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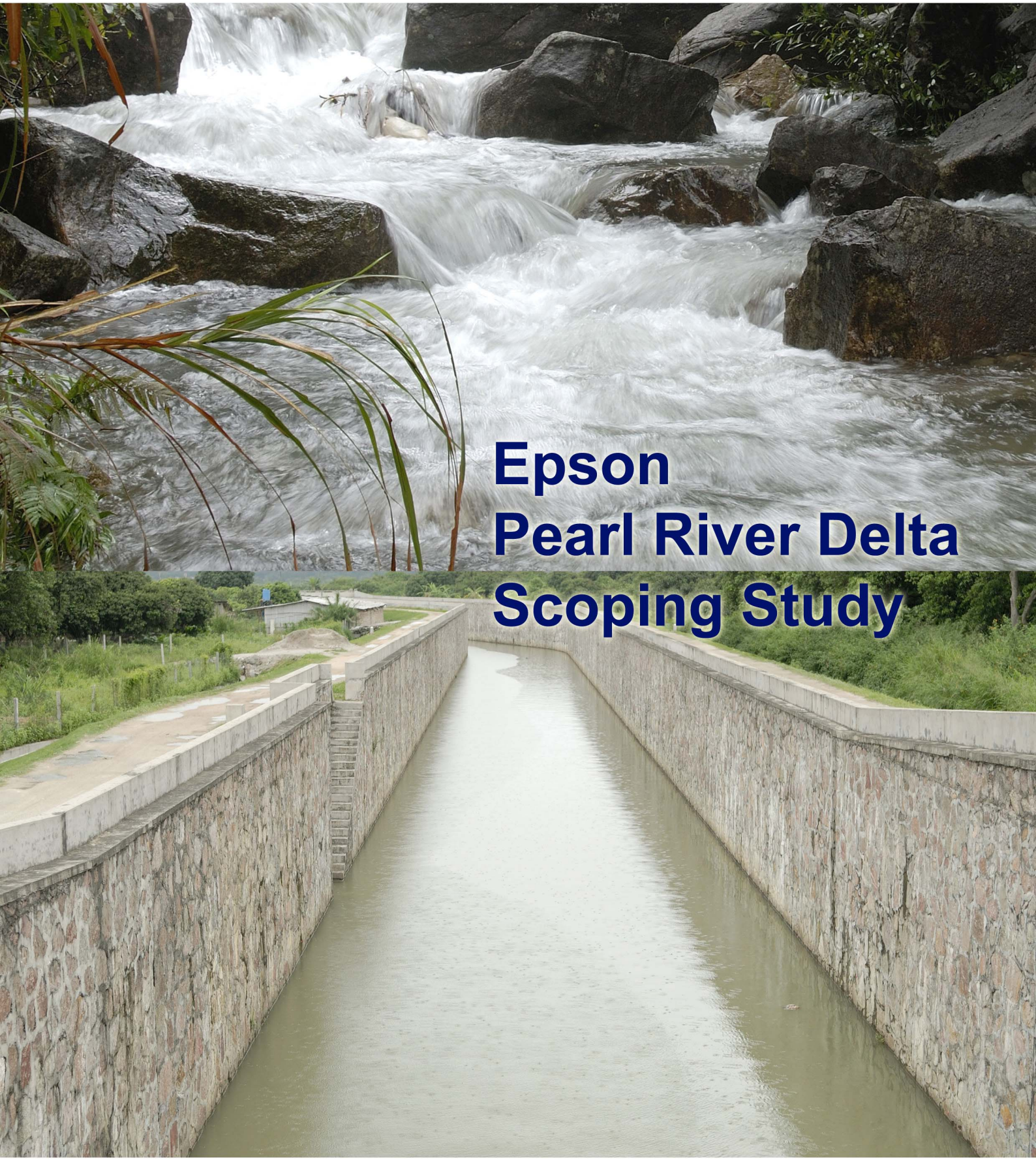

# Epson Pearl River Delta Scoping Study

WWF Hong Kong

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# Epson
# Pearl River Delta
# Scoping Study

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# EXECUTIVE SUMMARY

## Introduction

Freshwater ecosystems are considered amongst the world's most endangered ecosystems. The freshwater crisis facing the world today is one of the most serious global environmental challenges to both man and biodiversity. Freshwater issues in the Pearl River Delta (PRD) in Guangdong, China are considered to be a significant challenge to the future development of the region. The objectives of this report are to better understand the complex linkages among the various threats to freshwater biodiversity, and their causes, in order to identify opportunities and strategies for reducing these threats through future conservation actions in the region.

## An overview of the Pearl River Delta

The Pearl River consists of three major tributaries, namely the Xijiang (West River), Beijiang (North River), and Dongjiang (East River). The tributaries converge into an estuarine region, an extensive low-lying flood-plain formed by sediments deposited from the Pearl River over millennia, the Pearl River Delta (PRD).

Although the PRD is relatively rich in freshwater resources in comparison with the rest of China, over the last two decades rapid economic and population growth have resulted in water shortages and the combined pressure of deteriorating water quality. Degradation is of particular concern to WWF as historical records show the Pearl River as being rich in freshwater biodiversity.

## Threats to freshwater biodiversity

The threats facing freshwater biodiversity in the PRD may have a lower public profile than shortages of clean water for domestic and industrial uses, but these threats are immense and complex. Anthropological impacts are disrupting the ecological functions of the freshwater ecosystems, and causing a loss in biodiversity. For instance, some 381 species of freshwater fish occur in the Pearl

River according to a 1989 study, however, according to data from 2005, 92 species face extinction.

The major direct threats identified include flow alterations, habitat change and degradation, and pollution. Other threats endangering biodiversity include over-exploitation of natural resources (e.g. through fishing), human intrusion and disturbance to ecologically sensitive habitats, and invasive species. These threats impose direct and indirect impacts to the health of the freshwater ecosystem. The construction of dams has blocked fish migration and resulted in reduced water flow downstream, altering ecological functions. Channelisation of rivers using concrete has been widely used as a flood control measure, leading to localised destruction of the natural freshwater environment. Some pollutants, such as heavy metals and persistent organic pollutants, have likely affected the health of aquatic life, such as the Chinese white dolphin (*Sousa chinensis*) which lives downstream in the Pearl River Estuary, and man. Climate change and extreme weather events are predicted to increase in intensity in coming decades and compound the stress already experienced by freshwater ecosystems in the PRD, as well as the security of freshwater supply for humans.

## The way forward

The two major findings of this study are that: i) the threats facing the freshwater biodiversity of the PRD are many and severe, and the linkages among them are complex; and ii) up-to-date published information on the current status of freshwater species and habitats in the PRD is extremely scarce.

Substantial knowledge gaps exist making it difficult to answer such basic questions, such as, which freshwater species and which areas of freshwater habitats should be prioritised for conservation actions in the PRD? This lack of pertinent data severely limits the ability of this desktop study to identify potential opportunities to preserve freshwater biodiversity through focused conservation actions.

***Formulation of conservation actions***

The results of this study do however provide a useful starting point for the formulation of conservation projects. Clearly a range of actions or activities by various stakeholders is urgently required to address the direct and indirect threats to freshwater biodiversity. Although the lack of recent published materials on freshwater biodiversity has undermined WWF's capacity to prioritize detailed areas or issues for conservation actions at the time being, a number of possible areas for action which would contribute to the conservation of freshwater biodiversity in the PRD is apparent. Three potential areas are outlined below:

**i) Filling in gaps of our knowledge on freshwater biodiversity and its management**

- Data-sharing workshops or forums to gather and collate the most current information on freshwater biodiversity in PRD, including identification of important freshwater sites which are not effectively protected in the region, would be of great value to forming further conservation actions. It is understood that valuable information does exist in unpublished reports and on-going studies that could not be accessed for this report.

**ii) Communication of conservation messages**

- The global experience of WWF suggests that good awareness amongst relevant stakeholders greatly aids the chances of success for conservation actions and within an achievable timeframe. WWF is hiring a professional polling company to conduct a poll in Guangzhou in mid-2007 on public perceptions to freshwater problems of the Pearl River. Results of the poll are expected to shed light on the development of communication strategies for the region.
- As education is an important tool to conveying conservation message, a capacity-building training programme with the partnership between Shenzhen Bird Watching Society and WWF in the PRD has been carried out since 2005 to enable teachers to effectively teach Education for Sustainable Development (ESD) in their schools.

**iii) Offering best-practice solutions in flood control**

- Although flooding is a natural phenomenon in the PRD, human activities and climate change have resulted in increasing damage from floods which compromise the environment, as well as social and economic needs. Riding on the experience in organising the Wetland Training Course at the Mai Po Nature Reserve, WWF has the potential to offer training to policy makers, planners and engineers to introduce the concepts of ecological friendly designs and the considerations of allocating environmental flows on future essential engineering works in rivers.

***Challenges beyond the PRD – the need for an integrated ecosystem approach***

A key finding of this study is that the problems facing freshwater conservation in the PRD have complex linkages. Ultimately, an integrated approach, such as the Integrated River Basin Management (IRBM), may provide a good framework for coordination of the management and development of the water, the land, and other biological and related resources within a river basin to maximize the economic and social benefits in an equitable manner, and on the basis of an ecosystem approach. Conserving and repairing freshwater ecosystems is required to address the needs of freshwater for human beings as well as various components in the freshwater ecosystems, from organisms in the headwater to the Chinese white dolphin in the estuaries. More work needs to be undertaken, with the participation of a range of stakeholders of Pearl River, to learn from the experience of the IRBM implementation from the Yangtze as well as from the other parts of the World.

# Contents

# Section 1

# Introduction

## 1.1 Freshwater crisis – a challenge to the globe and the region

Water is a finite resource on Earth. About 97.5 percent is saline and only 2.5 percent is freshwater (Shiklomanov, 1999). Only a tiny 0.26 percent of all freshwater, such as that in lakes and river systems, is readily available for human use, while the majority of the rest is deep underground or locked in the form of ice (Shiklomanov, 1999). Despite its limited availability, freshwater habitats account for a disproportionately large proportion of global biodiversity. For instance, approximately 40 percent of the known species of fish live in freshwater (Lundberg *et al*., 2000). The freshwater wetlands and riparian habitats adjacent to rivers and lakes are also vital for a countless number of species.

Freshwater ecosystems provide a range of useful functions that support life on earth, as we know, especially by absorbing rainfall and gradually releasing it over time, preventing periodic mass flooding (WWF, 2004c). They also act as a kind of natural kidney, absorbing chemicals, filtering pollutants and sediments, breaking down suspended solids and neutralising harmful bacteria (WWF, 2004a). Indeed, it has been estimated that the global value of wetland functions for recreation, fishing, flood control, and water filtration, is worth approximately US$70 billion per year (WWF, 2004b).

The freshwater crisis facing the world today is one of the most serious global environmental challenges to both man and biodiversity. Population growth, industrial development and the expansion of irrigated agriculture have resulted in water scarcity to an extent that around one-third of the world's population is under water stress (UNEP, 2002a). More than one billion people worldwide do not have access to clean freshwater (WHO & UNICEF, 2004) and at least one in three Asians has no access to safe drinking water (UN, 2003).

Freshwater animals and plants are considered as the world’s most endangered (IUCN, 2004b; Dudgeon *et al.*, 2006). Using trends in the populations of 344 representative freshwater species between 1970 and 2003 as a proxy for all freshwater species, WWF estimates there has been a 30% decline in freshwater species populations over this period (WWF, 2006b).

The natural functioning of river systems in many regions has been dramatically altered for the purposes of hydropower, river navigation, irrigation and flood protection (Nilsson *et al*., 2005). Over 60% of the world's major rivers are now fragmented, wetlands have been drained and many fisheries decimated because of the interrupted water flow resulting from large dams and their associated infrastructures (WCD, 2000; WWF, 2004d). Rivers have also been straightened, deepened, and cut-off from natural floodplains. Human-induced climate change is likely to increase the frequency of flooding and droughts (Vörösmarty *et al*., 2000).

Pollution from towns and cities, industry and agriculture directly impacts water supplies for people and freshwater ecosystems (Revenga & Mock, 2000). Industrial sewage has produced some of the most toxic water pollutants released into the environment and affected human health (WBCSD & UNEP, 1998). Agricultural pollution, such as nitrate and ammonia (FAO, 2003a), has also led to undesirable changes in freshwater ecosystem structure and function (Smith *et al*., 1999). Freshwater biodiversity is under the combined threats of not only flow modifications and pollution, but also overexploitation, destruction and degradation of habitats, and invasion by exotic species (Dudgeon, 1999; Dudgeon *et al*., 2006).

### 1.2 Study objectives

With about 80% of Hong Kong's freshwater being imported from the Pearl River, WWF Hong Kong considers the health of the Pearl River to be a major conservation concern in South China, as this region, and particularly Guangdong, has become industrialised at breakneck speed in recent decades. Freshwater issues in Pearl River Delta (PRD) are also considered as significant challenges to the future development of the region as identified in the Environmental Protection Framework Plan for the PRD (2004 - 2020), prepared by the Guangdong Provincial Government. Although there is a widespread acknowledgement that a lack of sufficient clean freshwater in PRD has serious economic and social implications, considerations for conserving freshwater ecosystems and species are still of relatively low priority.

In order to better understand the freshwater issues in the PRD and with support from the Epson Foundation, WWF conducted the Epson Pearl River Delta Scoping Study between 2005 and 2006. The objectives of the study were to identify:

- important environmental issues threatening the freshwater biodiversity of the PRD and to investigate the interactions among them, and
- key areas that need to be addressed in formulating conservation strategies for the freshwater ecosystem of the PRD, so as to give a start point for WWF's conservation projects.

### 1.3 Study area

The geographical scope of the study primarily includes the nine cities in the Pearl River Delta Economic Zone surrounding the Pearl River (or Zhujiang) estuary in Guangdong Province, southern China (Fig. 1.1). Some information at the Guangdong provincial level, Hong Kong Special Administrative Region (SAR) and Macau SAR is also included.

### 1.4 Methodology

Information was collated mainly from primary and secondary information sources, including scientific journal articles and publications, Government reports, newspaper articles, and electronic content available online. Between September 2005 and June 2006, more than 1,700 pieces of English and Chinese literature were complied into a bibliographic database.

Twelve face-to-face interviews were also conducted with Hong Kong and Mainland Chinese academics and officials, the business sector and non-governmental organisations, in order to collect their views and opinions on freshwater issues facing the PRD.

In order to better understand the complex linkages among various threats to biodiversity in the PRD, and their causes, a situation analysis (IUCN, 2004c; WWF, 2005b) using the conceptual model approach (WWF, 2005a) was conducted (see

Section 3 for details). Such analysis is also useful for identifying opportunities and strategies for future conservation actions by WWF to reduce such threats.

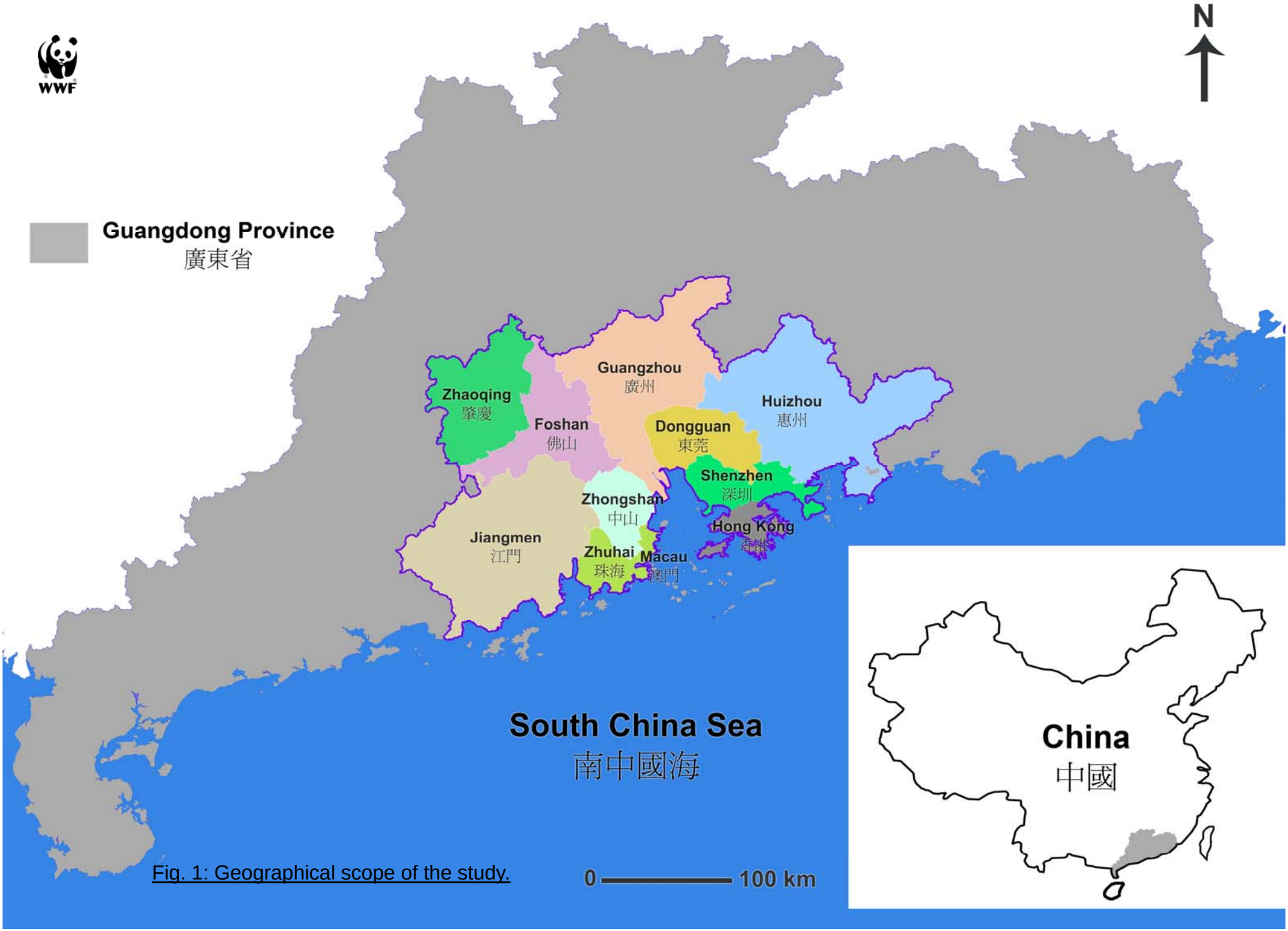



Fig. 1: Geographical scope of the study.

# Section 2

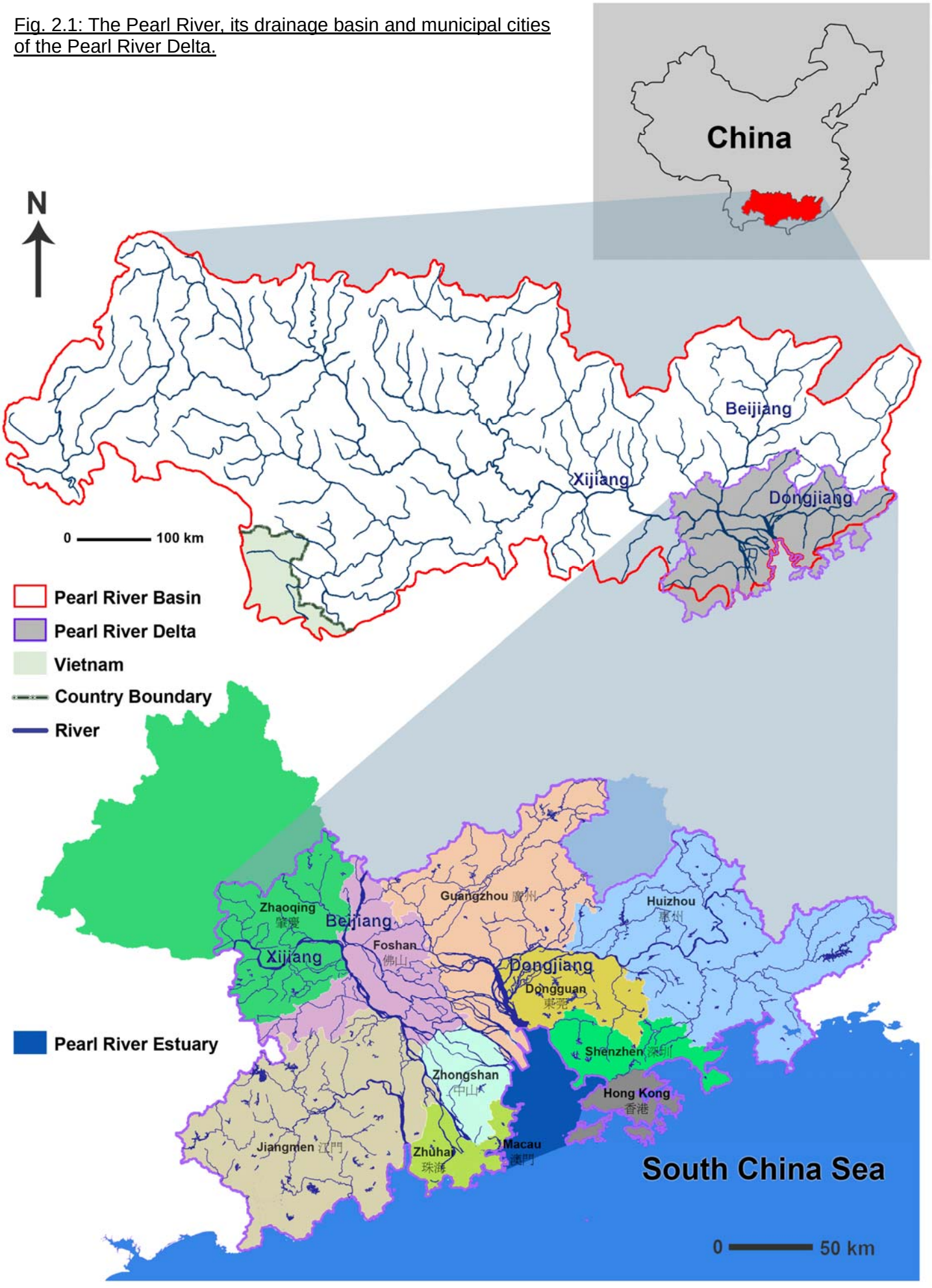
# An overview of the Pearl River Delta

## 2.1 The Pearl River & delta

Zhujiang (珠江), also known as the Pearl River, is the third longest river in China (Fig. 2.1), after the Yangtze River and Yellow River. Its total catchment area is 453,690km$^2$, with 11,590km$^2$ in Vietnam and 442,100km$^2$ within China (PRWRC, 1991), covering six provinces: Guangdong, Guangxi, Guizhou, Hunan, Jiangxi, and Yunnan. It consists of three major tributaries, namely, Xijiang (西江; West River), Beijiang (北江; North River), and Dongjiang (東江; East River). The Pearl River originates from Maxiong Mountain (馬雄山) in Yunnan Province in the Xijiang drainage basin (PRWRC, 1991). The three major tributaries converge at the Pearl River Delta (珠江三角洲; PRD) in the estuarine region, forming a complex river network system discharging into the South China Sea (Fig. 2.1). The river networks of the PRD consist of more than a thousand intersecting river channels of various sizes, with highly complicated water movements which are further influenced by tidal effects (Zhu, 2001; Yang *et al.*, 2002; Leung *et al.*, 2005b).

The PRD is an extensive low-lying flood-plain formed by sediments deposited from the Pearl River over millennia. It is located in the southern centre of Guangdong province at the converging points of the Xijiang, Beijiang and Dongjiang rivers. According to the boundary defined by the Guangdong Provincial Government, PRD is also referred to the PRD Economic Zone. The PRD is located within the boundaries of 9 municipal cities, including Guangzhou (廣州), Foshan (佛山), Zhongshan (中山), Zhuhai (珠海), Dongguan (東莞), Shenzhen (深圳), Huizhou (惠州), Jiangmen (江門) and Zhaoqing (肇慶), and two special administrative regions, namely Hong Kong (香港) and Macau (澳門) (Fig. 2.1). Under this definition, the PRD has an area of about 42,800 km$^2$.

Fig. 2.1: The Pearl River, its drainage basin and municipal cities of the Pearl River Delta.



| Catchment | Channel Length (km) | Catchment area ($km^2$) | Percentage of total catchment area |
|---|---|---|---|
| Xijiang[a] | 2,075 | 353,120 | 77.83% |
| Beijiang[a] | 468 | 46,710 | 10.30% |
| Dongjiang[b] | 520 | 27,040 | 5.96% |
| Pearl River Delta[c] | 1,600[c] | 26,820 | 5.91% |
| **Main river channel[d]** | **2,214** | **453,690** | **100%** |

Notes
[a] Upstream of Sixianjiao, Sanshui (思賢滘，三水) in Foshan
[b] Upstream of Shilong (石龍) in Dongguan
[c] Total length of river networks downstream of Sixianjiao and Shilong
[d] From Xijiang's origin to the South China Sea

Table 2.1: Size of the four major water catchments of the Pearl River (PRWRC, 1991).

## 2.2 Population

Over the last two decades, the human population of the PRD region has undergone rapid growth. From 1985 to 2004, the total permanent resident population of Guangdong Province grew about 50%, from 57 to 83 million (GDSTATS, 2005). However, such figures have not taken into account a large proportion of mobile population without residence registration. According to the fifth national population census in 2000, the total population of the PRD was 40.8 million with 17.7 million, or 43%, being mobile population (Li, 2005a). The growth was contributed almost entirely by people in non-agricultural sectors (Fig. 2.2).

The population sizes of all PRD cities are expanding, but the rate of growth varies widely among cities. For instance, between 1980 and 1994, the resident population in Guangzhou increased by 47%, while Shenzhen rose 416% (Table 2.2). While this growth trend is expected to continue, Guangdong Government has set a target to control its population to below 97.3 million by 2010 (South CN, 2006m).

| Location | Area ($km^2$) | Population ($10^4$) | | |
|---|---|---|---|---|
| | | 1980 | 2004 | % of Increase |
| Dongguan | 2,465 | 113 | 162 | 43 |
| Foshan | 3,814 | — | 351 | — |
| Guangzhou | 7,434 | 502 | 738 | 47 |
| Huizhou* | 11,158 | 192 | 293 | 53 |
| Jiangmen | 9,541 | — | 386 | — |
| Shenzhen | 1,953 | 32 | 165 | 416 |
| Zhaoqing* | 14,823 | 285 | 394 | 38 |
| Zhongshan | 1,800 | 101 | 139 | 38 |
| Zhuhai | 1,687 | 37 | 86 | 132 |
| Hong Kong# | 1,103 | 506 | 690 | 36 |
| Macau# | 27.5 | 32 | 46 | 44 |
| **Total** | **54,675** | — | **2714** | — |

Table 2.2: City area in 2004 and the population size of those with residence registration in nine municipal cities and the two Special Administrative Regions in the PRD region in 1980 and 2004 (Statistical Yearbooks of various cities, Census and Statistics Department, HKSAR , Statistics and Census Service, Macau SAR, & GDSTATS, 2005). "*" Parts of the city are outside the defined boundary of PRD (see Fig. 2.1); "—" data not available. "#" Population size includes both usual and mobile population.

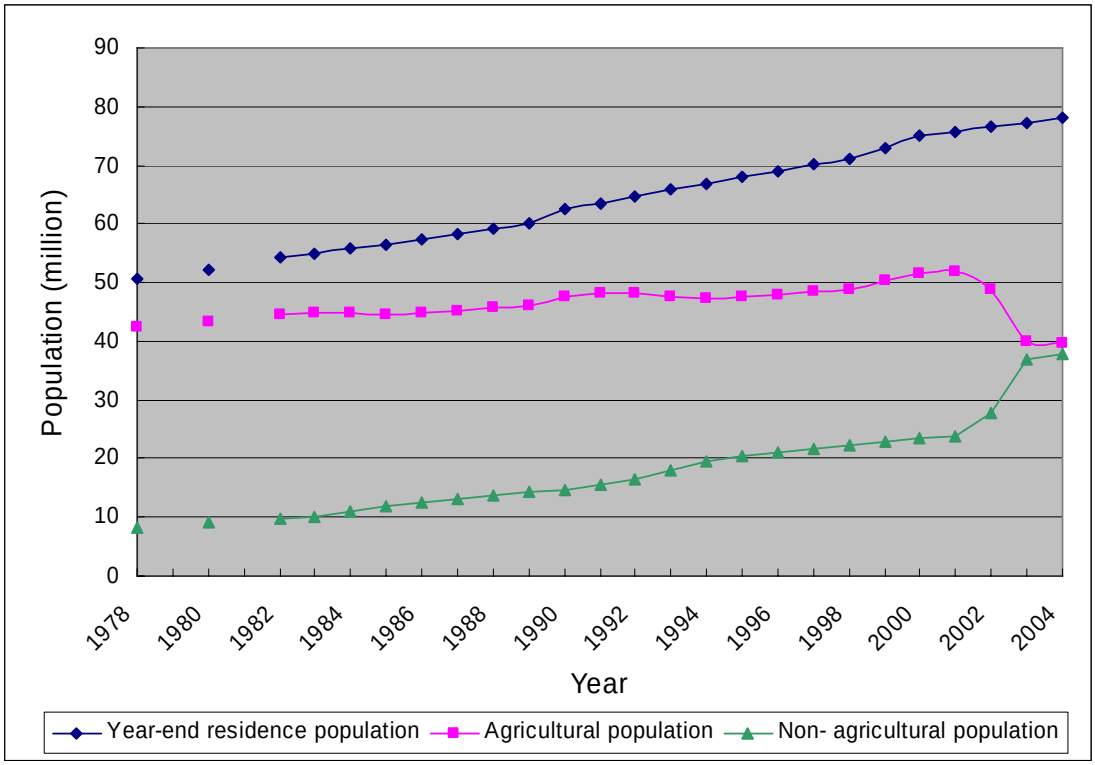



Fig. 2.2: Year-end residence population (i.e. the population with residence registration), and breakdown into agricultural population and non-agricultural population in Guangdong Province between 1978 and 2004. Data from the Guangdong Statistical Yearbook published by the Statistics Bureau of Guangdong Province in multiple years. Data for years 1979 and 1981 were unavailable.

## 2.3 Economic growth & urbanisation

Agricultural activities, including fish farming using dike-pond systems, used to be the major economic activities of the PRD (Shutes, 2001). Since the implementation of China's "open door policy" and economic reform in 1978, the economy of Guangdong has rocketed as a result of rapid urban and industrial development. The gross domestic product (GDP) of Guangdong has shot up 86 times, from RMB 18.6 billion Yuan in 1978 to RMB 1,604 billion Yuan in 2004 (Statistics Bureau of Guangdong Province, 2005). The PRD is the major contributor to this massive increase. Even though the PRD's area is about 23%, and its population about 35% of Guangdong as a whole, the PRD contributed 85% of the whole Province's GDP in 2004 (Statistics Bureau of Guangdong Province, 2005; People's Government of Guangdong Province, 2006).

From 1978 to 2004, the contribution to GDP from traditional primary industries (farming, forestry, animal husbandry and fishery) in Guangdong dropped from

about 30% to only 8% (Fig. 2.3). In contrast, secondary industry (mining and quarrying, manufacturing, production and supply of electricity, water and gas, and construction) as well as tertiary industry (service industries such as those providing finance, transport and public administration) have increased their contribution to the Guangdong economy (Fig. 2.3).

Extensive and intensive urbanisation has occurred throughout the region in parallel with economic and population growth, (Fig. 2.4). Since economic reform in the 80s, the central and provincial governments have gradually relaxed controls on land use, and local governments have clamoured to attract investment for development (Li and Yeh, 2004). Large areas of farmland were converted to industrial, commercial and residential use (The Baptist University, 2003; Zhu, 2004a), and urban areas increased by more than three times between 1988 and 1996 (Seto *et al*., 2002). The degree of urbanisation among provinces varied (Li & Yeh, 2004), and in general, manufacturing industries have concentrated in six cities: Guangzhou, Foshan, Zhongshan, Dongguan, Huizhou and Jiangmen (Wong, 2003). Over the past decade, urban developments have been relatively more concentrated on the eastern side of the Pearl River Delta. Proposed developments such as the Hong Kong-Zhuhai-Macao Bridge, if completed, would likely trigger more development on the western side of the Delta.

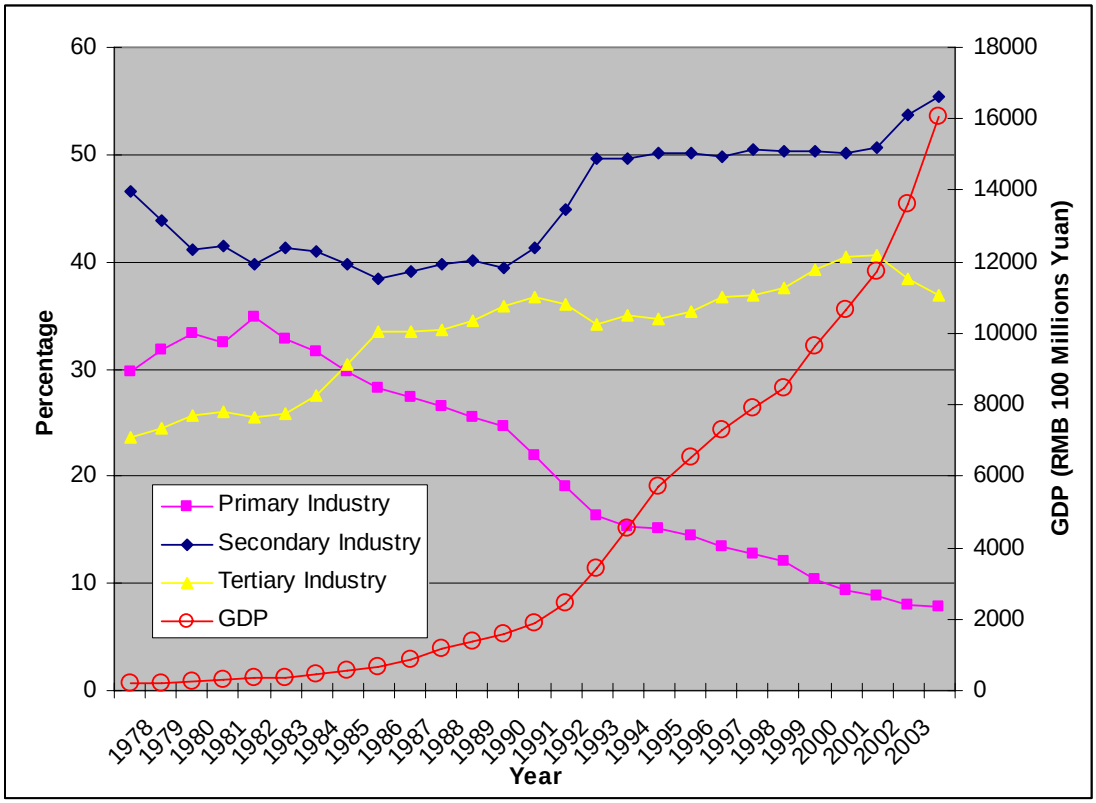



Fig. 2.3: Guangdong gross domestic product (GDP) and the relative contributions of primary industry, secondary industry and tertiary industry to the GDP from 1978 to 2004. Source data from Guangdong Statistical Yearbook 2005 (Statistics Bureau of Guangdong Province, 2005).


Fig. 2.4: Satellite images showing the development in the Deep Bay area between Shenzhen and Hong Kong to the east of the Pearl River Estuary in 1973 and 2001. Image credits: NASA/Goddard Space Flight Center, Scientific Visualization Studio (NASA, 2003)

## 2.4 Freshwater resources and shortages

With its basin located south of 27°N, Pearl River is influenced by a subtropical monsoon climate. The annual average temperature in different parts of the basin ranges between 14°C and 22°C (PRWRC, 1991). Rainfall intensity varies across the basin with generally more precipitation in the east compared to the west, and more in the south than the north (PRWRC, 1991; Woo *et al*., 1997). For instance, Guangdong Province has a higher annual average rainfall of 1,777 mm, compared to the total basin average of 1,470 mm. Most of the rainfall occurs during the wet season in summer. In the central and southeastern parts of the basin, about 60 to 70% of the annual rainfall occurs from May to August (PRWRC, 1991).

The Pearl River has the second largest total discharge in China following the Yangtze River, but a higher annual discharge per catchment area (Table 2.3). The water availability per person in Guangdong is 4,735$m^3$, which is around double the country's average of 2,200$m^3$ (MWR, 2005; Guangdong Government, 2006), indicating that the region has relatively rich water resources within China. Nevertheless, this is still considerably lower than the world average of 7,000$m^3$ in 2000 (UNEP, 2002b). The water availability per person in some areas, including the Dongjiang catchment which is currently the source of water supplies to Hong Kong, is even lower than the country's average (South CN, 2005k). Some cities in the PRD, including Guangzhou, Shenzhen, Zhuhai and Huizhou, are facing water shortages due primarily to high industrial consumption (Zhu & Pu, 2004; Zhu *et al.*, 2004b). Water shortages are most acute during the dry season and are exacerbated by pollution from city sewage discharge (Zhu *et al*., 2003; Guangdong Government, 2006; Yang *et al*., 2006) as well as agricultural sources (Yang *et al*., 2004).

A water forecast study estimated that there would be a more than 50% increase in the total water demand in the PRD (excluding Hong Kong and Macau SAR) from 2002 to 2020 (Zhu *et al.*, 2004b). Although the provision of more infrastructure can increase the water supply capacity, the same study showed that the current and projected water demand of PRD has been, and will be above its supply capacity (Zhu *et al.*, 2004b).

| River | Annual discharge ($10^9$ $m^3$) | Catchment area ($km^2$) | Annual discharge per catchment area ($10^3$ $m^3$ per $km^2$) |
|---|---|---|---|
| Yangtze River | 911 | 1,800,000 | 506 |
| Pearl River | 334 | 444,300 | 751 |
| Yellow River | 43 | 752,000 | 575 |

Table 2.3. Relationship between annual discharge and catchment area of the three major rivers in China (Data from (PRWRC, 1991).

## 2.5 Freshwater biodiversity

Although Guangdong is not one of the most species rich provinces in China, fragments of the remaining natural tropical forest still harbour a high species richness and a relatively high degree of endemism has been noted (Mackinnon *et al*., 1996), including the presence of a number of globally and nationally endangered species, such as the Smooth-coated otters (*Lutrogale perspicillata*), Sambar deer (*Rusa unicolor*) and Asian giant soft-shell turtle (*Pelochelys cantorii*) (Guangdong Forestry *et al*., 1997; CSIS, 2006). Some 381 species of fish have been recorded in the Pearl River (Liao *et al*., 1989) with up to an estimated 296 entirely freshwater species (Table 2.4). Amongst the Yangtze River, Yellow River and Pearl River, freshwater fish species density was comparatively much higher in the Pearl River, at 7 species per 10,000 $km^2$ catchment area as compared with 2 species per catchment area in the other two rivers (Fu *et al.*, 2003a).

Published materials on the biological resources of the Pearl River and estuary primarily focus on mangrove species and communities (see (Li & Lee, 1997), fisheries resources (e.g. (Pearl River Fisheries Resources Survey Editorial Board, 1985; Pan, 1987; Liao *et al.*, 1989; Zheng, 1989; Li, 2002; Zhang, 2005; PRWRC, 2006c), pollution indicator species (e.g. (Qi & Huang, 1993; Connell *et al.*, 2002; Ip *et al.*, 2005; Liu & Kueh, 2005) and some rare and charasmatic species, such as the Chinese white dolphin, *Sousa chinensis* (e.g. (Wang & Han, 1996; Chen *et al.*, 2004b; Porter, 2005). By 2005, it was estimated that 92 species of fish in the Pearl River were endangered (South CN, 2005g; PRWRC, 2006c). Studies confined to inland freshwater species or communities in the region are relatively scarce and

data-gaps exist (Table 2.4). In 2006, the Ministry of Land and Resources and the Guangdong Province initiated a study to establish a database on agricultural land resources and ecological resources for the PRD. This is expected to be completed in 2008 (South CN, 2006o).

## 2.6 Conservation & water management

Since 1992, China has signed up to a number of international treaties and agreements which obligate it to protect biodiversity, such as the Convention on Biological Diversity (CBD), the Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITIES) (Annex A). Chinese authorities have enacted a number of laws and regulations related to biodiversity protection (see Annex A), including environmental impact assessments, protected areas, and various permit systems (Mackinnon *et al*., 1996; Jahiel, 1998; SEPA, 1998; Xu *et al*., 1999; Liu & Jared, 2005). These are implemented from a variety of levels of administration, including the Central and local governments, environmental protection administrations, administrations relevant to different resources, and the Public Security Bureau (SEPA, 1998).

Following the formulation of a work plan for wetland conservation in Guangdong in 2006, 43 wetland conservation areas will be established by 2030 (Guangdong Forestry News, 2006). In addition, a number of new reserves has also been proposed to protect endemic freshwater fishes and endangered amphibians and reptiles in Guangzhou (South CN, 2005g). The enactment of the Regulation for Wetland Conservation of Guangdong Province on the 1st September 2006 has provided the administration with clear objectives for freshwater biodiversity conservation and management, including freshwater habitats and organisms (Forestry Administration of Guangdong, 2006).

| Taxonomic group | Geographic scope | No. of species |
|---|---|---|
| Vascular Plant | Guangdong | 7055[a] |
| | Wutongshan National Forest Park, Shenzhen | 372[b] |
| | Guangdong Dinghushan State Nature Reserve, Zhaoqing | 2054[c] |
| Mangrove and Semi-mangrove plants | Guangdong | 20[d] |
| Fish | Pearl River | Primary Freshwater: 262[e], 239[f], 296[g]<br>Brackish or diadromous: 119[f]<br>Total: 381[e] |
| | Guangdong | Total: 321[h]<br>Freshwater: 208[h] |
| | Pearl River, Guangdong sections | 161[e] |
| Amphibians | Guangdong | 31[a] |
| | Guangdong Dinghushan State Nature Reserve | 9[c] |
| | Wutongshan National Forest Park, Shenzhen | 9[b] |
| | Xiangtoushan Nature Reserve, Huizhou | 23[i] |
| Reptiles | Guangdong | 107[a] |
| | Guangdong Dinghushan State Nature Reserve | 14[c] |
| | Wutongshan National Forest Park, Shenzhen | 8[b] |
| Mammals | Guangdong | 98[a] |
| Phytoplankton | Pearl River (from 15 stream sections) | 219 genera[e] |
| Zooplankton | Pearl River | 410[e] |
| Benthos | Pearl River | 268[e] |

Source:
a. (Guangdong Forestry *et al*., 1997)
b. (KFBG, 2001)
c. (KFBG, 2002)
d. (Li & Lee, 1997)
e. (Liao *et al*., 1989)
f. (Zheng, 1989)
g. (Fu *et al.*, 2003a)
h. (Chinese Academy of Fisheries Science *et al*., 1991)
i. (Wu *et al*., 2003)

Table 2.4: Number of species in selected taxonomic groups recorded in the whole Pearl River, Guangdong or the PRD.

A number of national institutions are responsible for water management in China in various aspects, including the authorities on environmental protection, resource management, planning, public services and public health (see Box 2.1). While the provincial governments are responsible for the water management issues at the local level, for the big rivers across China, a number of management authorities for particular river basins are established to oversee the water management issues for the entire river basin across different provinces, such as the Pearl River Water Resources Committee 水利部珠江水利委員會 (PRWRC) (www.pearlwater.gov.cn/index.jsp) and the Changjiang Water Resources Commission水利部長江水利委員會 (www.cjw.com.cn/).

**Box 2.1: The institutions of water management in China**

| | |
|---|---|
| Ministry of Water Resources 水利部 | Administrative issues on water resources |
| State Environment Protection Administration 國家環境保護總局 | Water pollution control |
| Ministry of Construction 建設部 | Water supply, drainage and sewage treatment in urban areas |
| Ministry of Agriculture 農業部 | Non-point source pollution control, fishery area protection and aquatic wildlife conservation |
| State Forestry Administration 國家林業局 | Headwater forest protection and wetland management |
| National Development and Reform Commission (NDPC) 國家發展和改革委員會 | Participates in planning for water resource exploitation and ecological conservation; Coordinates planning and policies, such as agriculture, forestry and water resource |
| Ministry of Communications 交通部 | Inland navigation, pollution control of ships |
| Ministry of Public Health 衛生部 | Supervision on the implementation of drinking water health standards |
| Water management authorities in major river basins | Oversees water issues at the basin scale |
| Provincial governments | The Pearl River Basin, for instance, involves six provincial governments, including Guangdong, Guangxi, Guizhou, Hunan, Jiangxi, and Yunnan |

There are shortcomings, however, existing in the current river basin management system, such as the lack of coordination among various management authorities

and the indistinct duties and authorities on some water management issues. Together with the China Council for International Cooperation on Environment and Development, WWF China has submitted a report to the State Council in 2004 to put forward a more integrated approach to river basin management for the Yangtze River Basin, to balance conservation and development by all stakeholders, and to promote good governance for river basin and maximise public welfare in river basins (CCICED Task Force, 2004; China Daily, 2004). Similar initiatives have not yet begun for the Pearl River, as the focus of discussions is usually on the availability of water for human use (e.g. (South CN, 2002; Zhang, 2003), and the regulations of river flows by releasing the stored water from the reservoirs in the headwater provinces to the main rivers to combat saline intrusion downstream (Yue, 2004) but not on biodiversity conservation.

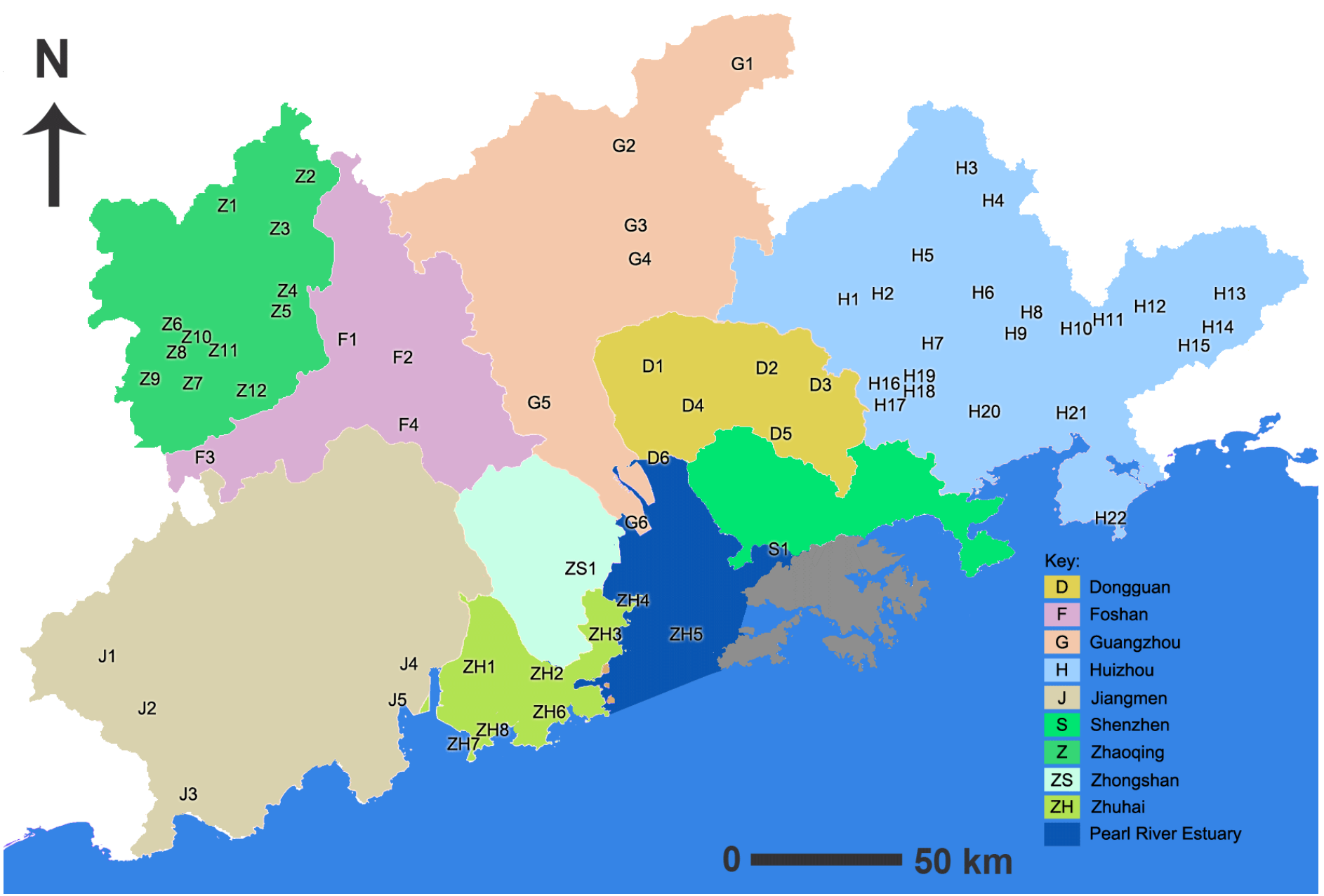



Fig. 2.5: Location of nature reserves in the PRD by 2006. The identity of each reserve is listed in Table 2.5.

Data sources: Information is adapted from published maps and Guangdong Wild Animal and Plant Conservation Management Office, Forestry Administration of Guangdong (http://wcm.gdf.gov.cn/zrbhq/js_bhq.php) and Guangdong Environmental Protection Bureau (http://app.gdepb.gov.cn/Vehicle/naturearea.aspx).

Table 2.5: Nature reserves in the Pearl River Delta up to 2006. Location map is shown at Fig. 2.5.
Data sources: Guangdong Wild Animal and Plant Conservation Management Office, Forestry Administration of Guangdong (http://wcm.gdf.gov.cn/zrbhq/js_bhq.php) and Guangdong Environmental Protection Bureau (http://app.gdepb.gov.cn/Vehicle/naturearea.aspx).

| City | ID No. | Name | Major Conservation Interests | Management Level | Area (ha) |
|---|---|---|---|---|---|
| Dongguan | D1 | Dongguan City Nature Reserve (東莞市自然保護區) | Surrounding natural ecological environment of the city | City / County | 2,022 |
| | D2 | Dongguan Dengxintang Nature Reserve (東莞燈心塘自然保護區) | Headwater forest; Burmese python; Pangolin; *Toona ciliata*; Wild type Litchi | City / County | 489 |
| | D3 | Dongguan Yinpingshan Nature Reserve (東莞銀瓶山自然保護區) | Migratory birds | City / County | 2,805 |
| | D4 | Dongguan Lianhuashan Nature Reserve (東莞蓮花山自然保護區) | Natural ecological environment; Native environment of wild animals and plants | City / County | 783 |
| | D5 | Dongguan Mashan Nature Reserve (東莞馬山自然保護區) | Natural ecological environment; Native environment of wild animals and plants | City / County | 2,276 |
| | D6 | Chinese Bahaba Nature Reserve (黃唇魚市級自然保護區) | Chinese Bahaba | City / County | 686 |
| Foshan | F1 | Nanhai Xiqiao Volcano Landscape Nature Reserve (南海西樵山火山地貌自然保護區) | Volcano landscape | City / County | 800 |
| | F2 | Gaoming Sanzhou Headwater Forest Nature Reserve (高明三洲區水源林自然保護區) | Headwater forest | City / County | 653 |
| | F3 | Gaoming Heshui Suoluo Nature Reserve (高明合水桫欏自然保護區) | Tree ferns | City / County | 1,038 |
| | F4 | Nanhai Jiujiang Huangji Nature Reserve (南海九江璜磯自然保護區) | Birds | City / County | 2,883 |
| Guangzhou | G1 | Conghua Chenhedong Nature Reserve (從化陳禾洞自然保護區) | Evergreen Forest | City / County | 2,219 |
| | G2 | Guangzhou Conghua Hot Spring Nature Reserve (廣州從化溫泉自然保護區) | Forest; Wild animals and plants | City / County | 2,886 |
| | G3 | Zengcheng Dadongkeng Secondary Forest Nature Reserve (增城大東坑次生林保護區) | Rare Secondary Forest | City / County | 250 |

Table 2.5 (*cont.*):

| | | | | | |
|---|---|---|---|---|---|
| Guangzhou | G4 | Zengcheng Wild-type Rice Nature Reserve (增城野生稻自然保護區) | Wild-type rice | City / County | 4 |
| | G5 | Panyu Dishuiyan Nature Reserve (番禺滴水岩自然保護區) | Birds | City / County | 400 |
| | G6 | Xinken Bird Nature Reserve (新墾鳥類自然保護區) | Birds | City / County | 3,300 |
| Huizhou | H1 | Boluo Taipingshan Nature Reserve (博羅太平山自然保護區) | Subtropical evergreen forest; Rare animals and plants | City / County | 525 |
| | H2 | Guangdong Boluo Luofushan Nature Reserve (廣東博羅羅浮山自然保護區) | Subtropical evergreen forest; Rare animals and plants | Provincial | 9,811 |
| | H3 | Boluo Huangshandong Nature Reserve (博羅黃山洞自然保護區) | Subtropical evergreen forest; Rare animals and plants | City / County | 1,400 |
| | H4 | Huiyang Dunzi Nature Reserve (惠陽墩子自然保護區) | Subtropical evergreen forest; Rare animals and plants | City / County | 1,923 |
| | H5 | Guangdong Xiangtoushan Nature Reserve (廣東惠州象頭山自然保護區) | Subtropical evergreen forest; Rare animals and plants | State | 10,697 |
| | H6 | Huizhou Yanglang Nature Reserve (惠州洋朗自然保護區) | Precious and rare animals and plants | City / County | 1,200 |
| | H7 | Huizhou Dashikeng Nature Reserve (惠州大石坑自然保護區) | Subtropical evergreen forest; Rare animals and plants | City / County | 848 |
| | H8 | Huidong Pingtianzhang Nature Reserve (惠東坪天嶂自然保護區) | Subtropical evergreen forest; Rare animals and plants | City / County | 1,793 |
| | H9 | Huiyang Baimianzi Nature Reserve (惠陽白麵石自然保護區) | Forest | City / County | 800 |
| | H10 | Guangdong Huidong Gutian Nature Reserve (廣東惠東古田自然保護區) | Subtropical evergreen forest; Rare animals and plants | Provincial | 3,600 |
| | H11 | Huidong Nanmuqiao (Nature Reserve 惠東南木橋自然保護區) | Subtropical evergreen forest; Rare animals and plants | City / County | 1,557 |
| | H12 | Huidong Shierkong Nature Reserve (惠東十二崆自然保護區) | Subtropical evergreen forest; Rare animals and plants | City / County | 2,006 |

Table 2.5 (*cont.*):

| | | | | | |
|---|---|---|---|---|---|
| Huizhou | H13 | Huidong Huzhuzhang Nature Reserve (惠東虎竹嶂自然保護區) | Subtropical evergreen forest; Rare animals and plants | City / County | 1,800 |
| | H14 | Huidong Lianhuashan Baipenzhu Nature Reserve (惠東蓮花山白盆珠自然保護區) | Subtropical evergreen forest; Rare animals and plants | Provincial | 14,034 |
| | H15 | Huidong Baimashan Nature Reserve (惠東白馬山自然保護區) | Forest | City / County | 9,333 |
| | H16 | Huiyang Huangchaozhang Nature Reserve (惠陽黃巢嶂自然環保區) | Forest | City / County | 4,788 |
| | H17 | Huiyang Baiyunzhang Nature Reserve (惠陽白雲嶂自然保護區) | Forest | City / County | 4,056 |
| | H18 | Huiyang Dakeng Nature Reserve (惠陽大坑自然環保區) | Forest | City / County | 1,866 |
| | H19 | Huizhou Liantangbu Nature Reserve (惠州連塘布自然保護區) | Subtropical evergreen forest; Rare animals and plants | City / County | 845 |
| | H20 | Huiyang Jinju Nature Reserve (惠陽金桔自然保護區) | Subtropical evergreen forest; Rare animals and plants | City / County | 2,222 |
| | H21 | Huidong Mangrove Nature Reserve (惠東紅樹林自然保護區) | Mangrove; Birds | City / County | 533 |
| | H22 | Huidong Gangkou Sea Turtle Nature Reserve (惠東港口海龜自然保護區) | Sea Turtle | State | 1,800 |
| Jiangmen | J1 | Enping Junzishan Nature Reserve (恩平君子山自然保護區) | *Information not available* | City / County | 7,000 |
| | J2 | Enping Qixingkeng Nature Reserve (恩平七星坑自然保護區) | Mature secondary forest; Rare animals and plants | City / County | 7,890 |
| | J3 | Tai Shan Zhenhaiwan Mangrove Nature Reserve (臺山鎮海灣紅樹林自然保護區) | Mangrove; Birds | City / County | 111 |
| | J4 | Guangdong Gudoushan Nature Reserve (廣東江門古兜山自然保護區) | Subtropical evergreen forest; Rare animals and plants | Provincial | 11,567 |
| | J5 | Enping Mangrove Nature Reserve (恩平紅樹林自然保護區) | Mangrove | City / County | 700 |



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Table 2.5 (*cont.*):

| | | | | | |
|---|---|---|---|---|---|
| Shenzhen | S1 | Guangzhou Neilingding Futian State Nature Reserve (廣東內伶仃福田國家級自然保護區) | Macaque; Mangrove; Birds | State | 922 |
| Zhaoqing | Z1 | Sihui Shierdai Nature Reserve (四會十二帶自然保護區) | Forest | City / County | 2,253 |
| | Z2 | Guangning Shenkeng Nature Reserve (廣寧深坑市級自然保護區) | Subtropical forest; Rare animals and plants | City / County | 3,025 |
| | Z3 | Sihui Suijiang Nature Reserve (四會綏江自然保護區) | Asian giant softshell turtle | City / County | 273 |
| | Z4 | Guangdong Dinghushan State Nature Reserve (廣東鼎湖山國家級自然保護區) | Subtropical evergreen forest; Rare animals and plants | State | 1,133 |
| | Z5 | Zhaoqing Dinghu Freshwater Clam Nature Reserve 肇慶鼎湖黃沙蜆自然保護區 | Freshwater clams | City / County | 6,000 |
| | Z6 | Guoyao Xijianghe Headwater Forest Nature Reserve (高要西江河水源林自然保護區) | Headwater forest; Rare wild animals and plants | City / County | 10,200 |
| | Z7 | Guoyao Yangmei Reservoir Headwater Forest Nature Reserve (高要楊梅水庫水源林自然保護區) | Headwater forest; Rare wild animals and plants | City / County | 1,830 |
| | Z8 | Guoyao Xinxingjiang Headwater Forest Nature Reserve (高要新興江水源林自然保護區) | Headwater forest; Rare wild animals and plants | City / County | 3,650 |
| | Z9 | Guoyao Liyuwei Reservoir Headwater Forest Nature Reserve (高要鯉魚尾水庫水源林自然保護區) | Headwater forest; Rare wild animals and plants | City / County | 980 |
| | Z10 | Zhaoqing Jilongding Nature Reserve (肇慶雞籠頂市級自然保護區) | Subtropical evergreen forest; Precious animals and plants | City / County | 2,312 |
| | Z11 | Guoyao Jinlong Reservoir Headwater Forest Nature Reserve (高要金龍水庫水源林自然保護區) | Headwater forest; Rare wild animals and plants | City / County | 1,830 |
| | Z12 | Guangdong Xijiang Lankeshan Nature Reserve (廣東西江爛柯山自然保護區) | Headwater forest; Rare wild animals and plants | Provincial | 7,962 |



26

Table 2.5 (*cont.*):

| | | | | | |
|---|---|---|---|---|---|
| Zhongshan | Z13 | Zhongshan Changjiang Reservoir Headwater Forest Nature Reserve (中山長江庫區水源林市級自然保護區) | Headwater forest | City / County | 4,240 |
| Zhuhai | ZH1 | Doumen Huangyangshan Nature Reserve (鬥門黃楊山自然保護區) | Subtropical evergreen forest; Rare animals and plants | City / County | 1,635 |
| | ZH2 | Zhuhai Quogaidong Nature Reserve (珠海鍋蓋棟自然保護區) | Forest | City / County | 1,425 |
| | ZH3 | Zhuhai Fenghuangshan Nature Reserve (珠海鳳凰山自然保護區) | Subtropical evergreen forest; Rare animals and plants | City / County | 807 |
| | ZH4 | Zhuhai Qiao Mangrove Nature Reserve (珠海淇澳擔杆島省級自然保護區) | Mangrove; Wetlands; Macaque | Provincial | 7,363 |
| | ZH5 | Zhujiangkou Chinese White Dolphin Nature Reserve (珠江口中華白海豚自然保護區) | Chinese white dolphin | State | 46,000 |
| | ZH6 | Zhuhai Doumen Zhugaoling Nature Reserve (珠海鬥門竹篙嶺自然保護區) | Forest | City / County | 460 |
| | ZH7 | Zhuhai Hebaodao Secondary Forest Nature Reserve (珠海荷包島次生林保護區) | Forest; Coastal environment | City / County | 1,020 |
| | ZH8 | Zhuhai Damangdao Wild Animal Nature Reserve (珠海大杧島野生動物放養保護區) | Deer; Macaque | City / County | 420 |
| | | | | Total: | 233,939 |

# Section 3

# Threats to freshwater biodiversity

A hillstream in the Beijiang Basin in Guangzhou © WWF / Alan S.L. Leung

## 3.1 Analysis of threats

Shortages of sufficient clean water have become a major social issue in the PRD and have been frequently highlighted in the regional media. The misuse and overexploitation of the freshwater environment and resources is having a real impact on the availability of freshwater for human and industrial consumption, with social and economic consequences.

The threats facing freshwater biodiversity in the PRD may have a lower public profile, but are immense and complex (Zhu *et al.*, 2001; Liang, 2003; Zhou *et al.*, 2003; Liu & Wu, 2004; Peng & Wang, 2004; Cui *et al.*, 2005; GDEPB, 2006g). Anthropological impacts are not only causing a loss in biodiversity, but are also disrupting the ecological functions of freshwater ecosystems (Peng *et al.*, 2004; PRWRC, 2005; GDEPB, 2006b). The major direct threats identified include flow alternations, habitat change and degradation, and pollution. Other impacts endangering biodiversity include over-exploitation of natural resources (e.g. through fishing), human intrusion and disturbance to ecologically sensitive habitats, and invasive species. Climate change and extreme weather events, which have emerged as significant threats in recent years, and are predicted to increase in intensity in coming decades, compound the stress already experienced by freshwater ecosystems in the PRD.

The wide variety of threats and complex linkages among them make analysing the problem and identifying solutions difficult. In this section, the various threats to freshwater biodiversity and the underlying causes are examined individually, and this information is then used to construct a conceptual model. Existing and potential solutions, with the latter having been derived from the conceptual model, are described in Section 4. Many of these are cross-cutting against a range of threats.

### 3.1.1 Flow regime alterations

- *Water extraction and transfer*

Freshwater systems provide water resources for our basic needs, such as drinking and cooking, and a huge variety of other uses, ranging from

manufacturing to recreation. The rapid population growth and industrialisation in the PRD have increased demands for freshwater (see Section 2.2, 2.3 & 2.4). Man's need for water is so fundamental that some of the earliest large engineering projects in civilisation were undertaken to transport water over considerable distances when the demand from populated areas exceeded what could be supplied from the nearby sources.

Bringing in water from other catchments is still a widespread water management strategy as a solution to water shortages in China, including the PRD (Shen, 1997; Shu *et al*., 2004). For instance, about 80% of Hong Kong freshwater resource is transferred from Dongjiang while the water captured by its local water catchments only supports about 20% of the Hong Kong's needs (Water Supplies Department, Hong Kong SAR Government). Macau depends almost entirely on water imported from Xijaing in Zhuhai (PRWRC, 1994; Macao Water, 2006).

- *Deforestation*

Another cause of flow alteration is deforestation, which increases soil erosion and reduces the capacity of the land to retain water, and release it gradually (Zhou *et al*., 2002; Walling & Fang, 2003). As a result, surface runoff from rainfall enters river systems more vigorously, leading to further soil erosion and flooding (diCenzo & Luk, 1997; Luk *et al.*, 1997; China Daily, 2006d).

Furthermore, as less water is captured and stored in the land in the wet season, the flow rate in water courses becomes reduced in the dry season. This may be exacerbated by changes in regional weather patterns which can result in droughts (as well as floods) and is described subsequently.

According to historical records, virtually all native forest in Guangdong had been destroyed by 1949 (Xia, 1999). In between 1975 and 1984, forest coverage in Guangdong dropped from 38% to 27%, for instance, at the Dongjiang headwaters (Zhang & Hu, 2004), mainly due to large scale destruction of natural forest for development, agricultural uses and commercial forest (Xia, 1999).

Although some reforestation initiatives since mid-80s increased forest coverage up to 57%, the ecological value for most of these plantations was low, being dominated by a few species of pine with poor understorey vegetation (Xia, 1999).

***Impacts to biodiversity***

- *Reduced environmental flow* – Disrupted flow regimes, including reduced flow rates and discharge volume, reduces the water available to the freshwater ecosystem, also referred to as the environmental flow (see Box 3.1). In extreme cases, freshwater habitats may completely dry up, particularly in the dry season. (see White cloud mountain minnow example, Box 3.2) Alteration of natural baseflow regime and volume may also result in changes to water temperature and conductivity. Increasingly shallow water bodies are likely to experience a wider range of daily temperature fluctuations for example, as they will follow air temperature fluctuations more closely. Also refer to Section 3.1.2.

- *Saline intrusion* – As a result of reduced flow, in particular during the dry season (see above), the hydraulic pressure from the river is also reduced. As a result, notably during the spring tide, the problem of saline intrusion amplifies as seawater travels further inland from the river mouth, causing an increase in salinity in the freshwater environment. Lowland marshes and wetlands may also be affected due to changes in soil acidity (Chen, 2005).

**Box 3.1: Environmental Flow**

The water flows in rivers are often regulated to allocate water for human uses. However, over-abstraction of water and improper flow management has affected the ability of river systems to maintain their ecological functions. An environmental flow refers to the water flow regime provided to a river, or an aquatic ecosystem, to maintain its ecological functions. The allocation for environmental flows not only ensures the continued availability of water to the freshwater ecosystems, it also provides critical contributions to the sustainable uses of water resources for both economic and social benefits (Dyson *et al*., 2003).

**Box 3.2: White cloud mountain minnow *Tanichthys albonudes***

This attractive fish is endemic to Guangdong. It was first named in 1932 and found only in the White Cloud Mountain and a few mountain streams. The species was thought to be extinct in the wild since as none were found for about 20 years, although it has survived in the aquarium trade. Fortunately, a wild population was rediscovered in Guangzhou in 2003 (Yi *et al*., 2004). Its decline is believed to be primarily the result of the drying up of streams due to soil erosion and stream diversions caused by deforestation, as well as competition from the exotic Mosquito fish *Gambusia affinis* (Yue & Y.Y., 1998; Chan, 2002; IUCN, 2004a; Yi *et al.*, 2004; Lee, 2006). Garnet minnow, *Aphyocypris lini*, another restricted fish, is also facing similar problems (Li, 2002).

### 3.1.2 Habitat change & degradation

Habitat change and degradation have been identified as a key driver to wetland loss worldwide and the resulting loss of biodiversity is predicted to continue at a rapid pace (Millennium Ecosystem Assessment, 2005). Floodplains are considered as one of the most globally threatened habitats (Tockner & Stanford, 2002). Over the last two decades, the human population (see Section 2.2) and developed areas of the PRD have expanded rapidly, leading to an overwhelming rate of change and degradation of freshwater habitats.

Urban encroachment to freshwater environment © WWF / Alan S.L. Leung

- *Urbanisation*

The large–scale changes to freshwater systems that occurred in the PRD in the 1980s and 1990s occurred during China's economic takeoff. Similar to cases in many other countries undergoing such growth, environmental concerns including the protection of important freshwater habitats and biodiversity became a secondary consideration. Floodplains have been converted for development (Lin, 2001; Wong *et al*., 2003; Ouyang *et al*., 2005) and river mouths were extended by reclamation to create more land (Zeng *et al.*, 2004b). Having said that, the conversion of freshwater habitats for agricultural and aquacultural purposes (Wu, 1998) has a history in the PRD dating back to early human settlement (PRWRC,

1991).

- *River regulation & channelisation*

While the floodplains of the PRD have been straightforward to build on as they are flat, they are prone to flooding as the name suggests, and hence flood control works are carried out in areas for development and social needs (see below). Works include river regulation and channelisation (Luo *et al.*, 2003; South CN, 2006e), and construction of embankments (South CN, 2005i; Zhuang *et al.*, 2005), which generally involves concreting, deepening and straightening water courses.

- *Dams*

Rivers have been dammed for a variety of purposes, such as water storage (Zhong, 2004) and power generation (e.g. Huizhou; (South CN, 2004). According to the PRWRC, about 14,000 reservoirs have been built over the Pearl River Basin (PRWRC, 2004). While the water stored in the reservoirs can provide water supply for the cities and agricultural irrigation, the release of stored water is also a water management strategy to reduce the degree of saline intrusion downstream during periods of reduced flow (Wang, 2006).

To meet the energy demand for development, numerous hydropower stations have been built in the Pearl River Basin. By the end of 1985, 13,657 hydropower stations of various power generation capacities had been built across the Pearl River Basin. 94% had small capacities below 500 kW while 19 medium and big hydropower stations with capacities over 25,000 kW were built, with 13 located in Xijiang, 3 in Beijiang, 2 in Dongjiang and 1 in the PRD (PRWRC, 1994). The first hydropower station in the Pearl River is located at Liuxihe in Guangzhou, having a maximum dam height of 78 m (PRWRC, 1994). Since then, more hydropower stations have been built (e.g. Boluo; (South CN, 2004) and are planned to be built (ERI, 2006).

- *Sand extraction & dredging*

To fulfil the huge demand for construction materials in the PRD, sand has been extracted from riverbeds (see Box 3.3), causing changes in river morphology and

hydrology (Zhou *et al*., 2001; Peng, 2004; Qian, 2004; Han *et al*., 2005). For navigation purposes to allow bigger vessels to pass through shallow rivers, deeper and larger river channels (South CN, 2005d, e, 2006k) have also been constructed through dredging (Zhu, 2004b; Zhuang, 2006) and blasting (Tu, 2003).

**Box 3.3: Sand and boulders extraction**

Sand and boulders as construction materials collected from the riverbed. New legislation has been enacted to control such activities in Guangdong since 2005.


***Impacts to biodiversity***

- *Habitat loss* – The physical alteration of freshwater areas to create land for development causes direct loss of habitats for freshwater flora and fauna. Traditional design approaches focused on the hydrological performance of the river channel to drain water, such as the use of concrete lining to replace the natural streambed and stream bank, which greatly reduces the ability of the habitat to support life (Su, 2005). For example, construction of embankments destroys riparian vegetation and the shallow, slow-flowing water areas which serve as fish nursery grounds, while the replacement of natural substratum with bare hard surfaces will provide an environment unsuitable for most freshwater organisms to survive.

- *Reduced environmental flow* – Dams have distorted the natural river flow from upstream to downstream and the amount of flow for downstream is heavily dependent upon the management strategy of the dams. Dams will usually retain large volumes of water during the wet season for regulated release during the dry season. The peak flow during floods has also reduced so that the ecological functions of natural flooding, such as migration of organisms over the floodplain, is impaired. Also refer to Section 3.1.1.

- *Disturbance and release of contaminants* – Sand collection and dredging destroys the benthic (bottom-living) organisms. Without proper mitigation measures, dredging of riverbed will also increase turbidity of the water course and potentially release any toxic or contaminated materials bonded with riverbed sediments.

- *Barriers to migratory animals* – Dams create physical barriers which prevent aquatic organisms, including fishes, migrating upstream and downstream (WCD, 2000; FAO, 2003b). For example, aggregated fishes downstream of big dams in the Beijiang have attracted fishermen to fish intensively, with some using destructive fishing methods such as electric fishing and explosives (Su, 2005). Dam construction and blockage of the spawning migration route (Wei *et al*., 1997; Dudgeon *et al*., 2006) were believed to be the major reason for the

collapse of the endangered Chinese sturgeon *Acipenser sinensis* in the Pearl River (Wei *et al*., 2004).

- *Habitat fragmentation* – Development of roads and infrastructures under rapid urbanisation has resulted in fragmentation of freshwater wetlands, particularly over the floodplain area.

- Saline intrusion – refer to Section 3.1.1.

### 3.1.3 Pollution

Similar to other threats to freshwater biodiversity in the PRD, the leading factors causing pollution are massive growth in residential, commercial, and industrial developments, coupled with inadequate sewage and waste treatment facilities.

Water pollution has been identified as one of the most serious environmental issues in Guangdong (Zhu *et al.*, 2002; Zhou *et al.*, 2003; Chen *et al.*, 2004a) as it reduces the quality of the already depleted water resources (see Section 2.4), and subsequently availability of clean water. The water quality of about 20% of streams and rivers in Guangdong was ranked among the lowest (Box 3.4) in 2005 as opposed to the much smaller 7% during the 1990s (GDEPB, 2006a). The water quality of rivers in city areas was even worse, with more than 35% classified in the lowest category in 2005 (GDEPB, 2006a).

**Box 3.4: Water quality category and some of their intended purposes**
(http://bjepb.gov.cn/bjhb/tabid/68/InfoID/8893/Default.aspx)

| Category | Some intended purposes |
|---|---|
| I | Headwater, State nature reserves |
| II | Drinking water source, habitats for rare and precious aquatic organisms, fish nursery grounds |
| III | Drinking water source, aquaculture, swimming |
| IV | Industrial, recreation with direct contact of water |
| V | Agricultural, amenity uses |
| Below V | Unusable |

While some pollutants remain in the water column, others are accumulated in sediments at the bottom of water courses (Zheng *et al.*, 2001; Zheng *et al.*, 2004;

Zhou *et al.*, 2004a). Persistent organic pollutants can also enter the freshwater environment from the atmosphere (Ye *et al*., 2005). Underground water has also become contaminated (Lu *et al*., 2004; GDEPB, 2005).

With improved economic conditions, environmental awareness has risen and policy implementation, law enforcement, and pollution reporting mechanism have also been tightened. (GDEPB, 2006i). However, the freshwater environment is still in critical condition as pollution loads continue to surpass the assimilation capacity of the environment (State Council, 2005).

- *Sewage & effluent*

Untreated or partially treated sewage and effluent, together with some highly toxic substances, such as persistent organic pollutants (POPs)[1] (Fu *et al.*, 2003b; Kong *et al.*, 2005; Xing *et al.*, 2005) from domestic, commercial and industrial sources have been released into the freshwater environment (Zhu *et al*., 2001; Zhu *et al*., 2002) legally or illegally. The scale of this problem is huge. For instance, by the end of 2005, more than 260 petroleum and chemical industries alone in Guangdong posed environmental safety concerns, contributing significantly to water pollution (South CN, 2006p).

Awareness on the importance of environmental protection, on both potentially polluting industries and local government authorities, seemed to be lacking or very low during the 1980s and 90s. Illegal discharge took place in areas where pollution control, policy implementation and law enforcement were weak. In areas where sewage treatment facilities had not kept pace with the growth of development, sewage was simply discharged without treatment. Aging industrial facilities, poor management of pollutants and sewage treatment, and inadequate levels of punishment have been quoted by officials as typical reasons for the pollution problems in recent years (GDEPB, 2006e).

[1] Persistent organic pollutants (POPs) are chemicals that persist in the environment for long periods, move long distances in the global environment, bio-accumulate in the fatty tissues of living organisms and cause harmful effects to humans and the wildlife UNEP (2006) Stockholm Convention on Persistent Organic Pollutants (POPs). United Nations Environment Programme. http://www.pops.int/.

- *Non-point source pollution*

Urban runoffs containing a variety of pollutants, including heavy metals, oil and diesel, dusts, detergents and other chemicals, have increased with the expansion of urbanised areas (Liu *et al.*, 2003a; Zhuo *et al.*, 2003; Zhang *et al.*, 2004). One study on the pollutants in rain runoffs in Zhuhai revealed that for a short period after rainfall, a marked increase of water pollution level was detected in urban rivers (Zhuo *et al*., 2003). Solid waste has also been dumped or washed by surface runoff into the freshwaters.

Agricultural pollutants, such as fertilisers, excess feedstuffs, waste products from fish in pond aquaculture, and sewage from pig farms (e.g. (South CN, 2006l), enter the freshwater environment, causing eutrophication (excessive nutrients in water) in rivers and reservoirs (Yin *et al.*, 2001; Huang *et al.*, 2003; Wang, 2004; Zhou *et al.*, 2004b; Zhu *et al.*, 2004a; Jiang *et al.*, 2005). Other agricultural by-products, such as pesticides and herbicides, end up in streams and rivers through runoff.

- *Accidental spillage*

With the increase of industrial activities, large quantities of pollutants and toxic chemicals have occasionally spilt accidentally into the freshwater environment during transportation or storage. Poor planning and a lack of proper waste treatment procedures at chemical and petrochemical facilities near major rivers have been responsible for creating significant pollution risks to rivers in China (Chinadaily, 2006) (see Box 3.4).

- *Mines & quarrying*

Mines and quarries not only release heavy metals into rivers during processing and operation, they can cause acid pollution downstream. For instance, iron mines in the Wengjiang, a tributary of the Beijiang, caused water downstream of the mines to become strongly acidic (with pH down to 3) due to the exposure of metal sulphides to the air, leading to an oxidation process and an acid end-product. No aquatic insects were recorded up to 30 km downstream of the mine, as compared to 36 species in an unaffected tributary nearby (Wu *et al*., 2005).

***Impacts to biodiversity***

- *Water contamination* – Pollution reduces the quality of the freshwater environment, and can result in changes in species composition, and reduce species diversity by reducing or eliminating the most pollution-sensitive species, and favouring the tolerant species (Rosenberg & Resh, 1993; Liu *et al.*, 2003b; Zeng *et al.*, 2004a).

- *Bioaccumulation and impacts to food webs* – Some pollutants, such as heavy metals (Zhou & Wong, 2000; Wei *et al*., 2002; Ip *et al*., 2005) and POPs (Zhou & Wong, 2004; Fung *et al*., 2005; Nie *et al*., 2005) in fish, and in bottom-living organisms (Yuan *et al*., 2001; Zhang & Ou, 2005) will be accumulated in the bodies of the organisms and of their predators, a process called bioaccumulation. With their toxicity being magnified along the food-chain, high levels of pollutants which could potentially cause health problems have been detected in top predators (Wang *et al.*, 2004b), such as the Chinese white dolphin (*Sousa chinensis*) (Parsons, 1999; Hung *et al.*, 2004; Leung *et al.*, 2005a) which inhabits the Pearl River Estuary, and man (China Daily, 2005; So *et al*., 2005).

### 3.1.4 Climate change & extreme weather events

- *Climate change*

Since the Industrial Revolution, man's reliance on fossil fuel, for energy production in particular, has resulted in enormous amounts of greenhouse gases, carbon dioxide in particular, being released into the atmosphere. At the same time, large areas of the carbon absorbing forest have been removed. As a result, the concentration of the heating trapping carbon dioxide present in the atmosphere has increased 30% since 1750, leading to global warming (Watson *et al.*, 2000; Tracy *et al.*, 2006).

According to a 2004 study by the Hong Kong Observatory, the annual mean temperature in Hong Kong at the last decade of this century can be expected to have risen by 3.5$^{o}$C above the 1961-1990 average of 23.0$^{o}$C. Due to its close

proximity, the trend of temperature rises in the PRD is anticipated to be similar. Indeed, air temperature is rising in Guangdong. Although it is likely due in part to increased urbanisation, annual increases are consistent with global warming trends (Liu, 2003).

With the effect of sea-level rise associated with global warming due to ocean thermal expansion and the melting of glaciers and ice caps (IPCC, 2001), lowland areas in the PRD are threatened with being inundated (Yang, 1996; Huang *et al*., 2004). To date, with the combination of typhoon and tidal effects, some areas in the PRD such as Guangzhou (Huang *et al*., 2004), have already experienced sea level rise of up to 3 m (Tracy *et al*., 2006). The increased temperature will also cause increased evaporation of water from soil through vegetation to the air (evapotranspiration), causing reduced flow in the headwaters and worsening saline intrusion (see Section 3.1.1) in coastal areas (Watson *et al.*, 2000; Ye, 2005). Significant saline intrusion problems have occurred in coastal cities, in the last two years (South CN, 2005f, 2006f), threatening freshwater resources as well as coastal development projects (Ye, 2005). Modelling by the Institute for the Environment, at The Hong Kong University of Science and Technology, suggested that if the sea level rises 4 m, almost all of Zhuhai, Jiangmen and Guangzhou will be flooded (Tracy *et al*., 2006).

- *Extreme climate events*

An increased frequency and magnitude of floods and drought was reported in the media widely over the Pearl River Basin in 2005 and 2006 (Luo & Pan, 2005; South CN, 2005a; PRWRC, 2006b; South CN, 2006n). Such events could be related to human activities that are changing the physical environment of the Pearl River Basin (Zhou & Ou, 2005). For example, flooding may be exacerbated by land use changes in the PRD. The development of wetlands reduces the amount of floodwater that these natural “sponges” can absorb, while the concreting over of all kinds of natural landscapes and agricultural land decreases the retention time of rainwater on land. Furthermore, large-scale surface and underground water extraction also reduces the environmental flow (see Box 3.1) in rivers and wetlands, reducing their ability to act as water sources during drought.

Localised urbanisation and changing landuse may also lead to change of local climatic conditions, such as temperature (Weng, 2001) and rainfall patterns. Climate change will worsen the situation, by increasing the variability of annual weather patterns, resulting in more natural floods and drought (Watson *et al.*, 2000; HKO, 2005; Tracy *et al.*, 2006). An increasing number of extreme floods may stimulate more protective works, such as river regulation and artificial sea walls (see Section 3.1.2), probably causing further stress to freshwater biodiversity (Dudgeon *et al*., 2006).

***Impacts to biodiversity***

- *Increased water stress* – Increased duration and degree of drought would impose water stress to freshwater species while habitats like freshwater marshes, could dry up for extended periods. Climate change leading to increase in temperature, rainfall patterns and evapotranspiration will likely cause water levels in freshwater habitats to decline and/or fluctuate more than normal (Watson *et al.*, 2000; Guo *et al.*, 2002; Tracy *et al.*, 2006).
- *Saline intrusion* – refer to Section 3.1.1.
- *More flood prevention works* – refer to Section 3.1.2.

### 3.1.5 Over-exploitation of natural resources, invasive alien species, human intrusion & disturbance

- *Over-exploitation of natural resources*

Freshwater biological resources, such as fishery resources (Zheng & Zhu, 2000) and some protected species, have been exploited at an increasing rate, with some species now considered to be over-exploited or fully-exploited (Jia, 2004; Li, 2005b). Destructive fishing methods, such as the use of explosives and electricity shocking, have devastated already depleted fish stocks in some rivers (Liao *et al*., 1989). Fisheries have become overexploited due to a combination of rapidly rising population and need for food, and ineffective freshwater fisheries management. The reclamation of many fishponds and natural river systems has increased the pressure on the remaining freshwater systems to provide food.

- *Invasive alien species*

Although China has established a database on invasive species (Xie *et al*., 2001; CSIS, 2006), the PRD apparently lacks effective control measures to prevent invasive alien species being released into the wild from aquacultural sources. It was reported that more than 150 species of invasive plants and 40 species of invasive animals have become established in Guangdong (People's Daily, 2005).

Invasive alien species have been introduced into freshwater ecosystems either intentionally or unintentionally by the public, which may be due to their religious beliefs, or simply a lack of awareness by releasing aquarium species, or from the escape of agricultural and aquacultural sources (Miao & Li, 2003; South CN, 2003). For instance, the South America herbivorous sailfin catfish *Pterygoplichthys* spp. (South CN, 2005c) which originated from the aquarium trade (Page & Robins, 2006), and the African catfish *Clarias* sp. (Yangcheng, 2005) which was brought to China for aquaculture, have been found to be widespread and abundant in the Guangzhou section of Pearl River. These species have upset the balance of the food webs due to their high rates of reproduction, and predation on indigenous species and domestic carps with high economic values, such as the Big head carp *Aristichthys nobilis* and Grass carp *Ctenopharyngodon idellus* (South CN, 2005c).

Apple snails *Pomacea canaliculata*, a species originating from South America, is now widely spreading in China, including the PRD, and is a significant threat to crop production (Zhou, 2004). The Red-eared slider *Trachemys scripta* (Karsen *et al*., 1998) and Tilapia *Oreochromis mossambicus* (Lee *et al*., 2004) are other examples likely to threaten the native species in the PRD through competition of resources and predation. Invasive plants, such as the Water hyacinth *Eichhornia crassipes*, are also causing ecological impacts, by occupying the space for native species in freshwater habitats of the PRD (e.g. (Wang *et al.*, 2004a; Yan *et al.*, 2004).

- *Human intrusion & disturbance*

Finally, areas of conservation value, including protected areas, are intruded and

disturbed by various human activities (Bian, 2003). Weakness in management in protected areas have also been identified as a major cause of loss in biodiversity (SEPA, 2006). Some protected species themselves are being exploited or threatened due to the weaknesses in resource management as well as policy and law enforcement.

***Impacts to biodiversity***

- *Depletion in numbers* – populations of freshwater organisms have diminished due to over-exploitation and destructive fishing practises.
- *Competition and predation from the invasive species* – invasive alien species reduce the resources available for native species (see example of the White cloud mountain minnow, Box 2) or impose predation pressure on native species. See also the examples above on the sailfin catfish *Pterygoplichthys* spp., African catfish *Clarias* sp., Red-eared slider *Trachemys scripta* and Tilapia *Oreochromis mossambicus*.
- *Disturbance* – Ecologically important areas, such as important breeding sites, feeding grounds or habitats for rare species may be disturbed by human intrusion and various activities, reducing the ability of these areas to act as sanctuaries for freshwater species amid the massive urbanisation

## 3.2 A conceptual model for the PRD

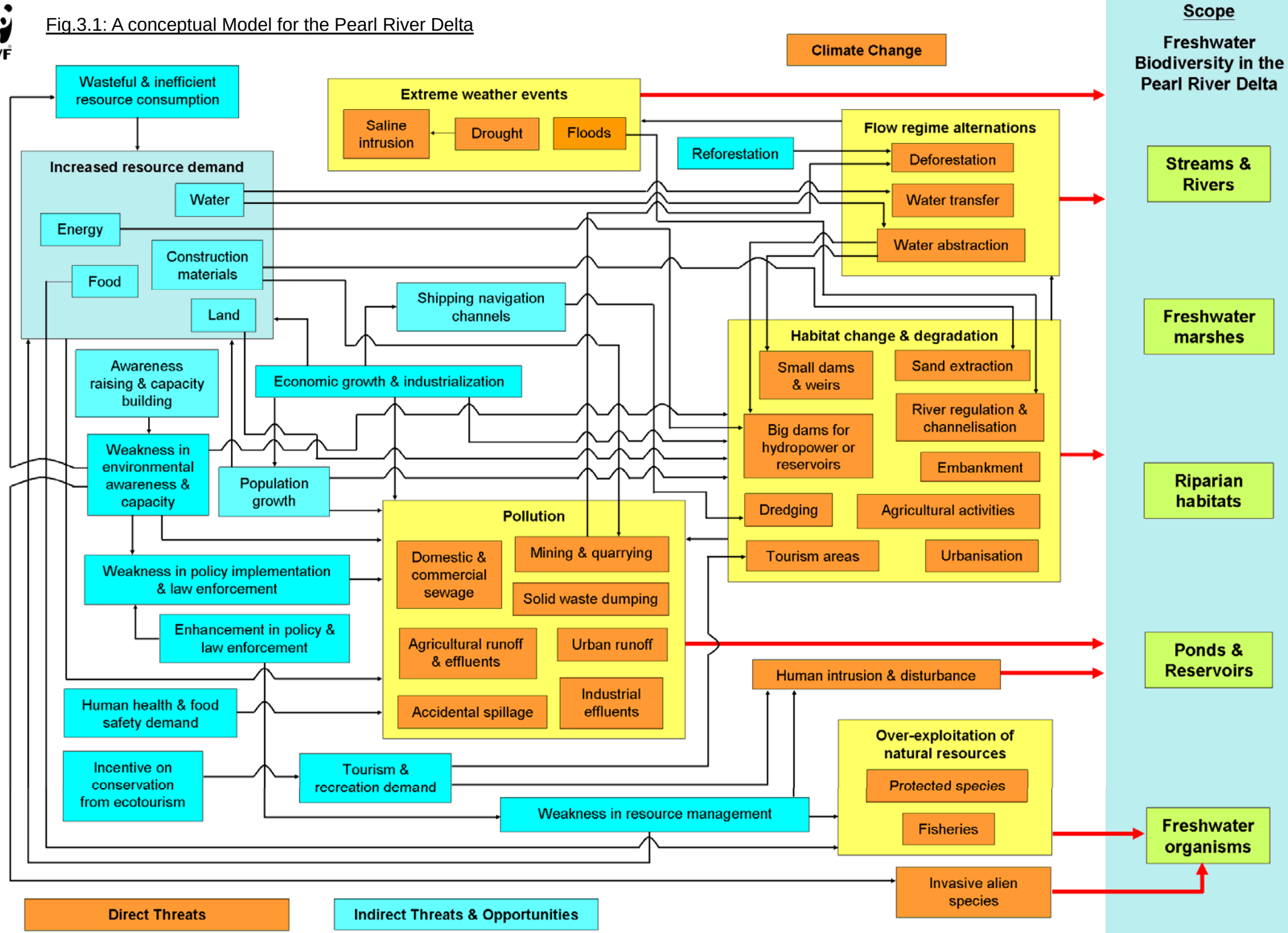
The wide variety of both the threats themselves and root causes, and multitude of interactions between them, makes it difficult to view the situation holistically. In order to help visualise the overall situation and better understand the underlying issues, and solutions to tackle them, a conceptual model was constructed. The scope of this situation analysis covers threats affecting the PRD freshwater biodiversity, including streams, rivers and associated riparian habitats, freshwater marshes, ponds, reservoirs and the organisms living or associated with natural freshwater systems (Fig. 3.1).

Quantitative studies examining trends in population size over time are amongst the most valuable information in determining the conservation status of a species (e.g. for the IUCN Red List). Very few such studies appear to have been carried

out on the aquatic biodiversity of the PRD, but some studies do show alarming declines.

The Reeves shad *Tenualosa reevesii*, for instance, is a protected fish which lives within a range from the South China Sea to the East China Sea, including the Pearl River. It is a migratory fish which matures at sea and returns to rivers to breed and reproduce. The wild population of this fish used to be commercially important, however, by the 1980s it was nearly extinct in the Xijiang, with only a small stock left in the lower reach of the Pearl River (Wang, 2003). The remaining population appears to have collapsed spectacularly since then, judging from catches of around 175,000 to 78,000 kg during 1980s which plummeted to only 200 kg in 1999 (Wang, 2003). The precise reasons for the collapse are not clear due to the multitude of potential causes. While over-exploitation might have contributed to the decline (Liao *et al*., 1989), water pollution in both rivers and the sea, the interruption of migratory routes from dams in rivers, the destructions of habitats due to river regulations and channelisation, and the reduced water flows in rivers could all have contributed to the commercial extinction of this species.

Fig.3.1: A conceptual Model for the Pearl River Delta



## 3.3 Existing conservation initiatives

### 3.3.1 Legislation & policy

The Government has introduced a number of legislations and policies in recent years (see Annex A) related to the protection of freshwater biodiversity, such as the China National Wetlands Conservation Action Plan (China Daily, 2000; Ramsar, 2000), Regulations for Wetland Conservation of Guangdong Province (Forestry Administration of Guangdong, 2006) and Aquatic Biological Resources Conservation Action Plan of China 中國水生生物資源養護行動綱要 (China Daily, 2006c; GDEPB, 2006b). At the provincial level, the Regulations on Wetland Conservation of Guangdong Province and the promotion of designating wetland reserves (Guangdong Forestry News, 2006; SFA, 2006) have highlighted the importance of freshwater habitat protection. At the city level, policies have been proposed for pollution control. For instance, Jiangmen issued an order in 2006 to terminate operations of, and relocate industries which were polluting reservoirs, in order to protect water resources (South CN, 2006c). Shenzhen has also committed to strengthen enforcement of pollution legislation and cancel the operations licences of businesses responsible for repeated pollution incidents (South CN, 2006j).

### 3.3.2 Strategic planning

The Environmental Protection Programme of the Pearl River Delta (2004-2020) 珠江三角洲環境保護規劃綱要 (2004-2020 年) introduced by the Guangdong Government in 2004, presented a clear target to employ sustainable development in the PRD (Box 3.5). The ideas of sustainability and strategic planning have started to be applied in the region. For instance, unlike the usual approach in the past where economic benefits were given as prime consideration, environmental considerations of a tourism development project in Jiangmen are recognised in the beginning of the planning process so as to control development in ecologically sensitive areas (South CN, 2005j). To better control industrial pollution, the concept of industrial parks in Zhongshan were proposed to better manage and coordinate industrial development in an area where centralised sewage treatment is possible (South CN, 2005b). In some areas, polluting facilities are being

**Box 3.5: The Environmental Protection Programme of the Pearl River Delta (2004-2020) 珠江三角洲環境保護規劃綱要 (2004-2020)**

(http://www.gdepb.gov.cn/hjgl/ghjh/index.html)

The Programme divides the PRD into three broad ecological functional zones at strategic planning levels: the ecological zone with forest areas surrounding the PRD, the economic zone for urban use and agricultural activities in flatland areas, and the ecological zone in coastal areas. These zonings are subsequently divided into 80 sub-zones according to the sensitivity of the ecological environment, the ecological functions, and social and economic factors.

About 5,058 km or 12 % of the PRD are considered as protection zones, comprising of the ecologically sensitive areas, such as the core areas of nature reserves and headwaters, which the local governments are obligated to protect. Other areas allow various degrees of development, according to their ecological sensitivity. The Implementation Plans of the Programme highlight the importance of coordination among administrations in different regions in considering the carrying capacity of the environment and ecosystems, with a specific focus on pollution controls for water and air.

The Plan has five focus areas with a total investment of 132.1 billions RMB, including "Work on Regional Sewage Treatment 區域汙水處理工程", "Work on Regional Ecological Safety Screening Development 區域生態安全屏障建設工程", "Work on Desulphurization in Coal-fired Power Plants 燃煤電廠脫硫工程", "Work on Solid Waste Treatment and Utilization 固體廢物處置利用工程", and "Work on Early Warning Systems for Environmental Monitoring 環境監測預警應急工程".

Specific targets are also set in each of the nine PRD cities for ecological protection, water environment protection, atmospheric environment protection and solid waste management. The indicators for ecological protection include, for instance, the area of forest and plantation, number and area of nature reserves, while those for water environmental protection include primarily the percentage of water being treated. It is unclear the degree to which adherence to these targets will protect freshwater species as they are not specific to biodiversity.

translocated, for instance, Guangzhou has decided to prohibit the development of factories in Nansha, in order to protect water quality in that region (South CN, 2006g).

In another positive move, and following the Decision of the State Council on Implementing Scientific Outlook on Development and Strengthening Environmental Protection in 2006, the State Environmental Protection Administration of China issued the Provisional Measures on Public Participation in Environmental Impact Assessment which has the potential to facilitate public involvement in the Environmental Impact Assessment process in relation to environmentally sensitive development projects (GDEPB, 2006j).

### 3.3.3 Pollution control

Chinese authorities from the state to local levels (see Section 2.6), have grave concerns on water pollution issues in the country (SEPA, 2005; China Daily, 2006b; Chinadaily, 2006) as indicated by tightened law enforcement (e.g. (GDEPB, 2006h, d; South CN, 2006h) and investment in pollution control by cities such as Shenzhen (South CN, 2006b), Foshan (South CN, 2006i), Guangzhou (South CN, 2005h). They include initiatives to improve sewerage systems, upgrade and build sewage treatment plants, clean up polluted riverbeds, and to improve strategic planning (see above). Funding and support have also been provided from international organisations such as the World Bank (China Internet Information Center, 2004) and the Hong Kong business sector (Curry *et al*., 2005; FHKI, 2005).

### 3.3.4 Rehabilitation & restoration

China has set clear targets to increase the percentage coverage of forests across the country due to their importance for soil protection and river flow, (Yao, 2006). In the PRD, in addition to the nature reserve designation (see Section 2.6), initiatives also include the protection of forest areas. For instance, the number of Forest Parks in Shenzhen will be increased from 8 in 2006 to 19 by 2010, contributing to 23% of the city's area (South CN, 2006d). Mangroves will also be planted in estuarine areas of Guangdong (GDEPB, 2006c).

In 2007, the six provinces within the Pearl River Basin, including Guangdong, will implement a fishing moratorium in the Pearl River tentatively between April and May each year, as a fisheries management measure to restore fisheries resources in the Pearl River (ChinaReviewNews.com, 2006; CNFM, 2006). Authorities have already carried out fish restocking programmes for the protected Chinese sturgeon *Acipenser sinensis*, as well as commercially important species in Xijiang (South CN, 2006a).

### 3.3.5 Knowledge building

In order to facilitate future planning of the PRD, the Ministry of Land and Resources and the Guangdong Government have initiated large scale geological and ecological surveys which are expected to be completed by 2008 (GDEPB, 2006f). Recent ecological surveys by mainland institutions and the Government have collected more up-to-date information on freshwater biodiversity in the region. Their recommendations have been proved useful for the designation and management of protected areas in the Pearl River (South CN, 2005g; PRWRC, 2006c). Also, Hong Kong institutions have conducted more environmental research in the PRD (e.g. (Wong *et al.*, 2001; CityU, 2003).

Using its experience in the management of the Mai Po and Inner Deep Bay Ramsar Site, WWF Hong Kong has provided reserve management training through the Wetland Training Course since 1988, with the Mai Po Nature Reserve as a living classroom to enhance the capacity of participating mainland wetland reserve staff, government officials and professionals on the effective management of wetlands for biodiversity conservation, particularly for migratory waterbirds. In recent years the course has focused on supporting wetland reserves in south China, including the PRD.

## 3.4 The needs for an integrated approach

One of the key findings of the study is that the problems of the freshwater biodiversity facing the PRD have complex linkages. As the threats facing the PRD have undermined the sustainable use of its water resources and the freshwater ecosystems, there is an urgent need to find sustainable solutions to not only

address the needs of a growing populace for natural resources and economic growth, but to also protect natural freshwater ecosystems and associated biodiversity (see Section 4.3).

One of the major challenges in determining the way forward is how to establish a coordinated institutional structure for various stakeholders with different interests and in different locations of the basin to work together and manage the river basin they share. Ultimately, for a healthy Pearl River, an integrated approach is required to address the use, allocation, and management of freshwater resources for humans, as well as the freshwater ecosystems and biodiversity, including amphibians, insects, fishes and plants in the headwaters to the Chinese white dolphins in the estuary.

# Section 4

# The way forward

## 4.1 Knowledge gaps

The two major findings of this study are that:

i) the threats facing the freshwater biodiversity of the PRD are many and severe, and the linkages among them are complex;

ii) up-to-date published information on the current status of freshwater species and habitats in the PRD is extremely scarce.

Substantial knowledge gaps exist, making it difficult to answer such basic questions as which freshwater species and which areas of freshwater habitats should be prioritised for conservation actions in the PRD. The published literature relating to biodiversity in the PRD (see Section 2.5) primarily consists of species lists from different geographical areas based on historical records and, in some cases, with supplementary field data. However, such lists are of limited use as they typically provide little information on whether the original freshwater flora and fauna has been able to survive in the massively altered landscape of the PRD today. This lack of pertinent data severely limits the ability of this desktop study to identify potential opportunities to preserve freshwater biodiversity through focused conservation actions.

## 4.2 Formulation of conservation actions

The broad-brush situation analysis in Section 3 provides a useful starting point for the formulation of conservation projects. Clearly, a range of actions or activities by various stakeholders are urgently required to address the direct and indirect threats to freshwater biodiversity. Although the lack of published materials on freshwater biodiversity have undermined our capacity to prioritize detailed areas or issues for conservation actions at this time, a number of possible areas for action which would contribute to the conservation of freshwater biodiversity in the PRD are apparent. These are outlined below:

### 4.2.1 Filling in gaps of our knowledge on freshwater biodiversity and its management

Although scientific journals are proved to be a poor source of information on the current status of freshwater biodiversity in the PRD, some experts who were

interviewed during the study suggested that some nature reserves in the PRD have additional and potentially useful biodiversity information collected for their own reserve management purposes. On the other hand, the 2003 rediscovery of a rare endemic fish, the White cloud mountain minnow (see Section 3.1.1) and the identification of other biological hotspots suggests that areas of conservation importance remain to be discovered and protected in the region.

According to the Aquatic Biological Resources Conservation Action Plan of China 中國水生生物資源養護行動綱要 issued in 2006, one of the priority actions is the conservation of biodiversity and the enhanced protection of endangered aquatic species through the designation of more nature reserves, the formulation of species-specific conservation action plan for endangered species, *ex-situ* (off-site) conservation, better natural resources management and the enhancement of monitoring of alien species. As suggested by the Action Plan, WWF believes that a better understanding of species population trends both across the PRD, and over time, is crucial for protecting freshwater biodiversity in the future. Resources for nature conservation are unlikely to be sufficient to enable widespread and effective conservation in the short-term, making it vital that up-to-date information be available for prioritizing actions.

*Potential actions by WWF*

- Organise data-sharing workshops or forums to gather and collate the most current information on freshwater biodiversity in the PRD, including the identification of important freshwater sites which are not effectively protected in the region, for the use of further conservation actions.

### 4.2.2 Communication of conservation messages

The global experience of WWF suggests that good awareness amongst relevant stakeholders on the environmental issue to be tackled greatly aids the chances of success for conservation actions. Therefore, raising public awareness on various freshwater challenges to freshwater biodiversity as well as to humans is a major first step for effective conservation works in the future.

*Potential actions by WWF*

- As the depth of knowledge within the public in the PRD on the threats facing freshwater biodiversity is unknown, it would be useful to gauge public understanding on the issue before a decision is made on whether any action for raising public awareness is needed. WWF is hiring a professional polling company to conduct a poll on public perceptions to freshwater problems of the Pearl River in Guangzhou in mid-2007 to shed light on future communication strategies for the region.

- Education is an important tool to communicate conservation messages. In parallel to this study, a capacity-building training programme in partnership with the Shenzhen Bird Watching Society and WWF for teachers in the PRD has been kicked off since 2005 to help teachers prepare for the Education for Sustainable Development (ESD) programmes in their schools. The programmes provide an effective channel to raise teachers and students' knowledge on freshwater biodiversity and through their active participation, a positive attitude change to support sustainable development is reinforced. Public commitment and their positive attitude towards sustainable development is crucial to any ESD programme.

### 4.2.3 Offering best-practice solutions to flood control

The growth in population, urban and industrial development and associated infrastructure in the PRD is far from any slowing down (see Section 2.2 & 2.3). Experiences from other parts of the world, including Hong Kong, may offer some best-practice solutions to balance the needs of development as well as the environment.

Although flooding is a natural phenomenon in the PRD, human activities and climate change (see Section 3) have increased the damage from floods which compromises the environment, social and economic needs. WWF launched the Anti-Channelisation Campaign in 2004 to prevent Hong Kong's remaining natural streams and rivers from being converted into artificial channels with very low conservation value, in order to reduce the risk of flooding. WWF understood the

need for Hong Kong to initiate flood control practices, but disagreed that freshwater habitats and organisms should be compromised for the sake of development. As such we advocate and support ecologically friendly designs for streams and rivers which are based on the principles (in order of priority) of avoidance, minimization and compensation. The avoidance approach should apply to streams and rivers of ecological importance in order to preserve the natural habitats for aquatic and riparian organisms. Where impacts from works are unavoidable, the designs should minimise the ecological impacts with careful consideration of the scale and timing of works. Compensation for any loss of biodiversity as well as ecological functions should be also considered. These approaches have subsequently been adopted by the Hong Kong Government (Drainage Services Department, 2005).

Environmental flow (see Box 3.1) to maintain the ecological functions of the freshwater habitats is a particular aspect of flood control that requires more attention. Flow management should not only focus on the minimum flow, but also at the right time to mimic natural variability in flows and water levels in the natural system (Poff *et al*., 1997; Dyson *et al*., 2003; Dudgeon *et al*., 2006).

*Potential actions by WWF*

- Riding on the experience of organising the Wetland Training Course (see Section 3.7.5), WWF Hong Kong has the potential to offer training to introduce the concept of ecological friendly designs and the importance of environmental flows (See Box 3.1) on future essential engineering works in rivers for the policy makers, planners and engineers (see also Section 4.3).

### 4.3 Exploration for an integrated ecosystem approach

In 2004 the Task Force on Integrated River Basin Management (IRBM), formed by the China Council for International Cooperation on Environment and Development (CCICED) and WWF, published a report entitled – *Promoting Integrated River Basin Management and Restoring China's Living Rivers*. This report recommends that China should adopt Integrated River Basin Management (IRBM) as a framework to coordinate the management and development of the water, land,

and biological and related resources within a river basin to maximize the economic and social benefits in an equitable way, based on an ecosystem approach for conserving and repairing the freshwater ecosystems (CCICED Task Force, 2004). In the first Yangtze Forum in Wuhan in 2005, a number of leaders of the administration, including provincial governors and key ministers from water, environment, forest, and agriculture sectors, signed the Yangtze Declaration, demonstrating their consensus on the urgent need for sustainable development in the Yangtze basin. The Chinese Government's leadership has also implemented a number of the Council's recommendations, including revision of the management plans for seven major river basins in China, including the Pearl River.

IRBM may provide a management solution for the well-being of man and the freshwater biodiversity in the PRD, as well as the entire Pearl River towards a more sustainable future. Some efforts to promote an integrated approach to addressing freshwater issues have already started. Under an initiative between the provinces including Guangxi, Yunnan and Guizhou in the headwaters and Guangdong located downstream, it was proposed that funding be provided by Guangdong to finance the afforestation programmes in the headwaters of the Xijiang in mitigating the impacts of saline intrusion near the coastal regions (China Daily, 2006a; PRWRC, 2006a). The proposal is a recognition of the ecological services provided by the forest within the river basin to increase water retention capacity by reducing soil erosion and improved soil condition (see Section 3.1.1). Such an ecological approach differentiates itself from the traditional water resource management approach by the use of engineering methods, such as damming rivers to store and release water, which creates significant ecological impacts on the river flow regimes and migratory pathways of freshwater wildlife (see Section 3.1.2).

The effective implementation of IRBM in the Pearl River requires precise messages for communication on the *what* and *why* of IRBM (WWF, 2006a), which are currently limited, or lacking in the region. It is acknowledged that not every decision and activity that contributes to IRBM need necessarily be organised at the *whole*-basin scale. Some water-resource management functions, could be

tackled at the ‘lowest appropriate level’ which may be a *sub*-basin (WWF, 2006a), for instance, Dongjiang or a tributary of Dongjiang of the Pearl River. The entire Pearl River Basin runs across six provinces, and a number of cities and counties under different administrative bodies and two countries (China and Vietnam), increasing the difficulties of applying the principles of IRBM, and the challenges of establishing a workable institutional mechanism for genuine and effective participation from different stakeholders (see (WWF, 2006a). Even so, the practical experiences gained from the Yangtze on the implementation of IRBM would undoubtedly be useful for the Pearl River. As the experience in applying IRBM matures, it would be useful for the Pearl River to start looking at its possible application as a management tool to support conservation of freshwater biodiversity in the whole basin, or sub-basins with conservation importance as is the case in Yangtze. IRBM can help, for instance, in decisions on how much water to allocate to humans and how much to freshwater ecosystems in order to sustain their functions (Dyson *et al*., 2003; Dudgeon, 2005). More work needs to be undertaken, with the participation with a range of Pearl River stakeholders, to learn from the experience the implementation of IRBM from Yangtze as well as the other parts of the World.

A stream being channelised with concrete in a small tributary of Beijiang (above). It may be possible to use a more environmental friendly approach with stream habitats preserved in the river channel, as in that of a Hong Kong stream (below).

Annex A: Major environmental policies, laws, regulations and measures relevant to freshwater conservation in the People's Republic of China (Zhu, 1989; SEPA, 1998; Xu *et al*., 1999) and various sources from Chinese Government websites, including the State of Environmental Protection Administration and the Ministries of Agriculture, Forestry, and Water Resources, and http://english.gov.cn/special/envir_lr.htm.

| Year | Events, Policy, Law or Legislation |
|---|---|
| 1956 | - First China's nature reserve established in Guangdong |
| 1979 | - Environmental Protection Law<br>- Regulations on Water Products and Resources Protection<br>- Regulations on Forestry<br>- Regulations on Fisheries |
| 1982 | - Regulations on Water and Soil Conservancy |
| 1983 | - Oceanic Environmental Protection Law<br>- Order to Protect Rare and Important Wild Animals |
| 1984 | - Forest Law<br>- Water Pollution Prevention Law |
| 1985 | - Regulations on Forest and Wildlife Nature Reserve Management<br>- Grassland Law<br>- Regulations on Scenic Spots |
| 1986 | - Fishery Law<br>- Implementing Regulations on Forestry Law<br>- Land Management Law<br>- Mineral Resources Law |
| 1987 | - State Council Emergency Notice on Strict Prohibition of Disorderly and Indiscriminate Use of Wildlife<br>- Implementing Regulations on Fishery Law<br>- China Conservation Strategy<br>- Regulations on Wild Medicinal Material Resources Conservation |
| 1988 | - Wild Animals Protection Law<br>- Regulations on Forest Fire Prevention<br>- Regulations on River Management |
| 1989 | - Revision of Environmental Protection Law (an Article added that Government at different levels should establish nature reserves to protect important natural ecosystems, habitats for rare and endangered wildlife, watersheds, and relict sites) |
| 1990 | - Regulations on the Management of the Control of Land-source Pollutants Affecting Marine Environment |
| 1991 | - Water and Soil Conservancy Law<br>- Import and Export Animal and Plant Quarantine Law |
| 1992 | - Convention on Biodiversity (become a signatory party)<br>- Agenda 21: the Rio Declaration on Environment and Development (become a signatory party)<br>- Ramsar Convention on Wetlands of International Importance (become a signatory party)<br>- Regulations on Implementing Terrestrial Wild Animal Conservation |
| 1993 | - Chinese Environmental Protection Action Plan 1991-2000<br>- Regulations on Implementing Aquatic Wild Animal Conservation |

Annex A (*cont*.):

| | |
|---|---|
| 1994 | - Chinese Biodiversity Conservation Action Plan<br>- Regulations on Nature Reserves |
| 1995 | - Regulations on Water Pollution Control of the Huaihe River Basin<br>- Prevention of Environmental Pollution Caused by Solid Waste Law |
| 1996 | - Regulations on Wild Plant Conservation<br>- Revision on Water Pollution Prevention Law (stipulated that the State should protect aquatic ecosystems)<br>- 9th Five-Year Plan |
| 1997 | - Criminal Law (revised and adopted for the provision of damage to the environment and resource protection)<br>- Guideline for Nature Reserves Development Planning in China (1996-2010)<br>- Flood Control Law<br>- Regulations on Pesticide Management |
| 1998 | - Revision on Forest Law (a "forest ecological benefit compensation fund" established to support afforestation and the tending, conservation and management of forest resources; forest administrations should set up nature reserves to protect forests with conservation value)<br>- Regulations on the Management of Environmental Protection of Development Works<br>- National Ecological Environment Development Plan |
| 2000 | - National Ecological Environment Action Plan<br>- National Wetland Conservation Action Plan<br>- Regulations on the Implementation of Forest Law |
| 2001 | - 10th Five-Year Plan |
| 2002 | - Water Law<br>- Regulations on Reforestation of Agricultural Lands<br>- Regulations on the Protection of Water Quality of Dongjiang River Systems of Guangdong Province |
| 2003 | - Environmental Impact Assessment Law<br>- National Plan for Pollution Control (2003-2005)<br>- Regulations on Water Resources Management of Guangdong Province<br>- Implementation Plan on Ecological Forest Development of Guangdong Province |
| 2004 | - Order to the Enhancement of Wetland Protection and Management<br>- Order to the Enhancement of Protection and Management of Biological Resources of Species<br>- National Plan on Wetland Conservation (2004-2030)<br>- Regulations on Environmental Protection of Guangdong Province<br>- Environmental Protection Programme of the Pearl River Delta (2004-2020) |
| 2005 | - Implementation Plan of the Environmental Protection Programme of the Pearl River Delta (2004-2020)<br>- Regulations on Sand Extraction in Rivers of Guangdong Province |

Annex A (*cont*.):

| | |
|---|---|
| 2006 | - 11th Five-Year Plan<br>- Regulations on the Import and Export of Endangered Wild Animals and Plants<br>- Aquatic Biological Resources Conservation Action Plan of China<br>- Yellow River Water Volume Regulation Provisions<br>- Regulations on Water Extraction Permit and Water Charges<br>- Regulations on Wetland Conservation of Guangdong Province<br>- Decision of the State Council on Implementing Scientific Outlook on Development and Strengthening Environmental Protection<br>- Provisional Measures on Public Participation in Environmental Impact Assessment<br>- White paper - Environmental Protection in China (1996-2005) |

Annex B: Various stakeholders and their possible interests and opportunities in the PRD.

| **Sectors** | **Interests** | **Opportunities** |
|---|---|---|
| Government | - Policy formulation and implementation<br>- Law formulation and enforcement<br>- Landuse planning<br>- Planning and development of infrastructure, such as flood control and pollution control works<br>- River basin management<br>- Natural resource and biodiversity management<br>- Protected area management<br>- Raising public awareness | - Enhancement and improvement of environmental policies and laws<br>- Enhancement in law enforcement<br>- Coordination of development and enhancement of landuse planning at different geographical locations within the river in a sustainable and integrated manner<br>- Providing incentives for clean development<br>- Enhancement in habitat and natural resource management in protected area<br>- Capacity building |
| Planners, engineers and Professionals | - Urban planning<br>- Technological solutions | - Incorporate environmental considerations into the urban planning and engineering designs |
| Commercial, industrial and agricultural sectors | - Investment in development<br>- Landuse conversion<br>- Waste and sewage generation<br>- Natural resources exploitation and extraction<br>- Large-scale consumption of energy and water | - Investment to technologies on clean development and production<br>- Waste and sewage reduction and management<br>- Enhancement on resource management and efficiency on resource use |
| Academia | - Building knowledge<br>- Incubation of solutions<br>- Advisory | - Reviewing the status of biodiversity<br>- Determining the needs of the freshwater ecosystems<br>- Offering scientific solutions to other stakeholders |
| Non-Government Organisation | - Monitoring environmental conditions<br>- Conduct studies and surveys<br>- Translation of solutions into actions<br>- Communicating conservation issues with various stakeholders (Poff *et al*., 1997) | - Prioritization of conservation actions<br>- Providing support and participating conservation actions<br>- Offering easy-to-follow solutions to various stakeholders<br>- Community education and awareness raising |
| General public | - Monitoring environmental conditions<br>- Consumption of natural resources<br>- Waste and sewage generation | - Supporting conservation actions<br>- Reduction of wasteful consumption<br>- Waste and sewage reduction |

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