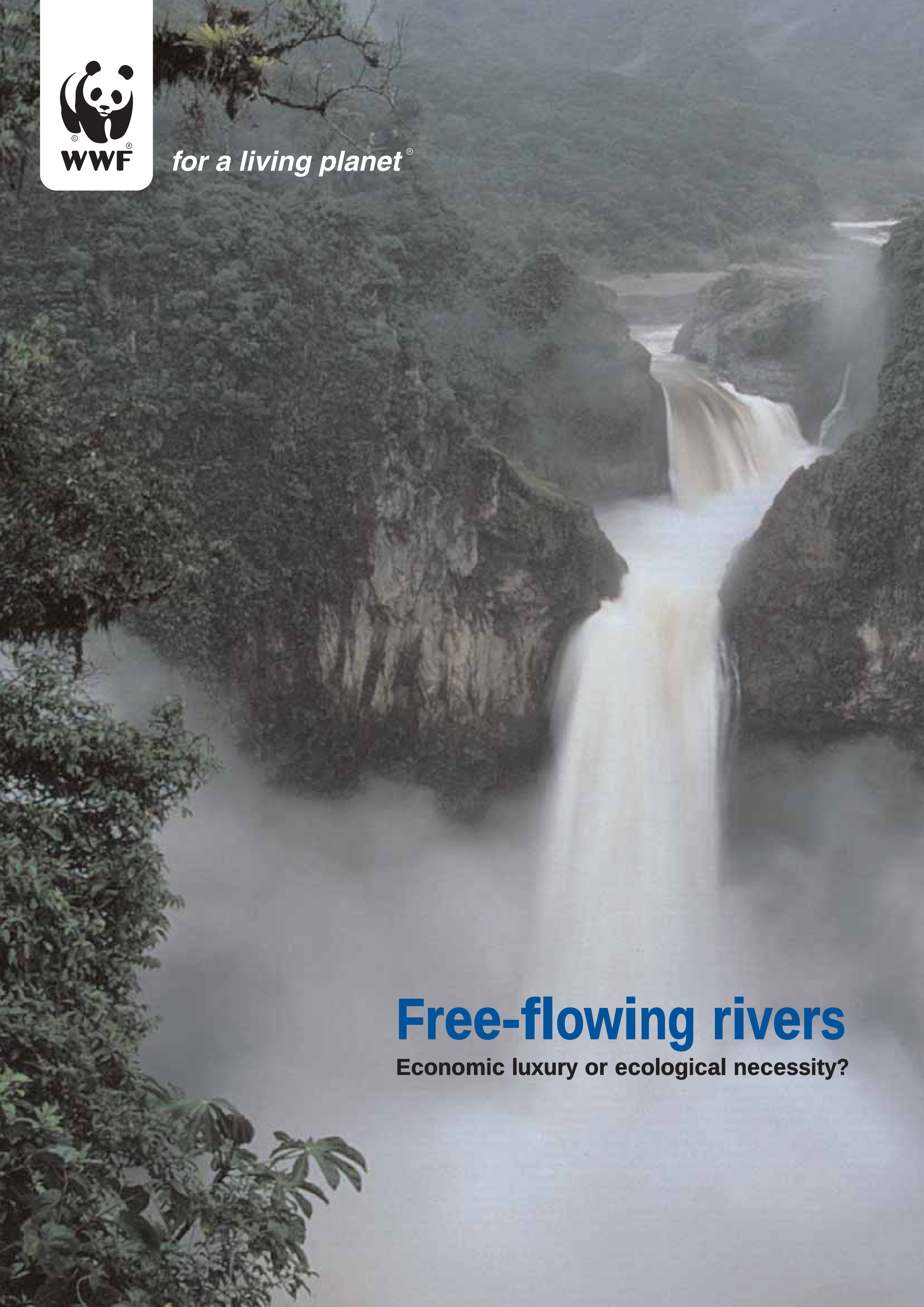

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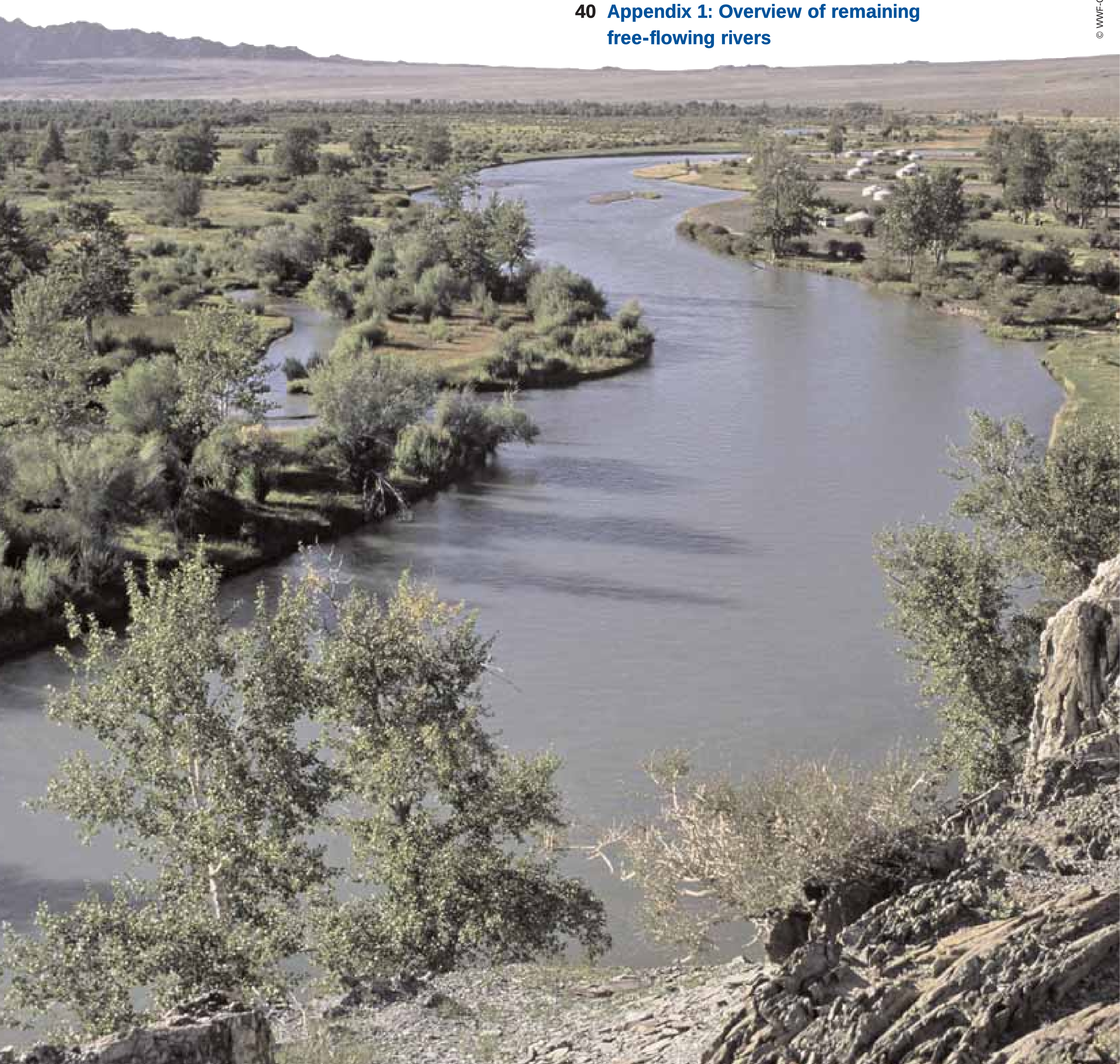
Free-flowing rivers

Economic luxury or ecological necessity?

Free-flowing rivers
– Economic luxury or ecological necessity?

Contents



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1.
Introduction

The history of human civilisation is inextricably linked to the world's rivers. Many of the world's ancient societies developed alongside major rivers, most notably the Nile, the Tigris and Euphrates, the Indus, and the Yellow River. Even today there are few major cities that are not built on river banks. Over time, society has developed an intimate relationship with rivers, which provide freshwater, fish, water for agriculture and a means of navigation. The bond between people and rivers is equally strong in urban and rural areas.

But the importance of rivers for human development has brought with it pollution, degradation and overexploitation. For a long time the world has taken a utilitarian view of rivers, diverting water for agricultural irrigation, straightening them to facilitate navigation or viewing them in terms of water flow volumes to be harnessed for hydropower. The growing world population and changes in lifestyle have put more and more demands on rivers and their watersheds, today leaving very few systems in a natural state.

The discussion on the importance of free-flowing rivers is closely related to the debate about large dams and perceptions are equally polarized. The notion of a natural or free-flowing river is one that is instinctively appealing to many people – conjuring images of wild, untamed rivers teeming with wildlife, offering great scenery and an experience of nature. But on the other hand, the same image of wild rivers can instil fear, and the notion of 'taming' the rivers is equally attractive to other people. Neither vision is particularly helpful in a rational analysis of the benefits, values and risks related to free-flowing rivers.

This report assesses the state of the world's remaining free-flowing rivers and seeks to answer the question why we should maintain our last free-flowing rivers and whether this is a luxury or a necessity. The report consists of four parts:

Firstly we analyse the contributions to human welfare and to biodiversity made by freshwater systems, and identify the specific value of a free-flowing river in contrast to one that has been dammed or otherwise modified. We also address some of the threats that are associated with free-flowing rivers.

We then present a global overview of remaining free-flowing large rivers. This section provides an analysis based on rivers with a length of over 1,000 kilometres. We show that out of 177 of the world's large rivers only a third remains free-flowing, whilst only 21 rivers longer than 1,000 km retain a direct connection with the sea.

Following from this global analysis, we present five case studies of free-flowing rivers in more detail. Finally, we give an overview of possible solutions to protect our remaining free-flowing rivers, examining conservation mechanisms from around the world.

As this report will show, few rivers remain free-flowing and a concerted effort for their conservation is urgently needed. WWF calls on governments to identify those free-flowing rivers that are ecologically important and that provide important services to people and to safeguard these rivers from being developed. WWF calls for the immediate protection of a number of rivers, including the Amur, the Salween, the Chishuihe and the Amazon.

Wild rivers are earth's renegades, defying gravity, dancing to their own tunes, resisting the authority of humans, always chipping away, and eventually always winning.

Richard Bangs, River Gods

2.
Understanding free-flowing rivers

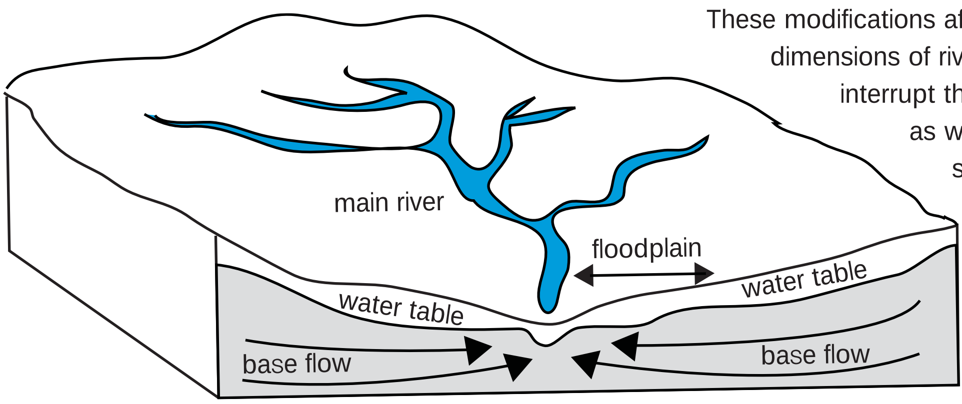
2.1 What is a free-flowing river?

There is no agreed definition of a free-flowing river. WWF defines a free-flowing river as any river that flows undisturbed from its source to its mouth, either at the coast, an inland sea or at the confluence with a larger river, without encountering any dams, weirs or barrages and without being hemmed in by dykes or levees. In today's world such rivers, particularly those that run over long distances, are increasingly rare. In large river systems distinct stretches of rivers can retain characteristics of a free-flowing river, despite the presence of water infrastructure upstream or downstream of this stretch.

Rivers and their landscapes are complex ecosystems that can be seen as an interaction between five main components: physical habitat, flow regime, the energy or food base of the system, biological interactions and water quality. All contribute to the maintenance of the biological or ecological integrity of the system which refers to the capacity to support and maintain a balanced, integrated, and adaptive biological system having the full range of elements and processes expected in a region's natural habitat (Karr, 1998).

The interactions within a river work in three different dimensions: vertically, including with groundwater; longditudinally as rivers flows from mountains to the sea, and latitudinally, as rivers move across floodplains, as illustrated in figure 1.

Figure 1: Vertical, longitudinal and latitudinal interactions in a river



Rivers have formed over a long time and continue to evolve because of their dynamic nature. Human activities accelerate and redirect these processes of change in many different ways, indirectly through anthropogenic stressors such as global warming or directly by interfering in the physical, geo-morphological characteristics of a river. Two key influences on river flow from source to mouth are:

a) flow modification structures, such as dams, weirs and barrages, for hydropower production, water supply and irrigation and flood control:
b) channel modification: the dredging and straightening of rivers for navigation purposes and constriction between levee banks.

These modifications affect one or more of the spatial dimensions of rivers. Flow modification structures interrupt the longitudinal connectivity of rivers as well as affect groundwater tables or seasonal flooding patterns (lateral dimension). Channel modification can affect flooding patterns as well as the variations in river depths.

1

2

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1&2 A free flowing river is a river that flows undisturbed from its source to its mouth, at either the confluence with a larger river. an inland sea or at the coast.

3 An example of channel modification – a canalised section of the São João River in Brazil

Abell et al. (2002) identify four stages of modification in large floodplain rivers.

Unmodified: River channel and floodplain retain most characteristic natural features. Flood regime unmodified by direct human interventions, but indirect effects of activities located elsewhere in the river basin may be apparent.

Slightly modified: Some drainage channels have been constructed for more rapid and efficient removal of floodwaters from the floodplain. Smaller depressions are filled or drained. Flooding is still largely unaltered in its timing and duration. Some small dams may be built on smaller streams.

Extensively modified: Smaller streams are largely dammed for flood control or irrigation. Drainage and irrigation are common, with some flood control through dams and levees that contain the main channel. Depressions are usually filled or regularized. Flooding is often modified in timing and duration.

Completely modified: Flooding is controlled by large upstream dams and by levees. The main channel is sometimes canalized. The floodplain is largely dry, although still subject to occasional catastrophic floods. The river is often reduced to a chain of reservoirs.

This report is concerned with whole rivers, from source to mouth. Based on the above, and taking into account the data limitations on river canalisation, weirs and small dams, we consider in this study both 'Unmodified' and 'Slightly modified' rivers, without large dams[1] over the entire length of the river from source to either the river mouth or confluence with a larger river.

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The Petit Saut Dam in French Guiana not only interrupts the flow of the river but is flooding 300 square km of forests.

[1] *The International Commission on Large Dams (ICOLD) defines a large dam as 15 metres or higher. Dams between 5 and 15 metres with a reservoir volume of more than 3 million cubic metres are also classified as large dams*

2.2 The functions of free-flowing rivers

Although freshwater ecosystems occupy less than one per cent of the world's surface, they make some of the largest contributions of all ecosystems to human welfare. People have long recognized the provisioning services of rivers for water, food and energy and the desire to maximize the benefits from rivers for irrigation, water supply and energy has led to a utilitarian approach to water resources management throughout the world. Joseph Stalin famously said that "water which is allowed to enter the sea is wasted", and such views were still echoed in the 1980s even by the World Bank (Bocking, 1998). Today these views are rarely printed, but are still heard from some water developers in international fora.

But recognition of other, equally important, services has grown. Regulating services of freshwater systems include water purification, flood mitigation and sediment deposition and cultural services vary from recreational opportunities to aesthetic and spiritual values.

Underlying these services are the supporting functions of freshwater ecosystems, playing a role in nutrient cycling, primary production and providing habitats and maintaining biodiversity.

Many provisioning services are provided by both free-flowing and fragmented rivers. For large scale uses of freshwater, such as irrigation and water supply, construction of water infrastructure, such as dams, canals etc, is a necessity. However, the benefits gained by water infrastructure are often at an environmental cost, the extent of which is difficult to quantify and subsequently difficult to take into account.

In this section we examine the ecological importance of free-flowing rivers, as well as the specific contributions made by free-flowing rivers to human society. The analysis follows the framework for ecosystem services, Figure 2, as set out by the Millennium Ecosystem Assessment (2005).

Figure 2: Ecosystem services provided by rivers

Provisioning Services *Products obtained from ecosystems*	**Regulating Services** *Benefits obtained from regulation of ecosystem processes*	**Cultural Services** *Nonmaterial benefits obtained from ecosystems*
• Food • Fresh water • Energy • Fibre • Biochemicals • Genetic resources	• Food • Fresh water • Energy • Fibre • Biochemicals • Genetic resources	• Spiritual & religious • Recreation & ecotourism • Aesthetic • Educational • Sense of place • Cultural heritage

Supporting Services
Services necessary for the production of all other ecosystem services
• Soil formation • Nutrient cycling • Primary Production • Habitat / biodiversity

Box 1: Loss of provisioning services – Pak Mun Dam, Thailand

The Pak Mun Dam was completed in 1995 on the Mun River, 5.5km upstream from the confluence with the Mekong. The 17 m high dam was operated as a run of river hydro plant. The 1981 EIA predicted a substantial increase in fish production from the reservoir, despite some expected impacts on migratory species. The predicted yield from the reservoir was 100 kg/ha/year without fish stocking and 220 kg/ha/year with a fish-stocking programme. These predictions were outrageously high. A review for the World Commission on Dams (2000) suggests that a prediction of ten kg/ha/year would have been more realistic and there is no evidence that the predicted yields were achieved.

In addition to the over estimating of the benefits of reservoir fisheries, the Pak Mun dam had negative impacts on migrating and rapid–dependent fish species. A fish ladder had been provided in the design, but proved inadequate to the local situation and a number of migratory species disappeared from the river altogether. The impacts on livelihoods were profound. Over 6202 fishermen demonstrated to a committee that they were engaged in fishing and that their income was affected following construction and operation of Pak Mun dam. Following the findings of the committee, the Electricity Generating Authority of Thailand paid compensation to 3955 fishermen in 1995 and to another 2200 fishermen in 2000 and has since been forced to open the sluice gates for part of the year.


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Free flowing rivers support fisheries that are vital to the survival of many of the worlds' poorest people.

Provisioning services

Rivers support many services to society, most crucially the provision of freshwater and food. Freshwater is necessary for drinking, hygiene and agriculture, whilst fish and fishery products are particularly important in developing countries. Many of these provisioning services can be maintained to some extent in modified rivers, and indeed large scale water supply services, particularly for irrigation, rely on dams and other water infrastructure to provide that service.

So, if some provisioning services can be maintained, and even maximized, in modified rivers, what then is the specific value of a free-flowing river for provisioning services?

With most river modifications aimed at water supply, the key provisioning benefit derived from free-flowing rivers over dammed rivers is food supply. Fisheries production is dependent on many different factors, such as length of river, the catchment area and physical conditions, and the life cycles of many species are heavily influenced by the natural variability in river flows (see also section on supporting services). Dams alter river ecosystems and in many cases will negatively affect fish species native to the river. This directly affects fisheries productivity both upstream and downstream of the dam (Marmulla, 2001; McAllister et al., 2001). Examples of a decline in the fisheries production of native species around the world are numerous and the impacts on migratory species in particular can be devastating.

Fisheries production of floodplains downstream from the dam is affected by changes in the flow regime. Floodplains are important feeding and spawning ground for fish, but by replacing seasonal flow patterns with a year round steady outflow, floodplains can no longer perform this function. Seasonal flood pulses are usually important triggers for the reproductive cycles of fish and loss of these can affect populations. Seasonal flooding of floodplains is also important to agricultural production, which depends on nutrients deposited by rivers.

Increased fisheries production in reservoirs sometimes partially compensates for the loss of fisheries from free-flowing rivers, but successful reservoir fisheries are often highly dependent on restocking and management, and often use exotic species. They are also susceptible to commercial fishery development by outsiders, which may out-compete local artisan fishermen.

Box 2: Loss of provisioning services – Salmon & the Rhine River

In the 18th century the Rhine was considered to be the most important and biggest salmon river in Europe, with salmon *(Salmo salar)* being a staple food for many people. But increasing obstructions of the fish's migration routes by weirs, navigating locks and hydropower plants, together with severe pollution led to the disappearance of Rhine salmon in the 1950's. And not just salmon declined – stock of trout *(Salmo trutta)* and eel *(Anguilla anguilla)* were also affected and the common sturgeon *(Acipenser sturio)* remains extinct in the river (ICPR, 2004).

Today, salmon is slowly returning to the river, thanks to concerted efforts by the riparian countries. The 1987 Rhine Action Programme (RAP) "Salmon 2000" was agreed a year after a fire at the Sandoz chemical plant near Basel which caused the release of huge amounts of pesticides into the river, and as a result of the plan salmon has started slowly to return to the river. More than 300 for example have used a new fish pass about 700 km upstream of the estuary. Salmon populations still depend on restocking programmes and intensive work continues under the "Rhine 2020" working programme of the International Commission on Protection of the Rhine (ICPR), which includes many measures such as fish passes to open up migratory routes. The ICPR is hopeful that by the year 2020 there will be stable wild salmon populations (ICPR, 2004).

Inflows of rivers into estuaries sustain important provisioning services that can be severely affected by river modification upstream. Shrimp fisheries on the Sofala Bank at the Zambezi River mouth for example, are related to river discharge. Following completion of the Kariba and Cahora Bassa dams, catches declined from 10,000 – 12,000 tons in 1974-76 to 8,000 tons in 1983 and 7900 tons in 1998 (WCD, 2000; ITC, 2004).

Regulating services

Rivers play an important part in the global water cycle, the movement of water in all its forms (vapour, liquid & ice) through the earth's biophysical environment, including the atmospheric, marine, terrestrial, aquatic and underground components. Water travels for the longest distances through the atmosphere, but rivers and streams are equally important in moving water over long distance over land.

Vörösmarty & Sahagian (2000) identify a number of impacts of human modification, including dam building and water diversion, on the terrestrial water cycle, including

- Distortion of continental runoff – artificial reservoirs have high evaporative losses compared to free-flowing rivers, resulting in reduced net basin runoff;
- Aging of runoff – as water is held for longer periods behind dams, the mean age of river water at the mouth (coastal area) of a modified river is two to four times greater than water passing through an unregulated river, reducing the water quality.

Friedl & Wuest (2002) argue that damming rivers modifies the biogeochemical cycle in different ways, by interrupting the flow of carbon, changing the nutrient balance and altering oxygen and thermal conditions. The consequences of these altered processes may happen over large distances, may not become immediately clear following the construction of dams and may get worse as a result of interactions with other anthropogenic interference. For example in the Danube River a slight retention of silicates in reservoirs can, in combination with increased nitrogen and phosphorus loads, result in increased degradation of the estuary.

Rivers also contribute to pollution control through transport and removal of pollutants and excess nutrients. Rivers passing through wetlands usually come out cleaner, because of the capacity of wetlands to filter out particles and toxins. This capacity is reduced because of dams, as pollutants are trapped behind dams through accumulation of sediment. This can pose a hazard when the lifespan of a dam comes to an end. Reservoirs generally are not very efficient at processing organic waste.

Furthermore, rivers also play an important role in the transport of sediment to estuaries. Free-flowing rivers can carry vast amounts of materials, part of which is deposited along the river's course, and large parts of which are carried all the way to the sea. Here, sediment deposition plays an important role in the build up of deltas, lagoons, sand banks and even coastal wetlands such as mangroves. This creates dynamic ecosystems which are subject to constant change and many deltas and estuaries have become important sites in terms of biodiversity.

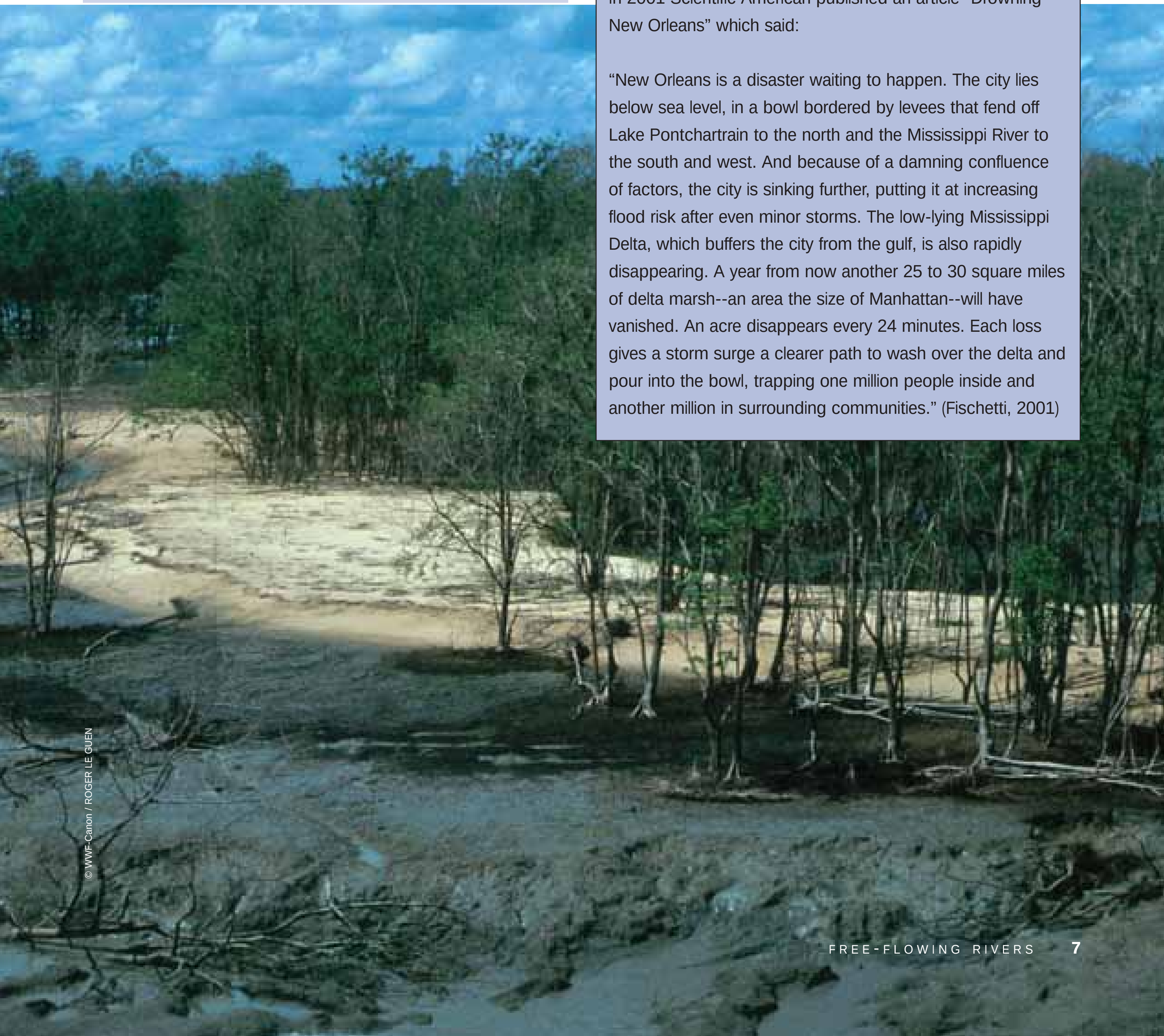
Finally, free-flowing rivers make it easier for ecosystems and species to adapt to the effects of climate change. The distribution of fish in rivers in the temperate zone for example is determined by temperature, rather than by physical barriers. Climate change is predicted to increase temperatures towards the poles, leading to a northward expansion of warm water fish in the northern hemisphere and a southward expansion on the southern hemisphere (Ficke et al., 2005). Fish in east-west orientated river systems or those in north-south systems fragmented by physical barriers will essentially be trapped, unable to move to more suitable habitats.

Box 3: Loss of regulating services
– The Mississippi Delta

The importance of the sediment carrying role of free-flowing rivers was clearly illustrated by the events in New Orleans following hurricane Katrina in 2005. The Mississippi Delta was formed by sediment and debris carried by the river from the upper watershed and deposited in the coastal areas. The extensive coastal wetlands, marshes and islands used to provide protection from storm surges but since the 1930s the sea has steadily eroded these wetlands. A major contributing factor has been the extensive modification of the Missouri and upper Mississippi watershed by large dams trapping sediment, reducing the overall sediment load by 67 per cent. Furthermore, the extensive levee systems on the lower Mississippi channels remaining silt too far into the Gulf of Mexico to replenish the delta’s marshes and coastline (Izzo, 2004). Engineers have been aware of the dangers for years. In 2001 Scientific American published an article “Drowning New Orleans” which said:

“New Orleans is a disaster waiting to happen. The city lies below sea level, in a bowl bordered by levees that fend off Lake Pontchartrain to the north and the Mississippi River to the south and west. And because of a damning confluence of factors, the city is sinking further, putting it at increasing flood risk after even minor storms. The low-lying Mississippi Delta, which buffers the city from the gulf, is also rapidly disappearing. A year from now another 25 to 30 square miles of delta marsh--an area the size of Manhattan--will have vanished. An acre disappears every 24 minutes. Each loss gives a storm surge a clearer path to wash over the delta and pour into the bowl, trapping one million people inside and another million in surrounding communities.” (Fischetti, 2001)

Free flowing rivers carry the sediments needed to sustain coastal estuaries and mangroves.



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Maori culture is closely linked to free flowing rivers

Cultural services

Whether it is Lao Tse or Winnie the Pooh – the wildness, flow and sense of direction attributed to rivers play a role in the world's cultural heritage. Free-flowing rivers provide aesthetic values, literary imagery and are important spiritually. On a more practical level, free-flowing rivers provide important recreational services, varying from salmon fishing to white water rafting, and are valuable for educational purposes. The ecosystems supported by free-flowing rivers are often economically important because of the tourists they attract.

In New Zealand, Maori tribes are closely linked to rivers. The Waikato River, on the North Island and the longest river in the country, is considered to be a 'Taonga' – a treasure – and is hugely important, not only as a food provider, but also for healing illnesses and spiritual cleansing (Environment Waikato, no date). Eight large dams on the river, varying in height between 37 and 87 metres, have disrupted the river's ecology, resulting in decreased water quality, and reduced fish stocks. This also has an effect on the spiritual values attributed to the river. Elders of the Waikato tribes consider the river to be ill, and believe that the disregard for the life giving capacity of the river means that the 'kaha' – strength – of the river is diminished (Environment Waikato, no date). In Australia the cultural heritage of aboriginal people is also closely linked to rivers. For example, the floodplain wetlands of the Paroo River Overflow and the Peery Lake are an important focus of the 'dreaming tracks' (sometimes called 'songlines') which connect traditional, spiritual places.

Throughout the world there are numerous examples of tribal people who live in close relationship with their rivers. The damming of the river does not only affect the rivers productivity or its spiritual values, but can also contribute to the weakening of communities and erosion of cultural traditions. One example in the United States concerns the Skokomish tribe, an Indian tribe living on the Skokomish River, which used to be the most productive salmon river of the Puget Sound area in Washington State. The construction of two dams in the 1930s resulted in the reduction of populations of plants and animals that were used by the Skokomish people, particularly the disappearance of salmon from the river. In addition to losses of income, the tribe also suffered losses of their so called 'natural capital', the disappearance of valuable natural resources resulting in a progressive weakening of the structure of the community (Lansing et al., 1998).

Certain fisheries, in particular salmon fisheries, can also be important to non-traditional cultures by providing recreational values. Wild salmon fisheries are economically important in many European countries, as well as in North America. In France many salmon fisheries remain closed as stocks are low due to the damming of rivers, but some progress is being made to

Rivers know this: there is no hurry, we shall get there some day

A.A. Milne (Winnie the Pooh)

Be still like a mountain and flow like a great river.

Lao Tse

restore these important fisheries. WWF, with the support of partners such as the French National Fisheries Association, has launched a campaign to remove the Poutès-Monistrol Dam on the Allier River, the biggest tributary of the Loire River. This 18 metre high hydroelectric dam is a major obstacle to the migration of Atlantic salmon on the river and the local salmon population is now on the verge of extinction. The dam's licence expires in 2007 and WWF and its partners are lobbying the government to not renew the licence. In WWF's view, the output of the hydro plant could easily be replaced by wind power and energy efficiency and removal of the dam could provide a showcase for sustainable development. Authorities on the upper Allier River are slowly coming round to this way of thinking, as studies show that alternatives sources of energy are feasible and can improve local employment prospects, while a return of wild Atlantic salmon to the river would boost tourism.

It has to be recognized that some river modification structures in themselves have a recreational or educational value. Many reservoirs in North America and Europe are used for recreational activities. Also, sometimes the dam or hydraulic works become visitor attractions. The best example of this is maybe the Three Gorges Dam in China. ChinaNews (28 Nov 2005) reports that the Three Gorges Dam on the Yangtze River is becoming China's largest industrial tourist destination, with over one million visitors in 2005 alone. However, very few of the world's large dams have become major tourist attractions – generally only the highest, the biggest or the widest.

© WWF-Canon / MICHEL GUNTHER

Tourists at the information centre of the Three Gorges Dam in China

© WWF-Canon/HARTMUT JUNGIUS

Salmon fisheries on the Allier River have declined because of dams

Supporting services

The supporting services provided by rivers and streams are crucial as they provide the basis for all other benefits gained from the river. Supporting services differ from regulating, cultural and provisioning services in that their impacts on people are either indirect or occur over a long period of time. It is these services, particularly biodiversity and habitat provision, that dams and water infrastructure often affect the most. However, the effects of their loss on people are not usually immediately noticeable.

Some services, such as sediment transport, can be considered as both a regulating and supporting service, depending on the time scale in which impacts make themselves noticed. The example of the Mississippi Delta was thus discussed under the section on regulating services.

The base flow of a river supports numerous ecological processes, and flow variations, such as seasonal high flows or flood events support many more. Table 1 provides a summary of some of these processes.

Table 1: Ecological functions of different river flow levels (after Postel & Richter, 2003)

Low (base) flows	**Normal level:** • Provide adequate habitat space for aquatic organisms • Maintain suitable water temperatures, dissolved oxygen, and water chemistry • Maintain water table levels in the floodplain and soil moisture for plants • Provide drinking water for terrestrial animals • Keep fish and amphibian eggs suspended • Enable fish to move to feeding and spawning areas • Support hyporheic organisms (those living in saturated sediments) **Drought level:** • Enable recruitment of certain floodplain plants • Purge invasive introduced species from aquatic and riparian communities • Concentrate prey into limited areas to benefit predators
High pulse flows	• Shape physical character of river channel, including pools and riffles • Determine size of stream bed substrates (sand, gravel, and cobble) • Prevent riparian vegetation from encroaching into channel • Restore normal water quality conditions after prolonged low flows, flushing away waste products and pollutants • Aerate eggs in spawning gravels and prevent siltation • Maintain suitable salinity conditions in estuaries
Large floods	• Provide migration and spawning cues for fish • Trigger new phase in life cycle (e.g., in insects) • Enable fish to spawn on floodplain, provide nursery area for juvenile fish • Provide new feeding opportunities for fish and waterfowl • Recharge floodplain water table • Maintain diversity in floodplain forest types through prolonged inundation (different plant species have different tolerances) • Control distribution and abundance of plants on floodplain • Deposit nutrients on floodplain • Maintain balance of species in aquatic and riparian communities • Create sites for recruitment of colonizing plants • Shape physical habitats of floodplain • Deposit gravel and cobbles in spawning areas • Flush organic materials (food) and woody debris (habitat structures) into channel • Purge invasive introduced species from aquatic and riparian communities • Disburse seeds and fruits of riparian plants • Drive lateral movement of river channel, forming new habitats (secondary channels and oxbow lakes) • Provide plant seedlings with prolonged access to soil moisture

River modification affects the pattern of flows and in particular reduces the occurrence of large floods in rivers subject to strong wet and dry season patterns. The impacts of these modifications are far reaching as fish life cycles and sediment and nutrient transport functions are disturbed.

The human impacts of the disruption to the supporting functions of rivers are described in the sections on provisioning, regulating and cultural services. But although the biodiversity and habitat values of a free-flowing river do not always provide a direct benefit to people, their loss is significant. Several sources suggest that freshwater biodiversity is being lost at a faster rate than any other ecosystem. The Millennium Ecosystem Assessment states that “the biodiversity of inland waters appears to be in worse condition than that of any other system, driven by declines in the area of wetlands and the quality of water in inland waters. It is speculated that 50 per cent of inland water area (excluding large lakes) has been lost globally. Dams and other infrastructure fragment 60 per cent of the large river systems in the world (MEA, 2005).” The WWF Living Planet Index (WWF, 2004) shows a decline in freshwater species populations of over 50 per cent compared to around 30 per cent for the forest and marine biomes. Globally there is agreement that these developments are of concern and there are a number of global commitments specifically targeted at reducing the loss of biodiversity. The Convention on Biological Diversity (CBD) is one of the key fora. Parties have committed to achieve by 2010 a significant reduction of the current rate of biodiversity loss at the global, regional and national level as a contribution to poverty alleviation and to the benefit of all life on earth. The World Summit on Sustainable Development adopted this target in 2002.

Political decision making is still primarily concerned with maximising the economic benefits of ecosystems. The Millennium Ecosystem Assessment points out that “major policy decisions in the next 50–100 years will have to address trade-offs among current uses of wetland resources and between current and future uses. Particularly important tradeoffs involve those between agricultural production and water quality, land use and biodiversity, water use and aquatic biodiversity, and current water use for irrigation and future agricultural production” (MEA, 2005).

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Freshwater biodiversity is being lost at a faster rate than any other biome

2.3 Wild rivers as a threat

Despite the important provisioning, regulating, supporting and cultural services provided by free-flowing rivers, in many places they are still seen as a threat, particularly in terms of flooding. Flooding from rivers has taken a large toll of human life over time, as well as caused large economic losses. Floods are often caused by a combination of several factors, frequently including heavy rainfall which causes rivers to overflow. Floods generally develop over a period of days, when there is too much rainwater for rivers to hold and water spreads over the adjoining floodplain. However, they can happen very quickly when a lot of heavy rain falls over a short period of time. These ‘flash floods’ occur with little or no warning and cause more loss of human life than any other type of flooding.

It is thus not surprising that throughout history people have sought to tame and control rivers by constructing dykes, diversions and dams. In Northern Italy for example, the river Fersina near the town of Trento was first dammed in the early 16th century to control the torrential flow resulting from snow melts in the Alps. The wooden dam collapsed after only five years and was replaced in 1550 by a stone and cement dam which survived for eight years. When it was rebuilt in 1613 it was 4.9 meters high and it has been heightened repeatedly, standing 37.8 meters high in 1883 and still functioning (Marland & Weinberg, 1988).

Today globally 6,266 dams out of 33,105 dams registered by ICOLD have been built for flood control or have a flood control component (ICOLD Register, January 2006). There is no data available globally on dykes, levees or river canalisation for flood control, but the evidence of this is everywhere. Few cities on rivers have anything resembling natural river banks and walls line most rivers.

As flood defences are developed, population pressures have resulted in increased inhabitation of former flood plains, increasing the risks of losses, both in terms of life and economic loss, in the case of extreme weather events. In some cases dams have actually contributed to exacerbating floods. This was for example the case in the central European floods in August 2002, when two periods of intensive rainfall triggered the floods. On August 6 and 7 rainfall in southwest Czech republic and Northwest Austria caused some localized flooding, but much runoff was contained in reservoirs upstream of Prague (Vltava Cascade) and gradually released. However a second, more expansive and more intensive period of rain followed a few days later sending a flood wave down the Vltava River, overtopping the reservoirs and continuing through Prague and then down the Elbe (RMS, 2003). It is also likely that canalisation of rivers accelerated the flood waves.

Whilst floods present a real threat, 'taming the river' by constructing reservoirs and dykes is not necessarily the best solution, and by providing a sense of security that may be partially false, can actually exacerbate the problems. In the case of multi-purpose reservoirs there is also a conflict of interest between electricity production and flood prevention. To optimize hydropower output, reservoirs need to be filled as much as possible, whilst for flood prevention reservoirs need to have a large capacity to capture extra water.

Flooding of river Main in Germany

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2.4 Impacts of dam siting on free-flowing rivers

Dams and other water infrastructures affect freshwater ecosystems by severing or changing connections between different parts of the river. Dams disconnect rivers from their floodplains and wetlands and reduce the speed at which water flows in rivers. They affect the migratory patterns of fish and flood riparian habitats, such as waterfalls, rapids, riverbanks and wetlands. They also affect the migratory patterns of fish, even if fish ladders are installed, as these are only partially effective as a mitigation measure for a limited number of species, such as salmon. By slowing the movement of water dams prevent the natural downstream movement of sediment to deltas, estuaries, flooded forests, wetlands, and inland seas, affecting species composition and productivity. Coastal fisheries, for example, depend on inflows to replenish nutrients. Water retention by dams eliminates or reduces spring runoff or flood pulses that often play a critical role in maintaining downstream riparian and wetland ecosystems. Dam operations also influence water quality. Older dams, for instance, tend to release water that is stored at the bottom of the dam, which is typically colder and adversely affects species adapted to warmer temperatures. The artificial timing and volume of releases from large dams play a role as well because they rarely replicate the natural flooding cycles of the natural river system. Finally, water and sediment retention affect water quality and the waste processing capacity of rivers, that is the ability to break down organic pollutants.

The degree to which these impacts take place and disrupt the services provided by free-flowing rivers depends to some extent on the siting of the dam. There are no hard rules about what ecologically constitutes the least damaging site for a dam and the level of damage also depends on the presence of other dams in the basin. One indicator in determining the impact of a dam is the percentage of flow contributed by a certain site to the total outflow of the river at the mouth. A dam situated just above the confluence with a large tributary which contributes a substantial percentage of the rivers flow will have a smaller impact than a dam just below the confluence, which effectively dams both the tributary and the main stem.
In general dams with the least impacts are those that: least interrupt natural water flows; keep the main stem free-flowing; have the smallest possible area inundated by the reservoir; and control only a small part of the inflows into the river's main stem.

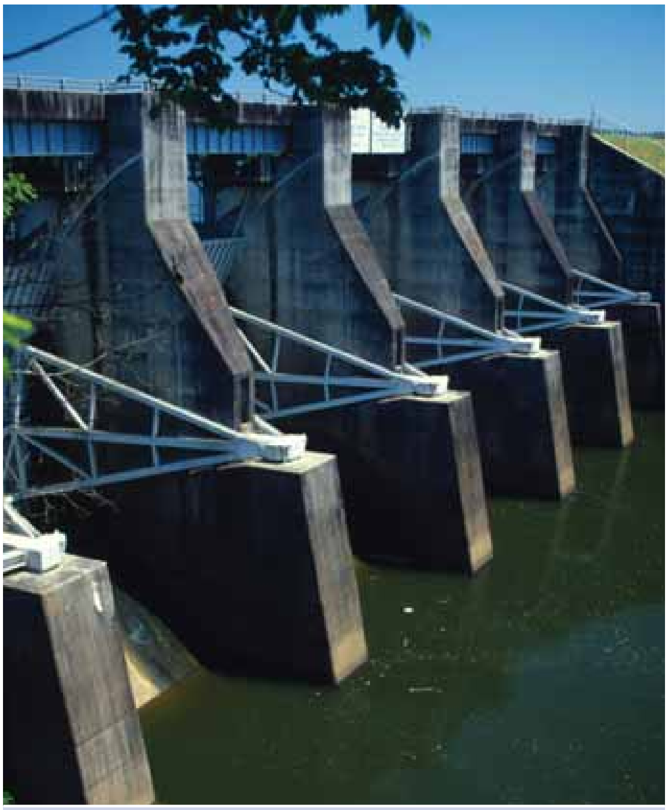
3.
The state of the world's longest rivers

Most people in the world live within reach of a river, stream or creek but there is a lack of data on the exact number of rivers worldwide. The size of a river can be characterized by either the total length from source to mouth, the size of the watershed drained by the stream or the average discharge at the mouth. Most global analyses of river fragmentation do not address individual rivers, but consider large river systems, consisting of a main stem together with its tributaries – some of which are regarded as a large river in their own right as for example the Missouri which joins the Mississippi River. A study by the World Resources Institute (Revenga et al., 2000) analysed 227 of the world's major river basins and found that only 40 per cent were unaffected – meaning that the system had no dams on the main stem and that any dams on tributaries cause a decline in river discharge no greater than two per cent. A more recent study by Nilsson et al. (2005) echoed these results. The study identified 292 large river systems, based on average discharge, and found that only 35 per cent of these remain unaffected, although nearly half (139 rivers) remain free of dams on the main stem. Unaffected river systems are mostly smaller watersheds. For example in South America nearly half of the large river systems were classified as unaffected (20 out of 38), but this accounts only for about seven per cent of the combined virgin mean annual discharge of the continent or about six per cent of the total area.

3.1 Methodology

This study presents an analysis of river fragmentation on a global scale, based on individual rivers with a length of more than 1,000 kilometres. Although river size can also be measured by its average discharge, for reasons of data consistency we have chosen to identify rivers by length only, excluding some rivers that have a very high average discharge, but a relatively short length. The following analysis is based on a dataset of 177[2] rivers longer than 1,000 km and throughout this report, whenever we talk about large rivers this refers to a river over 1,000 km long. In contrast to previous fragmentation studies on a global scale, this analysis is concerned with individual rivers rather than watersheds, and includes an analysis of individual tributaries of large rivers provided they are longer than 1,000 km in length.

Data on river fragmentation was obtained by cross referencing the 177 rivers against the World Register of Dams, maintained by the International Commission on Large Dams (ICOLD). The registry contains information on 33,105 large dams. Where a river was found to have one or more dams on the main stem it was classified as fragmented. As the register is not complete, with global estimates for large dams rising up to 48,000, rivers that according to the register were not dammed were subsequently checked for additional information on possible dams. For example, the Ganges main stem is not registered as having any large dams, but the Farakka Barrage is a major modification, whilst a dam at Haridwar diverts water to the Upper Ganges Canal.



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Where a river was found to have one or more large dams on the main stem it was classified as fragmented.

[2] *The dataset of rivers over 1,000 km in length was obtained by a cross reference of data from Babkin (2003) with data from the Discharge Catalogue, compiled by the Global Terrestrial Network for River Discharge (2005). Additional rivers were added by identification of major tributaries of the world's large river systems, such as the Lena, Yangtze, Congo and Amazon and a list of rivers over 1,000 km in length published on Wikipedia. Information obtained from the Wikipedia list was verified, mostly through the Encyclopædia Britannica online. This exercise has yielded a data set of 177 rivers over 1,000 km in length. Although the utmost care was taken in compiling this data set, it is not necessarily complete as data on rivers between 1,000 and 1,500 km is particularly difficult to compile.*

3.2 Where are the world's remaining free-flowing rivers?

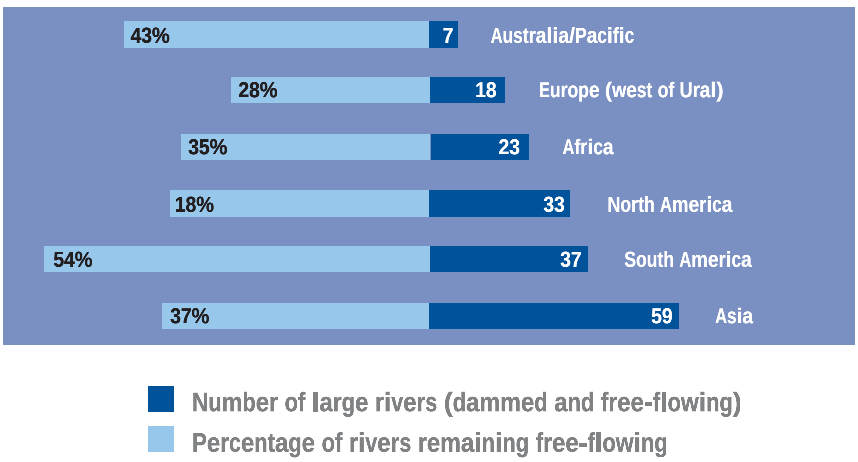
This analysis shows that out of 177 rivers longer than 1,000 km, only 64 rivers (less than 40 per cent) are still free-flowing. Most of the remaining free-flowing rivers are large tributaries of the world's major river systems. Rivers within the Amazon system alone account for 20 per cent of free-flowing rivers over 1,000 km. Tributaries in the Lena, Yenisei and Amur river systems in the far east of Russia account for another 20 per cent of free-flowing rivers.

The regional distribution of large free-flowing rivers, as a percentage of all rivers over 1,000 km long is given in Figure 3. The figure shows that most large rivers are in Asia, followed by South and North America. Australia/Pacific has the fewest large rivers, four of which are part of the Murray-Darling system (Murray, Darling, Lachlan & Murrumbidgee) and have all been modified. The three other large rivers in the region, Cooper Creek, Sepik and Fly Rivers remain free-flowing. Europe, including areas west of the Ural, has relatively few large rivers and has modified almost all of them. Rivers such as the Danube, Volga, Rhine and Tagus have been extensively dammed and modified. Only one of Europe's large rivers, the Pechora, remains free-flowing from source to sea, running for 1809 km from the Ural Mountains to the Barents Sea and its delta is part of the Nenetsky nature reserve. Four large tributary rivers also remain free-flowing, including the Vychegda, an 1130 km tributary of the Northern Dvina in north-western Russia, and three tributaries of the Volga. Asia and South America harbour both the highest number of large rivers and the highest number of large free-flowing rivers. In Asia just under half of large rivers remain free-flowing, mostly located in the North. In South America just over half of the continent's 37 large rivers remain free-flowing, many of these in the Amazon basin.

3.3 Connecting land and sea

Of particular concern is the loss of long distance connectivity between the sea and inland rivers. Only 21 rivers longer than 1,000 km remain undammed that drain into the sea (Map 1 & Appendix 1).
Ecologically, fragmentation is a problem as maintaining connectivity on all levels is essential to conserve freshwater biodiversity. This includes connectivity between and within aquatic habitats, connectivity with the riparian zone and floodplains and connectivity with subterranean systems (Abell et al., 2002). The loss of connectivity between different parts of a river basin fundamentally alters ecosystem processes and negatively affects species. So, whilst conservation of distinct freshwater sites, such as a lake or a stretch of river, is valuable, it is an incomplete solution to protecting biodiversity on a basin level.
The importance of the connections between a river's source and the sea over long distances is not yet fully understood. The importance of these links for diadramodous fish species (fish that migrate between sea and freshwater) are well known, but the underlying mechanisms of these relations and the distances over which this connectivity is important are a topic for which scientific research is urgently needed.
However, with so few rivers left that travel for more than 1,000 km inland and many of these facing the threat of dams, it is unlikely that we will ever have a chance to fully understand the relationships between the sea and the large rivers.

Figure 3: Regional distribution of rivers longer than 1,000 km and percentage of rivers remaining free-flowing

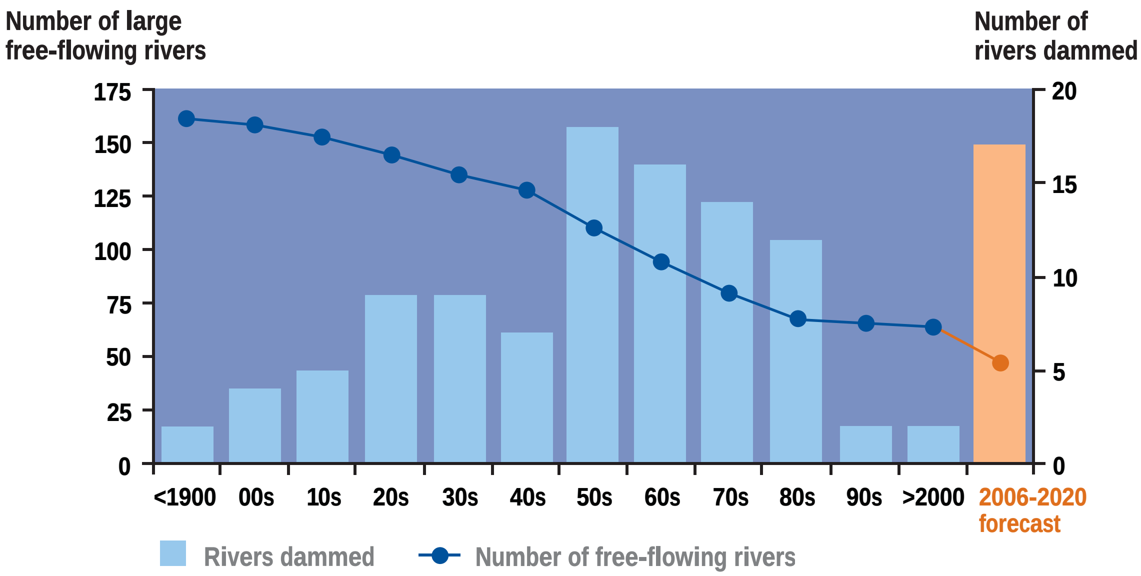


3.4 Losing free-flowing rivers – trend analysis

An analysis of the rate at which large free-flowing rivers have been lost shows that the decline started in the first half of the 20th century. Figure 4 presents an overview of the rate at which large free-flowing rivers have been dammed for the first time, based on a subset of 164 rivers[3]. By 1950 20 per cent of the world's large rivers was dammed, more than half of these in North America. The rate of damming increased rapidly in the 1950s in which decade 18 more free-flowing rivers were dammed for the first time, dominated by dam construction in Europe and Asia. The sixties and seventies saw equally large losses of free-flowing rivers, many of which were in Asia but increasingly free-flowing rivers were also lost in South America. The eighties were the last decade with high losses of free-flowing rivers. Twelve large rivers were dammed for the first time, four of which are in Africa. By 1990 only 68 large rivers were left free-flowing.

As dam construction slowed at the end of 20th century, the rate at which large free-flowing rivers are being lost has stabilized, with only four more free-flowing rivers dammed since 1991. But today the demand for dams, for either hydropower or water supply, is on the rise – driven by growing populations and growing demands for water, food and energy, together with the increasing threat of climate change. Many of these rivers face acute threats of being dammed in the near future and WWF estimates that of the world's remaining 64 large free-flowing rivers at least 17 large free-flowing rivers are in danger of being dammed by 2020.

Figure 4: Rates of damming of free flowing rivers



[3] All 164 large rivers are part of the dataset of 177 large rivers used for the initial analysis. On 13 rivers there is a lack of data on the year in which the river was first dammed.

3.5 Dam threats

In Africa, on the Gambia River plans are afoot for the Sambangalou Dam, whilst on the Rufiji River Stiegler's Gorge is a potential site for a 1400 MW hydropower development (IJHD, 2005). In South America, both the Amazon and Orinoco basins are subject to plans for hydropower development, although at present these appear more concentrated on large tributaries rather than on the main stem.

Many of the remaining undammed large rivers are in remote areas of the Russian Federation. Until now, the hydropower potential of these rivers has seen little development, but the government has recognized hydropower development as a priority, initially in the Far East and the Caucasus followed by the large Siberian rivers (Malik et al., 2000). The growing demand for energy in China is also likely to be an incentive for hydropower development on these rivers. The Aldan River, a major tributary of the Lena, has a significant hydropower potential. The creation of a South Yakutia

Map 1: Large free-flowing rivers from source to sea

hydro complex would contribute to the Far Eastern grid and enable export to Asia and the Pacific (IJHD, 2005). However, the unfavourable economic situation in the region means that in the near future most rivers are likely to remain free-flowing, although these freshwater systems face many other environmental threats, most notably pollution from heavy industry.

Asia (excluding Russia) has four large undammed rivers remaining that run from source to sea, most notably the Brahmaputra and Salween rivers. Both have their source on the Tibetan plateau and run respectively through China, India, Bangladesh and China, Myanmar & Thailand. The Brahmaputra basin is likely to see heavy development of hydropower on tributaries in India and Bhutan in the near future, though development on the main stem is at present unlikely. The Salween however, is under serious threat of fragmentation on the main stem, with plans for cascades of dams on both the Upper Salween (Nujiang) in China and the lower reaches in Myanmar. Appendix 1 presents an overview of the world's 64 large free-flowing rivers and an assessment of the risk of river modification.

4. Case studies

The rivers for case studies have been selected based on the following criteria:

- Threat to river integrity: This is based on an assessment of available information on planned dams on the river;
- Biodiversity value: an assessment of the variation in ecosystems linked by the river, as well as an assessment of the conservation value of ecosystems (uniqueness) and the presence of endangered or vulnerable species;

4.1 Salween River (Thanlwin, Nujiang)

Length: 2820 km
Source: T'ang Ku La, Eastern Tibet
Mouth: Gulf of Martaban, Andaman Sea
Countries: China, Myanmar, Thailand
Threat of modification: Extremely high

The Salween River has its source on the Tibetan plateau, flowing down through the steep valleys of China's Yunnan province and through the Shan states of Myanmar, before entering the Andaman Sea. The basin covers around 270,000 km^2 and supports a unique Indo-Burmese fauna, although it shares similarities with the Ganges and Irrawaddy River faunas. There are around 140 species of fish in the basin, of which 47 are endemic, and the area has the worlds' greatest diversity of turtles, including riverine species such as the stream terrapin *(Cyclemys dentata)*, giant Asian pond terrapin *(Heosemys grandis)*, and bigheaded turtle *(Platysternon megacephalum)* (WWF, 2001).
The basin spreads over several important terrestrial ecosystems, including Northern Indochina subtropical forests in the middle basin and the alpine conifer and mixed forests of the Nujiang (Salween) and Lancang (Mekong) Gorges. The forests of the lower Salween basin form an expanse of deciduous forests with large stands of teak.
The Salween basin is home to numerous different ethnic communities, many of whom rely on the river for their water supply and livelihoods. In Myanmar the main ethnic groups are the Shan and Karen, whilst in China there are numerous smaller groups including the Lisu and, one of China's smallest ethnic groups, the Nu. Fisheries are important along the length of the river, but are especially highly valued in Myanmar and Thailand.

Hydropower development along the Salween is not new, but until now has been confined to its tributaries. Now plans for large scale development of the main stem of the river are moving ahead in both China and Myanmar. In China plans exist for a cascade of 13 dams in the upper Salween River, with a total capacity of 21,320 MW and involving resettlement of up to 50,000 people. Hydropower development on the Salween stretch in Myanmar involve plans for two dams at Tasang and several dams in the lower reaches of the river, relatively close to the estuary. In November 2005 the Bangkok Post reported that the Hat Gyi Dam would be the first of a series of dams on the lower Salween to be developed together with neighbouring Thailand.

The dams will provide economic benefits through export of electricity to urbanized areas of Yunnan and Thailand where demand for electricity is high, whilst during the years of construction needed to complete the projects jobs will be created. But at what cost to the environment and to local communities?

The construction of up to 20 large dams will have a devastating impact on the ecological balance of this river. The table summarizes the potential losses to ecosystem services provided by the Salween as a result of the proposed dam developments.

Many losses are universal to dam developments worldwide, but one lost service particularly stands out. The upper reaches of the Salween, the Nujiang, are just being discovered as a site for white-water rafting and there is good potential for other forms of ecotourism in the region, including nature tours, cycling and trekking. Whilst it is unlikely that these kinds of industries will bring in similar amounts of money as the dam, combined with sensitive development of the potential of the Nu's tributaries it could offer a sustainable alternative.

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A cascade of 13 dams is planned for the upper Salween River

Services	Potential lost services as a result of loss of free-flowing character
Provisioning Food & Freshwater	• Disruption of traditional fisheries • Decreased water quality downstream
Regulating Hydrological regime, pollution control, natural hazards	• Natural connection between Tibetan plateau, South West China and Andaman Sea lost • Increased risk of flooding as a result of dam operations
Cultural Spiritual, recreational, aesthetic, educational	• Loss of the developing eco-tourism and white-water rafting industry • Loss of cultural values for Lisu, Nu, Shan, Karen & other minorities
Supporting Biodiversity, nutrient & sediment cycling	• Biodiversity will be affected both in and alongside the river through construction related infrastructure • Sediment retention in reservoirs will affect channel erosion and stability of river banks

Fisheries are important in the large river deltas of Myanmar, but may experience negative impacts in the future if the Salween River is dammed.

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4.2 Amur River / Heilongjiang

Length: 4510 (including Argun tributary)
Source: Inner Mongolia
Mouth: Tatar Strait
Countries: Russian Federation, China, Mongolia
Threat of modification: High

The Amur is one of Asia's major rivers and its main stem remains free-flowing from its source in Inner Mongolia to the mouth at the Sea of Okhotsk. The river catchment covers 1.855 million km^2 of which 0.8911 million km^2 lies within China. For a large part of its course the Amur forms the border between Russia and China. The main stream of the Amur, from the confluence of the Argun and Shilka rivers, is 2820km in length and takes in the tributaries of Zeya, Bureya, Armugong on the Russian side and the Huma, Sun and Songhua, rivers on the Chinese side. The Ussuri/Wussula forms the border between the two nations.
The Amur is located at a crossroads of several bio-geographic zones with high biodiversity values. Landscapes drained by the Amur include desert, steppe and taigas as well as extensive wetlands along the river and numerous lakes. The most valuable landscapes are the wide wetland belts along the Amur and its tributaries, which serve as spawning grounds for fish and migratory corridors for millions of birds on major Asian flyways.

The river provides habitat for over 120 species of fish, including seven species of migrating Pacific Ocean salmon and two species of sturgeon. One rare endemic species is the kaluga sturgeon *(Huso dauricus)* one of the world's biggest freshwater fish which can reach lengths of over five meters and weigh up to 1000 kg. Four populations are recognized in the Amur, in the estuary and coastal brackish waters of the Sea of Okhotsk and Sea of Japan, in the lower Amur, the middle Amur and in the lower reaches of the Zeya and Bureya rivers. Population numbers are in decline as a result of a large demand for the commercially valuable fish and its caviar, and only the estuary population survives relatively well. International trade is restricted under the CITES convention. The free-flowing character of the Amur is important in sustaining these populations, as damming the river would mean that many fish would be unable to reach their spawning sites upstream.

The Amur / Heilong River basin is home to many minority communities. On the Chinese side Manchu, Mongolian, Korean, Hezhe, Erlunchun as well as Han, rely on fisheries for a core income. Population density on the Russian side is far smaller, but here also many indigenous groups, such as the Nivkhi and Nanai, depend on the Amur River fisheries for their livelihoods.

Although until now the main stem of the Amur remains undammed, the wider river basin has seen considerable development of hydropower plants, some of which affect main stem flows.
Development of hydropower sources on the Chinese side is concentrated in the Songhua River basin, where there are eight stations with a total installed capacity of 3388 MW.

On the Amur River within the territory of Russia, two hydropower stations with a total capacity of 3290 MW have been built. The reservoir of the Zeskaya plant on the Zeya River in Russia started filling up in 1975. This has affected flows in the Amur, particularly in the winter season, as the outflow from the Zeya increases up to tenfold. There are more than another 100 dams planned for construction within the basin, which will tremendously change the natural hydrological regime of the rivers. There are also plans for dams on the river's mainstem. In December 1994, China and Russia published a report titled "Integrated Water Resources Utilization Planning Report for Erguna and Heilong/Amur Rivers at the Border Section between China and Russia". Among the list of hydropower projects proposed by the two countries, three – Mohe / Dgalinda, Lianfu /Amazar and Taipinggou / Khingan - are joint projects. China is planning to develop Mohe and Taipinggou hydropower stations by 2020. Russia has plans to develop cascades on the Zeya and Bureya rivers and some authorities support the construction of a dam on the main stem of the Amur in Khingan Gorge.

Services	Potential lost services as a result of loss of free-flowing character
Provisioning Food & Freshwater	• Disruption of commercially important salmon and sturgeon fisheries • Decreased water quality downstream
Regulating Hydrological regime, pollution control, natural hazards	• Natural connection between rivers and lakes, wetlands, and Tatar Strait lost • Increased pollution as result of construction, development of industry – whilst reducing capacity of the river to control pollution • Increased risk of flooding as a result of dam operations
Cultural Spiritual, recreational, aesthetic, educational	• Loss of cultural values for Nivkhi, Nanai and other minorities
Supporting Biodiversity, nutrient & sediment cycling	• Loss of wetlands and river corridors may affect habitats for migrating birds • Sediment retention in reservoirs will affect channel erosion and stability of river banks

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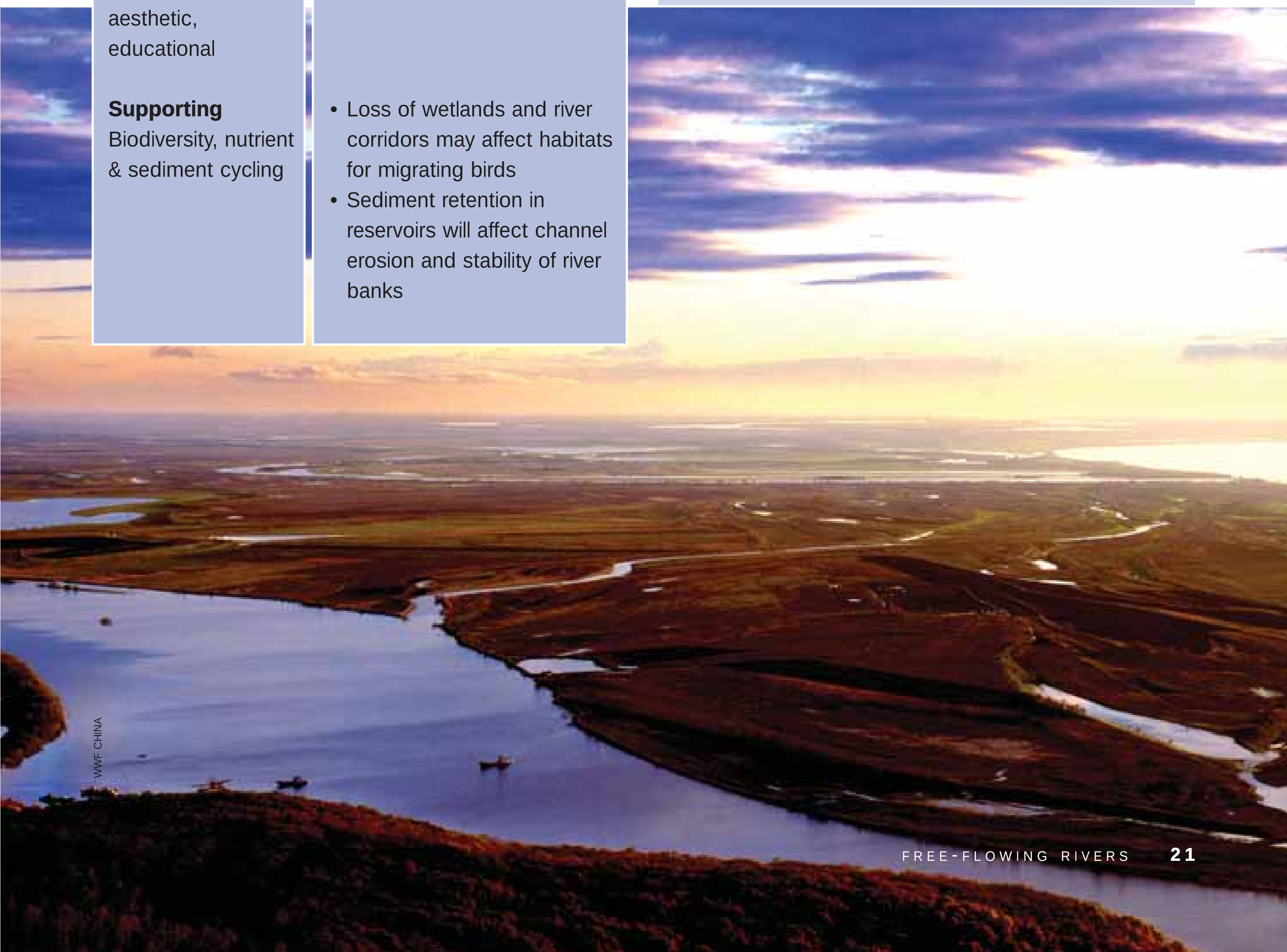
Fisheries of the Amur River sustain many indigenous groups, such as the Nivkhi.

The Amur / Heilong sustains important wetlands



WWF CHINA

4.3 Madeira River, Amazon basin

Length: 3352 km (to headwaters of Mamore)
Source: Bolivia
Mouth: Amazon River
Countries: Brazil, Bolivia
Threat of modification: High

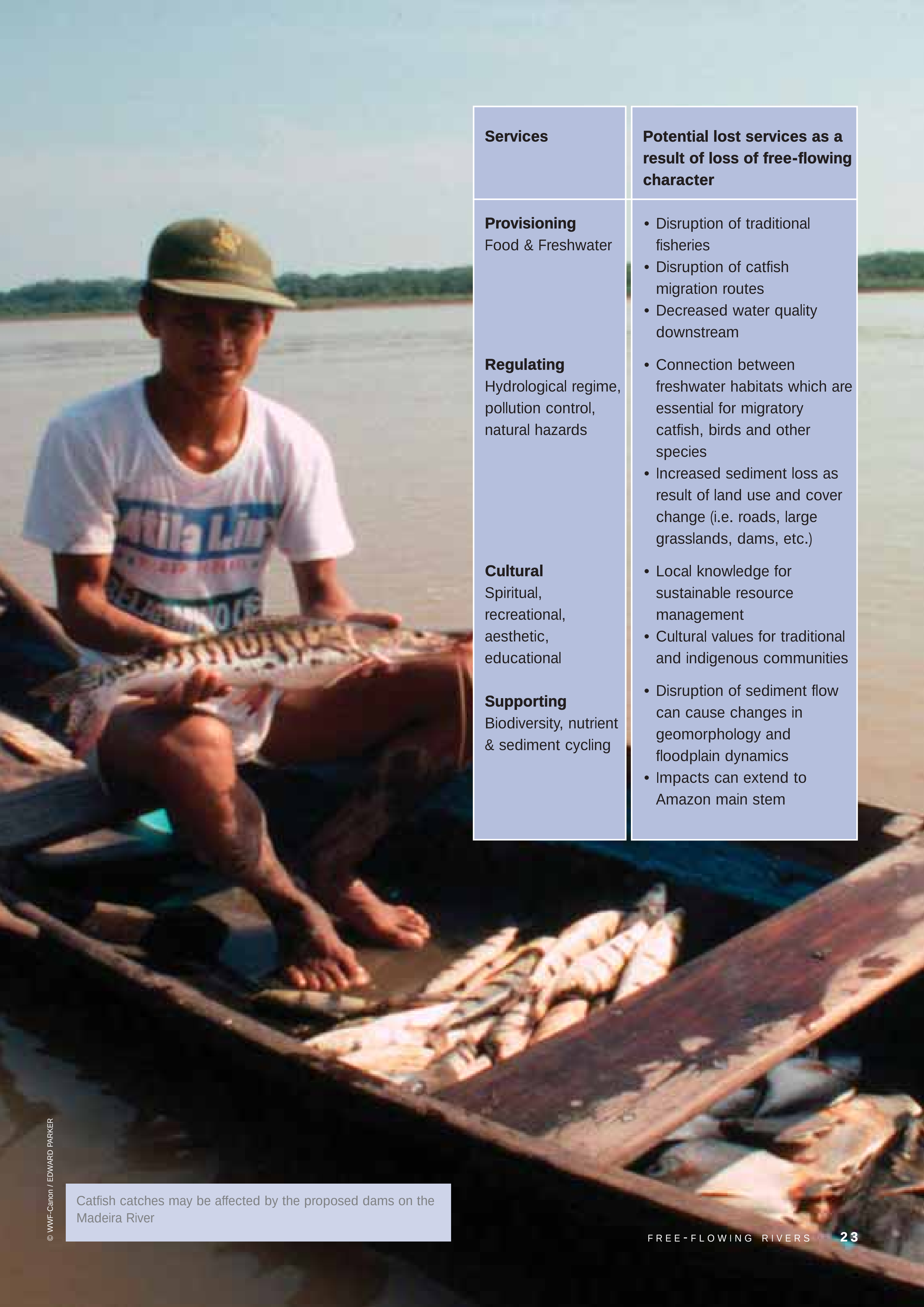
The Madeira is the largest of the Amazon's tributary catchments, with its upper tributaries originating in the Andes in Bolivia. The diverse landscapes and habitats have resulted in high species diversity for both flora and fauna. The expansive reach of the catchment provides a wide range of habitat for migratory species that depend on different aquatic habitats for different stages of their life cycles. The Madeira catchment embraces habitats that are important to fish distribution: high Andes above 800 meters; western region to about 800 meters; Médio Amazonas lowlands and the Brazilian Shield (WWF, 2005).

The Madeira River sustains important fisheries. Over 80 per cent of the total commercial fish catch in the Amazon Basin consists of migratory species and several of the most important species, such as the dourada catfish *(Brachyplatystoma filamentosum)*, use the Amazon River estuary as their nursery and migrate to the Andean foothills to spawn. In the case of the Madeira catchment these catfish migrate at least 3,500 km upstream to spawn in the foothill zone believed to be between about 500 and 800 meters in elevation. Migratory catfish have a complex life history that is also linked to other migratory species, especially the characins, which are their prey.

The river ecology in the Madeira catchment is under threat from rapid changes in land use, driven mostly by agricultural colonization in the Andean foothills and by upland and floodplain cattle ranching in eastern Bolivia, Rondonia State in Brazil, and along the Amazon River floodplain in Brazil. The soybean agricultural frontier is also expanding from central Brazil into the southern portion of the Madeira drainage and westwards to eastern Bolivia. Gold mining in the upper Beni River and Madre de Dios River basin is also a major environmental threat to aquatic ecosystems. These activities alter water quality, quantity, and the timing of flows in downstream freshwater systems.

On top of this, the Madeira River was earmarked for hydropower development in the late 1990s when it was proposed to develop Rondonia State as an electricity exporter (Fearnside, 2005). These plans were strengthened in 2001 when Brazil suffered severe acute electricity shortages. Two major projects proposed then were the 6300 MW Santo Antonio Dam and the 4200 MW Jirau Dam. The dams are still under study and have been downscaled to 3580 MW and 3900 MW respectively, but a final decision on progression has not yet been taken. An additional dam on the Beni River upstream, the 1500 MW Esperanza Dam, would also be part of the plans. The dams would flood the Madeira rapids and open up the river to navigation, facilitating the transport of soybean crops along the river. Thus the dams would not only disrupt the rivers, but also contribute to deforestation in Brazil and Bolivia (Fearnside, 2005).

Even in the downscaled versions, the dams will modify the pulse flow and the sediment and nutrient contribution to other freshwater habitats downstream. Considering that the Madeira River is one of the most important sediment suppliers for the Amazon River basin, the negative impacts of the proposed dams can modify the geomorphology of the floodplains and extend into the Amazon main stem.



Services	Potential lost services as a result of loss of free-flowing character
Provisioning Food & Freshwater	• Disruption of traditional fisheries • Disruption of catfish migration routes • Decreased water quality downstream
Regulating Hydrological regime, pollution control, natural hazards	• Connection between freshwater habitats which are essential for migratory catfish, birds and other species • Increased sediment loss as result of land use and cover change (i.e. roads, large grasslands, dams, etc.)
Cultural Spiritual, recreational, aesthetic, educational	• Local knowledge for sustainable resource management • Cultural values for traditional and indigenous communities
Supporting Biodiversity, nutrient & sediment cycling	• Disruption of sediment flow can cause changes in geomorphology and floodplain dynamics • Impacts can extend to Amazon main stem

Catfish catches may be affected by the proposed dams on the Madeira River

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4.4 Gambia River

Length: 1120 km
Source: Fouta Djallon Highlands
Mouth: Atlantic Ocean
Countries: Republic of Guinea, Senegal, The Gambia,
Threat of modification: High

The Gambia River is one of the easiest navigable rivers in Africa and has an important transportation function in the state of The Gambia, which is dissected by the river. The river Gambia rises from the central plateau of the Fouta Djallon highlands in west-central Guinea, which also hold the headwaters of the Senegal and Konkoure rivers and tributaries of the Niger. On its way to The Gambia, the river passes through the Niokolo-Koba National Park in south-eastern Senegal which has been inscribed on the World Heritage List since 1981. This predominantly savannah park supports 80 species of mammal and many species linked to the river, including 60 species of fish, all three species of African crocodile and populations of hippopotamus (WCMC, 1981).

The lower Gambia River encompasses the entire Gambian part of the river, with tidal effects perceptible up to the border with Senegal, but brackish waters are limited to the lower 180 km of the river where tidal floodplains are colonized by mangrove swamps (Albaret et al., 2004). The mangroves are home to a multitude of species and the estuary sustains important fisheries.

Marine fisheries of the coast of the Gambia are sustained by inflows of freshwater from the estuary, as fish are attracted to the area for feeding and spawning. Additionally there are substantial amounts of brackish and freshwater species that sustain fisheries further upriver (FAO, 2003). Fish is an important and relatively cheap source of protein and is widely eaten.

The Gambia is one of the last remaining large free-flowing rivers in Africa, but hydropower development is planned on the upper stretches of the river. The 120 MW Sambangalou scheme in Senegal, just upstream from Niokolo-Koba and close to the Guinean border is currently under preparation. The reservoir threatens to flood a recently designated Ramsar site in Guinea, Oundou-Liti (Ramsar, 2005) which in additional to important biodiversity values has a high potential for tourism that to date remains unexploited. Most environmental concerns however centre on the impacts the dam may have on the Gambia estuary and lower stretches of the river. There are fears that there may be similar impacts as after construction of dams on the nearby Senegal River which resulted in degradation of the floodplain ecosystems and increases in water borne diseases (WWAP, 2003).

Within the marine ecosystems of the coast of West Africa, the run-off from rivers and estuaries are the main sources of the sea's nutrients. The River Gambia plays a major role in this, particularly as the contributions of the Senegal River to this coastal area enrichment phenomenon have significantly diminished after completion of the Diama and Manantali dams. Furthermore, estuaries in Sine-Saloum, Casamance and Guinea have been carrying fewer nutrients down to the sea as a result of several decades of poor rainfall. The River Gambia is therefore one of the last well functioning rivers in the region.

The new dam is also likely to further exacerbate the already declining shrimp production in the coastal estuaries. The Gambia, Senegal, Casamance and Sine-Saloum estuaries used to be the biggest nursery grounds for shrimp in West Africa, but the productivity has declined considerably since the damming of the Senegal River, the poor rainfall record and overexploitation of juvenile shrimp in Casamance and Sine-Saloum. It is likely that hydrological changes caused by the construction of Sambangalou will affect the nursery function of the Gambian estuary for shrimps and cause further problems for local fishermen.

Services	Potential lost services as a result of loss of free-flowing character
Provisioning Food & Freshwater	• Contributes to further decline of shrimp fisheries in the Gambia estuary
Regulating Hydrological regime, pollution control, natural hazards	• Disruption of the nutrient balance within the West Africa coastal ecosystems
Cultural Spiritual, recreational, aesthetic, educational	• Potential decline of tourism in Ramsar site & National Park
Supporting Biodiversity, nutrient & sediment cycling	• Flooding of Oundou-Liti Ramsar site • Possible impacts on wildlife in Niokolo-Koba National Park

Fisheries off the coasts of Gambia and Senegal are linked to the inflow of freshwater from the Gambia and Senegal rivers.

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WWF-CHINA

The Chishuihe remains free of dams

4.5 Smaller rivers

Chishuihe River, China

The Chishui River is a 444 km long tributary of the Yangtze River and flows through Yunnan, Guizhou and Sichuan Provinces. It is the only Yangtze tributary with a natural flow regime as there has been no dam development yet. The Chishuihe is important for wildlife habitat and runs through diverse landscapes, including karst formations, virgin forests and extensive bamboo forests. The Chishuihe is culturally important as the river crossed four times during the Red Army's long march. The river also provides water for the production of mao-tai, the most famous Chinese liquor.

Biodiversity along and in the Chishuihe is very rich, sustaining 108 species of fish alongside numerous species of amphibians, reptiles and water fowl. The river is one of the last sanctuaries for many endangered species in the Yangtze River basin. The Yangtze basin has been extensively modified, and the confluence of the Chishuihe with the Yangtze is not far upstream of the Three Gorges Reservoir. The Three Gorges Dam together with numerous other dams still being considered in the upper Yangtze basin, including Xiluodu and Xiangjiaba, have a potentially devastating effect on freshwater ecosystems. Effects can be particularly severe for the 44 endemic species and the Chishuihe has been identified as a potential reserve for 22 of these species (Park et al., 2003).

The authorities have to some extent acknowledged the ecological importance of the river. The provinces of Yunnan, Guizhou and Sichuan have all recognized the conservation and development of Chishuihe as their common responsibility and the Provincial Government of Guizhou has clearly stated that no dam will be considered on the river section within Guizhou Province. Conservation of the river is also stimulated by the importance of the Chishuihe waters for mao-tai production. The capacity of the Chishuihe to act as a reserve for endemic species depends on the river remaining free-flowing. However, in the early 1990s plans were developed to exploit the 1270 MW potential hydropower capacity through a cascade of 6-10 dams in the upper watershed. It is now unlikely that these plans will progress. In October 2004, the IRBM Task Force of the China Commission of International Cooperation on Environment and Development (CCICED) suggested Chishuihe as one of the two basins for IRBM demonstration. In 2005, the State Council of China approved the "Natural Conservation Area for Rare, Treasure and Special Fishes of Upstream Yangtze River", which extended conservation to the middle and downstream sections of Chishuihe, and clearly specified the conservation requirements for water quality and flow regime of Chishuihe.

Mara River, Kenya & Tanzania

The Mara River is just under 400 km long and for part of its course forms the border between the Masai Mara Reserve in Kenya and the Serengeti National Park in Tanzania. The Mara supports relatively dense populations and large scale agriculture upstream and downstream of the parks, with some water used for irrigation. The inflows of the Mara into the Masai Mara and Serengeti sustain a large variety of wildlife, including populations of crocodile and wildebeest. People in the Mara River basin face a number of water problems, including increasing shortages and water quality issues, driven by deforestation and unsustainable agricultural expansion.

There are plans for a diversion of water from the Mara River to another river basin for hydropower development. The Ewaso Ng'iro hydro-electric project involves three dams on the Ewaso Ng'iro River in Kenya. However, the Ewaso Ng'iro has been suffering since the 1980s of prolonged periods of no flow (Liniger & Weingartner, 1998) and an essential part of the project is the diversion of water from the Amala River, a tributary of the Mara, into the Ewaso Ng'iro. Construction of the Amala Weir would substantially affect flows in the downstream Mara River, which are already under stress. Increased exploitation of the river for agriculture and tourism and increased deforestation already mean that there are water shortages and this is likely to be exacerbated by development of the Amala Weir.

There are particular concerns about the impacts of the water diversion on the Serengeti and Masai Mara ecosystems, particularly on wildebeest migration – one of the main features of the Serengeti. Studies have shown that if the Mara dried up this would have a devastating impact on wildlife, destroying the Serengeti migration (IUCN, 2001).

Karnali River, Nepal

The Karnali River is a perennial river, originating on the Tibetan plateau and cutting through the Himalayas in Nepal on its way to the confluence with the Sarda River in India where it forms the Ghagara River, a major tributary of the Ganges. The Karnali has a very high sediment load and not much is known about fish in the upper watershed. Further downstream fish diversity is rich with around 74 species (Shreshta, 2003).

The Karnali also provides the upper range for the Gangetic river dolphin *(Platanista gangetica)*, the largest freshwater mammals found on the Indian subcontinent. They are considered vulnerable species under CITES Appendix 1 and are classified as endangered on the IUCN Redlist (IUCN, 2004). The river dolphins are legally protected animals in Nepal as endangered mammal and fall under Schedule I of the protected list of National Parks and Wildlife Conservation Act, 1973. Living at the upstream range limit, dolphins in the Karnali River are particularly vulnerable to threats from habitat degradation. Dolphins need deep pools of water. They are often found in places where human activities are most intense and they are sometimes accidentally caught by the local people who live in the lower Karnali basin. The Karnali River supports the last potentially viable population of the Ganges River dolphin in Nepal. These dolphins are at their farthest upstream range and isolated by the Girijapur Barrage (a low gated dam), located about 20 km downstream of the Nepal/India border.

The Karnali, as most other Himalayan rivers in Nepal has a considerable potential for hydropower development. The Chisapani Dam is one possible project which could be as much as 270 meter high and have an installed capacity of over 10,000 MW (Onta, 2000). Other plans include a run of river facility in the upper watershed.

The potential impacts of the planned water development projects are not known, but can include habitat fragmentation, loss or disturbance of habitat and losses in food supply because of reduction of prey species and an assessment done shows that planned water development projects rarely consider river dolphins during construction or management (Smith and Reeves, 2000). Experience with other dam projects has shown that impacts on river dolphins can be devastating, with habitat fragmentation a particular concern. It is thus of utmost importance to evaluate any water development projects for the potential impacts on this endangered species.

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Wildebeest may be affected by water diversions from the Mara River

The Karnali River is the upper range for the Ganges river dolphin

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5. Protecting free-flowing rivers

The value of free-flowing rivers is increasingly recognized and a number of protection mechanisms are applied in different countries. The following section provides an overview of conservation mechanisms instated in some countries that take a whole river approach to river conservation. We also discuss some international conservation mechanisms that play a role in the protection of free-flowing rivers, although these do not apply specifically to whole rivers.

5.1 Whole river protection

United States

An important legal mechanism in the US is the 'Wild and Scenic Rivers Act', which was passed in 1968 and was designed to balance the need for dams on rivers with a policy aimed at protecting the free-flowing character and outstanding values of other rivers. The Act defines free-flowing to 'mean existing or flowing in natural condition without impoundment, diversion, straightening, rip-rapping, or other modification of the waterway.'

Under the Act, rivers are designated as a part of the National Wild and Scenic Rivers System. A classification system divides designated rivers into 'Wild river areas', 'Scenic river areas' and 'Recreational river areas'. (IWSRCC, 1998). The rate of accessibility if important in this classification (wild river areas are generally inaccessible), and wild and scenic river areas should be free from impoundments. Recreational river areas may have undergone some impoundment or diversion in the past

It is important to note that the Act does not only include rivers from source to mouth or confluence, but also considers sections of rivers. For example, a 53 mile section of the Rio Grande – a river that is on balance heavily modified and sometimes even fails to reach the sea – was designated as a wild river area when the Act was passed. The National Wild and Scenic Rivers System covers about 11,303 river miles, accounting for just over 0.25 per cent of US rivers.

It is hereby declared to be the policy of the United States that certain selected rivers of the Nation which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future generations. The Congress declares that the established national policy of dams and other construction at appropriate sections of the rivers of the United States needs to be complemented by a policy that would preserve other selected rivers or sections thereof in their free-flowing condition to protect the water quality of such rivers and to fulfil other vital national conservation purposes.


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The Cahaba River in Alabama, US is a potential addition the US wild and scenic rivers system

Canada

In neighbouring Canada, a comparable system, the Canadian Heritage River System (CHRS), is run as a public trust, a major difference with the US system being that the CHRS has no legislative authority. The CHRS was set up in 1984 by the federal, provincial and territorial governments and the objectives of the programme are “to give national recognition to Canada’s outstanding rivers and to ensure long-term management that will conserve their natural, cultural and recreational values for the benefit and enjoyment of Canadians, now and in the future” (CHRB, 2005). To date 39 rivers, stretching for 9,922 km, have been nominated and 34 have been designated, meaning that detailed management plans on protection of the rivers heritage valued have been lodged with the CHR board. The largest river designated under this system is the 1375 km long Fraser River. The river was designated in 1998 and supports an extremely productive fisheries as well as extensive water fowl breeding areas. Rapids and canyons provide many recreation opportunities for white water activities.

Australia

In Australia, much environmental legislation is implemented at the state level, and there have been numerous initiatives to protect rivers both through legislation and through multilateral agreements. In Victoria for example, the Victoria Heritage Rivers Act 1992 identifies 18 Heritage River Areas which have significant recreation, nature conservation, scenic or cultural heritage attributes that are protected under the Act. The Act protects three classes of rivers: remaining unmodified catchments, which are mostly relatively small; a representative river of each class of rivers in the state, which may be extensively modified; and wild & scenic rivers that contain particular natural, scenic and cultural values. Wild & scenic rivers include a number of large free-flowing rivers, such as the Mitchell River whose whole reach is designated and much of its surrounding area is protected by Mitchell River National Park. The Act specifically offers protection from the development of artificial barriers and structures which may affect the passage of water fauna or significantly impair the area’s recreation, nature conservation, scenic or cultural heritage attributes. Managing authorities are required to ‘take all reasonable steps to ensure that that part of the river which is in the area is maintained without further interference with its free-flowing state” (GoV, 1992).

A different type of protection mechanism is in place on the Paroo River in Queensland and New South Wales. The 600 km long Paroo River is part of the Murray-Darling river basin, but its highly variable river flow (which is dependent on rainfall) means that in many years the Paroo does not reach the Darling River. The Paroo River and floodplains support extensive wetlands all along its length, some of which are temporary and others which are permanent. In the mid 1990s the Paroo River became a candidate for irrigation development, but awareness about the high ecological costs and impacts on livelihoods led to a debate on alternative models for managing the Paroo River (Kingsford, 2002). This eventually led to the establishment of the Paroo River Agreement, a non-legislative agreement between the two state governments signed in July 2003, which has a heavy focus on conserving the ecological and cultural values of the river. The importance of the free-flowing character is recognized in a clause stating that “naturally variable flow regimes and the maintenance of water quality are fundamental to the health of the aquatic ecosystems in the Paroo River Agreement Area” (FAO, 2005).

Similar developments are taking place all over Australia, including in Queensland and the Lake Eyre Basin. Work is also underway to develop a national approach to protecting rivers in Australia, considering for example the potential for an Australian Heritage Rivers System (Kingsford et al., 2005).

5.2 Other conservation mechanisms

The number of specific conservation mechanisms aimed at whole rivers is limited, and many rivers or parts of rivers are protected under other conservation mechanisms. In general though, these measures do not provide specific protection against developments involving river modification, such as dams.

Protected areas

Protected areas are considered to be the most effective way of preserving biological diversity and most countries in the world have established or planned a national system of protected areas (Green et al., 1997). One of the most used definitions of a protected area is that adopted by IUCN "An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means." At country level there is considerable variation in meaning and interpretation of what a protected area is and the level of protection afforded. For example, in some countries national parks are wilderness areas without any habitation, whilst in other countries entire towns can be found within the park boundary. Protected areas usually have a terrestrial or marine focus, although they often encompass rivers and streams whose free-flowing character could be protected under this mechanism.

Internationally, the protected area mechanism works through the six different categories for protected areas management defined by IUCN, each with a different emphasis for conservation, such as science, recreation, wilderness or landscape protection (IUCN, 1994). A definitive list of the world's national parks and reserves is published under the authority of the United Nations (Chape et al., 2003). As at the national level, the focus is very much terrestrial and the latest list, published in 2003, does not specifically cite any river systems. Out of 90,260 sites only 261 refer to freshwater specifically (lake systems), protecting only 1.54 per cent of the biome (Chape et al., 2003).

Further protected area work takes place within the framework of the Convention on Biological Diversity (CBD). Under the Programme of Work on Protected Areas all governments are committed to establishing and effectively managing representative protected areas systems, including for inland waters, by 2010. The CBD suggests that parties take urgent action address the under-representation of marine and inland water ecosystems in existing national and regional systems of protected areas.

World Heritage Convention

The 1972 World Heritage Convention linked the protection of cultural and natural heritage and one of its fundamental premises is the recognition of the ways people interact with nature and the need to preserve the balance between the two. Signatories recognize that under the convention the State is primarily responsible for the protection of World Heritage Sites. According to the Convention the state will "do all it can to this end, to the utmost of its own resources and, where appropriate, with any international assistance and co-operation, in particular, financial, artistic, scientific and technical, which it may be able to obtain. Under the scheme some funding is available for protection, but to a large extent the responsibility lies with individual states. Experience with protection for free-flowing rivers through designation as a World Heritage Site is mixed.

Some of the best remaining temperate wilderness sites in Australia are on the island of Tasmania, with much of the area in a natural condition. In 1982 the 'Tasmanian Wilderness' was inscribed as a World Heritage Site, covering several national parks, state and forest reserves and conservation areas. The main human modification in the area is for hydro-electricity and in the 1970s the Gordon River was dammed. In 1982 the Tasmanian government approved further plans to develop the lower Gordon and Franklin rivers, but this met with strong national and international opposition. The inscription of the Tasmanian Wilderness as a World Heritage Site reinforced this opposition. The World Heritage Committee recommended that all possible steps be taken to protect the integrity of the site and subsequently the Australian Government intervened and passed the World Heritage Properties Conservation Act in 1983, under which the dam development was stopped (WCMC, 1987). The Act was replaced in 1999 by the 'Environment Protection and Biodiversity Conservation Act' which provides protection for the values of World Heritage Sites, as well as for National Heritage and Ramsar Sites.

But dam development can also go ahead unchecked and the World Heritage Committee can inscribe sites on a special list of 'World Heritage Sites in Danger'. To date 34 out of 812 sites are inscribed on this list, including the Ichkeul National Park in Tunisia. The Ichkeul Lake and wetlands were designated a World Heritage Site in 1980, as well as listed as a Ramsar site, being the last remaining lake in a chain that extended through North Africa and an important site for migrating birds. The construction of three dams on rivers flowing into the lake has cut off the supply of freshwater and resulted in increased salinity and the future of the site still is uncertain.

Another river in danger of being dammed is the Salween River which is part of the Three Parallel Gorges World Heritage Site. In view of the scale of development plans proposed for the Salween, it is unclear how the plans are being affected by the World Heritage Status.

Ramsar Convention

One international treaty with a strong water focus is the Ramsar Convention on Wetlands. Signed in 1971 this intergovernmental treaty provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. As of 31 January 2006 there are 150 Contracting Parties to the Convention, with 1579 wetland sites, totalling nearly 134 million hectares, designated for inclusion in the Ramsar List of Wetlands of International Importance. Under the Convention governments are required to designate at least one wetland for inclusion in the 'List of wetlands of international importance' and to promote the conservation and 'wise use' of all wetlands. The Convention has developed from a focus on wetland habitat provision for water birds to cover all aspects of wetland conservation and wise use, recognizing that wetland ecosystems are extremely important for biodiversity conservation in general as well as for the well-being of human communities. The definition of wetlands under the convention incorporates rivers and streams.

The Ramsar Convention does not automatically protect wetlands from the impacts of dam projects, but the requirement to maintain a certain 'ecological character' places an obligation on governments to minimize impacts of river modification on Ramsar sites. Governments are legally obliged to make all feasible efforts to maintain the ecological character of the site.
Following the report of the World Commission on Dams in 2000, the 8th meeting of the Conference of Contracting Parties (COP 8) adopted Resolution VIII.2. This resolution encourages "contracting Parties faced with managing or assessing the impact of dams on sensitive riverine and wetland ecosystems, to use, where appropriate, all available information, including information provided by

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Franklin-Gordon Wild Rivers National Park in Tasmania. World Heritage status helped to protect the Franklin River from being dammed.

the WCD, in association with the relevant guidance adopted by the Ramsar Convention to inform and guide local and national processes for allocation of water resources and decision-making, in order to ensure that wetlands and their values and functions are fully taken into account in decision-making on large dams."

Europe – Natura 2000

Natura 2000 is a European network of protected sites which represent areas of the highest value for natural habitats and species of plants and animals which are rare, endangered or vulnerable in the European Community. Natura 2000 follows from the 1992 EC Habitats Directive and includes two types of area: Special Areas of Conservation (SAC), supporting rare, endangered or vulnerable natural habitats and species of plants or animals (other than birds), and Special Protection Areas (SPA) which support significant numbers of wild birds and their habitats. Article 10 of the Directive recognizes the importance of rivers for the migration, dispersal and genetic exchange of wild species. Designation of SACs or SPAs can apply to rivers, and for example in the United Kingdom eight rivers have been proposed as an SAC. Under the Directive any project or development that will affect a site must be assessed on the implications on the conservation objectives of the site. If there is a negative assessment of the impacts on the site, the plan or project can only continue if it is in the overriding public interest.

5.3 River protection vs. River development

As shown above, measures are available to protect free-flowing rivers, but it is telling that measures awarding protection to whole rivers are currently limited to the developed countries, where water resources are often already over-exploited. Most remaining free-flowing rivers are found in developing countries, where there are some tough choices to be made between river protection and river development. The reality is that many rivers in the developing world will continue to be modified to provide water, food and energy where it is desperately needed.

In WWF's view a different approach to free-flowing rivers is needed in developing countries, aimed at balancing the need for developing rivers for energy and water supply and the importance of preserving free-flowing rivers and biodiversity.

The first step of such an approach should be the identification of remaining free-flowing rivers within a country or river basin. An analysis of the biodiversity and conservation values of these rivers, as well as an assessment of the services provided by these rivers to people can then be done to identify priority free-flowing rivers for conservation. These rivers should then be earmarked as 'no-go' rivers for hydropower development, large scale irrigation or canalisation. It is important that this process also considers major stretches of rivers that have already been dammed, but that still retain valuable characteristics of a free-flowing river.

Development of river infrastructure on non-priority rivers could then be considered in accordance with the strategic priorities and recommendations set out by the World Commission on Dams. This would involve comprehensive needs and options assessments, and an evaluation of the cumulative impacts of dams within the same basin.

WWF is pioneering this approach in the Mekong River basin. In 2001 the Living Mekong Programme identified large scale infrastructure, and particularly hydropower dams, as the single major threat to the aquatic biodiversity of the Mekong basin. However, experiences with individual infrastructure projects since this time, including the Nam Theun 2 Dam project consultation process led by the World Bank, have shown the limits of lobbying on individual projects. Attention to one project also often draws away the focus from other projects that go ahead with very limited consultation processes with conservation organizations. In an alternative approach WWF is now moving away from a case-by-case approach and engaging with key partners, such as the Mekong River Commission and Asian Development Bank, at a more strategic level. WWF is promoting a strategic approach to prioritising dam projects in the Mekong basin, which allows some rivers to remain free-flowing.

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Dams can bring substantial benefits, including hydro-electricity, water supply and irrigation.

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WWF is working to identify tributaries of the Mekong River that should be awarded protection from dam development.

6. Conclusions and recommendations

The importance of rivers to people is undeniable, supplying such resources as irrigation, industrial and household water and fish, waterfowl, mussels as important sources of food. In many places fisheries are the most important source of protein for people living in poverty. Other services provided are less obvious, but at least as important. Regulating services of freshwater systems include, amongst many others, water purification, flood mitigation and sediment deposition. Finally, freshwater systems offer numerous cultural services, varying from recreational opportunities to aesthetic and spiritual values.

Throughout history people have sought to optimize the provisioning benefits provided by rivers and dams and other river infrastructure have played an important role in this. But with advancing technology the exploitation of rivers has grown to such a scale that the capacity of rivers to provide regulating and supporting services is seriously degraded. Today the majority of river systems are fragmented and the plight of long rivers in particular is dire. Worldwide only 21 rivers longer than 1,000 km remain that retain a direct connection from source to sea.

With such pressure to utilize rivers for the benefit of people, and if dammed rivers give us energy, water and food, why should we retain free-flowing rivers?

One answer to this lies in the hidden costs of river fragmentation that do not show up on the balance sheet. Whilst the value of a dam's benefits can be objectively measured, the cost of a litre of water or a kilowatt-hour of electricity, we rarely attach an economic value to the regulating and supporting services of a free-flowing river that are lost as a river is dammed. This is changing slowly however. In 1997, a team of researchers argued that ecosystem services contribute to human welfare and therefore represent part of the total economic value of the planet. They estimated the economic value of 17 fundamental ecosystem services of the entire biosphere at an average of US$33 trillion annually. The value of wetlands was estimated at US$4.8 trillion, or about US$15,000 per hectare per year (Costanza et al., 1997). Although the study was rather crude, it did open up the debate on the economic value of ecosystems and more studies followed.

A recent WWF study concluded that the annual economic value of wetlands would at least be US$70 billion a year (Schuyt & Brander, 2004). These numbers are much lower than the Costanza study, but are based on individual economic studies of 89 wetlands, allowing for regional variations and differences in wetland types. As yet, there are no specific studies that give a global economic value of rivers and flood plains, but on individual basin levels we are getting to know more about the value of ecosystem services. For example, the estimated value of capture fishery alone in the lower Mekong Basin is estimated to be between $1 and $1.4 billion annually.

A second answer lies within the intrinsic value of biodiversity, freshwater ecosystems and rivers. The importance of conserving freshwater biodiversity is internationally recognized in several fora, including the Convention on Biological Diversity (1992) and the Ramsar Convention on Wetlands (1971). Protecting free-flowing rivers can be a key tool to meet the World Summit on Sustainable Development 2010 biodiversity target.

Thirdly, preserving free-flowing rivers would provide an opportunity to increase our understanding of the mechanisms of free-flowing rivers over long distances and the contributions made by these rivers to the global ecosystem. With so few long free-flowing rivers now left, we are on the brink of losing another natural phenomenon without fully understanding the costs of these losses. For scientific reasons alone it would be prudent to select free-flowing rivers that are representative of a particular ecoregion and ensure that their free-flowing character is maintained.

Finally, the importance of a free-flowing river is not only restricted to the freshwater stretches, as the water conditions in river deltas and marine coastal zones are dependent on rivers and dams higher up in the watershed can significantly impact coastal fisheries.

As this report has shown free-flowing rivers have substantial conservation, as well as economic value in the world today, and this is being recognized in many countries through the protection of whole rivers. Parts of rivers are also conserved by other measures, but these offer less protection for a river from future development. The very existence of free-flowing rivers is under threat. When we consider the world's largest rivers we find that only 64 rivers over 1,000 km remain free-flowing, and many of these rivers are immediately threatened. Perhaps the most acute threat is on the Salween River, where plans exist for up to 20 dams, many of which are in an advanced stage.

WWF recognizes that development of free-flowing rivers is driven by a need for water supplies or electricity, and that some free-flowing rivers will be dammed in the future. However, the evidence on the importance of free-flowing rivers is so overwhelming, that a concerted global effort is now needed to protect a large number of those that remain.


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Free-flowing rivers are not only an ecological necessity, but also an economic one.

For these reasons, WWF recommends that:

- Governments, as part of their commitments to significantly reduce the rate of loss of biological diversity by 2010, should fully recognize the importance of free-flowing rivers and identify their remaining free-flowing rivers and their biological and economic importance. Free-flowing rivers that are of high ecological importance or that are representative of certain types of rivers should be designated as ‘conservation rivers’ that should remain free from river modification. Governments should adopt laws and programmes to protect these rivers effectively.

- Countries who share rivers establish common river basin conservation and management mechanisms, including conservation of remaining free-flowing rivers.

- In each river basin, one or more tributaries should be protected as free-flowing. Remaining intact main stems of rivers should also be protected, as this will conserve fauna and flora and the ecological processes they depend on. Wherever possible such tributaries should link to free-flowing main stems to form an unbroken link from source to sea.

- Development of water infrastructure should follow the strategic priorities and recommendations outlined by the World Commission on Dams. Ideally dams should not be constructed on the main stems of rivers so as to maintain ecological processes from the source to the sea.

Based on the case studies in this report, WWF calls for the immediate protection of the following rivers:
- The Chishuihe River tributary of the Yangtze in China should be protected as a free-flowing river to ensure the survival of species endemic to the Yangtze basin that are affected by the Three Gorges and other large dam developments;
- The Salween in China and Myanmar is a unique river linking the Tibetan plateau to the Andaman Sea over a distance of nearly 3,000 kilometres. Its twin rivers, the Yangtze and Mekong, that follow a similar course in the upper watershed have already been dammed;
- The Mara River in Kenya and Tanzania, where the maintenance of adequate flows is crucial to sustaining wildebeest populations in the Masai Mara and Serengeti;
- The Amur River mainstem and appropriate tributaries;
- The mainstem and major tributaries of the Amazon River, including the Xingu and Madeira

Rivers have been dammed too often without consideration of the values and services that are lost. It is now time to take stock of the free-flowing rivers and take protective action to ensure that in twenty years time the world still has free-flowing rivers. Far from being an economic luxury, free-flowing rivers are not only an ecological necessity but also an economic one.
In the words of Hal Borland, the American journalist and nature writer:

“Any river is really the summation of the whole valley. To think of it as nothing but water is to ignore the greater part.”

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Appendix 1: Overview of remaining free-flowing rivers

River (river basin)	**Length** (km)	**Threat of modification**
Africa		
Kasai (Congo)	2153	yes
Lomami (Congo)	1500	n/a
Aruwimi (Congo)	1300	n/a
Okavango	1800	yes
Chari	1400	n/a
Rufiji	1400	yes
Gambia	1200	yes
Shabele	1130	n/a
Asia		
Amur	2820	yes
Argun (Amur)	1620	yes
Brahmaputra	2896	yes
Lena	4410	n/a
Aldan (Lena)	2273	Yes
Vitim (Lena)	1978	n/a
Olekma (Lena)	1320	n/a
Maya (Lena)	1053	n/a
Amga (Aldan)	1462	n/a
Ishim (Ob-Irtysh)	2450	n/a
Chulym (Ob-Irtysh)	1799	n/a
Lower Tunguska (Yenisei)	2989	n/a
Stony Tunguska (Yenisei)	1865	n/a
Selenga (Yenisei)	1480	n/a
Salween	2820	yes
Irrawaddy	2300	yes
Olenek	2270	n/a
Indigirka	1726	n/a
Khatanga	1634	n/a
Taz	1400	n/a
Kerulen / Herlen	1264	n/a
Anadyr	1150	yes
Australia / Pacific		
Cooper Creek	1420	n/a
Sepik	1120	n/a
Fly	1040	n/a

River (river basin)	**Length** (km)	**Threat of modification**
Europe		
Vychegda (Northern Dvina)	1130	n/a
Pechora	1809	n/a
Oka (Volga)	1500	n/a
Vyatka (Volga)	1370	n/a
Belaya (Volga)	1420	n/a
North America		
Mackenzie	5472	n/a
Athabasca (Mackenzie)	1231	n/a
Liard (Mackenzie)	1115	n/a
Yellowstone	1080	n/a
Fraser	1370	n/a
Kuskokwim	1050	n/a
South America		
Amazon	6516	n/a
Madeira (Amazon)	3239	yes
Jurua (Amazon)	3000	n/a
Xingu (Amazon)	2100	yes
Tapajos (Amazon)	1992	n/a
Putumayo / Ica (Amazon)	1575	yes
Maranon (Amazon)	1415	n/a
Madre de dios (Amazon)	1130	n/a
Purus (Amazon)	3379	n/a
Yapura (Amazon)	2820	n/a
Ucayali (Amazon)	2738	n/a
Mamore (Amazon)	1900	n/a
Beni (Amazon)	1599	yes
Huallaga (Amazon)	1100	n/a
Iriri (Amazon)	1300	n/a
Orinoco	2470	n/a
Guaviare (Orinoco)	1497	n/a
Pilcomayo (Paraguay)	2500	yes
Paraguay (Parana)	2549	yes
Araguaia (Tocantins)	2575	yes


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The mission of WWF is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by:

· conserving the world's biological diversity
· ensuring that the use of renewable resources is sustainable
· promoting the reduction of pollution and wasteful consumption

for a living planet®

WWF Global Freshwater Programme
P.O.Box 7
3700AA Zeist
Netherlands
T: +31 30 693 7803
F: +31 30 691 2064
dams@wwf.org.uk
www.panda.org/dams