Aeshnidae	*Anaciaeschna martini*	LC
Aeshnidae	*Anax guttatus*	LC
Aeshnidae	*Anax immaculifrons*	LC
Aeshnidae	*Anax nigrofasciatus*	LC
Aeshnidae	*Anax parthenope julius*	LC
Aeshnidae	*Boyeria karubei*	LC
Aeshnidae	*Cephalaeschna dinghuensis*	CR

Family	Binomial	IUCN Red List Category
Aeshnidae	*Gynacantha bayadera*	LC
Aeshnidae	*Gynacantha japonica*	LC
Aeshnidae	*Gynacantha saltatrix*	LC
Aeshnidae	*Gynacantha subinterrupta*	LC
Aeshnidae	*Periaeschna flinti*	LC
Aeshnidae	*Periaeschna gerrhon*	DD
Aeshnidae	*Periaeschna magdalena*	LC
Aeshnidae	*Periaeschna zhangzhouensis*	LC
Aeshnidae	*Planaeschna gressitti*	DD
Aeshnidae	*Planaeschna nanlingensis*	DD
Aeshnidae	*Planaeschna suichangensis*	LC
Aeshnidae	*Polycanthagyna erythromelas*	LC
Aeshnidae	*Polycanthagyna melanictera*	LC
Aeshnidae	*Polycanthagyna ornithocephala*	LC
Aeshnidae	*Tetracanthagyna waterhousei*	LC
Calopterygidae	*Archineura incarnata*	LC
Calopterygidae	*Atrocalopteryx atrocyana*	NT
Calopterygidae	*Caliphaea nitens*	LC
Calopterygidae	*Calopteryx atrata*	LC
Calopterygidae	*Matrona basilaris*	LC
Calopterygidae	*Mnais andersoni*	LC
Calopterygidae	*Mnais mneme*	LC
Calopterygidae	*Neurobasis chinensis*	LC
Calopterygidae	*Vestalaria miao*	LC
Chlorocyphidae	*Indocypha katharina*	DD
Chlorocyphidae	*Libellago lineata*	LC
Chlorocyphidae	*Rhinocypha drusilla*	LC
Chlorocyphidae	*Rhinocypha fenestrella*	LC
Chlorocyphidae	*Rhinocypha perforata*	LC
Chlorogomphidae	*Chlorogomphus papilio*	LC
Chlorogomphidae	*Chloropetalia soarer*	DD
Coenagrionidae	*Aciagrion huaanensis*	DD
Coenagrionidae	*Aciagrion migratum*	LC
Coenagrionidae	*Aciagrion tillyardi*	LC
Coenagrionidae	*Agriocnemis lacteola*	LC
Coenagrionidae	*Agriocnemis pygmaea*	LC
Coenagrionidae	*Argiocnemis rubescens*	LC
Coenagrionidae	*Ceriagrion auranticum*	LC
Coenagrionidae	*Ceriagrion azureum*	LC
Coenagrionidae	*Ceriagrion fallax*	LC
Coenagrionidae	*Ceriagrion melanurum*	LC
Coenagrionidae	*Ceriagrion olivaceum*	LC

Family	Binomial	IUCN Red List Category
Coenagrionidae	*Ischnura asiatica*	LC*
Coenagrionidae	*Ischnura aurora*	LC
Coenagrionidae	*Ischnura senegalensis*	LC
Coenagrionidae	*Mortonagrion hirosei*	NT
Coenagrionidae	*Onychargia atrocyana*	LC
Coenagrionidae	*Paracercion calamorum*	LC
Coenagrionidae	*Paracercion hieroglyphicum*	LC
Coenagrionidae	*Paracercion melanotum*	LC
Coenagrionidae	*Pseudagrion microcephalum*	LC
Coenagrionidae	*Pseudagrion pruinosum*	LC
Coenagrionidae	*Pseudagrion rubriceps*	LC
Coenagrionidae	*Pseudagrion spencei*	LC
Cordulegastridae	*Anotogaster flaveola*	DD
Cordulegastridae	*Anotogaster gregoryi*	LC
Cordulegastridae	*Anotogaster kuchenbeiseri*	LC*
Cordulegastridae	*Anotogaster sieboldii*	LC*
Cordulegastridae	*Sinorogomphus nasutus*	LC
Corduliidae	*Idionyx carinata*	LC
Corduliidae	*Idionyx claudia*	LC
Corduliidae	*Idionyx victor*	LC*
Corduliidae	*Macromidia ellenae*	None
Corduliidae	*Macromidia kelloggi*	LC
Corduliidae	*Macromidia rapida*	LC
Euphaeidae	*Anisopleura furcata*	LC
Euphaeidae	*Anisopleura qingyuanensis*	LC
Euphaeidae	*Bayadera bidentata*	LC
Euphaeidae	*Bayadera continentalis*	LC
Euphaeidae	*Bayadera melanopteryx*	LC
Euphaeidae	*Euphaea decorata*	LC
Euphaeidae	*Euphaea opaca*	DD
Euphaeidae	*Euphaea superba*	LC
Gomphidae	*Amphigomphus hansoni*	LC
Gomphidae	*Anisogomphus anderi*	LC
Gomphidae	*Anisogomphus koxingai*	LC
Gomphidae	*Burmagomphus vermicularis*	LC
Gomphidae	*Davidius fruhstorferi*	LC
Gomphidae	*Fukienogomphus choifongae*	LC
Gomphidae	*Fukienogomphus prometheus*	DD
Gomphidae	*Fukienogomphus promineus*	LC
Gomphidae	*Gomphidia kelloggi*	EN
Gomphidae	*Gomphidia kruegeri*	LC
Gomphidae	*Heliogomphus retroflexus*	LC

Family	Binomial	IUCN Red List Category
Gomphidae	*Heliogomphus scorpio*	LC
Gomphidae	*Ictinogomphus pertinax*	LC
Gomphidae	*Labrogomphus torvus*	LC
Gomphidae	*Lamelligomphus camelus*	LC
Gomphidae	*Lamelligomphus hainanensis*	LC
Gomphidae	*Leptogomphus divaricatus*	LC
Gomphidae	*Leptogomphus elegans*	LC
Gomphidae	*Leptogomphus intermedius*	DD
Gomphidae	*Leptogomphus perforatus*	LC
Gomphidae	*Megalogomphus sommeri*	LC
Gomphidae	*Melligomphus ardens*	LC
Gomphidae	*Nihonogomphus semanticus*	DD
Gomphidae	*Nihonogomphus simillimus*	DD
Gomphidae	*Ophiogomphus sinicus*	DD
Gomphidae	*Paragomphus capricornis*	LC
Gomphidae	*Phaenandrogomphus tonkinicus*	LC
Gomphidae	*Sieboldius alexanderi*	DD
Gomphidae	*Sieboldius deflexus*	LC
Gomphidae	*Sinictinogomphus clavatus*	LC
Gomphidae	*Sinogomphus telamon*	DD
Gomphidae	*Stylogomphus chunliuae*	LC
Gomphidae	*Stylogomphus tantulus*	DD
Gomphidae	*Stylurus clathratus*	LC
Gomphidae	*Stylurus nanningensis*	LC
Lestidae	*Indolestes peregrinus*	LC
Lestidae	*Lestes concinnus*	LC
Lestidae	*Lestes nodalis*	LC
Lestidae	*Lestes praemorsus*	LC
Libellulidae	*Acisoma panorpoides*	LC
Libellulidae	*Brachydiplax chalybea*	LC
Libellulidae	*Brachythemis contaminata*	LC
Libellulidae	*Cratilla lineata*	LC
Libellulidae	*Crocothemis servilia*	LC
Libellulidae	*Diplacodes nebulosa*	LC
Libellulidae	*Diplacodes trivialis*	LC
Libellulidae	*Hydrobasileus croceus*	LC
Libellulidae	*Libellula melli*	LC
Libellulidae	*Lyriothemis elegantissima*	LC
Libellulidae	*Lyriothemis pachygastra*	LC
Libellulidae	*Lyriothemis tricolor*	LC
Libellulidae	*Nannophya pygmaea*	LC
Libellulidae	*Neurothemis fulvia*	LC

Family	Binomial	IUCN Red List Category
Libellulidae	*Neurothemis tullia*	LC
Libellulidae	*Onychothemis testacea*	LC
Libellulidae	*Orthetrum chrysis*	LC
Libellulidae	*Orthetrum glaucum*	LC
Libellulidae	*Orthetrum luzonicum*	LC
Libellulidae	*Orthetrum melania*	LC
Libellulidae	*Orthetrum pruinosum*	LC
Libellulidae	*Orthetrum sabina*	LC
Libellulidae	*Orthetrum triangulare*	LC
Libellulidae	*Palpopleura sexmaculata*	LC
Libellulidae	*Pantala flavescens*	LC
Libellulidae	*Potamarcha congener*	LC
Libellulidae	*Pseudothemis zonata*	LC
Libellulidae	*Rhodothemis rufa*	LC
Libellulidae	*Rhyothemis fuliginosa*	LC
Libellulidae	*Rhyothemis variegata*	LC
Libellulidae	*Sympetrum baccha*	LC
Libellulidae	*Sympetrum darwinianum*	LC
Libellulidae	*Sympetrum infuscatum*	LC
Libellulidae	*Sympetrum parvulum*	LC
Libellulidae	*Sympetrum risi*	None
Libellulidae	*Sympetrum speciosum*	LC
Libellulidae	*Tetrathemis platyptera*	LC
Libellulidae	*Tholymis tillarga*	LC
Libellulidae	*Tramea transmarina*	LC
Libellulidae	*Tramea virginia*	LC
Libellulidae	*Trithemis aurora*	LC
Libellulidae	*Trithemis festiva*	LC
Libellulidae	*Trithemis pallidinervis*	LC
Libellulidae	*Urothemis signata*	LC
Libellulidae	*Zygonyx asahinai*	LC
Libellulidae	*Zygonyx iris*	LC
Libellulidae	*Zygonyx takasago*	LC
Libellulidae	*Zyxomma petiolatum*	LC
Macromiidae	*Epophthalmia elegans*	LC
Macromiidae	*Macromia berlandi*	LC
Macromiidae	*Macromia calliope*	LC
Macromiidae	*Macromia clio*	LC
Macromiidae	*Macromia daimoji*	LC*
Macromiidae	*Macromia flavocolorata*	LC
Macromiidae	*Macromia katae*	VU
Macromiidae	*Macromia urania*	LC

Family	Binomial	IUCN Red List Category
Megapodagrionidae	*Agriomorpha fusca*	LC
Megapodagrionidae	*Mesopodagrion tibetanum*	LC
Megapodagrionidae	*Philosina alba*	VU
Megapodagrionidae	*Philosina buchi*	DD
Platycnemididae	*Calicnemia chaoi*	DD
Platycnemididae	*Calicnemia sinensis*	LC*
Platycnemididae	*Coeliccia cyanomelas*	LC
Platycnemididae	*Coeliccia flavicauda*	LC
Platycnemididae	*Copera ciliata*	LC
Platycnemididae	*Copera marginipes*	LC
Platycnemididae	*Indocnemis orang*	LC
Platystictidae	*Drepanosticta brownelli*	NT
Platystictidae	*Drepanosticta hongkongensis*	LC
Platystictidae	*Protosticta beaumonti*	LC
Platystictidae	*Protosticta taipokauensis*	LC
Platystictidae	*Sinosticta debra*	LC
Platystictidae	*Sinosticta ogatai*	LC
Protoneuridae	*Prodasineura autumnalis*	LC
Protoneuridae	*Prodasineura croconota*	LC
Protoneuridae	*Prodasineura verticalis*	LC
Pseudolestidae	*Lestomima flavostigma*	DD
Pseudolestidae	*Rhipidolestes chaoi*	DD
Pseudolestidae	*Rhipidolestes cyanoflavus*	LC
Pseudolestidae	*Rhipidolestes janetae*	LC
Pseudolestidae	*Rhipidolestes truncatidens*	LC
Synlestidae	*Megalestes discus*	DD
Synlestidae	*Megalestes distans*	LC
Synlestidae	*Megalestes heros*	LC
Synlestidae	*Sinolestes editus*	LC
Aeshnidae	*Anax parthenope*	LC
Libellulidae	*Sympetrum eroticum*	LC

Plants

Phylum	Class	Order	Family	Binomial	Red List Category
Polypodiophyta	Polypodiopsida	Marsileales	Marsileaceae	*Marsilea crenata*	LC
Polypodiophyta	Polypodiopsida	Salviniales	Azollaceae	*Azolla pinnata*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Alisma canaliculatum*	LC*
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Alisma plantago-aquatica*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Caldesia grandis*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Sagittaria guayanensis*	LC

Phylum	Class	Order	Family	Binomial	Red List Category
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Sagittaria lichuanensis*	EN
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Sagittaria potamogetifolia*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Sagittaria pygmaea*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Sagittaria sagittifolia*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Sagittaria tengtsungensis*	DD
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Sagittaria trifolia*	LC
Tracheophyta	Liliopsida	Arales	Acoraceae	*Acorus calamus*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Lemna minor*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Lemna perpusilla*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Lemna trisulca*	LC
Tracheophyta	Liliopsida	Commelinales	Commelinaceae	*Commelina communis*	LC*
Tracheophyta	Liliopsida	Commelinales	Commelinaceae	*Murdannia triquetra*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Blysmus compressus var. brevifolius*	DD*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Bolboschoenus yagara*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Carex alopecuroides*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Carex dimorpholepis*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Carex muliensis*	DD*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Carex schmidtii*	DD*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Carex thibetica*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus serotinus*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Eleocharis acicularis*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Eleocharis acutangula*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Eleocharis pellucida*	DD*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Eleocharis tetraquetra*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Eleocharis valleculosa*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Fimbristylis aestivalis*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Fimbristylis cymosa*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Fimbristylis longispica*	DD*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Fimbristylis squarrosa*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Kobresia tibetica*	DD*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Kyllinga brevifolia*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Lepidosperma chinense*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Pycreus delavayi*	DD*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Pycreus flavidus*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Pycreus lijiangensis*	DD*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Pycreus sulcinux*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Pycreus unioloides*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Rhynchospora rugosa*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Schoenoplectiella juncoides*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Schoenoplectus mucronatus ssp. Mucronatus*	LC*

Phylum	Class	Order	Family	Binomial	Red List Category
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Schoenoplectus tabernaemontani*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Scirpus lushanensis*	DD*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Alopecurus aequalis*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Alopecurus japonicus*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Arthraxon hispidus*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Beckmannia syzigachne*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Calamagrostis pseudophragmites*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Catabrosa aquatica*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Chikusichloa mutica*	DD*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Coelachne simpliciuscula*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Coix lacryma-jobi*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Deschampsia cespitosa*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Echinochloa cruspavonis*	DD*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Echinochloa oryzoides*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Eriachne pallescens*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Eriochloa villosa*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Garnotia patula*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Glyceria maxima*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Hemarthria sibirica*	DD*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Hymenachne amplexicaulis*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Isachne globosa*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Ischaemum aristatum*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Ischaemum rugosum*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Leersia japonica*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Leersia sayanuka*	DD*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Leptochloa chinensis*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Milium effusum*	DD*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Miscanthus floridulus*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Miscanthus sacchariflorus*	DD*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Oplismenus undulatifolius*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Panicum bisulcatum*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Paspalum thunbergii*	DD*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Phragmites australis*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Polypogon fugax*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Polypogon monspeliensis*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Pseudoraphis brunoniana*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Sacciolepis indica*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Sphaerocaryum malaccense*	LC*
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Blyxa aubertii*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Blyxa japonica*	LC

Phylum	Class	Order	Family	Binomial	Red List Category
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Blyxa octandra*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Hydrilla verticillata*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Najas chinensis*	DD*
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Najas gracillima*	DD*
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Najas indica*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Najas marina*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Najas minor*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Nechamandra alternifolia*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Ottelia acuminata*	EN*
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Ottelia alismoides*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Ottelia balansae*	DD
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Vallisneria natans*	LC
Tracheophyta	Liliopsida	Juncales	Juncaceae	*Juncus alatus*	LC*
Tracheophyta	Liliopsida	Juncales	Juncaceae	*Juncus allioides*	DD*
Tracheophyta	Liliopsida	Juncales	Juncaceae	*Juncus effusus*	LC
Tracheophyta	Liliopsida	Juncales	Juncaceae	*Juncus setchuensis*	DD*
Tracheophyta	Liliopsida	Juncales	Juncaceae	*Juncus sikkimensis*	LC*
Tracheophyta	Liliopsida	Juncales	Juncaceae	*Juncus thomsonii*	DD*
Tracheophyta	Liliopsida	Liliales	Amaryllidaceae	*Crinum asiaticum var. sinicum*	DD*
Tracheophyta	Liliopsida	Liliales	Pontederiaceae	*Monochoria korsakowii*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton compressus*	LC*
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton crispus*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton cristatus*	DD*
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton distinctus*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton gramineus*	DD*
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton maackianus*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton natans*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton octandrus*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton oxyphyllus*	DD*
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton pusillus*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton tepperi*	LC*
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton wrightii*	LC
Tracheophyta	Liliopsida	Typhales	Typhaceae	*Typha angustifolia*	LC
Tracheophyta	Liliopsida	Typhales	Typhaceae	*Typha elephantina*	LC
Tracheophyta	Liliopsida	Typhales	Typhaceae	*Typha latifolia*	LC*
Tracheophyta	Liliopsida	Typhales	Typhaceae	*Typha orientalis*	LC
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Angelica polymorpha*	DD*
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Centella asiatica*	LC*
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Cicuta virosa*	DD*
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Cnidium monnieri*	LC*
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Oenanthe benghalensis*	LC*
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Oenanthe hookeri*	DD*

Phylum	Class	Order	Family	Binomial	Red List Category
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Oenanthe javanica*	LC
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Oenanthe linearis*	LC*
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Oenanthe rosthornii*	DD*
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Bidens tripartita*	LC*
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Hemisteptia lyrata*	LC
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Wedelia chinensis*	LC
Tracheophyta	Magnoliopsida	Campanulales	Campanulaceae	*Lobelia chinensis*	LC*
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Cardamine flexuosa var. debilis*	DD*
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Cardamine hirsuta*	LC*
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Cardamine macrophylla*	LC*
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Cardamine scutata*	DD*
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Rorippa cantoniensis*	LC*
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Rorippa globosa*	LC*
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Rorippa palustris*	LC*
Tracheophyta	Magnoliopsida	Caryophyllales	Amaranthaceae	*Alternanthera sessilis*	LC
Tracheophyta	Magnoliopsida	Euphorbiales	Euphorbiaceae	*Glochidion hirsutum*	LC*
Tracheophyta	Magnoliopsida	Fabales	Leguminosae	*Pongamia pinnata*	LC*
Tracheophyta	Magnoliopsida	Fabales	Leguminosae	*Sesbania cannabina*	LC*
Tracheophyta	Magnoliopsida	Fabales	Leguminosae	*Sesbania javanica*	LC
Tracheophyta	Magnoliopsida	Haloragales	Haloragaceae	*Myriophyllum spicatum*	LC*
Tracheophyta	Magnoliopsida	Lamiales	Labiatae	*Dysophylla cruciata*	DD*
Tracheophyta	Magnoliopsida	Lamiales	Labiatae	*Dysophylla pentagona*	DD*
Tracheophyta	Magnoliopsida	Lamiales	Labiatae	*Dysophylla sampsonii*	LC*
Tracheophyta	Magnoliopsida	Lamiales	Labiatae	*Dysophylla stellata*	LC*
Tracheophyta	Magnoliopsida	Lamiales	Labiatae	*Dysophylla yatabeana*	DD*
Tracheophyta	Magnoliopsida	Lamiales	Labiatae	*Lycopus lucidus*	LC*
Tracheophyta	Magnoliopsida	Lamiales	Labiatae	*Salvia plebeia*	LC*
Tracheophyta	Magnoliopsida	Lamiales	Labiatae	*Scutellaria barbata*	LC*
Tracheophyta	Magnoliopsida	Myrtales	Lythraceae	*Ammannia auriculata*	LC
Tracheophyta	Magnoliopsida	Myrtales	Lythraceae	*Ammannia multiflora*	LC
Tracheophyta	Magnoliopsida	Myrtales	Lythraceae	*Lythrum salicaria*	LC*
Tracheophyta	Magnoliopsida	Myrtales	Lythraceae	*Rotala cordata*	DD*
Tracheophyta	Magnoliopsida	Myrtales	Lythraceae	*Rotala indica*	LC
Tracheophyta	Magnoliopsida	Myrtales	Lythraceae	*Rotala rosea*	LC
Tracheophyta	Magnoliopsida	Myrtales	Lythraceae	*Rotala rotundifolia*	LC
Tracheophyta	Magnoliopsida	Myrtales	Lythraceae	*Rotala wallichii*	DD*
Tracheophyta	Magnoliopsida	Myrtales	Onagraceae	*Epilobium amurense*	LC*
Tracheophyta	Magnoliopsida	Myrtales	Onagraceae	*Epilobium hirsutum*	LC*
Tracheophyta	Magnoliopsida	Myrtales	Onagraceae	*Epilobium palustre*	LC*
Tracheophyta	Magnoliopsida	Myrtales	Onagraceae	*Epilobium parviflorum*	LC*
Tracheophyta	Magnoliopsida	Myrtales	Onagraceae	*Epilobium pyrricholophum*	LC*
Tracheophyta	Magnoliopsida	Myrtales	Onagraceae	*Ludwigia prostrata*	LC*

Phylum	Class	Order	Family	Binomial	Red List Category
Tracheophyta	Magnoliopsida	Myrtales	Trapaceae	*Trapa incisa*	LC*
Tracheophyta	Magnoliopsida	Nepenthales	Droseraceae	*Drosera oblanceolata*	DD*
Tracheophyta	Magnoliopsida	Nepenthales	Droseraceae	*Drosera peltata*	LC
Tracheophyta	Magnoliopsida	Nepenthales	Droseraceae	*Drosera rotundifolia*	LC*
Tracheophyta	Magnoliopsida	Nepenthales	Droseraceae	*Drosera spathulata*	DD*
Tracheophyta	Magnoliopsida	Nymphaeales	Ceratophyllaceae	*Ceratophyllum demersum*	LC
Tracheophyta	Magnoliopsida	Nymphaeales	Ceratophyllaceae	*Ceratophyllum muricatum ssp. kossinskyi*	LC*
Tracheophyta	Magnoliopsida	Nymphaeales	Ceratophyllaceae	*Ceratophyllum platyacanthum ssp. oryzetorum*	DD*
Tracheophyta	Magnoliopsida	Nymphaeales	Nymphaeaceae	*Euryale ferox*	LC
Tracheophyta	Magnoliopsida	Nymphaeales	Nymphaeaceae	*Nuphar pumila*	LC*
Tracheophyta	Magnoliopsida	Plantaginales	Plantaginaceae	*Plantago asiatica*	LC*
Tracheophyta	Magnoliopsida	Plantaginales	Plantaginaceae	*Plantago depressa*	LC*
Tracheophyta	Magnoliopsida	Podostemales	Podostemaceae	*Cladopus austrosinensis*	DD
Tracheophyta	Magnoliopsida	Podostemales	Podostemaceae	*Cladopus nymanii*	LC
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Persicaria maculosa*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Persicaria nepalensis*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Persicaria vivipara*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Polygonum chinense*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Polygonum maackianum*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Polygonum sibiricum*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Polygonum thunbergii*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Polygonum viscosum*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Rumex amurensis*	DD*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Rumex dentatus*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Rumex japonicus*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Rumex nepalensis*	DD*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Rumex trisetifer*	DD*
Tracheophyta	Magnoliopsida	Primulales	Primulaceae	*Lysimachia candida*	LC*
Tracheophyta	Magnoliopsida	Primulales	Primulaceae	*Lysimachia christinae*	LC*
Tracheophyta	Magnoliopsida	Primulales	Primulaceae	*Lysimachia stenosepala*	DD*
Tracheophyta	Magnoliopsida	Ranunculales	Ranunculaceae	*Batrachium bungei*	DD*
Tracheophyta	Magnoliopsida	Ranunculales	Ranunculaceae	*Batrachium eradicatum*	DD*
Tracheophyta	Magnoliopsida	Ranunculales	Ranunculaceae	*Caltha palustris*	DD*
Tracheophyta	Magnoliopsida	Ranunculales	Ranunculaceae	*Ranunculus cantoniensis*	LC*
Tracheophyta	Magnoliopsida	Ranunculales	Ranunculaceae	*Ranunculus chinensis*	LC*
Tracheophyta	Magnoliopsida	Ranunculales	Ranunculaceae	*Ranunculus japonicus*	LC*
Tracheophyta	Magnoliopsida	Ranunculales	Ranunculaceae	*Ranunculus nephelogenes*	DD*
Tracheophyta	Magnoliopsida	Ranunculales	Ranunculaceae	*Ranunculus popovii var. stracheyanus*	DD*
Tracheophyta	Magnoliopsida	Ranunculales	Ranunculaceae	*Ranunculus sieboldii*	LC*

Phylum	**Class**	**Order**	**Family**	**Binomial**	**Red List Category**
Tracheophyta	Magnoliopsida	Scrophulariales	Acanthaceae	*Hygrophila salicifolia*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia aurea*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia australis*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia bifida*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia brachiata*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia caerulea*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia exoleta*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia graminifolia*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia limosa*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia scandens*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia striatula*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia uliginosa*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Centranthera cochinchinensis var. cochinchinensis*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Limnophila sessiliflora*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Lindernia antipoda*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Lindernia crustacea*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Lindernia micrantha*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Lindernia procumbens*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Mazus miquelii*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Mazus pumilus*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Pedicularis longiflora var. tubiformis*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Scrophularia ningpoensis*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Veronica beccabunga ssp. muscosa*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Veronica undulata*	DD*

Section 2

Freshwater ecosystem services and biodiversity values at Buxa, West Bengal.

Freshwater ecosystem services and biodiversity values at Buxa, West Bengal

Work Package 3 report:

Highland Aquatic Resources Conservation and Sustainable Development (HighARCS)

Centre for the Development of Human Initiatives (CDHI)
Composite Complex, Jalpaiguri
West Bengal, India
www.cdhi.org

October 2011

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1. Introduction

1.1. Focus of the report

This report is a deliverables of an EC funded project called 'HighARCS' (see www.higharcs.org), which is using an integrated approach of biodiversity, livelihoods, economic surveys following the IUCN Integrated Wetland Assessment Toolkit (Springate-Baginsky *et al.* 2009) (see Figure 1), to value five wetland sites across Asia, and develop action plans to ensure aquatic resources are conserved and used sustainably. Here we present the findings of research taken to identify and value biodiversity and ecosystem services at one of these sites Buxa, Jailpaguri, West Bengal, India. This report, will be used alongside two others one on livelihoods and one on the stakeholders, institutions and markets to formulate an integrated action plan to address sustainable use of aquatic resources at the site in Buxa. For more detailed information on the Buxa site and in particular the geographical context, the social and livelihood setting and the aquatic resource use of the communities see the 'Situation Analysis Report on Buxa' (Ray *et al.* 2010).

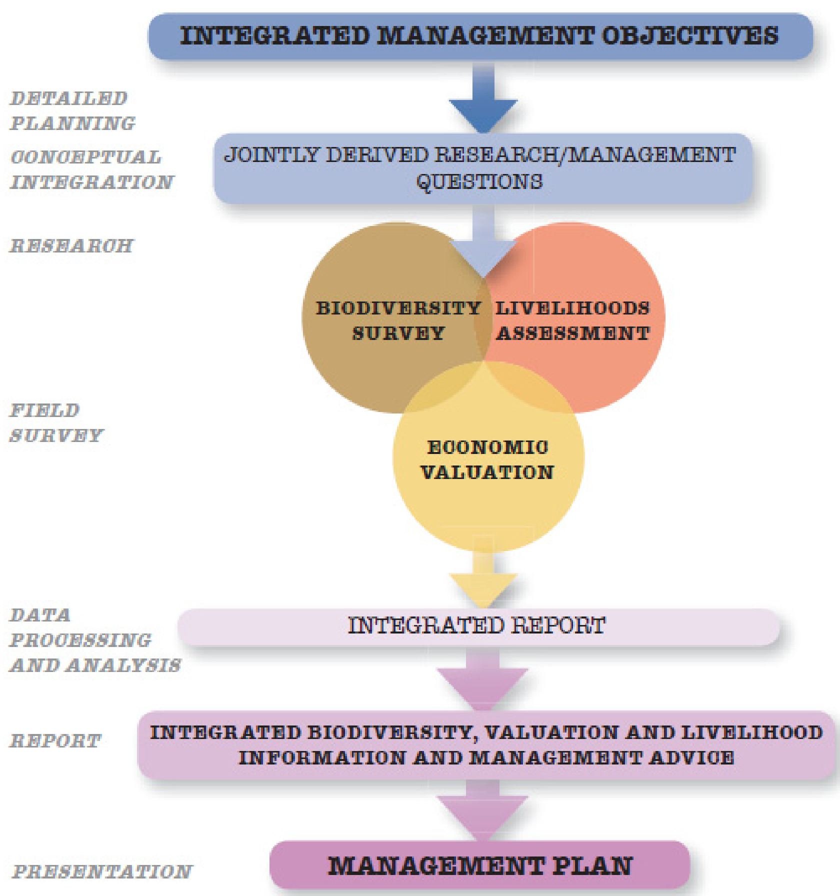


Figure 1. Integrated assessment approach from Springate-Baginsky *et al.* (2009)

1.2. Background to the natural environment of Buxa

The Buxa project site is found in the hills of the extreme north east of Kalchini block in the Jalpaiguri District of West Bengal, India (See figures 2 and 3). The site incorporates three 'clusters' of villages, Adma (Cluster I), Buxa Fort (II) and Jayanti (III), all of which are within the Buxa Tiger Reserve (BTR), the core of which is a National Park (which covers Adma and Buxa Fort only) (figures 4a and 4b). The reserve is 760km2 and has an elevation range of 60 to 1,750m, the northern part of the reserve containing the foothills to the Central Himalaya with the Sinchula Hills forming the border with Bhutan, but most of the reserve lies in the lowland Gangetic Plains. More than ten rivers, some seasonal, are found within the BTR including the Buxa, Adma, and Chunabhati rivers, they all merge together and form the Jayanti River runs into the Gadadhar River which flows to Bangladesh and finally into the Bay of Bengal.

The primary habitat of the BTR is tropical moist-deciduous forest, with some evergreen, semi-evergreen and riverine forest, scrub and grassland along with native tree plantations (Sivakumar *et al.* 2006). The majority of the rivers around the 'clusters' are in narrow gorges with steep hillsides and have a fast velocity (Schroll, H. pers. comm. 2010). According to Das (2005) the reserve is rich in biodiversity, including 60% of the floral endemic species of northeast India, 352 species of trees, 154 species of orchids, 246 species of birds, 68 species of mammals, 41 species of reptiles, 65 species of fish and four amphibian species. The BTR is known to hold many globally threatened species including the clouded leopard (*Neofelis nebulosa*, listed as Vulnerable on the IUCN Red List), Chinese pangolin (*Manis pentadactyla*, Endangered), black-necked crane (*Grus nigricollis*, Vulnerable) and of course the tiger (*Panthera tigris*, Endangered). Human wildlife conflicts are present, with elephants, tigers and leopards all coming into contact with human populations, their property, crops and livestock. Annually 47-80 cattle (plus sheep and goats) are lost to predators and between 1-9 human deaths and 1-8 human injuries are reported each year (Das 2000). The overarching policy framework that covers biodiversity and conservation in India is the Biodiversity Act (2002) and its enacting legislation the Biological Diversity Rules, 2004. This legislation is the Government of India's implementation of the UN Convention on Biological Diversity (1992). The Acts main aims are the conservation of biological resources and associated knowledge as well as facilitating access to them in a sustainable manner, and establishes the National Biodiversity Authority, the main provisions of the Act and Rules can be seen in Box 1.

Most of the people living within the BTR are poor and rely upon agriculture which is supplemented by animal husbandry, manual labour and the use and selling of non timber forest products (NTFPs) (Ray *et al.* 2010). The use of non timber forest products (NTFPs) has increased significantly since the creation of the BTR which reduced employment opportunities in the area (Das 2005). Most households in the three 'clusters' rely upon water collected from seasonal streams for drinking whereas the majority of agriculture is rain fed, apart from 'Jayanti' where river water irrigation is also used. Harvesting of biodiversity in the BTR falls under the provisions of the Biodiversity Act and Rules but also the Indian Wildlife Protection Act (1972 amended 2003) which aims to control poaching and illegal trade in wildlife.

Therefore harvesting is allowed in the BTR, but only by the local communities and only for subsistence use. However, the level of harvesting of aquatic species is relatively small and is ranked below agriculture, livestock and income generated from manual labour or employment gained outside the area (Ray *et al.* 2010).

Box 1. The main provisions of the Biological Diversity Act, 2002 and Biological Diversity Rules, 2004

1. Prohibition on transfer of Indian genetic material outside the country, without specific approval of the Indian Government.
2. Prohibition on anyone claiming an Intellectual Property Right (IPR), such as a patent, over biodiversity or related knowledge, without the permission of the Indian Government.
3. Regulation of collection and use of biodiversity by Indian nationals, while exempting local communities from such restrictions.
4. Measures for sharing the benefits from the use of biodiversity, including the transfer of technology, monetary returns, joint Research & Development, joint IPR ownership, etc.
5. Measures to conserve and sustainably use biological resources, including habitat and species protection, environmental impact assessments of projects, integration of biodiversity into the plans, programmes, and policies of various departments/sectors.
6. Provisions for local communities to have a say in the use of their resources and knowledge, and to charge fees for any access.
7. Protection of indigenous or traditional knowledge, through appropriate laws or other measures such as the registration of such knowledge.
8. Regulation of the use of genetically modified organisms.
9. Setting up of National, State, and Local Biodiversity Funds, to support conservation and benefit-sharing.
10. Setting up of Biodiversity Management Committees (BMC) at local, village and urban levels, State Biodiversity Boards (SBB) at the state level, and a National Biodiversity Authority (NBA).

Taken from Kalpavriksh and GRAIN (2009)

Fishing is freely allowed in the BTR, and fish harvested from the rivers is used to supplement food, and occasionally provide income. Fish culture is practiced in the wider Terai region, but in Buxa only a few households are trying culture fish including ornamental species. The government has conducted training to promote fish culture but this has not been widely adopted. There is scope for the development of pisciculture in BTR however the occurrence of flash floods is a major risk as water bodies (including village ponds) overflow during floods and the fish could be transported into the rivers, this would result in the potential introduction of non-native species into the rivers threatening native species, and the villages would lose their fish.

Many of the rivers in West Bengal and of the middle and lower reached of Ganges and Brahmaputra catchments in India are in an alarming condition, and have been for over a decade due to pollution and human modification including dams (Allen *et al.* 2010, Bhakta and Bandyopadhyay 2007). Threats to biodiversity in Buxa are driven by the large amount of people and livestock that depend upon the natural resources provided by the BTR. About 37,000 people live within the BTR, collecting fuel wood, non-timber forest products and (seasonally) grazing nearly 120,000 cattle which are degrading natural vegetation, competing with native species and allowing the invasion of non-native invasive plants (Das 2000). Poaching and illegal timber harvesting, often operating from across the close international border, is also present in the reserve. The reserve is also fringed by 34 tea plantations (Das 2005). Based on a PRA exercise with the communities, the ecosystem services provided by aquatic systems are in decline (see Ray *et al.* 2010). Water quality and quantity is in decline, the streams used to flow all year but are now seasonal, have less flow and are polluted, with fish catches declining. The decline of fish is blamed upon the increasing use of pesticides and use of small net sizes (including mosquito nets). Pesticides are used in agriculture but also used on a regular basis as a method of catching fish, which are then sold in local markets. Pesticides used in BTR include Endosulfan (Thiodan) which is known for adverse environment and human health impacts and has now been banned under the Stockholm Convention 2011, and in May 2011 the Indian Supreme Court banned its manufacture, sale and use for eight weeks until an expert committee reports upon the impacts of its use (Times of India May 13, 2011). Increasing levels of sediment in the rivers due to deforestation and mining (the collection of sand and boulders from the stream beds) upstream in Bhutan and then flowing into the BTR is deteriorating water quality. Alien species also pose a threat to native biodiversity, and India has a high number with more than 300 exotic species introduced so far for aquaculture, aquaria or pest (e.g. mosquito) control (Bhakta 2007). One example is the carnivorous Thai magur (*Clarias gariepinus*) which, due to its fast growth is a popular fish culture species across India in spite of the ban imposed by many regional governments including West Bengal (Indian Express 2008, The Telegraph 2006). A study of the Churni River in West Bengal by Bhakta and Bandyopadhyay (2007) showed that eight introduced species were present and while yields have [so far] increased indigenous species populations have declined. The introduced species included the African tilapias *Oreochromis mossambicus* and *Oreochromis niloticus*, the carps *Cyprinus carpio*, *Clarias gariepinus*, *Hypopthalmicthys molitrix*, *Hypopthalmicthys nobilis* and *Ctenopharyngodon idella*, and the catfishes *Clarias gariepinus* and *Pangasius sutchi*.

There is an ongoing legal dispute that will have major implications for the people and biodiversity of BTR. The new forest policy (2009) dictates that all the communities have to leave the reserve in order to provide better protection for the tiger population. However there is contradictory legislation (Forest Rights Act 2006) that states that any community who have resided within a forest for more than 75 years have a legal right to be there. This is not likely to be resolved in the near future.

2. Site maps

Maps of the site are important as they allow the results of this Work Package to be put into a geographic context. They will not only allow detailed information to be presented in an easy to understand format, but they will also be key in developing the IAP and identifying any potential indicators and monitoring plans. Site and catchment maps have been produced by IUCN, through the digitising of satellite images (Landsat imagery provided by the US Geological Survey - Earth Explorer) using GIS (geographic information systems) software. The maps were then reviewed, edited and land classifications were confirmed by CDHI staff at a mapping workshop which was held on 23-24 August, 2011 at the South China Agricultural University, Guangzhou, China.

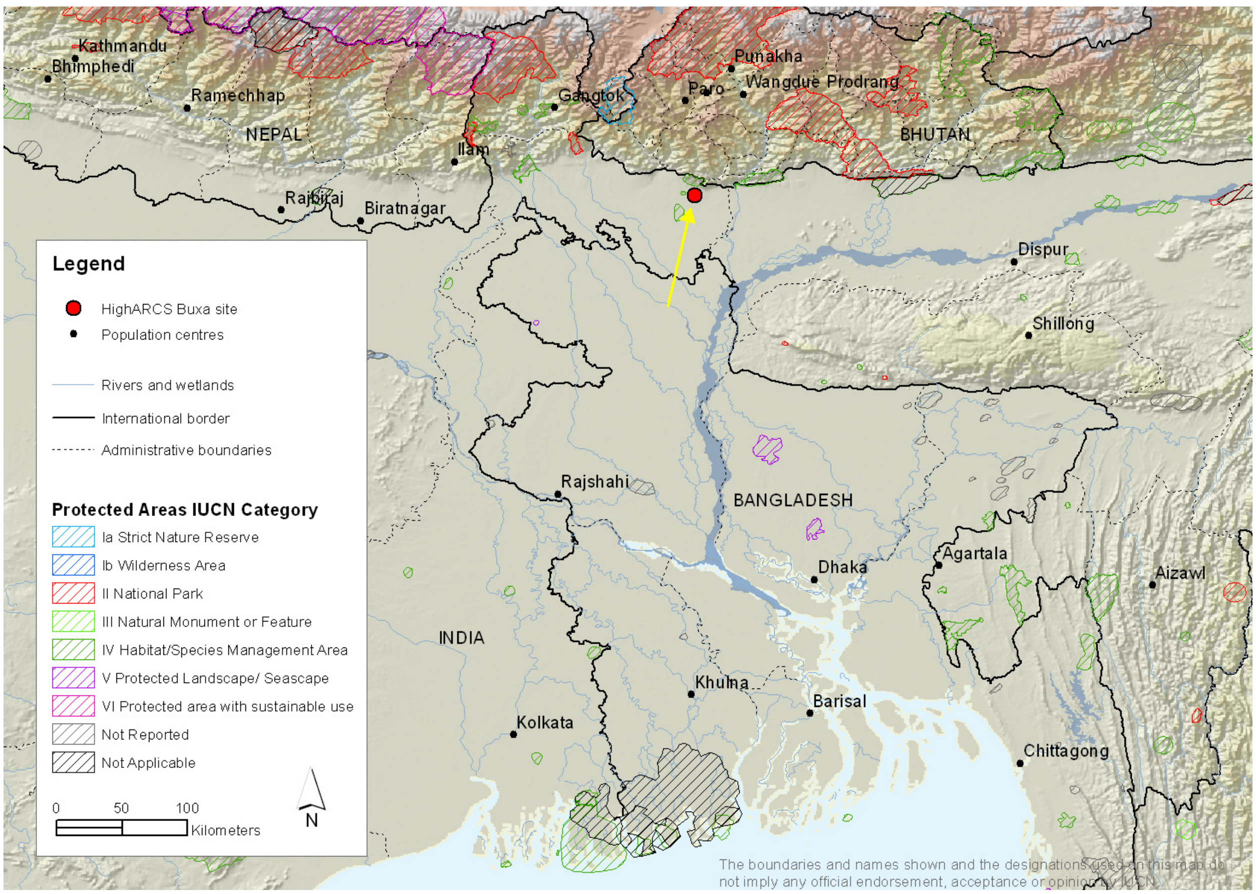


Figure 2. Map showing the location of the HighARCS site in Buxa within India.

The project site is found in the north-eastern part of India, in West Bengal, and touches the border of Bhutan, and is about 50km north of the border with Bangladesh (Figure 1). It is situated within the wider Brahmaputra catchment which drains into the Bay of Bengal.

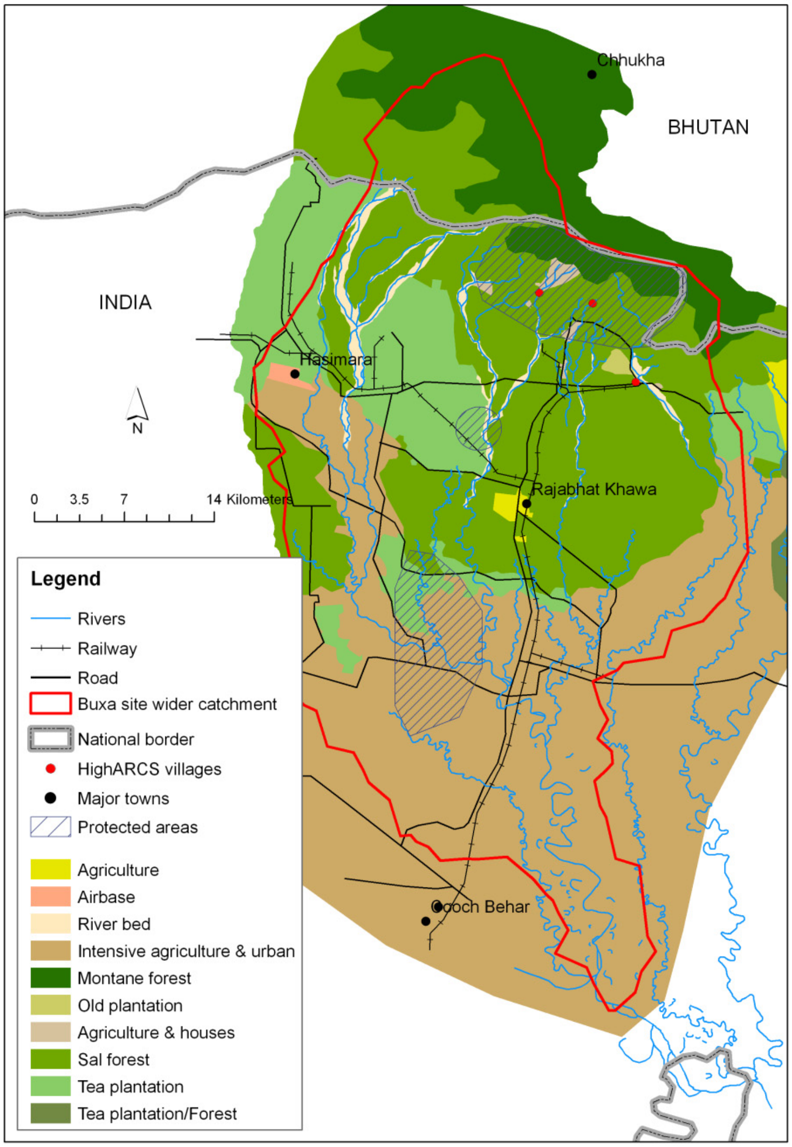


Figure 3. Map showing the sub-catchment that incorporated Buxa.

The catchment area of Buxa (Figure 3) is covered by forest, rivers, tea plantations and agriculture land. The majority of people living within this catchment belong to the Schedule Castes (also known as the Dalit) and Schedule Tribes and are amongst the poorest communities in India. They have few livelihood options though they have access to many resources. They suffer from poor quality water supplies and water scarcity for drinking and irrigation especially in summer (February to June). The project villages are found in the northern upper part of the catchment in the Himalayan foot hills with steep valleys surrounded by montane and sal forests, and are located within the Buxa Tiger Reserve. The Bhutan border is less than 5km upstream to the north and east.

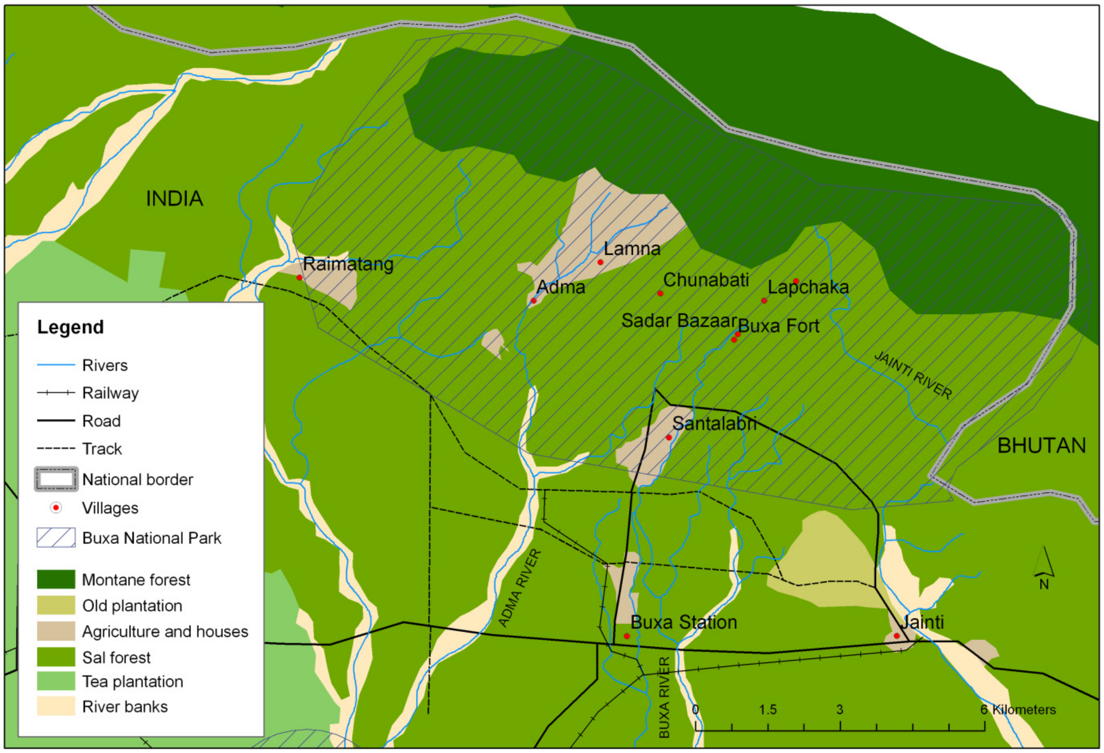


Figure 4a. Map showing the Buxa site.

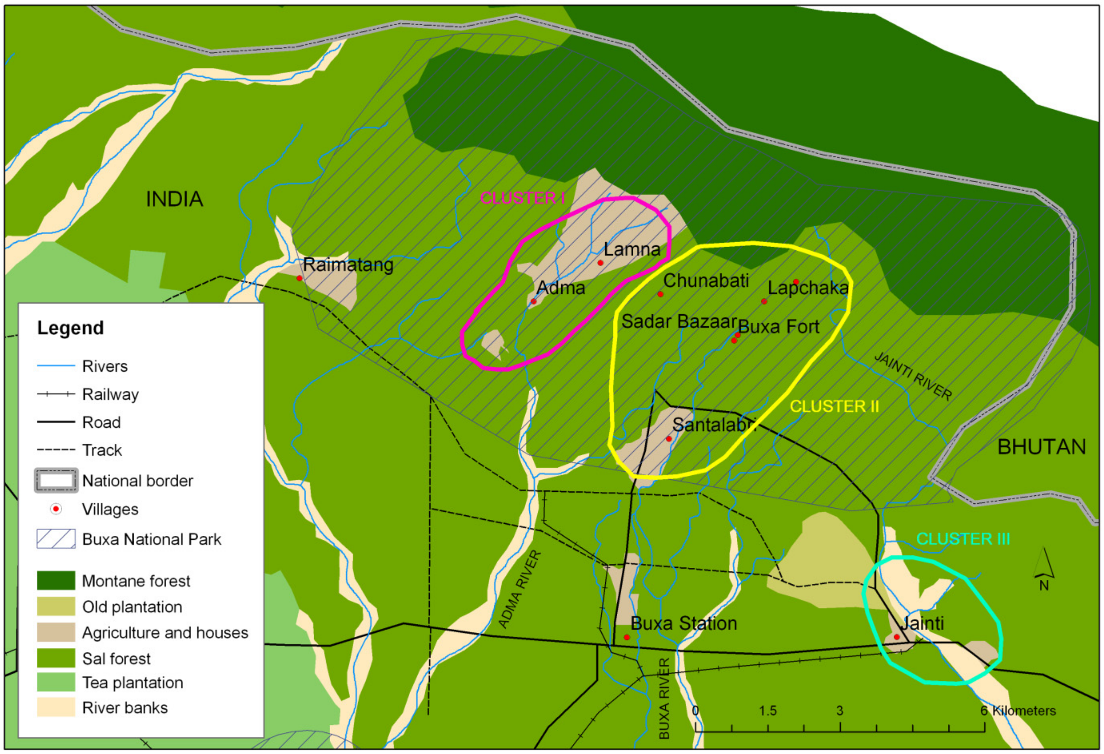


Figure 4b. Map showing the Buxa site, with each 'Cluster' highlighted

In figures 4a and 4b the project villages can be seen and their 'clusters' are identified. Most of the villages are close to the river banks and have areas of agriculture close by. The majority of the land is covered in sal forest (*Shorea robusta*) which is an important cultural and religious significance and is one of the most important sources of hardwood in India, but deforestation is now banned within the Buxa Tiger Reserve. The core of the BTR is the Buxa National Park, and two of the three clusters are found within it.

3. Biodiversity at Buxa

3.1. Taxonomic groups

To inform the Integrated Action Plan, we need to know what aquatic biodiversity is present at the sites and what their conservation status is. However, it is not possible to identify all aquatic biodiversity at the sites due to restricted time, money and scientific expertise. The taxonomic groups chosen to be examined in detail at Buxa are the fishes and aquatic plants. This is based upon the use of these groups as food and medicine by the local communities and also as they can potentially be used as indicators of the major threats to aquatic biodiversity allowing the state of the environment to be monitored.

3.2. Conservation status of biodiversity – IUCN Red List assessments

There are several methods of determining species conservation status and the most commonly used tool is the IUCN Red List Categories and Criteria (IUCN 2001), which allows consistency in approach across different taxonomic groups. It helps in determining the relative risk of extinction at a global scale and provides the basis for understanding if a species is Extinct, threatened (Critically Endangered, Endangered or Vulnerable), Near Threatened, of Least Concern, or lacking sufficient basic data for assessment (Data Deficient) (See Figure 5). The IUCN Red List of Threatened Species™ publishes the results of the global assessments (www.iucnredlist.org). The IUCN Red List also provides basic information on species taxonomy, distributions, habitat and ecology, threats, population trends, use and trade, livelihood information, ecosystem services provided, and research and conservation priorities. See Annex I for a summary of the IUCN Red List criteria.

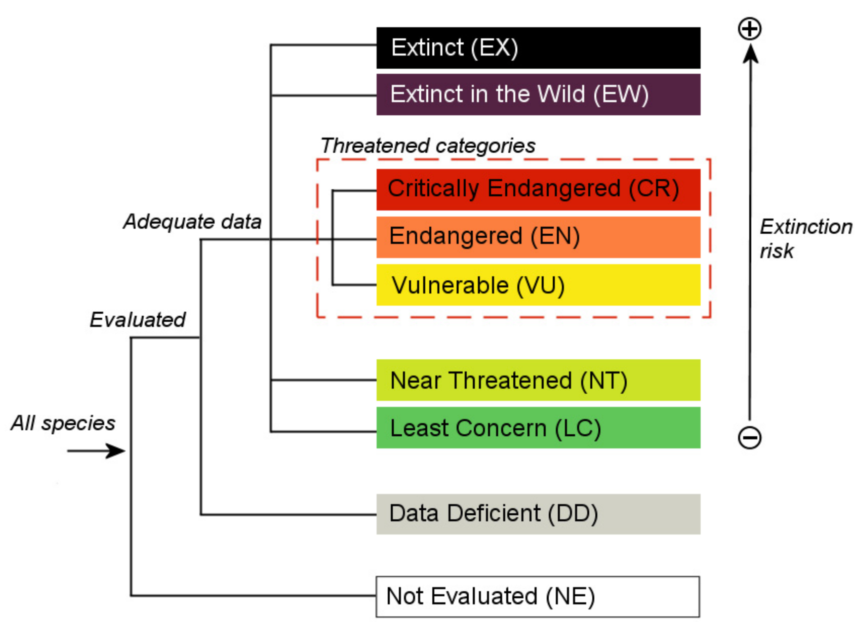


Figure 5. IUCN Red List Categories at a global level.

Biodiversity experts from the HighARCS project partners, including from CDHI, were trained at a workshop (06-09 June 2009, Kolkatta, India) in the use of the IUCN Species Information Service (SIS – the Red List species database), application of the IUCN Red List Categories and Criteria (IUCN 2001) (see Annex 1 for the Red List Criteria), and Geographic Information Systems (GIS) for digitally mapping species distributions. Following the training workshop, experts collated native species lists of freshwater fishes, dragonflies and damselflies (odonates), freshwater molluscs and aquatic plants for the wider catchment (see Figure 3), and input within the SIS, all available information on each species. The required data fields (with standard classification schemes) within SIS are species taxonomy, distribution, habitat and ecology, threats, population trends, use and trade, and research and conservation priorities, Red List Category and rationale. These species were then reviewed at a second workshop (22-26 March 2010, Kolkatta, India) and via email communications with other species experts. Data gaps were filled and corrections were made to the data from another overlapping IUCN project (Freshwater biodiversity assessment of the Eastern Himalaya) which was funded by the MacArthur Foundation (www.macfound.org) and published by IUCN in 2011 (Allen *at al.* 2011).

While these species will not all found at the site, it will allow the actions proposed through the IAP to take into consideration any globally threatened species within the wider catchment if necessary. It will also allow for all the species identified at the site, to be put into a global conservation context. For example a species may be stable and numerous at the site with no known threats and perceived locally as not being of conservation concern, but at a global scale the species may be threatened to impacts elsewhere within the species range, this would make the population at the site of high conservation concern. Alternatively, global conservation status is not the only aspect to identify important species at the site. A species may be of Least Concern globally but may be undergoing severe declines at the site and may also be of economic and livelihood concern and would therefore potentially qualify as a species to be incorporated into the IAP.

The resulting dataset allows 142 fish species, 81 molluscs and 82 odonate species to be identified as present in the Buxa wider catchment as shown in Figure 3. A list of these species with their IUCN Red List Category can be found in Annex II. Unfortunately due to the lack of reliable location data, it was not possible to identify the aquatic plant species from the wider catchment, however 185 species (from selected pant families) have been assessed from the wider Ganges region and the species that are found at the sites can be linked to these assessments, these species can also be found in Annex II. An extract of the globally threatened animal species from the Buxa wider catchment can be found in Table 1, these three species are all fishes: *Clarias magur* – known as the wagur (Endangered); *Botia rostrata* – known as the Dohser (Vulnerable); and *Cyprinion semiplotum* – known as the Assamese kingfish (Vulnerable). *Clarias magur,* the wagur, is highly threatened by over exploitation, threats to breeding grounds due to wetland conversion and pesticides in paddy fields, and from introduction of the Thai magur (*Clarias gariepinus*) which have led to a population decline of an estimated 50% over the past 10 years (Vishwanath 2010). *Botia rostrata* is widespread in the hill streams of the Brahmaputra basin, but populations have declined massively (more than 60% in five years in Arunchal Pradesh) due to mining of sand and boulders from rivers and destructive fishing practices (e.g. using poison), it is also an aquarium species (Chaudhry 2009). *Cyprinion semiplotum* is restricted to hill streams of the Ganges-Brahmaputra drainage, where its habitat and population is estimated to have declined by more than 30% over the past 10 years due to deforestation, pollution and over-exploitation (Singh 2009).

Based on the analysis undertaken on the whole Eastern Himalaya dataset (Allen *et al.* 2011) the Buxa wider catchment is one of the most species rich (for fishes, molluscs and Odonata) sub-catchments of the whole Ganges and Brahmaputra basin, it also has one of the highest levels of endemism (for fishes). The catchment is also triggered as potential Key Biodiversity Area, as it contains globally threatened or restricted range species (Allen *et al.* 2010).

Table 1. Globally threatened species (those listed as Critically Endangered, Endangered and Vulnerable) found within the Buxa wider catchment.

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Order	Family	Binomial	IUCN Red List Category
Cypriniformes	Cobitidae	*Botia rostrata*	VU
Cypriniformes	Cyprinidae	*Cyprinion semiplotum*	VU
Siluriformes	Clariidae	*Clarias magur*	EN

3.3. Literature review

Little published or grey literature is available on the aquatic biodiversity of BTR. Das (2005) states there are 65 species of fish present in Buxa however there is no reference for this figure and the species list cannot be retrieved, also it is reported on numerous websites that "…in a recent survey (2006) it has been found that Buxa Tiger Reserve has the highest number of fish species in the North Bengal region…" again there is no reference for this 2006 survey and therefore these species cannot be identified or the statement verified. Also no literature was available on the aquatic plants of Buxa.

3.4. Field surveys

Based on the literature surveys the full list of plants and in particular fishes present in BTR cannot be produced nor can the species of livelihood value be identified. Therefore the CDHI team undertook field surveys on the fishes and plants within the BTR.

3.4.1. Fishes

3.4.1.1. Methods

To collate information of the fishes of the BTR, an integrated approach was followed (i.e. while collecting data for the other livelihoods and stakeholders and policy reports) and different methodologies from the toolkit were used. Focus Group Discussions (FGD) were undertaken at each cluster, where between 10-12 local male, female and children shared their knowledge on the location of wetlands and areas to catch fish, maps of the habitats and potential survey sites were also produced. The CDHI field team accompanied by key fishermen and community members then visited the identified locations (four sites) and undertook fish surveys, each site was surveyed three times between July 2010 to December 2010. Each survey at a site was undertaken for one hour, using different fishing methods including net, hand net and fish trap, and each fish was photographed, measured and weighed. The locations of the surveys sites across the Buxa sites are shown in Figure 6. The species were identified by a fisheries officer from the office of Assistant Director of Fishery, Jalpaiguri and by CDHI staff and local fishermen using a field guide. To increase confidence on the species identifications made the species identifications and photographs were shown to additional officials in the district for confirmation. The species field survey recording form can be seen in Table 2. In addition to the field surveys, a market survey was undertaken at the weekly market at Santhalabari and Jayanti, which attracts people from Adma cluster, Jaynati cluster and Buxa cluster. The market was visited twice a month during the monsoon (July to September) and dry period (February to June), and the fish stall holders were asked where their catches were harvested and species were identified. An example of the forms used to collate this data is shown in Figure 7. All species identification was verified by the Assistant Directory of Fisheries, Government of West Bengal.

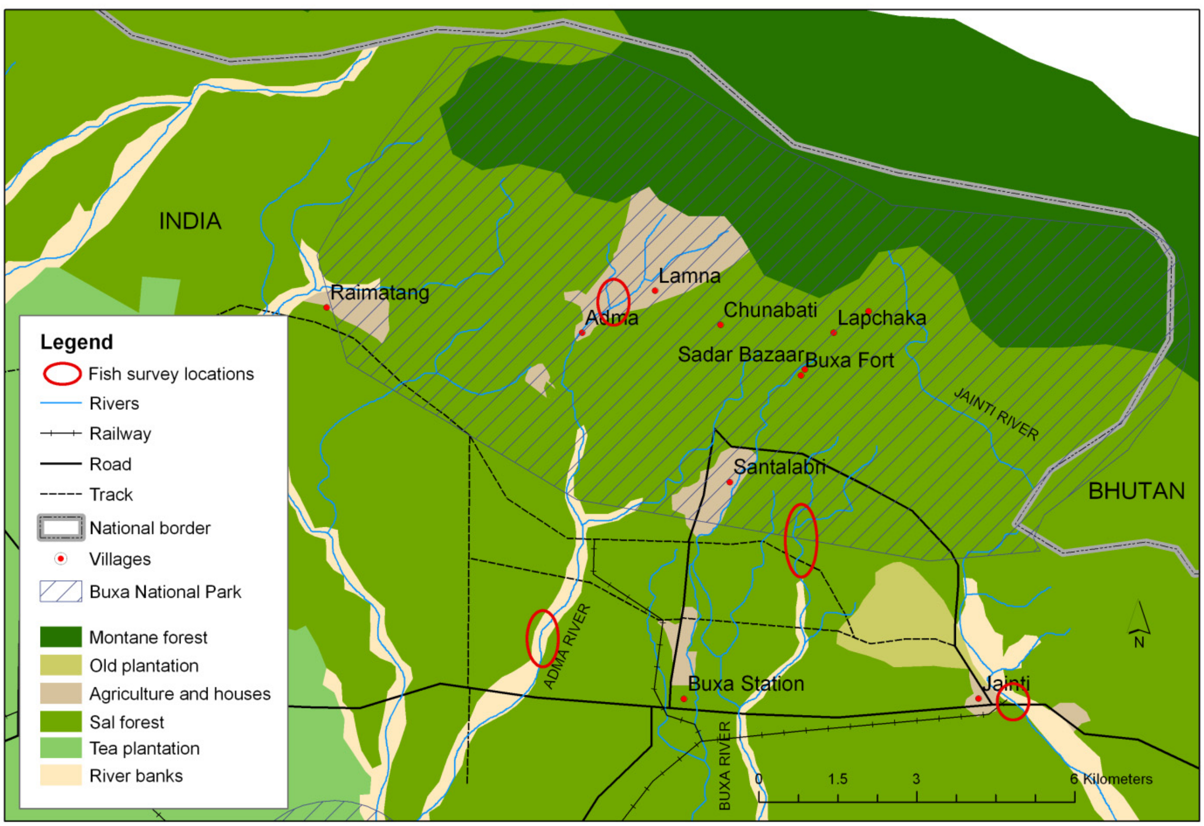


Figure 6. Fish species survey locations

Table 2. Species recording form used during fish sampling

Sl	Species	Local Name	Name of the River	Location	Photograph (Y / N)	Comments

Market Survey / HighARCS / CDHI-EC

Name of the Interviewee (Stall holder) Age:

Name of the market:
Contact No of interviewee:

Introduction about the project by Interviewer:

1. Fish selling experience:
2. Amount of fish sold per day (average) in Kg:
3. Size of fishes sold (big / small):
4. Local river fishes sold (list all species):
5. Local pond fishes sold (list all species):
6. Two best selling fishes:
7. Two most high economic value fishes:
8. Two most nutritional fishes:
9. Daily income from selling fish:
10. Are the weight (size) of the fishes you sell decreasing or increasing?:
11. Which fishes have you noticed that are declining:
12. Which fishes have disappeared:
13. What do you think is the reason for the fish declining/abandon:
14. Any local fish increasing:
15. What is the reason for Q14:
16. What is your suggestion to HighARCS Researcher to conserve the different fish species?

____
Signature and date of Surveyor

Figure 7. Example questionnaire used in the market survey to question stall holders and identify species


Fish survey on the Buxa River at Sadarbazar (Buxa cluster) © Henning Schroll


Fish survey on the Chunabhati River (Adma cluster) © Henning Schroll


Fish for sale at a stall at Santhalabari market, Buxa during market survey © Henning Schroll

3.4.1.2. Results

In total 46 species of fishes were identified through the field and market surveys. Table 3 lists all the species with their local name, IUCN Red List Category, location they were recorded from and their economic importance.

Table 3. Fish species of the HighARCS Buxa site.

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient. The categories CR, EN and VU are classed as the 'threatened' categories.

Family	Binomial	Local name	IUCN Red List Category	Status at site	Location	Economic importance
Belonidae	*Xenentodon cancila*	Kakila	LC	Declining	Buxa, Adma, Jayanti	Subsistence use
Clupeidae	*Gudusia chapra*	Chaila	LC	Declining	Buxa, Adma, Jayanti	Subsistence use
Balitoridae	*Schistura rupecula*	Puinya	LC	Declining	Adma, Jayanti	Subsistence use
Cobitidae	*Lepidocephalichthys guntea*	Gutum	LC	Declining	Buxa, Adma, Jayanti	Subsistence use
Cyprinidae	*Amblypharyngodon mola*	Mourala	LC	Declining	Buxa, Adma, Cluster	Sold locally
Cyprinidae	*Bangana dero*	Kharaya	LC	Declining	Buxa, Adma, Jayanti	Subsistence use
Cyprinidae	*Barilius barna*	Boroli	LC	Declining	Buxa, Adma, Jayanti	Sold locally and high economic value
Cyprinidae	*Chagunius chagunio*	Lal Puti	LC	Declining	Buxa, Adma, Jayanti	Sold locally

Family	Binomial	Local name	IUCN Red List Category	Status at site	Location	Economic importance
Cyprinidae	*Cirrhinus mrigala*	Mrigal	LC	Declining	Adma, Jayanti	Sold locally
Cyprinidae	*Cirrhinus reba*	Raichang	LC	Declining	Buxa, Adma, Jayanti	Subsistence use
Cyprinidae	*Ctenopharyngodon idella*	Grass Carp	Introduced	Declining	Buxa, Jayanti	Sold locally
Cyprinidae	*Cyprinus carpio*	Common Carp	Introduced	Declining	Adma, Jayanti	Subsistence use
Cyprinidae	*Esomus danrica*	Darika	LC	Declining	Jaynati,	Subsistence use and sold locally
Cyprinidae	*Garra gotyla*	Pathar Chata	LC	Declining	Buxa, Adma, Jayanti	Subsistence use
Cyprinidae	*Gibelion catla*	Catla	LC	Declining	Adma, Jayanti	Sold locally
Cyprinidae	*Hypophthalmichthys molitrix*	Silver Carp	Introduced	Declining	Adma, Jayanti	Subsistence use
Cyprinidae	*Labeo bata*	Bata	LC		Buxa, Adma, Jayanti	Sold locally
Cyprinidae	*Labeo calbasu*	Kalbasu	LC	Declining	Buxa, Adma, Jayanti	Sold locally
Cyprinidae	*Labeo gonius*	Kursa	LC	Declining	Jayanti	Subsistence use
Cyprinidae	*Labeo rohita*	Rohu	LC	Declining	Adma, Jayanti	Sold locally
Cyprinidae	*Puntius sarana*	Sarputi	LC	Declining	Buxa, Adma, Jayanti	Subsistence use
Cyprinidae	*Puntius sophore*	Puti	LC		Adma, Jayanti	Sold locally
Cyprinidae	*Puntius ticto*	Tetputi	LC	Declining	Adma, Jayanti	Subsistence use
Cyprinidae	*Salmophasia bacaila*	Chala	LC	Declining	Buxa, Adma, Jayanti	Subsistence use
Cyprinidae	*Tor tor*	Mahasoul	NT	Declining	Buxa, Adma, Jayanti	Locally sold and high economic value
Notopteridae	*Chitala chitala*	Chital	NT	Declining	Buxa, Adma, Jayanti	Subsistence use
Notopteridae	*Notopterus notopterus*	Falui	LC	Declining	Buxa, Adma, Jayanti	Subsistence use
Ambassidae	*Chanda nama*	Chanda	LC	Declining	Buxa, Adma, Jayanti	Subsistence use
Anabantidae	*Anabas testudineus*	Koi	DD	Declining	Buxa, Adma, Jayanti	High economic value
Channidae	*Channa marulius*	Sal	LC	Declining	Buxa, Adma, Jayanti	High economic

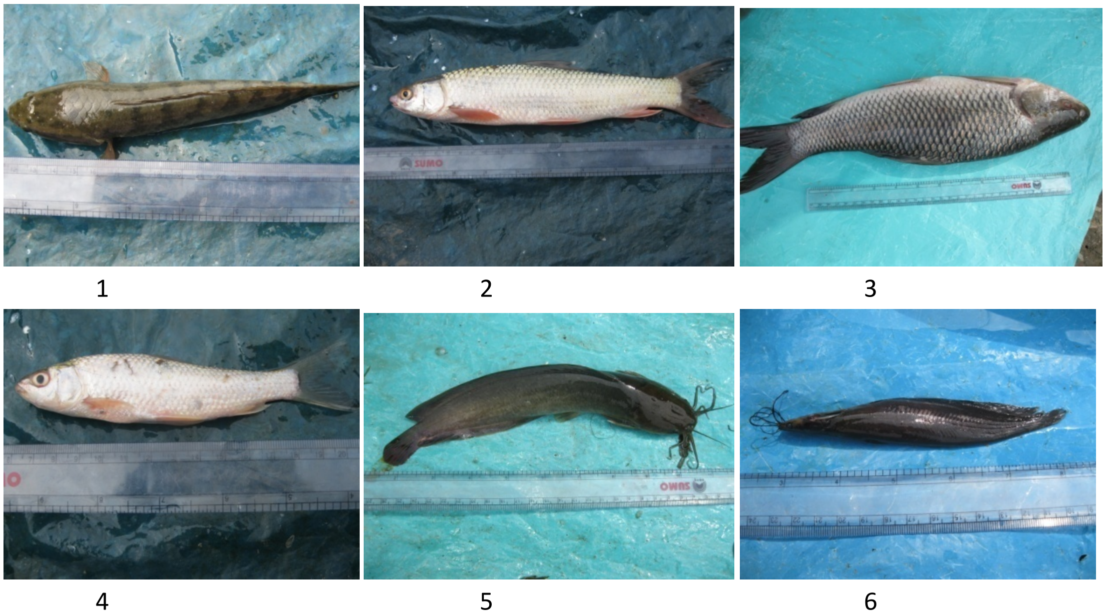
Family	Binomial	Local name	IUCN Red List Category	Status at site	Location	Economic importance
						value
Channidae	*Channa striata*	Taki	LC	Declining	Buxa, Adma, Jayanti	Sold locally
Gobiidae	*Glossogobius giuris*	Balia	LC	Declining	Buxa, Adma, Jayanti	Subsistence use
Nandidae	*Nandus nandus*	Bheda	LC	Declining	Adma, jayanti	Subsistence use
Bagridae	*Mystus cavasius*	Tangra	LC	Declining	Buxa, Adma, Jayanti	Sold locally
Bagridae	*Sperata seenghala*	Aor	LC	Declining	Buxa, Adma, Jayanti	Subsistence use
Clariidae	*Clarias batrachus*	Magoor	LC	Declining	Buxa, Adma, Jayanti	High economic value
Heteropneustidae	*Heteropneustes fossilis*	Singhi	LC	Declining	Buxa, Adma, Jayanti	High economic value
Schilbeidae	*Ailia coila*	Kajli	NT	Declining	Buxa, Adma, Cluster	Sold locally
Schilbeidae	*Clupisoma garua*	Ghara	LC	Declining	Buxa, Adma, Jaynati	Subsistence use
Schilbeidae	*Eutropiichthys vacha*	Bacha	LC	Declining	Buxa, Adma, Cluster	Subsistence use
Siluridae	*Ompok bimaculatus*	Pabda	NT	Declining	Buxa, Adma, Jayanti	High economic value
Siluridae	*Wallago attu*	Bowal	NT	Declining	Buxa, Adma, Jayanti	Sold locally
Sisoridae	*Bagarius bagarius*	Bhgha Aor	NT	Declining	Buxa, Adma, Jayanti	Subsistence use
Mastacembelidae	*Macrognathus aculeatus**	Gachi	LC	Declining	Buxa, Adma, Jayanti	Subsistence use
Mastacembelidae	*Mastacembelus armatus*	Bam	LC	Declining	Buxa, Adma, Jayanti	Sold locally
Synbranchidae	*Monopterus cuchia*	Kuchiya	LC	Declining	Buxa, Adma, Jayanti	Sold locally

**Macrognathus aculeatus* – this record is probably misnamed as due to taxonomic revision this species is now only found in Indonesia.

The 46 fish species recorded in our field surveys is 19 species fewer than is cited by Das (2005), unfortunately we cannot compare species lists with the one cited by Das so we do not know if we have identified species not previously recorded at the site. One of the key findings from the field surveys is that nearly every species of fish identified at through the surveys are utilised as food, with 24 out of the 46 species being used at a subsistence level providing important nutritional value to the poorest communities, and 23 species providing some degree of livelihood income, six of which having a high economic value. This indicates that the native fish fauna provide key ecosystem service value to the local communities. In terms of species conservation value at a global scale, none of the species recorded are globally threatened (*Clarias magur*; *Botia rostrata*; and *Cyprinion semiplotum* were not recorded at the site) and the majority are assessed as Least Concern (having a low risk of global extinction), however six species are classed as Near Threatened (this is the category assigned to species that are close to meeting the criteria for a threatened category). According to these species Red List assessments these species are threatened by over-exploitation (*Tor tor*, *Chitala chitala, Ailia coila, Ompok bimaculatus, Wallago attu, Bagarius bagarius*) pollution (*Chitala chitala*) and dams (*Tor tor*). All of the NT species are harvested as food in Buxa, two are utilised at a subsistence level providing nutritional value (*Bagarius bagarius; Chitala chitala*), and four provide some income for livelihoods as they are sold at the market (*Wallago attu; Ompok bimaculatus; Ailia coila; Tor tor*) with *Ompok bimaculatus* having a high commercial value. *Tor tor* (English common name Mahseeer) is an important food fish in the Himalayan region and also generates income from tourism as it is a sought after angling fish, however its migrations to headwaters with fast flowing water at the start of the rainy season (where it spawns on gravel substrate) have been blocked by dams (Rayamajhi *et al.* 2009), and while this species can be grown in ponds (aquaculture) it cannot breed there as it requires fast flowing water. *Ompok bimaculatus* (English common name butterfish) is a highly popular food fish across India, but has faced large declines in parts of its range due to overfishing. However this species can be cultured in ponds by farmers and research into aquaculture is ongoing and some success has been achieved in seed production using hormone injections (Bashar 2011).

Another key finding of the surveys is that nearly every species of freshwater fish in Buxa is declining. This information was gathered through through discussions and interview with the fishermen, fish traders local community members and fishery officials and they also noted that they are declining in numbers and size (weight of individuals) year by year. The factors that are causing these declines include soil erosion, reduction in water levels in dry period and pollution from agriculture and domestic sources. It is also thought that overharvesting at Jayanti is a potential threat to fish populations within the Buxa site. It is interesting to note that only three non-native species were identified in our survey, the carps *Ctenopharyngodon idella*, *Hypophthalmichthys molitrix* and *Cyprinus carpio* however all three of these species were identified by Bhakta and Bandyopadhyay (2007) as contributing to native species declines, and *Ctenopharyngodon idella* has been shown to negatively impact the native catla (*Gibelion catla*) (Seghal 1999). It is unknown to what extent these invasive species are impacting the native fish fauna.

Based on informal discussions with fishermen and information gathered through the market surveys, it is clear that fish production from within the Buxa project area is not meeting the demand from local communities in three clusters, as fish from outside the area (from other markets) are being brought into Buxa. If fish pond culture is to be developed to meet the demand, then we strongly recommend that native species that are suitable for pond culturing are used (such as *Gibelion catla*, *Labeo rohita* and *Cirrhinus mrigala*) rather than non-native species that have previously been used in many areas of the Himalaya region, such as the grass carp (*Ctenopharyngodon idellus*) and silver carp (*Hypophthalmichthys molitrix*), and Thai magur *(Clarias gariepinus*).



Photographs of fishes caught during the fish field surveys.
1. Taki (*Channa striata*) 2. Mrigal (*Cirrhinus mrigala*) 3. Rohu (*Labeo rohita*) 4. Bata (*Labeo bata*) 5. Magoor (*Calarius batrachus*) 6. Singh (*Heteropneustes fossilis*)

3.4.1.3. Indicator species

We recommend that a regular local market survey (during the monsoon two times a month), monitoring catches on sale (including the number fish, size and weight of fish, weight of total catches, prices, locations of harvesting) of the key fish species would be a suitable indicator of the status of the fish populations, and also as coarse indicator of environmental conditions of rivers at the Buxa site. The fish species we would recommend to be included in such a survey need to represent a variety of families, habitat requirements and life histories and are therefore sensitive to different threats, economic value and global conservation for example; Cyprinidae (*Gibelion catla, Esomus danrica, Puntius sophore, Labeo bata, Tor tor*); Clariidae (*Clarias batrachus*); Mastacembelidae (*Mastacembelus armatus*); Channidae (*Channa striata*); Heteropneustidae (*Heteropneustes fossilis*); Schilbeidae (*Ailia coila*); Siluridae (*Wallago attu, Ompok bimaculatus*); Synbranchidae (*Monopterus cuchia*).

3.4.2. Aquatic plants

3.4.2.1. Methods

To undertake the field survey of aquatic plants, focus group discussions (FGD) were undertaken at each cluster, where between 10-12 local male, female and children shared their knowledge on the location of wetlands and areas around all villages within the three clusters to collect plants, their medicinal and other uses. The CDHI field team visited each site (18 sites in total) identified by the FGDs once for two hours, these surveys took place throughout the year except in the months July and August. The species were identified by the local medicinal practitioner and local forestry officers including a Beat Officer (a forestry field officer) who accompanied CDHI staff on their field visits. A photograph of each species was taken. An example of the field recording sheet is given in Table 4.

Table 4. Form used to record fish species during field surveys

Sl	Species	Local Name	Name of the River	Location	Photograph (Y / N)	Comments

A focus group discussion creating a map of different habitats and sites for plant surveys © Henning Schroll

A GPS recording taking place during plant surveys © Henning Schroll

3.4.2.2. Results

A total of 25 wetland plant species were identified from the three 'cluster' sites. Table 5 lists all the species with their local name, IUCN Red List Category, location they were recorded from and their economic importance.

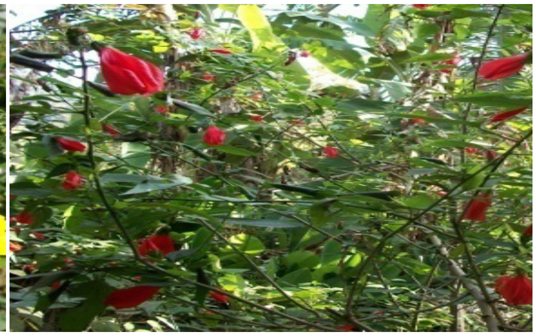
Table 5. Wetland plant species of the HighARCS Buxa site.

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient. The categories CR, EN and VU are classed as the 'threatened' categories. '*' Indicates a draft Red List Assessment.

Family	Binomial	Local name	IUCN Red List Category	Status at site	Habitat/ location	Economic importance
Oxalidaceae	*Oxalis latifolia*	Thankoni	Introduced		Available in all three cluster	Sold locally
Compositae	*Xanthium strumarium*	Bonokhra	Introduced	Declining	Available in all three cluster	
Araceae	*Pistia stratiotes*	Topa Pankachuri	LC/ Introduced?		Available in all three cluster	
Pontederiaceae	*Eichhornia crassipes*	Kachuripana	Introduced		Available in all three cluster	
Compositae	*Ageratum conyzoides*	Bhusbhusay	Introduced	Declining	Available in all three cluster	
Amaranthaceae	*Alternanthera philoxeroides*		Introduced		Available in all three cluster	
Compositae	*Ageratum houstonianum*	Chesi sakh	Introduced		Available in all three cluster	Sold locally
Gramineae	*Phragmites karka*		LC/ Introduced?		Available in all three cluster	
Typhaceae	*Typha angustifolia*	Hogla	LC		Available in all three cluster	
Cruciferae	*Coronopus didymus*	Kalmi Sakh	Introduced		Jayanti	Sold locally
Brassicaceae	*Rorippa cochlearioides*	Dalkalosh	Not assessed	Declining	Available in all three cluster	
Scrophulariaceae	*Lindernia crustacea*		LC*		Available in all three cluster	
Scrophulariaceae	*Veronica anagallis-aquatica*		LC*	Declining	Available in all three cluster	

Family	Binomial	Local name	IUCN Red List Category	Status at site	Habitat/ location	Economic importance
Apiaceae	*Centella asiatica*		LC*		Available in all three cluster	High economic value
Plantaginaceae	*Plantago orbignyana*	Jangli Isabgul	Introduced		Available in all three cluster	High economic value
Convolvulaceae	*Ipomoea aquatica*		LC*		Available in all three cluster	High economic value
Convolvulaceae	*Ipomoea fistulosa*		Introduced		Available in all three cluster	
Hydrocharitaceae	*Vallisneria spiralis*		LC		Available in all three cluster	
Ceratophyllaceae	*Ceratophyllum demersum*		LC	Declining	Available in all three cluster	
Urticaceae	*Laportea interrupta*		Not assessed		Available in all three cluster	High economic value
Urticaceae	*Pouzolzia zeylanica var. zeylanica*		Not assessed	Declining	Available in all three cluster	
Gramineae	*Imperata cylindrica*	Kushghash	LC*		Available in all three cluster	
Alismaceae	*Sagittaria guayanensis*		LC		Available in all three cluster	
Ricciaceae	*Riccia spp?*	Khira			Available in all three cluster	High economic value
Lycopodiaceae	*Lycopodium spp?*			Declining	Available in all three cluster	


1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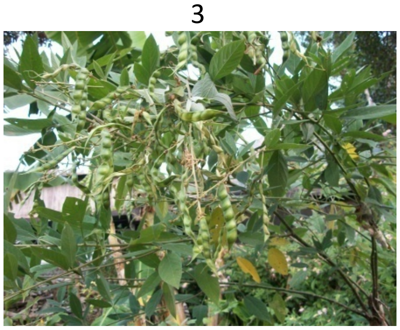
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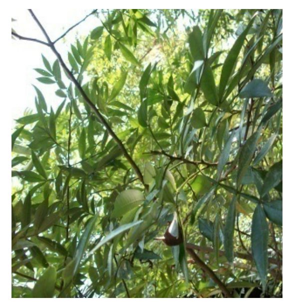
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11

Photos of the plants taken during the field surveys

Plants locally know as 1. Saipatri 2. Beli flower 3. Darshney 4. Tulshi 5. Chinijhar 6. Raharidal 7. Kalohaledo 8. Timbur 9. Sallya 10. Kaulyo 11. Shisnu

Based on the plant field surveys, no species of global conservation concern were found. In fact nine (possibly 11) of the 25 species were non-native species that have widely naturalised across many parts of Asia, often becoming invasive. *Pistia stratiotes*, is a pan-tropical free-floating plant (English common name water cabbage) that often forms large mats on waterways making it a problematic species in many areas. Its origin is unknown so it is unknown if the species is native to Asia or not. *Typha angustifolia*, is a cosmopolitan cattail plant commonly found in many different wetland habitat types. *Lindernia crustacean* and *Veronica anagallis-aquatica* are erect annual herbs, and are both widespread species found in many types of wetland habitats, that can exploit man-made habitats. *Centella asiatica*, the Asiatic pennywort, is well known for its medicinal properties and is sold under the name Gotu Kola, it is also a widespread species across Asia found in many different wetland habitats. *Ipomoea aquatica*, known as water spinach is harvested and grown in many parts of Asia for food, it is also a weed in North America where it is introduced (USDA 2011). *Vallisneria spiralis*, known as eel grass and *Ceratoct ophyllum demersum* a common species of hornwort, are both totally submerged plants widespread and common in Asia, and both are common in aquaria. *Laportea interrupta*, hens nettle, *Pouzolzia zeylanica,* and *Imperata cylindrical* are all widespread and common across Asia in many wetland and terrestrial habitats. *Sagittaria guayanensis*, Guyanese arrowhead is a widespread and common species across Asia growing in shallow water of drying ponds and margins of pools. However five of the native species found and identified at the site are thought to be undergoing a decline in population due to water pollution.

Based on discussions with key community individuals, forest officials and experts some of the plants found have high economic value and many more sold locally. Species like *Centella asiatica, Laportea interrupta, Plantago orbignyana* etc are having high economic values and are sold for medicinal uses. There are many local doctors without official medical training who are treating local people using these medicinal plants.

In addition to the field surveys an additional 33 species of wetland plants were identified by project team members and local people as being important for medicinal use (these were not found in the surveys). Unfortunately these plants could not be identified to species level and Table 6 lists their common names and their medicinal uses.

Table 6. Medicinal plants used by local people

Local Name	Used for
Dhaturo	Cough
Harlong	Biting of insect
Shishuno	High blood pressure
Totola	Pneumonia
Gita	Gastric
Dagur	Diarrhea
Anarosh	Stomach
Rohoridal	Jandis
Ashura	Malaria
Halud	Stomach

Local Name	Used for
Harora	Cough
Gurjo	Sugar
Shikari Lohora	Fracture
Kalo Holud	Food intake
Kalo Nigure	Blood problem
Ulto Karo	Breast milk problem
Ghoria Shisuno	Weak child
Uku	Jandis (Yellow body)
Akh	Fracture
Gito kumara	All purpose
Beth lohori	Jandis
Ghontiful	Stomach Problem
Chatibon	Gastric
Lankachani	Pregnancy
Dubo	White blood of teenager
Khamari	Jandis
Hachamey lata	Blooding
Timijhar	Pain on neck
Obijhal	Stomach problem
Pinar	Pneumonia
Ghortapre	Pneumonia
Ambak	Blood Problem
Piple	Fear of Fire

3.4.1.3. Indicator species

Based on the results of species surveys, all the native species are widespread and common, and found in a variety of habitats including degraded and man made. In addition two of the species have been used for phytoremediation (reduction and/or removal of contaminants). Yadev and Chandra (2011) find that *T. angustifolia* could be a used for phytoremediation of heavy metals as it is a highly tolerant species, and *Centella asiatica* can be utilized in the phytoremediation method to remove copper from wastewater (Mokhtar *et al.* 2011). The only species that are sufficiently specialised or sensitive to environmental degradation are the *Riccia* spp. (liverworts) as they are bryophytes which are often good indicators of environmental conditions (Glime 2007). Bryophytes lack a protective layer or cuticle and are therefore extremely sensitive to pollutants in the immediate environment, making them suitable as bio-indicators of water pollution (Hallinbäck and Hodgetts 2000). If the liverworts (*Riccia* spp.) are used as an indicator, and identifying them to genera level is not sufficient, a suitable trained botanist may need to be found to help identify *Riccia* species (or at least train CDHI staff to do so).

The presence of non-native species could indicate a degraded environment, but more information is needed on the invasive nature of these species, and more research is required on their presence and impacts at the Buxa site before they can be potentially used as an indicator.

3.5. Inclusion of data in online databases

Data collated through this research will be included in two online species databases; the IUCN Red List (www.iucnredlist.org) and Fishbase (www.fishbase.org).

Through Work Package 1 of this project the fish, odontata, molluscs and selected aquatic plant species of the Ganges River basin were assessed against the IUCN Red List categories and criteria and have been published on the Red List website (see section 3.2). Information on the species identified through this workpackage such as new information on species distributions, threats but in particular their utilisation by humans will be added to their Red List assessment and published online with the next IUCN Red List update in 2012. If the information provided is significant it may require the species to be reassessed, changing the species Red List Category.

The information on the fish species utilisation will also be added to the Fishbase online database, under the ‘Human Uses’ tag. For example, the species will be tagged as being ‘Fisheries: minor commercial’ or ‘aquarium: potential’.

4. Threats to biodiversity and ecosystem services

Based on the discussions with local communities, and observations during field work the major threats to freshwater biodiversity and ecosystem services have been identified and mapped. The two major rivers at the site, the Adma River and the Jayanti River are under threats from numerous sources including soil erosion (due to deforestation for agricultural land that when the monsoon comes washes soil into the river increasing sedimentation), water pollution (due to human and animal sewage as well as agricultural pesticides) and the mining of sand and boulders. These threats are taking place inside the project area as well as upstream, outside of the project area in Bhutan. Figures 8 to 10, show the sources of these threats to the site and which areas are being impacted by them.

4.1. Water pollution

Figure 8 shows the major sources of water pollution within the Buxa site. Most of the agricultural areas, where farmers use different types of chemical fertilizers and pesticides, are adjacent or close to the villages which are situated along river banks. This short distance to the rivers means that both domestic waste and agricultural chemicals quickly seep into the rivers, also some villagers are using poisons in the rivers for catching fish. These pollutants have made the water unsuitable for human consumption and degraded many habitats of aquatic biodiversity and killed fish and plants. There are also dolomite and quartzite mines just across the border in Bhutan in the headwaters of the catchment, one mine at Sakhu in Sarpang district of Bhutan is just 1km from the BTR and silt is carried down the Jainti River (Telegraph 2008), it is unknown if this particular mine is still in operation.

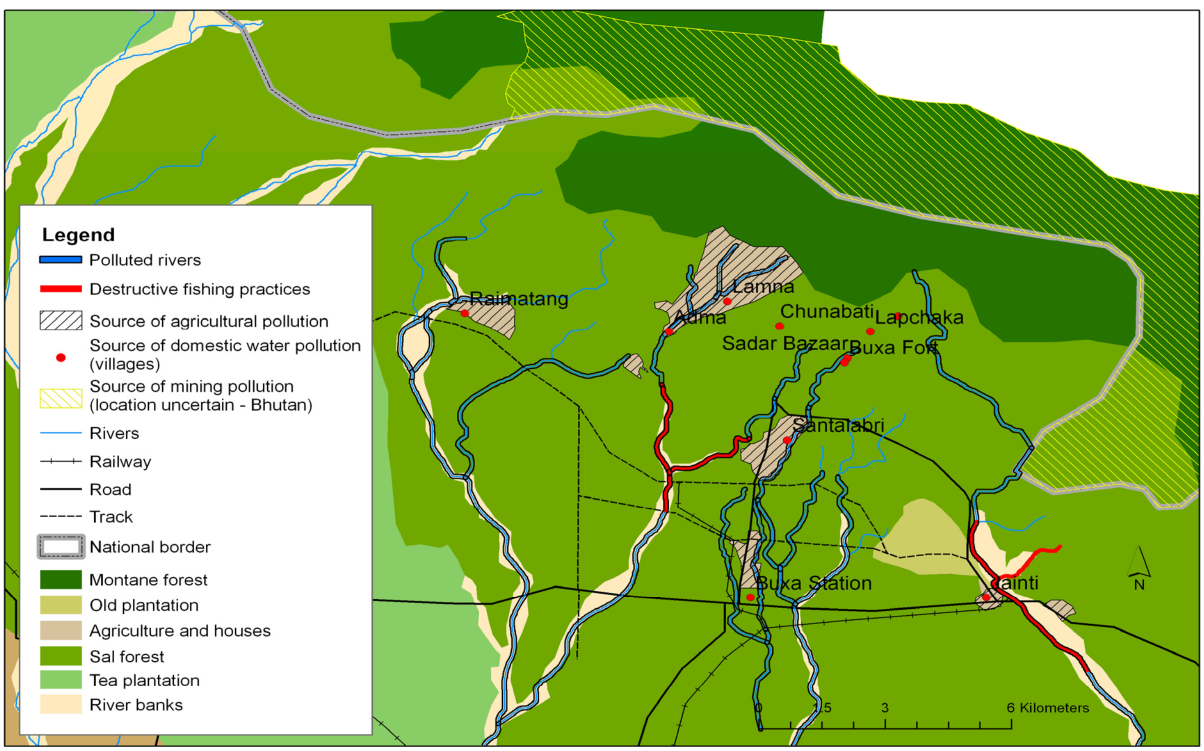

Figure 8. Sources of water pollution and areas impacted at the Buxa site.

4.2. Deforestation and sedimentation

Deforestation in the upper catchment in Bhutan and in Buxa (outside the BTR), and the existing agricultural land across the Buxa site are the major sources of sediment that enter the rivers (shown in Figure 9). The major soil erosion that leads to increased sediment loads of the rivers and a rising of the river beds, is taking place during the monsoon period (June to August) where rains wash the exposed soils into the rivers and destabilises land leading to landslides. Due to this reduced cover of natural vegetation, much of the heavy rainfall during the monsoon does not seep into the water table, but runs off the surface directly into the rivers, often flooding areas of Jayanti and Buxa Station. This reduced water table, when combined with the raised beds and unsustainable water extraction (especially in the Jayanti River) has left some rivers running at low levels during the dry season (February to May), often totally drying up. Even the Jayanti River (the largest in the site) is now dry for most of the dry season, which has led to large degree of water stress for many of the local communities. The government is undertaking some construction work including binding boulders with mesh, to try to protect the river banks from eroding and to protect major roads around Jainti, but they are unable to stop the natural soil erosion which is happening every year in the monsoon period.

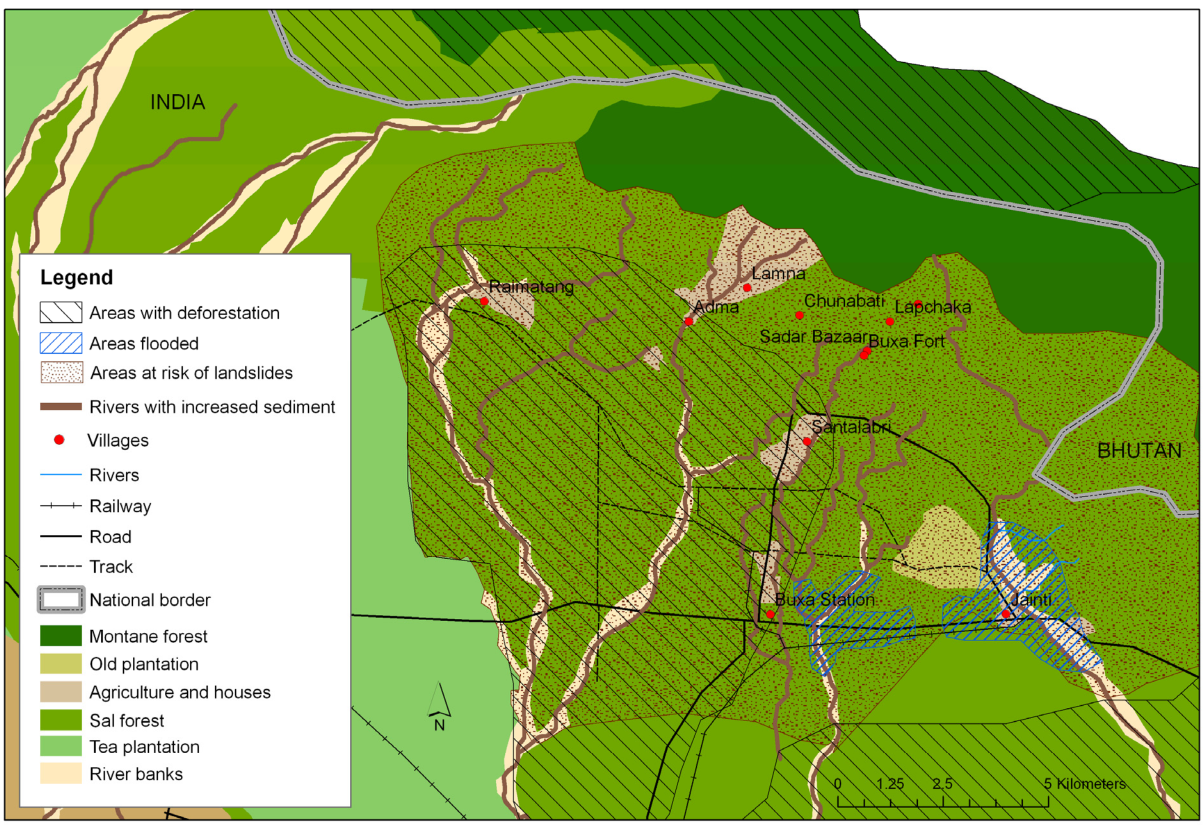

Figure 9. Sources of sedimentation and areas impacted at the Buxa site.

4.3. Sand mining

Sand mining from river beds to supply the building trade outside the BTR is also a threat to aquatic biodiversity. The mining destroys the river bed, and changes the flow regime and structure of the river. The major area of sand mining within the Buxa site is taking place in the Jayanti River (Figure 10). Forest officials are against this mining, but many local people who gain income from working as labourers support it.

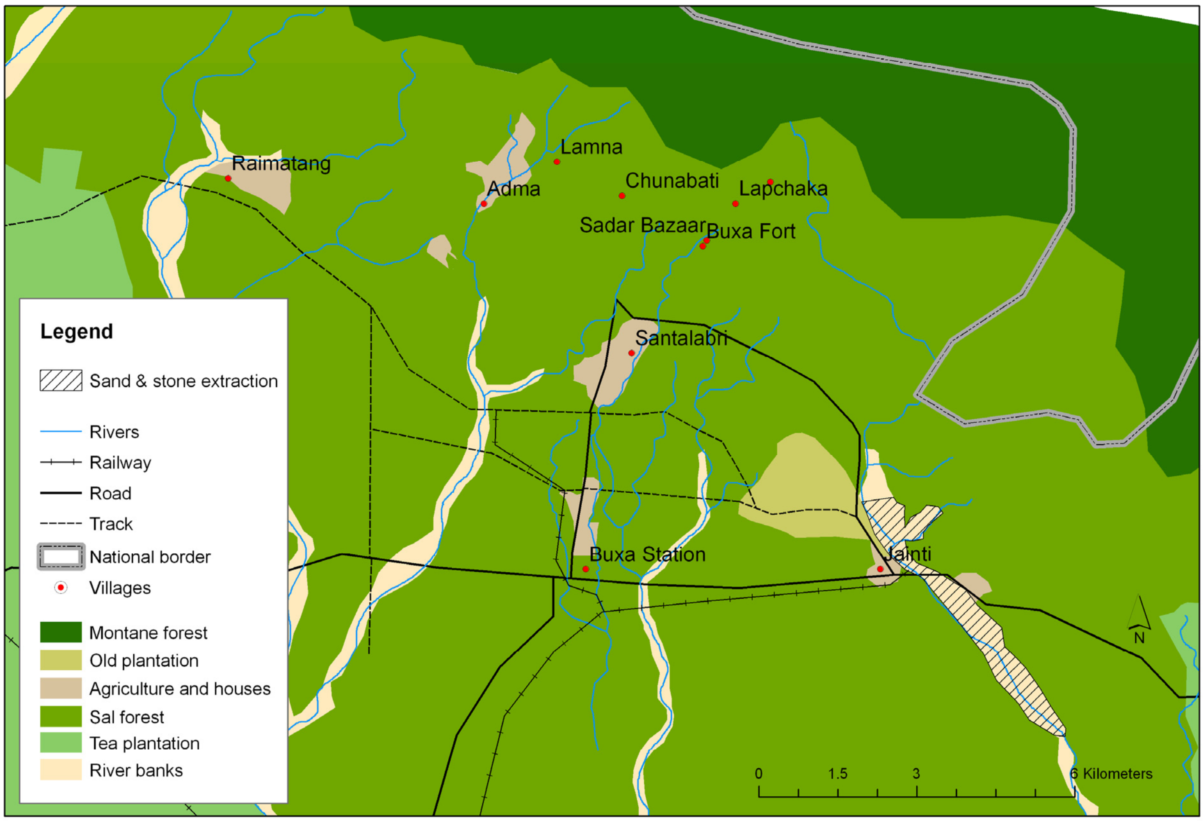

Figure 10. Sources of sand and stone mining at the Buxa site.

5. Ecosystem services

5.1. Types of ecosystem services at Buxa

Wetlands and other aquatic systems, underpinned by biodiversity provide a wide variety of products and services that play a major role in supporting human livelihoods and wellbeing. These 'ecosystem services' can be divided into provisioning services (e.g. food, water); supporting (e.g. nutrient cycling, primary production); regulating (e.g. flood regulation, water purification); and cultural (spiritual, recreational) see figure 11.

In Buxa, the services provided by aquatic systems are hugely important for supporting the communities wellbeing. For example, people rely upon direct services such as the provision of water to drink, wash, and irrigate crops, also the harvesting of fish provides food and income. The rivers and their catchments also provide many regulating and supporting services such as providing natural habitat for biodiversity, nutrient cycling, flood regulation, primary production and water filtration.

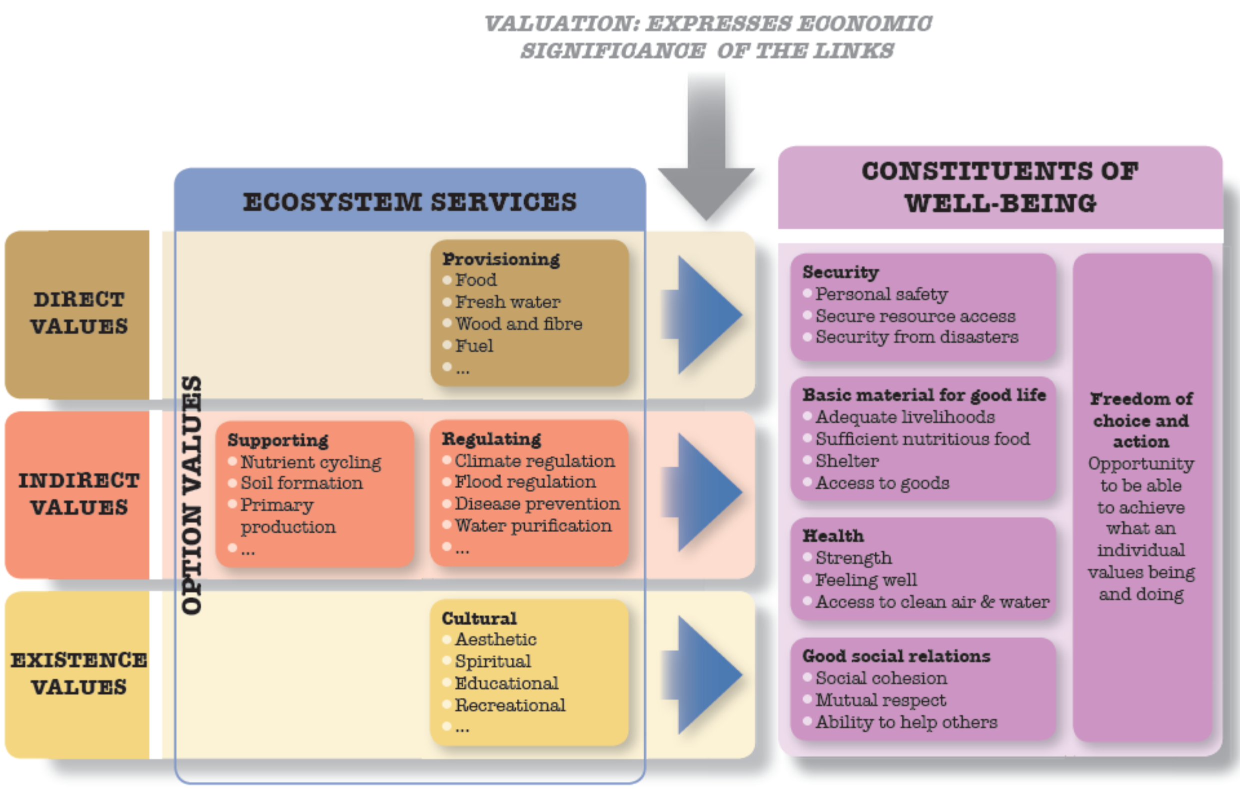

Figure 11. Ecosystem services and human wellbeing
(Taken from Springate-Baginsky *et al.* 2009, adapted from Millennium Ecosystem Assessment 2005)

5.2. Ecosystem service valuation

The aim of this analysis is to identify which ecosystem services are valued the most by the communities at the Buxa sites (it is not an economic valuation). Also through mapping the ecosystem services it will allow the areas where the services are being generated in the wider catchment and which areas are benefiting from the services. This will provide the relevant information for the integrated action planning process to help ensure that these services are identified, given full recognition by all stakeholders, are not negatively impacted by any actions recommended and that the links between the state of aquatic biodiversity in BTR, the quality of wider environment and these highly valued services is understood. It will also allow potential indictors to be developed that can be used to monitor any actions proposed through the IAP.

5.2.1. Methods

As with many subsistence based economies, conventional environmental valuation techniques (providing "$" values) have many problems as they can be difficult to use, the $ value often has little relevance to them, collection/use is often illegal and many services have no market price. To overcome these problems a 'participatory valuation technique' has been used (outlined in the 'Toolkit') which allows people to define wetland values within the context of their own perceptions, needs and priorities rather than according to externally-imposed categories or market prices (Springate-Baginsky *et al.* 2009).

Firstly the ecosystem services used by the three clusters were identified through stakeholder meetings at each site. In total there were 21 focus group discussions (FGD), with seven FGDs in each of the three clusters. The FGDs were organized to include different stakeholders including women SHG (Self Help Groups), local governance, male group, local clubs and community based organizations etc. In each FGD 8-15 participants attended and shared their experiences and perceptions. The FGDs resulted in a list of ecosystem services (and additional threats and needs) which were then listed in a questionnaire to undertake a quantitative analysis of the Buxa community valuation of ecosystem services (see Figure 12). This questionnaire was translated into the local language, pilot tested with different stakeholders and then finalized. It was taken into the communities, where a total of 68 households (10% of all households in the Buxa site) were questioned. The interviews were undertaken with the male and female heads of the families. Of the families questioned most (53) were farmers and/or labourers, 11 were fishermen and four were teachers. Each respondent was asked to score each service with 1, 2 or 3 (1 being less important or low value, and 3 being very important or high value).

Unfortunately the stakeholder group of the respondents to the questionnaires were not recorded so a cross stakeholder quantitative analysis could not be undertaken. However, the FGDs provided qualitative data on stakeholder specific views on their priority ecosystem services and threats. An additional PRA exercise allowed for an historical examination of the changes in the condition of different key ecosystem services over the past 25 years.

Ecosystem service maps have also been produced that show the areas that generate each ecosystem service and the areas/people that benefit from the service. The information used to create these maps has been gathered by CDHI staff through observations taken on field survey trips and the formal and informal discussions and exercises taken with the communities for this research. They were then discussed and hand drawn at the mapping workshop which was held on 23-24 August, 2011 at the South China Agricultural University, Guangzhou, China and then digitised (digitally drawn) by IUCN.

A Focus Group Discussion (FGD) meeting between community members and field researchers at Buxa

Figure 12. The participatory valuation for prioritising eco-services, threats and needs questionnaire used at the Buxa clusters [edited version]

Participatory Evaluation Sheet / High ARCS / EC-CDHI / Buxa / 2010

Name of the Interviewee_____________________Location______________Date________

Please make the tick mark according to your perception / according to the importance. Smaller number means less important (1 means less important and 3 means more important). You can add in the list.

Category		**1**	**2**	**3**
Ecosystem Services	**Water – human consumption**			
	Water – animal consumption			
	Flood regulation			
	Fishes for food – subsistence use			
	Fishes for food – commercial (to sell)			
	Sand/stone mining for both commercial and personal use			
	Plants – medicinal use			
	Other animals for food (non-fish – e.g. molluscs, shrimps etc)			
	Tourism			
	Transportation			
	Disease/vector regulation			
Ecosystem threats	**Soil erosion and sedimentation**			
	Water pollution from agriculture			
Needs/ recommendations	**Education for children**			
	Need of Research – aquatic resources			
	Need of Research – renewable energy			
	Protection of Biodiversity			

Name of Surveyor________________________________ Signature of Surveyor___________________

5.2.2. Results

Figures 13 and 14 show the ecosystem services valuation results for the Buxa site. Figure 14 presents the proportion of the different values (low - 1, medium - 2, high - 3) given to each ecosystem services. It shows that only two services have been selected as 'high value' by more than 50% of respondents, these are 'fishes for commercial use' (selling rather than subsistence use) which has been given the greatest proportion of high value preferences (78% of the 68 respondents) and 'disease/vector regulation' (63%). These services also had the fewest 'low value' preferences with 6% and 12% respectively and have the highest total scores with 185 and 171 (where a low value preference is given a score of 1, medium value preference a score of 2 and high value preference a score of 3), see Figure 14. Only two ecosystem services have been selected as 'low value' by more than 50% of the respondents, these are 'tourism' with 60% and 'sand and stone mining' with 54%. These are also the two lowest total scoring ecosystem services (see Figure 15). However the ecosystem services selected as 'high value' by the fewest number of respondents were 'other animals for food' and 'water for human consumption' with 16% and 19% respectively. A very surprising result was the scores given to the 'water - human consumption' service, which as noted above scored lowly in the valuation preferences and came third lowest in the total scores with 117, based on informal discussions with community members and through the FGDs this service was expected to be one of the highest valued.

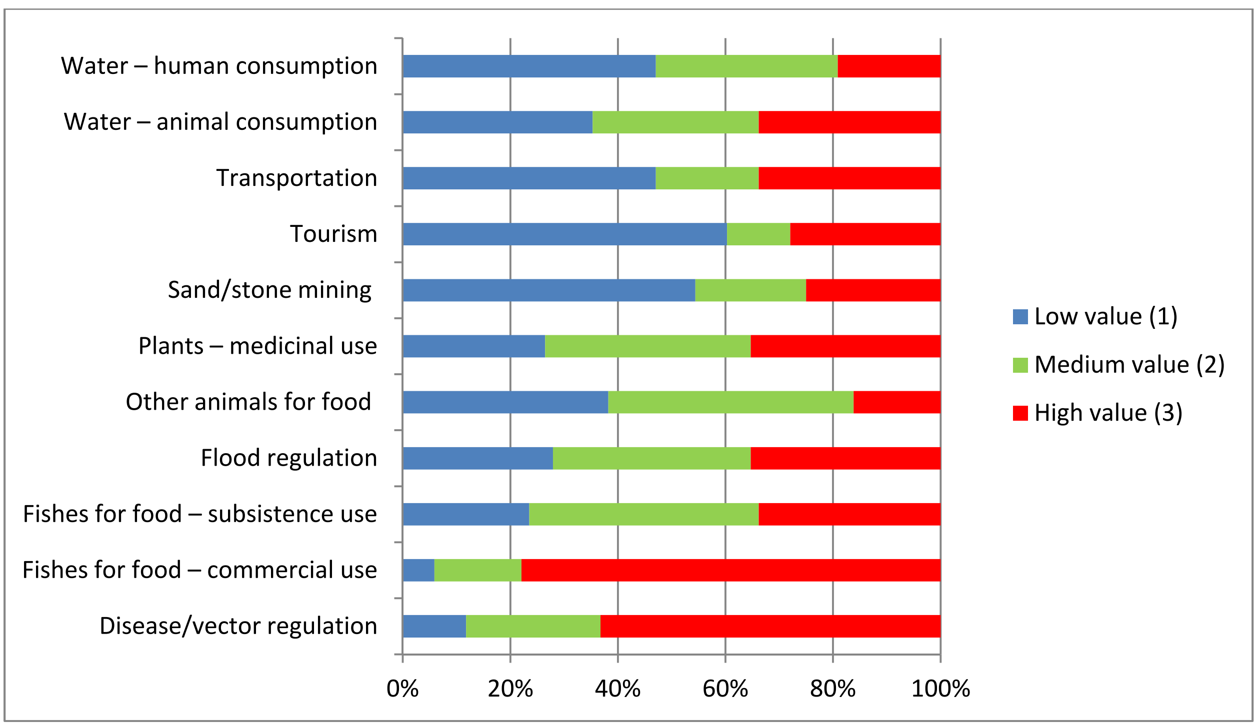

Figure 13. Proportion of low, medium and high value scores given to each ecosystem service at the Buxa site.

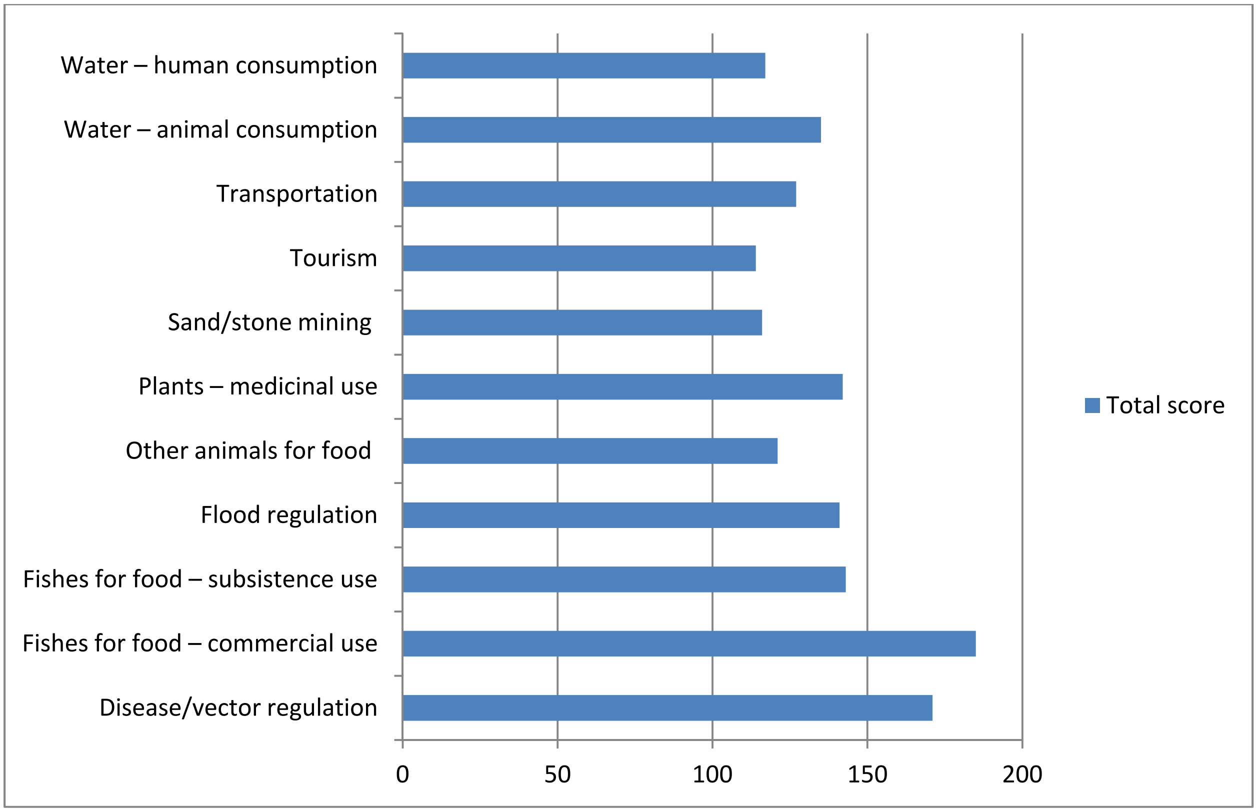

Figure 14. Ecosystem prioritisation results (total score) for the Buxa site. Scores are low value (1), medium value (2) and high value (3).

Figure 15 shows how the respondents prioritised the threats to ecosystem services. Water pollution from agriculture (pesticides etc.) was given the highest value (i.e. a more serious threat) with nearly 40% of respondents giving it a high value preference (score of 3) compared to 25% giving a high value preference for 'soil erosion and sedimentation'. In regards to the actions needed (Figure 16), 'research in renewable energy' was perceived to be the most important with 66% or respondents giving it a 'high value' preference. 'Biodiversity protection' also received a significantly high proportion of 'high value' preferences with 51%.

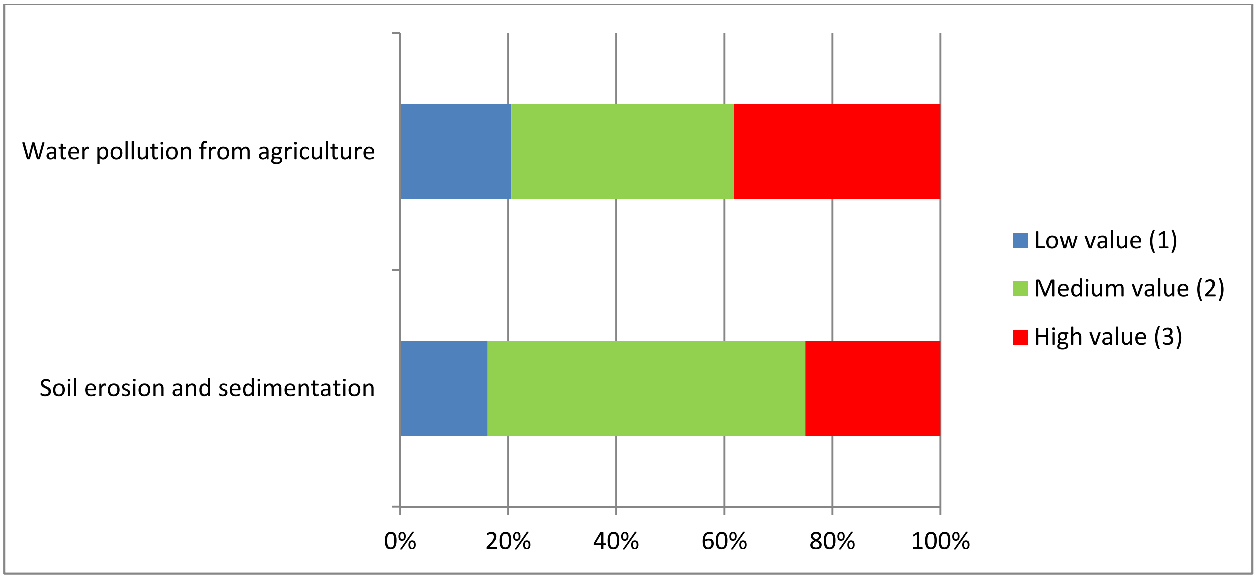

Figure 15. Ecosystem threats prioritisation results for the Buxa site.

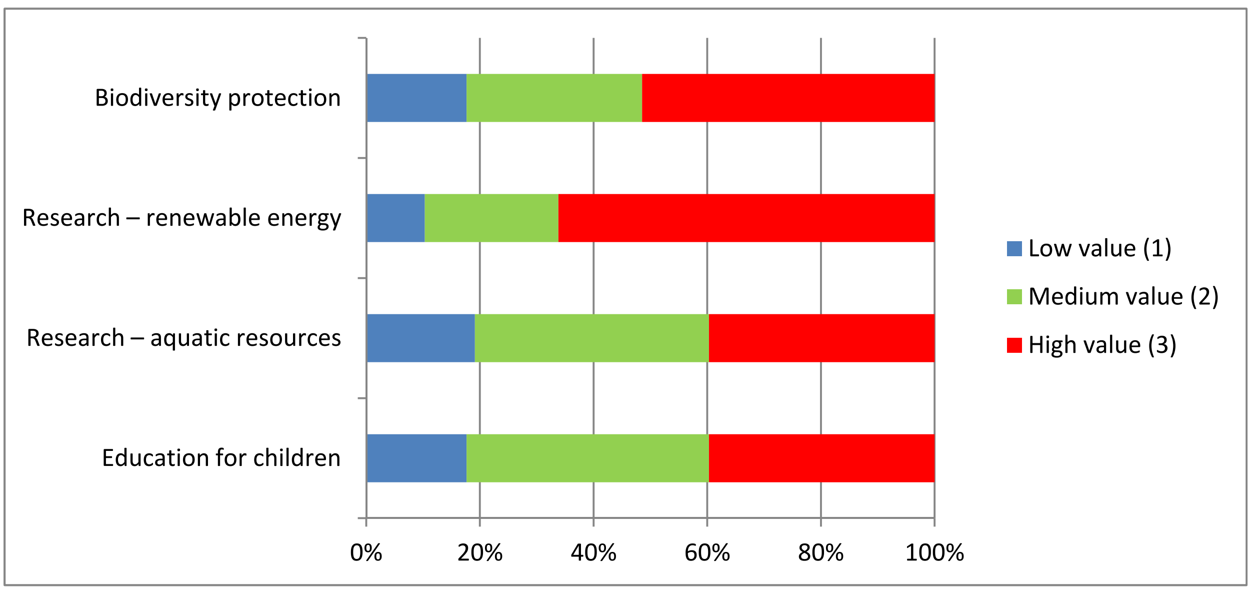

Figure 16. Community prioritisation of needs/recommendations for the Buxa site.

Table 7 shows the key perceptions regarding the ecosystem services and threats of the different stakeholder groups gathered though the interviews, meetings and the FGD's. It shows that there are some commonalities across the different stakeholder groups, including the decline of fishes, poor drinking water quality and need for alternative forms of income are highlighted by many of the groups as of particular concern. It is evolved that research on renewable energy and biodiversity protection services emerged as most important issue in Buxa as there is no electricity and environment and biodiversity is not protected due to deforestation and sedimentation. Then they are prioritizing the need of education and aquatic resources as they believed that proper education can solve all the problems related to ecosystem services.

Table 7. Individual stakeholder group priority ecosystem services and threats. Qualitative results of interviews, meetings and Focus Group Discussions held in 2010 and 2011.

Stakeholder	**Priority ecosystem services and threats as noted by CDHI staff**
Fisherman <u>This stakeholder group:</u> Fishermen living in communities within the Buxa site (they fish for subsistence use and for commercial use)	<u>Priority ecosystem services:</u> 1) Fishes for food – subsistence use More time is spent fishing to catch an sufficient amount to eat, and it is becoming increasing difficult to catch larger fishes (particularly in Adma Cluster) 2) Fishes for food – commercial use There is still a good demand to sell fish to the fish sellers (market) as well as the price of the local fishes / river fishes / small fishes is very high. 3) Other animals for food Some species of birds of are now becoming scarce <u>Threats:</u> 1) Soil erosion and sedimentation In the last seven to eight years deforestation has led to more severe floods and dry rivers, which is reducing the amount of fishes available.
Fish Sellers <u>This stakeholder group:</u> Fish sellers (all male) living within the project area.	<u>Priority ecosystem services:</u> 1) Fishes for food – commercial use The demand of local fish is still very high as it has high nutritional value. However, there is now a scarcity of local fishes / river fishes which is leading to a decline in the number of fishermen. <u>Threats:</u> 1)Water pollution The water is being polluted due to human and animal sewage as well as the use of pesticide, which is reducing the number of fishes. 2) Soil erosion and sedimentation One of the reasons for declining fish is reduced flow (caused by deforestation and sedimentation).
Builders <u>This stakeholder group:</u> Local people (men and women) who work either building flood protection or sand mining.	<u>Priority ecosystem services:</u> 1) Stone mining Concrete foundation (a compound mixture of cement, sand, pebbles etc) construction has been stopped in the area. Only the dikes / dams are constructed to protect the rivers and to stop the sedimentation. Many fishermen are willing to work as labourers for sand/boulder mining. <u>Threats:</u> 1) Soil erosion and sedimentation Within the past 10 years the flow of heavy river water has destroyed the river bed, leading to misbalances in the environment as plants on the river bed also

Stakeholder	Priority ecosystem services and threats as noted by CDHI staff
	destroyed. 2) Water pollution The quantity of fishes has been reduced due to sedimentation and pollution.
Women Self help group This stakeholder group: Women, especially housewives of Buxa households that have formed a self help group.	Priority ecosystem services: 1) Water – human consumption There is a crisis for water as in terms of quantity (during dry months) and quality (polluted due to sedimentation and human and animal sewage). The people, especially children are suffering from different diseases. Threats: 1) Sand and stone mining Officially the sand and stone mining has ceased , however it is still ongoing and is destroying the river beds 2) Water pollution Seriously impacting the quality of water for human consumption. Also due to water pollution fish catches are declining. Increasing numbers of tourists are now visiting the area which is generating litter. Other comments: This stakeholder group are concerned that the voice of women are not included in the planning and implementation process of local governance.
Men This stakeholder group: These are the male stakeholders from different villages of the project area	Priority ecosystem services: 1) Protection of plants The different committees (FRC-Forest Right Committee, EDC-Eco Development Committee, FDA-Forest Development Agency etc) have been formed by the BTR to protect the forest and environment. 2) Disease/vector regulation Threats 1. Soil erosion and sedimentation 2. Water pollution Other comments by men group: This stakeholder group believes the forest committee is not active, because of a sense of ownership is lacking among the people from the local communities. They want the government and nongovernmental organizations to work together to strengthen the communities representation on the committee and that public awareness across the communities needs to be improved to help protect the rivers. This stakeholder group also believes that more animal husbandry is good option to generate income. However, if this was to be done on a large scale in the project area (especially Buxa and Adma cluster) it will have serious impacts to the water

Stakeholder	**Priority ecosystem services and threats as noted by CDHI staff**
	quality of the rivers (and therefore drinking water).
Local governance This stakeholder group: The local level governance bodies e.g. Panchayats	Priority ecosystem services: 1) Fishes for food (subsistence use and commercial use) The government Scheme of Mahatma Gandhi National Rural Employment Grantee Act-2005 (MGNREGA) provides a legal guarantee for one hundred days of employment in every financial year to adult members of any rural household. This scheme is implemented by local governance. Through this scheme renovation of ponds, repairing of river bed can be included to protect the fishes and ecosystem services. The forest department, local governance, NGO has taken initiative to celebrate the "Forest week" to protect the plants and wild animals. This stakeholder group wants to increase the use of this scheme to improve the environmental conditions that are affecting fish decline. Threats 1) Soil erosion and sedimentation
Villagers This stakeholder group: The people who live in the villages of the project site	Priority ecosystem services: 1) Water – human consumption Water for drinking is also becoming scarce in the dry season, for example in Jayanti Cluster villagers have to dig the river bed every day to collect the water. Sima Dey (Villager, 34 years age) told us "First talk about the basic need of drinking water. The words ecosystem, biodiversity etc are not our present thinking, we are not so much worried about declining of fishes or protection of environment" Threats: 1) Soil erosion and sedimentation As farming is one of the major livelihood options in the project area, this group are very concerned about the loss of fertility of soils due to loss of soil during the monsoon rain. For example in 1999 torrential floods affected the soil structure and fertility resulting in reduced productivity in the orange orchards which was the main source of income for farmers. Now they are growing ginger, corn, turmeric etc. but the production of these crops is being impacted by pests and diseases which have increased in the last four to five years. The accessibility of road transport affects the sale of production in the bazaar due to flood and soil erosion damaging the roads. The sedimentation is also affecting water supplies in the dry season. 2) Water pollution The quality of drinking water has become poor resulting in water borne diseases.
Local Club / CBO This stakeholder group: Community Based Organizations	Priority ecosystem services: 1) Fishes for subsistence and commercial use The local youths are working together as local level community based organization (CBO). They want a dam to generate power and to create ponds (reservoirs) in the river to practice fish culture. They are willing to mobilize the community if there is

Stakeholder	Priority ecosystem services and threats as noted by CDHI staff
(CBO) are groups within villages e.g. tree growers club, cultural troops	campaigning on use of ponds and ecosystem services are being organized. Threats: Sedimentation and water pollution

In order to identify changes over time in the condition of ecosystem services a PRA, RRA exercise was conducted at each cluster to create an historical transect with the community members. They recalled the situation in 1985 (25 years previous) and compared to today (see Table 8 for results). Based on this exercise it is clear that many of the ecosystem services are changing for the worse.

Table 8. Changes in the condition of key ecosystem services between 1985 and 2010. Qualitative results based on discussions with local community members.

Ecosystem service	1985	2010 – change
Plants and water for animal consumption	Dark forest, water source, wild animals etc were available	Now getting scarce
Fishes for human consumption (subsistence and commercial)	- Sufficient amount of fishes to harvest - A wide variety of species available	- The amount of fish harvested has reduced - The variety of fish harvested has reduced
Resources for human and animal use	Water resources, natural resources, wild animals were more	Now these resources are decreasing
Water for human & animal consumption	- River water was clean - Sufficient amount of water all year round	- River water is now polluted - Amount of water available during the dry periods is often too low.
Medicinal plants	Natural resources was very rich	Medicinal plants have declined
Flood regulation	- Rivers were deep and narrow with low river beds.	- Rivers are now wide with high river beds (people often have to dig river beds for water harvesting during dry periods). - During monsoon rains areas often flood
Tourism	Less number of tourist	More tourist which has resulted some income bus also more pollution
Transportation	There was no bus service or major transportation links	Now roads are present transportation includes bus and jeeps
Disease/vector regulation	Few diseases present.	Now people are suffering from many different water borne diseases, which is also resulting in more expense in treatments

5.2.3. Discussion of ecosystem services at the Buxa site

5.2.3.1. Water for human consumption

The results of the quantitative questionnaire and FGD's with different stakeholder groups produced one significant difference, the value given to water for human use. During the FGD's it was apparent that the lack of potable drinking water is a high priority for many of the stakeholder groups, whereas through the questionnaire it was found have a relatively low value. It is believed that respondents were more open and honest when in a non-formal discussion setting, as in the FGD's, rather than with a formal questionnaire. Therefore we believe that the ecosystem services of water provision for human consumption should be given a high priority through this study.

Water consumption is severely impacted by reduced flow and drying up of rivers. In cluster-I (Adma) water is available almost year round, in cluster-II (Buxa) availability of water declines as most of the shallow rivers dry up soon after the monsoon (January to May), drying up completely sometime in the month of June. In cluster-III (Jayanti) the major river dries up (October to May) almost immediately after the monsoon. Some storage systems have been developed to store and transport river water to the villages, however not all villages are covered by this system as wells and pipes are leaking due to poor maintenance and water tanks are not cleaned on a regular basis. Few households have rain collection systems to supplement their water use as Buxa has the highest rainfall in West Bengal, the collected water can also be used for animals.

Quality, as well as quantity, of drinking water is an issue in all three clusters. The rivers often contain several physical and chemical impurities, and bacterial contamination due to human and animal sewage as well as pesticides is common. The concentration of the pollutants in the water increases in the dry season as the water flow of the main river and tributaries become very low and dried up. Due to the poor quality water, diseases including diarrhoea, gastric diseases (incl. gastritis), cholera, itching etc. are becoming more prevalent.

Figure 17, shows the areas of land that are critical for the provision of water to the people and animals of the Buxa site. It shows that the entire upper catchment generates this service and therefore if any of these areas are degraded (e.g. further deforestation, pollution) then there will likely be a further degradation in the quantity and quality of water provided as an ecosystem service. The map also shows that all the villages benefit (rely) upon this free service for their drinking water, either through harvesting directly from rivers or through pipes and storage systems which transport water from upstream areas to villages.

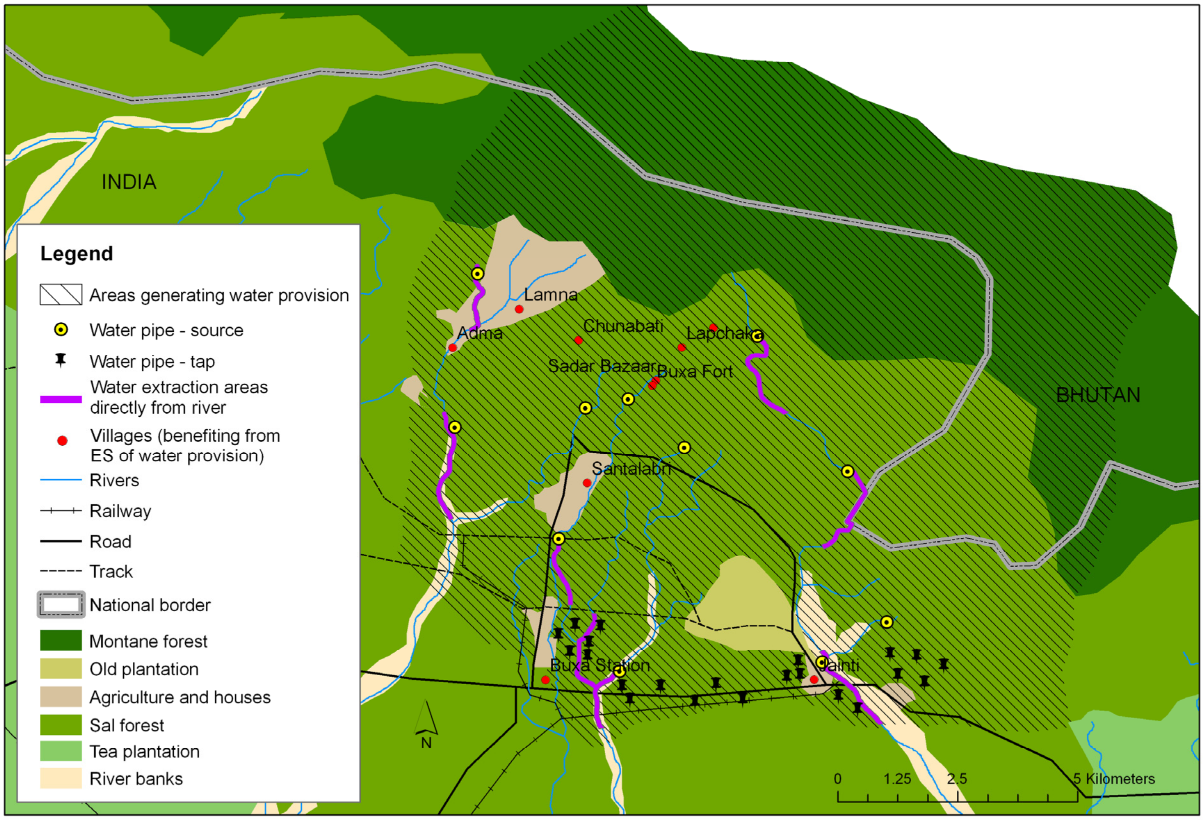

Figure 17. Areas generating and benefiting from the ecosystem service of water provision for human use.

5.2.3.2. Fishes for commercial use and subsistence use

Figure 18 shows that large areas both within the Buxa site and outside 'benefit' from the provisioning ecosystem service of fishes for food generated within the Buxa site. These areas (people) benefit as the fish are caught are sold at markets many kilometres out site of the Buxa site, often being sold at high prices due to their good taste and high nutritional value. The local fishermen benefit as they often make a good profit. However as already discussed harvesting of fish is declining in the site and to provide a sustainable supply of fishes for subsistence use and commercial use many issues need to be addressed. Critically an improvement in water quality and an increase in flow in the dry periods needs be achieved. The supply chain from the harvester to market needs to be improved as there is poor market infrastructure as well as unavailability of local level markets, there is only one market at Santhalabari which is weekly.

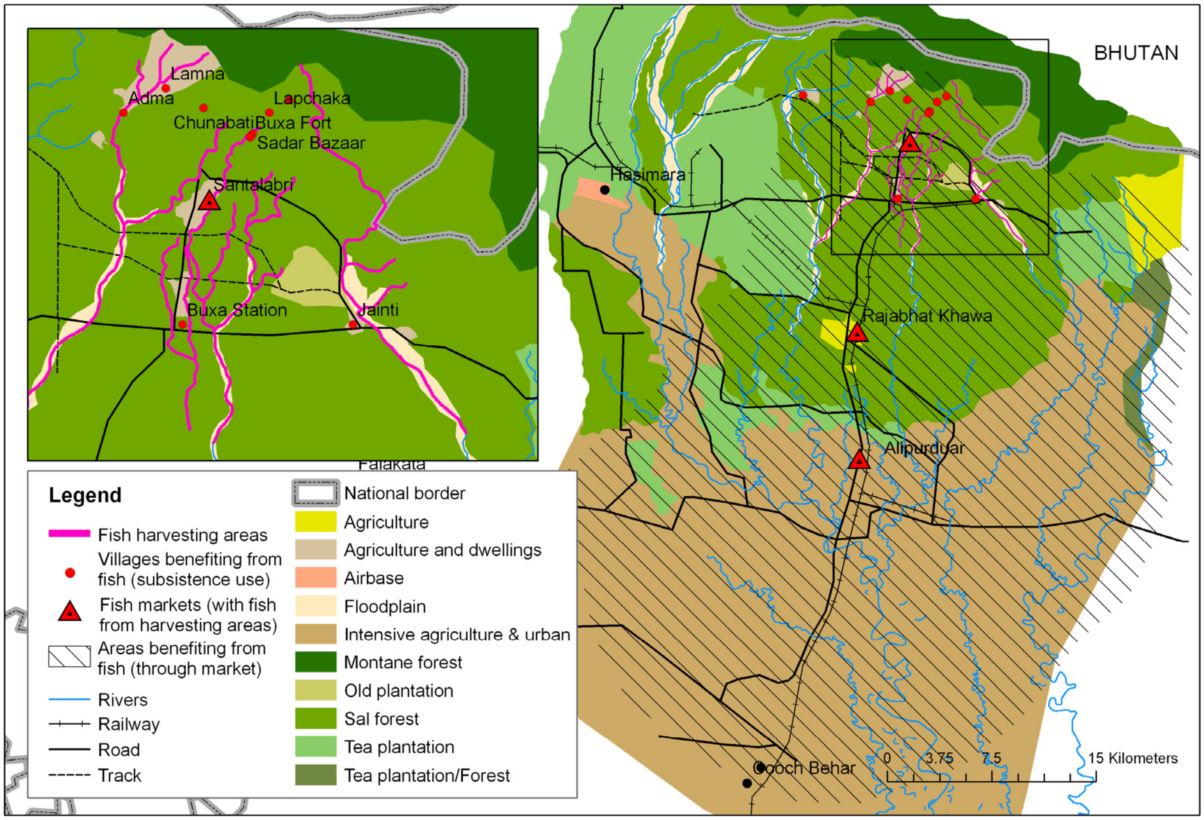

Figure 18. Areas benefiting from the ecosystem service of fishes for subsistence and commercial use.

5.2.3.3. Tourism

Figure 19 shows that the wider landscape of mountains, forest and rivers and the high levels of bio-diversity and Dukpa communities are providing an environment which is attracting increasing numbers of tourists from places including Kolkata, Bangladesh and further afield. The local communities benefit from tourism through providing accommodation or acting as tour guides. Threats such as water pollution, deforestation and subsequent loss of biodiversity will only negatively impact the benefits received by the local community from tourism. However, an increase in tourism if it continues in an unregulated way could be a potential threat to the natural habitats (including aquatic systems) in BTR, and there is a need for awareness building and sensitization within the local communities toward the adverse impact of tourism.

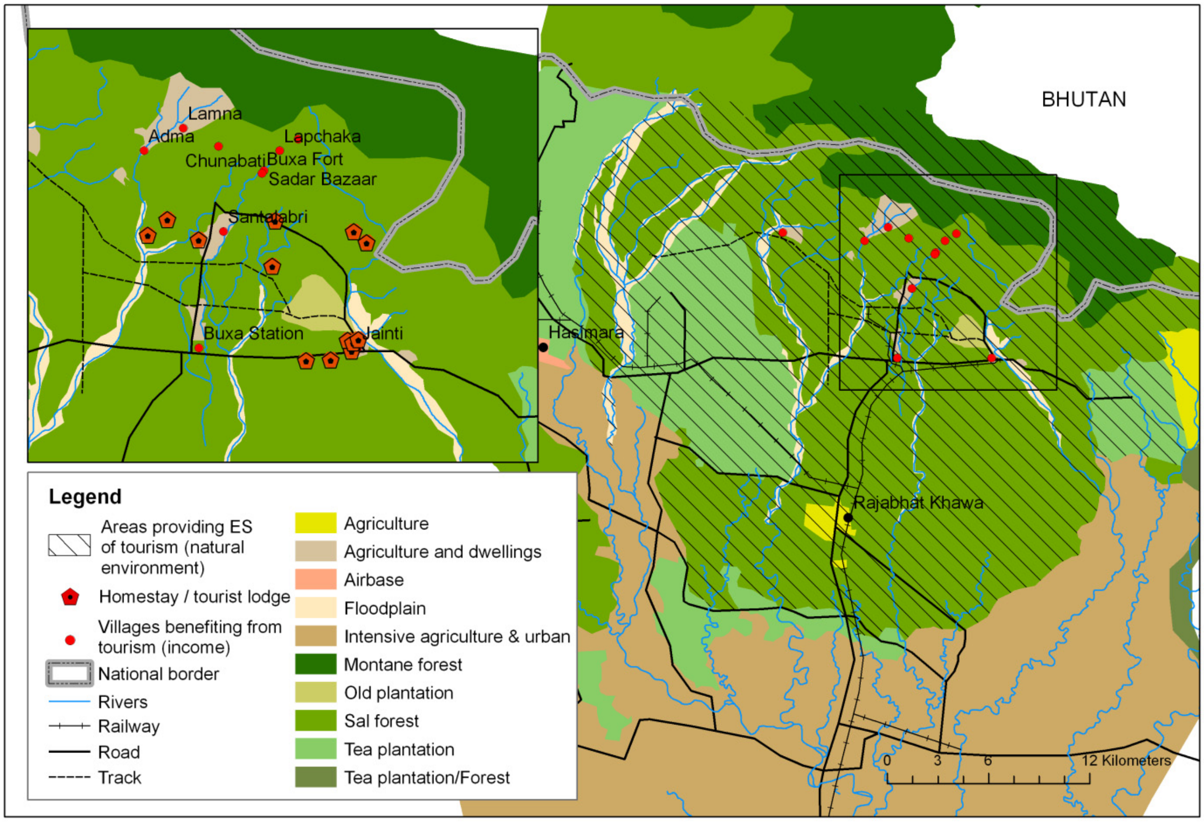

Figure 19. Areas generating the ecosystem service of tourism.

5.2.3.4. Flood regulation

Flood regulation is an ecosystem service that has been severley degraded in the BTR, and flooding has been highlighted as one of the key impacts to communities. This loss of flood regulation has been caused by deforestation, increased runoff and soil erosion (leading to sedimentation) which has reduced the systems natural ability to regulate flood waters during the monsoons. Currently there are no management strategies in place or in development (from the government) to try and strengthen the flood regulating services naturally provided by aquatic systems and their catchments. The villagers are using their own manpower and are constructing temporary dikes made of bamboo and wood, they have also constructed boats which they use during flooding. See Figure 9 in the Threats section for a map of the areas that are being flooded, and the key threats to this ecosystem service.

5.2.3.5. Sand and stone mining

The extraction of sand and stone has been one of the major issues within the Buxa site for past 18 years. Calling this an ecosystem service is debateable, as while it is generating a service (provision of building materials) it is also a threat to other services and biodiversity. Mining of sand and stone from Jayanti River is ongoing even though it is now officially banned. Local communities are also now realizing the negative impacts, however the mining provides work for the poorer sections of the community.

5.2.4. Potential indicators for monitoring the condition of ecosystem services at the Buxa site

In order to monitor the changes in the ecosystem services, or any impact or effectiveness of any action that is suggested through the Integrated Action Planning (IAP) process, indicators need to be identified. However, it is not the role of this report to state which indicators will be used, this will be done through the IAP which builds on the information in this report (and others). Therefore the indicators listed below (Table 9) are only potential indicators, which can be used if the actions suggested in the IAP are suitable

Table 9. Potential indicators for monitoring environmental conditions at Buxa

Ecosystem service	Potential indicators	Source of information
Water – human consumption	Water quality	Water quality tests (chemical and sediment levels). CDHI undertook water quality tests 10 years ago.
	Water availability	Field (social) survey. One undertaken already by CDHI in 2010
	Number of houses with access to water storage systems	Field (social) survey
Water – animal consumption	Water availability for households (particularly during dry season)	Social survey. One undertaken already by CDHI in 2010
Flood regulation	Number of flooding events in the Buxa site	Field survey and secondary data
	Number of landslides in the Buxa site	Field survey, and FGD meetings with locals
Fishes for food – subsistence use	Amount of fish harvested by fishermen for subsistence use	Field (social & biological) surveys (amount of fish, species variety, catching effort needed)
Fishes for food – commercial (to sell)	Amount of fish harvested and sold	Field (social, market & biological) surveys (amount of fish, species variety, effort needed, price)
Sand/stone mining for both commercial and personal use	Number of trucks/amount mined per year	Field survey and Focus Group Discussion (FGD)
	Number of labourers	Focus Group Discussion (FGD)
	Depth of rivers (in wet & dry season)	Field survey (measure depth of rivers where mining taking place)
Plants – medicinal use	Use of medicinal plants by communities	Field (social) survey (number of households harvesting medicinal plants, variety of species harvested)
	Knowledge of medicinal plants in communities	Field (social) survey (generational studies on knowledge of medicinal plant use)
Other animals for food (non-fish – e.g. molluscs, shrimps etc)	Amount of non-fish species harvested by community	Field (social & biological) surveys (amount harvested, species variety, effort needed, market survey)
Tourism	Number of tourist lodges within Buxa site	Field (social) survey and government data from Forest department

Ecosystem service	Potential indicators	Source of information
	Number of tourist guides from community	Field (social) survey and government data from Forest department
	Existence of local level tourism institution	Government data from Forest department
	Number of households with income from tourism	Field (social) survey
Disease/vector regulation	Prevalence of water borne diseases within community	Government data from Block Primary Health Centre (BPHC)
	Number of health clinics run in the Buxa site	Government data from Block Primary Health Centre (BPHC)

6. Conclusions

The freshwater systems within Buxa are rich in biodiversity, and provide an array of ecosystem services that local communities depend upon. However, these important services are also facing a range of threats from within the site and upstream which are seriously impacting the benefits they provide.

The rivers in Buxa reportedly contain 65 species of freshwater fishes (Das 2005) and "…the Buxa Tiger Reserve has the highest number of fish species in the North Bengal region…" (unknown author). Unfortunately the species list or the citation for the quote could not be sourced, so we cannot compare lists or know whether the list cited by Das contains only native species or be able to identify if our field surveys identified species not previously recorded at the site. The field surveys (including market surveys) undertaken for this report identified 43 species of native fishes, 22 species fewer than that cited by Das, and 34% of the species that are recorded as being in the wider catchment using the IUCN Red List data. Even though none of the species are assessed as globally threatened on the IUCN Red List, six are assessed as Near Threatened (close to meeting the criteria for a threatened category) and are impacted across their ranges by over-exploitation, pollution and dams. However, nearly all the species at the site are through to be declining due to increased water pollution and reduced water levels/flow in the dry season. Fishing within the communities at the site is not thought to be a key income livelihood strategy, however nearly every species of freshwater fish recorded has some type of value, either through the provision of food (at a subsistence level) or income (sold at the market). Twenty five species of wetland plants were also recorded, with all the native species being widespread and common, and assessed as Least Concern on the IUCN Red List. However a large proportion of the species, nine (possibly 11) are non natives and could pose a threat to the natural ecosystems through outcompeting native species.

The major threats at the Buxa site to freshwater biodiversity and ecosystem services includes water pollution from agricultural pesticides and fertilisers and domestic sewage. With the agricultural areas and villages all close to the rivers, the runoff quickly carries these pollutants to the streams. Mining in Bhutan is also impacting the rivers generating silt which is washed down into Buxa. Deforestation within the site and in the Bhutan part of the catchment (upstream) as led to increased levels of sedimentation in the rivers as soil is washes off the land (due to lack of natural vegetation cover) during monsoons. Due to more water running off straight into the rivers rather than soaking into the water table, areas are often flooded and rivers run at very low levels and occasionally dry up during the dry periods. Sand mining is also present in the site (the major site is near Jainti) and is destroying the river bed habitat.

According to the ecosystem services valuation survey the services that are valued most by the different stakeholders are 'fishes for commercial use' and 'disease/vector regulation'. Even though 'water for human consumption', a service that nearly all the communities within the site depend upon scored relatively low in the valuation survey, it was very highly prioritised in the Focus Group Discussions and should therefore be accepted as one of the high value services.

In order to help secure the conservation of freshwater biodiversity and ecosystem services a number of conservation actions can be recommended, aspects of which could potentially taken forward by the IAP. Measures such as the improving of farming methods used by the villages to reduce the levels of pollution, potential control of invasive plant species, the re-vegetation of areas that have been eroded, aquaculture of *native* fish species to provide food and income security. Also one of the drivers of the threats facing the freshwater systems of Buxa is the low literacy rates among the villagers, the lack of awareness of the relationship between behaviours and actions and the impacts they have upon the services that they rely upon, and a lack of understanding and agreement among the different stakeholders. Therefore we also recommend that education and awareness programmes to promote the understanding of human reliance upon biodiversity and ecosystem services within BTR are needed for all stakeholders (including the government). This may be through separate programmes or helping to support existing Community Based Institutions (CBI's) that have been set up by the Forest Department and Local Governance bodies. This could be achieved through Delphi technique to help mobilise government officials and departments, providing of maps (and interpretation) to assist in strategic planning, training villages on pollution monitoring (already been undertaken by CDHI), training programmes to develop skills on more environmentally friendly farming methods and awareness campaigns (legal requirements of the Forest Act, role of the environment in providing livelihoods).

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Annex 1. Summary of IUCN Red List criteria

Summary of the five criteria (A–E) used to evaluate if a taxon belongs in a threatened category (Critically Endangered, Endangered or Vulnerable).

Use any of the criteria A–E	Critically Endangered	Endangered	Vulnerable
A. Population reduction	Declines measured over the longer of 10 years or 3 generations		
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%
A1. Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible AND understood AND have ceased, based on and specifying any of the following: (a) direct observation (b) an index of abundance appropriate to the taxon (c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality (d) actual or potential levels of exploitation (e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.			
A2. Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased OR may not be understood OR may not be reversible, based on (a) to (e) under A1.			
A3. Population reduction projected or suspected to be met in the future (up to a maximum of 100 years) based on (b) to (e) under A1.			
A4. An observed, estimated, inferred, projected or suspected population reduction (up to a maximum of 100 years) where the time period must include both the past and the future, and where the causes of reduction may not have ceased OR may not be understood OR may not be reversible, based on (a) to (e) under A1.			
B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)			
B1. Extent of occurrence (EOO)	< 100 km²	< 5,000 km²	< 20,000 km²
B2. Area of occupancy (AOO)	< 10 km²	< 500 km²	< 2,000 km²
AND at least 2 of the following:			
(a) Severely fragmented, **OR** Number of locations	= 1	≤ 5	≤ 10
(b) Continuing decline in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals.			
(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals.			
C. Small population size and decline			
Number of mature individuals	< 250	< 2,500	< 10,000
AND either C1 or C2:			
C1. An estimated continuing decline of at least: (up to a max. of 100 years in future)	25% in 3 years or 1 generation	20% in 5 years or 2 generations	10% in 10 years or 3 generations
C2. A continuing decline **AND** (a) and/or (b):			
(a i) Number of mature individuals in each subpopulation:	< 50	< 250	< 1,000
or			
(a ii) % individuals in one subpopulation =	90–100%	95–100%	100%
(b) Extreme fluctuations in the number of mature individuals.			
D. Very small or restricted population			
Either: Number of mature individuals	< 50	< 250	**D1.** < 1,000
			AND/OR
	Restricted area of occupancy		**D2.** typically: AOO < 20 km² or number of locations ≤ 5
E. Quantitative Analysis			
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations (100 years max.)	≥ 20% in 20 years or 5 generations (100 years max.)	≥ 10% in 100 years

Annex 2. Species lists from the Buxa wider catchment

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Fishes

Order	Family	Binomial	IUCN Red List Category
Anguilliformes	Anguillidae	*Anguilla bengalensis*	LC
Beloniformes	Belonidae	*Xenentodon cancila*	LC
Clupeiformes	Clupeidae	*Gonialosa manmina*	LC
Clupeiformes	Clupeidae	*Gudusia chapra*	LC
Clupeiformes	Engraulidae	*Setipinna phasa*	LC
Cypriniformes	Balitoridae	*Schistura rupecula*	LC
Cypriniformes	Balitoridae	*Schistura scaturigina*	LC
Cypriniformes	Cobitidae	*Botia dario*	LC
Cypriniformes	Cobitidae	*Botia rostrata*	VU
Cypriniformes	Cobitidae	*Canthophrys gongota*	LC
Cypriniformes	Cobitidae	*Lepidocephalichthys annandalei*	LC
Cypriniformes	Cobitidae	*Lepidocephalichthys goalparensis*	LC
Cypriniformes	Cobitidae	*Lepidocephalichthys guntea*	LC
Cypriniformes	Cobitidae	*Lepidocephalichthys menoni*	DD
Cypriniformes	Cobitidae	*Neoeucirrhichthys maydelli*	LC
Cypriniformes	Cyprinidae	*Amblypharyngodon microlepis*	LC
Cypriniformes	Cyprinidae	*Amblypharyngodon mola*	LC
Cypriniformes	Cyprinidae	*Aspidoparia jaya*	LC
Cypriniformes	Cyprinidae	*Aspidoparia morar*	LC
Cypriniformes	Cyprinidae	*Bangana ariza*	LC
Cypriniformes	Cyprinidae	*Bangana dero*	LC
Cypriniformes	Cyprinidae	*Barilius barna*	LC
Cypriniformes	Cyprinidae	*Barilius bendelisis*	LC
Cypriniformes	Cyprinidae	*Barilius shacra*	LC
Cypriniformes	Cyprinidae	*Barilius vagra*	LC
Cypriniformes	Cyprinidae	*Chagunius chagunio*	LC
Cypriniformes	Cyprinidae	*Chela cachius*	LC
Cypriniformes	Cyprinidae	*Cirrhinus mrigala*	LC
Cypriniformes	Cyprinidae	*Cirrhinus reba*	LC
Cypriniformes	Cyprinidae	*Crossocheilus latius*	LC
Cypriniformes	Cyprinidae	*Cyprinion semiplotum*	VU
Cypriniformes	Cyprinidae	*Danio dangila*	LC
Cypriniformes	Cyprinidae	*Danio rerio*	LC
Cypriniformes	Cyprinidae	*Devario devario*	LC

Order	Family	Binomial	IUCN Red List Category
Cypriniformes	Cyprinidae	*Esomus danrica*	LC
Cypriniformes	Cyprinidae	*Garra gotyla*	LC
Cypriniformes	Cyprinidae	*Garra kempi*	LC
Cypriniformes	Cyprinidae	*Garra lamta*	LC
Cypriniformes	Cyprinidae	*Garra lissorhynchus*	LC
Cypriniformes	Cyprinidae	*Gibelion catla*	LC
Cypriniformes	Cyprinidae	*Labeo bata*	LC
Cypriniformes	Cyprinidae	*Labeo boga*	LC
Cypriniformes	Cyprinidae	*Labeo calbasu*	LC
Cypriniformes	Cyprinidae	*Labeo dyocheilus*	LC
Cypriniformes	Cyprinidae	*Labeo gonius*	LC
Cypriniformes	Cyprinidae	*Labeo nandina*	NT
Cypriniformes	Cyprinidae	*Labeo pangusia*	NT
Cypriniformes	Cyprinidae	*Labeo rohita*	LC
Cypriniformes	Cyprinidae	*Laubuca laubuca*	LC
Cypriniformes	Cyprinidae	*Megarasbora elanga*	LC
Cypriniformes	Cyprinidae	*Opsarius tileo*	LC
Cypriniformes	Cyprinidae	*Oreichthys cosuatis*	LC
Cypriniformes	Cyprinidae	*Osteobrama cotio*	LC
Cypriniformes	Cyprinidae	*Puntius chola*	LC
Cypriniformes	Cyprinidae	*Puntius conchonius*	LC
Cypriniformes	Cyprinidae	*Puntius gelius*	LC
Cypriniformes	Cyprinidae	*Puntius guganio*	LC
Cypriniformes	Cyprinidae	*Puntius phutunio*	LC
Cypriniformes	Cyprinidae	*Puntius sarana*	LC
Cypriniformes	Cyprinidae	*Puntius sophore*	LC
Cypriniformes	Cyprinidae	*Puntius terio*	LC
Cypriniformes	Cyprinidae	*Puntius ticto*	LC
Cypriniformes	Cyprinidae	*Rasbora daniconius*	LC
Cypriniformes	Cyprinidae	*Rasbora rasbora*	LC
Cypriniformes	Cyprinidae	*Salmophasia bacaila*	LC
Cypriniformes	Cyprinidae	*Salmophasia phulo*	LC
Cypriniformes	Cyprinidae	*Schizothorax molesworthi*	DD
Cypriniformes	Cyprinidae	*Securicula gora*	LC
Cypriniformes	Cyprinidae	*Tor tor*	NT
Cypriniformes	Psilorhynchidae	*Psilorhynchus balitora*	LC
Cypriniformes	Psilorhynchidae	*Psilorhynchus gracilis*	LC
Cypriniformes	Psilorhynchidae	*Psilorhynchus sucatio*	LC
Cyprinodontiformes	Aplocheilidae	*Aplocheilus lineatus*	LC
Mugiliformes	Mugilidae	*Sicamugil cascasia*	LC

Order	Family	Binomial	IUCN Red List Category
Osteoglossiformes	Notopteridae	*Chitala chitala*	NT
Osteoglossiformes	Notopteridae	*Notopterus notopterus*	LC
Perciformes	Ambassidae	*Chanda nama*	LC
Perciformes	Ambassidae	*Parambassis lala*	NT
Perciformes	Ambassidae	*Pseudambassis baculis*	LC
Perciformes	Ambassidae	*Pseudambassis ranga*	LC
Perciformes	Anabantidae	*Anabas testudineus*	DD
Perciformes	Badidae	*Badis badis*	LC
Perciformes	Badidae	*Badis blosyrus*	LC
Perciformes	Channidae	*Channa amphibeus*	LC
Perciformes	Channidae	*Channa gachua*	LC
Perciformes	Channidae	*Channa marulius*	LC
Perciformes	Channidae	*Channa punctata*	LC
Perciformes	Channidae	*Channa stewartii*	LC
Perciformes	Channidae	*Channa striata*	LC
Perciformes	Gobiidae	*Glossogobius giuris*	LC
Perciformes	Nandidae	*Nandus nandus*	LC
Perciformes	Osphronemidae	*Trichogaster chuna*	LC
Perciformes	Osphronemidae	*Trichogaster fasciata*	LC
Perciformes	Osphronemidae	*Trichogaster lalius*	LC
Perciformes	Sciaenidae	*Otolithoides pama*	LC
Siluriformes	Amblycipitidae	*Amblyceps apangi*	LC
Siluriformes	Bagridae	*Batasio batasio*	LC
Siluriformes	Bagridae	*Batasio fasciolatus*	LC
Siluriformes	Bagridae	*Batasio tengana*	LC
Siluriformes	Bagridae	*Mystus carcio*	LC
Siluriformes	Bagridae	*Mystus cavasius*	LC
Siluriformes	Bagridae	*Mystus tengara*	LC
Siluriformes	Bagridae	*Sperata aor*	LC
Siluriformes	Bagridae	*Sperata seenghala*	LC
Siluriformes	Chacidae	*Chaca chaca*	LC
Siluriformes	Clariidae	*Clarias batrachus*	LC
Siluriformes	Clariidae	*Clarias magur*	EN
Siluriformes	Erethistidae	*Erethistes pusillus*	LC
Siluriformes	Erethistidae	*Erethistoides sicula*	DD
Siluriformes	Erethistidae	*Hara hara*	LC
Siluriformes	Erethistidae	*Hara horai*	LC
Siluriformes	Erethistidae	*Hara jerdoni*	LC
Siluriformes	Erethistidae	*Pseudolaguvia ferruginea*	DD
Siluriformes	Erethistidae	*Pseudolaguvia ferula*	DD

Order	Family	Binomial	IUCN Red List Category
Siluriformes	Erethistidae	*Pseudolaguvia foveolata*	DD
Siluriformes	Erethistidae	*Pseudolaguvia ribeiroi*	LC
Siluriformes	Erethistidae	*Pseudolaguvia shawi*	LC
Siluriformes	Heteropneustidae	*Heteropneustes fossilis*	LC
Siluriformes	Schilbeidae	*Ailia coila*	NT
Siluriformes	Schilbeidae	*Clupisoma garua*	LC
Siluriformes	Schilbeidae	*Clupisoma montana*	LC
Siluriformes	Schilbeidae	*Eutropiichthys murius*	LC
Siluriformes	Schilbeidae	*Eutropiichthys vacha*	LC
Siluriformes	Schilbeidae	*Neotropius atherinoides*	LC
Siluriformes	Schilbeidae	*Silonia silondia*	LC
Siluriformes	Siluridae	*Ompok bimaculatus*	NT
Siluriformes	Siluridae	*Pterocryptis gangelica*	DD
Siluriformes	Siluridae	*Wallago attu*	NT
Siluriformes	Sisoridae	*Bagarius bagarius*	NT
Siluriformes	Sisoridae	*Gagata sexualis*	LC
Siluriformes	Sisoridae	*Glyptothorax botius*	LC
Siluriformes	Sisoridae	*Glyptothorax cavia*	LC
Siluriformes	Sisoridae	*Glyptothorax telchitta*	LC
Siluriformes	Sisoridae	*Gogangra viridescens*	LC
Siluriformes	Sisoridae	*Nangra assamensis*	LC
Siluriformes	Sisoridae	*Nangra nangra*	LC
Siluriformes	Sisoridae	*Parachiloglanis hodgarti*	LC
Siluriformes	Sisoridae	*Pseudecheneis sulcata*	LC
Synbranchiformes	Mastacembelidae	*Macrognathus aculeatus*	LC
Synbranchiformes	Mastacembelidae	*Mastacembelus armatus*	LC
Synbranchiformes	Synbranchidae	*Monopterus albus*	LC
Synbranchiformes	Synbranchidae	*Monopterus cuchia*	LC

Molluscs

Class	Order	Family	Binomial	IUCN Red List Category
Bivalvia	Arcoida	Arcidae	*Scaphula celox*	LC
Bivalvia	Arcoida	Arcidae	*Scaphula deltae*	LC
Bivalvia	Unionoida	Unionidae	*Lamellidens consobrinus*	LC
Bivalvia	Unionoida	Unionidae	*Lamellidens corrianus*	LC
Bivalvia	Unionoida	Unionidae	*Lamellidens generosus*	LC
Bivalvia	Unionoida	Unionidae	*Lamellidens jenkinsianus*	LC
Bivalvia	Unionoida	Unionidae	*Lamellidens lamellatus*	LC

Class	Order	Family	Binomial	IUCN Red List Category
Bivalvia	Unionoida	Unionidae	*Lamellidens marginalis*	LC
Bivalvia	Unionoida	Unionidae	*Lamellidens narainpirensis*	LC
Bivalvia	Unionoida	Unionidae	*Lamellidens unioides*	DD
Bivalvia	Unionoida	Unionidae	*Parreysia andersoniana*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia bonneaudi*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia caerulea*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia corrugata*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia lima*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia occata*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia olivaria*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia pachysoma*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia rajahensis*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia sikkimensis*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia theobaldi*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia triembolus*	LC
Bivalvia	Veneroida	Corbiculidae	*Corbicula striatella*	LC
Bivalvia	Veneroida	Corbiculidae	*Polymesoda bengalensis*	LC
Bivalvia	Veneroida	Solecurtidae	*Novaculina gangetica*	LC
Bivalvia	Veneroida	Sphaeriidae	*Pisidium clarkeanum*	LC
Bivalvia	Veneroida	Sphaeriidae	*Pisidium prasongi*	LC
Bivalvia	Veneroida	Sphaeriidae	*Tanysiphon rivalis*	LC
Gastropoda	Allogastropoda	Bullinidae	*Indoplanorbis exustus*	LC
Gastropoda	Architaenioglossa	Ampullariidae	*Pila globosa*	LC
Gastropoda	Architaenioglossa	Viviparidae	*Bellamya bengalensis*	LC
Gastropoda	Architaenioglossa	Viviparidae	*Bellamya crassa*	LC
Gastropoda	Architaenioglossa	Viviparidae	*Bellamya dissimilis*	LC
Gastropoda	Architaenioglossa	Viviparidae	*Cipangopaludina lecythis*	LC
Gastropoda	Cycloneritimorpha	Neritidae	*Clithon reticularis*	LC
Gastropoda	Cycloneritimorpha	Neritidae	*Nerita articulata*	LC
Gastropoda	Cycloneritimorpha	Neritidae	*Neritina obtusa*	LC
Gastropoda	Cycloneritimorpha	Neritidae	*Neritina smithi*	LC
Gastropoda	Cycloneritimorpha	Neritidae	*Neritina sulculosa*	LC
Gastropoda	Cycloneritimorpha	Neritidae	*Neritina violacea*	LC
Gastropoda	Cycloneritimorpha	Neritidae	*Septaria lineata*	LC
Gastropoda	Cycloneritimorpha	Neritidae	*Theodoxus reticularis*	LC
Gastropoda	Hygrophila	Lymnaeidae	*Lymnaea acuminata*	LC
Gastropoda	Hygrophila	Lymnaeidae	*Lymnaea luteola*	LC
Gastropoda	Hygrophila	Lymnaeidae	*Lymnaea swinhoei*	LC
Gastropoda	Hygrophila	Planorbidae	*Camptoceras terebra*	DD

Class	Order	Family	Binomial	IUCN Red List Category
Gastropoda	Hygrophila	Planorbidae	*Ferrissia baconi*	LC
Gastropoda	Hygrophila	Planorbidae	*Ferrissia verruca*	LC
Gastropoda	Hygrophila	Planorbidae	*Gyraulus barrackporensis*	LC
Gastropoda	Hygrophila	Planorbidae	*Gyraulus convexiusculus*	LC
Gastropoda	Hygrophila	Planorbidae	*Gyraulus labiatus*	LC
Gastropoda	Hygrophila	Planorbidae	*Hippeutis umbilicalis*	LC
Gastropoda	Hygrophila	Planorbidae	*Segmentina calatha*	LC
Gastropoda	Hygrophila	Planorbidae	*Segmentina cantori*	DD
Gastropoda	Hygrophila	Planorbidae	*Segmentina trochoidea*	LC
Gastropoda	Littorinimorpha	Assimineidae	*Assiminea beddomeana*	LC
Gastropoda	Littorinimorpha	Bithyniidae	*Bithynia pulchella*	LC
Gastropoda	Littorinimorpha	Bithyniidae	*Digoniostoma cerameopoma*	LC
Gastropoda	Littorinimorpha	Bithyniidae	*Gabbia orcula*	LC
Gastropoda	Littorinimorpha	Iravadiidae	*Iravadia ornata*	LC
Gastropoda	Littorinimorpha	Iravadiidae	*Iravadia princeps*	DD
Gastropoda	Littorinimorpha	Stenothyridae	*Gangetia miliacea*	LC
Gastropoda	Littorinimorpha	Stenothyridae	*Stenothyra blanfordiana*	LC
Gastropoda	Littorinimorpha	Stenothyridae	*Stenothyra deltae*	LC
Gastropoda	Littorinimorpha	Stenothyridae	*Stenothyra foveolata*	DD
Gastropoda	Littorinimorpha	Stenothyridae	*Stenothyra monilifera*	LC
Gastropoda	Littorinimorpha	Stenothyridae	*Stenothyra nana*	DD
Gastropoda	Littorinimorpha	Stenothyridae	*Stenothyra ornata*	LC
Gastropoda	Littorinimorpha	Stenothyridae	*Stenothyra soluta*	LC
Gastropoda	Littorinimorpha	Stenothyridae	*Stenothyra woodmasoniana*	DD
Gastropoda	Sorbeoconcha	Pachychilidae	*Brotia costula*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Melanoides tuberculatus*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Paludomus blanfordiana*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Paludomus conica*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Paludomus regulata*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Thiara granifera*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Thiara lineata*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Thiara paludomoidea*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Thiara riqueti*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Thiara rudis*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Thiara scabra*	LC

Odonata

Family	Binomial	IUCN Red List Category
Aeshnidae	*Gynacantha bayadera*	LC

Family	**Binomial**	**IUCN Red List Category**
Aeshnidae	*Gynacantha dravida*	DD
Aeshnidae	*Gynacantha incisura*	LC
Aeshnidae	*Gynacantha khasiaca*	DD
Aeshnidae	*Gynacanthaeschna sikkima*	LC
Aeshnidae	*Periaeschna magdalena*	LC
Aeshnidae	*Petaliaeschna fletcheri*	DD
Aeshnidae	*Polycanthagyna erythromelas*	LC
Aeshnidae	*Polycanthagyna ornithocephala*	LC
Aeshnidae	*Tetracanthagyna waterhousei*	LC
Chlorocyphidae	*Rhinocypha fenestrella*	LC
Chlorocyphidae	*Rhinocypha ignipennis*	LC
Chlorocyphidae	*Rhinocypha immaculata*	LC
Chlorocyphidae	*Rhinocypha quadrimaculata*	LC
Chlorocyphidae	*Rhinocypha spuria*	LC
Chlorocyphidae	*Rhinocypha trifasciata*	LC
Chlorocyphidae	*Rhinocypha unimaculata*	LC
Coenagrionidae	*Himalagrion exclamationis*	DD
Coenagrionidae	*Ischnura aurora*	LC
Coenagrionidae	*Ischnura forcipata*	LC
Coenagrionidae	*Ischnura rufostigma*	LC
Coenagrionidae	*Paracercion calamorum*	LC
Coenagrionidae	*Pseudagrion australasiae*	LC
Coenagrionidae	*Pseudagrion microcephalum*	LC
Coenagrionidae	*Pseudagrion spencei*	LC
Cordulegastridae	*Neallogaster hermionae*	LC
Cordulegastridae	*Neallogaster latifrons*	LC
Cordulegastridae	*Neallogaster ornata*	NT
Euphaeidae	*Euphaea ochracea*	LC
Gomphidae	*Gomphidia williamsoni*	DD
Gomphidae	*Ictinogomphus distinctus*	DD
Gomphidae	*Ictinogomphus rapax*	LC
Gomphidae	*Lamelligomphus biforceps*	LC
Gomphidae	*Macrogomphus robustus*	DD
Gomphidae	*Macrogomphus seductus*	DD
Gomphidae	*Megalogomphus flavicolor*	DD
Gomphidae	*Merogomphus martini*	NT
Gomphidae	*Onychogomphus risi*	DD
Gomphidae	*Onychogomphus schmidti*	LC
Gomphidae	*Onychogomphus striatus*	DD
Gomphidae	*Paragomphus lineatus*	LC
Gomphidae	*Perissogomphus stevensi*	LC
Gomphidae	*Platygomphus dolabratus*	LC
Lestidae	*Indolestes cyaneus*	LC
Lestidae	*Lestes praemorsus*	LC
Lestidae	*Lestes umbrinus*	DD
Lestidae	*Platylestes platystylus*	LC
Libellulidae	*Crocothemis erythraea*	LC

Family	Binomial	IUCN Red List Category
Libellulidae	*Diplacodes nebulosa*	LC
Libellulidae	*Diplacodes trivialis*	LC
Libellulidae	*Hydrobasileus croceus*	LC
Libellulidae	*Indothemis carnatica*	NT
Libellulidae	*Lathrecista asiatica*	LC
Libellulidae	*Lyriothemis bivittata*	LC
Libellulidae	*Lyriothemis tricolor*	LC
Libellulidae	*Macrodiplax cora*	LC
Libellulidae	*Nannophya pygmaea*	LC
Libellulidae	*Neurothemis fulvia*	LC
Libellulidae	*Neurothemis intermedia*	LC
Libellulidae	*Neurothemis tullia*	LC
Libellulidae	*Onychothemis testacea*	LC
Libellulidae	*Orthetrum cancellatum*	LC
Libellulidae	*Orthetrum chrysis*	LC
Libellulidae	*Orthetrum pruinosum*	LC
Libellulidae	*Orthetrum taeniolatum*	LC
Libellulidae	*Palpopleura sexmaculata*	LC
Libellulidae	*Potamarcha congener*	LC
Libellulidae	*Rhodothemis rufa*	LC
Libellulidae	*Rhyothemis plutonia*	LC
Libellulidae	*Rhyothemis variegata*	LC
Libellulidae	*Sympetrum commixtum*	LC
Libellulidae	*Sympetrum fonscolombii*	LC
Libellulidae	*Sympetrum himalayanum*	DD
Libellulidae	*Sympetrum hypomelas*	LC
Libellulidae	*Sympetrum orientale*	DD
Libellulidae	*Tetrathemis platyptera*	LC
Libellulidae	*Tramea basilaris*	LC
Macromiidae	*Macromia flavocolorata*	LC
Macromiidae	*Macromia moorei*	LC
Platystictidae	*Drepanosticta carmichaeli*	LC
Protoneuridae	*Prodasineura autumnalis*	LC
Synlestidae	*Megalestes major*	LC

Plants (selected plant families of the Ganges/Brahmaputra basin)

Phylum	Class	Order	Family	Binomial	Red List
Bryophyta	Sphagnopsida	Sphagnales	Sphagnaceae	*Sphagnum palustre*	DD*
Charophyta	Charophyaceae	Charales	Characeae	*Chara braunii*	LC*
Charophyta	Charophyaceae	Charales	Characeae	*Chara corallina*	LC*
Charophyta	Charophyaceae	Charales	Characeae	*Chara zeylanica*	LC*
Charophyta	Charophyaceae	Charales	Characeae	*Nitella acuminata*	LC*
Charophyta	Charophyaceae	Charales	Characeae	*Nitella furcata*	LC*
Charophyta	Charophyaceae	Charales	Characeae	*Nitella hyalina*	LC*

Phylum	Class	Order	Family	Binomial	Red List
Lycopodiophyta	Isoetopsida	Isoetales	Isoetaceae	*Isoetes cormandeliana*	LC
Lycopodiophyta	Isoetopsida	Isoetales	Isoetaceae	*Isoetes indica*	NA
Marchantiophyta	Jungermanniopsida	Pelliales	Pelliaceae	*Pellia epiphylla*	NA
Marchantiophyta	Marchantiopsida	Marchantiales	Ricciaceae	*Ricciella fluitans*	NT*
Marchantiophyta	Marchantiopsida	Marchantiales	Ricciaceae	*Ricciocarpus natans*	DD*
Polypodiophyta	Polypodiopsida	Marsileales	Marsileaceae	*Marsilea quadrifolia*	LC
Polypodiophyta	Polypodiopsida	Salviniales	Azollaceae	*Azolla pinnata*	LC
Polypodiophyta	Polypodiopsida	Salviniales	Salviniaceae	*Salvinia cucullata*	LC
Polypodiophyta	Polypodiopsida	Salviniales	Salviniaceae	*Salvinia natans*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Alisma plantago-aquatica*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Caldesia oligococca*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Caldesia parnassifolia*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Limnophyton obtusifolium*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Sagittaria guayanensis*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Sagittaria sagittifolia*	LC
Tracheophyta	Liliopsida	Arales	Araceae	*Colocasia esculenta*	LC
Tracheophyta	Liliopsida	Arales	Araceae	*Cryptocoryne ciliata*	LC
Tracheophyta	Liliopsida	Arales	Araceae	*Cryptocoryne cognata*	EN
Tracheophyta	Liliopsida	Arales	Araceae	*Cryptocoryne retrospiralis*	LC
Tracheophyta	Liliopsida	Arales	Araceae	*Cryptocoryne spiralis*	LC*
Tracheophyta	Liliopsida	Arales	Araceae	*Lagenandra meeboldii*	LC*
Tracheophyta	Liliopsida	Arales	Araceae	*Lasia spinosa*	LC
Tracheophyta	Liliopsida	Arales	Araceae	*Pistia stratiotes*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Landoltia punctata*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Lemna aequinoctialis*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Lemna minor*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Lemna perpusilla*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Lemna trisulca*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Wolffia arrhiza*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Wolffia microscopica*	DD*
Tracheophyta	Liliopsida	Commelinales	Commelinaceae	*Commelina longifolia*	LC*
Tracheophyta	Liliopsida	Commelinales	Commelinaceae	*Commelina undulata*	LC*
Tracheophyta	Liliopsida	Commelinales	Commelinaceae	*Cyanotis axillaris*	LC
Tracheophyta	Liliopsida	Commelinales	Commelinaceae	*Murdannia nudiflora*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Actinoscirpus grossus*	LC
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus alopecuroides*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus articulatus*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus cephalotes*	LC
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus compressus*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus corymbosus*	LC*

Phylum	Class	Order	Family	Binomial	Red List
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus difformis*	LC
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus exaltatus*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus haspan*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus iria*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus laevigatus*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus platystylis*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Eleocharis dulcis*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Eleocharis palustris*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Fimbristylis dichotoma*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Fimbristylis woodrowii*	DD*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Lipocarpha squarrosa*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Pycreus pumilus*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Schoenoplectiella articulata*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Schoenoplectiella erecta*	NA
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Schoenoplectiella supina*	DD*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Arundo donax*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Brachiaria mutica*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Brachiaria reptans*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Coix aquatica*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Echinochloa colona*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Hygroryza aristata*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Imperata cylindrica*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Leersia hexandra*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Panicum paludosum*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Paspalidium flavidum*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Paspalidium geminatum*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Paspalum distichum*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Paspalum scrobiculatum*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Phragmites karka*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Pseudoraphis minuta*	DD*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Pseudoraphis spinescens*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Sacciolepis interrupta*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Sacciolepis myuros*	NA
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Blyxa aubertii*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Blyxa octandra*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Hydrilla verticillata*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Hydrocharis dubia*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Najas graminea*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Najas kurziana*	DD*
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Najas marina*	LC

Phylum	Class	Order	Family	Binomial	Red List
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Najas minor*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Nechamandra alternifolia*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Ottelia alismoides*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Vallisneria spiralis*	LC
Tracheophyta	Liliopsida	Juncales	Juncaceae	*Juncus bufonius*	LC
Tracheophyta	Liliopsida	Juncales	Juncaceae	*Juncus concinnus*	DD*
Tracheophyta	Liliopsida	Juncales	Juncaceae	*Juncus inflexus*	LC
Tracheophyta	Liliopsida	Juncales	Juncaceae	*Juncus prismatocarpus*	LC
Tracheophyta	Liliopsida	Liliales	Amaryllidaceae	*Crinum viviparum*	LC
Tracheophyta	Liliopsida	Liliales	Pontederiaceae	*Monochoria hastata*	LC
Tracheophyta	Liliopsida	Liliales	Pontederiaceae	*Monochoria vaginalis*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton crispus*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton lucens*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton nodosus*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton octandrus*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton perfoliatus*	LC*
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Ruppia maritima*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Stuckenia pectinata*	LC
Tracheophyta	Liliopsida	Typhales	Typhaceae	*Typha angustifolia*	LC
Tracheophyta	Liliopsida	Typhales	Typhaceae	*Typha domingensis*	LC
Tracheophyta	Liliopsida	Typhales	Typhaceae	*Typha elephantina*	LC
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Centella asiatica*	LC*
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Oenanthe stolonifera*	DD*
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Oenanthe thomsoni*	DD*
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Artemisia scoparia*	LC*
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Caesulia axillaris*	LC
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Enydra fluctuans*	LC
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Ethulia conyzoides*	LC
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Grangea maderaspatana*	LC
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Vicoa vestita*	NA
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Cochlearia flava*	LC*
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Nasturtium officinale*	LC*
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Rorippa indica*	LC*
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Trochiscus cochlearioides*	DD*
Tracheophyta	Magnoliopsida	Euphorbiales	Euphorbiaceae	*Phyllanthus reticulatus*	LC*
Tracheophyta	Magnoliopsida	Fabales	Leguminosae	*Aeschynomene aspera*	LC
Tracheophyta	Magnoliopsida	Fabales	Leguminosae	*Aeschynomene indica*	LC
Tracheophyta	Magnoliopsida	Fabales	Leguminosae	*Alysicarpus bupleurifolius*	DD*
Tracheophyta	Magnoliopsida	Fabales	Leguminosae	*Neptunia oleracea*	LC
Tracheophyta	Magnoliopsida	Fabales	Leguminosae	*Sesbania procumbens*	DD*

Phylum	Class	Order	Family	Binomial	Red List
Tracheophyta	Magnoliopsida	Myrtales	Lythraceae	*Ammannia baccifera*	LC
Tracheophyta	Magnoliopsida	Myrtales	Onagraceae	*Jussiaea perennis*	LC*
Tracheophyta	Magnoliopsida	Myrtales	Onagraceae	*Jussiaea repens*	NA
Tracheophyta	Magnoliopsida	Myrtales	Onagraceae	*Jussiaea suffruticosa*	DD*
Tracheophyta	Magnoliopsida	Myrtales	Onagraceae	*Ludwigia adscendens*	LC*
Tracheophyta	Magnoliopsida	Myrtales	Trapaceae	*Trapa maximowiczii*	DD*
Tracheophyta	Magnoliopsida	Myrtales	Trapaceae	*Trapa natans*	LC
Tracheophyta	Magnoliopsida	Nepenthales	Droseraceae	*Aldrovanda vesiculosa*	LC*
Tracheophyta	Magnoliopsida	Nepenthales	Droseraceae	*Drosera burmanni*	LC
Tracheophyta	Magnoliopsida	Nepenthales	Droseraceae	*Drosera indica*	LC
Tracheophyta	Magnoliopsida	Nymphaeales	Ceratophyllaceae	*Ceratophyllum demersum*	LC
Tracheophyta	Magnoliopsida	Nymphaeales	Nymphaeaceae	*Euryale ferox*	LC
Tracheophyta	Magnoliopsida	Nymphaeales	Nymphaeaceae	*Nymphaea lotus*	LC*
Tracheophyta	Magnoliopsida	Nymphaeales	Nymphaeaceae	*Nymphaea nouchali*	LC
Tracheophyta	Magnoliopsida	Nymphaeales	Nymphaeaceae	*Nymphaea pubescens*	LC
Tracheophyta	Magnoliopsida	Nymphaeales	Nymphaeaceae	*Nymphaea rubra*	LC
Tracheophyta	Magnoliopsida	Plantaginales	Plantaginaceae	*Plantago major*	LC*
Tracheophyta	Magnoliopsida	Podostemales	Podostemaceae	*Hydrobryum griffithii*	LC
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Persicaria barbatum*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Persicaria glabrum*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Persicaria hydropiper*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Persicaria orientalis*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Polygonum pulchrum*	NA
Tracheophyta	Magnoliopsida	Ranunculales	Ranunculaceae	*Ranunculus natans*	DD*
Tracheophyta	Magnoliopsida	Ranunculales	Ranunculaceae	*Ranunculus sceleratus*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Acanthaceae	*Cardanthera difformis*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Acanthaceae	*Hygrophila auriculata*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Acanthaceae	*Hygrophila pinnatifida*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Acanthaceae	*Hygrophila polysperma*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Acanthaceae	*Hygrophila serpyllum*	NA
Tracheophyta	Magnoliopsida	Scrophulariales	Acanthaceae	*Hygrophila spinosa*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia aurea*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia bifida*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia brachiata*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia exoleta*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia furcellata*	NA
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia hirta*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia inflexa*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia minutissima*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia polygaloides*	LC*

Phylum	Class	Order	Family	Binomial	Red List
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia scandens*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia stellaris*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia striatula*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Dopatrium junceum*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Dopatrium lobelioides*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Ilysanthes parviflora*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Limnophila aquatica*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Limnophila aromatica*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Limnophila heterophylla*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Limnophila indica*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Limnophila racemosa*	NA
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Limnophila rugosa*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Lindernia crustacea*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Mazus japonicus*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Striga euphrasioides*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Veronica anagallis-aquatica*	LC*
Tracheophyta	Magnoliopsida	Solanales	Convolvulaceae	*Ipomoea aquatica*	LC*
Tracheophyta	Magnoliopsida	Solanales	Convolvulaceae	*Ipomoea carnea*	LC*
Tracheophyta	Magnoliopsida	Solanales	Hydrophyllaceae	*Hydrolea zeylanica*	LC

Section 3

Freshwater ecosystem services and biodiversity values at Nainital, Uttrakhand.

Freshwater ecosystem services and biodiversity values at Nainital, Uttrakhand

Work Package 3 report:
Highland Aquatic Resources Conservation and Sustainable Development (HighARCS)

Dr. Mausumi Pal
Centre For Environmental Management And Participatory Development
Saila Bhawan
Hb-150, Sector-Iii, Salt Lake
Kolkata- 700 106

Dr. Nitai Kundu
Institute Of Environmental Studies And Wetland Management
Dd-24, Salt Lake, Sector-I
Kolkata- 700 064

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1. Introduction

1.1. This report

This project, the Highland Aquatic Resources Conservation and Sustainable Development (HighARCS) primary aim is to complete a detailed multidisciplinary analysis of highland aquatic resources and wise-use options at five sites in Asia (Guangdong, China; Uttrakhand and West Bengal, India; and northern and central Vietnam) through integrated assessments on the livelihoods, biodiversity and ecosystem services and the policy and institutional frameworks at each site. Based on these, an integrated action plans (IAPs) will be developed to address the issues identified through the analysis phase. This report presents the results of Work Package 3 'Ecosystem Services and Biodiversity Values' for the field site in Uttarakhand, India, which incorporates Nainital on Nainital Lake, Pandeygaon near Bhimtal Lake and Chanaoti near Naukuchiatal Lake (Figures 1 to 3).

Biological diversity, or biodiversity, is defined by the United Nations Convention on Biological Diversity (1992) as '…the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems". It is from biodiversity (species and ecosystems) that humanity gains vast amounts resources and services for free, such as food, clean water, pollination of crops, recreation and climate control. These services are felt at a multitude of scales from the sites scale (e.g. communities), to national, continental and global. However, through development we often alter these ecosystems, which in turn impact the services we receive from them.

This project is focusing on the biodiversity and ecosystem services provided by freshwater systems at the site scale. If we are to propose actions with the aim of sustainable or wise use of freshwater resources we need to understand what biodiversity is present and how any potential actions may impact the ecosystems and the services they provide. This report provides this information, and will guide the development of the Integrated Action Plan (IAP) for the project site in Uttarakhand and ensure that any proposed actions do have a negative impact upon biodiversity or ecosystem services.

1.2. Background of the Uttarakhand site

The central Himalaya forms one of the important watersheds for the Indo-Gangetic region having innumerable natural rivers, streams and lakes. In this region the majority of the lakes are located in the lower elevations with a few high altitude lakes. Many of these lakes are found within the Kumaon Range of the Himalaya, which is the part of the Himalaya in the Uttarakhand (India) districts of Nainital, Almorah and Pithoragarh. The three lakes used as sites for this project are found within Nainital which lies in a valley of the Gagar range running east to west, bounded to the north by the China Peak rising to a height of 2,611.61 m. Geographically the district is divided into two zones; Hilly and Bhabhar (foothills). The hilly region in the outer Himalayas is known to geologists as krol which is a group of rocks comprising slates, marls, sandstones, limestones and dolomites with a few small dykes, and is the dominant formation of the lake's surroundings. The highest peak of the district, Baudhansthali standing at 2,623 m high, is near Binayak which adjoins Nainital town. This hilly region of the district has many lakes, the larger ones being Bhimtal, Sattal, Naukuchiatal, Khurpatal, Nainital, Malwatal, Harishtal and

Lokhamtal. The foothill area of the district is known as Bhabhar, which is derived from a tall grass that grows in this zone. The underground water levels are very deep in this region and rivers often run underground. The Kosi River is the main river of the district. The hills are unstable and many landslides have occurred causing damage to infrastructure in the past. Construction is now prohibited in most of the hills however, unauthorized commercial and domestic construction is undertaken which is damaging to the natural drainage system as well as the stability of the slopes.

For this project the Uttarakhand field site consists of three lakes; Nainital, Bhimtal and Naukuchiatal. All these lakes, and in particular Nainital, attract huge numbers of tourists due to their high aesthetic value and proximity to large population centres. Nainital District is situated 34 km from Kathgodam, which is known as the gateway of the Kumaon Himlaya and is the terminus of the north eastern railway. Major Indian cities are also within a day's travel, including Delhi which is also only 304 km away, Dehradun is 360 km and Lucknow is 388 km away. Figure 1 shows the location of the sites within India. While tourism is the major industry of the region there is lack of employment opportunities outside of tourism, which has led to imbalanced development and huge impacts to the aquatic systems. However, the regions tourism (and the income it brings) depends upon the lakes, and there is a great need to understand how tourism is impacting the supply of ecosystem services, including those that support the livelihoods of poorest and vulnerable groups. The different ecosystem services provided by these highland lakes include the provision of freshwater and food, they also help regulating local climate, and flooding and support water purification, sediment retention and nutrient cycling and contributing to cultural life including spiritual, recreational, aesthetic and educational values.

For a more detailed account of each site (lake) please see section 2 (site maps). Also please read the Work Package 1 report 'Uttarakhand: Situation Analysis Report' (Kundu, Pal and Jutta 2010) available on the HighARCS website (www.higharcs.org).

2. Site maps

Maps of the sites are important as they allow the results of this Work Package to be put into a geographic context. They will not only allow detailed information to be presented in an easy to understand format, but they will also be key in developing the IAP and identifying any potential indicators and monitoring plans. The maps of the site below were produced by initially digitizing satellite imagery using ESRI Arc Geographic Information Software (GIS) by IUCN. Then through a mapping workshop held on 23-24 August, 2011 at the South China Agricultural University, Guangzhou, China the maps were reviewed, edited and land classifications were identified by CEMPD and IESWM staff based on their knowledge and field observations taken while at the site.

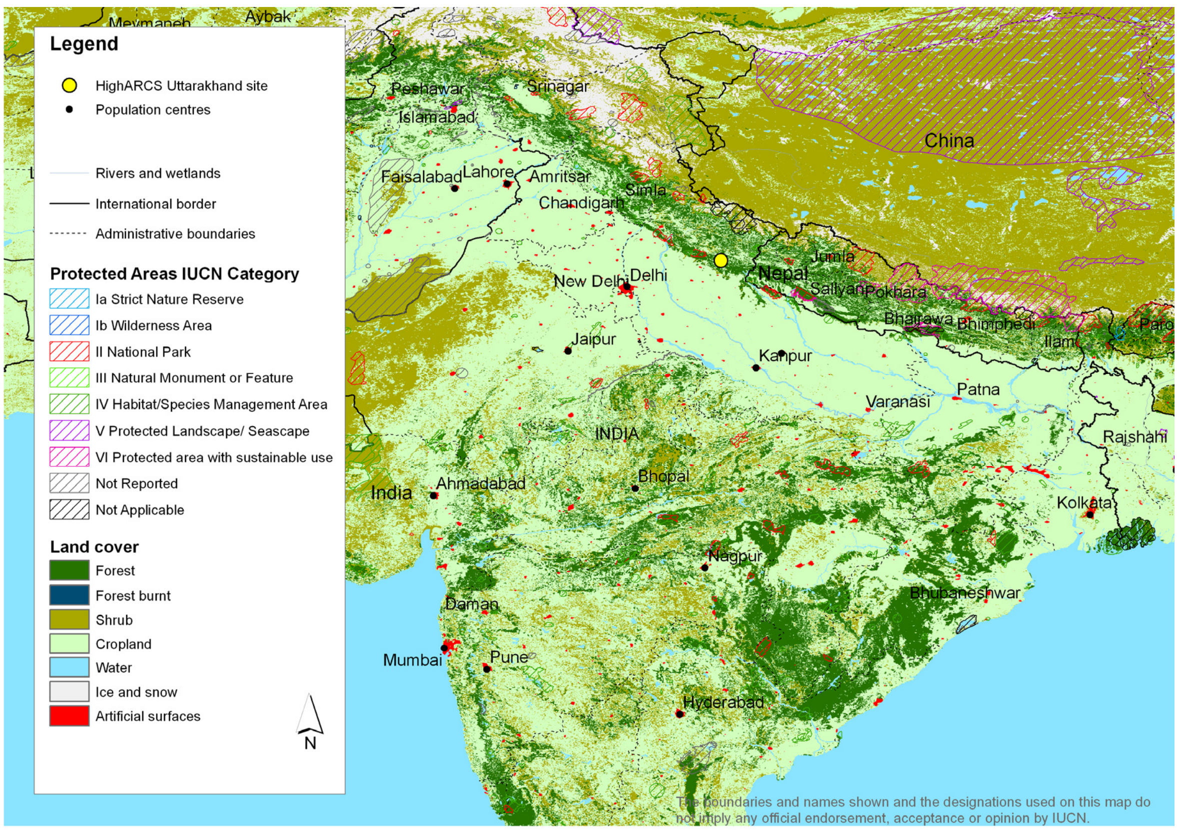

Figure 1. Map showing the location of the Uttarakhand HighARCS site within India.

Figure 1 shows the location of the HighARCS site within India. The site is situated within Nainital District of the northern Indian state of Uttarakhand (formerly Uttaranchal). This is a mountainous state situated within the Himalayas, and its glaciers are the source of the Ganges River. Over 60% of the state is still forested even though much deforestation occurred particularly during colonial times. Nainital District with over 100 lakes is known as the Lake District and boasts of some of the most scenic vistas in India, making it a popular destination for tourists. Nainital District is positioned close to many large population centres that provide the large numbers of tourists that visit the area. Delhi is situated 300 km to the southwest of Nainital, Dehradun is 360 km to the northwest, and Lucknow is 388 km to the south.

Nainital is situated at a distance of 34 km from Kathgodam, which is the gateway of Kumaon and the terminus of north eastern railway, 40 km from Haldwani which is known as the entry point to Nainital.

Figure 2 shows the wider catchment that the sites are a part of. The purpose of the catchment map is to understand the connectivity of the freshwater system (and therefore ecosystem services) beyond the site scale. This will ensure that any recommendations made in the IAP can be viewed at more than just the site scale, as we need to make sure that they do not have negative implications for people or biodiversity downstream. The sites are located in the upper catchment of the Gola River in the Himalayas. The Gola River rises in the Himalaya region from the lakes and springs of the Nainital Lake District. It flows for about 500km, flowing down past the town of Haldwini on to the Gangetic Plain. Once past Haldwini the river runs through dense agricultural and urban areas before joining the Ramanga River, itself a tributary of the Ganges. The Gola River has been severely affected by increased sedimentation and reduced flows due to deforestation within its sub-catchments, which has had serious impacts to communities water supplies (Haigh *et al.* 1990, Valdiya and Bartarya 1991). Bhimtal Lake, which is dammed, is used to provide water to the Gola River in the summer, supplying Haldwani with drinking and irrigation water.

Lake Nainital with tourist boats © Henning Schroll.

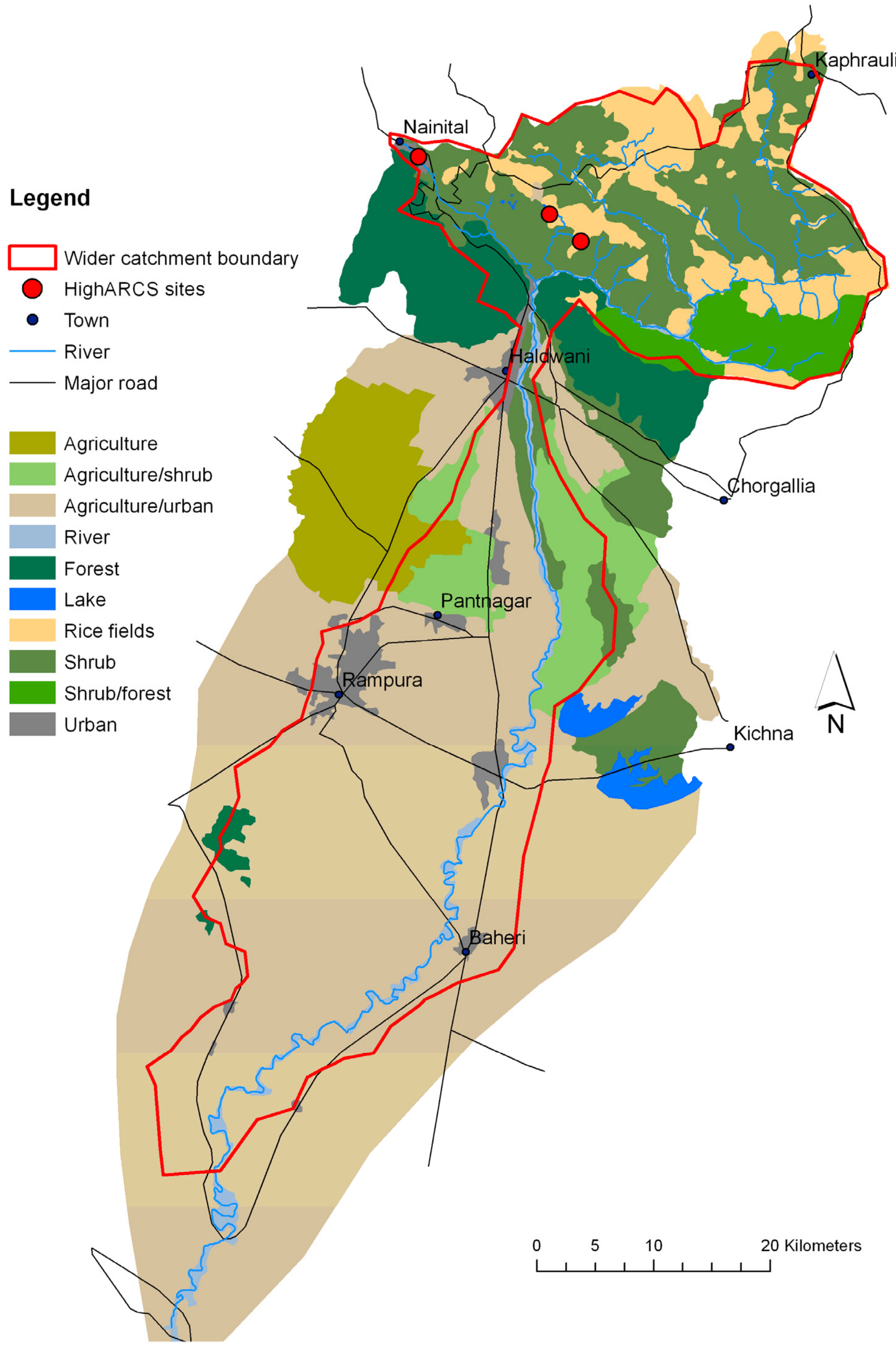

Figure 2. Uttarakhand site wider catchment map

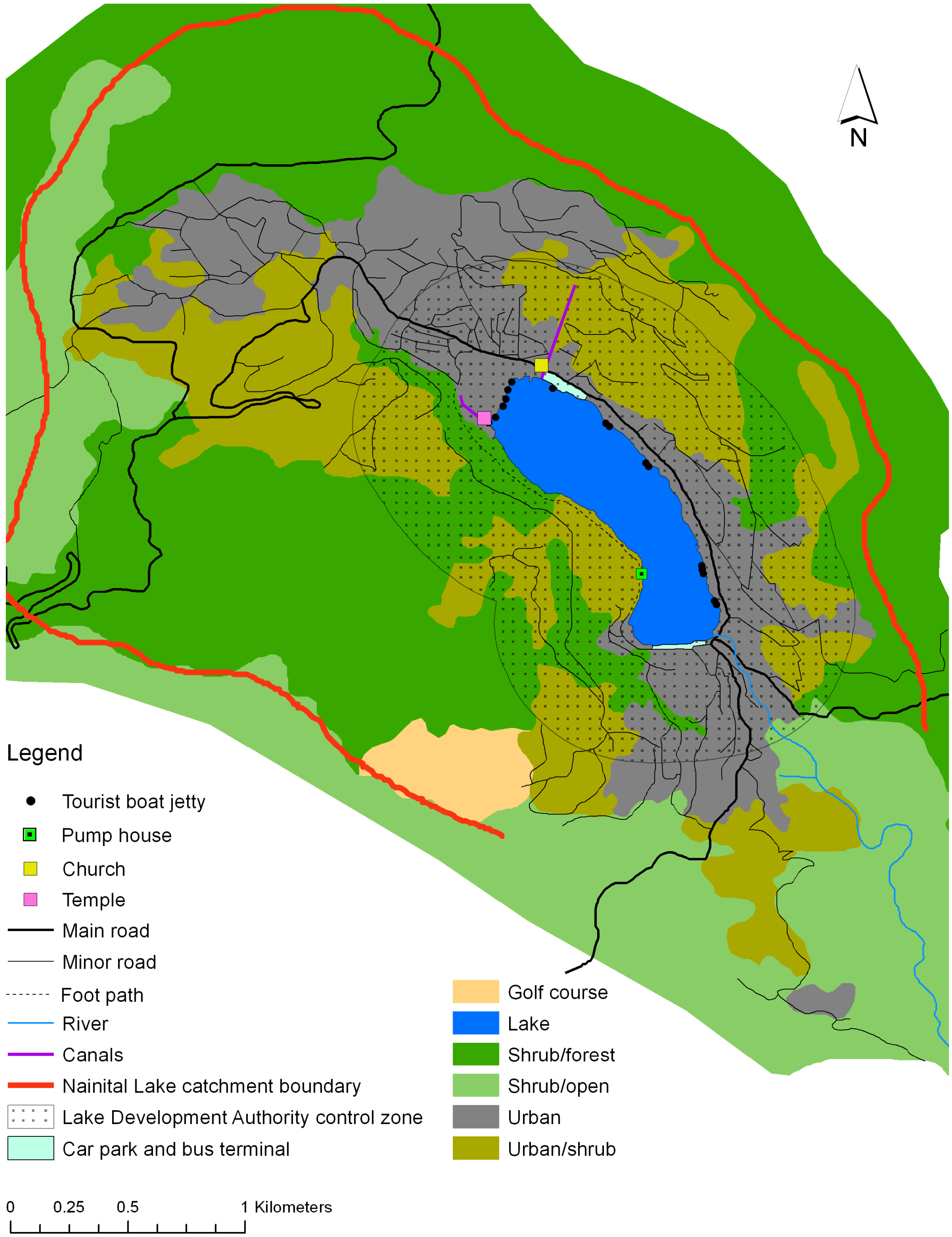

Figure 3. Site map for Nainital Lake.

Nainital Lake (6,000 feet above sea level) is situated in the very upper parts of the river system and has a very small catchment (Figure 3). The south east end of the lake, known as 'Tallital', is a comparatively low area and is the location of the outflow of the river. The northern part is famous as 'Mallital' a comparatively high area, with steep slopes. To the east of the lake remains large areas of forest and shrub, some settlements, and a quiet road/track known as 'Thandi Sadak', The western and northern parts of the lake catchment are more developed with relatively dense urban areas spreading up the hill slopes with hotels and guesthouses close to the lake shore, only the very upper catchment areas are forested/shrub. The shoreline along these areas of the lake is fenced by steel fence. There are also dense settlement areas to the south of the lake. In the far south-western segment of Nainital Lake catchment there is a golf course. It should be noted that there is little to no agriculture in within the catchment of the lake. The Maa Naina Devi Mandir, is an important religious temple and popular tourist attraction and is situated just to the north of the lake on an area called the 'Flats'. The major road through Nainital runs along the eastern side of the lake from Tallital to Mallital, with a bus terminal on southern edge of the lake, and a car park on the, the 'Flats'. There is no river that flows into the lake but there are a number of canals, with the two largest ones in the northern region of the lake. The canals control the water level of the lake but also drain water (not sewage water but the rain water or household use water) from urban areas. The canals are fitted with large filters or nets to catch solid wastes. Nainital Lake attracts many tourists and there are a number of jetties where tourist boats can be hired along the northern and eastern side of the lake.

The lake and adjoining land (known as the Lake Development Control Zone) is controlled by the National Lake Region Special Area Development Authority (NLRSADA), locally known as Lake Development Authority (LDA). The LDA was established under the Act Uttar Pradesh Special Area Development Authority Act, 1986. The aim of the Act is to promote and secure development in a planned manner, and requires the established authority (LDA) to prepare a development plan, which will be implemented after it has been approval by the State Government. The authority (LDA) controls all development within the area of its jurisdiction (in this case the Lake Development Control Zone).

Due to excessive nutrients from pollution from urban areas Nainital Lake is eutrophic, and has a dissolved oxygen content of 4.31 mg/1 (NRC on Coldwater Fisheries 2003), and the lake has seen large fish kills during the winter months due to very low oxygen levels. After a visit to Nainital in 2001 the Ex-Prime Minister, Atal Bihari Vajpayee created the National Lake Conservation Programme (NLCP) which is managed by the Ministry of Environment and Forests and aims to conserve and manage polluted and degraded lakes in urban and semi-urban areas. The first conservation plan developed through the NLCP was for Nainital Lake. One of the management actions was to establish a pump house that generates oxygen and pumps it into the lake. This helps to generate dissolved oxygen in the Lake and maintain the lake biodiversity.

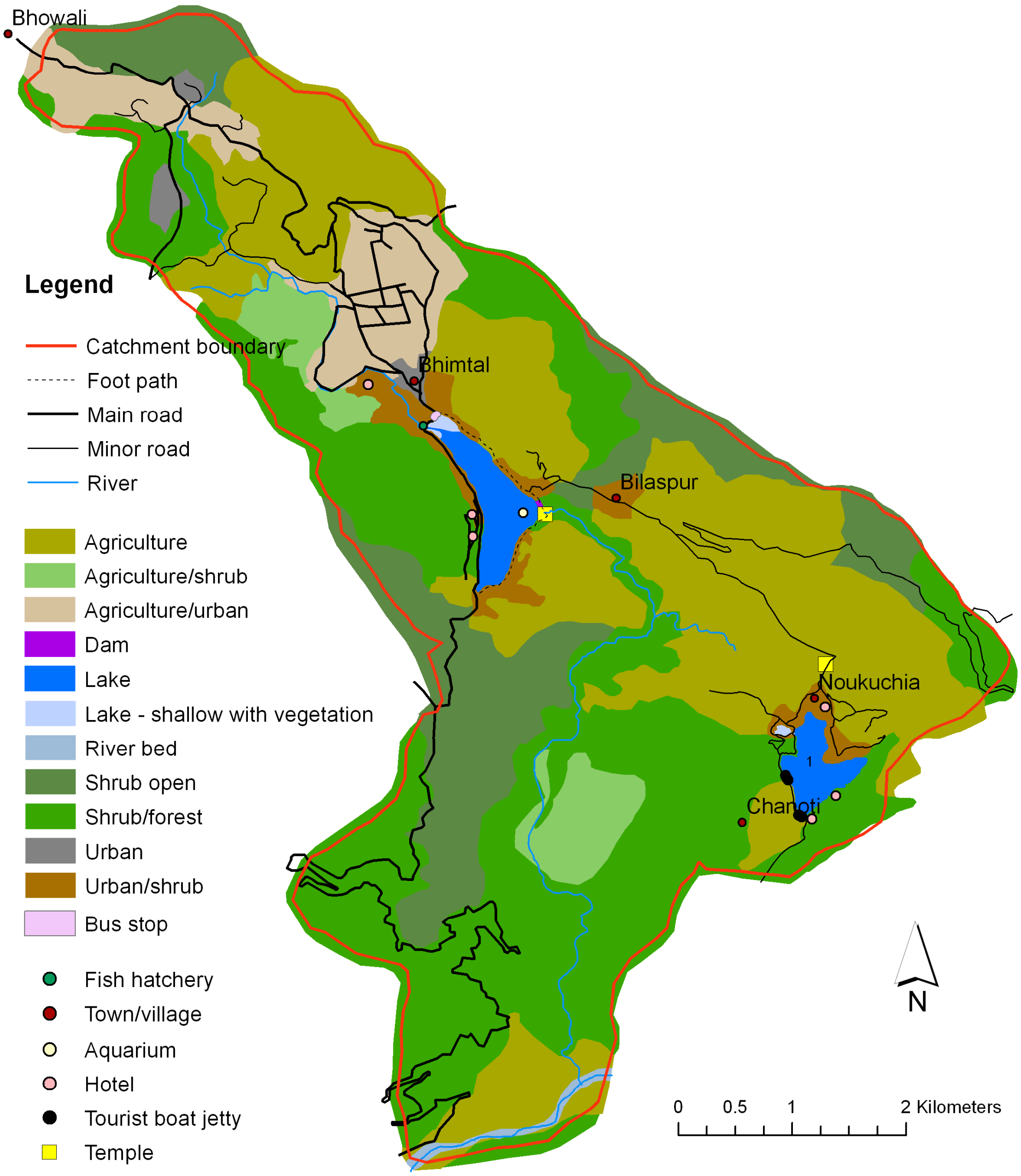

Figure 4. Site map for Bhimtal and Naukuchiatal lakes.

Figure 4 shows Bhimtal and Naukuchiatal lakes, which are 24 km to the southeast of Nainital. The areas surrounding these lakes are much less developed than Nainital. However on the eastern corner of Bhimtal Lake there is a dam (500 ft long and 50 ft high, named Victoria Dam) regulating the flow into the out flowing river which is managed by the Irrigation Department of Bhimtal. The Lake is a natural lake, but the dam was built in 1883 to controls the lake water levels. The inflow river which is a turbulent stream, flows through Bhimtal town and numerous agricultural areas and enters the lake at the northern tip. However this is not the major source of water for Bhimtal Lake, as it receives most of its water from runoff and underground springs and seepage (AHEC 2001). The shores of the lake are steep apart from the northern part that partially dries during dry months and is covered by vegetation. The north, east and southern sections of the lake catchment are mostly occupied by low density settlement with shrub and household agriculture, whereas the western part of the catchment is predominantly shrub and forest. Most of the shore line of the lake is still natural with vegetation, with the dam being the only concreted section. There is growing tourism here, with hotels found on the eastern shore of the lake and in Bhimtal town, there is also an aquarium on the island in the lake which can be visited by boat. At the northern tip of the lake, in an area called Techonia also known as 'Malli', is a bus stop where trekkers follow the footpath (known as 'Thandi Sadak') via the Bhimeshwar Temple and walk to Naukuchiatal. A road with heavy traffic runs along the western side of the lake taking commercial goods to Bhimtal and Bohwali.

Lake vegetation in the shallow northwestern part of Lake Bhimtal © Henning Schroll.

Naukuchiatal Lake (Figure 4) is located 4 km southeast of Bhimtal Lake. It is named after the number of 'points' within its shape 'Nau' (nine) 'kuchia' (points) tal (lake). It is a deep lake (more than 28 meters) that has no inflowing rivers and receives its water from underground springs, seepage and rainfall/runoff. There is a small outflowing stream at the north of the lake and the surrounding land is steep with trees and vegetation very close to the lake. The eastern and western areas of land surrounding the lake are the natural vegetation of forest and shrub, whereas the northern and southern areas are mostly agricultural with some settlements, including Chanoti Village. To the northwestern edge of the lake is an area of shallow water known as the 'Lotus Pond' as it is covered with lotus flowers, which is annexed from the lake by a divider only. The lake shoreline is all natural with vegetation and no concrete, although there is a paved road running along the western edge of the lake. As with Bhimtal, tourism is present but not at the same levels as Nainital, there are hotels located on the southern and northern sections of the lake where there are also jetty's with tour boats for hire.

Lake Naukuchiatal © Henning Schroll

3. Biodiversity at the Uttarakhand sites

3.1. Taxonomic groups chosen

If we are ensure that aquatic resources are to be sustainably used and conserved, we need to know what aquatic biodiversity is present at the sites and what their conservation status is. However, it is not possible to identify all aquatic biodiversity at the sites due to restricted time, money and scientific expertise. Therefore taxonomic groups to be researched at the site have been selected based on the availability of resources (time and financial), expertise and existing data, on the direct utilization of species by communities and on the use of species as indicators to monitor potential actions put in place through the IAP.

There is limited utilization of aquatic products from the sites. The majority of the population surrounding the lakes are vegetarian, therefore the only fishes harvested are eaten by tourists. Plant harvesting for medicinal purposes is not permitted by the Forest Department of Uttarakhand. Available information on aquatic biodiversity at the sites is very good for fishes, but less so for other groups. For use as indicators of water quality (which is the major threat to ecosystem services at the sites – section 4 Threat Analysis) the monitoring of toxic contamination, bio accumulation and fluctuating populations and/or growth of certain species of fishes, molluscs, and plants could be used. As an indicator of overharvesting monitoring certain fish species populations would be best.

Therefore the taxonomic groups selected to research for the Uttarakhand sites are fishes, molluscs, and plants.

3.2. Conservation status of biodiversity – IUCN Red List assessments

There are several methods of determining species conservation status and the most commonly used tool is the IUCN Red List Categories and Criteria (IUCN 2001), which allows consistency in approach across different taxonomic groups (a summary of the Red List criteria can be found in Annex I). It helps in determining the relative risk of extinction at a global scale and provides the basis for understanding if a species is Extinct, threatened (Critically Endangered, Endangered or Vulnerable), Near Threatened, of Least Concern, or lacking sufficient basic data for assessment (Data Deficient) (See Figure 5). The IUCN Red List of Threatened Species™ publishes the results of the global assessments (www.iucnredlist.org). The IUCN Red List also provides basic information on species taxonomy, distributions, habitat and ecology, threats, population trends, use and trade, livelihood information, ecosystem services provided, and research and conservation priorities.

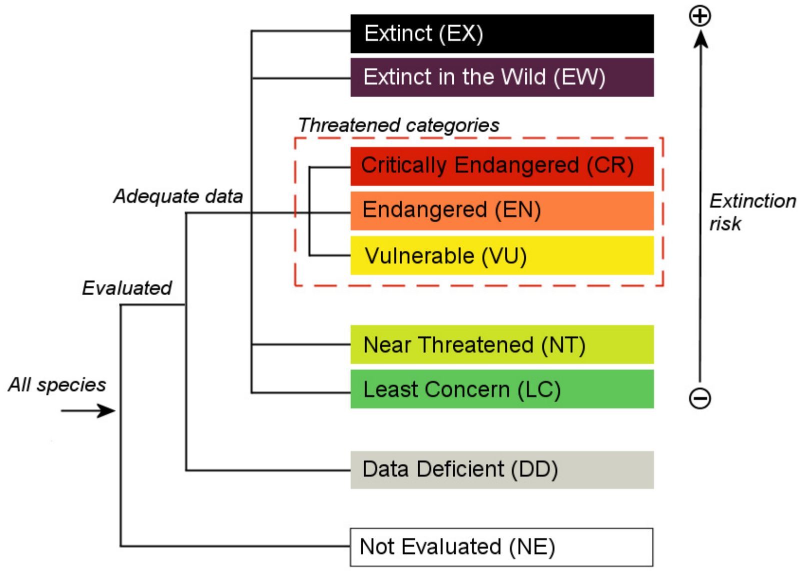

Figure 5. IUCN Red List Categories at a global level.

Biodiversity experts from CEMPD and IESWM were trained at a workshop (06-09 June 2009, Kolkata, India) in the use of the IUCN Species Information Service (SIS – the Red List species database), application of the IUCN Red List Categories and Criteria (IUCN 2001) (see Annex 1 for the Red List Criteria), and Geographic Information Systems (GIS) for digitally mapping species distributions. Following the training workshop, CEMPD and IESWM experts collated native species lists of freshwater fishes, dragonflies and damselflies (odonates), freshwater molluscs and aquatic plants for the wider catchment (see Figure 2), and input within the SIS, all available information on each species. The required data fields (with standard classification schemes) within SIS are species taxonomy, distribution, habitat and ecology, threats, population trends, use and trade, and research and conservation priorities, Red List Category and rationale. These species were then reviewed at a second workshop (22-26 March 2010, Kolkata, India) and via email communications with other species experts.

While these species are not all found at the site, it will allow the actions proposed through the IAP to take into consideration any globally threatened species within the wider catchment if necessary. It will also allow for all the species identified at the site, to be put into a global conservation context. For example a species may be stable and numerous at the site with no known threats and perceived locally as not being of conservation concern, but at a global scale the species may be threatened to impacts elsewhere within the species range, this would make the population at the site of high conservation concern. Alternatively, global conservation status is not the only aspect to identify important species at the site. A species may be of Least Concern globally but may be undergoing severe declines at the site and may also be of economic and livelihood concern and would therefore potentially qualify as a species to be incorporated into the IAP.

A total of 91 species of fish, 56 molluscs and 62 odonates have been identified and assessed for the wider catchment, a list of these species with their IUCN Red List Category can be found in Annex II.

Unfortunately due to the lack of reliable location data, it was not possible to identify the aquatic plant species from the wider catchment, however 185 species of aquatic plants from selected plant families have been assessed from the wider Ganges/Brahmaputra basins and the species that are found at the sites can be linked to these assessments, these species can also be found in Annex II and none of these species are globally threatened. An extract of the globally threatened animal species can be found in Table 1. All four of these threatened species are fishes. *Clarias magur* (Wagur) is an Endangered catfish that is distributed in the Ganga and Brahmaputra river basins in northern and northeastern India, Nepal, Bhutan and Bangladesh. It is highly threatened by exploitation, threats to breeding grounds due to wetland conversion and pesticides in paddy fields, and from introduction of the Thai magur (*Clarias gariepinus*). Population declines of more than 50% in the last few years and predicted decline at the same or slightly higher rate throughout the species range makes it qualify for the Endangered category (Vishwanath 2010). *Puntius chelynoides* (Dark Mahseer) is known from the head water drainages of the Ganges. The exact distribution and population status of the species is not known but it is reported to be locally extinct from Assam, and is a very rare species elsewhere. While the range is wide, the area of occupancy is very small, estimated to be less than 2,000 km^2. It is assessed as Vulnerable on the grounds that the species is restricted to only headwaters and currently known from five fragmented populations and some populations in Kumaon and Assam have gone locally extinct due to introduced Mahseer species (Dahanukar 2010). *Schizothorax richardsonii* is widely distributed along the Himalayan foothills and previous studies have indicated that it is abundantly and commonly found, however recent observations over the last 5 to 10 years indicate drastic declines in many areas of its range due to introduction of exotics, damming and overfishing. While in some areas the declines are more than 90%, the overall reduction is inferred to be less than 50% with similar rates predicted in the future. The species is therefore assessed as Vulnerable. However, there is a strong belief that if alien species introductions are carried out throughout its range, this species may completely be displaced by exotic salmonids (Vishwanath 2010). *Tor putitora* (golden mahseer) has been reported from across the Himalayan region and elsewhere in south and southeast Asia, however it is a heavily fished species, and it is inferred that its population has declined by between 40-50% over the last ten years and is fast approaching extinction in the streams and lakes of northern India. The stress on the population is not only due to its over exploitation, but also due to the rise in developmental activities, especially the growing number of hydroelectric and irrigation projects which have fragmented and deteriorated its natural habitat. At present, attempts to culture and conserve *Tor* spp. have been initiated in most trans-Himalayan countries to compensate for the decline, including in Nainital Lake (Jha and Rayamajhi 2009).

Table 1. Globally threatened species (those listed as Critically Endangered, Endangered and Vulnerable) found within the wider catchment.

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Family	Binomial	IUCN Red List Category	IUCN Red List Criteria
CLARIIDAE	*Clarias magur*	EN	A3cde+4acde
CYPRINIDAE	*Puntius chelynoides*	VU	B2ab(i,ii,iii,iv,v)
CYPRINIDAE	*Schizothorax richardsonii*	VU	A2acd+3cde+4acde
CYPRINIDAE	*Tor putitora*	EN	A4acde

3.3. Literature review

To identify which species from the selected taxonomic groups are present at the sites, a literature review was undertaken. A wide variety of literature was used including data from previous field survey, published books and journals and records obtained from various offices and organizations, these sources are listed in table 2.

Table 2. Reference list used in the literature review.

Reference number	Reference
1	Gupta, P.K. and Bhagat, P. (Department of Zoology, Kumaun University, Nainital). 2004. Assemblage of Zooplankton Community in lake Naukuchiatal, a Subtropical Lake of the Kumaun Himalaya, India. *Environmental Biology and Conservation* 9:29-42
2	Gupta, P.K. and Pant, M.C. 1986. Analysis of the Inshore Macrozoobenthic Community in Lake Nainital, U.P., India. *International Review of Hydrobiology*. 71(1):115-125
3	Vass, K.K. and Raina, H.S. 2002. *Highland Fisheries & Aquatic Resource Management*. National Research Centre on Coldwater Fisheries (ICAR), Bhimtal, India.
4	Mahanta, P.C., Sharma, D., Vishwanath, W., Anganthoibi, N. *Coldwater Fishes of India. An Atlas*. Directorate of Coldwater Fisheries Research
5	Gupta P. K. 1981. *An Ecological Study of Macro benthic Communities in Kumaon Lake*. PhD Thesis. Department of Zoology, Kumaun University, Nainital
6	Vass, K.K., Raina, H.S., Joshi, C.B., Basade, Y., Nayak, A.K., and Haldar, R.S. 2003. *Ecological modeling & Fishery Enhancement in Lakes/wetlands of Himalayan/ Sub- Himalayan region*. National Research Center on Coldwater Fisheries, Nainital, Uttarakhand.
7	Informal grey literature from DPR of Bhimtal and Naukuchiatal
8	Vass, K.K., Raina, H.S. and Haldar, R.S. 2004. Fishery Restoration in Nainital Lake. *Bulletin No. 9*. National Research Center on Coldwater Fisheries (ICAR).
9	Talwar, P.K. and Jhingran, A.G. 1991. *Inland fishes of India and adjacent countries* (Vol. I & II). Oxford & IBH Pub. New Delhi. Pp 1097
10	Subbarao, N.V., 1989. *Handbook Freshwater Molluscs of India, Fauna of West Bengal State (Part-9 Mollusca).* Fauna Series 3. Zoological Survey India.
11	Communications with the Directorate of Cold Water Fisheries Research
12	Subba Rao, N.V. 1989. Handbook Freshwater Molluscs of India. Fauna of Meghalaya (Part-8, Mollusca). State Fauna Series 4, Zoological Survey India.
13	Subba Rao, N.V. 1989. Handbook Freshwater Molluscs of India. Fauna of Manipur (Part-3, Invertebrates). State Fauna Series 10. Zoological Survey India.
14	Assemblage of Aquatic Plant Community in the Kumaon Lakes, subtropical Lakes, Uttarakhand, India

3.3.1. Fishes

Forty two species of freshwater fish species have been identified from the lakes, 28 from Nainital and 27 from Bhimtal and Naukuchiatal (Table 3). In the three field sites the dominant species are carps and mahseers. However many of these including *Cyprinus carpio*, *Ctenopharyngodon idella, Gibelion catla* and *Hypophthalmichthys molitrix* are not native to the lake systems but are important economically as food fish. After eutrophication of the lakes fish stocks severley declined with the mahseers (*Tor* spp.) and other species becoming extirpated. After conservation measures improved water quality Govind Ballabh Pantnagar University of Agriculture and Technology (for Nainital) and the Directorate of

Coldwater Fisheries Research (DCRF) (in Bhimtal and Naukuchiatal) have released mahseer fish fingerlings (*Tor tor* and *Tor putitora*) and are continuing conservation stocking of the lakes.

In Nainital the common indigenous species are the barbs (*Puntius* species), Rohu (*Labeo rohita*) and Barna baril (*Barilius barna*), all except the barbs are of some economic importance. There are however six introduced species in the lake all of which apart from the crusian carp (*Carassius carassius*) are abundant. The mosquito fish (*Gambusia affinis*) was introduced to control mosquito larvae and the silver carp (*Hypophthalmichthys molitrix*) was introduced to help control algal blooms. Catla are native to India, but are primarily riverine species but have been widely stocked in lakes as they are an important food fish. In Bhimtal and Naukuchiatal, the common native species are Rohu and Mrigala carp (*Cirrhinus mrigala*) which is harvested for food. Those native species that are relatively rare include the Chaguni (Chagunius chagunio), orange fish (Labeo calbasu) and spiny eel (Mastacembelus armatus) all of which have a high economic importance. The introduced species are the same as in Nainital apart from the addition of grass carp (*Ctenopharyngodon idella*) and the exclusion of crusian carp (*Carassius carassius*). There are two species that are globally threatened according to the IUCN Red List, the snow trout *Schizothorax richardsonii* which is assessed as Vulnerable and *Tor putitora*, Endangered, both are recorded from all three lakes (see section 3.2 for more information on these species).

Table 3. Freshwater fishes present with the sites

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Species binomial	Common name	Lakes present	IUCN Red List Category	Economic importance	Population trend at site	Reference
Acanthocobitis botia		Nainital	LC			8 *(as Nemacheilus botia)*
Barilius barila		Nainital	LC			8
Barilius barna	Barna baril	Nainital	LC		Common	Field visit
Barilius bendelisis		Nainital; Bhimtal; Naukuchiatal	LC			8
Barilius vagra		Bhimtal; Naukuchiatal	LC			6
Carassius carassius	Crusian carp	Nainital	Introduced	Negligible	Occasionally found	9
Chagunius chagunio	Chaguni	Bhimtal; Naukuchiatal	LC	High	Occasionally found	9
Channa gachua		Bhimtal; Naukuchiatal	LC			6
Channa marulius		Bhimtal; Naukuchiatal	LC			6
Channa punctata		Bhimtal; Naukuchiatal	LC			6(as *Channa punctatus*)
Channa striata		Bhimtal; Naukuchiatal	LC			9 (as *Channa striatus*)
Cirrhinus mrigala	Mrigala	Bhimtal;	LC	Food fish	Common	9

Species binomial	Common name	Lakes present	IUCN Red List Category	Economic importance	Population trend at site	Reference
	carp	Naukuchiatal				
Crossocheilus latius		Nainital	LC			8
Ctenopharyngodon idella	Grass carp	Bhimtal; Naukuchiatal	Introduced			6 *(as Ctenopharyngodon idellus)*
Cyprinus caprio	Common carp	Nainital; Bhimtal; Naukuchiatal	Introduced	Dominant in fish catches	Abundant	11
Gambusia affinis	Mosquito fish	Nainital; Bhimtal; Naukuchiatal	Introduced		Abundant	9
Garra gotyla	Sueku head	Nainital	LC	High	Occasionally found	9
Garra lamta		Nainital	LC			5
Gibelion catla	Catla	Nainital; Bhimtal; Naukuchiatal	LC		Abundant	5 (as *Catla catla*)
Hypophthalmichthys molitrix	Silver carp	Nainital; Bhimtal; Naukuchiatal	Introduced		Abundant	5
Labeo bata		Bhimtal; Naukuchiatal	LC			6
Labeo calbasu	Orange fish labeo	Bhimtal; Naukuchiatal	LC	Food fish	Occasionally found	9
Bangana dero		Nainital	LC		unknown	8 (as *Labeo dero*)
Labeo dyocheilus		Nainital	LC			8
Labeo rohita	Rohu	Nainital; Bhimtal; Naukuchiatal	LC	High value food fish	Abundant	9
Mastacembelus armatus	Spiny eel	Bhimtal; Naukuchiatal	LC	High value food fish	Occasionally found	9
Paraschistura montana		Nainital; Bhimtal; Naukuchiatal	Not assessed			8 (as *Nemacheilus montanus*)
Puntius conchonius	Rosy barb	Nainital; Bhimtal; Naukuchiatal	LC		Common	9
Puntius sophore		Bhimtal; Naukuchiatal	LC			6
Puntius ticto	Fine fin barb/ ticto barb	Nainital; Bhimtal; Naukuchiatal	LC		Common	9
Raiamas bola		Bhimtal; Naukuchiatal	LC			6 (as *Bailius bola*)
Raiamas bola		Nainital;	LC			8

Species binomial	Common name	Lakes present	IUCN Red List Category	Economic importance	Population trend at site	Reference
		Bhimtal; Naukuchiatal				
Schistura beavani		Nainital; Bhimtal; Naukuchiatal	LC			8 *(as Nemacheilus beavani)*
Schistura corica		Nainital	LC			8 *(as Nemacheilus corica)*
Schistura multifasciata		Nainital	LC			8 *(as Nemacheilus multifasciatus)*
Schistura rupecula		Nainital	LC			8 *(as Nemacheilus rupecola)*
Schizothorax kumaonensis		Nainital	DD	Important for angling		8
Schizothorax plagiostomus	Hill trout	Nainital	Not assessed	Important for angling		11 (as *Schizothorax plagiostomus* and its synonym *Schizothorax sinuatus*).
Schizothorax richardsonii	Snow trout	Nainital; Bhimtal; Naukuchiatal	VU	Important for angling		8
Tor putitora	Golden Mahseer	Nainital; Bhimtal; Naukuchiatal	EN	Food fish and angling	Abundant	9
Tor tor	Mahseer	Nainital; Bhimtal; Naukuchiatal	NT	Food fish and angling	Abundant	9

3.3.2. Molluscs

Nine species of molluscs, six gastropods and 3 bivalves, are identified from Nainital Lake through the literature review in the shallow water near the shore in Nainital (Table 4). All the species are common and widespread, and *Lymnaea acuminata*, *Lymnaea luteola*, *Indoplanorbis exustus* and *Parreysia olivaria* all can occur in heavily polluted waters. Lymnaea sp., Gyraulus convexiusculus, viviparus bengalensis or Bellamya bengalensis are the important species of molluscs in Nainital and in Bhimtal and Naukuchiatal, mainly Lymnaea sp. are found (Table 5). Lymnaea acuminate and Gyraulus convexiusculus are declining in the lakes as their eggs are eaten by the introduced mosquito fish *Gambusia affinis*.

Table 4. Freshwater mollusc species of Lake Nainital

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Class	Species binomial	IUCN Red List	Economic importance	Population trend at site	Reference

		Category			
Gastropoda	Lymnaea acuminata	LC	None	Declining	12
Gastropoda	Indoplanorbis exustus	LC	None	Unknown	12
Gastropoda	Bellamya bengalensis	LC	None	Unknown	12
Gastropoda	Bellamya dissimilis	LC	None	Unknown	12
Gastropoda	Lymnaea luteola	LC	None	Unknown	12
Gastropoda	Gyraulus convexiusculus	LC	None	Declining	13
Bivalvia	Parreysia caerulea	LC	None	Unknown	13
Bivalvia	Parreysia olivaria	LC	None	Unknown	13
Bivalvia	Sphaerium indicum	LC	None	Unknown	14

Table 5. Freshwater mollusc species of Lake Bhimtal and Naukuchiatal

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Class	Species binomial	IUCN Red List Category	Economic importance	Population trend at site	Reference
Gastropoda	Lymnaea acuminata	LC	None	Unknown	12
Gastropoda	Indoplanorbis exustus	LC	None	Unknown	12

3.3.3. Plants

In Nainital the references for 5 aquatic plant species were found, and the dominant species are *Potamogeton crispus*, *Hydrilla verticillata* and *Persicaria* sp. In Bhimtal, 9 species and in Naukuchiatal 11 species have been identified through the literature. None of the species are of global conservation concern and none of the species are known to be utilised but *Nelumbo nucifera* (lotus flower) is used for decorative purposes.

Table 6. Macrophyte species of lakes Nainital, Bhimtal and Naukuchiatal

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Species binomial	Common name	Lakes present	IUCN Red List	Economic importance	Population trend at site	Reference
Ceratophyllum demersum	Coontail	Naukuchiatal	LC	None	unknown	
Hydrilla verticillata	Indian star grass or water thyme	Nainital; Bhimtal; Naukuchiatal	LC	None	unknown	8
Lemna minor	Common duckweed	Bhimtal	LC	None	unknown	8
Muriophyllum indicum		Bhimtal; Naukuchiatal	LC	None	unknown	
Myriophyllum oliganthum		Bhimtal; Naukuchiatal	LC	None	unknown	8

Species binomial	**Common name**	**Lakes present**	**IUCN Red List**	**Economic importance**	**Population trend at site**	**Reference**
Myriophyllum tuberculatum		Bhimtal; Naukuchiatal	LC	None	unknown	8
Nelumbo nucifera	Lotus flower	Naukuchiatal	Not assessed	None	unknown	
Nymphoides indica	Water snowflake	Naukuchiatal	LC	None	unknown	
Persicaria amphibia	Water knotweed or water smartweed	Bhimtal	LC	None		8 (as *Polygonum amphibium*)
Persicaria glabrum	Dense flower knotweed	Nainital; Bhimtal; Naukuchiatal	LC	None		8 (as Polygonum glabrum)
Persicaria hydropiper		Nainital; Naukuchiatal	LC	None	Unknown	8 (as Polygonum hydropiper)
Persicaria lapathifolia		Bhimtal	LC	None		8 (as Polygonum lanatum)
Potamogeton crispus	Curled pondweed	Nainital; Bhimtal; Naukuchiatal	LC	None	unknown	8
Stuckenia pectinata	Fennel pondweed	Nainital; Naukuchiatal	LC	None	unknown	8 (or Potamogeton pectinatus)

3.4. Indicator species

The major threats to the biodiversity and ecosystem services in the lakes are pollution created by sewage and garbage from nearby hotels, domestic sources and tourists. This has led to algal blooms and a decreasing level of dissolved oxygen in the lakes (see section 4). According to Negi (1998) cold water carps are sensitive to low oxygen concentrations, and have been subjected to mass winter killings in Nainital due to low oxygen levels. Therefore the all species from the cypriniidae family (the carps) would make suitable indicators for the lake conditions. The relevant authorities; Govind Ballabh Pantnagar University of Agriculture and Technology (for Nainital) and the Directorate of Coldwater Fisheries Research (DCRF) (in Bhimtal and Naukuchiatal) who are involved in stocking in the lakes monitor water quality and fish stock levels. This data will be available to us if requested. Other potential indicator species are the bivalves, *Parreysia caerulea*, *Parreysia olivaria* and *Sphaerium indicum* as they are sedentary suspension feeders tissue samples can indicate pollutant levels (e.g. heavy metals) and they are also sensitive to periods of low dissolved oxygen (Grabarkiewicz and Davis 2008, Nedeau *et al.* 2009).

3.5. Field surveys

It has not been necessary for field surveys of aquatic species at the sites to be undertaken as the lists produced through the literature review has been reviewed and confirmed as up to date by the NRC on Coldwater Fisheries (ICAR). In addition from the literature review we have been able to identify suitable potential indicator species to suit the management issues at the sites. Market surveys have not been conducted as so few species are utilized. A local market was visited and it was found that traders did not sell fish caught from the three lakes but rather from a dam at Kichha a nearby town in Nainital district.

3.6. Inclusion of data in online databases

Data collated through this research will be included in two online species databases; the IUCN Red List (www.iucnredlist.org) and Fishbase (www.fishbase.org).

Through Work Package 1 of this project the fish, odontata, molluscs and selected aquatic plant species of the Ganges River basin were assessed against the IUCN Red List categories and criteria and have been published on the Red List website (see section 3.2). Information on the species identified through this workpackage such as new information on species distributions, threats but in particular their utilisation by humans will be added to their Red List assessment and published online with the next IUCN Red List update in 2012. If the information provided is significant it may require the species to be reassessed, changing the species Red List Category.

The information on the fish species utilisation will also be added to the Fishbase online database, under the ‘Human Uses’ tag. For example, the species will be tagged as being ‘Fisheries: minor commercial’ or ‘aquarium: potential’.

4. Threats to biodiversity and ecosystem services

Based on the discussions with local communities, and observations during field work (for this and other workpackages) the major threats to freshwater biodiversity and ecosystem services have been identified and mapped. The three lakes all face increasing pressure from tourism, pollution (increased nutrients) and non-native species which are impacting the lakes ability to support biodiversity and provide the ecosystem services that local communities depend upon. Figures 6 to 10, show the sources of these threats to the site and which areas are being impacted by them.

4.1. Water pollution and eutrophication

Water pollution is the key threat to biodiversity and ecosystem services in both Nainital and Bhimtal lakes. Nainital's population as reported by the Census-2001 was little over 38 thousand, which has since then grown to 44 thousands. It is estimated that this population at least doubles during tourist season (three summer months). In 2003, the tourist population of Nainital was 424,000, which increased to 518,000 by 2005. With increasing numbers of tourists and urban waste making its way into Nainital Lake, the water quality has been deteriorating alarmingly in the past. Nainital is classed as a nutrient rich hyper-eutrophic lake, with very low water transparency, and suffers from frequent blue-green algae blooms (Gupta *et al.* 2007). The key causes of the eutrophication are high levels of nitrogen (and eutrophiocation) from sewerage discharge (Nainital is connected to 62 drains out of which 23 drains directly fall into the lake), surface runoff and leaf litter; and high levels of phosphorous due to anoxic (low oxygen) sediments, excretion from high density of introduced mosquito fish (*Gambusia holbrooki*) and external input from the catchment (Gupta *et al.* 2007). The suspended solids in the water also affect the respiratory processes of fish and make them susceptible to infection of various pathogens. The level of oxygen in the hypolimnic layer (the bottom, colder, stagnant, and constant temperature layer) is now too low (anoxic) to sustain fish, and in winter due to the colder water temperature this layer moves to the surface and causes mass fish mortality (mostly cold water carps – the last major event occurring in 2006). Increasing amounts of sediment entering the lake due to loss of natural vegetation in the catchment, is not only another contributing factor to eutrophication but it is also destroying the cold water carps spawning areas (Negi 1998), and has caused the depth of the lake to decrease from 29m in 1871 to 16m (Pangare *et al.* 2006). Another contributing factor is thought to be the large amounts of tourists that feed the fish in the lake as the visit the 'Maa Nanda Devi Mandir' temple. Inorganic pollution is also a problem with manganese, lead salts, copper cobalt and zinc all polluting the lake. Figure 6 shows a map of Lake Nainital and the major sources of pollution which includes the urban and agricultural areas that drain into the lake (run off, sediment), the canals/sewers (domestic waste) that empty into the lake and the tourist fish feeding areas at the north of the lake.

However some action has been taken and there is now a programme run by the National Lake Region Special Area Development Authority (NLRSADA) to oxygenate the hypolimnic layer of the lake through a hypolimnetic aeration system, with aim of increase fish growth and reducing winter kills. Also in 2007 the National Lake Region Special Area Development Authority (NLRSADA) set up a project called Mission Butterfly, which developed an Integrated Solid Waste Management (ISWM) system for 25 clusters (each consisting approximately 250 families) in Nainital town. They provided blue and green buckets for sewage and garbage disposal, where the green bucket is used for dry wastes and the blue bucket for wet waste. A team set up by NLRSADA segregates the waste in to composing and non-composting parts. The Sewage Treatment Plant (STP) in Narayannagar then takes all the compostable waste, and the dry waste is sent to a recycling plant in Haldwani.

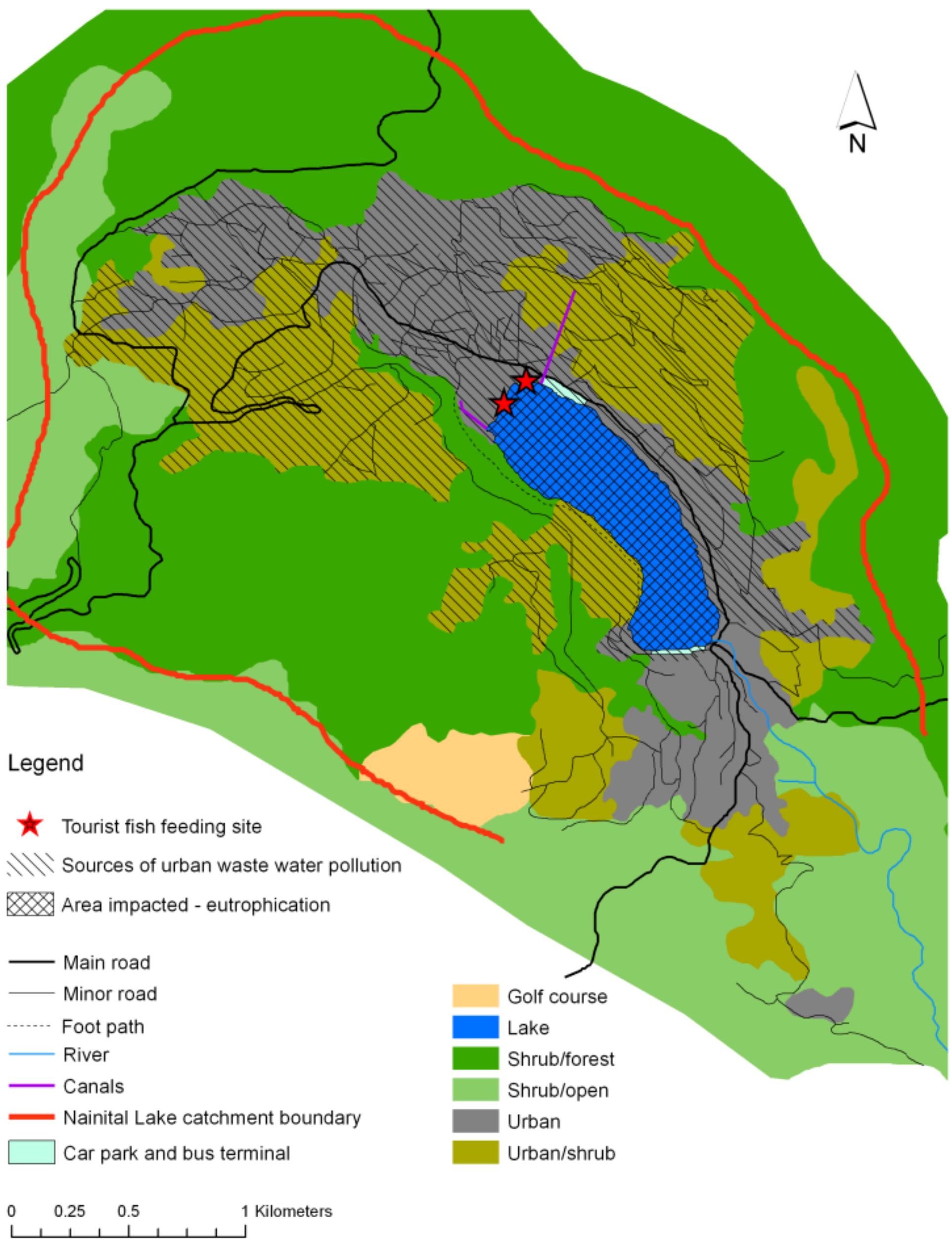

Figure 6. Sources of pollution in Lake Nainital

Pump house for the hypolimnetic aeration system in Nainital Lake © Henning Schroll

Resulting oxygenation of Nainital Lake © Henning Schroll

Bhimtal and Naukuchiatal lakes are classed as mesotrophic (Pangare *et al.* 2006). High rates of sedimentation (Bhimtal with 4.70 mm/yr, and Naukuchiatal with 3.72 mm/yr) have resulted in reduced depth of the lakes (Bhimtal has decreased from 39 m deep in 1871 to 22 m in 1985 Pangare *et al.* 2006), less absorption of heavy metals, leading to their depletion in the bed sediments of the lake. Agricultural runoff and pesticides for agricultural activities (Bhimtal has 64 industrial units and 50 ha of agricultural in its catchment (Pangare *et al.* 2006)) also pollutes the water of Naukuchiatal and Bhimtal as agricultural practices are common there. Bhimtal water is now classified as unfit for human drinking (Pangare *et al.* 2006). Figures 7 and 8 show the areas that are generating the pollution and sediment that are impacting Bhimtal Lake.

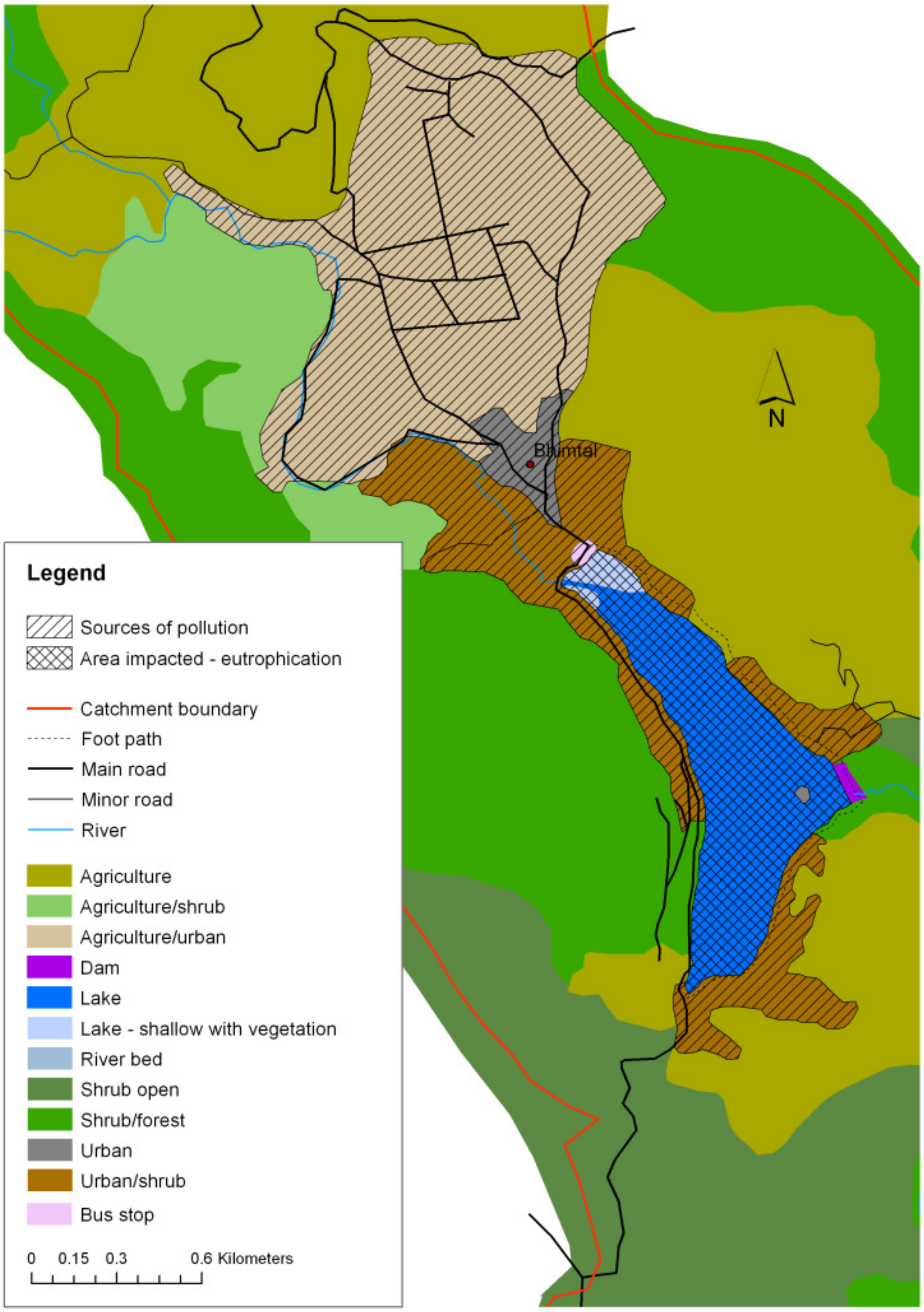

Figure 7. Sources of pollution in Lake Bhimtal

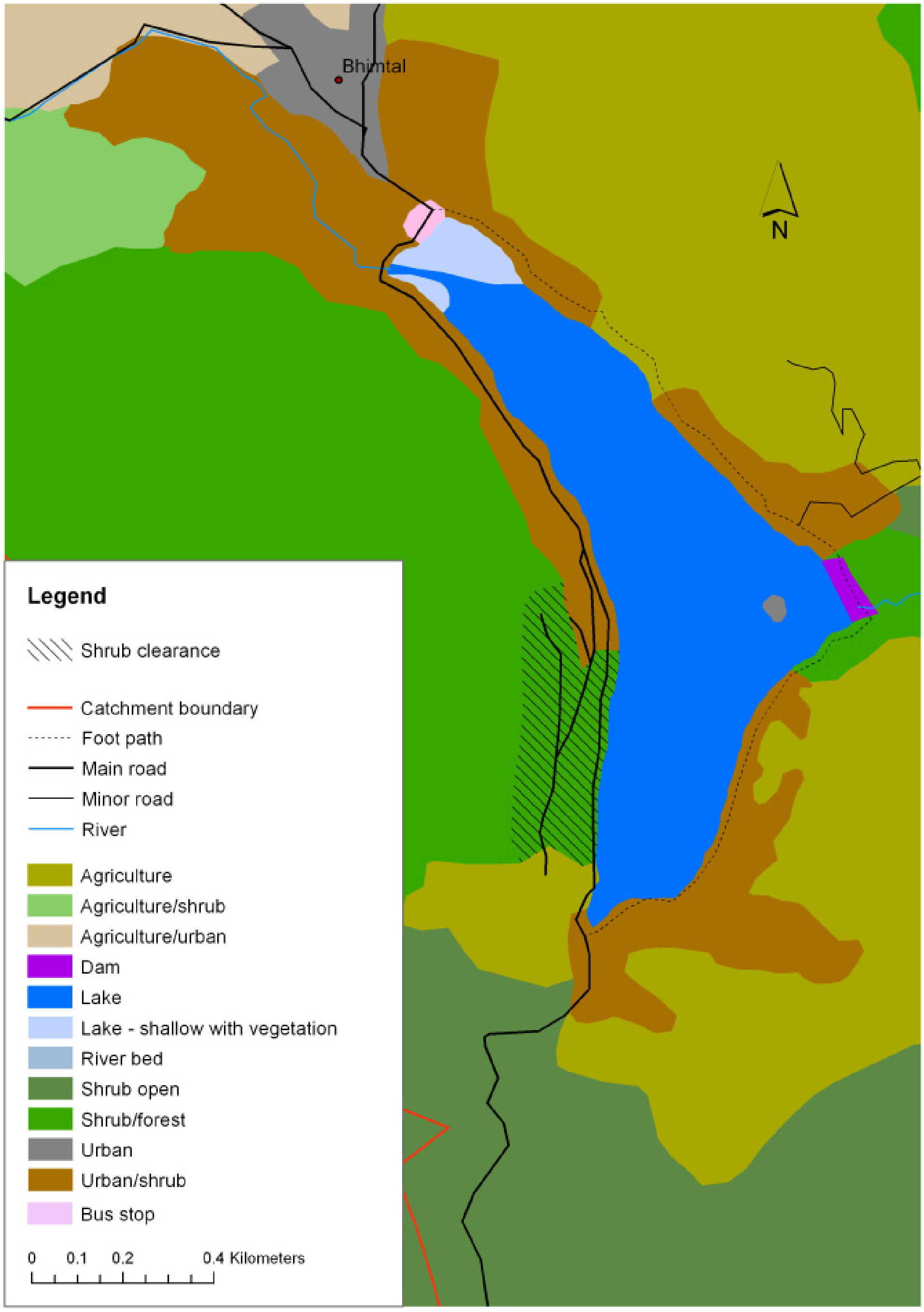

Figure 8. Current shrub clearance around Lake Bhimtal

4.2. Introduced species

All the lakes have non-native fish species in. The introduced fishes including the carps *Hypophthalmichthys molitrix, Carassius carassius, Ctenopharyngodon idella* and *Cyprinus caprio* and the mosquito fish *Gambusia affinis* can all have negative impacts to native species and ecosystems. According to the Invasive Species Specialist Group of the IUCN Species Survival COmmission

Hypophthalmichthys molitrix impacts systems where it is introduced by feeding on plankton that is required by native species including larval fishes and bivalves; *Ctenopharyngodon idella* and *Cyprinus caprio* are known to completely eliminate aquatic plants in introduced habitats altering trophic structure, they also remove spawning substrate, disurb sediment and muddy waters; and *Gambusia affinis* are extremely aggressive and attack other fish, shredding fins and sometimes killing them, they are also increasing the nutrients in the lake due to their large population size and are eating the eggs of native gastropod species. Figure 10 shows in the north-western part of the lake there is a Hatchery of Directorate of Coldwater Fisheries Research (DCRF) but this now mainly performs experiments of different species of native fishes (including mahseer).

Fish cages in Lake Bhimtal © Henning Schroll

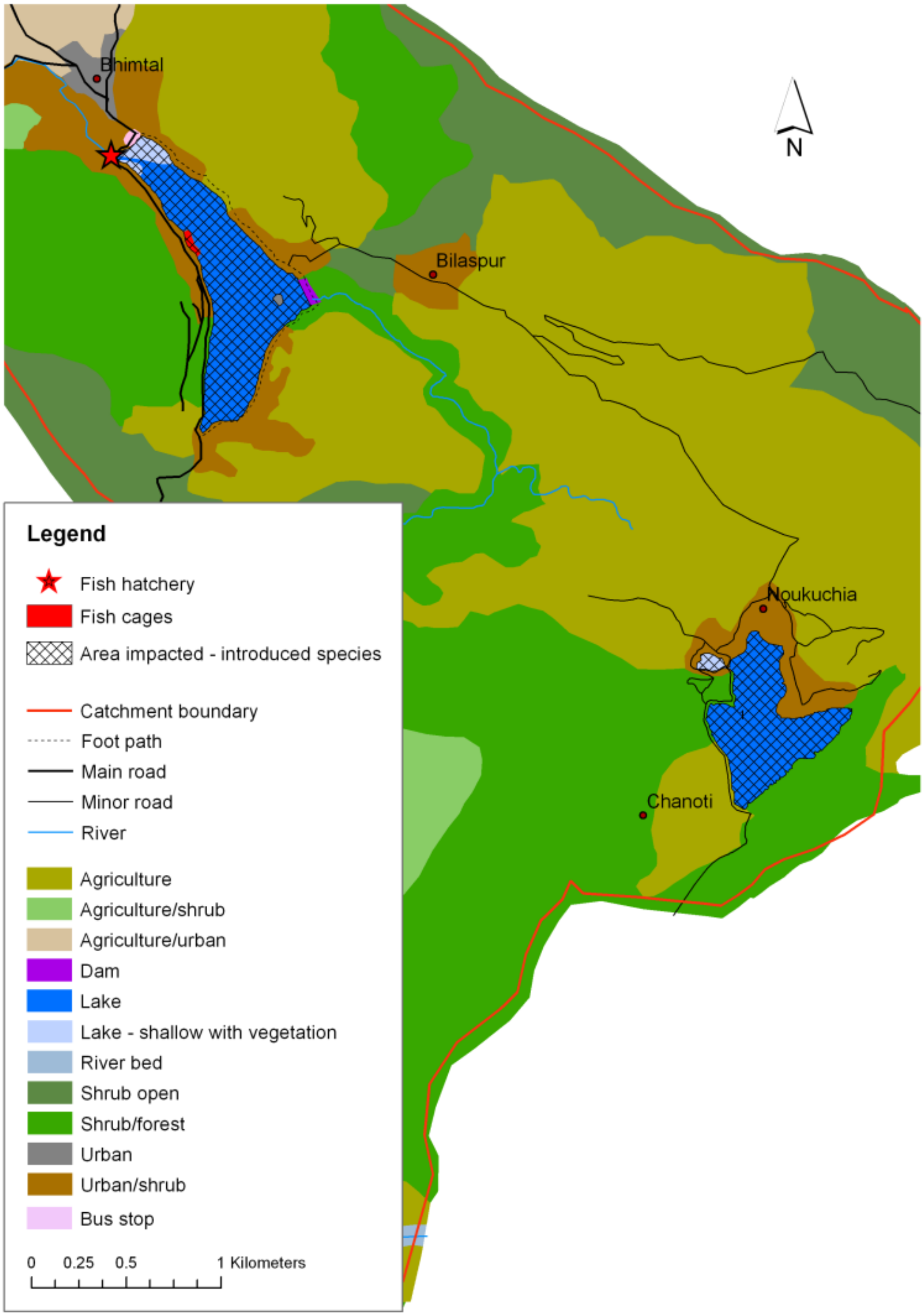

Figure 10. Fish hatchery and cages, and introduced species in lakes Bhimtal and Naukuchiatal

4.3. Litter

Litter is an increasing problem in all the lakes, and is again tied to the increasing numbers of tourists. In Bhimtal the major source of litter is Techonia, 'the bus stop' where people waiting for buses throw litter into the lake and it gathers in the shallow areas (marked as red in Figure 9). Polythene bags are prohibited in Nainital and there are also proposal to ban them in Bhimtal. The tourists who enjoy boating in the lake throw left over edibles and polythene-bags in to the lake even though some bins are present on the lake side. In a bid to reduce litter pollution, residents have now moved to a more modern garbage disposal system. Under the project named 'Mission Butterfly', the sweepers collect waste from each and every household and then directly transfer it to the compost pits where it is converted to manure. In Naukuchiatal there are small amounts of litter around the lake due to fewer tourists.

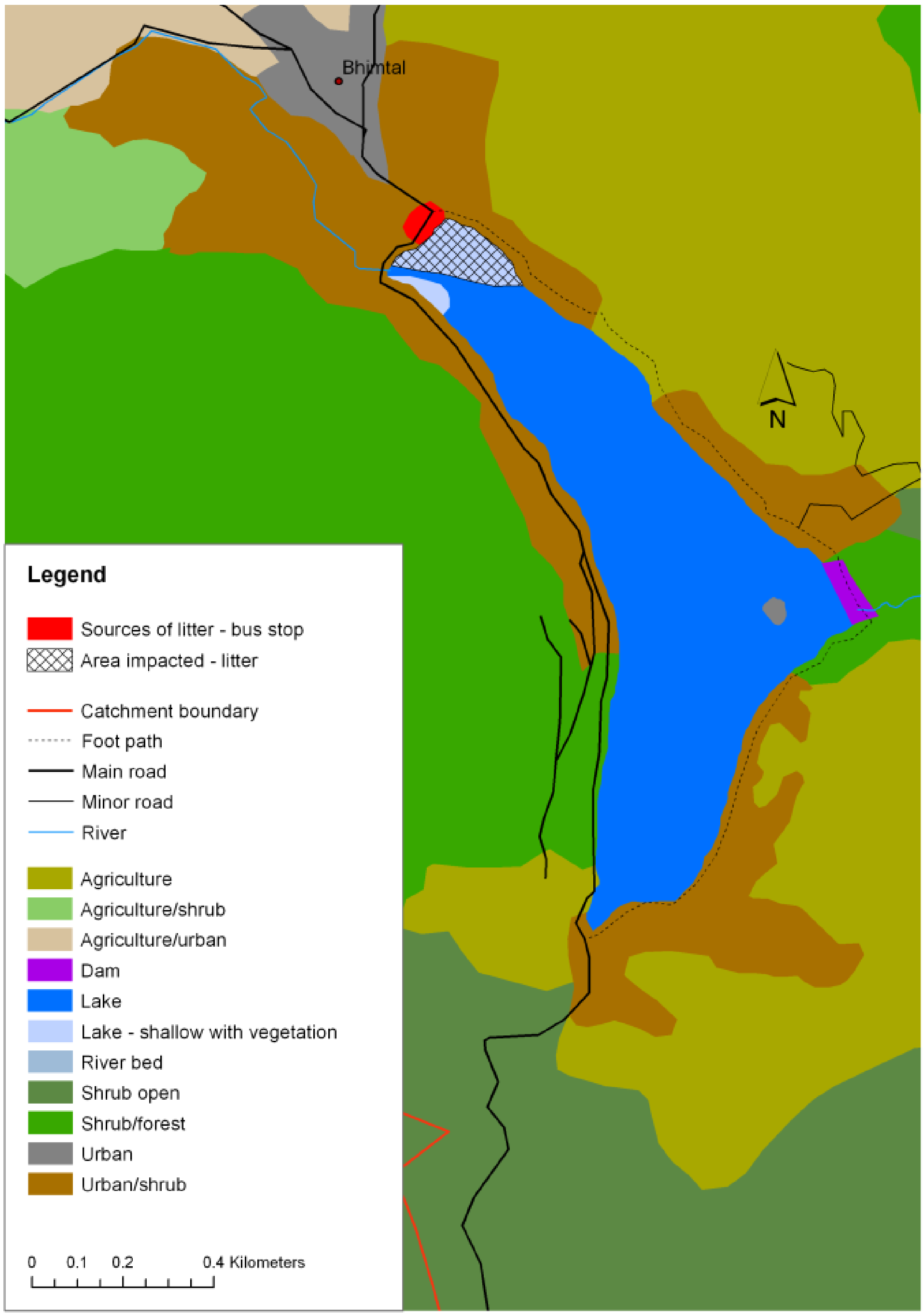

Figure 9. Sources of litter around Lake Bhimtal

4.4. Overharvesting of fishes

While consuming fish is not a traditional practice in the region, the harvesting of fishes in Nainital has increased dramatically mostly to supply the tourist industry. The National Lake Region Special Area Development Authority (NLRSADA) has been authorized by the Govind Ballabh Pantnagar University of Agriculture and Technology to formulate decisions regarding the cultivation and catching of fish. Due to the over harvesting of fishes, the University decided to ban all fishing activities in Nainital. However, enforcement of this ban is a problem and illegal fishing activities are common. In Bhimtal, fishing is allowed but only up to 4kg per person per day throughout the year. Mainly mahseer and carps are harvested due to tourist demand in Bhimtal. In Naukuchiatal due to the degrading water quality fishing is not common. In addition, there is a lack of co-ordination of management of fishing regulations between Bhimtal and Naukuchiatal.

5. Ecosystem services

5.1. Types of ecosystem services at the sites

An ecosystem is a community of animals and plants, continually interacting with one another and their physical environment (ESA 1990). Ecosystem Services are the benefits provided by ecosystems to households, communities and economies (Boyd and Banzhaf 2006). The Millennium Ecosystem Assessment (2005) described four major categories of ecosystem services: provisioning, for example the production of food and water; regulating, such as the control of climate and disease; supporting, for example nutrient cycles and crop pollination; and cultural, such as spiritual and recreational benefits. Table 8 provides examples of the different types of ecosystem services provided by Nainital.

Table 8. Types of ecosystem services, with examples from Nainital

Service categories	Specific services	Examples from Nainital
Provisioning services	Food	Production of fish (In Nainital, Bhimtal, Naukuchiatal)
	Fresh water	Storage and retention of water for domestic and agricultural use (In Nainital, Bhimtal, Naukuchiatal)
	Drinking water	Drinking water supply extracted from the lakes
Regulating services	Climate regulation	Nainital Lake regulates high temperatures, making the area cooler (a reason for it popularity with tourists).
	Water purification	Water purification undertaken by physical environment and plants.
Cultural Services	Spiritual activities	Spiritual and religious activities are performed and many temples are situated around these lakes.
	Recreational & tourism activities	Boating, angling, yachting are performed in these lakes (Nainital, Bhimtal, Naukuchiatal) – providing a major income for local residents
	Educational activities	Educational tour and trips are held around these lakes by many institutions.
Supporting services	Sediment retention	Eroded sediments are accumulated in these lakes.
	Nutrient Cycling	Storage, recycling, processing and acquisition of nutrients.

5.2. Ecosystem valuation

The aim of this analysis is to identify which ecosystem services are valued the most by the communities at the Uttarakhand sites (it is not an economic valuation). Also through mapping the ecosystem services it will allow the areas where the services are being generated in the wider catchment and which areas are benefiting from the services. This will provide the relevant information for the integrated action planning process to help ensure that these services are identified, given full recognition by all stakeholders, are not negatively impacted by any actions recommended and that the links between the state of aquatic biodiversity in the lakes, the quality of wider environment and these highly valued services is understood. It will also allow potential indictors to be developed that can be used to monitor any actions proposed through the IAP.

5.2.1. Methods

To identify which ecosystem services are perceived to be important by the local communities at the sites, the various stakeholders needed to be identiofied. Based on meetings with the communities at the sites the various stakeholders were identified, see table 9 for the stakeholder groups and their reason for inclusion in this study.

Table 9. The stakeholder groups identified for ecosystem service prioritisation analysis

Stakeholder group	Reason for inclusion in ecosystem service prioritisation
Boatmen	Gain an income by taking tourists taking boat rides on the lakes.
Fishermen	Gain an income from harvesting fish and selling to tourism industry (hotels etc.)
Hotel/ resort owner or restaurant owner	Gain an income from tourists who visit the area due to the lakes and their wider environment.
Irrigation Department	Have the responsibility to manage Bhimtal Lake as it provides water for irrigation.
Cold Water Fisheries Department (DCFR)	Maintain the fish biodiversity of Bhimtal and Naukuchiatal lakes.
National Lake Region Special Area Development Authority (NLRSADA)	In charge for maintaining all the lakes in the Kumaon Region.
Jal Sansthan	The drinking water supply department of Nainital. They supply drinking water to Nainital town. The drinking water is drawn from the Nainital Lake.
Tourists	Tourists visit the area because of the lakes, providing income to the local communities
Small shop owner	These are locals who earn an income by selling goods to tourists
School / college teacher	Responsible for educating local children and students about the environment in which they live
Students	Local students who live around the lakes and, and being educted are likely to be involved in decision making in later years.
Farmer	Farmers from Bilaspur Village rely upon irrigation water from Bhimtal Lake, and farmers from Chanoti Village rely upon water from Naukuchiatal Lake for irrigation.
Nainital Nagar Palika Parishad (NNPP)	Nainital Nagar Palika Parishad is the Municipality of Nainital town. NNPP is chiefly liable for the maintenance for the roads and lakeside roads.

To identify the ecosystem services to be used in the study, group discussions involving all the stakeholder groups were held and the services were listed. Then each person was asked to give a 'value' to each ecosystem service, where 10 is the highest value and 1 is the lowest value. In order to inform the results of the prioritization analysis each persons (and therefore stakeholder groups) understanding and perceptions of the ecosystem services provided by the lakes was assessed by asking them a set of questionnaires:

1. How much tourism has an importance as an ecosystem services according to you?
2. Is there any impact of tourism in your daily life?
3. According to you what is the impact of the spiritual sites and activity in your life?
4. What is the importance of recreation as an ecosystem services to you?
5. Has education as an ecosystem services any impact in this region?
6. What is your opinion about:
   a) Water use for household work:
   b) Water use for agriculture:
   c) Fishes for own consumption:
7. Does climate regulation by lake have any impact in your life?
8. Does water regulation by lake have any impact in your life?
9. Does water purification by lake have any impact in your life?
10. Is nutrient cycling related to your life?
11. Does sediment retention accrue any benefit to you?

5.2.2. Results

Table 10 shows the results of the ecosystem service prioritization survey. It shows the score (value) given by each stakeholder group for each ecosystem service provided by Nainital, Bhimtal and Naukuchiatal lakes. The scores in red boxes are the highest score given by that stakeholder group, and those in the blue boxes are the lowest scores given by that group. For example teachers highest scoring ecosystem services is water for human use and fishes for own consumption, both scoring 7 (they didn't score any service above this number) and their lowest valuing ecosystem services are climate regulation, water regulation and nutrient cycling to which they gave a score of 2. The table shows that tourism received the highest scores from 7 of the 13 stakeholder groups (boatmen, fishermen, hotel owner, LDA, tourists, small shop owner and the NNPP). Nutrient cycling received the lowest scores from all groups apart from the DCFR and the LDA who selected spiritual sites, recreation, water use for agriculture and education respectively as their lowest valued services.

5.2.3. Analysis

Figure 11 presents the average score given by all the stakeholder groups to each ecosystem service that is provided by Nainital, Bhimtal and Naukuchiatal lakes. Tourism scored the highest with an average score of 8.2, meaning that is was the most valued service provided. Water purification (7.6), recreation (6.8) and water for drinking (6.3) were the following 3 highest scores. Nutrient cycling was the only service to score below 3, with 1.3, with climate regulation (3.0) and water regulation (3.1) the next two lowest scoring services. The remaining services are education (4.3), water for irrigation (5.1), fish for consumption (5.5) and spiritual sites (5.9).

Table 10. Results of the ecosystem service prioritisation survey

Types of Ecosystem Service		Stakeholder Group (10= high value, 1 = low value) Red square = Each stakeholder group highest ranked service Blue square = Stakeholder group lowest ranked service												
		Boat man	Fisherman	Hotel owner	Irrigation Dp.	DCFR	NLRSADA	Jal Sansthan	Tourists	Small shop owner	Teacher	Student	Farmer	NNPP
Cultural	Tourism	10	10	10	9	4	9	9	10	10	3	6	7	10
	Spiritual sites and areas	9	5	8	7	2	4	4	8	8	5	5	5	7
	Recreation	8	7	8	7	2	7	7	9	9	3	7	7	8
	Education	7	3	8	1	7	1	1	2	8	6	9	1	3
Provisioning services	Water use for human	6	5	6	7	3	7	10	6	5	7	6	7	7
	Water use for agriculture water	7	7	6	10	2	3	3	3	3	5	5	10	3
	Fishes for own consumption	6	7	5	3	3	2	2	8	7	7	8	8	6
Regulating Services	Climate regulation	2	2	4	3	6	4	4	4	2	2	1	2	3
	Water regulation	2	3	2	5	7	3	3	3	2	2	2	2	5
	Water purification	7	8	7	8	8	9	9	9	7	5	6	7	9
Supporting services	Nutrient cycling	1	1	1	1	3	2	1	1	1	2	1	1	1

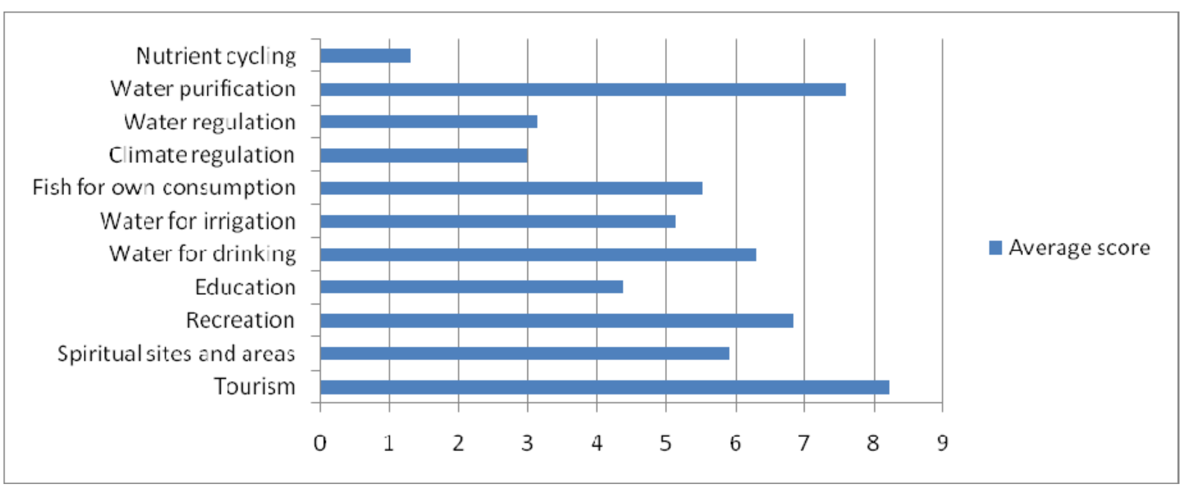

Figure 11. Average score given to each ecosystem service

Figure 12 shows the average score given by each stakeholder group, it can be used to indicate how much value each group places on the ecosystem services provided as a whole. All groups score between 4 and 6, with hotel owners and boatmen giving the highest average score of 5.9, closely followed by tourists (5.7) and NNPP and small shop owner (5.6). Teachers and the DCFR give the lowest average score of 4.3.

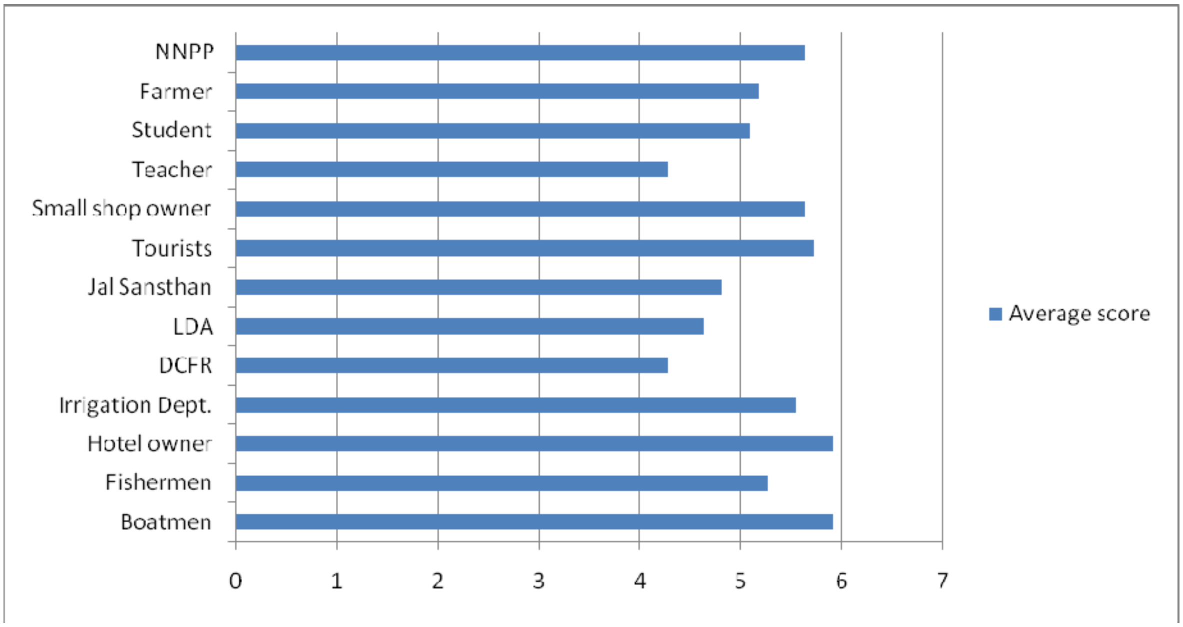

Figure 12. Average score given by each stakeholder group

Figure 13 shows the scores given by each stakeholder group for the cultural services. Tourism is the only cultural ecosystem service to receive the highest value score of 10, it receives this from NNPP, small shop owner, tourists, hotel owner, fishermen and boatmen. Tourism receives a score of 8 or more from all the stakeholder groups apart from the farmers (7), students (6), DCFR (4) and teachers (3). Recreation receives a score of between 7 and 9 by all groups, apart from teachers (3) and the DCFR (2). Spiritual sites receives its highest score of 9 from the boatmen and its lowest of 2 from DCFR. Education receives a relatively low score from many groups, receiving a score of 1 from Irrigation Department, the LDA, Jal Sansthan and farmers and a score of 2 from tourists and 3 from NNPP. The students give the highest value for this service scoring it with 9, and shop owners give it 8.

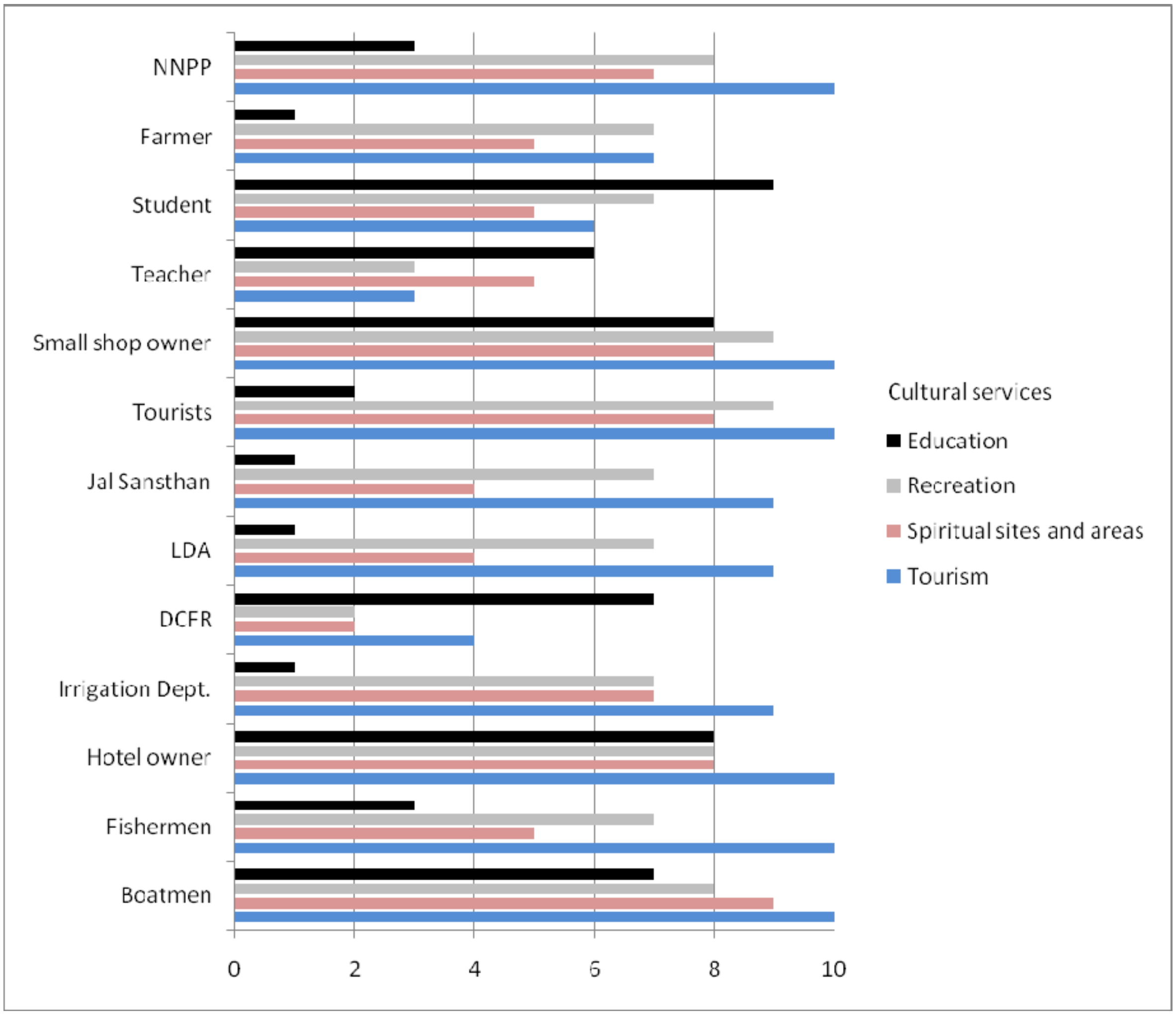

Figure 13. Score given by each stakeholder group to each cultural ecosystem service

Figure 14 shows the scores given by each stakeholder group for the provisioning services. Of all the provisioning services only 2 services are given the highest value score of 10, this is for water for irrigation (by farmers and Irrigation Dept.) and for water for drinking (by Jal Sansthan). Fish for human consumption receives its highest score of 8, which is given by 3 stakeholder groups, the farmers, students and tourists; its lowest score is 2 given by Jal Sansthan and LDA. Water for drinking receives a lowest score of 3, given by DCFR, but is scored as 5 or more by all other stakeholder groups. Water for irrigation receives relatively low scores and is given its lowest value by DCFR (2), closely followed by LDA, Jal Sansthan, tourists, small shop owner and NPP who all score this service as 3.

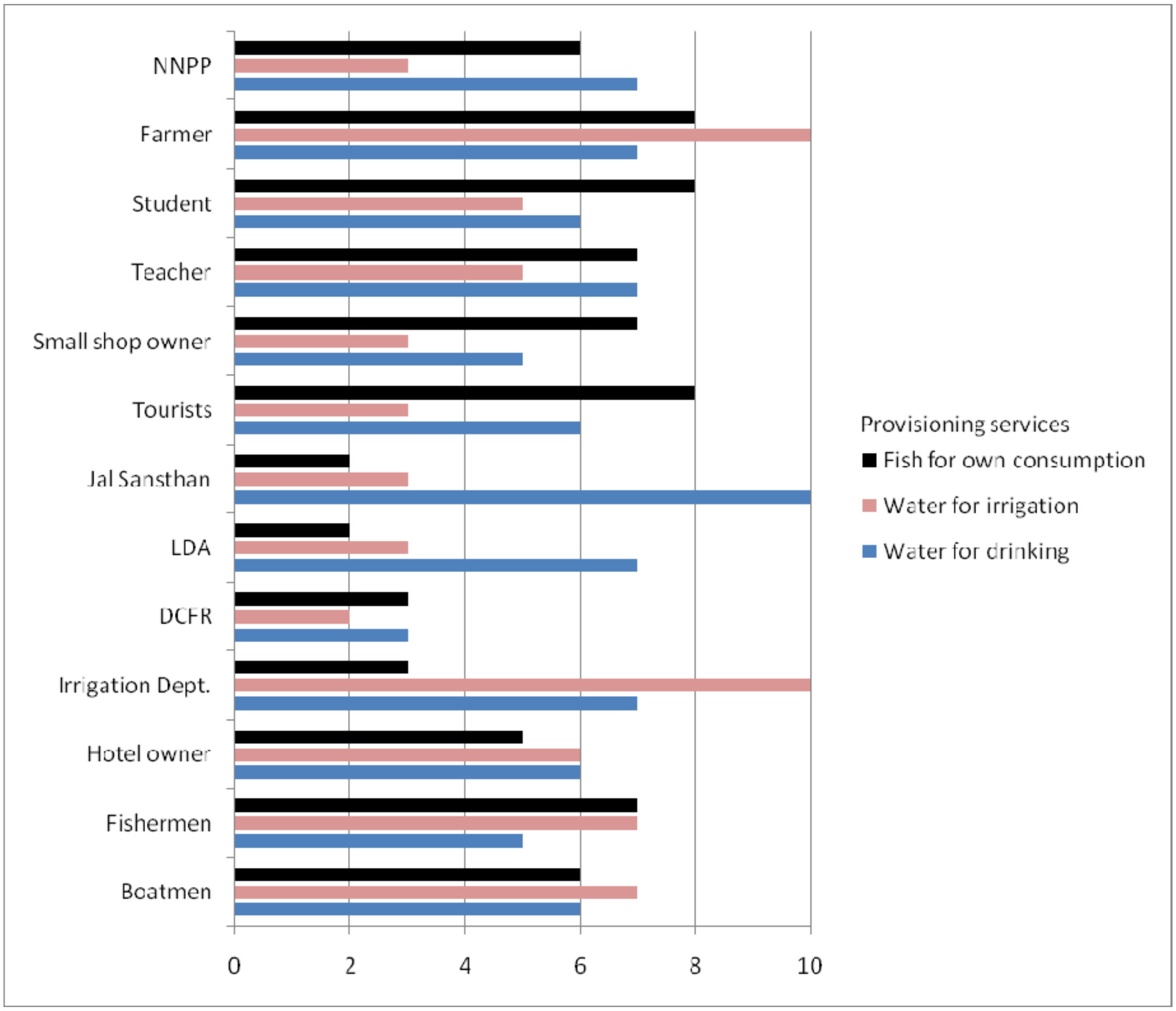

Figure 14. Score given by each stakeholder group to each provisioning ecosystem service

Figure 15 shows the scores given by each stakeholder group for the regulating and supporting services. Water purification is given the highest score amongst this type of service, by all stakeholder groups, receiving its lowest score of 5 from teachers, and its highest score of 9 from the NNPP, tourists, Jal Sansthan and LDA. Only DCFR score any of the other regulating or supporting services above 5, with water regulation (7) and climate regulation (6). Nutrient cycling scores a maximum of 3 (by DCFR) and receives a score of 1 by 10 of the remaining stakeholder groups.

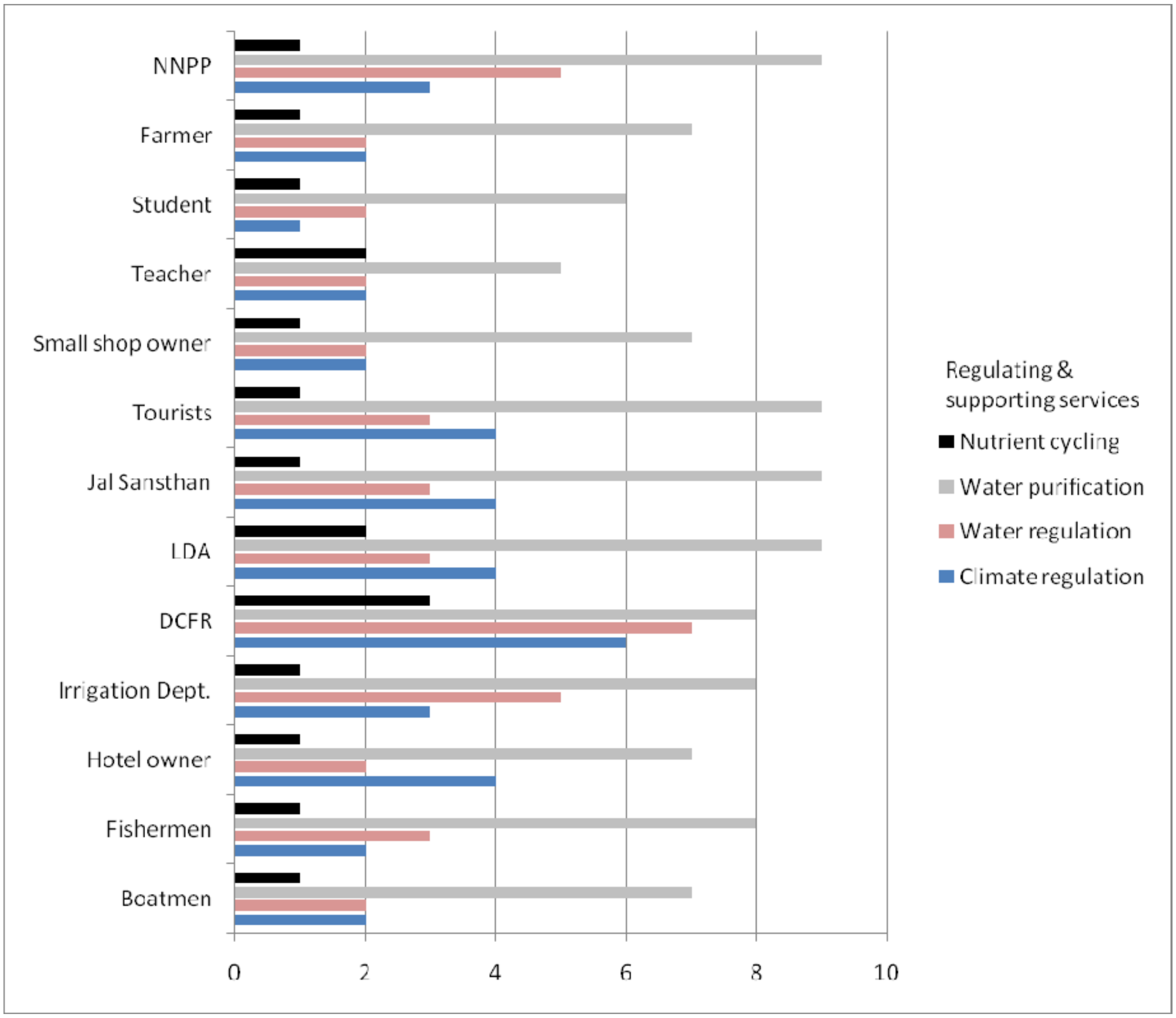

Figure 15. Score given by each stakeholder group to each regulating and supporting ecosystem service

5.2.4. Tourism as an ecosystem service

Tourism is the major industry of the Nainital district, providing income for many of the local residents and is clearly the most valued ecosystem service provided by the lakes. It is therefore understandable that those groups that depend directly upon tourism for their livelihood (boatmen, hotel owners, small shop owner) rank tourism as 10 (highest possible value), and that tourists themselves also give the same score. Fishermen rank tourism with the highest value (10) as, even though commercial fishing is not legally undertaken in the three lakes (fishing is now banned in Nainital and regulated in Bhimtal and Naukuchiatal), illegal fishing does exist and is marketed to locals as well as tourists. With more inflow of tourists, the demand for fish increases. NNPP who score tourism 10, issue licenses for boating, impose toll taxes, and collect tax for keeping clean adjacent areas of Nainital Lake. This revenue is highly linked with the tourists, and they generate a larger revenue during tourist season. The Irrigation Department scores tourism as a high value ecosystem service (giving it 9), this is likely because they are responsible for issuing boating licences for Bhimtal and Naukuchiatal and generate an income from tourism, and also that they are responsible for maintaining high levels of water in the lakes to increase aesthetic value of the lakes for the tourists. NLRSADA (LDA) also scores tourism as a high value (9) and is the regulatory authority regulates Nainital Lake and catchment area, and is responsible for many of the projects to improve the environment of lake for locals for the tourism industry, including the aeration project, re-introduction of native fishes, water quality maintenance and desiltation programs. Students (score tourism 6) and farmers (7) often gain part time employment in the tourism industry in the peak season such as guiding boats in the lakes, driving trekkers and private cars for the tourists. Fisure 16 shows that the entire upper catchment that contain the 3 lakes generate the natural aesthetic value that attracts tourist to the region. The figure also shows that the areas benefiting are much wider as the whole of Nainital District is benefiting as people from the district travel to the lakes to gain employment in the tourism industry, also the tourists themselves who benefit come to Nainital from across northern India from towns and cities like Amritsar, Chandigarh, Delhi, Kanpur, Varanasi. However it should be notes that tourism itself, as a cultural ecosystem service, depends significantly on other ecosystem services such as climate regulation (lakes cooling the surrounding area making it more hospitable) and water purification (if the system can no longer clean itself due excessive loads of pollution it will lose some of its aesthetic value).

Potential indicators for tourism:

-Local government taxes on tourist activities

-Number of hotel rooms booked during tourist season

-Number of boatmen on the lakes, and the number of boat trips taken.

5.2.5. Water use for human consumption and water purification

As water for human use is heavily reliant upon water purification, we will discuss these services together. These are probably the second most highly valued ecosystem service provided by the lakes. Unsurprisingly, Jal Sansthan who are responsible for supplying drinking water to households rank water consumption for drinking as an ecosystem service the highest possible value of 10, and scoring water purification, a service which they wholly depend upon, 9. NLRSADA (LDA) and NNPP who both aim to improve water quality in the lakes for human use, both give water use for drinking a relatively high score of 7. Tourists, shop owners, teachers, farmers and students all valued drinking water the same (scoring 7) as they need water from the lake for their personal and household use rather than for livelihood purposes. Improved and pure water would be to the benefit of everyone. DCFR and NNPP have given almost the same score to water purification (8 and 9 respectively) as their main role is to monitor quality and purity of the water in the lakes so that they can maintain the fish biodiversity over there. The fisherman score water purification highly at 8, as cleaner water will help fishermen to catch larger amounts of good quality fish. NLRSADA (LDA) and Jal Sansthan who both score water purification at 9, have key roles in the management and conservation of the lakes, making maintenance of water quality one of their primary goals. Many of the other stakeholder groups, who rely upon water purification on a personal level rather than for an income or institutional role, have scored this service slightly less but still all above 5, this is probably acknowledging the importance of this service to many of the other services (tourism, fish harvesting, drinking water etc). Figure 17, shows that the remaining naturally vegetated areas within the catchments of Bhimtal and Naukuchiatal are key to the generation of these services, even though the lakes are not purely fed by surface water but by underground springs etc. if these areas were to be degraded or lost entirely these important ecosystem services would be significantly damaged. It also illustrates the areas that benefit, the urban areas that get drinking water (Bhimtal, Bilaspur, and Chanoti) and also the town of Haldwani that receives drinking water from Bhimtal lake.

Potential indicators for water for drinking and water purification:

-LDA water quality and lake water level surveys

-The secchi depth measurements

-Species (cold water carps and bivalves) indicators of water quality – work undertaken by Cold Water Fisheries Dept.

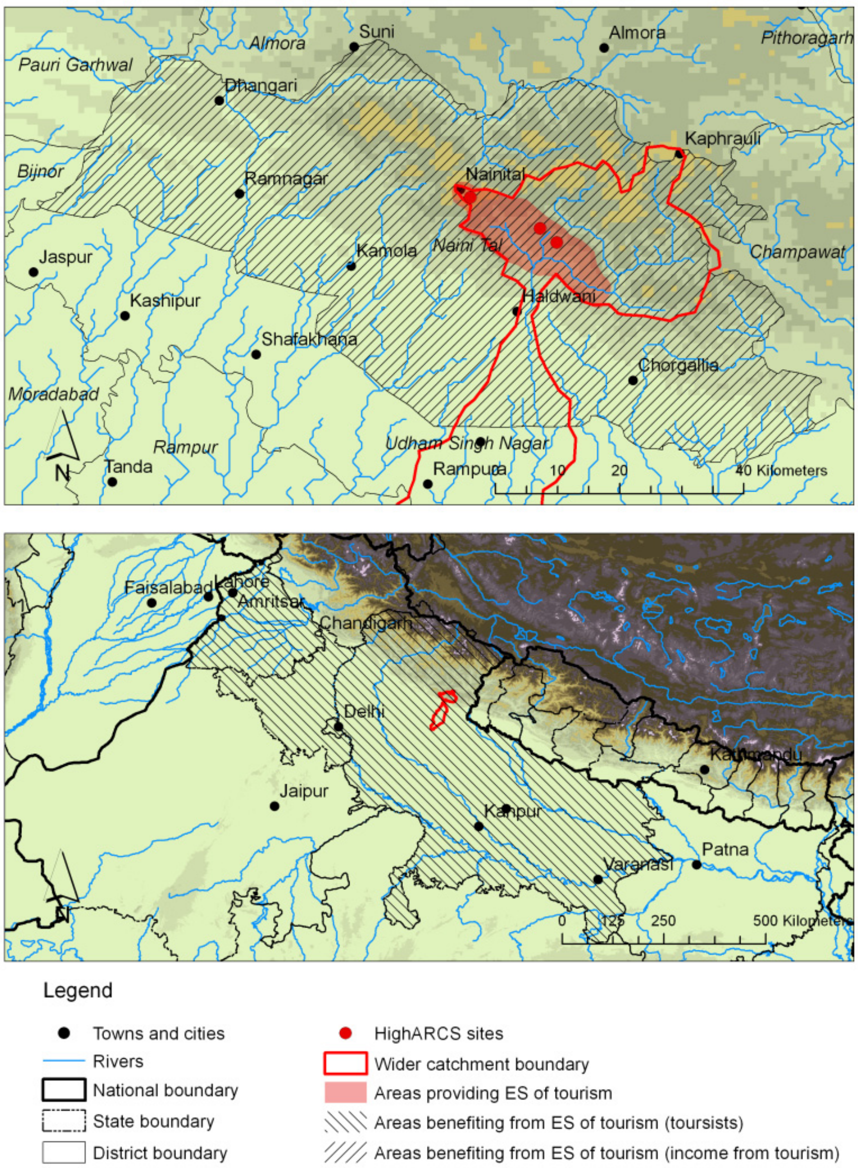

Figure 16. Areas generating and benefiting from tourism

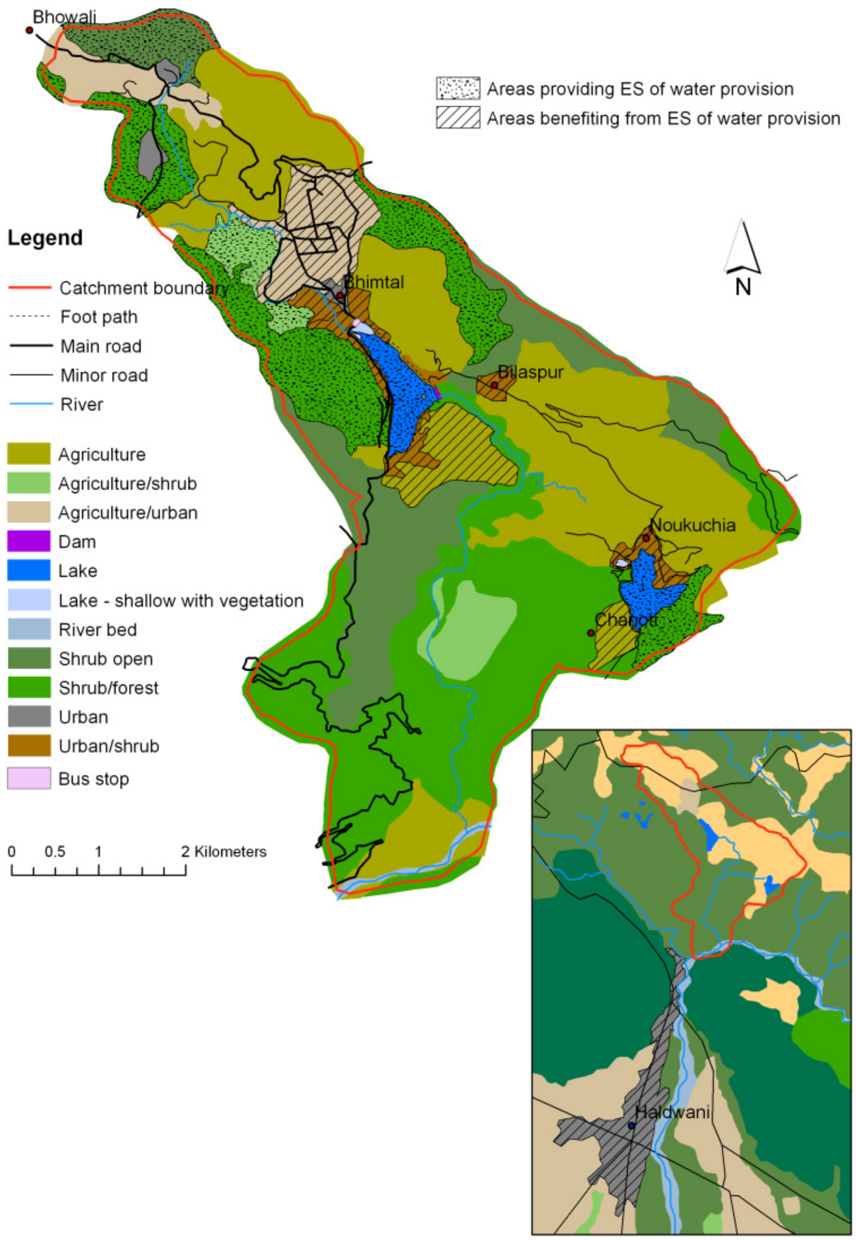

Figure 17. Areas generating and benefiting from water provision

5.2.6. Spiritual sites and areas

Uttarakhand is known as the 'DevBhoomi' the 'abode of God' because the region is has many divine and historical places. Within our field site i.e. in Nainital, Bhimtal and Naukuchiatal there are many temples such as Nanda Devi temple, Bhimeshwar Mandir in Bhimtal and Hanuman Mandir in Naukuchiatal. The local people are great followers of these divine places and many of the groups that are local residents value this service highly. Tourists also know about them and it is one of the reasons for their visit to the area, benefiting those stakeholder groups that also benefit directly from tourism. There are also some masjids (mosque), majhars (grave site) and churches in the surrounding region of these three lakes.

Boatmen, who score this service highly (9) benefit from Nanda Devi Mandir and Bhimeshwar Mandir especially as they are on the lake side.

Potential indicators for spiritual sites and areas

-None

5.2.7. Recreation

Recreation is on average the third highest valued ecosystem service. Many activities such as boating in these lakes, angling, yatching, horse riding along the shore are part of the reason many tourists visit the area (who score it 9), and they are also enjoyed by many local people. Small shop owner, boatmen and hotel owners who all depend upon these tourists also score this service very highly (9, 8, 8 respectively), as do other groups that benefit from tourists e.g. NNPP who issue boating licences.

Potential indicators for recreation

-Angling licences issuedNumber of boatmen on the lakes, and the number of boat trips taken.

5.2.8. Water for irrigation

Agriculture is another lucrative sector for the people residing around Bhimtal and Naukuchiatal. The villages of Chanaoti and Pandeygaon directly depend on the water from Naukuchiatal and Bhimtal respectively for irrigation of their crops and therefore both the irrigation department and the farmers both give this service the highest value (10). The Irrigation Department controls the water of Bhimtal Lake and they decide the amount of water to be drawn for irrigation purposes and they also earn revenue by imposing tax on irrigation. Fishermen and boatmen also score this service highly (7) as they often work as farmers or farm labourers in the tourist off season.

Potential indicators for water for irrigation

-LDA water quality and lake water level surveys

-Irrigation Department data

5.2.8. Fish harvesting

Interestingly tourists, students and farmers (score 8) value this service slightly higher than fishermen (score 7). NNPP issues licenses for fishing and angling in Nainital, and rank it relatively highly at 6.

Potential indicators for water for fish harvesting

-Fishing licences issued for fish harvesting in Bhimtal

5.2.9. Climate regulation

Climate regulation is valued relatively lowly. Only DCFR give it a score of above 5 (6). The climate regulation provided by the lake is critical for the survival of the cold water fishes this institute is set up to research. However this service may not be fully understood by most of the stakeholder groups, and they have subsequently ranked it with a low value. The climate of the area that is in part regulated by the lakes, is critical to the tourism industry.

Potential indicators for climate regulation

-Temperatures recordings at the lakes

5.2.10. Education

The educational value of the lakes is highly valued by students (score of 9). Aside from tourists, many educational tours also visit the area, often occurring outside the tourist season providing valuable income for hotel owners and shop owners (who rank this service highly at 8). Boatmen (score 7) also benefit by taking researchers and educational tours on the lake. Of the stakeholders in this only DCFR is involved in research on the lakes, and they have given this service a relatively high value (7). Rather surprisingly teachers scored this service with a value of 6.

Potential indicators for education

-None

5.2.11. Nutrient cycling

The lakes of Uttarakhand field site offer cycling of different nutrients and the benefits are felt by all the different stakeholders, for example by providing nutrients to the lake food chain allowing fish to thrive. As with climate regulation this service may not be fully understood by most of the stakeholder groups and they have subsequently ranked it with a low value.

Potential indicators for nutrient cycling

-None

6. Conclusions

The lakes contain a diverse array of aquatic biodiversity, including 37 native species of fish and at least 9 species of molluscs and 14 species of aquatic plants. The lakes also contain two globally threatened species *Tor putitora* (golden mahseer) and *Schizothorax richardsonii* (snow trout), the two tor species in the lakes (including *T. tor*) were extirpated from the Nainital lake due to excessive pollutants and eutrophication, but are now re-stocked for conservation reasons. Potential indicator species have been identified as the cold water carps (which are already monitored) and the freshwater bivalves, both groups being sensitive to low oxygen levels.

The lakes are facing many threats, primarily pollution from urban waste, agricultural pollution, sedimentation and surface runoff which is causing increased nutrient levels in the lakes. Nainital is now eutrophic where in winter months low oxygen levels have led to major fish kills of the cold water carps, and Bhimtal and Naukuchiatal are mesotrophic. There are also a number of introduced species that are impacting the native species and ecosystem, in particular the introduced carps *Ctenopharyngodon idella* (grass carp), *Cyprinus caprio* (common carp), *Hypophthalmichthys molitrix* (silver carp) and *Carassius carassius* (crusian carp), and the mosquito fish *Gambusia affinis*. Litter is also an increasing problem due to the increasing numbers of tourists, in particular in Bhimtal. The overharvesting of fish has caused the declines of many fish species, but now fishing is banned in Nainital and regulated in Bhimtal.

The ecosystem services that are valued the highest by the various stakeholders are tourism, water purification, recreation and water for drinking., with nutrient cycling, climate regulation and water regulation being the least valued. Different stakeholder groups prioritized different services, with boatmen, fishermen, hotel owners, Lake Development Authority, tourists, small shop owners and Nainital Nagar Palika Parishad all valuing tourism the highest, whereas the Irrigation department and farmers valued water for agricultural use the highest, teachers valued water for drinking and fish harvesting the highest, the Cold Water Fisheries Department and Lake Development Authority valued water purification, whereas the students valued the educational services provided by the lakes the highest.

Even though the lakes are under a great deal of stress, many conservation actions have taken place under many different organistions including the Govind Ballav Pant University of Agriculture and Technology, and Directorate of Coldwater Fisheries National Lake Conservation Project, NLCP. There is stocking of native *Tor* species in the lakes, fish harvesting is regulated, an aeration programme in Nainital Lake is increasing the dissolved oxygen content in the lake and there are many projects reducing the sources of pollution under the National Lake Region Special Area Development Authority. However we recommend that greater awareness about how the quality of the lakes water is impacting its biodiversity and ecosystem and how it links to livelihoods is needed among the local people.

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Annex 1. Summary of the IUCN Red List criteria

Summary of the five criteria (A–E) used to evaluate if a taxon belongs in a threatened category (Critically Endangered, Endangered or Vulnerable).

Use any of the criteria A–E	Critically Endangered	Endangered	Vulnerable
A. Population reduction	Declines measured over the longer of 10 years or 3 generations		
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%

A1. Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible **AND** understood **AND** have ceased, based on and specifying any of the following:

- (a) direct observation
- (b) an index of abundance appropriate to the taxon
- (c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality
- (d) actual or potential levels of exploitation
- (e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

A2. Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased **OR** may not be understood **OR** may not be reversible, based on (a) to (e) under A1.

A3. Population reduction projected or suspected to be met in the future (up to a maximum of 100 years) based on (b) to (e) under A1.

A4. An observed, estimated, inferred, projected or suspected population reduction (up to a maximum of 100 years) where the time period must include both the past and the future, and where the causes of reduction may not have ceased **OR** may not be understood **OR** may not be reversible, based on (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)

	Critically Endangered	Endangered	Vulnerable
B1. Extent of occurrence (EOO)	< 100 km²	< 5,000 km²	< 20,000 km²
B2. Area of occupancy (AOO)	< 10 km²	< 500 km²	< 2,000 km²
AND at least 2 of the following:			
(a) Severely fragmented, **OR** Number of locations	= 1	≤ 5	≤ 10

(b) Continuing decline in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals.

(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals.

C. Small population size and decline

	Critically Endangered	Endangered	Vulnerable
Number of mature individuals	< 250	< 2,500	< 10,000
AND either C1 or C2:			
C1. An estimated continuing decline of at least: (up to a max. of 100 years in future)	25% in 3 years or 1 generation	20% in 5 years or 2 generations	10% in 10 years or 3 generations
C2. A continuing decline **AND** (a) and/or (b):			
(a i) Number of mature individuals in each subpopulation:	< 50	< 250	< 1,000
or			
(a ii) % individuals in one subpopulation =	90–100%	95–100%	100%
(b) Extreme fluctuations in the number of mature individuals.			

D. Very small or restricted population

	Critically Endangered	Endangered	Vulnerable
Either: Number of mature individuals	< 50	< 250	**D1.** < 1,000
			AND/OR
Restricted area of occupancy			**D2.** typically: AOO < 20 km² or number of locations ≤ 5

E. Quantitative Analysis

	Critically Endangered	Endangered	Vulnerable
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations (100 years max.)	≥ 20% in 20 years or 5 generations (100 years max.)	≥ 10% in 100 years

Annex 2. Species of the Nainital wider catchment

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Fishes

Order	Family	Binomial	IUN Red List Category
Beloniformes	Belonidae	*Xenentodon cancila*	LC
Clupeiformes	Clupeidae	*Gonialosa manmina*	LC
Clupeiformes	Clupeidae	*Gudusia chapra*	LC
Clupeiformes	Engraulidae	*Setipinna phasa*	LC
Cypriniformes	Balitoridae	*Acanthocobitis botia*	LC
Cypriniformes	Balitoridae	*Paraschistura montana*	NA
Cypriniformes	Balitoridae	*Schistura beavani*	LC
Cypriniformes	Balitoridae	*Schistura corica*	LC
Cypriniformes	Balitoridae	*Schistura multifasciata*	LC
Cypriniformes	Balitoridae	*Schistura rupecula*	LC
Cypriniformes	Cobitidae	*Botia almorhae*	LC
Cypriniformes	Cobitidae	*Botia dario*	LC
Cypriniformes	Cobitidae	*Lepidocephalichthys guntea*	LC
Cypriniformes	Cyprinidae	*Amblypharyngodon microlepis*	LC
Cypriniformes	Cyprinidae	*Aspidoparia morar*	LC
Cypriniformes	Cyprinidae	*Bangana ariza*	LC
Cypriniformes	Cyprinidae	*Bangana dero*	LC
Cypriniformes	Cyprinidae	*Bangana diplostoma*	LC
Cypriniformes	Cyprinidae	*Barilius barila*	LC
Cypriniformes	Cyprinidae	*Barilius barna*	LC
Cypriniformes	Cyprinidae	*Barilius bendelisis*	LC
Cypriniformes	Cyprinidae	*Barilius shacra*	LC
Cypriniformes	Cyprinidae	*Barilius vagra*	LC
Cypriniformes	Cyprinidae	*Chagunius chagunio*	LC
Cypriniformes	Cyprinidae	*Chela cachius*	LC
Cypriniformes	Cyprinidae	*Cirrhinus mrigala*	LC
Cypriniformes	Cyprinidae	*Crossocheilus latius*	LC
Cypriniformes	Cyprinidae	*Danio rerio*	LC
Cypriniformes	Cyprinidae	*Devario devario*	LC
Cypriniformes	Cyprinidae	*Garra gotyla*	LC
Cypriniformes	Cyprinidae	*Garra lamta*	LC
Cypriniformes	Cyprinidae	*Gibelion catla*	LC
Cypriniformes	Cyprinidae	*Labeo bata*	LC
Cypriniformes	Cyprinidae	*Labeo boga*	LC
Cypriniformes	Cyprinidae	*Labeo calbasu*	LC
Cypriniformes	Cyprinidae	*Labeo dyocheilus*	LC
Cypriniformes	Cyprinidae	*Labeo gonius*	LC

Order	Family	Binomial	IUN Red List Category
Cypriniformes	Cyprinidae	*Labeo microphthalmus*	LC
Cypriniformes	Cyprinidae	*Labeo pangusia*	NT
Cypriniformes	Cyprinidae	*Labeo rohita*	LC
Cypriniformes	Cyprinidae	*Osteobrama cotio*	LC
Cypriniformes	Cyprinidae	*Puntius chelynoides*	VU
Cypriniformes	Cyprinidae	*Puntius chola*	LC
Cypriniformes	Cyprinidae	*Puntius conchonius*	LC
Cypriniformes	Cyprinidae	*Puntius gelius*	LC
Cypriniformes	Cyprinidae	*Puntius phutunio*	LC
Cypriniformes	Cyprinidae	*Puntius sarana*	LC
Cypriniformes	Cyprinidae	*Puntius sophore*	LC
Cypriniformes	Cyprinidae	*Puntius terio*	LC
Cypriniformes	Cyprinidae	*Puntius ticto*	LC
Cypriniformes	Cyprinidae	*Rasbora daniconius*	LC
Cypriniformes	Cyprinidae	*Schizothorax kumaonensis*	DD
Cypriniformes	Cyprinidae	*Schizothorax plagiostomus*	NA
Cypriniformes	Cyprinidae	*Schizothorax richardsonii*	VU
Cypriniformes	Cyprinidae	*Securicula gora*	LC
Cypriniformes	Cyprinidae	*Tor putitora*	EN
Cypriniformes	Cyprinidae	*Tor tor*	NT
Mugiliformes	Mugilidae	*Sicamugil cascasia*	LC
Osteoglossiformes	Notopteridae	*Chitala chitala*	NT
Osteoglossiformes	Notopteridae	*Notopterus notopterus*	LC
Perciformes	Ambassidae	*Chanda nama*	LC
Perciformes	Ambassidae	*Parambassis lala*	NT
Perciformes	Ambassidae	*Pseudambassis baculis*	LC
Perciformes	Ambassidae	*Pseudambassis ranga*	LC
Perciformes	Anabantidae	*Anabas testudineus*	DD
Perciformes	Badidae	*Badis badis*	LC
Perciformes	Channidae	*Channa gachua*	LC
Perciformes	Channidae	*Channa marulius*	LC
Perciformes	Channidae	*Channa punctata*	LC
Perciformes	Channidae	*Channa striata*	LC
Perciformes	Osphronemidae	*Trichogaster fasciata*	LC
Perciformes	Osphronemidae	*Trichogaster lalius*	LC
Siluriformes	Bagridae	*Sperata aor*	LC
Siluriformes	Bagridae	*Sperata seenghala*	LC
Siluriformes	Chacidae	*Chaca chaca*	LC
Siluriformes	Clariidae	*Clarias magur*	EN
Siluriformes	Heteropneustidae	*Heteropneustes fossilis*	LC
Siluriformes	Schilbeidae	*Clupisoma garua*	LC
Siluriformes	Schilbeidae	*Eutropiichthys murius*	LC
Siluriformes	Schilbeidae	*Eutropiichthys vacha*	LC

Order	Family	Binomial	IUN Red List Category
Siluriformes	Schilbeidae	*Neotropius atherinoides*	LC
Siluriformes	Schilbeidae	*Silonia silondia*	LC
Siluriformes	Sisoridae	*Glyptothorax gracilis*	DD
Siluriformes	Sisoridae	*Glyptothorax pectinopterus*	LC
Siluriformes	Sisoridae	*Glyptothorax stolickae*	LC
Siluriformes	Sisoridae	*Glyptothorax telchitta*	LC
Siluriformes	Sisoridae	*Nangra nangra*	LC
Siluriformes	Sisoridae	*Parachiloglanis hodgarti*	LC
Synbranchiformes	Mastacembelidae	*Mastacembelus armatus*	LC
Synbranchiformes	Synbranchidae	*Monopterus albus*	LC
Synbranchiformes	Synbranchidae	*Monopterus cuchia*	LC

Molluscs

Class	Order	Family	Binomial	IUCN Red List Category
Bivalvia	Arcoida	Arcidae	*Scaphula celox*	LC
Bivalvia	Unionoida	Unionidae	*Lamellidens consobrinus*	LC
Bivalvia	Unionoida	Unionidae	*Lamellidens corrianus*	LC
Bivalvia	Unionoida	Unionidae	*Lamellidens marginalis*	LC
Bivalvia	Unionoida	Unionidae	*Lamellidens narainpirensis*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia andersoniana*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia bonneaudi*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia caerulea*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia corrugata*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia lima*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia occata*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia olivaria*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia rajahensis*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia shurtleffiana*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia sikkimensis*	LC
Bivalvia	Unionoida	Unionidae	*Parreysia triembolus*	LC
Bivalvia	Veneroida	Corbiculidae	*Corbicula assamensis*	LC
Bivalvia	Veneroida	Corbiculidae	*Corbicula aurea*	DD
Bivalvia	Veneroida	Corbiculidae	*Corbicula striatella*	LC
Bivalvia	Veneroida	Solecurtidae	*Novaculina gangetica*	LC
Bivalvia	Veneroida	Sphaeriidae	*Pisidium clarkeanum*	LC
Bivalvia	Veneroida	Sphaeriidae	*Pisidium nevillianum*	LC
Bivalvia	Veneroida	Sphaeriidae	*Pisidium prasongi*	LC
Bivalvia	Veneroida	Sphaeriidae	*Sphaerium indicum*	LC
Gastropoda	Allogastropoda	Bullinidae	*Indoplanorbis exustus*	LC
Gastropoda	Architaenioglossa	Ampullariidae	*Pila globosa*	LC
Gastropoda	Architaenioglossa	Viviparidae	*Bellamya bengalensis*	LC

Class	Order	Family	Binomial	IUCN Red List Category
Gastropoda	Architaenioglossa	Viviparidae	*Bellamya crassa*	LC
Gastropoda	Architaenioglossa	Viviparidae	*Bellamya dissimilis*	LC
Gastropoda	Cycloneritimorpha	Neritidae	*Clithon reticularis*	LC
Gastropoda	Hygrophila	Lymnaeidae	*Lymnaea acuminata*	LC
Gastropoda	Hygrophila	Lymnaeidae	*Lymnaea auricularia*	LC
Gastropoda	Hygrophila	Lymnaeidae	*Lymnaea biacuminata*	DD
Gastropoda	Hygrophila	Lymnaeidae	*Lymnaea luteola*	LC
Gastropoda	Hygrophila	Lymnaeidae	*Lymnaea persica*	LC
Gastropoda	Hygrophila	Planorbidae	*Camptoceras lineatum*	LC
Gastropoda	Hygrophila	Planorbidae	*Camptoceras terebra*	DD
Gastropoda	Hygrophila	Planorbidae	*Ferrissia verruca*	LC
Gastropoda	Hygrophila	Planorbidae	*Gyraulus barrackporensis*	LC
Gastropoda	Hygrophila	Planorbidae	*Gyraulus convexiusculus*	LC
Gastropoda	Hygrophila	Planorbidae	*Gyraulus labiatus*	LC
Gastropoda	Hygrophila	Planorbidae	*Gyraulus rotula*	LC
Gastropoda	Hygrophila	Planorbidae	*Hippeutis umbilicalis*	LC
Gastropoda	Hygrophila	Planorbidae	*Segmentina calatha*	LC
Gastropoda	Littorinimorpha	Bithyniidae	*Bithynia pulchella*	LC
Gastropoda	Littorinimorpha	Bithyniidae	*Bithynia textum*	DD
Gastropoda	Littorinimorpha	Bithyniidae	*Digoniostoma cerameopoma*	LC
Gastropoda	Littorinimorpha	Bithyniidae	*Gabbia orcula*	LC
Gastropoda	Littorinimorpha	Pomatiopsidae	*Tricula montana*	LC
Gastropoda	Littorinimorpha	Stenothyridae	*Stenothyra ornata*	LC
Gastropoda	Sorbeoconcha	Pachychilidae	*Brotia costula*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Melanoides pyramis*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Melanoides tuberculatus*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Thiara lineata*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Thiara rudis*	LC
Gastropoda	Sorbeoconcha	Thiaridae	*Thiara scabra*	LC

Ododnata

Family	Binomial	IUCN Red List Category
Aeshnidae	*Gynacantha bayadera*	LC
Aeshnidae	*Gynacanthaeschna sikkima*	LC
Aeshnidae	*Polycanthagyna erythromelas*	LC
Aeshnidae	*Polycanthagyna ornithocephala*	LC
Chlorocyphidae	*Rhinocypha immaculata*	LC
Chlorocyphidae	*Rhinocypha quadrimaculata*	LC
Chlorocyphidae	*Rhinocypha spuria*	LC
Chlorocyphidae	*Rhinocypha trifasciata*	LC
Chlorocyphidae	*Rhinocypha unimaculata*	LC

Family	Binomial	IUCN Red List Category
Coenagrionidae	*Ischnura aurora*	LC
Coenagrionidae	*Ischnura forcipata*	LC
Coenagrionidae	*Ischnura rufostigma*	LC
Coenagrionidae	*Paracercion calamorum*	LC
Coenagrionidae	*Pseudagrion australasiae*	LC
Coenagrionidae	*Pseudagrion decorum*	LC
Coenagrionidae	*Pseudagrion laidlawi*	LC
Coenagrionidae	*Pseudagrion microcephalum*	LC
Coenagrionidae	*Pseudagrion spencei*	LC
Gomphidae	*Ictinogomphus kishori*	DD
Gomphidae	*Ictinogomphus rapax*	LC
Gomphidae	*Lamelligomphus biforceps*	LC
Gomphidae	*Macrogomphus robustus*	DD
Gomphidae	*Onychogomphus cerastis*	DD
Gomphidae	*Onychogomphus grammicus*	DD
Gomphidae	*Onychogomphus schmidti*	LC
Gomphidae	*Onychogomphus striatus*	DD
Gomphidae	*Paragomphus lineatus*	LC
Gomphidae	*Platygomphus dolabratus*	LC
Gomphidae	*Scalmogomphus bistrigatus*	LC
Lestidae	*Indolestes cyaneus*	LC
Lestidae	*Lestes praemorsus*	LC
Lestidae	*Lestes thoracicus*	LC
Libellulidae	*Crocothemis erythraea*	LC
Libellulidae	*Diplacodes lefebvrii*	LC
Libellulidae	*Diplacodes nebulosa*	LC
Libellulidae	*Diplacodes trivialis*	LC
Libellulidae	*Hylaeothemis gardeneri*	DD
Libellulidae	*Indothemis carnatica*	NT
Libellulidae	*Lyriothemis bivittata*	LC
Libellulidae	*Lyriothemis tricolor*	LC
Libellulidae	*Nannophya pygmaea*	LC
Libellulidae	*Neurothemis fulvia*	LC
Libellulidae	*Neurothemis intermedia*	LC
Libellulidae	*Neurothemis tullia*	LC
Libellulidae	*Onychothemis testacea*	LC
Libellulidae	*Orthetrum cancellatum*	LC
Libellulidae	*Orthetrum chrysis*	LC
Libellulidae	*Orthetrum pruinosum*	LC
Libellulidae	*Orthetrum taeniolatum*	LC
Libellulidae	*Palpopleura sexmaculata*	LC
Libellulidae	*Potamarcha congener*	LC
Libellulidae	*Rhodothemis rufa*	LC

Family	Binomial	IUCN Red List Category
Libellulidae	*Rhyothemis variegata*	LC
Libellulidae	*Sympetrum commixtum*	LC
Libellulidae	*Sympetrum fonscolombii*	LC
Libellulidae	*Tetrathemis platyptera*	LC
Libellulidae	*Tramea basilaris*	LC
Macromiidae	*Macromia moorei*	LC
Platystictidae	*Drepanosticta carmichaeli*	LC
Synlestidae	*Megalestes major*	LC
Aeshnidae	*Anax imperator*	LC
Libellulidae	*Trithemis aurora*	LC

Plants (selected plant families of the Ganges/Brahmaputra basin)

Phylum	Class	Order	Family	Binomial	IUCN Red List Category
Bryophyta	Sphagnopsida	Sphagnales	Sphagnaceae	*Sphagnum palustre*	DD*
Charophyta	Charophyceae	Charales	Characeae	*Chara braunii*	LC*
Charophyta	Charophyceae	Charales	Characeae	*Chara corallina*	LC*
Charophyta	Charophyceae	Charales	Characeae	*Chara zeylanica*	LC*
Charophyta	Charophyceae	Charales	Characeae	*Nitella acuminata*	LC*
Charophyta	Charophyceae	Charales	Characeae	*Nitella furcata*	LC*
Charophyta	Charophyceae	Charales	Characeae	*Nitella hyalina*	LC*
Lycopodiophyta	Isoetopsida	Isoetales	Isoetaceae	*Isoetes cormandeliana*	LC
Lycopodiophyta	Isoetopsida	Isoetales	Isoetaceae	*Isoetes indica*	NA
Marchantiophyta	Jungermanniopsida	Pelliales	Pelliaceae	*Pellia epiphylla*	NA
Marchantiophyta	Marchantiopsida	Marchantiales	Ricciaceae	*Ricciella fluitans*	NT*
Marchantiophyta	Marchantiopsida	Marchantiales	Ricciaceae	*Ricciocarpus natans*	DD*
Polypodiophyta	Polypodiopsida	Marsileales	Marsileaceae	*Marsilea quadrifolia*	LC
Polypodiophyta	Polypodiopsida	Salviniales	Azollaceae	*Azolla pinnata*	LC
Polypodiophyta	Polypodiopsida	Salviniales	Salviniaceae	*Salvinia cucullata*	LC
Polypodiophyta	Polypodiopsida	Salviniales	Salviniaceae	*Salvinia natans*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Alisma plantago-aquatica*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Caldesia oligococca*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Caldesia parnassifolia*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Limnophyton obtusifolium*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Sagittaria guayanensis*	LC
Tracheophyta	Liliopsida	Alismatales	Alismataceae	*Sagittaria sagittifolia*	LC
Tracheophyta	Liliopsida	Arales	Araceae	*Colocasia esculenta*	LC
Tracheophyta	Liliopsida	Arales	Araceae	*Cryptocoryne ciliata*	LC
Tracheophyta	Liliopsida	Arales	Araceae	*Cryptocoryne cognata*	EN
Tracheophyta	Liliopsida	Arales	Araceae	*Cryptocoryne retrospiralis*	LC

Phylum	Class	Order	Family	Binomial	IUCN Red List Category
Tracheophyta	Liliopsida	Arales	Araceae	*Cryptocoryne spiralis*	LC*
Tracheophyta	Liliopsida	Arales	Araceae	*Lagenandra meeboldii*	LC*
Tracheophyta	Liliopsida	Arales	Araceae	*Lasia spinosa*	LC
Tracheophyta	Liliopsida	Arales	Araceae	*Pistia stratiotes*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Landoltia punctata*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Lemna aequinoctialis*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Lemna minor*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Lemna perpusilla*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Lemna trisulca*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Wolffia arrhiza*	LC
Tracheophyta	Liliopsida	Arales	Lemnaceae	*Wolffia microscopica*	DD*
Tracheophyta	Liliopsida	Commelinales	Commelinaceae	*Commelina longifolia*	LC*
Tracheophyta	Liliopsida	Commelinales	Commelinaceae	*Commelina undulata*	LC*
Tracheophyta	Liliopsida	Commelinales	Commelinaceae	*Cyanotis axillaris*	LC
Tracheophyta	Liliopsida	Commelinales	Commelinaceae	*Murdannia nudiflora*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Actinoscirpus grossus*	LC
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus alopecuroides*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus articulatus*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus cephalotes*	LC
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus compressus*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus corymbosus*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus difformis*	LC
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus exaltatus*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus haspan*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus iria*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus laevigatus*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Cyperus platystylis*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Eleocharis dulcis*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Eleocharis palustris*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Fimbristylis dichotoma*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Fimbristylis woodrowii*	DD*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Lipocarpha squarrosa*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Pycreus pumilus*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Schoenoplectiella articulata*	LC*
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Schoenoplectiella erecta*	NA
Tracheophyta	Liliopsida	Cyperales	Cyperaceae	*Schoenoplectiella supina*	DD*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Arundo donax*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Brachiaria mutica*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Brachiaria reptans*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Coix aquatica*	LC*

Phylum	Class	Order	Family	Binomial	IUCN Red List Category
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Echinochloa colona*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Hygroryza aristata*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Imperata cylindrica*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Leersia hexandra*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Panicum paludosum*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Paspalidium flavidum*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Paspalidium geminatum*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Paspalum distichum*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Paspalum scrobiculatum*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Phragmites karka*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Pseudoraphis minuta*	DD*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Pseudoraphis spinescens*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Sacciolepis interrupta*	LC*
Tracheophyta	Liliopsida	Cyperales	Gramineae	*Sacciolepis myuros*	NA
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Blyxa aubertii*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Blyxa octandra*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Hydrilla verticillata*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Hydrocharis dubia*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Najas graminea*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Najas kurziana*	DD*
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Najas marina*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Najas minor*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Nechamandra alternifolia*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Ottelia alismoides*	LC
Tracheophyta	Liliopsida	Hydrocharitales	Hydrocharitaceae	*Vallisneria spiralis*	LC
Tracheophyta	Liliopsida	Juncales	Juncaceae	*Juncus bufonius*	LC
Tracheophyta	Liliopsida	Juncales	Juncaceae	*Juncus concinnus*	DD*
Tracheophyta	Liliopsida	Juncales	Juncaceae	*Juncus inflexus*	LC
Tracheophyta	Liliopsida	Juncales	Juncaceae	*Juncus prismatocarpus*	LC
Tracheophyta	Liliopsida	Liliales	Amaryllidaceae	*Crinum viviparum*	LC
Tracheophyta	Liliopsida	Liliales	Pontederiaceae	*Monochoria hastata*	LC
Tracheophyta	Liliopsida	Liliales	Pontederiaceae	*Monochoria vaginalis*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton crispus*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton lucens*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton nodosus*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton octandrus*	LC
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Potamogeton perfoliatus*	LC*
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Ruppia maritima*	LC

Phylum	**Class**	**Order**	**Family**	**Binomial**	**IUCN Red List Category**
Tracheophyta	Liliopsida	Najadales	Potamogetonaceae	*Stuckenia pectinata*	LC
Tracheophyta	Liliopsida	Typhales	Typhaceae	*Typha angustifolia*	LC
Tracheophyta	Liliopsida	Typhales	Typhaceae	*Typha domingensis*	LC
Tracheophyta	Liliopsida	Typhales	Typhaceae	*Typha elephantina*	LC
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Centella asiatica*	LC*
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Oenanthe stolonifera*	DD*
Tracheophyta	Magnoliopsida	Apiales	Umbelliferae	*Oenanthe thomsoni*	DD*
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Artemisia scoparia*	LC*
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Caesulia axillaris*	LC
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Enydra fluctuans*	LC
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Ethulia conyzoides*	LC
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Grangea maderaspatana*	LC
Tracheophyta	Magnoliopsida	Asterales	Compositae	*Vicoa vestita*	NA
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Cochlearia flava*	LC*
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Nasturtium officinale*	LC*
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Rorippa indica*	LC*
Tracheophyta	Magnoliopsida	Capparales	Cruciferae	*Trochiscus cochlearioides*	DD*
Tracheophyta	Magnoliopsida	Euphorbiales	Euphorbiaceae	*Phyllanthus reticulatus*	LC*
Tracheophyta	Magnoliopsida	Fabales	Leguminosae	*Aeschynomene aspera*	LC
Tracheophyta	Magnoliopsida	Fabales	Leguminosae	*Aeschynomene indica*	LC
Tracheophyta	Magnoliopsida	Fabales	Leguminosae	*Alysicarpus bupleurifolius*	DD*
Tracheophyta	Magnoliopsida	Fabales	Leguminosae	*Neptunia oleracea*	LC
Tracheophyta	Magnoliopsida	Fabales	Leguminosae	*Sesbania procumbens*	DD*
Tracheophyta	Magnoliopsida	Myrtales	Lythraceae	*Ammannia baccifera*	LC
Tracheophyta	Magnoliopsida	Myrtales	Onagraceae	*Jussiaea perennis*	LC*
Tracheophyta	Magnoliopsida	Myrtales	Onagraceae	*Jussiaea repens*	NA
Tracheophyta	Magnoliopsida	Myrtales	Onagraceae	*Jussiaea suffruticosa*	DD*
Tracheophyta	Magnoliopsida	Myrtales	Onagraceae	*Ludwigia adscendens*	LC*
Tracheophyta	Magnoliopsida	Myrtales	Trapaceae	*Trapa maximowiczii*	DD*
Tracheophyta	Magnoliopsida	Myrtales	Trapaceae	*Trapa natans*	LC
Tracheophyta	Magnoliopsida	Nepenthales	Droseraceae	*Aldrovanda vesiculosa*	LC*
Tracheophyta	Magnoliopsida	Nepenthales	Droseraceae	*Drosera burmanni*	LC
Tracheophyta	Magnoliopsida	Nepenthales	Droseraceae	*Drosera indica*	LC
Tracheophyta	Magnoliopsida	Nymphaeales	Ceratophyllaceae	*Ceratophyllum demersum*	LC
Tracheophyta	Magnoliopsida	Nymphaeales	Nymphaeaceae	*Euryale ferox*	LC
Tracheophyta	Magnoliopsida	Nymphaeales	Nymphaeaceae	*Nymphaea lotus*	LC*
Tracheophyta	Magnoliopsida	Nymphaeales	Nymphaeaceae	*Nymphaea nouchali*	LC
Tracheophyta	Magnoliopsida	Nymphaeales	Nymphaeaceae	*Nymphaea pubescens*	LC
Tracheophyta	Magnoliopsida	Nymphaeales	Nymphaeaceae	*Nymphaea rubra*	LC

Phylum	Class	Order	Family	Binomial	IUCN Red List Category
Tracheophyta	Magnoliopsida	Plantaginales	Plantaginaceae	*Plantago major*	LC*
Tracheophyta	Magnoliopsida	Podostemales	Podostemaceae	*Hydrobryum griffithii*	LC
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Persicaria barbatum*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Persicaria glabrum*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Persicaria hydropiper*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Persicaria orientalis*	LC*
Tracheophyta	Magnoliopsida	Polygonales	Polygonaceae	*Polygonum pulchrum*	NA
Tracheophyta	Magnoliopsida	Ranunculales	Ranunculaceae	*Ranunculus natans*	DD*
Tracheophyta	Magnoliopsida	Ranunculales	Ranunculaceae	*Ranunculus sceleratus*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Acanthaceae	*Cardanthera difformis*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Acanthaceae	*Hygrophila auriculata*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Acanthaceae	*Hygrophila pinnatifida*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Acanthaceae	*Hygrophila polysperma*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Acanthaceae	*Hygrophila serpyllum*	NA
Tracheophyta	Magnoliopsida	Scrophulariales	Acanthaceae	*Hygrophila spinosa*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia aurea*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia bifida*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia brachiata*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia exoleta*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia furcellata*	NA
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia hirta*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia inflexa*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia minutissima*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia polygaloides*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia scandens*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia stellaris*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Lentibulariaceae	*Utricularia striatula*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Dopatrium junceum*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Dopatrium lobelioides*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Ilysanthes parviflora*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Limnophila aquatica*	DD*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Limnophila aromatica*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Limnophila heterophylla*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Limnophila indica*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Limnophila racemosa*	NA
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Limnophila rugosa*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Lindernia crustacea*	LC
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Mazus japonicus*	LC*
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Striga euphrasioides*	LC*

Phylum	**Class**	**Order**	**Family**	**Binomial**	**IUCN Red List Category**
Tracheophyta	Magnoliopsida	Scrophulariales	Scrophulariaceae	*Veronica anagallis-aquatica*	LC*
Tracheophyta	Magnoliopsida	Solanales	Convolvulaceae	*Ipomoea aquatica*	LC*
Tracheophyta	Magnoliopsida	Solanales	Convolvulaceae	*Ipomoea carnea*	LC*
Tracheophyta	Magnoliopsida	Solanales	Hydrophyllaceae	*Hydrolea zeylanica*	LC

Section 4

Freshwater ecosystem services and biodiversity values of the Dakrong River, Quang Tri, Viet Nam.

Freshwater ecosystem services and biodiversity values of the Dakrong River, Quang Tri, Viet Nam

Work Package 3 report:

Highland Aquatic Resources Conservation and Sustainable Development (HighARCS)

Research Institute for Aquaculture No.1
RIA1 Co-ordinator: Nguyen Thi Dieu Phuong
And research team: Nguyen Thi Hanh Tien,
Do Van Thinh,
Nguyen Thi Trang,
Nguyen Hai Dang
October 2011

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1. Introduction

1.1. Report aims and outline

The project "Highland Aquatic Resources Conservation and Sustainable Development" (HighARCS) has been funded by the European Commission and coordinated by interdisciplinary Centre for Environment and Society, University of Essex. Involving ten partners from Europe and Asia the project is scheduled to run from Jan 2009 to Dec 2013. The projects main aim is to value five wetland sites across Asia using an interdisciplinary approach, and develop action plans to ensure aquatic resources are conserved and used sustainably. Five study sites have been identified through the projects first phase, which include three villages on the Beijiang River, Guangdong, China; three lakes in Uttarakhand, India; Buxa, West Bengal, India; and Quang Tri in central Viet Nam; and Son La in northern Vietnam.

The project comprises a set of nine work packages divided into three phases. Phase 1 is an interdisciplinary analysis (incorporates Work Package 1 – Situation appraisal) that identifies the sites for the project to focus on. Phase 2 is an assessment of ecosystem functioning, livelihoods dependent on highland aquatic resources and associated social and institutional issues at the sites and the development of integrated action plans (WP3 - Ecosystem services and biodiversity values; WP4 - Highland aquatic resources and livelihoods; WP5 - Stakeholders, institutions and markets). Phase 3 is the implementation and monitoring of the action plans developed in Phase 2 (WP 6 - Conserving ecosystems services and biodiversity values; WP 7 - Sustainable highland aquatic resources development and livelihoods; WP8 - Policy development to support conservation and wise-use). This report is part of WP3 and presents the findings of the assessment of biodiversity and ecosystem services found at Dakrong Commune, Dakrong District, Quang Tri Province.

The HighARCS project is following an *integrated* approach to assessing the 'value' of the aquatic systems at the sites. This methodology, defined by IUCN in the *Integrated Wetland Assessment Toolkit* the 'Toolkit' (Springate-Baginski *et al.* 2009), combines biodiversity, livelihoods and economic assessments from the planning stage through to the development of recommendations, rather than as separate assessments that can end up with contradictory conclusions (see Figure 1). An integrated approach captures the inter-linkages and connectivity between wetlands and livelihoods in an efficient way and reduces biased recommendations towards any of the different sectors. While this report deals with the biodiversity and ecosystem services, the data collection from Phase 2 of the project has been integrated, and the resulting action plan that will be produced will address biodiversity, livelihood and policy issues together.

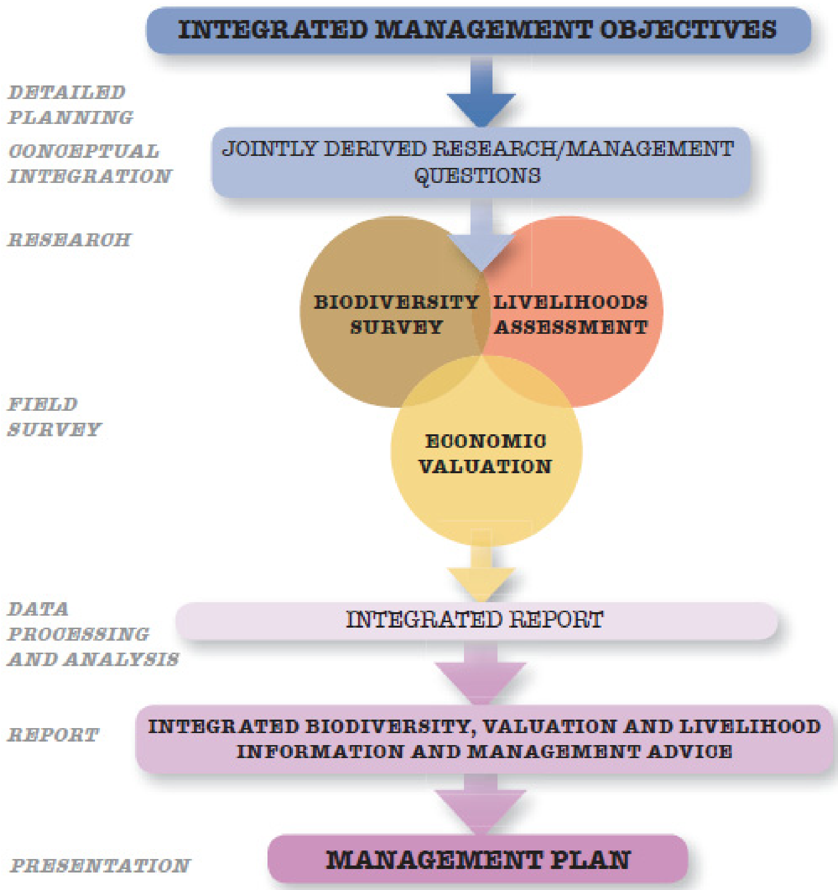

Figure 1. Integrated assessment approach from Springate-Baginsky *et al.* (2009)

The specific aims of the assessment work presented in this report is to:
-identify ecosystem services and biodiversity supported by highland aquatic resources;
-evaluate stakeholder ecosystem service priorities;
-recommend potential management options for conservation, sustaining ecosystem services, resolving conflicts and ensuring sustainable and wise-use of highland aquatic resources.

This information will be used to formulate the Integrated Action Plans in consultation with the stakeholder groups.

1.2. Background

Quang Tri Province is 600km from Hanoi and is located 160^{0}18' – 170^{0}10' north and 106^{0}32' – 107^{0}24' east in the central region of Vietnam. Lying to the north is Quang Binh Province, and the south is Hue Province, and Lao P.D.R. has a 186.8km long shared border to the west. The geography of Quang Tri is varied including mid-range mountains, hills and coastal areas. Total areas is 4746 km^2 (Institute of

Science and Technology and People's Committee of Quang Tri, 2007). There is one city, one town and 8 districts in Quảng Trị (Quang Tri Statistical yearbook 2010a). One of these districts is Dakrong, a high mountainous district in the southwest of Quang Tri and was officially established on 1st January 1997 (The Vietnamese Government 1996). Dakrong is located at 160^{0}17'55" to 160^{0}49'12" north latitude and 106^{0}44'01" to 107^{0}14'15" east longitude. Dakrong has a total areas of 1,223.3 km^2, and contains 1 town and 13 communes (Quang Tri Statistical Office, 2010a).

Three communities within the Dakrong commune that rely upon the Quang Tri River and its tributary the Dakrong River constitute the project site (Figure 2). This commune was officially recognized as a 'highland commune' by decision No 21/UB-QD date 26 January 1993 signed by the Minister and chairman of the Committee for Ethnic Minorities. Aquatic resources in the Dakrong River are declining due to the impacts of hydropower dams, deforestation, gold mining and overfishing which is impacting the livelihoods of the communities. For more information on the background of Dakrong site, including the social and natural setting of the commune please see the Work Package 1 report "Situation analysis report on highland aquatic resource and sustainable development in Northern and Central Vietnam" (Nguyen *et al.* 2010)

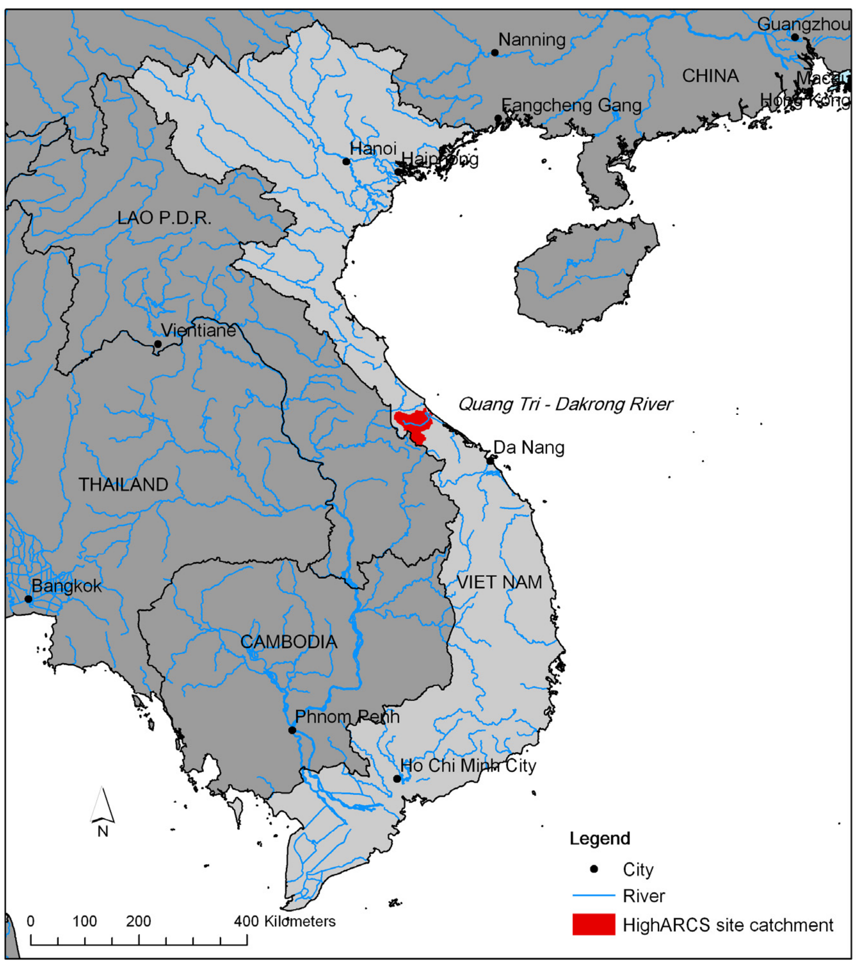

Figure 2. The location of the Quang Tri and Dakrong river catchment in central Vietnam

2. Site maps

Maps of the site and catchment are important as they allow the results of this Work Package to be put into a geographic context. They will not only allow detailed information to be presented in an easy to understand format, but they will also be key in developing the IAP and identifying any potential indicators and monitoring plans. Site and catchment maps have been produced by IUCN, through the digitising of satellite images (Landsat imagery provided by the US Geological Survey - Earth Explorer) using ESRI ArcInfo geographic information systems (GIS) software. Then, through a mapping workshop held on 23-24 August, 2011 at the South China Agricultural University, Guangzhou, China, the maps were reviewed, edited and land classifications were identified by RIA1 staff based on their knowledge and field observations taken while at the site.

The three selected communities (Kalu, Chan Do and Cupua) within the Dakrong Commune, are situated along a 20km stretch of the Quang Tri River halfway up the watershed just below the confluence of the Dakrong River with the Rao Quan River in the foot hills of the Truong Son mountain range (Figure 3). The Rao Quan River flows from Huong Hoa District whilst the Dakrong River originates in the Truong Son mountain range in the south of the Dakrong District. The majority of the land cover upstream to the south is forest partially protected by the Dakrong Nature Reserve, with patches of agriculture, but upstream to the north is predominantly agriculture and shrub with some settlements. Large areas of developed land (urban and managed wetlands) are found downstream, and particularly along the costal areas.

The Dakrong River is characterised by a high gradient and high speed flow that floods seasonally. At the site villages, river habitats are varied and the water level is strongly influenced by the weather conditions. In some sections, particularly around Cu Pua there are sections of fast flowing water that is channelled between large rocks, has a sloping gradient and a gravel and rock riverbed (Figure 4). In other sections, the channel is slow flowing with a wide channel and sandy deep pools. On the river banks, vegetation changes from plantation woodland and natural forest on the mountains upstream, to maize cultivations closer to the villages on the sandy banks down to the river itself. Here the river forms a number of braided channels; the south side has a series of rapids with fast flowing water, while the north bank is mostly shallow and slow with many stagnant pools. However, the river floods during the wet season or when the hydropower station in Rao Quan (Huong Hoa District) discharges water and the water becomes brown and sediment heavy after flooding.

Fast flowing water over large rocks © Fraser Sugden

Slow flowing river, deep pools with sandy beds © Nguyen Thi Hanh Tien

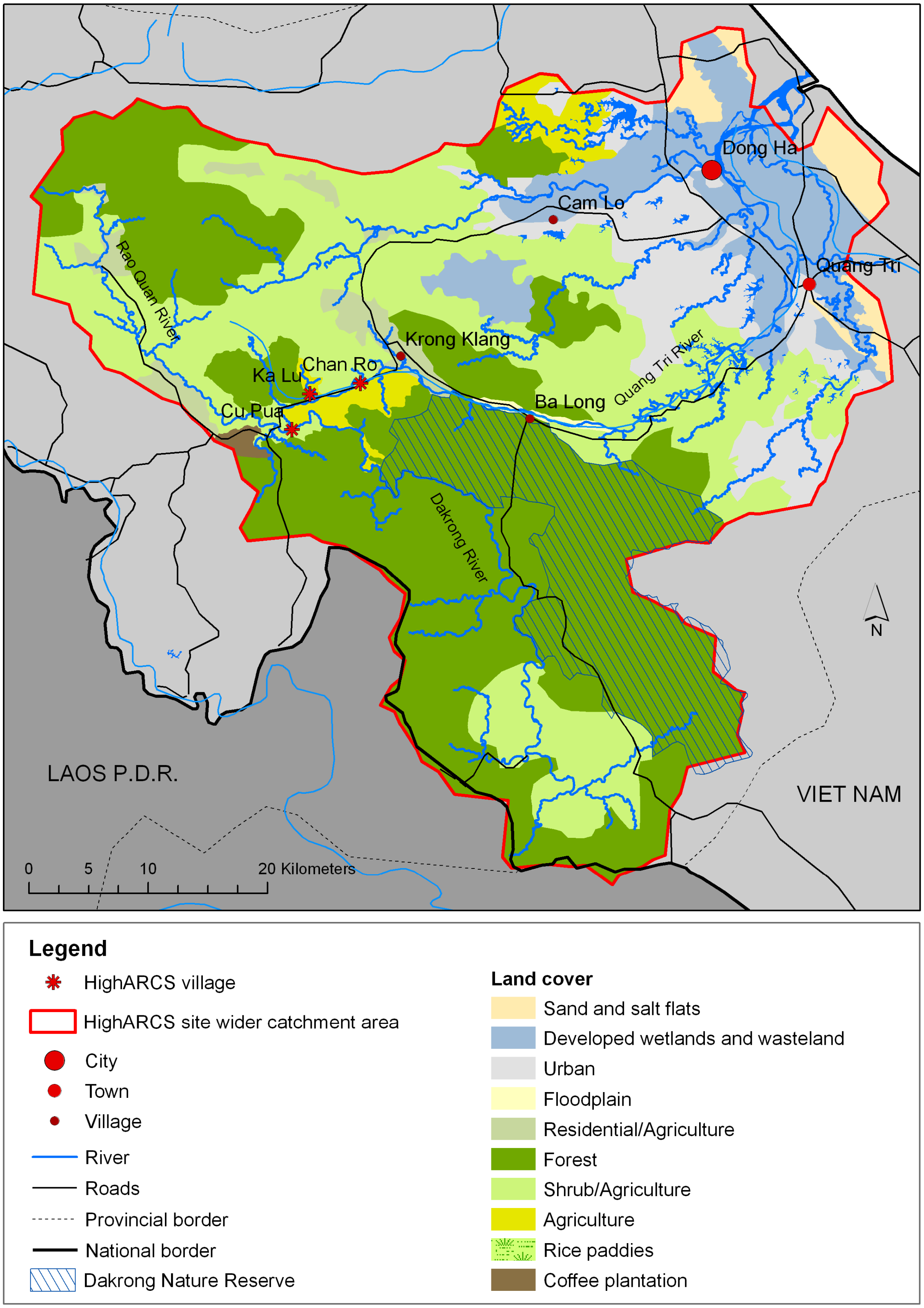

Figure 3. Map of the Dakrong river catchment showing the HighARCS communities and land cover types

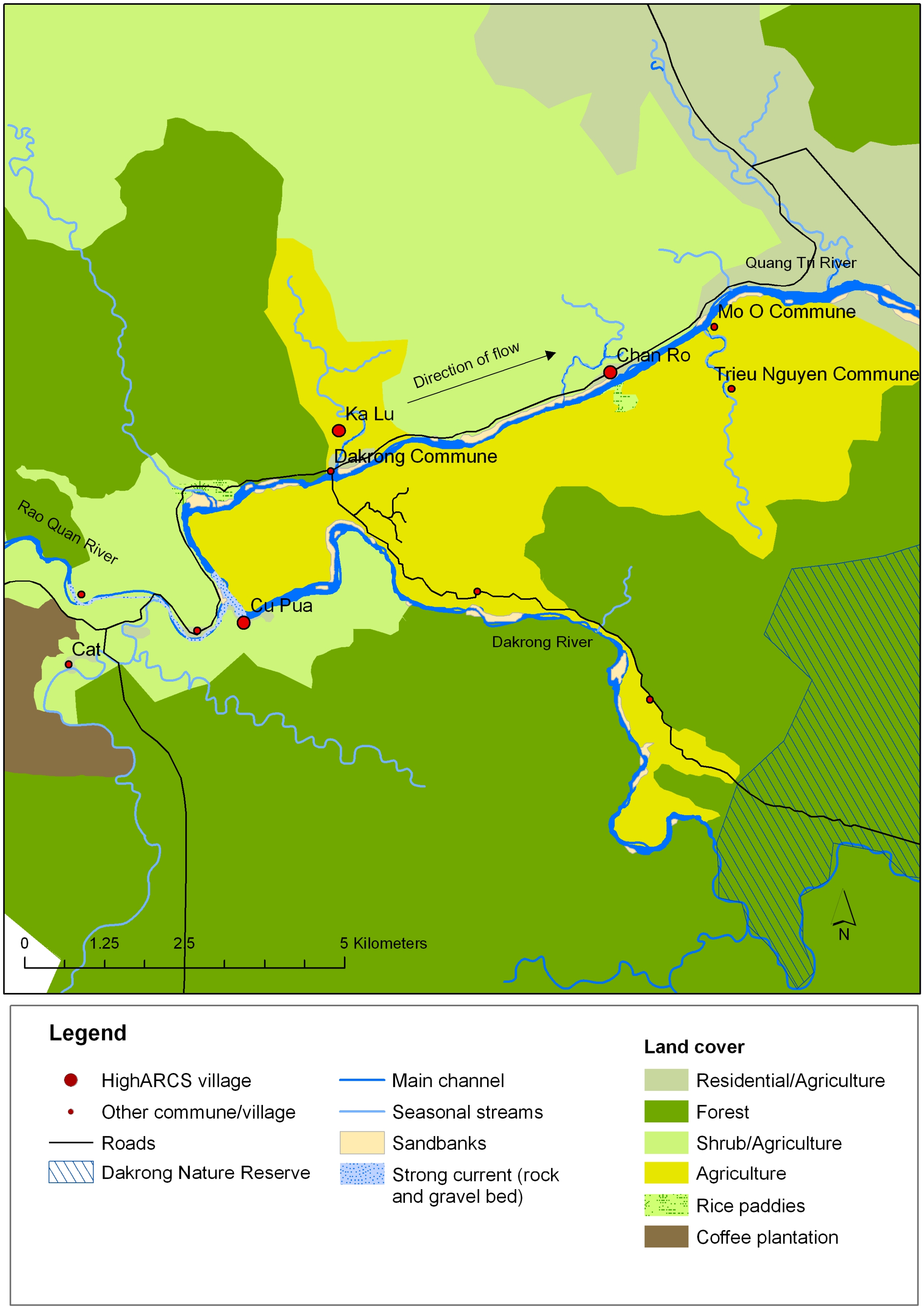

Figure 4. Map of the HighARCS Quang Tri study site showing the villages and land cover types

3. Biodiversity surveys

3.1. Taxonomic groups

To inform the Integrated Action Plan, we need to know what aquatic biodiversity is present at the sites and what their conservation status is. However, it is not possible to identify all aquatic biodiversity at the sites due to restricted time, money and scientific expertise. Therefore species need to be identified that can be an indicator of environmental threats at the site and also are of livelihood importance to the local communities. Many aquatic species are present within the Dakrong River at the site such as fish, aquatic plants, molluscs and dragonflies (Odonata). In the Dakrong Commune fish are the most important product harvested from the river providing food and income, dragonflies are not used for any purpose and molluscs and aquatic plants are rarely collected and do not have a direct economic value. According to informal consultations with fishermen at the villages fish resources in the Dakrong River have declined in both quantity and number of species landed. Therefore based the fish species have been chosen as the taxonomic group to survey at the sites for this project. The results will provide suitable indicators for both environmental health and livelihoods, and will help inform the proposed actions in the Integrated Action Plan for the site.

3.2. Conservation status of biodiversity – IUCN Red List assessments

There are several methods of determining species conservation status and the most commonly used tool is the IUCN Red List Categories and Criteria (IUCN 2001), which allows consistency in approach across different taxonomic groups. It helps in determining the relative risk of extinction at a global scale and provides the basis for understanding if a species is Extinct, threatened (Critically Endangered, Endangered or Vulnerable), Near Threatened, of Least Concern, or lacking sufficient basic data for assessment (Data Deficient) (see Figure 5). The IUCN Red List of Threatened Species™ publishes the results of the global assessments (www.iucnredlist.org). The IUCN Red List also provides basic information on species taxonomy, distributions, habitat and ecology, threats, population trends, use and trade, livelihood information, ecosystem services provided, and research and conservation priorities.

Biodiversity experts from the HighARCS project partners, including from RIA1, were trained at a workshop (06-09 June 2009, Kolkata, India) in the use of the IUCN Species Information Service (SIS – the Red List species database), application of the IUCN Red List Categories and Criteria (IUCN 2001) (see Appendix I for a summary of the IUCN Red List Criteria), and Geographic Information Systems (GIS) for digitally mapping species distributions. Following the training workshop, experts collated native species lists of freshwater fishes, dragonflies and damselflies (odonates), freshwater molluscs and aquatic plants for the coastal catchments of northern and central Viet Nam, and input within the SIS, all available information on each species. The required data fields (with standard classification schemes) within SIS are species taxonomy, distribution, habitat and ecology, threats, population trends, use and trade, and research and conservation priorities, Red List Category and rationale. Data gaps were filled and corrections made to the data from another overlapping IUCN project (Freshwater biodiversity assessment of Indo-Burma) which is funded by the Critical Ecosystem Partnership Fund (www.cepf.org). These species were then reviewed at a second workshop (17-22 January 2011, Vientiane, Lao P.D.R.) and via email communications with other species experts after the workshop. The IUCN Indo-Burma project is due to be published in March 2012.

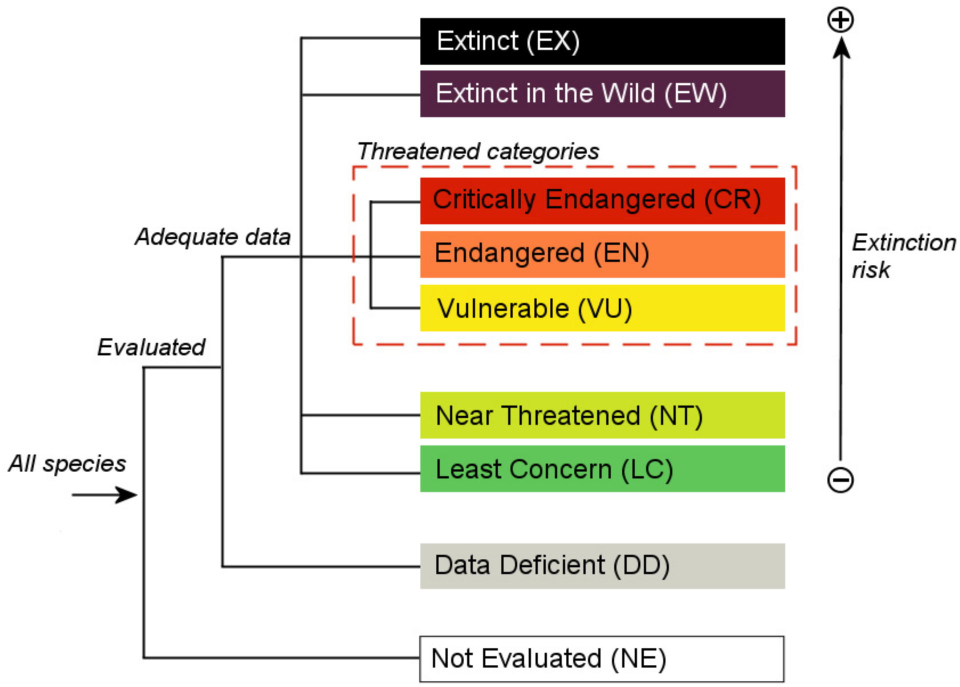

Figure 5. IUCN Red List Categories

While these species will not all be found at the fishing villages, it will allow the actions proposed through the IAP to take into consideration any globally threatened species within the wider catchment if necessary. It will also allow for all the species identified at the site, to be put into a global conservation context. For example a species may be stable and numerous at the site with no known threats and perceived locally as not being of conservation concern, but at a global scale the species may be threatened to impacts elsewhere within the species range, this would make the population at the site of high conservation concern. Alternatively, global conservation status is not the only aspect to identify important species at the site. A species may be of Least Concern globally but may be undergoing severe declines at the site and may also be of economic and livelihood concern and would therefore potentially qualify as a species to be incorporated into the IAP.

The resulting dataset allows 198 fish species found within northern and central Viet Nam coastal catchments, a list of these species with their IUCN Red List Category can be found in Appendix II. An extract of the globally threatened species can be found in Table 1. There are two threatened species, *Bangana tonkinensis* (VU) which is found in northern Viet Nam in Ba Be Lake (Sung 1998) and Ngoi-Thia river (Kottelat 2001) and in Yunnan in China all within the Hong River catchment (Red River) and *Pseudohemiculter dispar* which is found in northern and southern Viet Nam, southern China and in the Mekong in Lao P.D.R. Both of these species are impacted by pollution from agriculture, industry and urban areas and dams which has led to an estimated population decline in both species of more than 30% over the past 10 years (Jenkins, Kullander and Tan 2009a,b).

Table 1. Globally threatened (those listed as Critically Endangered, Endangered and Vulnerable) and Extinct species found within northern and central Viet Nam.

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Order	Family	Binomial	IUCN Red List category
Cypriniformes	Cyprinidae	*Bangana tonkinensis*	VU
Cypriniformes	Cyprinidae	*Pseudohemiculter dispar*	VU

3.3. Literature review

Quang Tri is widely regarded as one of the most picturesque provinces within the central Truong Son Range and is reputed to support outstanding biodiversity and landscape values. Central Truong Son has a high level of endemism and distinctiveness largely resulting from the complex topography (Dickinson *et al.* 2006).

The taxonomic literature for fish of Central Vietnam is limited (WWF 2006a). However, there have been relatively recent surveys of fish fauna in the neighbouring province (to the south of Quang Tri) of Thua Thien Hue: the WWF Green Corridor Project in the central Truong Son Range; Huong River (large river and lagoons); Bach Ma National Park (see WWF 2006a,b,c). At the Green Corridor Project in the central Truong Son Range, 79 species were recorded, 22 of which were of economic importance and fish populations and catches were declining, severely in some species (e.g. *Anguilla marmorata*) and two species were listed on the Red Book of Viet Nam (2000) *Anguilla marmorata* (Rare) and *Onychostoma laticeps* (Vulnerable).

According to Phu (2006) there has also been a study of the freshwater fish of the Dakrong Nature Reserve (upstream of the HighARCS site) by Mai Dinh Yen *et al.* (2004) which reported 72 fish species. However the full report cannot be obtained meaning that this species list cannot be used to inform this assessment or used to compare against the species found at the HighARCS site.

A comparison of the species numbers between the four surveys from the central Viet Nam region can be seeing in Table 2. It shows that the two surveys from the central Truong Son Range contain a similar number of species, although the Dakrong site has a higher diversity of orders and families. The most diverse is the Huong River, with almost twice the number of species than the other surveys.

Table 2. Fish species from the different fish surveys in the region (WWF 2006)

Area	Order	Family	Species	Author
Green Corridor area	5	13	79	WWF, 2006
Bach Ma National Park	6	17	57	Vo Van Phu, 2004
Huong river fresh water fish	13	43	121	Vo Van Phu, 2005
Dakrong Nature Reserve	9	17	72	Mai Dinh Yen, 2004

3.4. Fish Field surveys

While there are existing data concerning the fish diversity from Dakrong Nature Reserve and neighbouring districts, the literature did not provide the list of species for the part of the river used by the HighARCS villages. The species identified from the literature (in particular from Dakrong the Green Corridor Project) are expected to be found in HighARCS study sites but we need to identify the commonly caught species that are important for the livelihoods of local people or species commonly found in the HighARCS site, therefore field surveys were undertaken to fill these data gaps.

3.4.1. Methods

Fish specimens from the site were collected by buying fish from Krong Klang market on 21-23 March and 24 April 2011, only fish were collected if the seller identified the origin as the Dakrong river. Fish were also collected through the monitoring of fish catches of the fishermen along the river from Cu Pua to Chan Do village (using nets) on 22 March 2011. Also formalin bottles were given to 9 fishermen households (three fishermen in each village), and the fishermen were asked (after training) to keep samples which they caught from the fishing grounds in their villages. Specimens were collected using this method from January to June 2011 in Cu Pua, Chan Do, Ka Lu village. Fish specimens were fixed in formalin and photographed (see Annex III). The identification of which species were economically important and information on population trends was done through consultation with the fishermen at the site.

The collected samples were identified by RIA1 staff using Vietnamese fish fauna books including Mai Dinh Yen (1978, 1992), Tran Thi Thu Huong (1993), Nguyen Van Hao and Ngo Sy Van (2001) Nguyen Van Hao (2005) and Kottelat (2001); Chinese fish fauna by Chu *et al.* (1989, 1990), Amon (1986) and Pan (1991), Cambodian fish fauna by Rainboth (1996) and Lao fish fauna by Kotlelat (2001). Furthermore to confirm species identification, samples collected at the site were compared with the standard samples at the fish museum of RIA1 by Mr Nguyen Van Hao, the RIA1 expert ichthyologist regarding fish identification. The systematics followed was from the Vietnamese Freshwater Fish by Nguyen Van Hao (2001, 2005).

Photographing and fixing fish samples in the field © Fraser Sugden

Fish surveying with local fishermen in the Dakrong river © Fraser Sugden

Market survey at KrongKlang market © Nguyen Thi Hanh Tien

3.4.2. Results

The results show that there are 38 fish species identified belonging to 26 genera, 9 families and 5 different orders (Tables 3 & 4, Figure 6). The family Cyprinidae showed the highest diversity with 19 species (50%), followed by Gobiidae with 6 species (16%) and Balitoridae (4 species, 10%).

Table 3. Fish composition of the Dakrong River by Order.

Order	Families	Genera	Species
Anguilliformes	1	1	1
Cypriniformes	3	18	25
Siluriformes	2	2	2
Synbranchiformes	1	1	2
Perciformes	2	4	8
Total	**9**	**26**	**38**

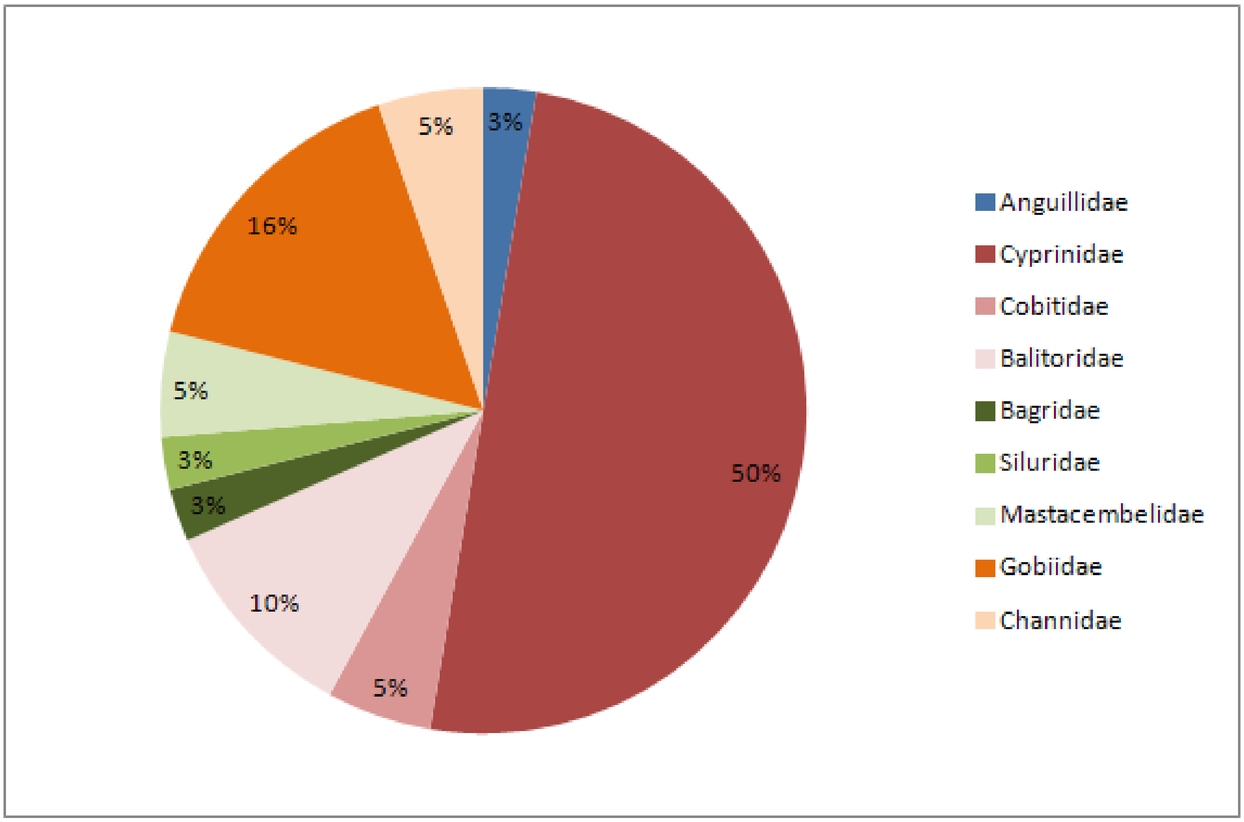

Figure 6. Fish species composition of the field survey in the Dakrong River by family
(Blue = Anguilliformes, Red = Cypriniformes, Green = Siluriformes, Orange = Perciformes)

Of the 38 species identified 13 could only be identified to their genus, however they have been confirmed as likely to be separate species and five of which (*Acrossocheilus* sp3, *Spinibarbus* sp, *Channa* sp1, *Channa* sp2 and *Cryptrocentrus* sp) are possibly new species to science. The total of 38 species is also likely to be an under representation of the true diversity of fish species present at the site, based on the findings from similar habitats from the Dakrong Nature Reserve (72 species) and within the Truong

Son Range Green Corridor area in Thua Thien Hue Province (79 species) (WWF. 2006a). It is possible that some expected fish species were not found this study. This may be due to the effects of past agriculture disturbance or dioxin spraying during the American War (WWF. 2006a) or during the short time of research.

Three species *Anguilla marmorata, Spinibarbus hollandi* and *Onychostoma laticeps* are on the list of 'endangered aquatic species in Vietnam which need protection, reproduction and development' issued by the Ministry of Agriculture and Rural Development (2008) and are all declining in parts of their ranges due to overfishing and in the case of *A. marmorata* dams also. There are no globally threatened fish species, although one species *Onychostoma gerlachi* is assessed as Near Threatened based on population declines caused by dams and pollution across its range in Indo-Burma. There are however six Data Deficient species, and a DD listing does not mean a species is not threatened, and many of these species are known to be declining but information is lacking in order to identify a rate of decline needed to place it in a Red List category (e.g. *Squalidus argentatus* and *Onychostoma laticeps*). Also eight species are known to be declining, and three species are rapidly declining at the site, all apart from one have economic value to the local communities. Fifteen species in total have been identified as economically exploited fish species, of which 7 species have high value. These high value species are *Anguilla marmorata* (rapidly declining), *Arossocheilus sp1*, *Spinibarbus hollandi* (rapidly declining), *Onychostoma laticeps* (rapidly declining), *Neolisschilus stracheyi*, *Cyprinus carpio*, *Mastacembelus armatus* and *Channa sp2*. Only one species in the survey, *Cyprinus carpio* is not native to the catchment, however it too is declining and is important to livelihoods, its negative impacts to the native species at the site is unknown. It is recommended to carry out further data on quantity, classified species, categorization, and detailed descriptions of form, biological and genetic characteristics of fish fauna in this area. Thus, it will allow new species to be published, adding more species to the known fish composition of the area (WWW 2006a).

Table 4. Fish species identified from the Dakrong River through field surveys.
The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Family	Binomial	Common name	National Red List status	IUCN Red List status	Economic importance	Population trends at the site
Anguillidae	*Anguilla marmorata*	*Cá Chình hoa*	VU	LC	High value economic species	Rapidly declining
Cyprinidae	*Opsariichthys bidens*	*Cá Cháo*		LC*		
Cyprinidae	*Nicholsicypris normalis*	*Cá Dầm đất suối*		LC* (as *Yaoshanicus*)		
Cyprinidae	*Hemiculter leucisculus*	*Cá Mương*		LC		
Cyprinidae	*Microphysogobio*	*Cá Đục*		LC		

Family	Binomial	Common name	National Red List status	IUCN Red List status	Economic importance	Population trends at the site
	kachekensis	*đanh chấm*				
Cyprinidae	*Microphysogobio yunnanensis*	*Cá Đục đanh chấm mõm ngắn*		DD		
Cyprinidae	*Squalidus argentatus*	*Cá Đục trắng*		DD		
Cyprinidae	*Acrossocheilus sp1*	*Cá Chát đuôi chấm*		-	High value economic species	
Cyprinidae	*Acrossocheilus sp2*	*Cá Chát xám*		-	Economic species	
Cyprinidae	*Acrossocheilus sp3*	*Cá Chát vây đen*		-	Economic species	
Cyprinidae	*Spinibarbus hollandi*	*Cá Chày đất*	VU	DD*	High value economic species	Rapidly declining
Cyprinidae	*Spinibarbus sp*	*Cá Bỗng vây đen*		-	Economic species	
Cyprinidae	*Onychostoma laticeps*	*Cá Sỉnh gai*	VU	DD*	High value economic species	Rapidly declining
Cyprinidae	*Onychostoma gerlachi*	*Cá Sỉnh*		NT	Economic species	Declining
Cyprinidae	*Onychostoma babeensis* Hảo & Hiệp, 2001	*Cá Sỉnh thân cao*		NA	Economic species	Declining
Cyprinidae	*Neolissochilus stracheyi*	*Cá Dầm*		LC	High value economic species	Declining
Cyprinidae	*Garra orientalis*	*Cá Bậu*		LC		
Cyprinidae	*Carassius auratus*	*Cá Diếc*		LC		
Cyprinidae	*Carassioides cantonensis*	*Cá Nhưng*		LC (as *C. acuminatus*)	Economic species	Declining
Cyprinidae	*Cyprinus carpio*	*Cá Chép*		Introduced	High value economic species	Declining
Cobitidae	*Cobitis laoensis*	*Cá Chạch hoa Lào*		LC		
Cobitidae	*Misgurnus anguillicaudatus*	*Cá Chạch bùn*		LC		
Balitoridae	*Schistura fasciolata*	*Cá Chạch suối sọc*		DD		
Balitoridae	*Sewellia sp1*	*Cá Đép thấp*		-		
Balitoridae	*Sewellia sp2*	*Cá Đép cao*		-		
Balitoridae	*Annamia sp*	*Cá vây bằng miền trung*		-		

Family	Binomial	Common name	National Red List status	IUCN Red List status	Economic importance	Population trends at the site
Bagridae	*Hemibagrus centralus*	*Cá Lăng miền trung*		DD*	Economic species	Declining
Siluridae	*Pterocryptis cochinchinensis*	*Cá thèo*		LC		
Mastacembelidae	*Mastacembelus armatus*	*Cá Chạch sông 1*		LC	High value economic species	
Mastacembelidae	*Mastacembelus sp*	*Cá Chạch sông 2*		-		
Gobiidae	*Rhinogobius giurinus*	*Cá Bống khe*		LC* (as *Papuligobius ocellatus*)		
Gobiidae	*Rhinogobius ocellatus*	*Cá Bống chấm*		LC		
Gobiidae	*Rhinogobius sp1*	*Cá Bống trắng*		-		
Gobiidae	*Rhinogobius sp2*	*Cá Bống ngắn*		-		
Gobiidae	*Cryptrocentrus sp*	*Cá Bống sọc ngang*		-		
Gobiidae	*Glossogobius giuris*	*Cá Bống cát*		LC		
Channidae	*Channa sp1*	*Cá Tràu suối quảng trị*		-		Declining
Channidae	*Channa sp2*	*Cá Sộp quảng trị*		-	High value economic species	Declining

3.4.3. Indicator species

In the Dakrong River, several species could be proposed for use as indicators for overharvesting and pollution:

Anguilla marmorata, Spinibarbus hollandi, Onychostoma laticeps: These species are all harvested species with a high economic value. They are rapidly declining at the site and have been listed as VU (2008) by the Viet Nam government. Monitoring the catches of this species over time, and conducting social surveys with fishermen and market holders will allow the species population trend at the site to be monitored.

Hemibagrus centralus: Another economic species that is declining at the site. The species is only known from Viet Nam. Its population doubling time is about 5-14 years making this species highly sensitive to overharvesting. Monitoring the presence of this species at the site, fishermen's catches of this species over time and conducting social surveys with fishermen and market holders will allow the species population trend at the site to be monitored.

Neolissochilus stracheyi: This is an economic species which inhabits clear forested streams and rivers. It requires swift flowing streams, and when the habitat is degraded it is one of the first species to disappear. Monitoring the presence of this species at the site, fishermen's catches of this species over time and conducting social surveys with fishermen and market holders will allow the species population trend at the site to be monitored.

3.4.4. Biodiversity policy

While the legislative framework in Vietnam provides a solid basis for the conservation and sustainable use of biodiversity, implementation is frequently constrained by unclear and overlapping institutional jurisdictions, weak inter-agency cooperation and capacity limitations among government institutions (Wetlands Alliance 2011). The different legislation that is in place that directs the conservation of aquatic biodiversity in Viet Nam can be seen in Table 5. The responsibility for implementing the legislation is divided between different ministries (including the Ministry of Agriculture and Rural Development (MARD), the Ministry of Natural Resources and Environment (MONRE), the Ministry of Fisheries (MOF), and the Ministry of Planning and Investment (MPI)) and also at different levels from central government to Provincial and District. For example in Quang Tri, the Quang Tri People's Committee (Provincial level) have issued a number of documents and proposed implementation plans: Action Plan on Protection of Biodiversity, Biosecurity to 2010 and Orientation to 2020 in Quang Tri province; Direction No 09/CT-UB (1993) on Environment Protection; Direction No 14/CT-UB (1996) on Environmental Impact Assessment Reporting, Decision No 53/2006/QD-UB on Fishery Development Planning to 2010.

Informal interviews carried out with different stakeholder groups in Quang Tri, indicate that the implementation of legal requirements at provincial level is quite good but at district and commune level it is weak due to a lack of qualified staff and capacity. The financial investment for biodiversity conservation is limited which makes implementation of policies difficult and there is neither equipment nor facilities for inspection and monitoring. Also the management and protection of biodiversity is considered a minor task for staff and collaboration between organizations is inefficient and duplication of management functions can hinder implementation. This has led to biodiversity conservation becoming almost abandoned at district and commune levels.

Table 5. Key legislation and decrees influencing conservation of freshwater biodiversity in Viet Nam (sources listed in table)

Legislation / Ministry responsible	Key aims of legislation
The Water Resources Law (1998)	Integrated water resources management. It states "managing, protecting, and rationally, economically and efficiently exploiting the water resource; preventing, combating and overcoming the harmful effect caused by water with a view to ensuring water for living of the people,[…] protecting the environment and serving the sustainable development of the country" (Guignier 2011). Decree 120/2008/NĐ-CP provides a framework assigning powers for river basin management and planning

Legislation / Ministry responsible	Key aims of legislation
Environmental Protection Law in 1993 (amended in 2005)	Regulates public and private activities to protect the environment and establishes the Ministry of Natural Resources and Environment (USAID 2007). It states "as "environmental protection must be in harmony with economic development and assure social advancement for national sustainable development" (Guignier 2011).
Forest Protection and Development Law in 1991 (amended in 2004)	Defines forests into three categories; protection forest, special use forest and production forest. Each category has obligations of both the state and users to manage and protect it (Pham 2005).
The Law on Minerals 1996 (amended in 2006)	Provides the basis for a 'mineral master plan'. Any mining activities in violation of the mineral master plan are prohibited. Decree 160 sets out some elements to be included in master plans (e.g. socio-economic conditions) but they remain in general terms (Freshfields Bruckhaus Deringer 2006).
The Law on Biodiversity (2009)	Provides for the principles of the conservation and use/exploitation of biodiversity. One of the main tenets is to combine conservation with rational exploitation/use of biodiversity and with hunger eradication and poverty alleviation (Guignier 2011). Decision 79/2007/QD-TTg established the National Biodiversity Action Plan up to 2010 and vision to 2020.
Fishery Law in 2003	Empowers resource managers, particularly at the Provincial level, to effectively and sustainably manage their resources. Promotes economic effectiveness in accordance with the protection, rehabilitation and development of fisheries resources and biodiversity and protection of the environment (World Bank 2005). Decree No 27/2005/ND-CP provides detailed guidelines on how to implement the fisheries law.
Land Law in 1993 (amended in 1998 and 2003)	Permitted the State to transfer and lease out land to organizations, households and individuals for long-term stable use, and allowed land users to pass on the right to use land to another user within the duration of the lease. Also approaches the concept of comprehensive management of land resources owned by the state in close connection with environmental protection (Nguyen 2010).
Decree 112/2008/NĐ-CP	Framework for management, protection, integrated exploitation of natural resources and environmental management of irrigation and hydropower reservoirs
Decree 80/2006/ND-CP	Detailed guidelines for implementation of the EIA framework
Decree 109/2003/ND-CP dated 23/9/2003	Detailed guidelines for conservation and sustainable development of wetlands,
Decision 131/2004/QD-TTg	Program for protection and development of aquatic resources, approved by the Prime Minister
Decision 29/2007/QD-TTg	Establishment of fund for renewable aquatic resources in Vietnam

3.5. Inclusion of data in online databases

Data collated through this research will be included in two online species databases; the IUCN Red List (www.iucnredlist.org) and Fishbase (www.fishbase.org).

Through Work Package 1 of this project the fish species from the northern and central Viet Nam basins were assessed against the IUCN Red List categories and criteria and have been published on the Red List website (see section 3.2). Information on the species identified through this workpackage such as new information on species distributions, threats but in particular their utilisation by humans will be added to their Red List assessment and published online with the next IUCN Red List update in 2012. If the information provided is significant it may require the species to be reassessed, changing the species Red List Category.

The information on the fish species utilisation will also be added to the Fishbase online database, under the ‘Human Uses’ tag. For example, the species will be tagged as being ‘Fisheries: minor commercial’ or ‘aquarium: potential’.

4. Threat surveys

The threats to freshwater biodiversity at the site were identified (between April 2010-July 2011) using the focus group discussions including the drawing of maps, through RIA1 researcher site visits and while collating information for other work packages in particular the Delphi results for Work Package 5 (Nguyen Thi Dieu Phuong *et al.* 2011). The Delphi method aims to gather and share information, ideas and viewpoints of all stakeholder groups. The stakeholders include those who manage the aquatic resources, policy makers, researchers and the people who exploit and depend directly upon the aquatic resources at the study site. Please see deliverable 5.2 (Nguyen Thi Dieu Phuong *et al.* 2011) for further details of this research and methods.

The maps are based on those produced for the site and catchment maps and the threats were discussed and drawn by RIA1 staff and IUCN during the mapping workshop held on 23-24 August, 2011 at the South China Agricultural University, Guangzhou, China. The results were then digitised using GIS software by IUCN. The maps will allow the sources of the threats to be identified and the areas impacted, informing the IAP the potential monitoring of proposed actions taken through the project.

The key threats to aquatic resources and biodiversity of the Dakrong River at the HighARCS site have been identified as hydropower dams, deforestation, and water pollution particularly from gold mining.

4.1. Development of hydropower

Four hydropower dams have been proposed along a 50km stretch of the Dakrong River, but by the end of 2011, only three have been constructed; Dakrong 1 in Huc Nghi Commune with the capacity of 12MW, Dakrong 2 (under construction) in Dakrong Commune with the capacity of 14.4 MW, and Darkong 4 (21 MW) in Ta Long Commune. Dakrong 3 (8MW) hydropower dam has not yet been constructed due to financial constraints (Ho Enot, 25/11/2011, personal communication). Also in 2004 the Rao Quan 1 lau roi, 2-h/d 2010 hydroelectric company started building a hydropower dams in Khe Sanh town. Dakrong 1 (Huc Nghi), Dakrong 4 (Ta Long commune) and Rao Quan 1 (Khe Sanh town) dams are all located upstream of the HigARCS villages along the Dakrong river, and Dakrong 2 is located at the HigARCS site. Unfortunately the precise location of these dams could not be mapped. These hydropower stations have created changes in the Dakrong River stream morphology and flow regime, and have led to reduced flow during dry periods. The operation of the dam (water discharges) creates floods downstream destroying stream and marginal habitats (Vietnam Union of Science and Technology Associations 2007) and impacting livelihoods by damaging local community micro-hydropower generators and disrupting river transport. It is not only the impacts of the dams in place that are impacting the site, the construction of new hydropower stations is resulting in habitat loss (as the forest needs to be cut down to open up service links including road and power connections) and increased sedimentation in the rivers impacting water quality. Reports indicate that to enable 1 MW of hydroelectric power generation it is necessary to cut down 10-30 ha of forest (Thanh Huyen 2009).

The construction of Dakrong 2 hydropower station in Dakrong Commune ©Nguyen Thi Hanh Tien

The outcomes of a socio-economic development and rapid poverty reduction project in Dakrong District 2009-2020 indicated that the district should give priority to small scale industrial development, especially mineral exploitation and hydropower. Dakrong district is now planning to open four additional medium and small hydropower stations along the Dakrong river (A Cho hydropower in Huc Nghi commune within the Dakrong Nature Reserve, Ra Lây – Ba Nang, Giang Thoan in Hướng Hiệp commune and Rào Vịnh in Triệu Nguyên commune) to create jobs and increase income for local people and the district (Quang Tri Planning and Investment Department 2011). However by the end of 2011 those medium and small hydropower have not been constructed (Ho Enot, 25/11/2011, personal communication).

4.2. Deforestation

Local people cut forest wood for burning and clear areas to establish fields for planting with crops within the wider catchment of the Dakrong River. Deforestation for hydropower construction has also exacerbated problems of soil erosion. This deforestation is leading to increased levels of sedimentation in the rivers and affecting local hydrology, damaging the habitat of fish species and degrading both biodiversity and aquatic resources (Dakrong People's Committee 2010). Figure 8 shows the areas of deforestation that are impacting the HighARCS villages.

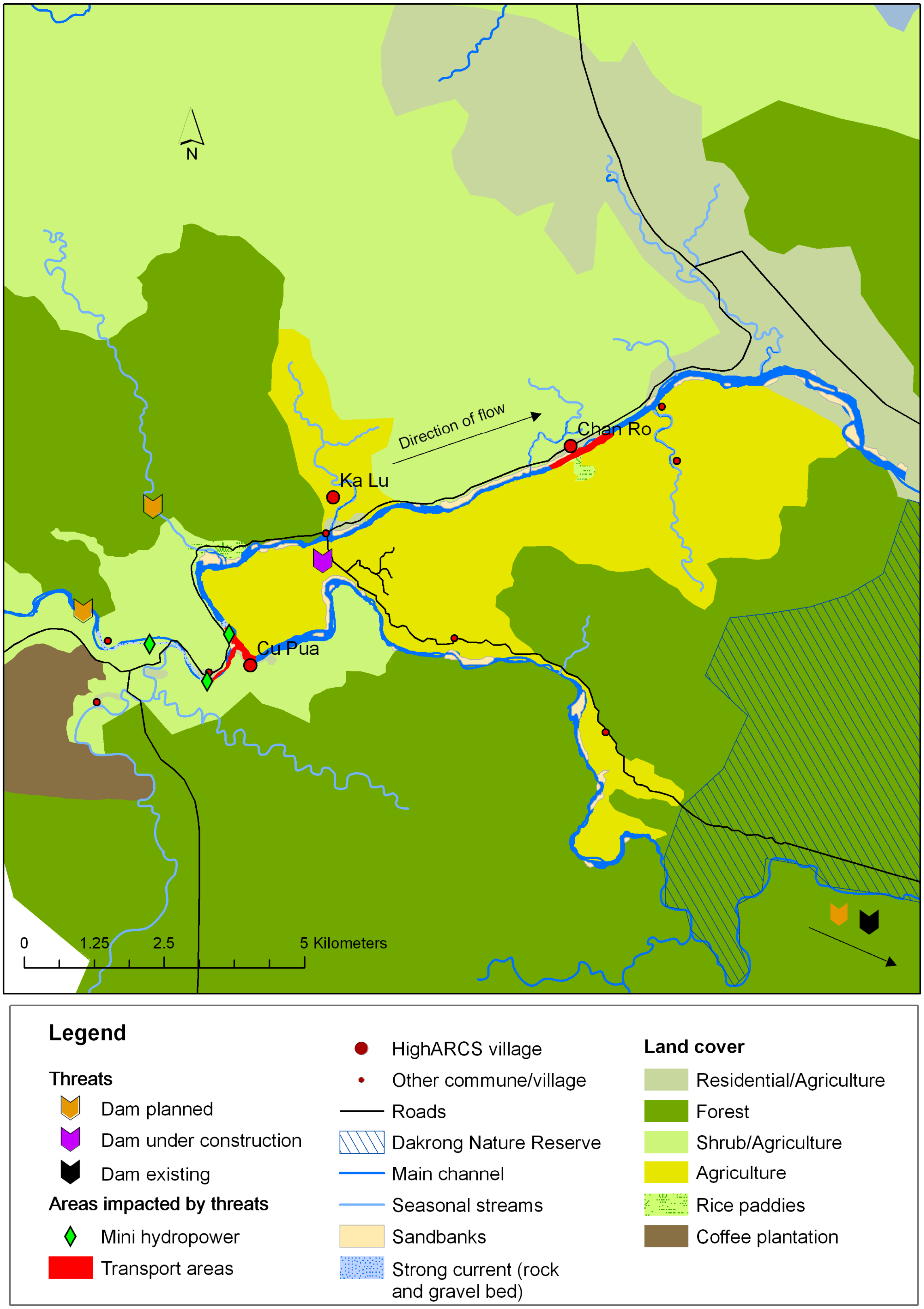

Figure 7. Threats due to hydropower dams

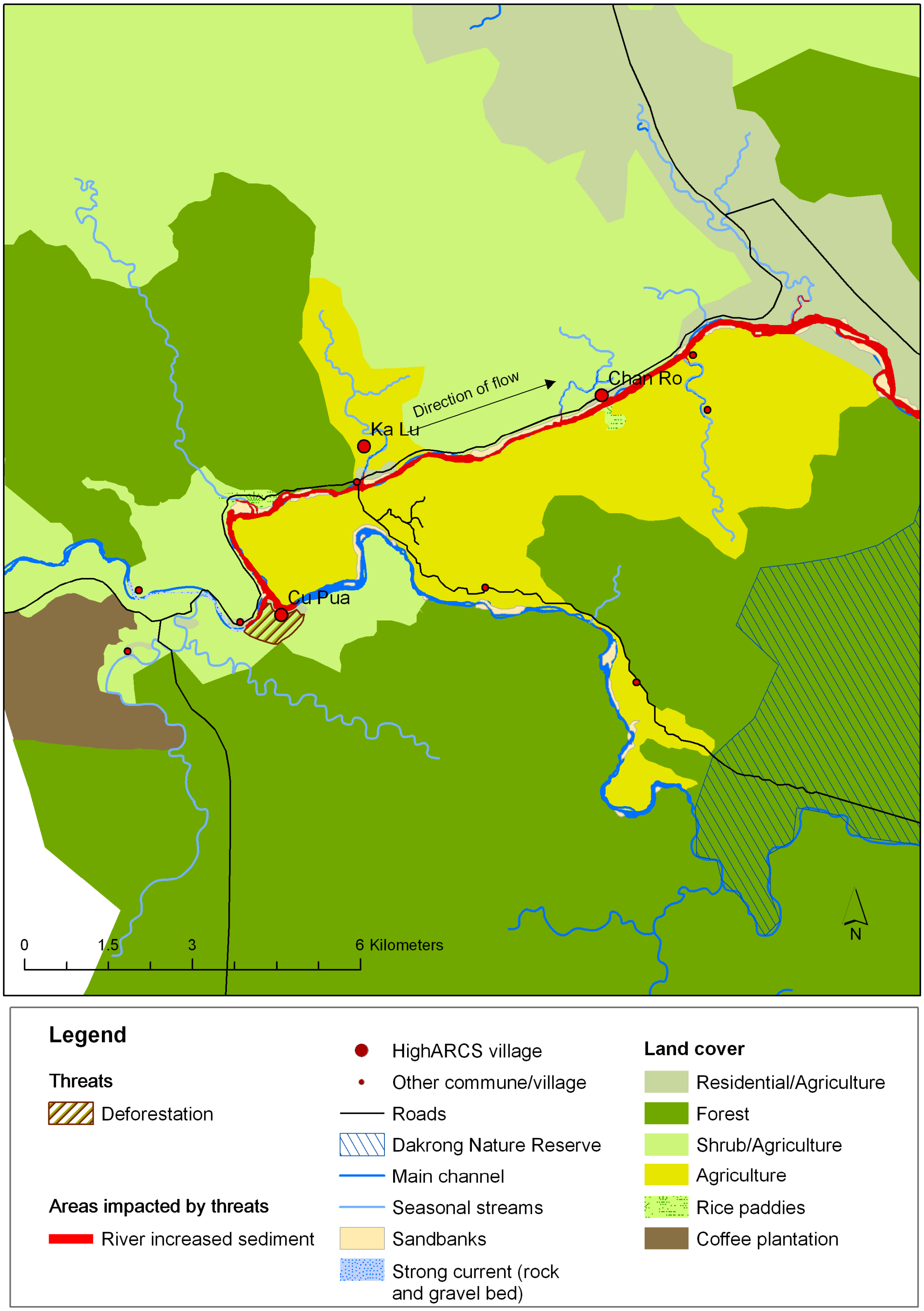

Figure 8. Threats due to deforestation

4.3. Water pollution

The major sources of water pollution (excluding sedimentation see – 4.1 and 4.2) are agricultural chemicals from coffee plantations, domestic waste, and sand and gold mining (Figure 9). Coffee plantations are found upstream of the site villages in Huong Hoa District (the upstream neighbouring community) where agricultural pollutants that are used enter the river. During floods domestic waste enters the river from Khe Sanh town (also in Huong Hoa District) polluting the water downstream. Also Dakrong District has many gold and sand mining operations that bring some benefits in terms of economic development, however they seriously degrade water quality due to the chemicals used in the mining operations and physically destroy terrestrial and aquatic habitats. Illegal gold mining along the Dakrong River was mentioned by 55% of respondents in the Delphi survey as one of the most important threats to biodiversity (Nguyen *et al.* 2011). In addition, Quang Tri was a centre of operations during the American War (1955-1975) and received 350,000 tonnes of bombs. It is estimated that 83% of land area is contaminated by chemicals, notably Agent Orange (Landmines Vietnam 2011). Those toxins have probably impacted biodiversity in Dakrong and will continue to do so in the future.

Sand mining in Kalu village © Nguyen Thi Hanh Tien

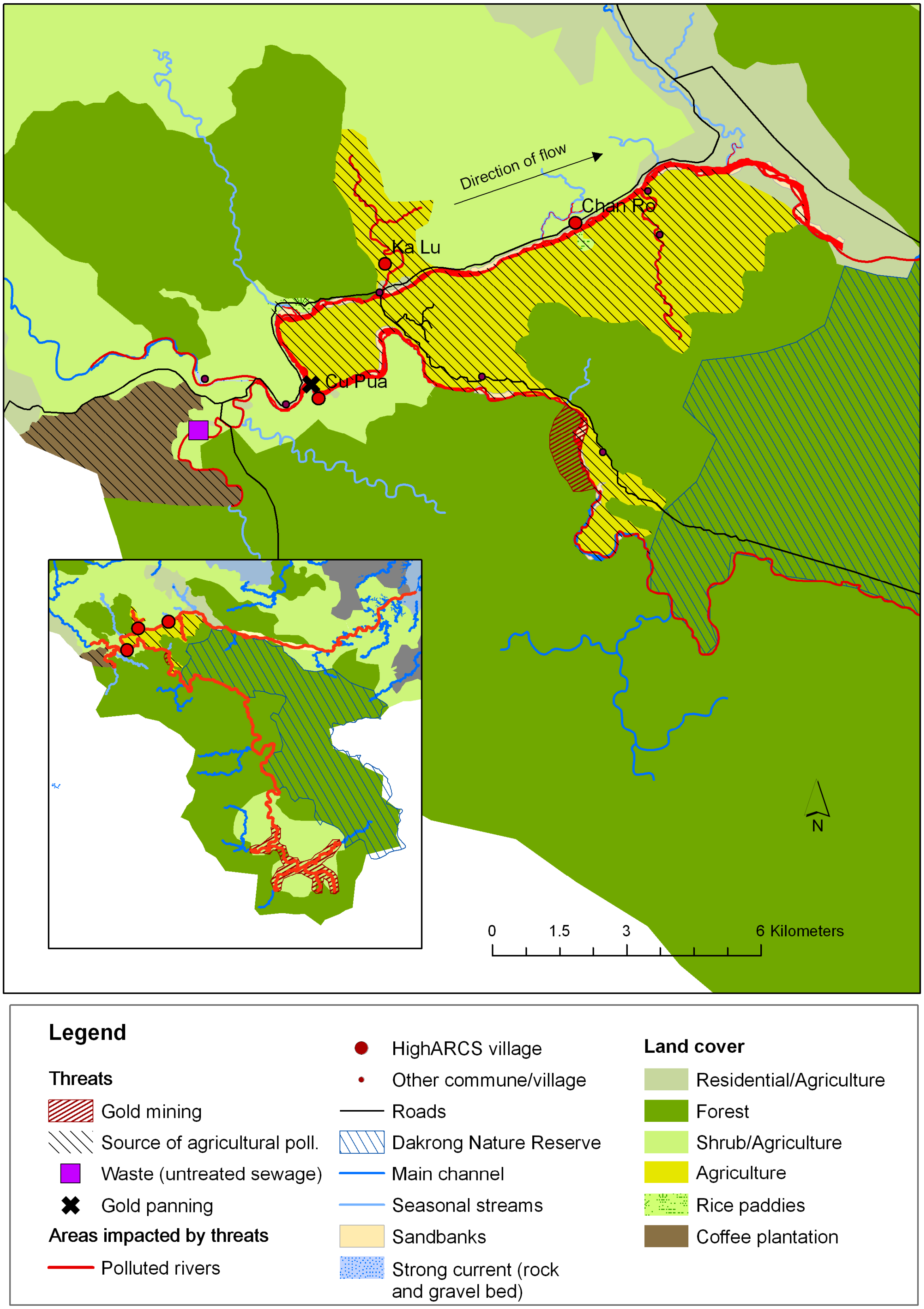

Figure 9. Threats due to water pollution

5. Ecosystem Services

5.1. Types of ecosystem services

People around the world depend upon natural ecosystems to supply a range of services for their survival and well-being. Ecosystem services can be defined as the "benefits people obtain from ecosystems" (Springate-Baginski *et al.* 2009) and are commonly classified as being one of four types: provisioning, regulating, cultural, or supporting (Millennium Ecosystem Assessment 2005). Following this classification Groot *et al*. (2010), identified 22 ecosystem services (Table 6).

Table 6. Typology of ecosystem services (adapted from Groot *et al.* 2010 and Springate-Baginsky *et al.* 2009)

Main service category	Ecosystem service
Provisioning services	Food (e.g. fish, game, fruit) Water (e.g. for drinking, irrigation, cooling) Raw materials (e.g. fibre, timber, fuel wood, fodder, fertilizer) Genetic resources (e.g. for crop-improvement and medicinal purposes) Medicinal resources (e.g. biochemical products, model and test-organisms) Ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion)
Regulating & Supporting services	Air quality regulation (e.g. capturing (fine)dust, chemicals, etc) Climate regulation (incl. C-sequestration, influence of vegetation on rainfall, etc.) Moderation of extreme events (e.g. storm protection and flood prevention) Regulation of water flows (e.g. natural drainage, irrigation and drought prevention) Waste treatment (especially water purification) Erosion prevention Maintenance of soil fertility (including soil formation) Pollination Biological control (e.g. seed dispersal, pest and disease control) Maintenance of life cycles of migratory species (incl. nursery service) Maintenance of genetic diversity (especially in gene pool protection)
Cultural services	Aesthetic information Opportunities for recreation and tourism Inspiration for culture, art and design Spiritual experience Information for cognitive development

5.2. Ecosystem prioritisation

To ensure that all ecosystem services provided by the Dakrong River to all stakeholders are given full recognition within the integrated action planning process a participatory prioritisation exercise has been undertaken.

5.2.1. Methods

To indentify the types of ecosystem services and threats associated with the Dakrong River at the study site, questionnaires were carried out (integrated with WP4) with 91 households in the 3 communities (Kalu, Chan Do and Cu Pua) and 34 focus groups during May and October 2010. The resulting ecosystem services were listed in a second questionnaire (along with the key threats to ecosystem services) and conducted with 26 people that represented to 3 different levels of governance of the resources at the site. Group 1 were those involved in Provincial and District level governance (live outside study site, involved in Province and District level policy making and management); Group 2 were those people involved at Commune level governance (live in study site involved in Commune level decision making, may partly partake in fishing); Group 3 were those individuals at the site villages (fishermen and others relying on freshwater resources within the HighARCS villages). Respondents were asked to score each ecosystem service and threat according to their importance with low numbers indicating lesser importance (1 means lowest important and 5 means highest important).

5.2.3. Results

The services with the highest value (average score) are water purification and water for human use, both scoring 4.8 followed by habitat provision for biodiversity (4.7), water storage and educational value, both scoring 4.5 (Table 7, Figure 10). The lowest average scores were given to water for gold panning (1.7), tourism and fishes/shrimps for commercial use (both scoring 2.8). Regulating services received the higher scores with as all four were given an average score of above 4, whereas only two of the seven provisioning services and four of the six cultural services did the same.

Table 7. Ecosystem service valuation results. average scores by stakeholder group.
Group 1 = Provincial and District level governance; Group 2 = Commune level governance; Group 3 = villagers. Prioritisation score = 1 is lowest value, 5 is highest value.

Category	Eco-system service/*threats*	All	Group 1 n=15	Group 2 n=8	Group 3 n=3
Provisioning services	Fishes/shrimp for commercial use	2.8	2.3	3.0	5.0
	Fishes/shrimp for subsistence use	4.3	3.9	4.9	5.0
	Hydropower (small scale provision for villages)	3.3	3.3	3.4	-
	River transportation	3.6	3.9	3.0	3.3
	Water for gold panning	1.7	1.5	2.0	2.0
	Water for human use	4.8	4.8	4.6	5.0
	Water for livestock	3.2	3.5	2.6	3.0
Average provisioning services score		3.4	3.3	3.4	3.3
Regulating & supporting services	Flood control	4.3	4.9	3.6	3.0
	Habitat provision for biodiversity	4.7	4.9	4.3	5.0
	Water purification	4.8	4.9	4.9	4.7
	Wetland water storage (providing water in dry season)	4.5	4.9	3.9	5.0
Average regulating & supporting services score		4.6	4.9	4.2	4.4
Cultural service	Aesthetic value	4.1	4.5	3.6	3.7
	Educational value	4.5	4.4	4.5	4.7
	Recreation	3.1	2.7	4.0	2.5

	Research value	4.2	4.2	4.3	4.3
	Spiritual value	4.2	4.5	3.8	4.0
	Tourism	2.8	3.1	2.4	2.0
Average cultural service score		3.8	3.9	3.8	3.5
Threats	*Fish/shrimp declines due to river pollution*	4.7	4.8	4.5	4.7
	Water pollution due to Gold/sand mining	4.6	4.9	3.9	4.7
	Floods and high sediment due to hydropower	4.0	4.3	3.3	4.7
	Hydropower stores water causes drought in dry season	4.3	4.3	4.0	5.0
Average threats score		4.4	4.6	3.9	4.8

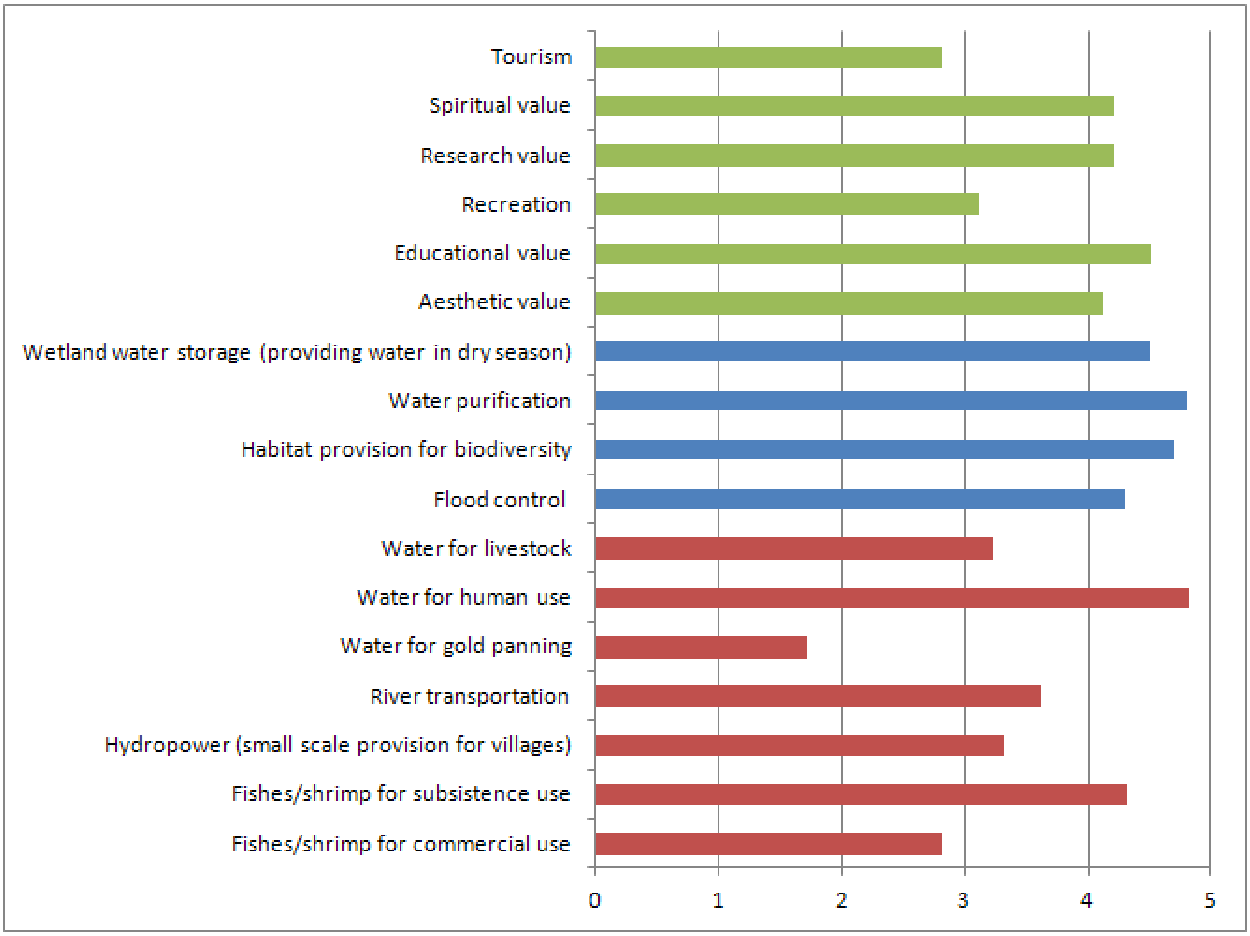

Figure 10. Average score given to each ecosystem service.
Green = Cultural services; Blue = Regulating and supporting services; Red = Provisioning services

However, these average scores are heavily weighted by the dominant stakeholder group (in terms of numbers within the survey), the Provincial and District governance group (Group 1) as 15 of the 26 people (58%) responding to the questionnaire were from this group, and only three (11%) were from the villagers group (Group 3) and eight (31%) were from the Commune level governance group (Group 2). If the scores are averaged within each stakeholder group, their different priorities can be identified (Table 7, Figure 11). Some of the services show distinct differences in the values given by each group, for example the Provincial and District level governance group prioritised flood control by over a whole point higher than the other groups, and tourism and aesthetic value by almost a point higher. Spiritual value, water for livestock and river transportation were also valued the highest by this group. The Commune level governance group (Group 2) scored only recreation higher by over a whole point than any other group, and the villagers group (Group 3) scored the fishes/shrimps for commercial use two points higher than any other group. Table 10 also shows that while provisioning services were scored on average similarly across the groups (3.3 and 3.4) the regulating and supporting services were scored higher by the Provincial and District governance group (Group 1) at 4.9 (to 4.1. and 4.4) and cultural services were scored lower by the villagers group (Group 3) at 3.5 (to 3.9 and 3.8).

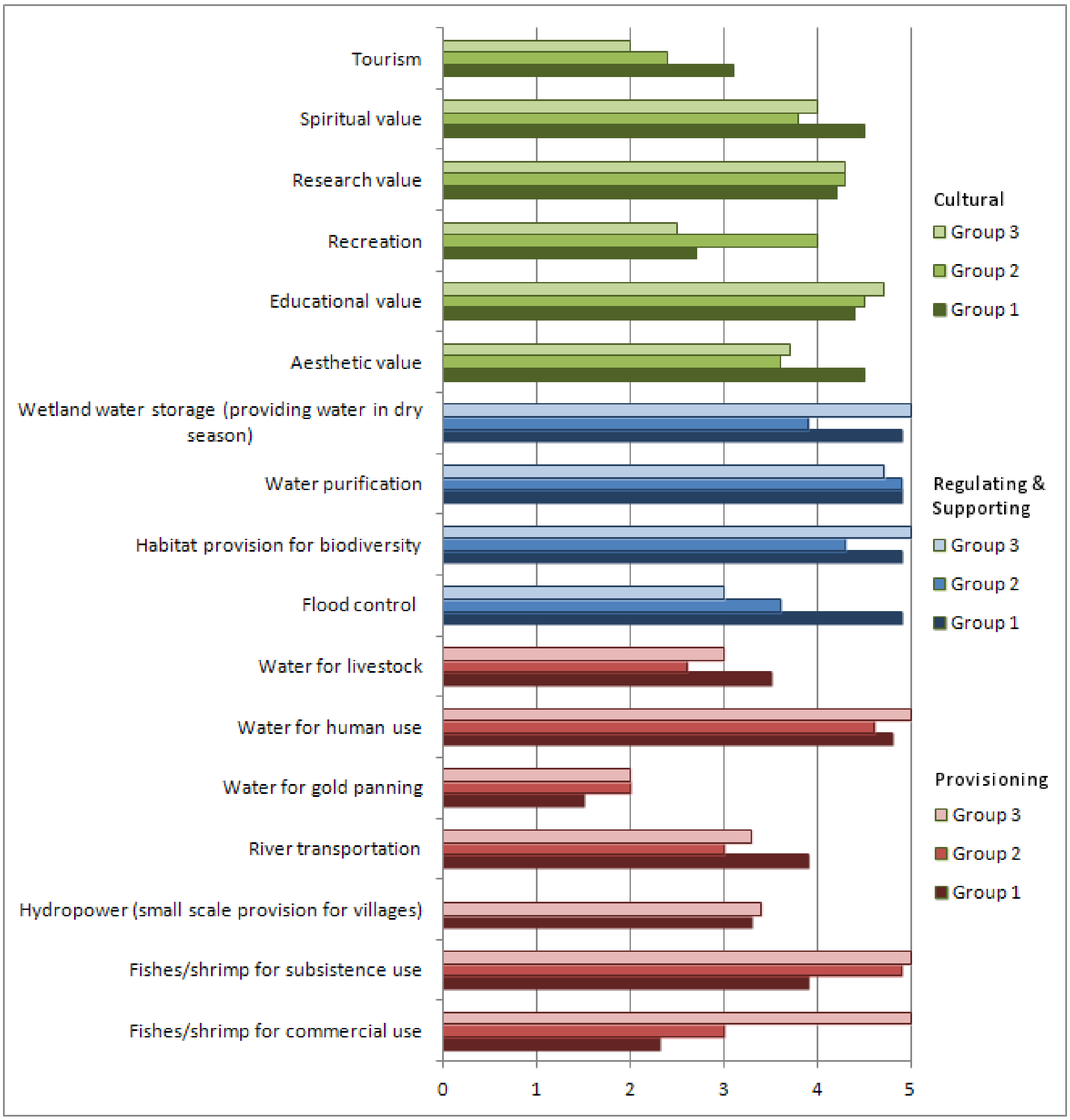

Figure 11. Average score given to ecosystem services by each stakeholder group.
Group 1 Provincial District level governance; Group 2 Commune level governance; Group 3 individuals at villages.

The threats to ecosystem services and biodiversity are all scored highly, with all threats scoring 4.0 or above (Table 7, Figure 12). When the average score given to the threats by each stakeholder group is examined (Table 6, Figure 13), differences between the groups can be seen. The villages (Group 3) give a higher score, by almost a whole point to low water levels in the dry season due to hydropower water storage than the other groups, they also score the floods and high sediment loads caused by hydropower discharge higher than the other groups. Another clear result is that the Commune level governance group (Group 2) score all the threats lower than the other groups, with an average threats score of 3.9 (compared to 4.6 and 4.8).

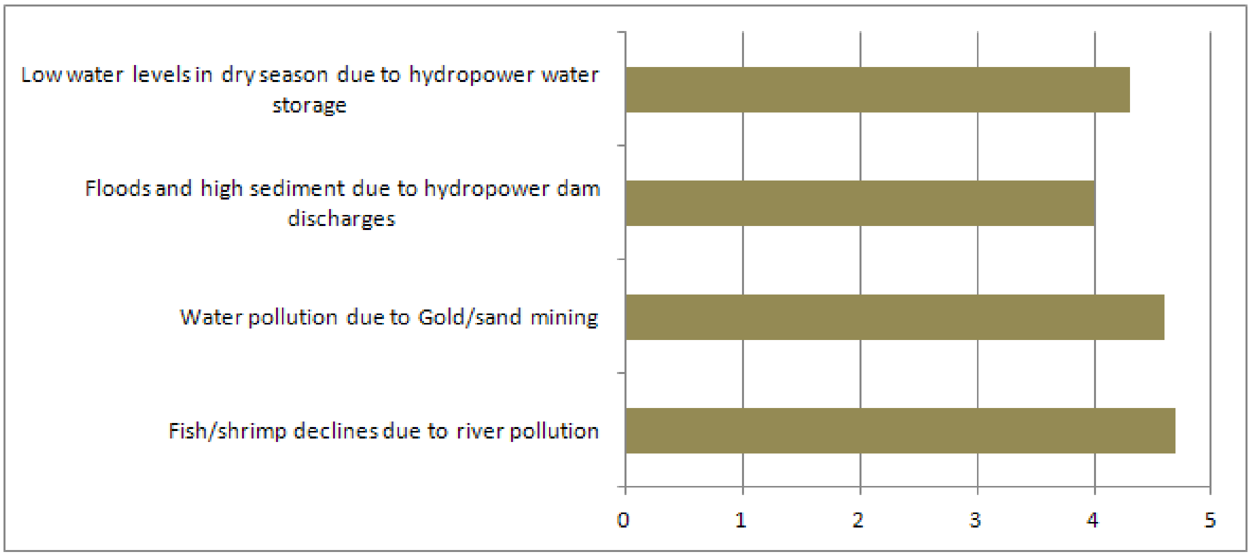

Figure 12. Average score given to each threat.

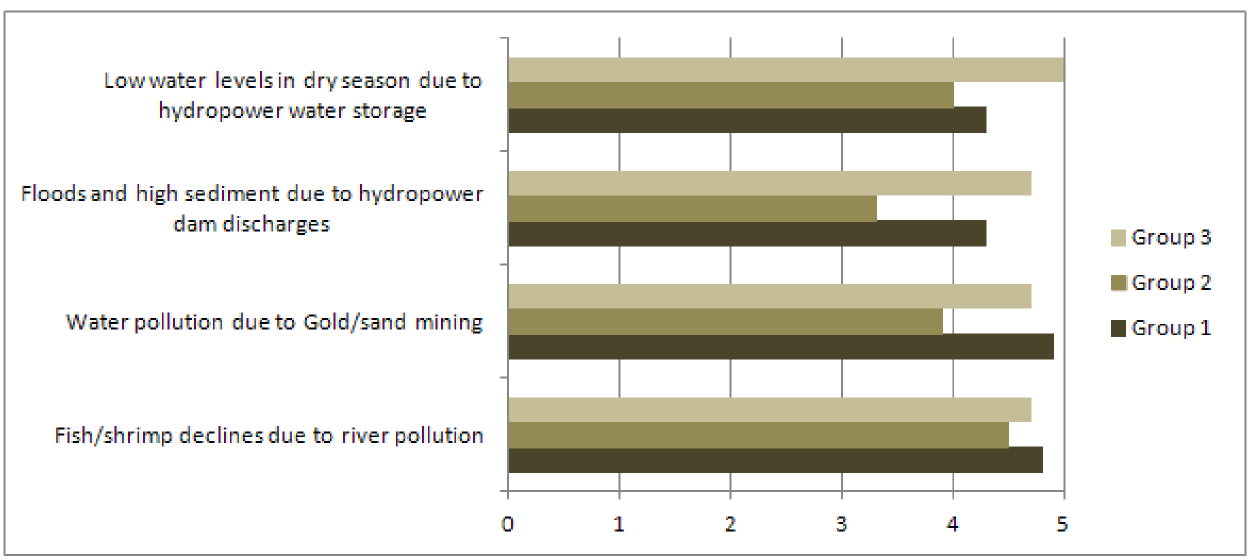

Figure 13. Average score given to threats by each stakeholder group.

5.2.4. Ecosystem services discussion and maps

The results show that the wetland biodiversity and ecosystems provide many benefits for humans in both direct and indirect ways. It was mentioned by an elderly Van Kieu ethnic person living in Dakrong district that "Mountain and river are our living sources, we could not live without it. Mountains provide land for production; rivers provide shrimp, fish, dinking water and irrigation water as well" (Hoang Nam Bang, 2011). Based on the annual report of Dakrong commune, the commune has a total of 16.5 ha of water surface with the major contribution from the Dakrong and Quang Tri rivers (Dakrong People Committee 2010). The areas and water volume are highly dependent upon the seasons and weather conditions.

Each ecosystem service is discussed below in the context of the HighARCS site villages, and potential indicators to monitor the state of that ecosystem service have been suggested. These indicators will be discussed and developed with local communities and some will be put in place through the IAP to monitor the impacts of any actions proposed. Some of the ecosystem services have been mapped (Figures 14-19) and show at a watershed and site scale the areas generating the services and the areas receiving (or benefiting) from the services. This information is based on the results of the analysis in this Work Package, field observations by RIA1 staff and formal and informal discussions with the various stakeholder groups undertaken for this and other Work Packages. The maps are based on those produced for the site and catchment maps with the ecosystem service generating and benefiting areas shown. These areas were identified and drawn by RIA1 staff and IUCN during the mapping workshop held on 23-24 August, 2011 at the South China Agricultural University, Guangzhou, China. The results were then digitised using GIS software by IUCN. The maps will allow geographic areas that are critical for the continuation of ecosystem service to be identified and the wider benefits of the service to be visualised. They will also allow the IAP to identify potential actions needed to protect the service and also the indicators needed to monitor the quality or continuance of the service.

Water provision, purification and storage (Figure 14):

Water provision for human use and water purification were the two highest scoring (based on average scores) services and along with wetland water storage, make up the services that allow the local communities (including people from Groups 2 and 3) to have access to clean drinking water all year round. In the dry season, the main Dakrong River is the only source of water for domestic use such as drinking, bathing and washing water. During the rest of the year water is also harvested from seasonal streams. However, water quality degradation and a decline in dry season water levels are the major issues affecting these services. Pollution from the gold mining, agricultural chemicals and domestic waste is deteriorating the quality of water reaching the HighARCS village water harvesting areas (Figure 9). Also the amount of water in the dry season is also threatening these services as water is held back by the upstream hydropower dams.

Potential indicators:

- Regular water quality monitoring at the water harvesting areas in the main channel of the Dakrong River.

- Water level monitoring (during the dry season) at the water harvesting areas in the main channel of the Dakrong River.

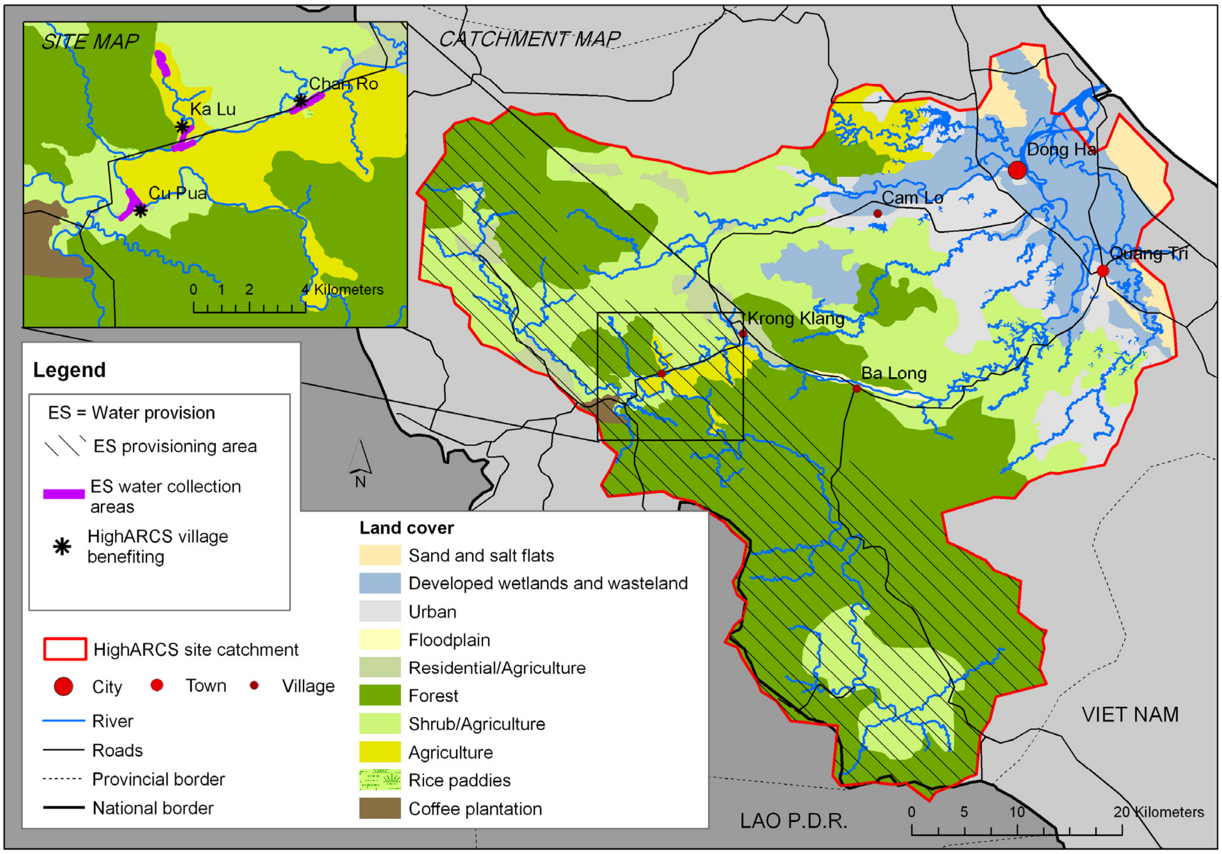

Figure 14. Ecosystem service of water provision.

Girl carrying water from the river for home consumption © Fraser Sugden

Hydropower (Figure 15)

In the villages that have no electricity generators (including Cu Pua in the HighARCS site) the river provides temporary power through micro-hydropower generators allowing houses to have lighting etc. Currently within the site there are nine micro hydropower generators (near Cu Pua). However, the power they provide depends on the flow of water in the river, and it is therefore dependant upon suitable flows and is impacted by both low water flow in the dry season (due to water being held back by large hydropower station upstream) and the flood waters caused by the large hydropower station upstream discharging water (Figure 7). While it is only the villages that benefit from the micro-hydropower generators, the large scale hydropower stations along the Dakrong River (including Dakrong 2 a run of the river dam under construction at the site, see Figure 7) provide power to the national grid, benefiting people across the country.

Potential indicators:

- For micro-hydropower – Field site surveys on the number of micro-hydropower generators used. Water level monitoring at micro-hydropower station sites to identify low lows and floods.
- For large scale hydropower – The annual power output of the dams along the Dakrong River contributed to the national grid.

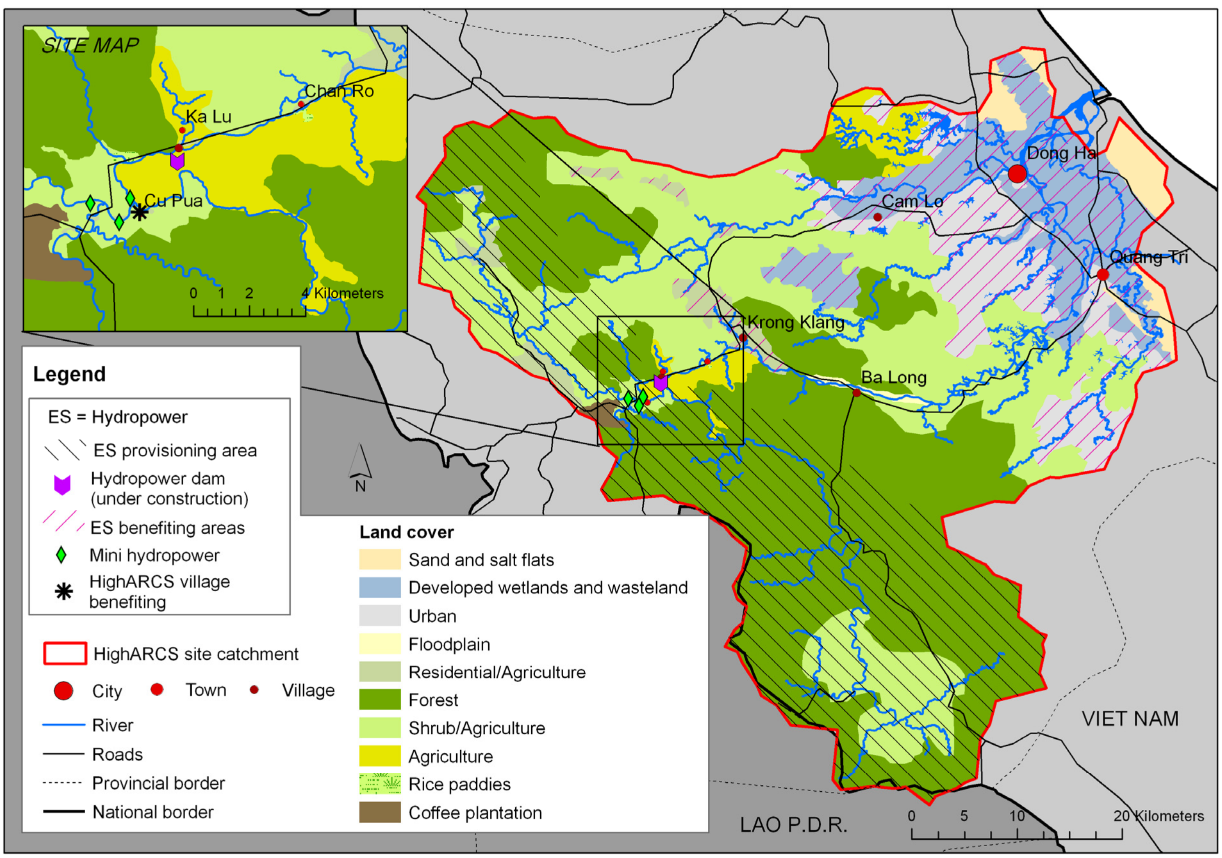

Figure 15. Ecosystem service of hydropower.

Micro-hydropower generators near Cu Pua village © Fraser Sugden

Water transportation (Figure 16)

Water transportation plays an important role in the daily activities of local people from Chan Ro and Cu Pua. During the wet season, people use boats to cross the river to go to the forest and carry their agri-products from the mountains to the villages and markets. This service is impacted by the flood waters caused by hydropower stations discharging water.

Potential indicators:

- Annual social surveys to identify the number of days during the wet season the river was unnavigable due to flood waters.

Travelling to the forest by boat across the river © Fraser Sugden

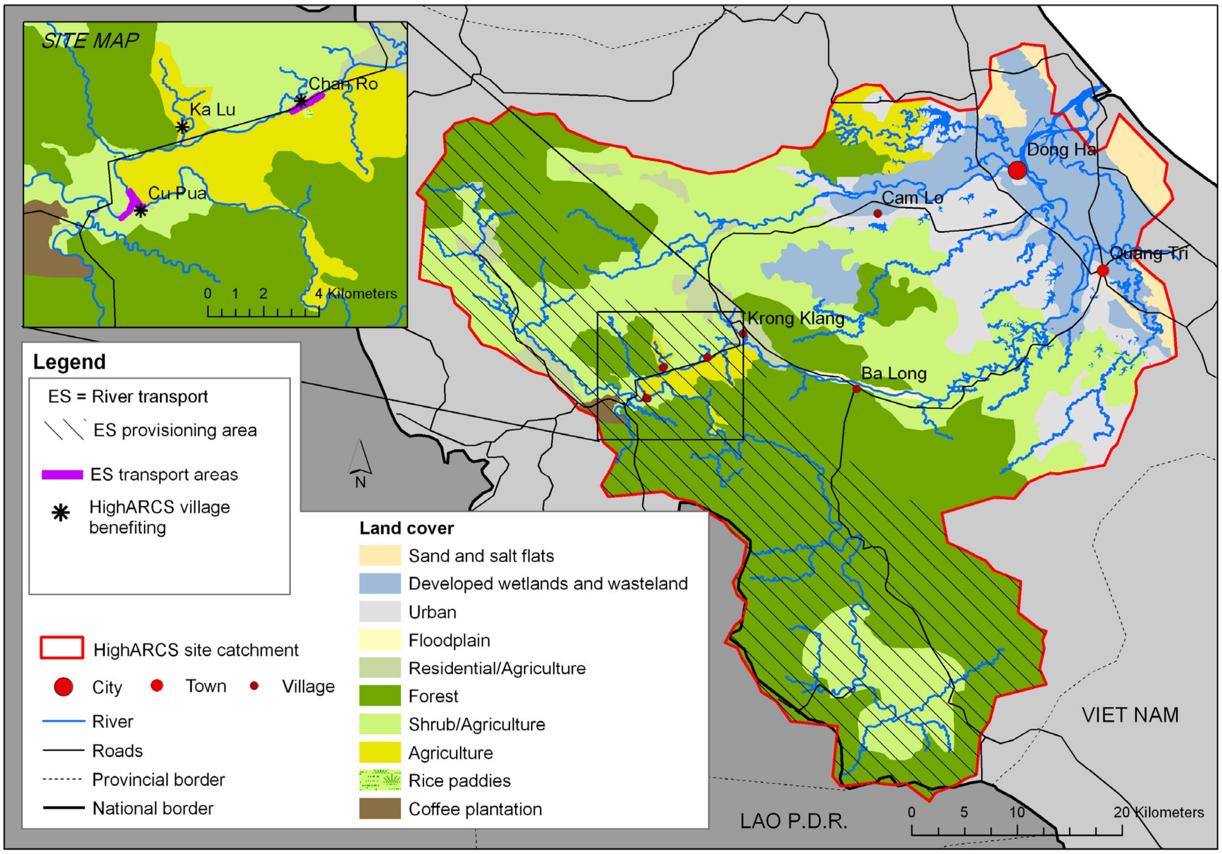

Figure 16. Ecosystem service of river transportation

Fish/shrimp provision (Figure 17)

In the HighARCS villages, fishing is an important food source for local people, particularly in Ka Lu and Chan Ro villages which have the steepest and poorest quality agricultural land. Fish consumption is an important food source in Dakrong District with 38% of household eating fish twice or more times per week (Fleischer 2004). The statistical year book of 2009 for Quang Tri reported that the production of fish caught within the Dakrong district has more than doubled since 2005 (13.5 tons in 2005, 30.5 tons in 2009) (Quang Tri Statistical Office, 2010b). However, through our focus group discussions the fishermen believed that catches are declining and generally not high, at just 0.5 - 2kg per day per household and that the fish caught are very small (less than 12 cm) and not suitable for selling. This service is being impacted by water pollution (Figure 9), and possibly the flow alteration caused by the hydropower dams upstream. While fish/shrimp provision is scored higher by those people that partake in fishing at the site (Group 3 and partly Group 2) it also benefits a wider community as fishermen from downstream visit the site to catch fish and the fish caught at the site are sold at local markets to households that do not fish. In terms of areas generating or providing this ecosystem service, the whole catchment has been identified as some species (e.g. *Anguilla marmorata*) require unhindered access to the sea to complete their life cycles. If the delta area of the Quang Tri River was heavily polluted or a dam constructed downstream of the site the species would disappear from the area. Upstream of the site is also very important for all the fish and shrimp species, as they need suitable flow regimes and water quality which is provided by the upper catchment.

Potential indicators:

- Regular water quality monitoring at water harvesting areas in the Dakrong River.
- Regular fish market surveys, identifying species, harvesting locations and catch levels.
- Annual social surveys of fishermen to identify trends in quantity and quality of fish.

Fish for sale at a market in Krong Klang © Henning Schroll

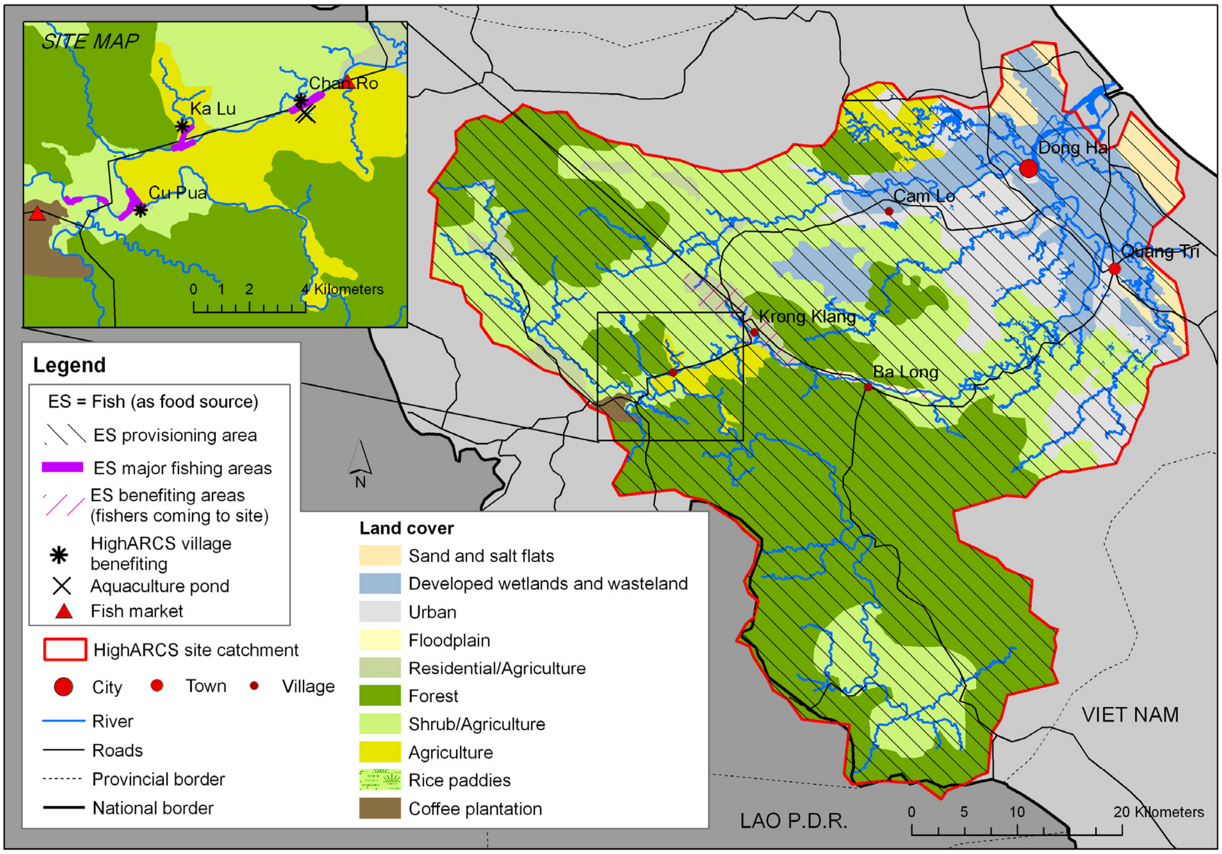

Figure 17. Ecosystem service of fish/shrimp provision

Water for gold panning

The river water and flow regimes erode and wash the silt and gravel that contain gold downstream allowing villagers to collect it. This service is scored relatively lowly by all of the groups, with a maximum score of two. However, there are some households who pan for gold in the river, and can earn between VND 100,000 and 300,000 per week. The gold can be retained as a saving and sold when the household needs food.

Potential indicators:

- Annual social surveys of households that pan for gold to identify their income generated from harvesting of gold from the river.

Gold panning at Cu Pua village ©Fraser Sugden

Flood and climate regulation (Figure 18)

Quang Tri has a hot climate with temperatures reaching 34^{o} C in June/August (maximum recorded of 40^{o}C) and an average humidity of 76% (high of 85%) (www.climatetemp.info 2011). The climate is also relatively harsh, with hot dry south-westerly winds and tropical storms and cyclones and is vulnerable to the El Nino Southern Oscillation, making the climate very much unstable (Asian Disaster Preparedness Center 2003).

The upper Dakrong River catchment is steep and with tropical storms depositing large amounts of rain, flood waters can quickly arrive in the plains (flooding season last from September to November) (Asian Disaster Preparedness Center 2003). The forested upper catchment plays a significant role in absorbing rainfall and slowing down the flood waters, reducing the severity of the floods downstream in the urban areas. This is why the Provincial and District level governance (Group 1) rank this service as highly valuable (scoring it 4.9 out of 5).

Although climate regulation was not included within the prioritisation assessment, based on discussions at the mapping workshop it was decided that it is an important service and should be mapped and discussed. The upper catchment of forest cover provides some degree of protection from the full force of the dry winds coming from the south west to the people lower in the catchment nearer the coast. The upper catchment also provides temperature regulation for the immediate environment and communities at the site and the wider upper catchment.

Potential indicators:

- Severity of floods and levels of deforestation (taken from government records)

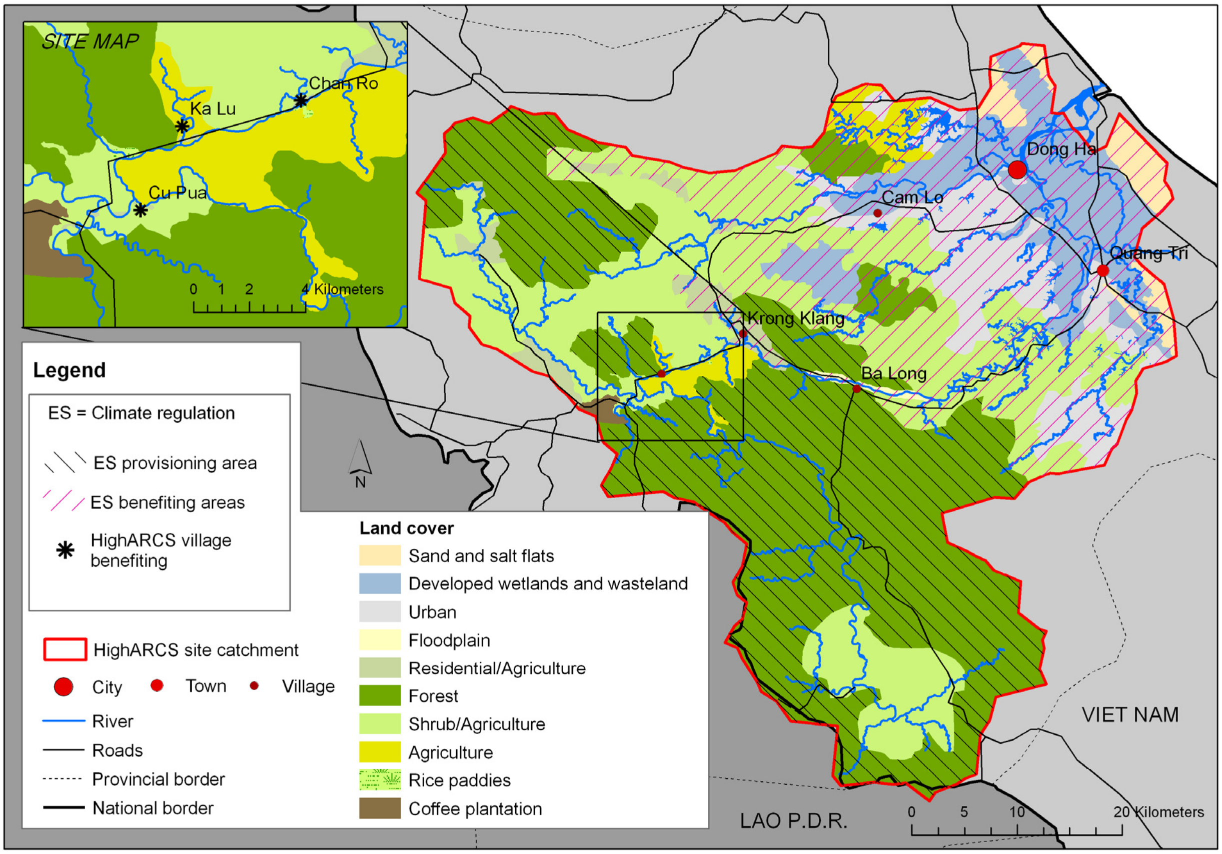

Figure 18. Ecosystem service of flood and climate regulation.

Cultural services and tourism (Figure 19)

Cultural services provided by the Dakrong River include aesthetic and spiritual values, recreation, tourism, educational and research uses. In this study it is difficult to define the culture services but all respondent groups ranked them highly. While tourism at the site is relatively small, with just one guesthouse (and one in development) there is a potential for increasing tourist numbers, which would allow villagers to increase and diversify their income. Apart from the general aesthetic value at the site there is a hot spring in Kalu village that could attract visitors and the Dakrong Bridge is very important, it was made famous during the American War and is already a stop on historical tours. Every year Quang Tri welcomes between 201 to 294 thousand domestic visitors and 26 to 36 thousand foreign visitors (Quang Tri Statistical Office, 2010c) demonstrating the good potential for tourism development capitalising on the aesthetic value of the Dakrong River catchment. The Dakrong River also has a legend, that describes the love of a Dakrong couple which represents the beauty of diligent, spirit and love of all the Dakrong people (Luong An, 2010). Recreation is also popular, particularly with the children. Through focus group discussions, many children indicated that they enjoyed swimming in the river. Moreover, local people agreed that river makes their home become more beautiful and thus the Dakrong River is considered as a landscape comprised of beautiful rock and valley features (Hoang Nam Bang 2011).

Potential indicators:

- Monitor the Dakrong District tourist numbers (Government figures)

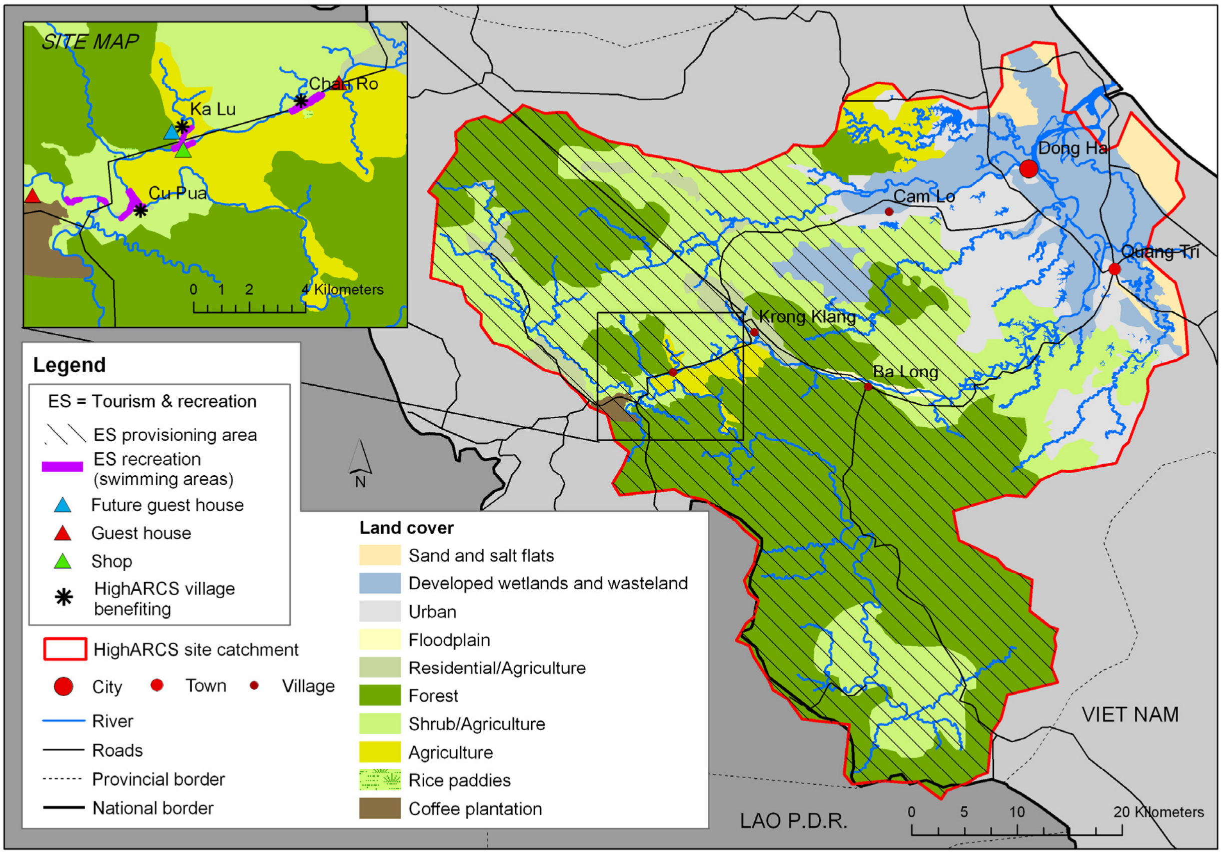

Figure 19. Ecosystem service of tourism

6. Conclusions

The results of this report show that 38 fish species belonging to 26 genera, 9 families and 5 different orders were indentified in Dakrong River in Dakrong Commune. A fish survey conducted in the Dakrong Nature Reserve, upstream from the site, found 72 fish species which indicates that the species recoded by our survey is an under estimate of the true fish diversity at the site. While no globally threatened species were identified at the site, three species *Anguilla marmorata, Spinibarbus hollandi* and *Onychostoma laticeps* are on the list of endangered aquatic species in Vietnam (Ministry of Agriculture and Rural Development 2008) and are all declining in parts of their ranges due to overfishing including at the HighARCS site. One species *Onychostoma gerlachi,* is globally assessed as Near Threatened, and some of the species listed as Data Deficient (e.g. *Squalidus argentatus* and *Onychostoma laticeps*) are also known to be declining across their ranges. Fifteen of the 38 species have an economic value, with 7 identified as 'high value', unfortunately many of these species are declining at the site. These economically important and declining species could be included within a monitoring scheme (potentially through market surveys) at the site to monitor impacts of any actions taken through the IAP to improve the sustainable use of resources.

Through the survey work 5 possible new and endemic species were found these were: *Acrossocheilus* sp3, *Spinibarbus* sp, *Channa* sp1, *Channa* sp2 and *Cryptrocentrus* sp. It is important the more survey work is undertaken specifically for these species at the site and surrounding connected areas and that these specimens taxonomic status are examined to identify if they are indeed new species. This is not uncommon as similar recommendations were made by a WWF survey of the Green Corridor Forest Landscape, Thua Thien Hue Province (WWF 2006a). If these species are indeed new species to science they may be endemic to very small area and be threatened (based on the threats identified through this work) this would make the area very important for conservation and would require suitable research and actions to be undertaken by the different government levels.

The key threats at the site include the hydropower stations upstream of the site that hold back water during the dry season and discharge high sediment loaded water creating flood surges which damages the villagers micro-hydropower generators, disrupts river transportation and reduces water quality. There are also a number of new dams under construction, including Dakrong II which is situated at the site. While this dam is a run of the river dam (there will be no blocking of the river or creation of a reservoir) its construction will destroy species habitats at the site which is likely to impact aquatic resources, and the running of the dam (the diversion of water) will have unknown implications to the rivers biodiversity. Water pollution from gold mining, agricultural chemicals and domestic waste are also reducing the quality of water at the site.

Ecosystem system services provided by the Dakrong River are highly valued by all stakeholder groups questioned and water provision for human use and water filtration are considered the most important. However, there are some differences between the different governance stakeholder groups (Provincial and District; Commune; and village) as the villagers scored the fishes/shrimps for commercial use higher than the other groups, and the Provincial and District level governance group prioritised flood control and tourism and aesthetic value higher than the other groups. The Commune governance group scored only recreation higher than the others. The upper forested catchment of the Dakrong River is essential for the provision of all the ecosystem services, and in the case of migratory species that are utilised in fisheries, the lower catchment is also critical.

This report ensures that biodiversity and ecosystem service values are understood at the site, allowing for the IAP to formulate relevant actions to help secure the aquatic resources conservation and sustainable use. It will also allow for suitable indicators and monitoring to be established to monitor the actions proposed through the IAP.

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Annex I. Summary of the IUCN Red List criteria

Summary of the five criteria (A–E) used to evaluate if a taxon belongs in a threatened category (Critically Endangered, Endangered or Vulnerable).

Use any of the criteria A–E	Critically Endangered	Endangered	Vulnerable
A. Population reduction	Declines measured over the longer of 10 years or 3 generations		
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%

A1. Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible **AND** understood **AND** have ceased, based on and specifying any of the following:
- (a) direct observation
- (b) an index of abundance appropriate to the taxon
- (c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality
- (d) actual or potential levels of exploitation
- (e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

A2. Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased **OR** may not be understood **OR** may not be reversible, based on (a) to (e) under A1.

A3. Population reduction projected or suspected to be met in the future (up to a maximum of 100 years) based on (b) to (e) under A1.

A4. An observed, estimated, inferred, projected or suspected population reduction (up to a maximum of 100 years) where the time period must include both the past and the future, and where the causes of reduction may not have ceased **OR** may not be understood **OR** may not be reversible, based on (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)

	Critically Endangered	Endangered	Vulnerable
B1. Extent of occurrence (EOO)	< 100 km²	< 5,000 km²	< 20,000 km²
B2. Area of occupancy (AOO)	< 10 km²	< 500 km²	< 2,000 km²
AND at least 2 of the following:			
(a) Severely fragmented, **OR** Number of locations	= 1	≤ 5	≤ 10

(b) Continuing decline in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals.

(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals.

C. Small population size and decline

	Critically Endangered	Endangered	Vulnerable
Number of mature individuals	< 250	< 2,500	< 10,000
AND either C1 or C2:			
C1. An estimated continuing decline of at least: (up to a max. of 100 years in future)	25% in 3 years or 1 generation	20% in 5 years or 2 generations	10% in 10 years or 3 generations
C2. A continuing decline **AND** (a) and/or (b):			
(a i) Number of mature individuals in each subpopulation:	< 50	< 250	< 1,000
or			
(a ii) % individuals in one subpopulation =	90–100%	95–100%	100%
(b) Extreme fluctuations in the number of mature individuals.			

D. Very small or restricted population

	Critically Endangered	Endangered	Vulnerable
Either: Number of mature individuals	< 50	< 250	**D1.** < 1,000
			AND/OR
	Restricted area of occupancy		**D2.** typically: AOO < 20 km² or number of locations ≤ 5

E. Quantitative Analysis

	Critically Endangered	Endangered	Vulnerable
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations (100 years max.)	≥ 20% in 20 years or 5 generations (100 years max.)	≥ 10% in 100 years

Annex II. Fish species list from northern and central Viet Nam

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Order	Family	Binomial	IUCN Red List Category
Anguilliformes	Anguillidae	*Anguilla marmorata*	LC
Anguilliformes	Ophichthidae	*Pisodonophis boro*	LC
Anguilliformes	Ophichthidae	*Pisodonophis cancrivorus*	LC
Beloniformes	Hemiramphidae	*Hyporhamphus limbatus*	LC
Clupeiformes	Clupeidae	*Tenualosa reevesii*	DD*
Cypriniformes	Balitoridae	*Annamia normani*	LC*
Cypriniformes	Balitoridae	*Balitora lancangjiangensis*	LC*
Cypriniformes	Balitoridae	*Beaufortia leveretti*	DD
Cypriniformes	Balitoridae	*Beaufortia pingi*	LC
Cypriniformes	Balitoridae	*Liniparhomaloptera disparis*	DD
Cypriniformes	Balitoridae	*Micronemacheilus pulcher*	LC
Cypriniformes	Balitoridae	*Micronemacheilus taeniatus*	LC
Cypriniformes	Balitoridae	*Pseudogastromyzon loos*	DD
Cypriniformes	Balitoridae	*Schistura caudofurca*	LC
Cypriniformes	Balitoridae	*Schistura fasciolata*	DD
Cypriniformes	Balitoridae	*Schistura incerta*	DD*
Cypriniformes	Balitoridae	*Sinogastromyzon chapaensis*	DD
Cypriniformes	Balitoridae	*Sinogastromyzon rugocauda*	DD*
Cypriniformes	Balitoridae	*Sinogastromyzon tonkinensis*	DD
Cypriniformes	Balitoridae	*Sinohomaloptera kwangsiensis*	LC*
Cypriniformes	Balitoridae	*Vanmanenia multiloba*	DD
Cypriniformes	Balitoridae	*Vanmanenia tetraloba*	DD
Cypriniformes	Cobitidae	*Cobitis laoensis*	LC
Cypriniformes	Cobitidae	*Cobitis longitaeniatus*	DD*
Cypriniformes	Cobitidae	*Cobitis phongnhaensis*	DD*
Cypriniformes	Cobitidae	*Cobitis sinensis*	LC*
Cypriniformes	Cobitidae	*Cobitis squataeniatus*	DD*
Cypriniformes	Cobitidae	*Cobitis ylengensis*	DD*
Cypriniformes	Cobitidae	*Misgurnus anguillicaudatus*	LC
Cypriniformes	Cyprinidae	*Abbottina binhi*	DD
Cypriniformes	Cyprinidae	*Acheilognathus macropterus*	DD
Cypriniformes	Cyprinidae	*Acheilognathus tonkinensis*	DD

Order	**Family**	**Binomial**	**IUCN Red List Category**
Cypriniformes	Cyprinidae	*Acrossocheilus clivosius*	DD
Cypriniformes	Cyprinidae	*Acrossocheilus iridescens*	DD
Cypriniformes	Cyprinidae	*Acrossocheilus lamus*	DD
Cypriniformes	Cyprinidae	*Ancherythroculter daovantieni*	DD
Cypriniformes	Cyprinidae	*Bangana lemassoni*	DD
Cypriniformes	Cyprinidae	*Bangana tonkinensis*	VU
Cypriniformes	Cyprinidae	*Bangana xanthogenys*	DD
Cypriniformes	Cyprinidae	*Barbonymus gonionotus*	LC
Cypriniformes	Cyprinidae	*Carassioides acuminatus*	LC
Cypriniformes	Cyprinidae	*Carassius auratus*	LC
Cypriniformes	Cyprinidae	*Chanodichthys erythropterus*	LC
Cypriniformes	Cyprinidae	*Chanodichthys flavipinnis*	DD
Cypriniformes	Cyprinidae	*Cirrhinus molitorella*	NT
Cypriniformes	Cyprinidae	*Cirrhinus mrigala*	LC
Cypriniformes	Cyprinidae	*Ctenopharyngodon idella*	DD
Cypriniformes	Cyprinidae	*Cyclocheilichthys armatus*	LC
Cypriniformes	Cyprinidae	*Cyprinus dai*	DD
Cypriniformes	Cyprinidae	*Cyprinus hyperdorsalis*	DD
Cypriniformes	Cyprinidae	*Cyprinus multitaeniata*	NT
Cypriniformes	Cyprinidae	*Discogobio microstoma*	DD
Cypriniformes	Cyprinidae	*Elopichthys bambusa*	DD
Cypriniformes	Cyprinidae	*Esomus metallicus*	LC*
Cypriniformes	Cyprinidae	*Folifer brevifilis*	DD*
Cypriniformes	Cyprinidae	*Garra caudofasciatus*	DD*
Cypriniformes	Cyprinidae	*Garra fuliginosa*	LC*
Cypriniformes	Cyprinidae	*Garra imberba*	DD
Cypriniformes	Cyprinidae	*Garra laichowensis*	DD*
Cypriniformes	Cyprinidae	*Garra orientalis*	LC
Cypriniformes	Cyprinidae	*Garra poilanei*	DD
Cypriniformes	Cyprinidae	*Gibelion catla*	LC
Cypriniformes	Cyprinidae	*Gobiobotia kolleri*	DD
Cypriniformes	Cyprinidae	*Gobiobotia longibarba*	DD*
Cypriniformes	Cyprinidae	*Hainania serrata*	DD
Cypriniformes	Cyprinidae	*Hemiculter elongatus*	DD*
Cypriniformes	Cyprinidae	*Hemiculter leucisculus*	LC
Cypriniformes	Cyprinidae	*Hypophthalmichthys harmandi*	DD
Cypriniformes	Cyprinidae	*Labeo rohita*	LC
Cypriniformes	Cyprinidae	*Luciobrama macrocephalus*	DD
Cypriniformes	Cyprinidae	*Megalobrama skolkovii*	DD*

Order	Family	Binomial	IUCN Red List Category
Cypriniformes	Cyprinidae	*Megalobrama terminalis*	LC
Cypriniformes	Cyprinidae	*Metzia formosae*	LC
Cypriniformes	Cyprinidae	*Metzia lineata*	LC
Cypriniformes	Cyprinidae	*Microphysogobio kachekensis*	LC
Cypriniformes	Cyprinidae	*Microphysogobio labeoides*	DD*
Cypriniformes	Cyprinidae	*Microphysogobio vietnamica*	DD
Cypriniformes	Cyprinidae	*Microphysogobio yunnanensis*	DD
Cypriniformes	Cyprinidae	*Mylopharyngodon piceus*	DD
Cypriniformes	Cyprinidae	*Neolissochilus benasi*	DD
Cypriniformes	Cyprinidae	*Neolissochilus stracheyi*	LC
Cypriniformes	Cyprinidae	*Ochetobius elongatus*	DD*
Cypriniformes	Cyprinidae	*Onychostoma elongatum*	DD*
Cypriniformes	Cyprinidae	*Onychostoma fusiforme*	LC
Cypriniformes	Cyprinidae	*Onychostoma gerlachi*	NT
Cypriniformes	Cyprinidae	*Onychostoma laticeps*	DD*
Cypriniformes	Cyprinidae	*Onychostoma lepturum*	DD*
Cypriniformes	Cyprinidae	*Onychostoma lini*	DD*
Cypriniformes	Cyprinidae	*Onychostoma ovale*	DD
Cypriniformes	Cyprinidae	*Onychostoma simum*	DD
Cypriniformes	Cyprinidae	*Opsariichthys bidens*	LC*
Cypriniformes	Cyprinidae	*Opsarius pulchellus*	LC*
Cypriniformes	Cyprinidae	*Osteochilus salsburyi*	LC
Cypriniformes	Cyprinidae	*Osteochilus vittatus*	LC*
Cypriniformes	Cyprinidae	*Paraspinibarbus macracanthus*	DD
Cypriniformes	Cyprinidae	*Parator zonatus*	DD*
Cypriniformes	Cyprinidae	*Parazacco fasciatus*	LC
Cypriniformes	Cyprinidae	*Parazacco spilurus*	DD
Cypriniformes	Cyprinidae	*Parazacco vuquangensis*	DD
Cypriniformes	Cyprinidae	*Poropuntius kontumensis*	DD
Cypriniformes	Cyprinidae	*Poropuntius krempfi*	DD*
Cypriniformes	Cyprinidae	*Poropuntius normani*	LC*
Cypriniformes	Cyprinidae	*Pseudohemiculter dispar*	VU
Cypriniformes	Cyprinidae	*Pseudohemiculter hainanensis*	LC
Cypriniformes	Cyprinidae	*Pseudohemiculter pacboensis*	Not assessed
Cypriniformes	Cyprinidae	*Pseudolaubuca sinensis*	LC
Cypriniformes	Cyprinidae	*Puntius semifasciolatus*	LC*
Cypriniformes	Cyprinidae	*Rasbora steineri*	LC
Cypriniformes	Cyprinidae	*Rasbora sumatrana*	Not assessed
Cypriniformes	Cyprinidae	*Rasbora trilineata*	LC*

Order	Family	Binomial	IUCN Red List Category
Cypriniformes	Cyprinidae	*Rectoris posehensis*	DD*
Cypriniformes	Cyprinidae	*Rhodeus ocellatus*	DD
Cypriniformes	Cyprinidae	*Rhodeus spinalis*	LC
Cypriniformes	Cyprinidae	*Sarcocheilichthys nigripinnis*	LC*
Cypriniformes	Cyprinidae	*Saurogobio dabryi*	LC*
Cypriniformes	Cyprinidae	*Saurogobio immaculatus*	DD
Cypriniformes	Cyprinidae	*Scaphiodonichthys acanthopterus*	LC*
Cypriniformes	Cyprinidae	*Scaphiodonichthys macracanthus*	DD
Cypriniformes	Cyprinidae	*Semilabeo notabilis*	DD
Cypriniformes	Cyprinidae	*Semilabeo obscurus*	LC
Cypriniformes	Cyprinidae	*Sinibrama melrosei*	DD*
Cypriniformes	Cyprinidae	*Spinibarbus denticulatus*	LC
Cypriniformes	Cyprinidae	*Spinibarbus hollandi*	DD*
Cypriniformes	Cyprinidae	*Spinibarbus ovalius*	DD
Cypriniformes	Cyprinidae	*Spinibarbus sinensis*	DD*
Cypriniformes	Cyprinidae	*Squalidus argentatus*	DD
Cypriniformes	Cyprinidae	*Squalidus atromaculatus*	LC
Cypriniformes	Cyprinidae	*Squalidus chankaensis*	DD*
Cypriniformes	Cyprinidae	*Squaliobarbus curriculus*	DD
Cypriniformes	Cyprinidae	*Toxabramis houdemeri*	LC
Cypriniformes	Cyprinidae	*Xenocypris davidi*	LC*
Cypriniformes	Cyprinidae	*Xenocypris macrolepis*	LC
Cypriniformes	Cyprinidae	*Yaoshanicus kyphus*	DD*
Cypriniformes	Cyprinidae	*Yaoshanicus normalis*	LC*
Cypriniformes	Cyprinidae	*Zacco acutipinnis*	LC*
Osmeriformes	Salangidae	*Neosalanx tangkahkeii*	LC
Osmeriformes	Salangidae	*Salanx ariakensis*	Not assessed
Osmeriformes	Salangidae	*Salanx chinensis*	DD
Osteoglossiformes	Notopteridae	*Notopterus notopterus*	LC
Perciformes	Ambassidae	*Ambassis ambassis*	LC
Perciformes	Anabantidae	*Anabas testudineus*	DD
Perciformes	Channidae	*Channa asiatica*	LC*
Perciformes	Channidae	*Channa gachua*	LC
Perciformes	Channidae	*Channa maculata*	LC
Perciformes	Channidae	*Channa orientalis*	Not assessed
Perciformes	Channidae	*Channa striata*	LC
Perciformes	Eleotridae	*Bostrychus sinensis*	LC*
Perciformes	Eleotridae	*Butis butis*	LC
Perciformes	Eleotridae	*Eleotris balia*	Not assessed

Order	Family	Binomial	IUCN Red List Category
Perciformes	Eleotridae	*Eleotris fusca*	LC
Perciformes	Eleotridae	*Eleotris melanosoma*	LC
Perciformes	Eleotridae	*Eleotris oxycephala*	LC
Perciformes	Gerreidae	*Gerres filamentosus*	LC
Perciformes	Gobiidae	*Boleophthalmus boddarti*	LC*
Perciformes	Gobiidae	*Caragobius urolepis*	LC*
Perciformes	Gobiidae	*Glossogobius giuris*	LC
Perciformes	Gobiidae	*Papuligobius ocellatus*	LC*
Perciformes	Gobiidae	*Rhinogobius brunneus*	DD
Perciformes	Gobiidae	*Rhinogobius giurinus*	LC
Perciformes	Gobiidae	*Rhinogobius leavelli*	LC
Perciformes	Gobiidae	*Taenioides gracilis*	LC*
Perciformes	Odontobutidae	*Neodontobutis tonkinensis*	DD
Perciformes	Odontobutidae	*Sineleotris chalmersi*	LC
Perciformes	Osphronemidae	*Macropodus baviensis*	Not assessed
Perciformes	Osphronemidae	*Macropodus opercularis*	LC
Perciformes	Osphronemidae	*Macropodus phongnhaensis*	Not assessed
Perciformes	Osphronemidae	*Trichopodus trichopterus*	LC
Perciformes	Percichthyidae	*Coreoperca whiteheadi*	LC
Perciformes	Percichthyidae	*Siniperca chuatsi*	Not assessed
Perciformes	Percichthyidae	*Siniperca kneri*	DD
Perciformes	Percichthyidae	*Siniperca scherzeri*	DD
Perciformes	Terapontidae	*Terapon jarbua*	LC
Pleuronectiformes	Cynoglossidae	*Cynoglossus trigrammus*	LC*
Siluriformes	Bagridae	*Hemibagrus centralus*	DD*
Siluriformes	Bagridae	*Hemibagrus guttatus*	DD*
Siluriformes	Bagridae	*Hemibagrus pluriradiatus*	LC*
Siluriformes	Bagridae	*Hemibagrus vietnamicus*	DD*
Siluriformes	Bagridae	*Mystus gulio*	LC
Siluriformes	Bagridae	*Tachysurus fulvidraco*	LC
Siluriformes	Bagridae	*Tachysurus vachellii*	DD*
Siluriformes	Bagridae	*Tachysurus virgatus*	DD*
Siluriformes	Clariidae	*Clarias fuscus*	LC*
Siluriformes	Cranoglanididae	*Cranoglanis henrici*	LC
Siluriformes	Siluridae	*Pterocryptis cochinchinensis*	LC
Siluriformes	Siluridae	*Silurus asotus*	LC
Siluriformes	Sisoridae	*Bagarius rutilus*	LC*
Siluriformes	Sisoridae	*Bagarius yarrelli*	NT
Siluriformes	Sisoridae	*Glyptothorax honghensis*	DD

Order	Family	Binomial	IUCN Red List Category
Siluriformes	Sisoridae	*Glyptothorax interspinalum*	NT
Siluriformes	Sisoridae	*Glyptothorax laosensis*	LC*
Siluriformes	Sisoridae	*Pareuchiloglanis macrotrema*	DD
Siluriformes	Sisoridae	*Pseudecheneis paviei*	DD
Synbranchiformes	Mastacembelidae	*Macrognathus aculeatus*	LC*
Synbranchiformes	Mastacembelidae	*Mastacembelus armatus*	LC
Synbranchiformes	Mastacembelidae	*Sinobdella sinensis*	LC
Synbranchiformes	Synbranchidae	*Macrotrema caligans*	Not assessed
Synbranchiformes	Synbranchidae	*Monopterus albus*	LC
Tetraodontiformes	Tetraodontidae	*Tetraodon biocellatus*	LC*

Annex III: Photos of fish collected through field surveys in Dakrong river

1. Cá Chình hoa
Anguilla marmorata Quoy & Gaimard, 1824

2a. Cá Cháo (cá đực)
Opsariichthys bidens Günther,1873

2b. Cá cháo (cá cái)
Opsariichthys bidens Günther,1873

3. Cá Dầm đất suối
Nicholsicypris normalis (Nichols & Pope, 1927)

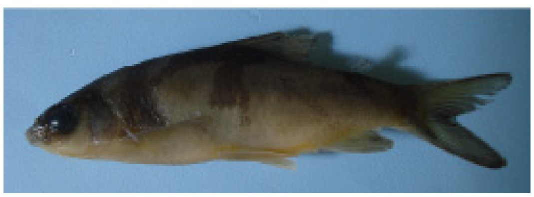
4. Cá Mương
Hemiculter leucisculus (Barilewrsky, 1858)

5. Cá Đục đanh chấm
Microphysogobio kachekensis (Oshima, 1926)

6. Cá Đục đanh chấm mõm ngắn
Microphysogobio yunnanensis (Yao & Yang 1977)

7. Cá Đục trắng
Squalidus argentatus (Sauvage & Dabry, 1874)

8. Cá Chát đuôi chấm
Acrossocheilus sp1



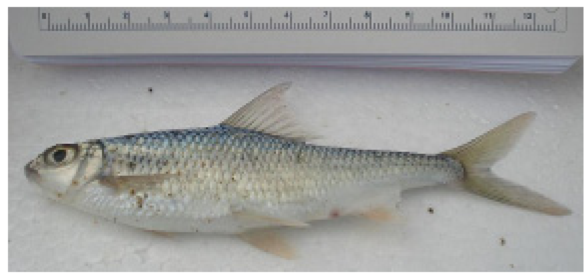
9. Cá Chát xám
Acrossocheilus sp2

10. Cá Chát vây đen
Acrossocheilus sp3

11. Cá Chày đất
Spinibarbus hollandi (Oshima, 1919)

12. Cá Bỗng vây đen
Spinibarbus sp

13. Cá Sỉnh gai *Onychostoma laticeps* (Günther, 1896)



14. Cá Sỉnh
Onychostoma gerlachi (Peters, 1880)

15. Cá Sỉnh cao
Onychostoma babeensis Hảo & Hiệp, 2001

16. Cá Dầm
Neolisso chilus stracheyi (Day, 1871)

17. Cá Bậu (Cá Sứt môi)
Garra orientalis (Nichols, 1925)

18. Cá Diếc
Carassius auratus (Linnaeus, 1758)

19. Cá Nhưng
Carassioides cantonensis (Heincke, 1892)

20. Cá Chép
Cyprinus carpio (Linnaeus, 1758)

21. Cá Chạch hoa lào
Cobitis laosensis (Sauvage, 1878)

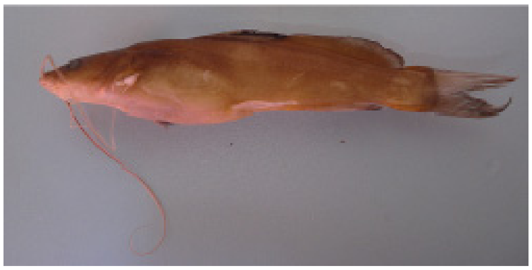
22. Cá Chạch bùn
Misgurnus anguillicaudatus (Cantor, 1842)

23. Cá Chạch suối sọc
Schistura fasciolatus (Nichols &Pope 1927)

24. Cá Đép thấp
Sewellia sp1

25. Cá Đép cao
Sewellia sp2

26. Cá vây bằng miền trung
Annamia sp

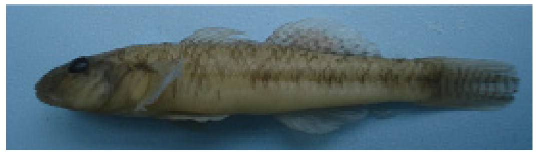


27. Cá Lăng miền trung
Hemibagrus centralus Yên, 1978

28.Cá Thèo
Ptenocypsis cochinchinensis (Valenciennes, 1839)

29. Cá Chạch sông
Mastacembelus armatus (Lacépède, 1800*)*

30. Cá Chạch sông
Mastacenbelus sp



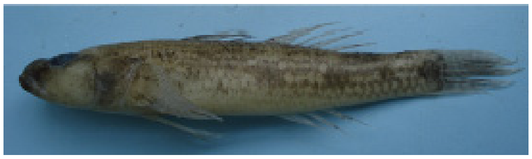
31. Cá Bống khe
Rhinogobius giurinus (Rüter, 1879)

32. Cá Bống chấm
Rhinogobius ocellatus (Fowler, 1937)

33. Cá Bống trắng
Rhinogobius sp1

34. Cá Bống ngắn
Rhinogobius sp2

35. Cá Bống sọc ngang
Cryptrocentrus sp



36. Cá Bống cát
Glossogobius giurus (Hamilton, 1822)

38. Cá Sộp Quảng Trị
Channa sp2

7. Cá Tràu suối Quảng Trị
Channa sp1

Section 5

Freshwater ecosystem services and biodiversity values at Phu Yen District, Son La, Viet Nam.

Biodiversity and ecosystem services values of Phu Yen District, Son La, Viet Nam

Research Institute for Aquaculture No.1
RIA1 Co-ordinator: Nguyen Thi Dieu Phuong
And research team: Nguyen Thi Hanh Tien
Do Van Thinh
Nguyen Thi Trang
October 2011

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The report presents results of 92 households interviews including quantitative and qualitative approaches as well as results from 38 focus group discussions, 26 ecosystem service questionnaires in Tuong Ha and Tuong Tien Communes of Phu Yen District, Son La Province. In addition the positive support received from the chairman and party committee secretary of these communes (Mr Dinh Thanh Su, Mr Cam Chien, Mr Luong Van Cuong), districts (Mr Cam Tan, Mr. Nguyen Duy Hoang, Mr. Cam Ngoc Lien) and province (Mr. Chan, Mr. Bieng) and broad stakeholder participation have helped produce successful project activities. We would like to sincerely thank all who have taken part in our research and wish you all wealth, happiness and success in the future.

Nguyen Thi Dieu Phuong, on behalf of RIA1 team.

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1. Introduction

1.1. Report outline and objectives

The project “Highland Aquatic Resources Conservation and Sustainable Development” (HighARCS) has been funded by the European Commission and coordinated by interdisciplinary Centre for Environment and Society, University of Essex. Involving ten partners from Europe and Asia the project is scheduled to run from Jan 2009 to Dec 2013. The projects main aim is to value five wetland sites across Asia using an interdisciplinary approach, and develop action plans to ensure aquatic resources are conserved and used sustainably. Five study sites have been identified through the projects first phase, which include three villages on the Beijiang River, Guangdong, China; three lakes in Uttarakhand, India; Buxa, West Bengal, India; and Quang Tri in central Viet Nam; and Son La in northern Vietnam.

The project comprises a set of nine work packages divided into three phases. Phase 1 is an interdisciplinary analysis (incorporates Work Package 1 – Situation appraisal) that identifies the sites for the project to focus on. Phase 2 is an assessment of ecosystem functioning, livelihoods dependent on highland aquatic resources and associated social and institutional issues at the sites and the development of integrated action plans (WP3 - Ecosystem services and biodiversity values; WP4 - Highland aquatic resources and livelihoods; WP5 - Stakeholders, institutions and markets). Phase 3 is the implementation and monitoring of the action plans developed in Phase 2 (WP 6 - Conserving ecosystems services and biodiversity values; WP 7 - Sustainable highland aquatic resources development and livelihoods; WP8 - Policy development to support conservation and wise-use). This report is part of WP3 and presents the findings of the assessment of biodiversity and ecosystem services found at Phu Yen District, Son La Province, northern Viet Nam.

The HighARCS project is following an *integrated* approach to assessing the ‘value’ of the aquatic systems at the sites. This methodology, defined by IUCN in the *Integrated Wetland Assessment Toolkit* the ‘Toolkit’ (Springate-Baginski *et al.* 2009), combines biodiversity, livelihoods and economic assessments from the planning stage through to the development of recommendations, rather than as separate assessments that can end up with contradictory conclusions (see Figure 1). An integrated approach captures the inter-linkages and connectivity between wetlands and livelihoods in an efficient way and reduces biased recommendations towards any of the different sectors. While this report deals with the biodiversity and ecosystem services, the data collection from Phase 2 of the project has been integrated, and the resulting action plan that will be produced will address biodiversity, livelihood and policy issues together.

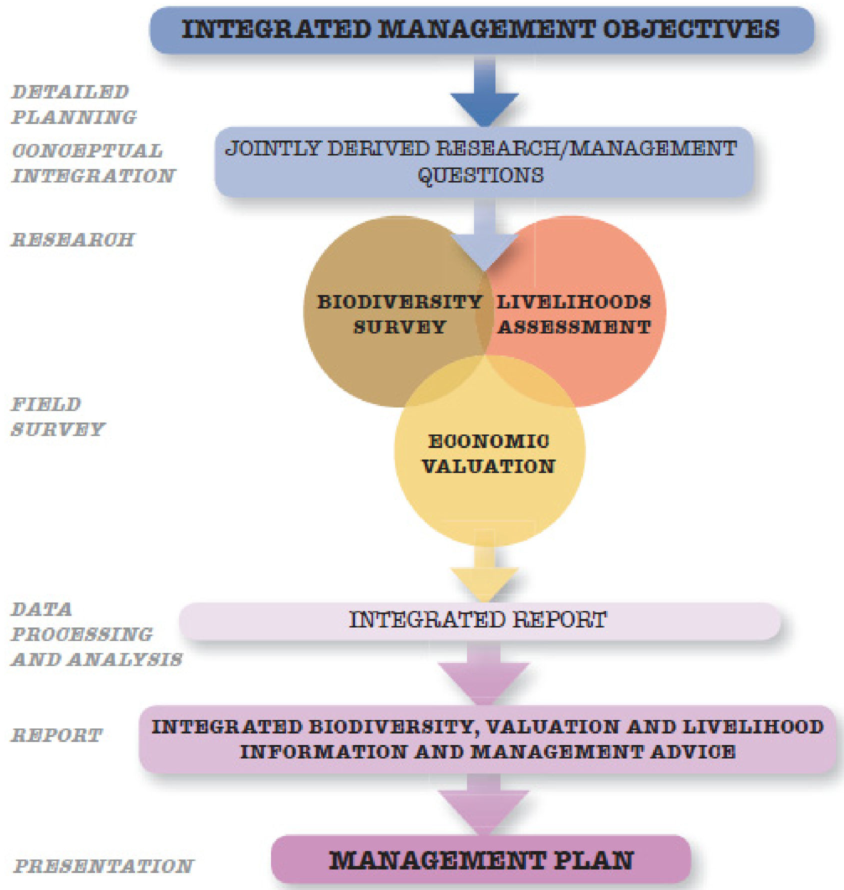


Figure 1. Integrated assessment approach from Springate-Baginsky *et al.* (2009)

The specific aims of the assessment work presented in this report is to:
-identify ecosystem services and biodiversity supported by highland aquatic resources;
-evaluate stakeholder ecosystem service priorities;
-recommend potential management options for conservation, sustaining ecosystem services, resolving conflicts and ensuring sustainable and wise-use of highland aquatic resources.

This information will be used to formulate the Integrated Action Plans in consultation with the stakeholder groups.

1.2 Background

The High ARCS study site is the Phu Yen district which is located in the east of Son La province, northern Viet Nam. Son La is a mountainous province the third poorest province in Viet Nam with over 70% of people living below the poverty line (Minot and Baulch 2001 in Australian Agency for International Development 2002). In Phu Yen, there are many poor communities whose livelihoods are highly dependent upon fishing and harvesting aquatic resources. However, the aquatic resources in this area are declining.

Phu Yen is only 174 km from Hanoi (the capital of Vietnam) and 153 km from Son La City the most important area of the economic development strategy of Son La Province and the northwest region of Vietnam. The district consists of 27 communes and towns and is within the Da River (=Black River) catchment, which in 1979 was dammed at Hoa Binh (Hao Binh Province) creating Viet Nam's largest hydro electric power plant with a 128m high dam (Bergesen 2011). The dam created the Song Da reservoir which has a surface area of 720 km^2 (ARCBC 2011) and stretches through Hoa Binh, Phu Tho, Moc Chau, Phu Yen and Bac Yen provinces. Figure 2 shows the location of the reservoir catchment within Viet Nam, which can be seen in more detail in Section 2 - Site maps (Figure 3). Within Phu Yen, the reservoir covers 3,079ha and partly covers 9 of the 27 communes (Son La People's Committee 2006, Phu Yen People's Committee 2009).

The district has dry and cold winters from October to April and hot, wet and rainy summers from April to September. In the rainy season, the rainfall fluctuates, with high average rainfall in June, July and August (80% rainfall for the year), accompanied by flooding and soil erosion (Phu Yen People's Committee, 2009). The district has a total area of 1,236 km^2 ha covering 8.7% of Son La Province. Phu Yen is located in mountain areas which are characterised by steep slopes channeling most rivers and streams in a northwest to southeast direction and has a high vulnerability to soil erosion with small-areas of cultivated land. There are 1,200 rivers and streams that belong to 4 main river systems: Tac River, Sap River, Mua River and Khoang River, which all eventually flow to the Da River (53km of the Da River runs through the south of the district).

For more information on the background of this site, including the social and natural setting please see the Work Package 1 report "Situation analysis report on highland aquatic resource and sustainable development in Northern and Central Vietnam" (Nguyen *et al.* 2009).

Figure 2. HighARCS Phu Yen site catchment within Viet Nam.

2. Site maps

Maps of the site and catchment are important as they allow the results of this Work Package to be put into a geographic context. They allow detailed information to be presented in an easy to understand format, and will also be key in developing the IAP and identifying any potential indicators and monitoring plans. Site and catchment maps have been produced by IUCN, through the digitising of satellite images (Landsat imagery provided by the US Geological Survey - Earth Explorer) using ESRI ArcInfo geographic information systems (GIS) software. Then, through a mapping workshop held on 23-24 August, 2011 at the South China Agricultural University, Guangzhou, China, the maps were reviewed, edited and land classifications were identified by RIA1 staff based on their knowledge and field observations taken while at the site.

In Phu Yen Dictrict, three communities were selected to be used in the study. These communities belong to two communes, Tuong Ha and Tuong Tien that are found at the extreme northern arm of the Song Da reservoir (Figure 3). These communes are made up of 5 villages, Dan (1 and 2) village and Tam Oc (1 and 2) village which belong to Tuong Ha Commune and Tat village which belongs to Tuong Tien Commune (Figure 4). The reservoir at the site is slowly flowing and at times when the reservoir levels are low it reverts back to a stream (used to be named the Tac Stream before the dam was built) and occasionally dries up. The fluctuating water level depends on weather, the requirement of water for electricity generation and for irrigation. At the start of the dry season (October) the reservoir increases in volume based on water storage by the hydropower dam for electricity generation, water levels can reach 25-30m in depth with high transparency (Oct to April). Figure 4 shows the reservoir/river at this level. These floodwaters inundate crop rice fields and much of the surrounding land. This extensive water body provides an important habitat for many fish searching for food and breeding areas. Thus, people living within this watershed are fishing on the river, and using the water for agricultural irrigation and home consumption. However, during rainy season, the dam operators discharge large amount of water lowering the level of reservoir until it is only a stream, which occasionally dries up (May to Sept). The management of the dam for hydroelectric power is a major issue in this area, as it dictates the availability of aquatic resources for the livelihoods of local people.

At the site there are two major types of seasonal wildlife habitats (see Figure 4), namely:
Riverine/reservoir habitats: during the storage water phase of the dam, the water level is high and the river/reservoir is wide. In the central section, water flow is slow and mudflats develop on the bottom. Close to the banks shallow waters are used to establish rice fields, and there are also some areas of gravel/rocky shores.
Stream habitats: occurs when the reservoir levels are lowered and creates a stream which has a strong flow the now dry areas are mud flats and crop land.

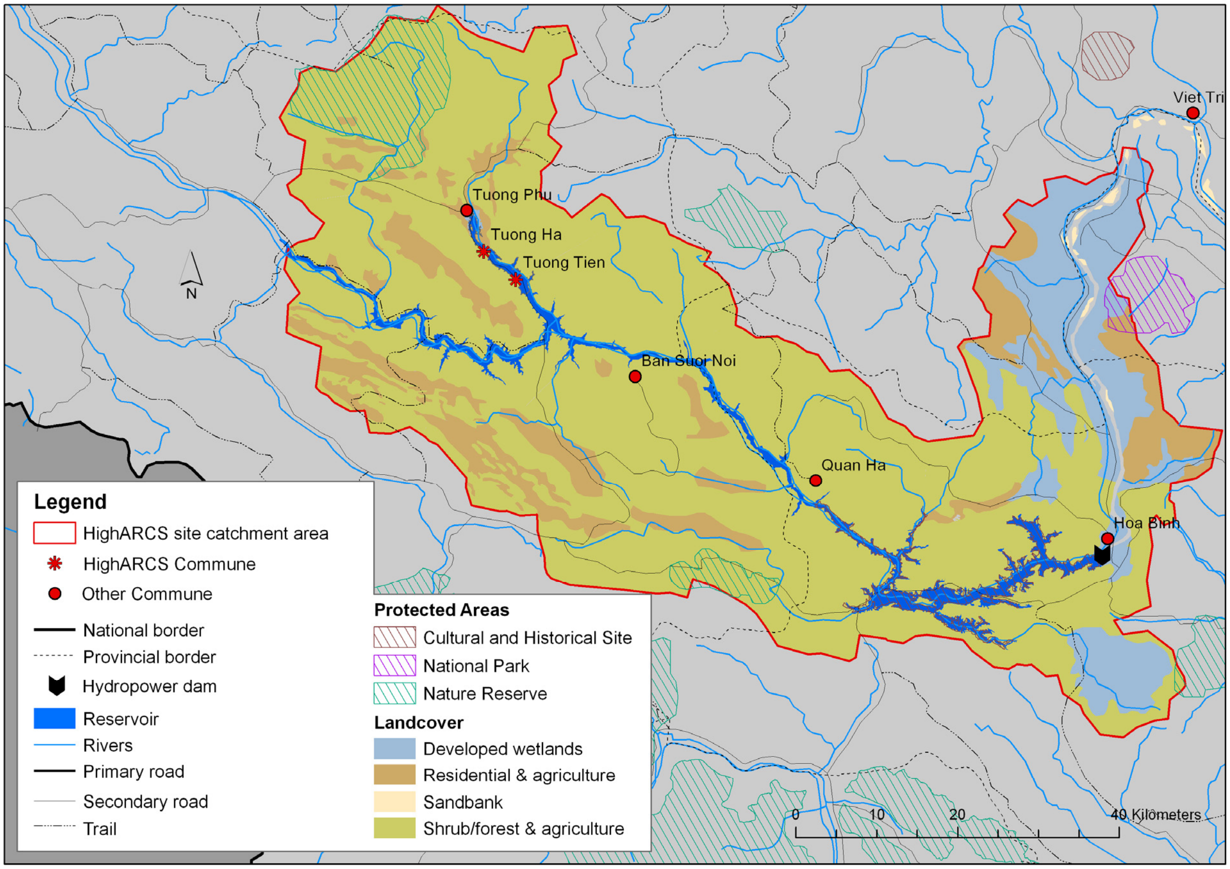


Figure 3. The HighARCS site at Phu Yen wider catchment area.

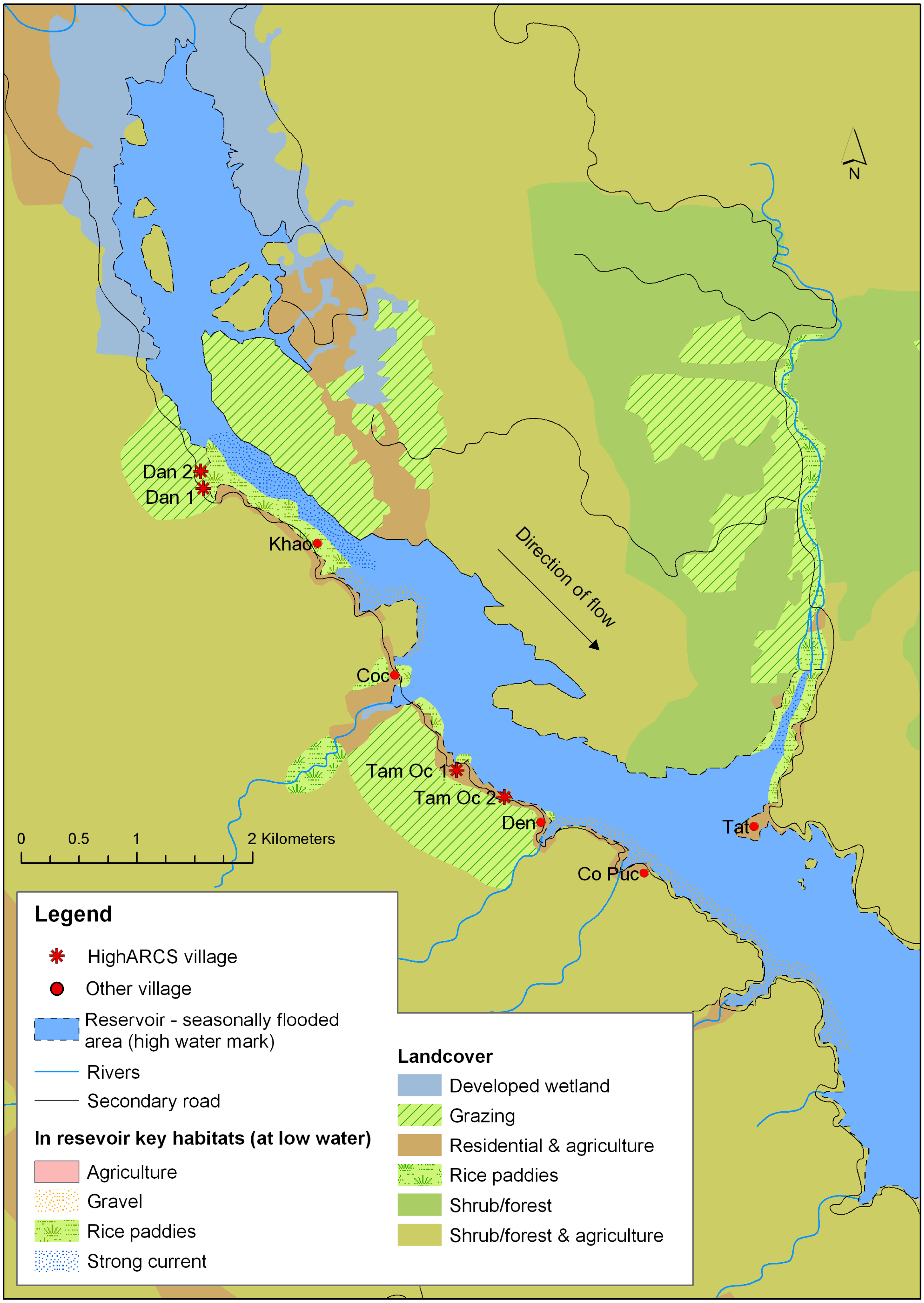


Figure 4. Map of HighARCS site villages and key habitats

3. Biodiversity surveys

3.1. Taxonomic groups

To inform the Integrated Action Plan, we need to know what aquatic biodiversity is present at the sites and what their conservation status is. However, it is not possible to identify all aquatic biodiversity at the sites due to restricted time, money and scientific expertise. Therefore species need to be identified that can be an indicator of environmental threats at the site and also are of livelihood importance to the local communities. People from the three communities selected are highly dependent on fishing for their livelihoods both for home consumption and selling at the market. The main aquatic products they harvest from the river are fish and to a lesser extent shrimps. RIA1 also have fish taxonomists and aquaculture expertise. Therefore fishes are the selected group to be assessed at the site in order to provide information for integrated action plan.

3.2. Conservation status of biodiversity – IUCN Red List assessments

There are several methods of determining species conservation status and the most commonly used tool is the IUCN Red List Categories and Criteria (IUCN 2001), which allows consistency in approach across different taxonomic groups. It helps in determining the relative risk of extinction at a global scale and provides the basis for understanding if a species is Extinct, threatened (Critically Endangered, Endangered or Vulnerable), Near Threatened, of Least Concern, or lacking sufficient basic data for assessment (Data Deficient) (see Figure 5). The IUCN Red List of Threatened Species™ publishes the results of the global assessments (www.iucnredlist.org). The IUCN Red List also provides basic information on species taxonomy, distributions, habitat and ecology, threats, population trends, use and trade, livelihood information, ecosystem services provided, and research and conservation priorities.

Biodiversity experts from the HighARCS project partners, including from RIA1, were trained at a workshop (06-09 June 2009, Kolkata, India) in the use of the IUCN Species Information Service (SIS – the Red List species database), application of the IUCN Red List Categories and Criteria (IUCN 2001) (see Appendix I for a summary of the IUCN Red List Criteria), and Geographic Information Systems (GIS) for digitally mapping species distributions. Following the training workshop, experts collated native species lists of freshwater fishes, dragonflies and damselflies (odonates), freshwater molluscs and aquatic plants for the coastal catchments of northern and central Viet Nam, and input within the SIS, all available information on each species. The required data fields (with standard classification schemes) within SIS are species taxonomy, distribution, habitat and ecology, threats, population trends, use and trade, and research and conservation priorities, Red List Category and rationale. Data gaps were filled and corrections made to the data from another overlapping IUCN project (Freshwater biodiversity assessment of Indo-Burma) which is funded by the Critical Ecosystem Partnership Fund (www.cepf.org). These species were then reviewed at a second workshop (17-22 January 2011, Vientiane, Lao P.D.R.) and via email communications with other species experts after the workshop. The IUCN Indo-Burma project is due to be published in March 2012.

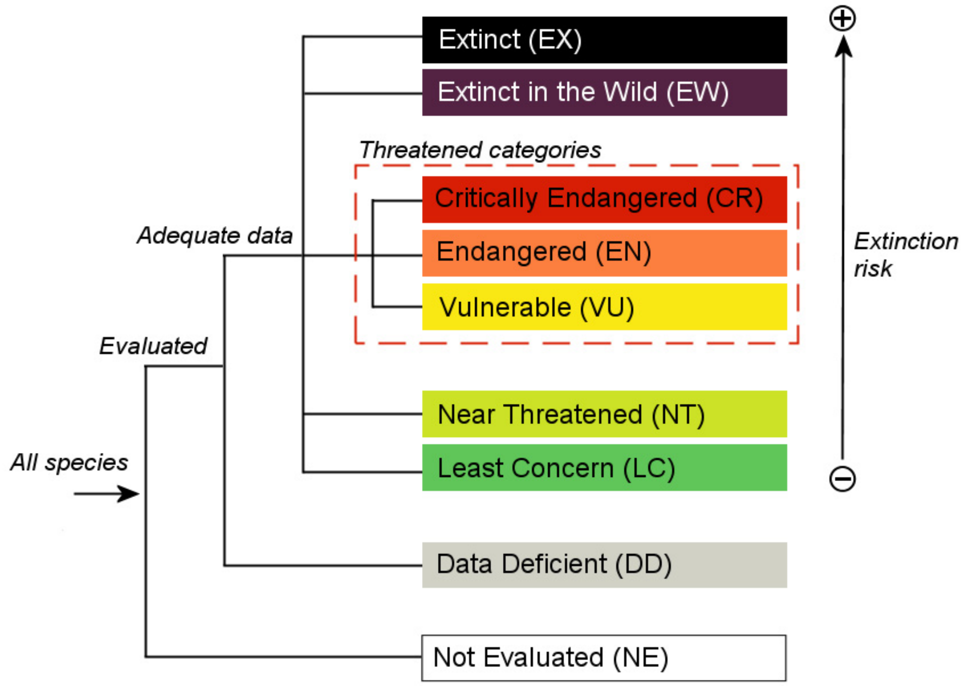


Figure 5. IUCN Red List Categories

While these species will not all be found at the fishing villages, it will allow the actions proposed through the IAP to take into consideration any globally threatened species within the wider catchment if necessary. It will also allow for all the species identified at the site, to be put into a global conservation context. For example a species may be stable and numerous at the site with no known threats and perceived locally as not being of conservation concern, but at a global scale the species may be threatened to impacts elsewhere within the species range, this would make the population at the site of high conservation concern. Alternatively, global conservation status is not the only aspect to identify important species at the site. A species may be of Least Concern globally but may be undergoing severe declines at the site and may also be of economic and livelihood concern and would therefore potentially qualify as a species to be incorporated into the IAP.

The resulting dataset allows 198 fish species found within northern and central Viet Nam coastal catchments, a list of these species with their IUCN Red List Category can be found in Appendix II. An extract of the globally threatened species can be found in Table 1. There are two threatened species, *Bangana tonkinensis* (VU) which is found in northern Viet Nam in Ba Be Lake (Sung 1998) and Ngoi-Thia river (Kottelat 2001) and in Yunnan in China all within the Hong River catchment (Red River) and *Pseudohemiculter dispar* which is found in northern and southern Viet Nam, southern China and in the Mekong in Lao P.D.R. Both of these species are impacted by pollution from agriculture, industry and urban areas and dams which has led to an estimated population decline in both species of more than 30% over the past 10 years (Jenkins *et al.* 2009a,b).

Table 1. Globally threatened (those listed as Critically Endangered, Endangered and Vulnerable) and Extinct species found within northern and central Viet Nam.

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Order	Family	Binomial	IUCN Red List category
Cypriniformes	Cyprinidae	*Bangana tonkinensis*	VU
Cypriniformes	Cyprinidae	*Pseudohemiculter dispar*	VU

3.3. Literature review

From 2008 to 2009, there was a collaboration project between Research Institute for Aquaculture No1 and the Ministry of Agriculture and Rural Development called *Assessment of inland fisheries in Son La province*. The project was carried out in the Da and Ma Rivers. In the Da River, sampling was undertaken in Phu Yen, Bac Yen, Muong La and Moc Chau Districts. In Phu Yen, surveys were undertaken in the river within the districts of Tuong Phong, Tuong Thuong and Tuong Tien communes – covering the same area as the HighARCS study areas. The project provides an overview of fisheries in Son La province as well as the list of fish species found during the 2008-2009 sampling campaign (Bui The Anh *et al.* 2009).

Bui The Anh *et al.* (2009) identified 126 fish species that occur in the Da river (Table 2), this includes two globally threatened species *Sinilabeo tonkinensis* (assessed as VU on the IUCN Red List under the name *Bangana tonkinensis* also assessed as VU in the Viet Nam national Red List) and *Pseudohemiculter dispar* (VU) (see section 3.2. for more information on their status) and five Near Threatened species (*Cirrhinus molitorella, Cyprinus multitaeniata, Onychostoma gerlachi, Bagarius yarrelli* and *Glyptothorax interspinalum*). *Cirrhinus molitorella* is heavily impacted by fishery pressure and, probably, from the disruption of its migratory routes through the construction of dams (Nguyen *et al.* 2011), *Cyprinus multitaeniata* has been impacted in Viet Nam by deforestation, and fish stocks depleted by overfishing, including destructive fishing methods (Zhao 2011), it is also assessed as Extinct in the Wild in Viet Nam (Ministry of Agriculture and Rural development 2008). *Onychostoma gerlachi* is inferred to have declined by nearly 30% in the past 10 years as a result of high levels of pollution and a large number of hydrological changes, including dams across its range (Jenkins *et al.* 2009c). *Bagarius yarrelli* while has taxonomic issue that need to be reviewed, is being impacted by fishing pressure (at least on the Indian subcontinent) which is likely to be unsustainable and local declines reported in some studies (Ng 2010). *Glyptothorax interspinalum* has been assessed as Near Threatened with an inferred population decline of 20-29% in the past ten years, as a result of heavy pollution in the Red River (Jenkins *et al.* 2009d). Of these threatened and Near Threatened species three are important for livelihoods *Cirrhinus molitorella, Sinilabeo tonkinensis* and *Bagarius yarrelli.* In total there are 36 species of economic/livelihood importance in the Da river, three of which are globally threatened or Near Threatened (mentioned above), five are assessed as Vulnerable on the Viet Nam National Red List *Hemibagrus guttatus* (DD IUCN Red List), *Elopichthys bambusa* (DD IUCN Red List), *Semilabeo obscures* (LC IUCN Red List), *Sinilabeo lemassoni* (DD under the name *Bangana lemassoni* on the IUCN Red List) and *Sinilabeo* *tonkinensis* (VU under the name Bangana tonkinensis on the IUCN Red List), and one, *Channa maculata* (LC on the IUCN Red List) is Endangered.

Eight of the 126 species are not native to the catchment, *Oryzias latipes Clarias gariepinus Cobitis taenia Carassius auratus Cyprinus carpio Oreochromis mossambicus Oreochromis niloticus Gambusia affinis.* Many of these species are known to have adverse ecological impacts when introduced. For example *Gambusia affinis,* often introduced to control mosquito larvae eat the eggs of economically desirable fish and preys on and endangers rare indigenous fish and invertebrate species (ISSG 2011). Also *Oreochromis niloticus* effective mouthbrooding reproductive strategy allows it to increase in numbers at a rate which, not only crowds native species, but pollutes and unbalances the water column, and along with *O. mossambicus* which competes with native species for resources are often introduced as a result of aquaculture (ISSG 2011). *Cyprinus carpio* through its feeding behaviour is a keystone ecosystem engineer altering habitats for native fish and other aquatic species as it churns up the sediments on the bottom of the water and uproots macrophytes (ISSG 2011).

Table 2: Fish species identified from Da river based on Bui The Anh *et al.* (2009)

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Family	Binomial	National Red List Category	IUCN Red List Category	Economic importance
Adrianichthyidae	*Oryzias latipes*		Introduced	
Anabantidae	*Anabas testudineus*		DD	Economic species
Bagridae	*Hemibagrus guttatus*	VU	DD*	High value species
Bagridae	*Hemibagrus pluriradiatus*		LC*	
Bagridae	*Hemibagrus vietnamicus*		DD*	
Bagridae	*Mystus pluriadiatus*		LC* (as *Hemibagrus pluriradiatus*)	
Bagridae	*Pelteobagrus fulvidraco*		LC (as *Tachysurus fulvidraco*)	
Bagridae	*Pelteobagrus vachellii*		DD* (as *Tachysurus vachellii*)	
Bagridae	*Pseudobagrus kyphus*		not assessed	
Bagridae	*Pseudobagrus virgatus*		DD* (as *Tachysurus virgatus*)	
Balitoridae	*Beaufortia leveretti*		DD	
Balitoridae	*Beaufortia pingi*		LC	
Balitoridae	*Nemacheilus pulcher*		LC (as *Micronemacheilus pulcher*)	

Family	Binomial	National Red List Category	IUCN Red List Category	Economic importance
Balitoridae	*Pseudogastromyzon loos*		DD	
Balitoridae	*Schistura caudofurca*		LC	
Balitoridae	*Schistura fasciolata*		DD	
Balitoridae	*Schistura incerta*		DD*	
Balitoridae	*Sinogastromyzon rugocauda*		DD*	
Balitoridae	*Sinogastromyzon tonkinensis*		DD	
Balitoridae	*Vanmanenia monoloba*		not assessed	
Balitoridae	*Vanmanenia multiloba*		DD	
Channidae	*Channa asiatica*		LC*	High value species
Channidae	*Channa maculata*	EN	LC	High value species
Channidae	*Channa orientalis*		not assessed	High value species
Channidae	*Channa striata*		LC	High value species
Clariidae	*Clarias fuscus*		LC*	Economic species
Clariidae	*Clarias gariepinus*		Introduced	Economic species
Cobitidae	*Cobitis taenia*		Introduced	Economic species
Cobitidae	*Misgurnus anguillicaudatus*		LC	Economic species
Cranoglanididae	*Cranoglanis multiradiatus*		not assessed	
Cyprinidae	*Acheilognathus macropterus*		DD	
Cyprinidae	*Acheilognathus tonkinensis*		DD	
Cyprinidae	*Acrossocheilus clivosius*		DD	
Cyprinidae	*Acrossocheilus iridescens*		DD	
Cyprinidae	*Barilius maropterus*		DD (as *Acheilognathus macropterus*)	
Cyprinidae	*Barilius nammuensis*		LC* (as *Opsarius pulchellus*)	
Cyprinidae	*Capoeta semifasciatus*		LC* (as *Puntius semifasciolatus*)	
Cyprinidae	*Carassioides cantonensis*		LC (as *Carassioides acuminatus*)	
Cyprinidae	*Carassius auratus*		Introduced	Economic species
Cyprinidae	*Catla catla*		LC (as *Gibelion catla*)	Economic species
Cyprinidae	*Chanodichthys erythropterus*		LC	Economic species
Cyprinidae	*Cirrhinus molitorella*		NT	Important economic

Family	Binomial	National Red List Category	IUCN Red List Category	Economic importance
Cyprinidae	*Cirrhinus mrigala*		LC	Economic species
Cyprinidae	*Ctenopharyngodon idella*		DD	High value species
Cyprinidae	*Culter flavipinnis*		DD (as *Chanodichthys flavipinnis*)	Economic species
Cyprinidae	*Cyprinus carpio*		Introduced	High important economic
Cyprinidae	*Cyprinus multitaeniata*	EW	NT	
Cyprinidae	*Elopichthys bambusa*	VU	DD	Economic sepcies
Cyprinidae	*Garra orientalis*		LC	
Cyprinidae	*Garra pingi*		DD* (as *Garra imberba*)	
Cyprinidae	*Gobiobotia kolleri*		DD	
Cyprinidae	*Gobiobotia longibarba*		DD*	
Cyprinidae	*Hainania serrata*		DD	
Cyprinidae	*Hemibarbus labeo*		not assessed	
Cyprinidae	*Hemibarbus maculatus*		not assessed	
Cyprinidae	*Hemiculter leucisculus*		LC	Economic species
Cyprinidae	*Hypophthalmichthys harmandi*		DD	Economic species
Cyprinidae	*Labeo rohita*		LC	Economic species
Cyprinidae	*Luciobrama macrocephalus*		DD	
Cyprinidae	*Megalobrama skolkovii*		DD*	Economic species
Cyprinidae	*Megalobrama terminalis*		LC	Economic species
Cyprinidae	*Metzia lineata*		LC	
Cyprinidae	*Microphysogobio labeoides*		DD*	
Cyprinidae	*Microphysogobio vietnamica*		DD	
Cyprinidae	*Mylopharyngodon piceus*		DD	High value species
Cyprinidae	*Nicholsicypris normalis*		not assessed	
Cyprinidae	*Ochetobius elongatus*	VU	DD*	
Cyprinidae	*Onychostoma elongatum*		DD*	
Cyprinidae	*Onychostoma gerlachi*		NT	
Cyprinidae	*Onychostoma laticeps*		DD*	
Cyprinidae	*Onychostoma ovale*		DD	
Cyprinidae	*Opsariichthys bidens*		LC*	

Family	Binomial	National Red List Category	IUCN Red List Category	Economic importance
Cyprinidae	*Oreochromis mossambicus*		Introduced	Important economic
Cyprinidae	*Oreochromis niloticus*		Introduced	Important economic
Cyprinidae	*Osteochilus salsburyi*		LC	
Cyprinidae	*Paraspinibarbus macracanthus*		DD	
Cyprinidae	*Parazacco vuquangensis*	VU	DD	
Cyprinidae	*Placocheilus caudofasciatus*		DD (as *Garra caudofasciatus*)	
Cyprinidae	*Placocheilus cyclostomatus*		DD (as *Garra poilanei*)	
Cyprinidae	*Placocheilus microstomus*		DD (as *Discogobio microstoma*)	
Cyprinidae	*Poropuntius krempfi*		DD*	
Cyprinidae	*Pseudohemiculter dispar*		VU	
Cyprinidae	*Pseudohemiculter hainanensis*		LC	
Cyprinidae	*Pseudolaubuca sinensis*		LC	
Cyprinidae	*Rhodeus ocellatus*		DD	
Cyprinidae	*Rhodeus spinalis*		LC	
Cyprinidae	*Saurogobio dabryi*		LC*	
Cyprinidae	*Saurogobio immaculatus*		DD	
Cyprinidae	*Semilabeo obscurus*	VU	LC	High value speceis
Cyprinidae	*Sinibrama melrosei*		DD*	
Cyprinidae	*Sinilabeo lemassoni*	VU	DD (as *Bangana lemassoni*)	High value species
Cyprinidae	*Sinilabeo tonkinensis*	VU	VU (as *Bangana tonkinensis*)	Economic species
Cyprinidae	*Spinibarbus denticulatus*		LC	High value species
Cyprinidae	*Spinibarbus hollandi*		DD*	High value species
Cyprinidae	*Squalidus argentatus*		DD	
Cyprinidae	*Squalidus chankaensis*		DD*	
Cyprinidae	*Squaliobarbus curriculus*		DD	Economic species
Cyprinidae	*Tor brevifilis*	VU	DD* (as *Folifer brevifilis*)	
Cyprinidae	*Toxabramis houdemeri*		LC	
Cyprinidae	*Varicorhinus lepturus*		DD (as *Onychostoma lepturum*)	

Family	Binomial	National Red List Category	IUCN Red List Category	Economic importance
Cyprinidae	*Xenocypris argentea*		LC (as *Xenocypris macrolepis*)	
Cyprinidae	*Yaoshanicus kyphus*		DD*	
Eleotridae	*Eleotris melanosoma*		LC	
Gobiidae	*Glossogobius giuris*		LC	
Gobiidae	*Rhinogobius brunneus*		DD	
Gobiidae	*Rhinogobius cliffordpopei*		not assessed	
Gobiidae	*Rhinogobius giurinus*		LC	
Hemiramphidae	*Hemirhamphus sinensis*		LC (as *Hyporhamphus limbatus*)	
Mastacembelidae	*Macrognathus aculeatus*		LC*	
Mastacembelidae	*Mastacembelus armatus*		LC	
Odontobutidae	*Percottus chalmersi*		LC (as *Sineleotris chalmersi*)	
Osphronemidae	*Macropodus opercularis*		LC	
Percichthyidae	*Coreoperca whiteheadi*		LC	
Percichthyidae	*Siniperca chuatsi*		not assessed	
Percichthyidae	*Siniperca kneri*		DD	
Percichthyidae	*Siniperca kwangsiensis*		DD (as *Siniperca scherzeri*)	
Poeciliidae	*Gambusia affinis*		Introduced	
Salangidae	*Salanx chinensis*		DD	
Siluridae	*Silurus asotus*		LC	Economic species
Siluridae	*Silurus cochinchinensis*		LC (as *Pterocryptis cochinchinensis*)	
Sisoridae	*Bagarius yarrelli*		NT	High values species
Sisoridae	*Glyptothorax hainanensis*		not assessed	
Sisoridae	*Glyptothorax interspinalum*		NT	
Sisoridae	*Glyptothorax laosensis*		LC	
Sisoridae	*Pseudecheneis paviei*		DD	
Synbranchidae	*Monopterus albus*		LC	Economic species

3.4. Field surveys

Based on the research results of Bui The Anh *et al.* (2009), the list of fish species expected to be currently found at the study site is provided in Table 2. Therefore additional field fish surveys were not undertaken. However, to provide information on status of the fish populations, particularly the economic species and to identify potential threats to aquatic biodiversity and ecosystem services, field research was undertaken.

3.4.1. Methods

Information was collected on the freshwater fishes at the site through focus group discussions, market surveys and a stakeholder Delphi study.

- Focus groups: 6 Focus Group Discussions were carried out each with 5-6 experienced local fishermen in October 2010 in Tuong Ha and Tuong Tien Communes. Each focus group identified and discussed the trends in wetland species, key species harvested, season of fishing for different species, fishing methods used, fishing grounds and the threats to aquatic resources within their fishing zones.

- Market surveys: Market surveys were carried out by RIA1 researchers using key informant interviews with fish traders at the site villages and at the district market from 1 - 10 October 2010. Species for sale at the market were identified along with the origin of the fish (to make sure it was from the site) the trading route, prices and constraints in fish marketing. In addition, photographs of fish commonly on sale were taken and local names recorded.

3.4.2. Results

Based on the focus group discussions with local fishermen and market surveys, 18 fish species are harvested in the rivers, streams and wetlands around the study area (see Table 3). The list of most frequently caught fish species includes Common carp Cá Chép (*Cyprinus carpio)*, cá thiểu (*Chanodichthys erythropterus),* tép dầu (*Pseudohemiculter dispar*), Cá Bò (*Pelteobagrus fulvidraco)*, Cá Ngão (*Culter flavipinnis*), Trắm cỏ (*Ctenopharyngodon idella*), mè trắng (*Hypophthalmichthys harmandi)*, Cá Măng (*Elopichthys bambusa)*, and Rô phi (*Oreochromis niloticus).* Of these nine frequently caught species, two *Cyprinus carpio* and *Oreochromis niloticus* are non-native species and have been known to cause ecological damage to areas they are introduced, for examples and general information of their impacts see the Global Invasive Species Database www.issg.org/database (ISSG 2011). *Elopichthys bambusa* is Vulnerable on the Viet Nam National Red List, and *Pseudohemiculter dispar* is Vulnerable on both the Viet Nam National Red List and the IUCN Red List (i.e. its global status). Only three species *Channa striata, Clarias fuscus* and *Bagarius yarrelli* are known to have declined at the site since 1990 (Table 3), and only *Bagarius yarrelli* is listed as nationally threatened (VU on the national Red List but NT on the IUCN Red List). While many other species have remained rare, four species are known to have increased in numbers since 1990, these are *Cirrhinus mrigala, Squaliobarbus curriculus, Pseudohemiculter dispar,* and *Chanodichthys erythropterus.* One of these species *Pseudohemiculter dispar* is assessed as VU on the IUCN Red List.

Fishing activities are undertaken in all months of the year but the main season for harvesting fish species in Phu Yen is from September to April with a peak fishing season from February-March which corresponds to the high water levels (for the hydropower dam to store water) and low levels of turbidity. From May to August, the water level is often low, but flooding occurs due to high rainfall leading to high turbidity and there is little to no fishing undertaken. On average water level is 3-4 meters, with the highest depth at 30 meters and the lowest at 20 centimeters.

Table 3: Fish species harvested in Tuong Ha and Tuong Tien communes, identified through focus group discussions.

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient. The categories CR, EN and VU are classed as the ‘threatened’ categories. ‘*’ indicates a draft Red List assessment, that still needs to be peer reviewed.

Vietnamese name	Binomial	Viet Nam National Red List	IUCN Red List	Collected before 1990?	Collected now?	Fishing season	Fishing ground
Cá Thiểu	*Chanodichthys erythropterus*		LC	No	Many	Jul-Aug	Tuong Ha commune
Tép dầu	*Pseudohemiculter dispar*		VU	No	Many	Jul-Aug	Tuong Ha commune
Lươn đồng	*Monopterus albus*		LC	Rare	Rare		Rice fields
Cá Trê	*Clarias fuscus*		LC*	Rare	No		
Cá quả	*Channa striata*		LC	Rare	Rarer		
Cá chày mắt đỏ	*Squaliobarbus curriculus*		LC	No	Many		
Trôi trắng	*Cirrhinus mrigala*		LC	Rare	More than before		Tuong Ha commune
Trắm đen	*Mylopharyngodon piceus*		DD	Rare	Rare		
Cá Chiên	*Bagarius yarrelli*	VU	NT	Rare	No	Aug-Sep	Tac stream
Chạch bùn	*Misgurnus anguillicaudatus*		LC	Rare	Rare		
Cá chép	*Cyprinus carpio*		Introduced		Common species	Any time of year whenever water is high	Along the river
Rô phi	*Oreochromis niloticus*		Introduced				
Mè trắng	*Hypophthalmichthys harmandi*		DD				
Trắm cỏ	*Ctenopharyngodon idella*		DD				
Cá Trôi	*Labeo rohita*		LC				
Cá ngão	*Culter flavipinnis*		DD (as *Chanodichthys*)				

Vietnamese name	Binomial	Viet Nam National Red List	IUCN Red List	Collected before 1990?	Collected now?	Fishing season	Fishing ground
Cá Bò	*Pelteobagrus fulvidraco*		LC (as *Tachysurus*)				
Cá măng	*Elopichthys bambusa*	VU	DD				

Cá Bò (*Pelteobagrus fulvidraco*)

Cá Măng (*Elopichthys bambusa*)

Cá dầu (*Pseudohemiculter dispar*)

Cá Ngão (*Culter flavipinnis*)

Rô phi (*Oreochromis niloticus*)

Trắm cỏ (*Ctenopharyngodon idella*)

Photographs of some commonly caught fish species in the HighARCS site villages © Nguyen Thi Dieu Phuong and Nguyen Thi Hanh Tien

3.4.3. Indicator species

Fish species indicators will allow the status of fish resources, and particularly those that are declining at the site or are globally threatened with extinction to be monitored, possibly in response to actions proposed through the IAP. These indicators will be identified in consultation with local stakeholders, and will be included as one of the first activities for the IAP.

3.4.4. Biodiversity policy

While the legislative framework in Vietnam provides a solid basis for the conservation and sustainable use of biodiversity, implementation is frequently constrained by unclear and overlapping institutional jurisdictions, weak inter-agency cooperation and capacity limitations among government institutions (Wetlands Alliance 2011). The different legislation that is in place that directs the conservation of aquatic biodiversity in Viet Nam can be seen in Table 4. The responsibility for implementing these legislation is divided between different ministries (including the Ministry of Agriculture and Rural Development (MARD), the Ministry of Natural Resources and Environment (MONRE), the Ministry of Fisheries (MOF), and the Ministry of Planning and Investment (MPI)) and also at different levels from central government to Provincial and District.

Table 4. Key legislation and decrees influencing conservation of freshwater biodiversity in Viet Nam (sources listed in table)

Legislation	Key aims of legislation
The Water Resources Law (1998)	Integrated water resources management. It states "managing, protecting, and rationally, economically and efficiently exploiting the water resource; preventing, combating and overcoming the harmful effect caused by water with a view to ensuring water for living of the people,[…] protecting the environment and serving the sustainable development of the country" (Guignier 2011). Decree 120/2008/NĐ-CP provides a framework assigning powers for river basin management and planning
Environmental Protection Law in 1993 (amended in 2005)	Regulates public and private activities to protect the environment and establishes the Ministry of Natural Resources and Environment (USAID 2007). It states "as "environmental protection must be in harmony with economic development and assure social advancement for national sustainable development" (Guignier 2011).
Forest Protection and Development Law in 1991 (amended in 2004)	Defines forests into three categories; protection forest, special use forest and production forest. Each category has obligations of both the state and users to manage and protect it (Pham 2005).
The Law on Minerals 1996 (amended in 2006)	Provides the basis for a 'mineral master plan'. Any mining activities in violation of the mineral master plan are prohibited. Decree 160 sets out some elements to be included in master plans (e.g. socio-economic conditions) but they remain in general terms (Freshfields Bruckhaus Deringer 2006).
The Law on Biodiversity (2009)	Provides for the principles of the conservation and use/exploitation of biodiversity. One of the main tenets is to combine conservation with rational exploitation/use of biodiversity and with hunger eradication and poverty alleviation (Guignier 2011). Decision 79/2007/QD-TTg established the

Legislation	Key aims of legislation
	National Biodiversity Action Plan up to 2010 and vision to 2020.
Fishery Law in 2003	Empowers resource managers, particularly at the Provincial level, to effectively and sustainably manage their resources. Promotes economic effectiveness in accordance with the protection, rehabilitation and development of fisheries resources and biodiversity and protection of the environment (World Bank 2005). Decree No 27/2005/ND-CP provides detailed guidelines on how to implement the fisheries law.
Land Law in 1993 (amended in 1998 and 2003)	Permitted the State to transfer and lease out land to organizations, households and individuals for long-term stable use, and allowed land users to pass on the right to use land to another user within the duration of the lease. Also approaches the concept of comprehensive management of land resources owned by the state in close connection with environmental protection (Nguyen 2010).
Decree 112/2008/NĐ-CP	Framework for management, protection, integrated exploitation of natural resources and environmental management of irrigation and hydropower reservoirs
Decree 80/2006/ND-CP	Detailed guidelines for implementation of the EIA framework
Decree 109/2003/ND-CP dated 23/9/2003	Detailed guidelines for conservation and sustainable development of wetlands,
Decision 131/2004/QD-TTg	Program for protection and development of aquatic resources, approved by the Prime Minister
Decision 29/2007/QD-TTg	Establishment of fund for renewable aquatic resources in Vietnam

Son La Provincial People's Committee have also issued many official decisions that aim to strengthen fisheries as well as aquatic resources conservation (see Table 5). However, through focus group discussions and key informant interviews with local stakeholders it was found that activities to protect fisheries resources within Phu Yen District are less focused. The district has not issued its own policies and only implements the policies from the provincial level and encourages people to adhere to them accordingly. The Son La Department of Agriculture and Rural Development has sent written instructions on prohibiting the use of destructive fishing equipment but this is not enforced within the commune. In 2003, Son La Agriculture and Rural Development Department organized training in cage culture and integration with dissemination in aquatic resources conservation. The promotional and dissemination aspects of fishery laws and regulations have not been implemented in recent years.

Table 5. Official decision by Son La People's Committee for strengthening fisheries and aquatic resources conservation

Document	Main content of document
Decision No: 57/QD-UBND dated 09/01/2001.	A master plan for fisheries development in Son La Province for the period 2000-2010
Resolution: 20/NQ-TU dated 18/6/2007	Protection and development of aquatic resources in the period 2010 – 2015.
Decision: 1530/QD – UBND dated 06/23/2008	Project in developing fisheries resources in the reservoir of Hoa Binh and Son La hydropower in association with stabilize life of people residing along the dam from 2008 to 2015".
Resolution 332/NQ-HDND, dated 8th July 2010	Approved the master plan for aquatic development from 2010 to 2015 and orientation to 2020.

3.5. Inclusion of data in online databases

Data collated through this research will be included in two online species databases; the IUCN Red List (www.iucnredlist.org) and Fishbase (www.fishbase.org).

Through Work Package 1 of this project the fish species from the northern and central Viet Nam basins were assessed against the IUCN Red List categories and criteria and have been published on the Red List website (see section 3.2). Information on the species identified through this Work Package such as new information on species distributions, threats but in particular their utilisation by humans will be added to their Red List assessment and published online with the next IUCN Red List update in 2012. If the information provided is significant it may require the species to be reassessed, changing the species Red List Category.

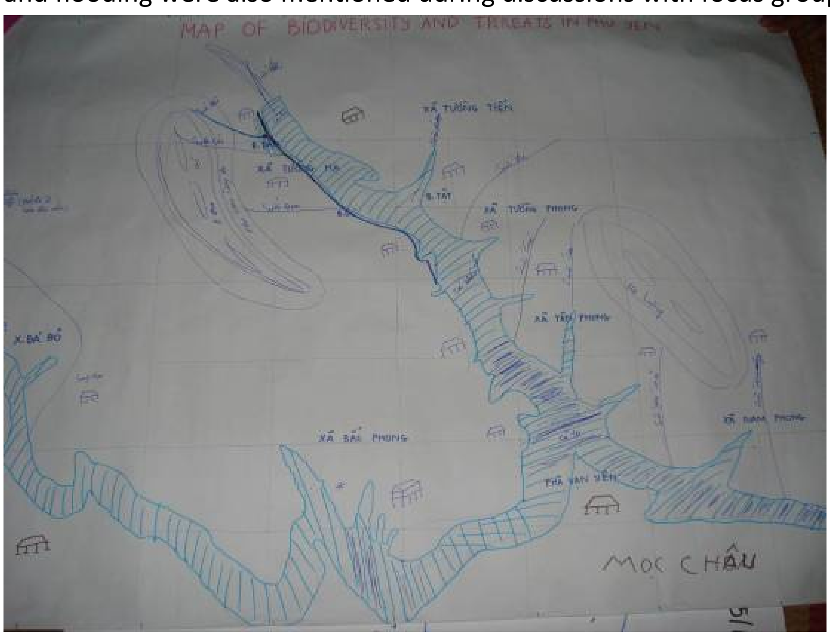
The information on the fish species utilisation will also be added to the Fishbase online database, under the 'Human Uses' tag. For example, the species will be tagged as being 'Fisheries: minor commercial' or 'aquarium: potential'.

4. Threat surveys

Human action to capture and exploit freshwater ecosystem services can result in negative impacts upon biodiversity. The threats to freshwater biodiversity at the site were identified (between April 2010-July 2011) using the focus group discussions including the drawing of maps, through RIA1 researcher site visits and while collating information for other work packages in particular the Delphi results for Work Package 5 (Nguyen *et al.* 2011). The Delphi method aims to gather and share information, ideas and viewpoints of all stakeholder groups. The stakeholders include those who manage the aquatic resources, policy makers, researchers and the people who exploit and depend directly upon the aquatic resources at the study site. Please see deliverable 5.2 (Nguyen Thi Dieu Phuong *et al.* 2011) for further details of this research and methods.

The maps are based on those produced for the site and catchment maps and the threats were discussed and drawn by RIA1 staff and IUCN during the mapping workshop held on 23-24 August, 2011 at the South China Agricultural University, Guangzhou, China. The results were then digitised using GIS software by IUCN. The maps will allow the sources of the threats to be identified and the areas impacted, informing the IAP the potential monitoring of proposed actions taken through the project.

At the Phu Yen site, the main threats identified are overfishing and the use of destructive fishing methods, agricultural pollution, deforestation, and the changing water levels caused by hydropower dam operation. Other threats including climate change and the harsh climate leading to heavy storms and flooding were also mentioned during discussions with focus groups and stakeholders.



A map drawn at a focus group discussion by fishermen from Tuong Ha and Tuong Tien communes © Nguyen Thi Hanh Tien

4.1. Overharvesting and destructive fishing methods

Based on the results of research (Delphi approach) for Work Package 5, just under 70% of villagers described the status and condition of aquatic resources as either ‘seriously declining’ or ‘declining’ (Nguyen *et al.* 2011). During survey work at the sites in 2010, the use of fine nets and small mesh sizes were observed by research staff, and these will have resulted in the harvesting of many fingerlings that do not then get the chance to reproduce. It is possible that this has contributed to the decline of many fish populations. Focus group members indicated that illegal fishing techniques such as using explosives or electricity are used, even though all fishermen understand that these methods are illegal. Also many fishermen do not adhere to fishing regulations that regulate the harvestable species, minimum size of individuals allowed to be caught, fishing grounds or seasons and just try to catch as much fish as possible, especially the commercially valuable species. Through the Delphi survey the need for fisheries management at the site was one of the key recommendations suggested by many of the participants. The areas that are targeted by the fishermen are shown in Figure 6.

4.2. Water pollution and sedimentation

Based on the results of research (Delphi approach) for Work Package 5, 91% respondents indicated erosion and water turbidity, and 25% mentioned agricultural pollution as significant threats facing aquatic biodiversity at the site (Nguyen *et al.* 2011). Figure 7 shows that the entire upper catchment of the river/reservoir that the site communes are situated on is being used for agriculture (maize and soybeans) within in a mosaic of shrub and forest, although some removal of natural vegetation has taken place in these hilly areas. In addition the clearance of natural vegetation has occurred in the less hilly areas (in light red on the map) to provide land for more intensive agriculture. These agricultural areas are using increasing amounts of fertilizers and pesticides that are washing into the rivers and polluting the water, also the exposed soils (due to deforestation) are being washed away into the rivers (especially during high rainfall and floods) leading to increased sediment.

4.3. Dams

In Phu Yen District, Tuong Ha and Tuong Tien Communes are located on the reservoir of the Hoa Binh hydropower plant. The management of the dam, as it controls the level of water at the communes, dictates the availability of many of the aquatic resources to the communities as where there is little water, there are few fish. According to the fishermen at the focus group discussions, fish quantity and the number of species have greatly reduced since the hydropower dam was constructed (but there are no official statistic available). The construction of the dam, changing flow regimes and increased sedimentation have destroyed fish breeding grounds and blocked fish migrations. Also during floods and when the hydropower dam discharges water, sediment load increases turning the water turbid which has resulted in massive fish kills in the Van Yen area (the main fishing ground see Figure 6).

In addition, according to the Master Plan of Social Economic Development from 2009-2020 of Phu Yen Peoples Committee four small hydropower stations are planned (each with capacity of 8-15 MW) in Phu Yen District; (Suoi Sap 1, Suoi Sap 2, Suoi Sap 3 and Muong Lang) (Phu Yen People's Committee, 2009).

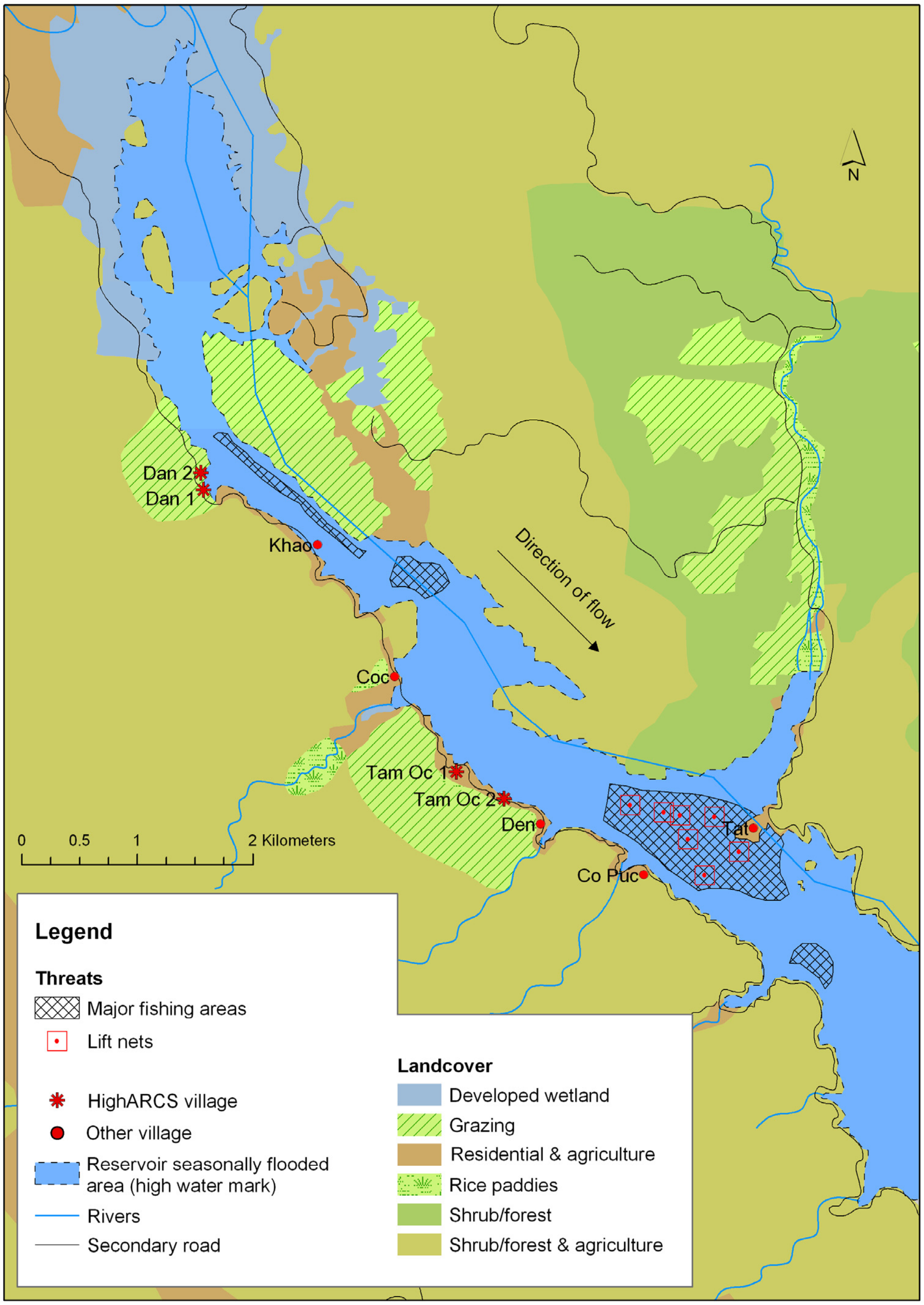


Figure 6. Map showing the major fishing grounds used by the fisherman in the area

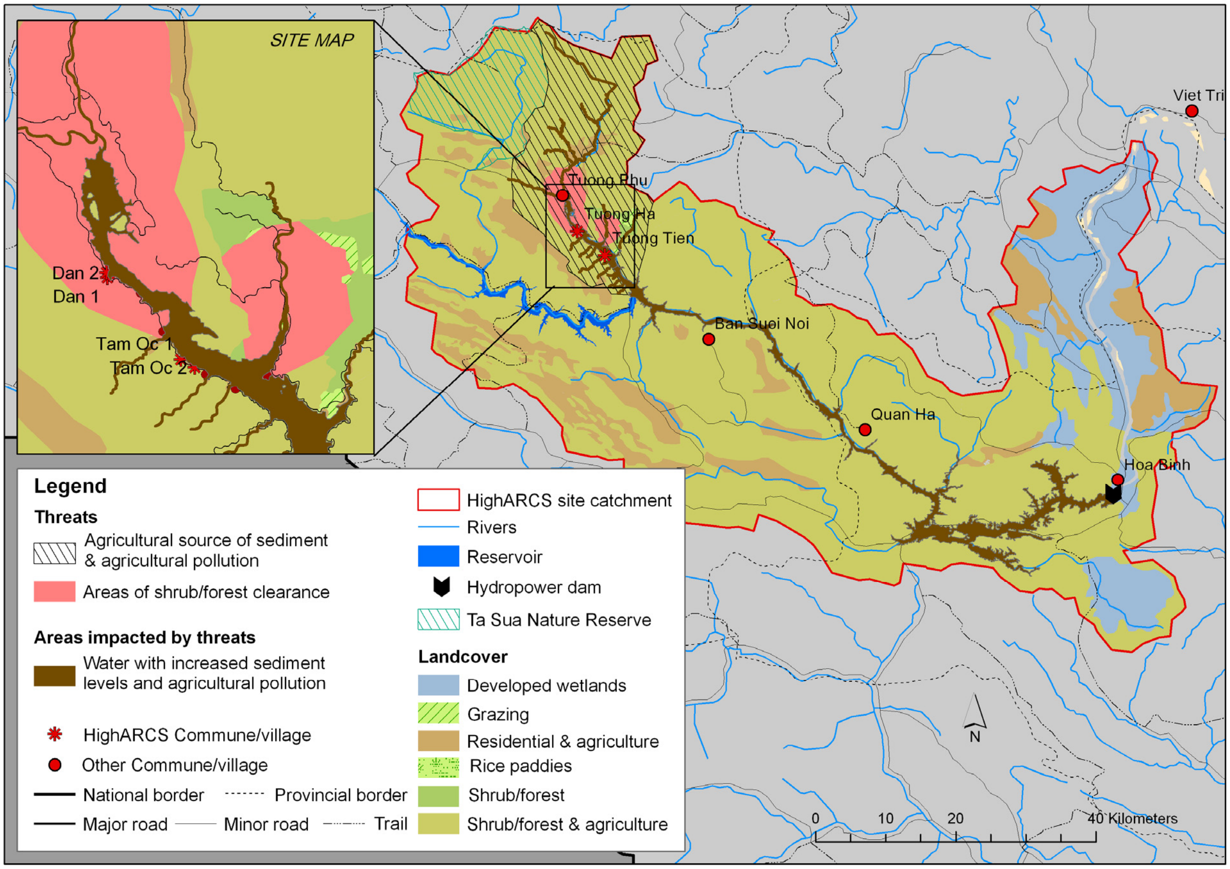


Figure 7. Deforestation and agricultural pollution impacting the Phu Yen site.

5. Ecosystem Services

5.1. Types of ecosystem services

People around the world depend upon natural ecosystems to supply a range of services for their survival and well-being. Ecosystem services can be defined as the “benefits people obtain from ecosystems” (Springate-Baginski *et al.* 2009) and are commonly classified as being one of four types: provisioning, regulating, cultural, or supporting (Millennium Ecosystem Assemssment 2005). Following this classification Groot *et al*. (2010), identified 22 ecosystem services (Table 6).

Table 6: Typology of ecosystem services (adapted from Groot *et al.* 2010 and Springate-Baginsky *et al.* 2009)

Main service category	Ecosystem service
Provisioning services	Food (e.g. fish, game, fruit) Water (e.g. for drinking, irrigation, cooling) Raw materials (e.g. fibre, timber, fuel wood, fodder, fertilizer) Genetic resources (e.g. for crop-improvement and medicinal purposes) Medicinal resources (e.g. biochemical products, model and test-organisms) Ornamental resources (e.g. artisan work, decorative plants, pet animals, fashion)
Regulating & Supporting services	Air quality regulation (e.g. capturing (fine)dust, chemicals, etc) Climate regulation (incl. C-sequestration, influence of vegetation on rainfall, etc.) Moderation of extreme events (e.g. storm protection and flood prevention) Regulation of water flows (e.g. natural drainage, irrigation and drought prevention) Waste treatment (especially water purification) Erosion prevention Maintenance of soil fertility (including soil formation) Pollination Biological control (e.g. seed dispersal, pest and disease control) Maintenance of life cycles of migratory species (incl. nursery service) Maintenance of genetic diversity (especially in gene pool protection)
Cultural services	Aesthetic information Opportunities for recreation and tourism Inspiration for culture, art and design Spiritual experience Information for cognitive development

5.2. Ecosystem prioritisation

To ensure that all ecosystem services provided by the wetlands in Phu Yen to all stakeholders are given full recognition within the integrated action planning process a participatory prioritisation exercise has been undertaken.

5.2.1. Methods

To indentify the types of ecosystem services associated with the Phu Yen study site, questionnaires were carried out (integrated with WP4) with 92 households in the 5 communities (Tam Oc 1, Tam Oc 2, Dan 1, Dan 2 and Tat) and 37 focus groups between May and October 2010. The resulting ecosystem services were listed in a second questionnaire (along with the key threats to ecosystem services) and conducted with 26 people that represented 3 different levels of governance of the resources at the site. Group 1 were those involved in Provincial and District level governance (live outside study site, involved in Province and District level policy making and management); Group 2 were those people involved at Commune level governance (live in study site involved in Commune level decision making, may partly partake in fishing); Group 3 were those individuals at the site villages (fishermen and others relying on freshwater resources within the HighARCS villages). Respondents were asked to score each ecosystem service and threat according to their importance with low numbers indicating lesser importance (1 means lowest important and 5 means highest important).

5.2.2. Results

The services with the highest value (average score, all groups) are all regulating or supporting services; wetland water storage during dry season (4.7), habitat provision for economic species (fish/shrimp) (4.6), flood control (4.5) and maintenance of genetic diversity of valuable fish species (4.5) (Table 7, Figure 8). The lowest average scores were given to water for irrigation (3.2), water for livestock (3.3) and recreation (3.3). Regulating and supporting services received on average, higher scores than the other categories, with 4.5, compared to 4.0 for provisioning services and 3.9 for cultural services.

Table 7. Ecosystem service valuation results. Average scores by stakeholder group.
Group 1 = Provincial and District level governance; Group 2 = Commune level governance; Group 3 = villagers.
Prioritisation score = 1 is lowest value, 5 is highest value.

Category	Ecosystem service	All groups	Group 1 n=9	Group 2 n=11	Group 3 n=6
Provisioning services	Fishes/shrimp for commercial use	4.3	4.4	4.0	4.6
	Fishes/shrimp for subsistence use	4.3	4.4	4.0	4.8
	Hydropower	4.3	4.0	4.4	4.6
	River transport	4.3	4.4	4.0	4.5
	Water for irrigation	3.2	3.8	3.0	2.8
	Water for human use	4.0	4.0	4.2	3.7
	Water for livestock	3.3	4.1	2.6	3.5
Average provisioning services score		4.0	4.2	3.7	4.1
Regulating & Supporting services	Climate regulation	4.4	4.1	4.7	4.2
	Flood control	4.5	4.7	4.7	3.8
	Habitat for economic species (fish/shrimp)	4.6	4.7	5.0	4.6
	Water purification	4.4	4.2	4.2	4.2
	Wetland water storage during dry season	4.7	4.8	4.7	4.7
	Biodiversity protection	4.4	4.6	4.5	3.6

Category	Ecosystem service	All groups	Group 1 n=9	Group 2 n=11	Group 3 n=6
	Maintain genetic resources of valuable fish	4.5	4.3	4.6	4.4
Average regulating & supporting services score		4.5	4.5	4.6	4.2
Cultural services	Aesthetic value	3.9	4.0	3.6	4.2
	Educational value	4.4	4.3	4.5	4.3
	Recreation	3.3	3.6	3.3	2.8
	Research value	4.1	4.2	3.9	4.2
	Spiritual value	4.0	4.1	4.0	4.0
	Tourism	3.7	3.9	3.7	3.2
Average cultural services score		3.9	4.0	3.8	3.8
Total		4.1	4.2	4.1	4.0

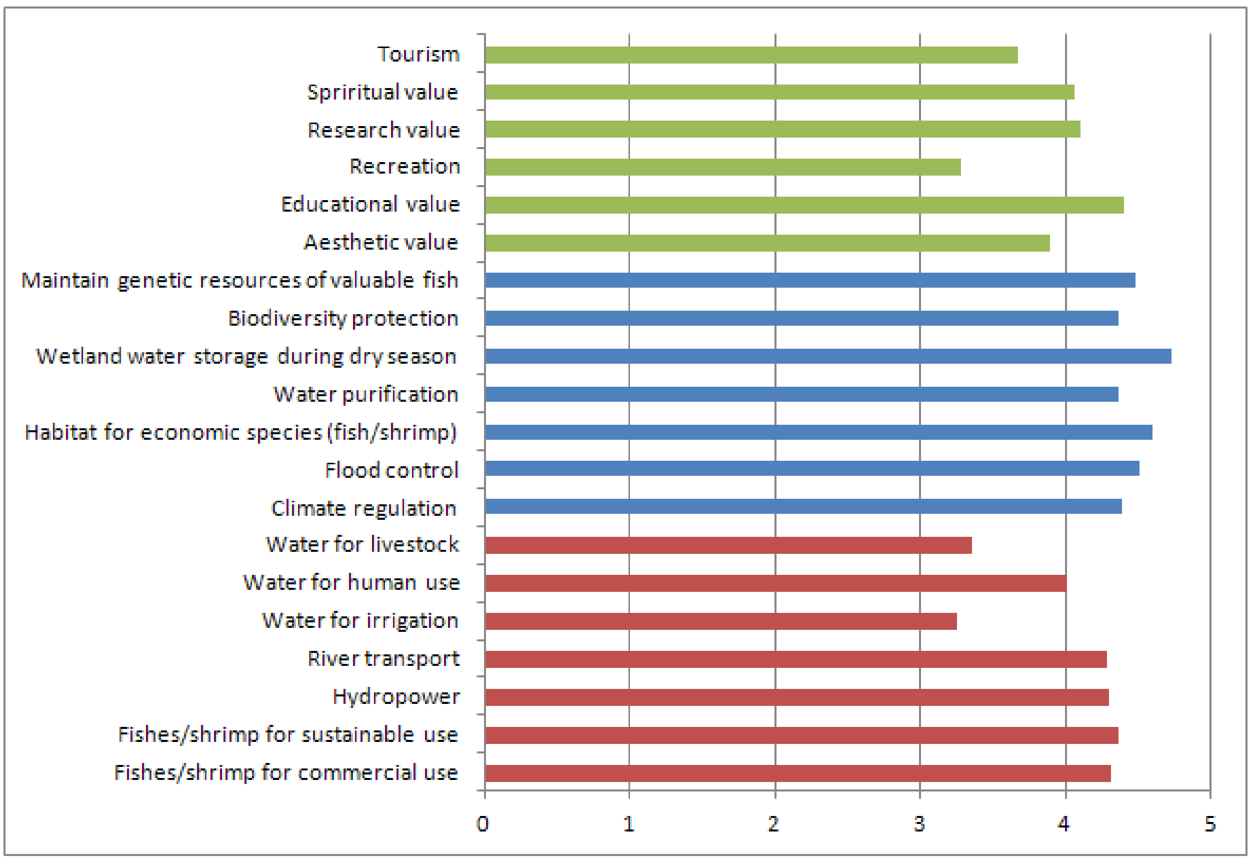


Figure 8. Average score given to each ecosystem service.
Green = Cultural services; Blue = Regulating and supporting services; Red = Provisioning services

However, the different stakeholder groups have shown different priorities (Figure 9, Table 7). For example, while groups 1 (Provincial governance) and 2 (Commune level governance) include only the regulating and supporting services in their top ranked services (flood control, habitat for economic species, wetland water storage), Group 3 (village governance) include the provisioning services of ‘fishes/shrimps for subsistence’ and ‘commercial use’ along with ‘habitat for economic species’ and ‘wetland water storage’ in their top ranked services. Group 1 (Provincial governance) score ‘water for irrigation’ (3.8) and ‘livestock’ (4.1) relatively low when compared to other ecosystem services, but they do score these services by over half a point (0.5) higher than the other two groups (Group 2 – 3.0 and Group 1 – 2.8 respectively / Group 2 – 2.6 and Group 1 – 3.5 respectively). All of the Group 2 (Commune level governance) respondents score ‘habitat provision for economic species’ the highest possible score, giving an average score of 5 (the only ecosystem service to be given this score by any group, although it is score highly by the other groups). This group also score ‘fishes/shrimps for commercial’ and ‘subsistence use’ (both 4.0) almost half a point less than the other groups (Group 1 - 4.4. and 4.4. respectively/ Group 3 - 4.6 and 4.8 respectively). Group 3 score many cultural and regulating and supporting services significantly (at least 0.5) less than the other groups including ‘tourism’, ‘recreation’, ‘biodiversity protection’ and ‘flood control’.

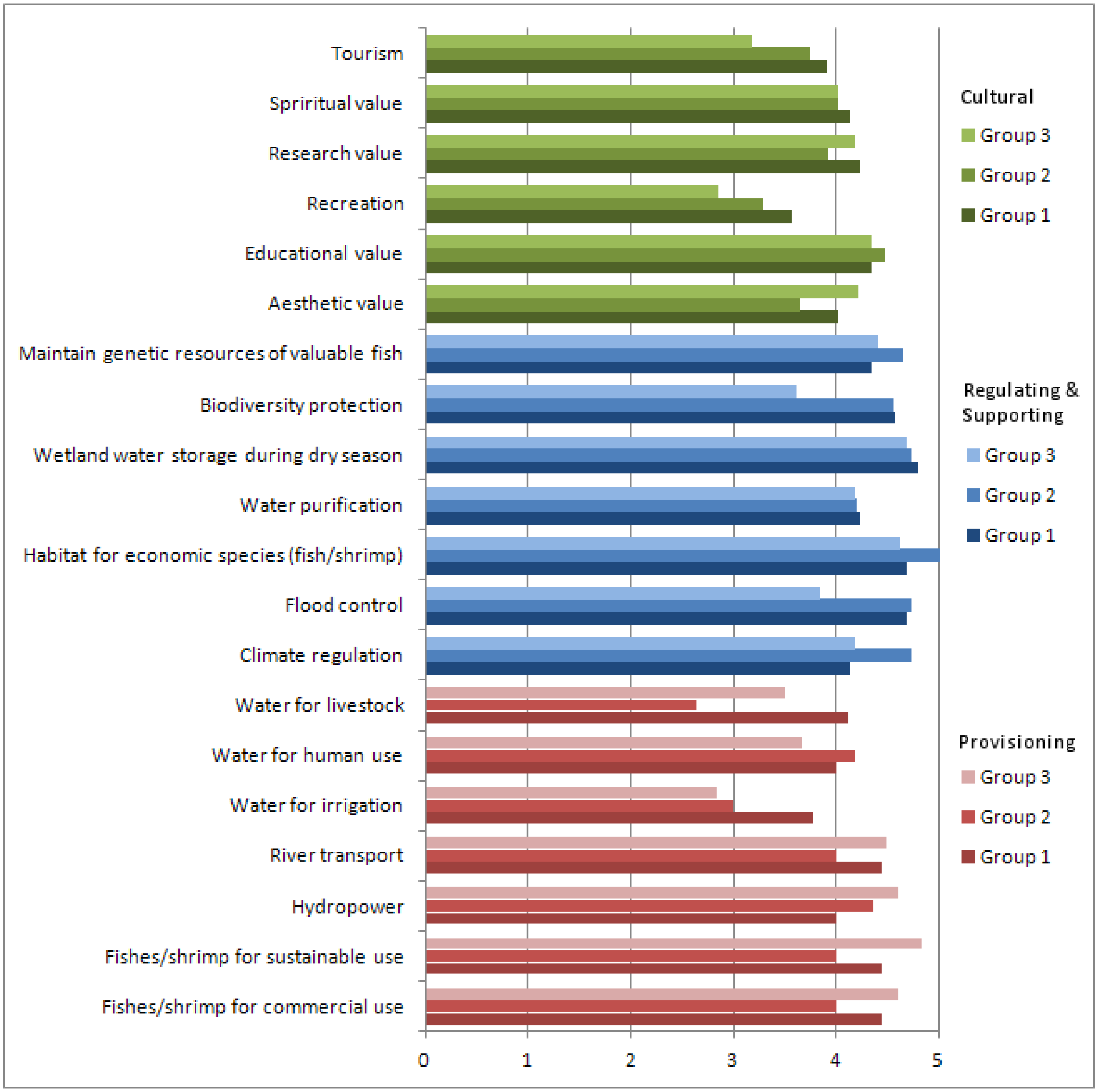


Figure 9. Average score given to ecosystem services by each stakeholder group.

5.2.3. Ecosystem services discussion and maps

Some of the ecosystem services have been mapped (Figures 10-12) and show at a watershed and site scale the areas generating the services and the areas receiving (or benefiting) from the services. This information is based on the results of the analysis in this Work Package, field observations by RIA1 staff and formal and informal discussions with the various stakeholder groups. The maps are based on those produced for the site and catchment maps with the ecosystem service generating and benefiting areas overlaid. The ecosystem services were discussed and drawn by RIA1 staff and IUCN during the mapping workshop held on 23-24 August, 2011 at the South China Agricultural University, Guangzhou, China. The results were then digitised using GIS software by IUCN. The maps will allow geographic areas of importance for the continuation of the service to be identified and the wider benefits of the service to be visualised. They will also inform the IAP to identify potential actions needed to protect the service and also indicators to monitor the quality or continuance of the service.

Fish and shrimp harvesting (Figure 10):

Fish and shrimps for commercial and subsistence use are ranked relatively highly by all groups of respondents, but in particular by Group 3 (village group). The annual report from Phu Yen district shows that the total fisheries product was estimated at 156 tons with a value of 2.29 billion VND (~83,500 Euros at current exchange rates) in 2000, 323 tons worth 3.55 billion (~129,500 Euros) VND in 2005, and 306 tons worth 3.98 billion (~145,000 Euros) VND in 2007 (Phu Yen Peoples Committee 2009). According to the annual report of Tuong Ha and Tuong Tien People's Committee, the total yield of fishing was 46 tons in 2009 in Tuong Ha commune and 14 tons in Tuong Tien (Tuong Ha People Committee 2010; Tuong Tien Peoples Committee 2010). On average fishermen catch between 3-10kg of fish per day including common species such as prawns, common carp (*Cyprinus carpio*), silver carp (*Hypophthalmichthys harmandi*) and mud carp *(Labeo rohita)* and a mix of small native fish. Local people confirmed that their daily income coming from fishing on the river was important (Nguyen *et al* 2010). Fish are the main protein source for local people within the site villages, and they also help save family expenses on other foods. As market networks are underdeveloped in the rural, remote and isolated mountain regions (The Socialist Republic of Vietnam 2003) people spend a long time (up to a day) travelling to market to purchase food, goods and exchange commodities (Thuan 2005). Therefore, local people also save time that would otherwise be spent travelling to buying food.

Potential indicators:

- Regular fish market surveys, identifying species composition, harvesting locations and catch levels.
- Annual social surveys of fishermen to identify their perception of trends in quantity and quality of fish.
- Monitoring of official fish harvesting statistics reported by Phu Yen Local Peoples Committee

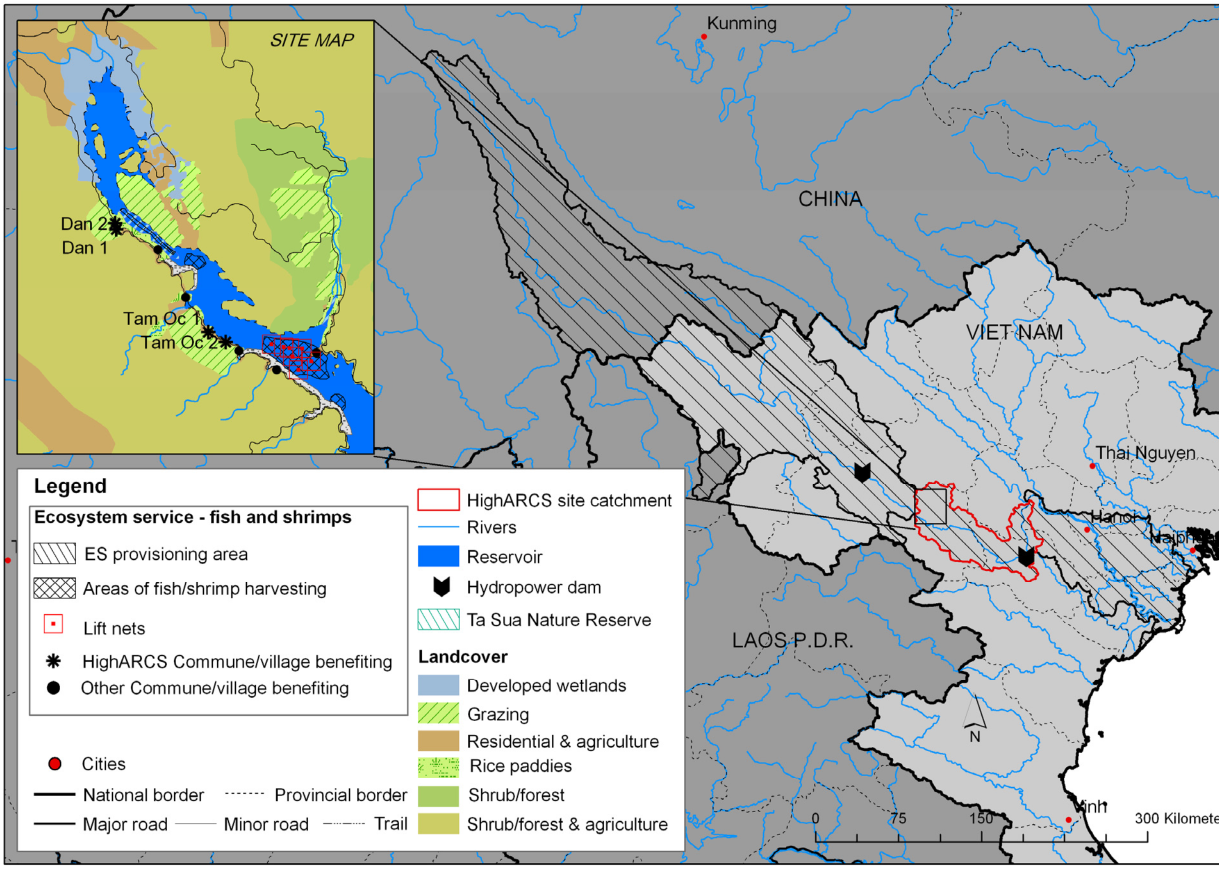


Figure 10: Ecosystem service of fish/shrimp provision

Water provision and water purification (Figure 11)

Water supplies for human use and livestock are also rated as important services. The local communities rely upon the water from the reservoir/river when the water levels are high, but during the rainy season they also harvest water from mountain streams, which in some cases is piped to the villages. Water for crop irrigation is generally seen as less important as many of the local people farm in mountain areas where crops are generally rain-fed and water from the river is only needed to farm one crop of rice.

Potential indicators:

- To be identified through the IAP in consultation with stakeholders

Water transportation (Figure 12)

Water transportation plays an important role in the daily activities of local people. During the flood season, people use boats to cross the river and carry their agri-products from mountain areas to the villages. During the dry season, or when the water levels are low people have to spend more time on walking cross the river carrying goods by hand.

Potential indicators:

- Annual social surveys to identify the how often boats can be used to transport goods and people across the river.
- Monitoring of water levels in the reservoir (use of official statistics)

Hydropower

Total installed capacity of Hoa Binh hydropower is 1,920 MW (Hirsch *et al.* 1992) and the study area makes an important contribution (through water storage) regarding the operation of this hydropower scheme. However, it is difficult to calculate its actual contributed proportion.

Potential indicators:

- The annual power output of the Hoa Binh hydropower station (and the potential new dams being built along the Da River in Phu Yen).

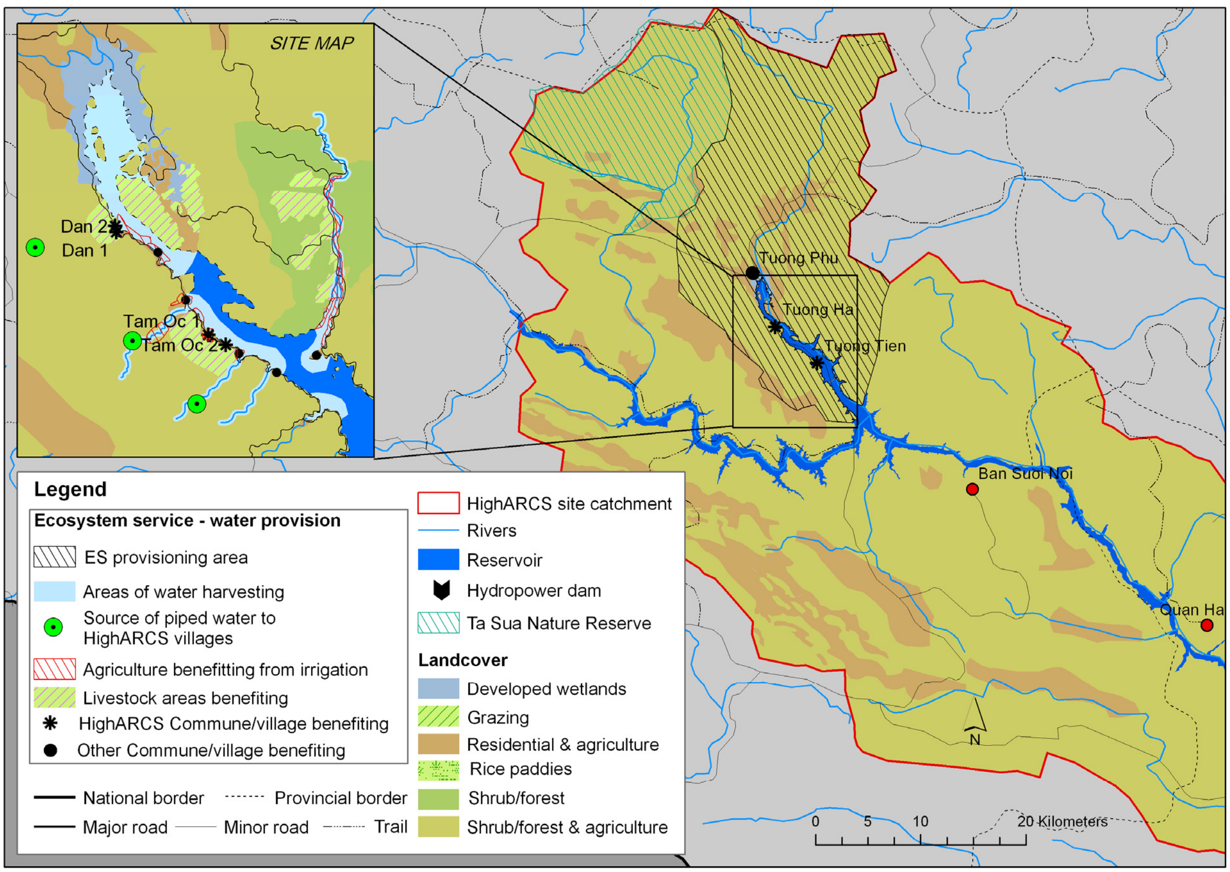


Figure 11: Ecosystem service of water provision

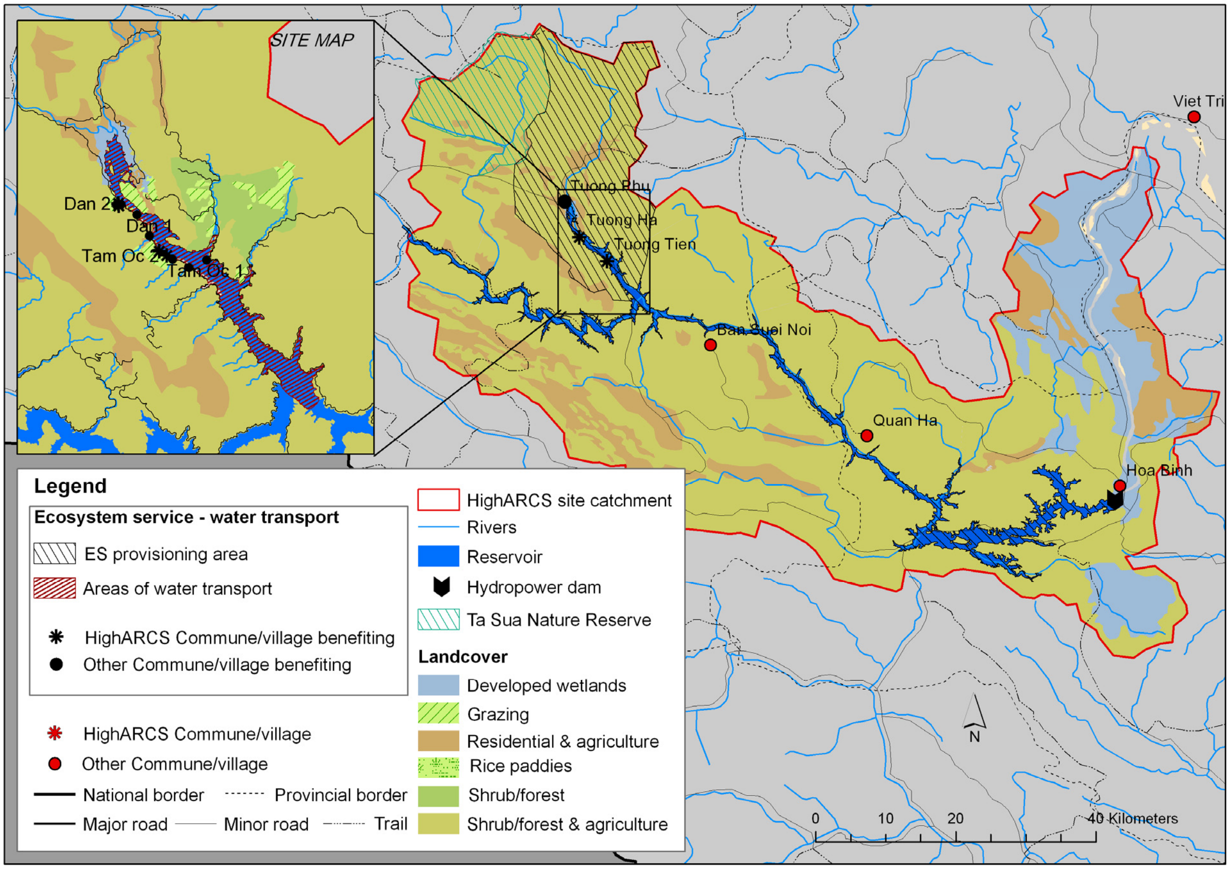


Figure 12: Ecosystem service of water transport areas

Climate regulation

In terms of local climate regulation the role of the rivers/reservoir is unclear. Through the focus group discussions, local people indicated that the climate seems to be more harsh and there are more 'Laos's winds' (hot and dry wind blowing from Lao) since the hydropower dam was created in 1994. However this may be due to the changing wider climate or the moving of the settlement position (the villages moved further up the hills/catchment when the reservoir was formed). It is necessary to monitoring the local climatic parameters to evaluate this regulating service.

Potential indicators:

- Monitoring at the temperature, wind and rainfall at the site

Flood control

The natural vegetation in the catchment still provides some degree of flood protection to the communities at the site, however flooding still occurs at the site and the continued loss of vegetation in the catchment will only increase the severity of flood events. The flooding at the site needs to better understood, as the water levels at the site are dependent upon rainfall and the reservoir levels controlled by the dam operations. The dam operators do communicate when water levels are going to rise or fall to local authorities which then inform local people.

Potential indicators:

- Monitoring of water levels in the reservoir (use of official statistics)
- Annual social surveys to identify number of flood events at the site

Habitat for economic species, maintenance of genetic resources of valuable fish species and biodiversity protection

These services were rated with high importance by all groups (apart from biodiversity protection by Group 3 – villagers). Son La People Committee (2009) indicated that the fish fauna in Son La Province is diverse with 162 identified fish species, of those 126 are found in the Da River (Bui The Anh 2011) (see Table 2) and many of them are economically important and endemic species (see Table 3). In terms of biodiversity protection, although many native species survive in the reservoir it is an artificial habitat and the construction of the dam and subsequent reservoir will have changed and destroyed many natural habitats causing many species (particularly those that require flowing water, or plants that cannot survive the large changes in water levels, and migratory species that cannot pass the dam) to be extirpated from the area.

Potential indicators:

- Regular fish market surveys, identifying species composition, harvesting locations and catch levels.
- Annual social surveys of fishermen to identify their perception of trends in quantity and quality of fish.
- Monitoring of official fish harvesting statistics reported by Phu Yen Local Peoples Committee

Tourism and other cultural services

Cultural services including educational value, research value, spiritual, aesthetics, recreation and tourism have proved difficult to define in this study. They were scored with relatively low value (apart from education), especially for recreation and tourism. However, Phu Yen District is an important economic development area of northwest region and it is not too far from Ha Noi the capital. Consequently there is potential for the development of tourism in this area in the future.

Potential indicators:

- Use of official government statistics to monitor the number of tourist visits every year in Phu Yen


Landscape of Phu Yen overlooking the reservoir © Fraser Sugden

6. Conclusions

The major aquatic habitats at the HighARCS site in Phu Yen are artificial, with the reservoir levels dictated by the management of the Hoa Binh hydro electric dam which was constructed in 1979 (communities were relocated up the catchment to allow for the reservoir). The construction of the dam on the Da River is likely to have had major impacts upon the native biodiversity, particularly those not adapted to lacustrine conditions, requiring migrations to complete their lifecycles or not able to survive large changes in water levels. The exact impacts (which species no longer occur at the site) are unknown, though many native species still occur there providing an important resource to the local communities. Based on a collaboration project between Research Institute for Aquaculture No1 and the Ministry of Agriculture and Rural Development called *Assessment of inland fisheries in Son La province 2008-09* 126 species of fish are known to occur in the Da River (Bui The Anh *et al.* 2009). Of these, 8 species are non-native, many of which are known to have negative impacts upon native species and habitat quality. The Da River also contains a significant amount of species that are of global conservation concern with two globally threatened species *Sinilabeo tonkinensis* (assessed as VU on the IUCN Red List under the name *Bangana tonkinensis*) and *Pseudohemiculter dispar* (VU) both are impacted by pollution from agriculture, industry and urban areas and dams (Jenkins, Kullander and Tan 2009a,b), and five Near Threatened species. Another key finding is that almost half of all the species are assessed as Data Deficient (DD), meaning that there is not enough information available to assess their global extinction risk, therefore many of these species may actually be threatened. According to the focus group discussions with the fishermen and market surveys, 18 species are of economic importance at site, two of which are of conservation concern *Elopichthys bambusa* VU on the Viet Nam National Red List, and *Pseudohemiculter dispar* VU on both the Viet Nam National Red List and the IUCN Red List (i.e. its global status). Only three species are thought to have declined at the site since 1990 with only *Bagarius yarrelli* is listed as nationally threatened (VU on the national Red List but NT on the IUCN Red List). While many other species have remained rare, four species are thought to have increased in numbers since 1990, these are *Cirrhinus mrigala, Squaliobarbus curriculus, Pseudohemiculter dispar,* and *Chanodichthys erythropterus.* One of these species *Pseudohemiculter dispar* is assessed as VU on the IUCN Red List. More research is needed to identify the status of the species at the site, particularly the species of conservation concern, those assessed as Data Deficient and those of economic importance

The key threats to biodiversity and ecosystem services at the site are overfishing and the use of destructive fishing methods, agricultural pollution, deforestation, and the changing water levels caused by hydropower dam operation. All the threats apart from overharvesting are driven by factors outside of the communities control, with the land use changes upstream and dam control impacting the biodiversity and ecosystem services at the site.

The ecosystem service prioritisation work has shown that different stakeholder groups value the services differently. The regulating services were valued the highest by the Provincial and District level governance (group 1) and the Commune level governance (Group 2), in particular wetland water storage during dry season, habitat provision for economic species, flood control and the maintenance of genetic diversity of valuable fish species. Whereas the villagers (group 3) also value the provisioning services, especially fishes for commercial and subsistence use as highly as the regulating services. Many of the highly prioritised ecosystem services are dependant upon the reservoir (an artificial environment) and the dam management providing suitable levels of water for harvesting of fish and water etc.

This report ensures that biodiversity and ecosystem service values are understood at the site, allowing for the IAP to formulate relevant actions to help secure the aquatic resources conservation and sustainable use. It will also allow for suitable indicators and monitoring to be established to monitor the actions proposed through the IAP.

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Annex I. Summary of the IUCN Red List criteria

Summary of the five criteria (A–E) used to evaluate if a taxon belongs in a threatened category (Critically Endangered, Endangered or Vulnerable).

Use any of the criteria A–E	**Critically Endangered**	**Endangered**	**Vulnerable**
A. Population reduction	Declines measured over the longer of 10 years or 3 generations		
A1	≥ 90%	≥ 70%	≥ 50%
A2, A3 & A4	≥ 80%	≥ 50%	≥ 30%

A1. Population reduction observed, estimated, inferred, or suspected in the past where the causes of the reduction are clearly reversible **AND** understood **AND** have ceased, based on and specifying any of the following:

- (a) direct observation
- (b) an index of abundance appropriate to the taxon
- (c) a decline in area of occupancy (AOO), extent of occurrence (EOO) and/or habitat quality
- (d) actual or potential levels of exploitation
- (e) effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.

A2. Population reduction observed, estimated, inferred, or suspected in the past where the causes of reduction may not have ceased **OR** may not be understood **OR** may not be reversible, based on (a) to (e) under A1.

A3. Population reduction projected or suspected to be met in the future (up to a maximum of 100 years) based on (b) to (e) under A1.

A4. An observed, estimated, inferred, projected or suspected population reduction (up to a maximum of 100 years) where the time period must include both the past and the future, and where the causes of reduction may not have ceased **OR** may not be understood **OR** may not be reversible, based on (a) to (e) under A1.

B. Geographic range in the form of either B1 (extent of occurrence) AND/OR B2 (area of occupancy)			
B1. Extent of occurrence (EOO)	< 100 km^2	< 5,000 km^2	< 20,000 km^2
B2. Area of occupancy (AOO)	< 10 km^2	< 500 km^2	< 2,000 km^2
AND at least 2 of the following:			
(a) Severely fragmented, **OR** Number of locations	= 1	≤ 5	≤ 10

(b) Continuing decline in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals.

(c) Extreme fluctuations in any of: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals.

C. Small population size and decline			
Number of mature individuals	< 250	< 2,500	< 10,000
AND either C1 or C2:			
C1. An estimated continuing decline of at least: (up to a max. of 100 years in future)	25% in 3 years or 1 generation	20% in 5 years or 2 generations	10% in 10 years or 3 generations
C2. A continuing decline **AND** (a) and/or (b):			
(a i) Number of mature individuals in each subpopulation:	< 50	< 250	< 1,000
or			
(a ii) % individuals in one subpopulation =	90–100%	95–100%	100%
(b) Extreme fluctuations in the number of mature individuals.			

D. Very small or restricted population			
Either:			
Number of mature individuals	< 50	< 250	**D1.** < 1,000
			AND/OR
Restricted area of occupancy			**D2.** typically: AOO < 20 km^2 or number of locations ≤ 5

E. Quantitative Analysis			
Indicating the probability of extinction in the wild to be:	≥ 50% in 10 years or 3 generations (100 years max.)	≥ 20% in 20 years or 5 generations (100 years max.)	≥ 10% in 100 years

Annex II. Fish species list from northern and central Viet Nam

The IUCN Red List categories are EX – Extinct; EW Extinct in the Wild; CR – Critically Endangered; EN – Endangered; VU – Vulnerable; NT – Near Threatened; LC – Least Concern; DD – Data Deficient; NA – Not assessed. The categories CR, EN and VU are classed as the 'threatened' categories. '*' indicates a draft Red List assessment, that still needs to be peer reviewed.

Order	**Family**	**Binomial**	**IUCN Red List Category**
Anguilliformes	Anguillidae	*Anguilla marmorata*	LC
Anguilliformes	Ophichthidae	*Pisodonophis boro*	LC
Anguilliformes	Ophichthidae	*Pisodonophis cancrivorus*	LC
Beloniformes	Hemiramphidae	*Hyporhamphus limbatus*	LC
Clupeiformes	Clupeidae	*Tenualosa reevesii*	DD*
Cypriniformes	Balitoridae	*Annamia normani*	LC*
Cypriniformes	Balitoridae	*Balitora lancangjiangensis*	LC*
Cypriniformes	Balitoridae	*Beaufortia leveretti*	DD
Cypriniformes	Balitoridae	*Beaufortia pingi*	LC
Cypriniformes	Balitoridae	*Liniparhomaloptera disparis*	DD
Cypriniformes	Balitoridae	*Micronemacheilus pulcher*	LC
Cypriniformes	Balitoridae	*Micronemacheilus taeniatus*	LC
Cypriniformes	Balitoridae	*Pseudogastromyzon loos*	DD
Cypriniformes	Balitoridae	*Schistura caudofurca*	LC
Cypriniformes	Balitoridae	*Schistura fasciolata*	DD
Cypriniformes	Balitoridae	*Schistura incerta*	DD*
Cypriniformes	Balitoridae	*Sinogastromyzon chapaensis*	DD
Cypriniformes	Balitoridae	*Sinogastromyzon rugocauda*	DD*
Cypriniformes	Balitoridae	*Sinogastromyzon tonkinensis*	DD
Cypriniformes	Balitoridae	*Sinohomaloptera kwangsiensis*	LC*
Cypriniformes	Balitoridae	*Vanmanenia multiloba*	DD
Cypriniformes	Balitoridae	*Vanmanenia tetraloba*	DD
Cypriniformes	Cobitidae	*Cobitis laoensis*	LC
Cypriniformes	Cobitidae	*Cobitis longitaeniatus*	DD*
Cypriniformes	Cobitidae	*Cobitis phongnhaensis*	DD*
Cypriniformes	Cobitidae	*Cobitis sinensis*	LC*
Cypriniformes	Cobitidae	*Cobitis squataeniatus*	DD*
Cypriniformes	Cobitidae	*Cobitis ylengensis*	DD*
Cypriniformes	Cobitidae	*Misgurnus anguillicaudatus*	LC
Cypriniformes	Cyprinidae	*Abbottina binhi*	DD
Cypriniformes	Cyprinidae	*Acheilognathus macropterus*	DD
Cypriniformes	Cyprinidae	*Acheilognathus tonkinensis*	DD

Order	Family	Binomial	IUCN Red List Category
Cypriniformes	Cyprinidae	*Acrossocheilus clivosius*	DD
Cypriniformes	Cyprinidae	*Acrossocheilus iridescens*	DD
Cypriniformes	Cyprinidae	*Acrossocheilus lamus*	DD
Cypriniformes	Cyprinidae	*Ancherythroculter daovantieni*	DD
Cypriniformes	Cyprinidae	*Bangana lemassoni*	DD
Cypriniformes	Cyprinidae	*Bangana tonkinensis*	VU
Cypriniformes	Cyprinidae	*Bangana xanthogenys*	DD
Cypriniformes	Cyprinidae	*Barbonymus gonionotus*	LC
Cypriniformes	Cyprinidae	*Carassioides acuminatus*	LC
Cypriniformes	Cyprinidae	*Carassius auratus*	LC
Cypriniformes	Cyprinidae	*Chanodichthys erythropterus*	LC
Cypriniformes	Cyprinidae	*Chanodichthys flavipinnis*	DD
Cypriniformes	Cyprinidae	*Cirrhinus molitorella*	NT
Cypriniformes	Cyprinidae	*Cirrhinus mrigala*	LC
Cypriniformes	Cyprinidae	*Ctenopharyngodon idella*	DD
Cypriniformes	Cyprinidae	*Cyclocheilichthys armatus*	LC
Cypriniformes	Cyprinidae	*Cyprinus dai*	DD
Cypriniformes	Cyprinidae	*Cyprinus hyperdorsalis*	DD
Cypriniformes	Cyprinidae	*Cyprinus multitaeniata*	NT
Cypriniformes	Cyprinidae	*Discogobio microstoma*	DD
Cypriniformes	Cyprinidae	*Elopichthys bambusa*	DD
Cypriniformes	Cyprinidae	*Esomus metallicus*	LC*
Cypriniformes	Cyprinidae	*Folifer brevifilis*	DD*
Cypriniformes	Cyprinidae	*Garra caudofasciatus*	DD*
Cypriniformes	Cyprinidae	*Garra fuliginosa*	LC*
Cypriniformes	Cyprinidae	*Garra imberba*	DD
Cypriniformes	Cyprinidae	*Garra laichowensis*	DD*
Cypriniformes	Cyprinidae	*Garra orientalis*	LC
Cypriniformes	Cyprinidae	*Garra poilanei*	DD
Cypriniformes	Cyprinidae	*Gibelion catla*	LC
Cypriniformes	Cyprinidae	*Gobiobotia kolleri*	DD
Cypriniformes	Cyprinidae	*Gobiobotia longibarba*	DD*
Cypriniformes	Cyprinidae	*Hainania serrata*	DD
Cypriniformes	Cyprinidae	*Hemiculter elongatus*	DD*
Cypriniformes	Cyprinidae	*Hemiculter leucisculus*	LC
Cypriniformes	Cyprinidae	*Hypophthalmichthys harmandi*	DD
Cypriniformes	Cyprinidae	*Labeo rohita*	LC
Cypriniformes	Cyprinidae	*Luciobrama macrocephalus*	DD
Cypriniformes	Cyprinidae	*Megalobrama skolkovii*	DD*
Cypriniformes	Cyprinidae	*Megalobrama terminalis*	LC

Order	Family	Binomial	IUCN Red List Category
Cypriniformes	Cyprinidae	*Metzia formosae*	LC
Cypriniformes	Cyprinidae	*Metzia lineata*	LC
Cypriniformes	Cyprinidae	*Microphysogobio kachekensis*	LC
Cypriniformes	Cyprinidae	*Microphysogobio labeoides*	DD*
Cypriniformes	Cyprinidae	*Microphysogobio vietnamica*	DD
Cypriniformes	Cyprinidae	*Microphysogobio yunnanensis*	DD
Cypriniformes	Cyprinidae	*Mylopharyngodon piceus*	DD
Cypriniformes	Cyprinidae	*Neolissochilus benasi*	DD
Cypriniformes	Cyprinidae	*Neolissochilus stracheyi*	LC
Cypriniformes	Cyprinidae	*Ochetobius elongatus*	DD*
Cypriniformes	Cyprinidae	*Onychostoma elongatum*	DD*
Cypriniformes	Cyprinidae	*Onychostoma fusiforme*	LC
Cypriniformes	Cyprinidae	*Onychostoma gerlachi*	NT
Cypriniformes	Cyprinidae	*Onychostoma laticeps*	DD*
Cypriniformes	Cyprinidae	*Onychostoma lepturum*	DD*
Cypriniformes	Cyprinidae	*Onychostoma lini*	DD*
Cypriniformes	Cyprinidae	*Onychostoma ovale*	DD
Cypriniformes	Cyprinidae	*Onychostoma simum*	DD
Cypriniformes	Cyprinidae	*Opsariichthys bidens*	LC*
Cypriniformes	Cyprinidae	*Opsarius pulchellus*	LC*
Cypriniformes	Cyprinidae	*Osteochilus salsburyi*	LC
Cypriniformes	Cyprinidae	*Osteochilus vittatus*	LC*
Cypriniformes	Cyprinidae	*Paraspinibarbus macracanthus*	DD
Cypriniformes	Cyprinidae	*Parator zonatus*	DD*
Cypriniformes	Cyprinidae	*Parazacco fasciatus*	LC
Cypriniformes	Cyprinidae	*Parazacco spilurus*	DD
Cypriniformes	Cyprinidae	*Parazacco vuquangensis*	DD
Cypriniformes	Cyprinidae	*Poropuntius kontumensis*	DD
Cypriniformes	Cyprinidae	*Poropuntius krempfi*	DD*
Cypriniformes	Cyprinidae	*Poropuntius normani*	LC*
Cypriniformes	Cyprinidae	*Pseudohemiculter dispar*	VU
Cypriniformes	Cyprinidae	*Pseudohemiculter hainanensis*	LC
Cypriniformes	Cyprinidae	*Pseudohemiculter pacboensis*	Not assessed
Cypriniformes	Cyprinidae	*Pseudolaubuca sinensis*	LC
Cypriniformes	Cyprinidae	*Puntius semifasciolatus*	LC*
Cypriniformes	Cyprinidae	*Rasbora steineri*	LC
Cypriniformes	Cyprinidae	*Rasbora sumatrana*	Not assessed
Cypriniformes	Cyprinidae	*Rasbora trilineata*	LC*
Cypriniformes	Cyprinidae	*Rectoris posehensis*	DD*
Cypriniformes	Cyprinidae	*Rhodeus ocellatus*	DD

Order	Family	Binomial	IUCN Red List Category
Cypriniformes	Cyprinidae	*Rhodeus spinalis*	LC
Cypriniformes	Cyprinidae	*Sarcocheilichthys nigripinnis*	LC*
Cypriniformes	Cyprinidae	*Saurogobio dabryi*	LC*
Cypriniformes	Cyprinidae	*Saurogobio immaculatus*	DD
Cypriniformes	Cyprinidae	*Scaphiodonichthys acanthopterus*	LC*
Cypriniformes	Cyprinidae	*Scaphiodonichthys macracanthus*	DD
Cypriniformes	Cyprinidae	*Semilabeo notabilis*	DD
Cypriniformes	Cyprinidae	*Semilabeo obscurus*	LC
Cypriniformes	Cyprinidae	*Sinibrama melrosei*	DD*
Cypriniformes	Cyprinidae	*Spinibarbus denticulatus*	LC
Cypriniformes	Cyprinidae	*Spinibarbus hollandi*	DD*
Cypriniformes	Cyprinidae	*Spinibarbus ovalius*	DD
Cypriniformes	Cyprinidae	*Spinibarbus sinensis*	DD*
Cypriniformes	Cyprinidae	*Squalidus argentatus*	DD
Cypriniformes	Cyprinidae	*Squalidus atromaculatus*	LC
Cypriniformes	Cyprinidae	*Squalidus chankaensis*	DD*
Cypriniformes	Cyprinidae	*Squaliobarbus curriculus*	DD
Cypriniformes	Cyprinidae	*Toxabramis houdemeri*	LC
Cypriniformes	Cyprinidae	*Xenocypris davidi*	LC*
Cypriniformes	Cyprinidae	*Xenocypris macrolepis*	LC
Cypriniformes	Cyprinidae	*Yaoshanicus kyphus*	DD*
Cypriniformes	Cyprinidae	*Yaoshanicus normalis*	LC*
Cypriniformes	Cyprinidae	*Zacco acutipinnis*	LC*
Osmeriformes	Salangidae	*Neosalanx tangkahkeii*	LC
Osmeriformes	Salangidae	*Salanx ariakensis*	Not assessed
Osmeriformes	Salangidae	*Salanx chinensis*	DD
Osteoglossiformes	Notopteridae	*Notopterus notopterus*	LC
Perciformes	Ambassidae	*Ambassis ambassis*	LC
Perciformes	Anabantidae	*Anabas testudineus*	DD
Perciformes	Channidae	*Channa asiatica*	LC*
Perciformes	Channidae	*Channa gachua*	LC
Perciformes	Channidae	*Channa maculata*	LC
Perciformes	Channidae	*Channa orientalis*	Not assessed
Perciformes	Channidae	*Channa striata*	LC
Perciformes	Eleotridae	*Bostrychus sinensis*	LC*
Perciformes	Eleotridae	*Butis butis*	LC
Perciformes	Eleotridae	*Eleotris balia*	Not assessed
Perciformes	Eleotridae	*Eleotris fusca*	LC
Perciformes	Eleotridae	*Eleotris melanosoma*	LC
Perciformes	Eleotridae	*Eleotris oxycephala*	LC

Order	Family	Binomial	IUCN Red List Category
Perciformes	Gerreidae	*Gerres filamentosus*	LC
Perciformes	Gobiidae	*Boleophthalmus boddarti*	LC*
Perciformes	Gobiidae	*Caragobius urolepis*	LC*
Perciformes	Gobiidae	*Glossogobius giuris*	LC
Perciformes	Gobiidae	*Papuligobius ocellatus*	LC*
Perciformes	Gobiidae	*Rhinogobius brunneus*	DD
Perciformes	Gobiidae	*Rhinogobius giurinus*	LC
Perciformes	Gobiidae	*Rhinogobius leavelli*	LC
Perciformes	Gobiidae	*Taenioides gracilis*	LC*
Perciformes	Odontobutidae	*Neodontobutis tonkinensis*	DD
Perciformes	Odontobutidae	*Sineleotris chalmersi*	LC
Perciformes	Osphronemidae	*Macropodus baviensis*	Not assessed
Perciformes	Osphronemidae	*Macropodus opercularis*	LC
Perciformes	Osphronemidae	*Macropodus phongnhaensis*	Not assessed
Perciformes	Osphronemidae	*Trichopodus trichopterus*	LC
Perciformes	Percichthyidae	*Coreoperca whiteheadi*	LC
Perciformes	Percichthyidae	*Siniperca chuatsi*	Not assessed
Perciformes	Percichthyidae	*Siniperca kneri*	DD
Perciformes	Percichthyidae	*Siniperca scherzeri*	DD
Perciformes	Terapontidae	*Terapon jarbua*	LC
Pleuronectiformes	Cynoglossidae	*Cynoglossus trigrammus*	LC*
Siluriformes	Bagridae	*Hemibagrus centralus*	DD*
Siluriformes	Bagridae	*Hemibagrus guttatus*	DD*
Siluriformes	Bagridae	*Hemibagrus pluriradiatus*	LC*
Siluriformes	Bagridae	*Hemibagrus vietnamicus*	DD*
Siluriformes	Bagridae	*Mystus gulio*	LC
Siluriformes	Bagridae	*Tachysurus fulvidraco*	LC
Siluriformes	Bagridae	*Tachysurus vachellii*	DD*
Siluriformes	Bagridae	*Tachysurus virgatus*	DD*
Siluriformes	Clariidae	*Clarias fuscus*	LC*
Siluriformes	Cranoglanididae	*Cranoglanis henrici*	LC
Siluriformes	Siluridae	*Pterocryptis cochinchinensis*	LC
Siluriformes	Siluridae	*Silurus asotus*	LC
Siluriformes	Sisoridae	*Bagarius rutilus*	LC*
Siluriformes	Sisoridae	*Bagarius yarrelli*	NT
Siluriformes	Sisoridae	*Glyptothorax honghensis*	DD
Siluriformes	Sisoridae	*Glyptothorax interspinalum*	NT
Siluriformes	Sisoridae	*Glyptothorax laosensis*	LC*
Siluriformes	Sisoridae	*Pareuchiloglanis macrotrema*	DD
Siluriformes	Sisoridae	*Pseudecheneis paviei*	DD

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Synbranchiformes	Mastacembelidae	*Macrognathus aculeatus*	LC*
Synbranchiformes	Mastacembelidae	*Mastacembelus armatus*	LC
Synbranchiformes	Mastacembelidae	*Sinobdella sinensis*	LC
Synbranchiformes	Synbranchidae	*Macrotrema caligans*	Not assessed
Synbranchiformes	Synbranchidae	*Monopterus albus*	LC
Tetraodontiformes	Tetraodontidae	*Tetraodon biocellatus*	LC*