Technical Report

Interconnected Disaster Risks
2020/2021

Chinese Paddlefish Extinction

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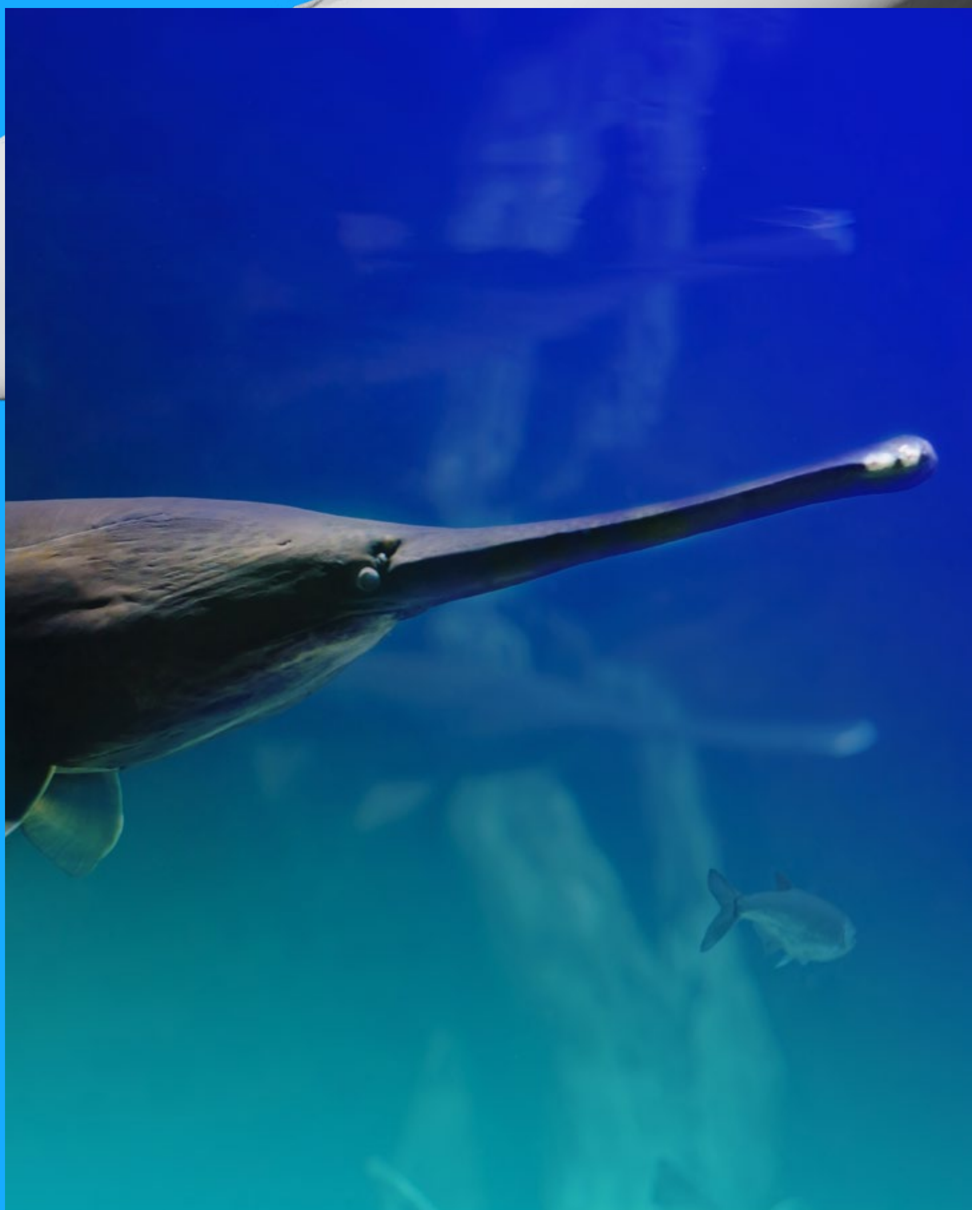

Table of Contents

1. Case description

In January 2020, the International Union for Conservation of Nature (IUCN) officially declared the Chinese Paddlefish (Psephurus gladius) extinct. It was one of the world's largest and oldest freshwater fishes (Box 1). In the last 50 years, multiple dam construction, overfishing and pollution in the Yangtze River led to its habitat being fragmented and degraded, reducing the number of individuals and altering its migration and breeding patterns, which ultimately lead to its extinction. The extinction of the Chinese Paddlefish presents an irreversible loss of the species. The Chinese Paddlefish is not an isolated case: the IUCN declared at least 80 freshwater fishes extinct with 16 disappearing in 2020 alone, with 115 being classified as 'critically endangered possibly extinct' (WWF, 2021).

Freshwater fish extinction results in significant long-term impacts, including changes and losses in freshwater food webs and freshwater biodiversity, loss of biological control for water quality, and loss of livelihood and food security for millions of people around the world. However, just like the Chinese Paddlefish extinction, which went rather unnoticed, freshwater fish extinction rates do not get much attention in comparison with other animals at the global scale, and many fishes may be disappearing without a clear record (Darwall & Freyhof, 2016).

Box 1. Paddlefish who?

The Chinese Paddlefish (Psephururs gladius), also called 'elephant fish' due to its long nose, was part of the order Acipenseriformes, which includes the sturgeons. It was an anadromous species native to the Yangtze River in China, spending some part of its life in the sea and migrating upstream to spawn. They were one of the largest freshwater fishes (a maximum of 7 m in length) and one of the oldest (the Acipenseriformes have existed since the Lower Jurassic, 200 million years ago). With the declaration of extinction by IUCN in 2020, the only living species in the paddlefish family is the American paddlefish (Zhang and others, 2020; Darwall and Freyhof 2016).

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2. Impacts

The Chinese Paddlefish is a unique species as it was one of the largest and most prehistoric freshwater fishes on Earth. Its extinction is an irreversible loss. It was a top predator, feeding on freshwater fish, shrimp and crab. It was a strong swimmer with powerful jaws for feeding on prey. The impacts of the Chinese Paddlefish extinction on the food web are unknown but the loss of a top predator often results in changes in the food web leading to so called 'trophic cascades'. Top predators not only influence the abundance of the pray but also other species, such as primary producers, water quality and nutrient cycling (Su and others, 2021). The extinction of a large freshwater fish has significant impacts also on society in terms of food security and livelihoods. These impacts are particularly relevant when considering that the Chinese Paddlefish extinction is an emblematic case within the wider picture of freshwater fish extinction. In fact, in the last 50 years the population of larger fish species has fallen by 94 per cent. Additionally, nowadays one out of every three freshwater fish species is threatened with extinction.

While freshwater makes up only 1 per cent of Earth's area, it provides habitat for 51 per cent of known fish species, meaning they play an important role in terms of biodiversity. Their loss would further escalate the biodiversity crisis (see main report, Chapter 3.3 Emerging risks). Furthermore, freshwater fish represent an important source of nutrition and income for communities around the world (WWF, 2021). Their loss thus has implications on food security and livelihoods. With at least 43 per cent of the wild freshwater fish harvest coming from 50 low-income, food-deficient countries, the extinction of freshwater fish would make these communities particularly vulnerable as access to other forms of quality food is limited (Darwall & Freyhof, 2016) (Figure 1).

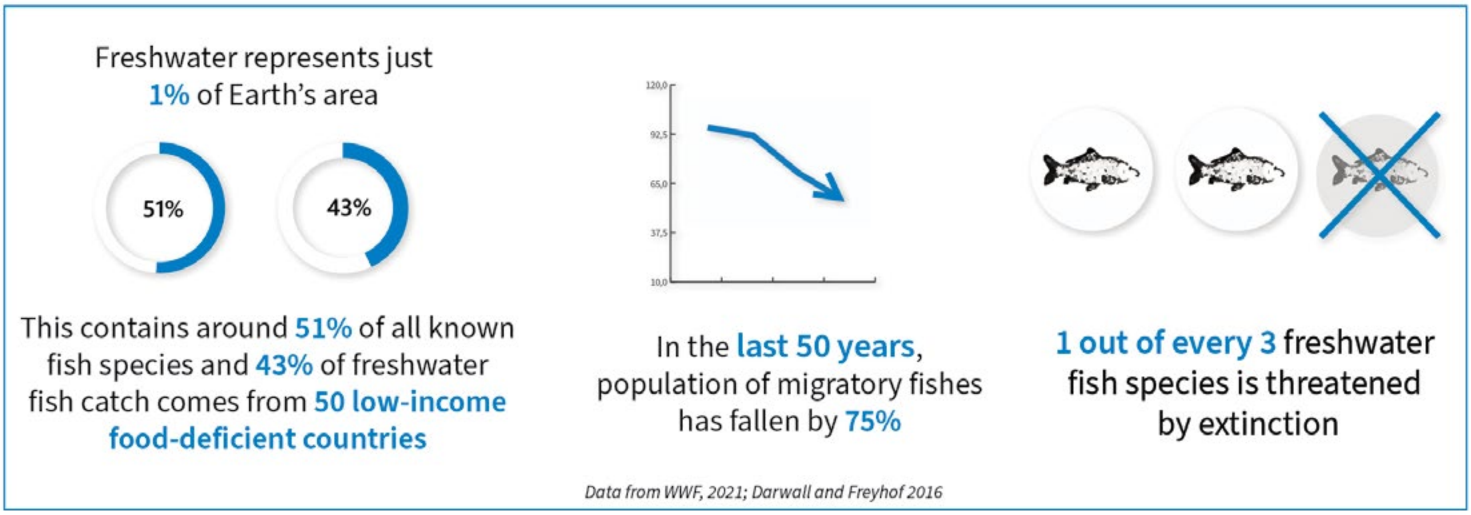


Figure 1. Freshwater fishes in numbers (Data from Darwall & Freyhof, 2016; WWF, 2021).

Loss of biodiversity

Each species is unique and shaped over millions of years of evolution (Rounsevell and others, 2020). Just like with the Chinese Paddlefish, the extinction of many freshwater fishes marks an irreversible loss. Loss is not just concentrated in one specific place, it is also distributed across the globe. For instance, the IUCN Red List of 2019 revealed that over half of Japan's endemic freshwater fishes were threatened with extinction (Ghai, 2019). Similarly in Mexico, a recent study in 2020 showed that at least 165 species (representing 40 per cent of all species assessed) were also threatened with extinction (Lyons and others, 2020).

Loss of food and livelihood sources

The loss of biodiversity is inextricably linked to human wellbeing and can compromise ecosystem functions and ecosystem services (TEEB, 2010). For riverine-dependent communities, the loss of freshwater fishes can translate into loss of livelihoods and loss of food. For instance, the degradation of freshwater ecosystems linked to dams has already impacted more than 120 rivers in 70 countries, deepening the poverty and hunger of hundreds of millions living downstream of dams (Richter and others, 2010).

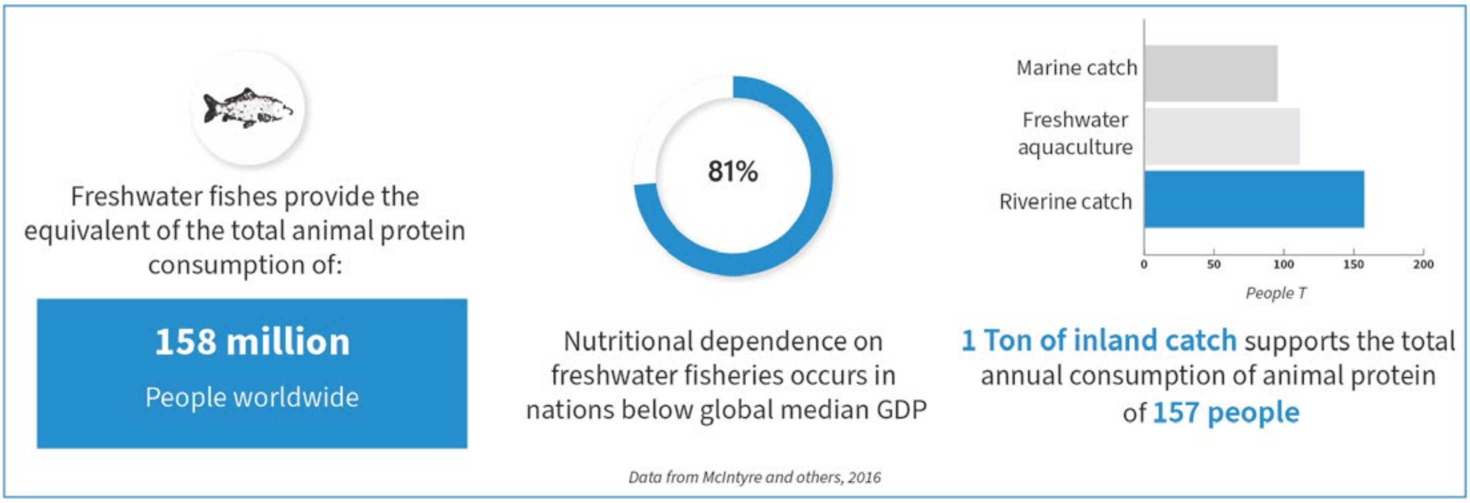
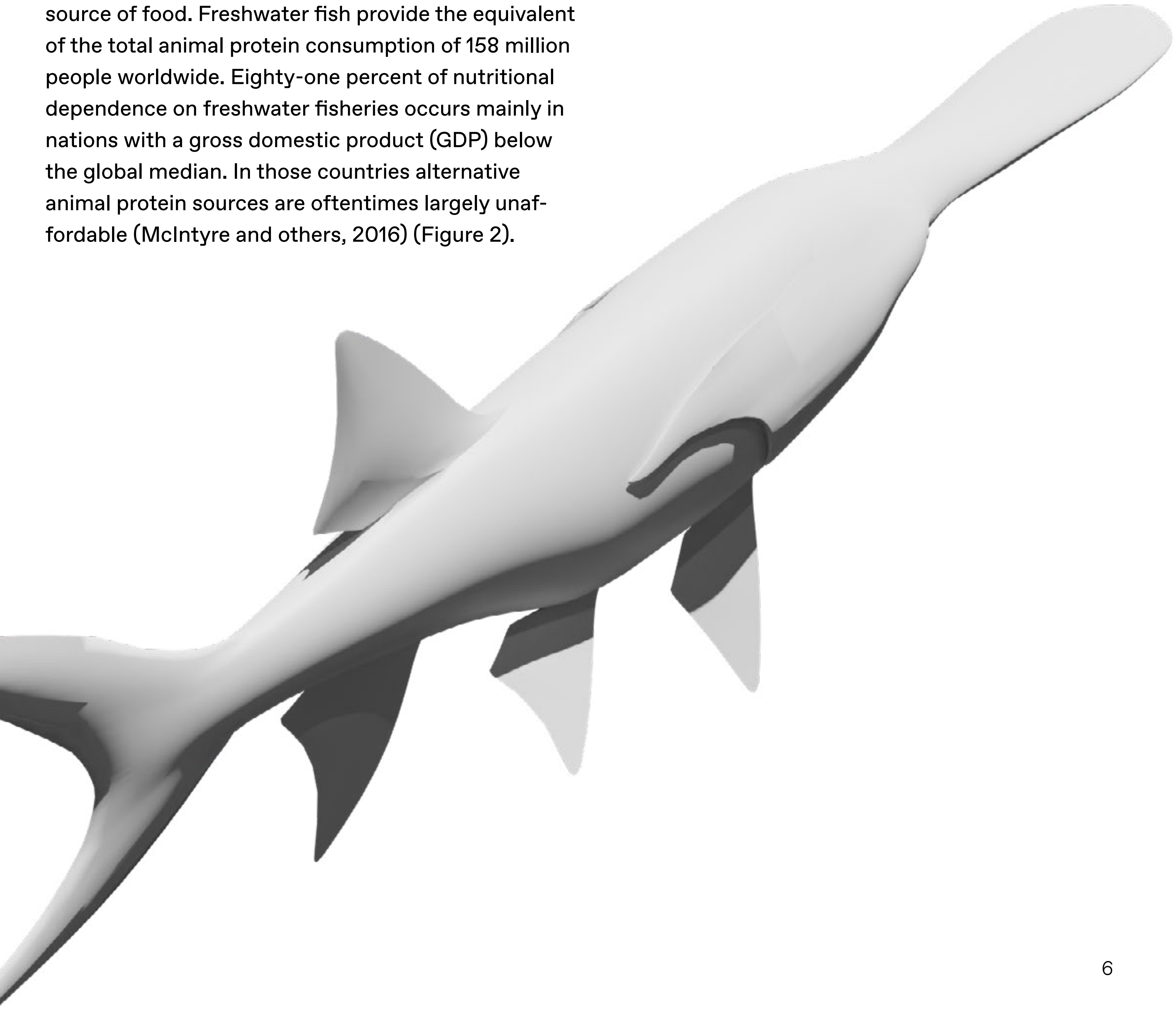


Figure 2. Freshwater fishes and food security around the world (Data from McIntyre and others, 2016).

Particularly in developing countries, fishing plays a crucial role in the generation of livelihoods. It not only includes capture, but also the processing, packing, transport and retailing activities, which represent the main income for many families in rural areas with limited alternative job opportunities (Allan and others, 2005). For many of these families, besides a source of employment freshwater fish are a direct source of food. Freshwater fish provide the equivalent of the total animal protein consumption of 158 million people worldwide. Eighty-one percent of nutritional dependence on freshwater fisheries occurs mainly in nations with a gross domestic product (GDP) below the global median. In those countries alternative animal protein sources are oftentimes largely unaffordable (McIntyre and others, 2016) (Figure 2).



3. Drivers

The main drivers of the Chinese Paddlefish extinction as well as the decreasing number of freshwater fish around the world are habitat fragmentation by dam construction, overfishing and water pollution.

Dams

Dams illustrate the brilliance and arrogance of human ingenuity. They generate one-sixth of the world's electricity and irrigate one-seventh of our food crops. They have flooded land areas the size of California, displaced a population the size of Germany's, and turned freshwater into the ecosystem most threatened by species extinction (Bosshard, 2015)

From a historical and cultural point of view, dam constructions are symbols of modernization (Kaika, 2006), supporting development through the provision of energy and water for human consumption, agricultural irrigation, and in some cases flood risk reduction (Barbarossa and others, 2020). However, they also represent one of the most intense human interventions on the environment, disrupting the hydrology of freshwater systems, and compromising their biodiversity – and consequently the wellbeing of the communities which depend on them (Brown and others, 2009).

With more than 40,000 large dams built since the 1950s globally (McCully, 2001), scientists report that hydropower projects have already altered almost 50 per cent of the river volume due to flow regulation or fragmentation (Barbarossa and others, 2020; Grill and others, 2019). Adding the 3,700 pending construction projects to the equation, it is expected that 93 per cent of global river volume will be altered (Barbarossa and others, 2020; Dasgaputa, 2021; Grill and others, 2015). Although the giant hydroelectric dams are the largest concern, small dams should not be considered less worrisome either: they also disrupt the hydrology and fragment river habitats while being at least three times more abundant than large dams, particularly in tropical regions with high biodiversity value (Vörösmarty and others, 2010). Technical solutions to help migratory fishes overcome these barriers, such as different kind of fish passage structures, are often ineffective and can even turn into 'ecological traps', particularly for migratory freshwater species in the neotropics (Pelicice & Agostinho, 2008; Pompeu and others, 2012; Pelicice and others, 2015).

Dams have been broadly debated worldwide for social impacts such as displacement of people in the areas flooded and their impacts on the livelihoods of riverine communities (Kaika, 2006). They also impact sediment transport, leading to river delta recession and consequently coastal degradation (Luo and others, 2017). Similarly, the role of dams on freshwater biodiversity has been well studied, leading to a good understanding of the processes and impacts involved (Reid and others, 2019).

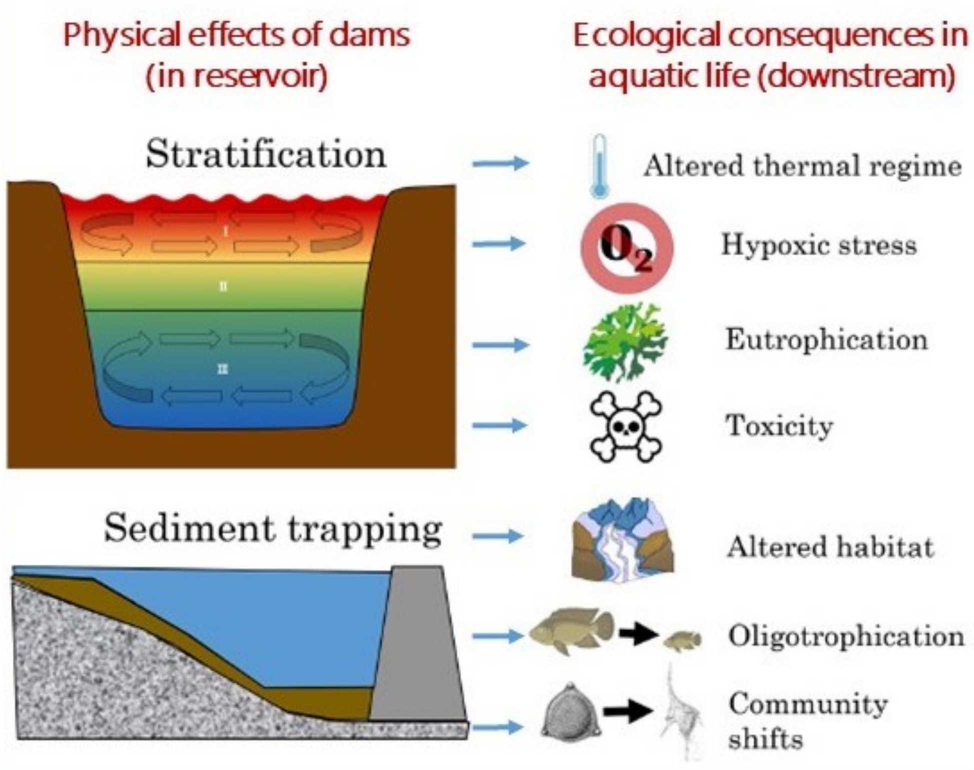


Figure 3. Physical effects and ecological consequences of dams (Adapted from Winton and others, 2019).

In terms of freshwater fish extinction, although understanding the size, location and mode of operation of each dam is critical, the direct impacts can be summarized as:

- The movement of fishes is obstructed (which affects particularly migratory species) as dams fragment the habitat (e.g. obstructing migration routes vital for spawning and feeding).

- Stratification of the water body takes place as a result of the dam, meaning there is no mixing of the water. This can alter flow and thermal regimes and can lead to oxygen depletion (hypoxic stress). Furthermore, stratification changes the nutrient balance that allows algae to bloom (eutrophication), and can result in toxic levels of nutrients (Barbarossa and others, 2020; Dudgeon, 2019). The reduced diffusive vertical nutrient supply due to strengthened stratification and the 'sediment trapping' of dams reduces the nutrients (oligotrophication) available to fish, consequently changing species' metabolism. Furthermore, changes in sediment load may also compromise spawning success due to increasing turbidity leading to environmental degradation (Kjelland and others, 2015) (Figure 3).

The combination of the above-mentioned aspects, along with the specific water conditions of each dam location, can favour generalist species over specialists and promote invasive species and biotic homogenization (community shifts) among others, resulting in freshwater fish extinction in the long-run (Poff and others, 2007; Arantes and others, 2019; Winton and others, 2019) (Figure 3).

It is, therefore, important to consider these implications also in the projection of future dams. For instance, future dam projects include the Amazon, the Niger, the Congo and the Mekong River basins (Barbarossa and others, 2020; Zarfl and others, 2015). Yet, these are all located in the tropics and neotropics where freshwater fishes occur in high diversity. Fishes in these areas amount to approximately 30 per cent of the world's freshwater fish species and about 10 per cent of all living vertebrate species (Pelicice and others, 2017). Furthermore, these regions host most of the emerging economies worldwide and it is in these regions where losing freshwater fish species could have serious impacts on development, including migration, due to loss of income and food insecurity.

Overfishing

Overfishing is one of the major causes of declining fish populations around the world. Although its negative impacts are widely acknowledged in marine ecosystems, the impacts of overfishing have generally been undervalued in freshwater species (Bailey, 2005). Historical disregard for the health and sustainable use of freshwater ecosystems has resulted in alarming rates of loss in the quality and availability of aquatic habitat. The term overfishing generally refers to a form of over-exploitation, where the fish mortality rate is higher than reproduction and stocks of aquatic organisms are consequently depleted to critical levels (FAO, 2001). Specifically, inland overfishing has been identified as one of the reasons for freshwater biodiversity decline in the last 50 years (Allan and others, 2005; WWF, 2021). Typically, overfishing starts with the depletion of late-maturing species, which alters the food chain by removing the larger members of a multispecies assemblage and forcing their replacement by smaller ones. In the case of the Chinese Paddlefish, for instance, large-to-medium-sized individuals were massively fished until 1970. However, the sizes started to dramatically drop in the following 20 years (Zhang and others, 2020), resulting in 'fishing down the food web' through the introduction of a reduced mesh size (Allan and others, 2005) and the exploitation of small, rapidly maturing species.

Overfishing in most cases happens as a response to different global demand pressures, including an increasing food consumption that is connected with the increasing population worldwide (see section 4, Root causes). Both factors have increased pressure on fish supply, and to meet this rising fish demand freshwaters are overfished. Furthermore, the race for higher fish harvests encourages some very destructive techniques, including electric fishing and poisoning, which affect juvenile and adult fish equally and compromise the health of the freshwater ecosystem (Chen and others, 2020). Such practices have been identified also in the Yangtze River basin, which used to be the natural habitat for the Chinese Paddlefish (see Box 1).

Pollution

Pollution of freshwater ecosystems is one of the main threats to the environment and human well-being (Qadri & Bhat, 2020; Winemiller, 2018). The many types of water pollution vary in relation to the different sources – such as runoff from agricultural lands, industrial wastewater and domestic sewage – and the specific characteristics of the freshwater bodies (e.g. lake Vs rivers). Therefore, pollution can have several impacts on freshwater fish species, from alterations to the animal physiology – which could compromise growth and development – to increased mortality and, in extreme cases, the extinction of a species (Winemiller, 2018).

In the case of the Chinese Paddlefish extinction, the pollution in the Yangtze River is one of the main drivers for its disappearance (Zhang and others, 2020). The river is heavily polluted, as it receives 43 per cent of the national total wastewater and several heavy and chemical industries are settled along the river basin. For instance, in 2011 the discharge from industry and urban sewage surpassed 34.2 billion tonnes (37.7 billion tons), which represents more than twice the amount discharged in 1980 – partly due to the increasing growth of four megacities along the basin: Chongqing, Wuhan, Nanjin and Shanghai (Chen and others, 2020). Other examples of freshwater fish extinctions linked to pollution exist around the world, including the crayfish (Austropotamobius pallipes) in Europe (Manenti and others, 2019).

4. Root causes

Full environmental costs undervalued in decision-making

Dams clearly exemplify how environmental costs are not always taken into consideration. Portrayed as symbols of modernity, dams are among the strongest allegories of economic growth over the last 100 years (Kaika, 2006; Zarfl and others, 2015). They support development by providing energy and water for human consumption, agricultural irrigation and, in some cases, protection against floods (Barbarossa and others, 2020). In most cases dams serve two or more purposes and, therefore, have been fundamental for economic development and technical innovation (Chen and others, 2016; Poff and others, 2007). The construction of high dams is favoured by national economic planners because they bring many perks in terms of development (Dasgaputa, 2021).

As a result it is difficult to separate the development of many urban and industrial areas from the landscape interventions of dams. On the other hand, it is almost equally difficult not to reflect on the environmental and social costs for many around the world: the construction of dams clearly threatens both human food security and freshwater biodiversity. The reality is though that development pressures are often stronger and the voice of biodiversity advocacy is not always heard (Vörösmarty and others, 2010).

A literature review by Richter and others (2010) on the effects of dams on people living along more than 120 rivers in 70 countries shows that some people benefitted from dams in terms of improved access to water and electricity, irrigation, flood protection and additional benefits (e.g. health and educational programmes). However, the review also finds that the degradation of freshwater ecosystems has also had the opposite effect for others, deepening the poverty and hunger of hundreds of millions of river-dependent communities located downstream of the dam projects, where the loss of biodiversity is directly connected to the loss of livelihood and food sources. For example, the construction of the Maga dam in 1979 resulted in Cameroon's Logone River losing 90 per cent of its riverine fishes, impacting 130,000 people along the river and leading to the displacement of many (Moritz and others, 2016).

The benefits provided by freshwater ecosystems and their biodiversity are rarely taken into account during dam planning and management (Richter and others, 2010), or they tend to be overshadowed by all the economic benefits the dam will potentially bring, including generation of employment. However, the new jobs and other benefits are not necessarily enjoyed by the communities near the dams and rivers and the consequences of relocating or displacing people, including indigenous people with strong cultural connections to the ecosystem, is a major concern with dam projects, as is the unequal distribution of economic benefits across society (Zarfl and others, 2015).

Global demand pressures and fast development issues

During the last century, dams have become popular and they are now found across the world. In 1950 the total number of large dams was 5,000 globally, mostly distributed in industrial regions of North America and Europe. By the year 2000 that number had reached 45,000, spreading over more than 140 countries, including emergent economies (ICOLD, 2018, in Richter and others, 2010). Many of these dams have helped provide water to cities located in desert regions, such as Phoenix, Arizona; they have provided electricity across the world and they have pushed agricultural growth by supporting irrigation, especially in Asia (Richter and others, 2010). Currently, we are facing numerous pressures linked to global economic development which continuously spur global demand and consumption patterns (Marques and others, 2019). One of these pressures, which involves freshwater ecosystem wellbeing, is the increasing global demand for energy and water consumption. According to the United Nations World Population prospects, by 2050 the world's population will be near 10 billion (UN-DESA, 2021). Along with this population growth, it is expected that demand for water, food and energy will rapidly increase (Chen and others, 2016).

At the same time, there is also an increasing global pressure for reducing carbon emissions (UNEP, 2020) for which hydroelectric dams are considered as one of the best alternatives. Dams could provide electricity for the increasing global population without having to rely on fossil fuels. Countries like China, for example, are building massive hydroelectricity dams as relatively cheap and clean ways to generate electricity to help meet the country's target of being ‘carbon neutral’ by 2060 (Cai, 2021). Finally, global demand pressures can also reinforce the two other drivers: pollution and overfishing (see section 3, Drivers).

At the time the report was published a high-quality photo of the Chinese paddlefish was not available. Therefore the photo shows the American paddlefish (not extinct) which has a strong physical resemblance with the now extinct Chinese paddlefish.

5. Solutions

The dam paradox: when, where and how to build?

In order to address the above-mentioned root causes linked to freshwater fish extinction, and avoid the extinction of other fishes like the Chinese Paddlefish, the single most effective dam development strategy for protecting both social and ecological assets is to avoid constructing dams in the 'wrong locations' (Richter and others, 2010). But how do we know which are those wrong locations? Zarfl and others (2019) analysed future dam projects, finding that most of them are planned primarily in the tropics and subtropics, which – as mentioned previously – encompass key biodiversity hotspots. Therefore, balancing hydropower and biodiversity in basins like the Congo, the Mekong and the Amazon is critical to minimize impacts in such mega-diverse rivers (Winemiller and others, 2016).

Dam construction needs to acknowledge and mediate the trade-offs between different development goals – such as sustainable, clean energy production, irrigation, water supply, biodiversity and riverine livelihood protection – and also acknowledge the different beneficiaries of these benefits both close to and distant from the rivers. Tools, such as the Integrative Dam Assessment Modelling (IDAM), allow us to understand the biophysical, socio-economic and geopolitical relationships involved in dam planning, encouraging heuristic decision-making which, in principle, ensures less damage to freshwater biodiversity (Brown and others, 2009). In addition, dependent on the connectivity of each river basin, both upstream and downstream impacts of each dam building project need to be part of the assessment (Zarfl and others, 2019). The so-called 'river report cards' created by WWF for the Orinoco River basin in Colombia allow for such holistic assessment, by including social, economic and environmental aspects. In addition to the ranking system methodology based on indicators, these cards involve local stakeholders to ensure a participatory and inclusive process in decision-making (WWF, 2016). Finally, if the ultimate decision is to build a dam, it is recommended to include an active adaptive management plan for each dam project in order to understand, and adequately react to, the changing ecosystem conditions in each river basin. To that end, it is important that both governments and stakeholders understand that once a dam intervention is planned, the process is not concluded with its construction; rather, continuous monitoring and evaluation needs to be included through the life span of each project (Richter and others, 2010).

Acknowledgements

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At the time the report was published a high-quality photo of the Chinese paddlefish was not available. Therefore the photo shows the American paddlefish (not extinct) which has a strong physical resemblance with the now extinct Chinese paddlefish.

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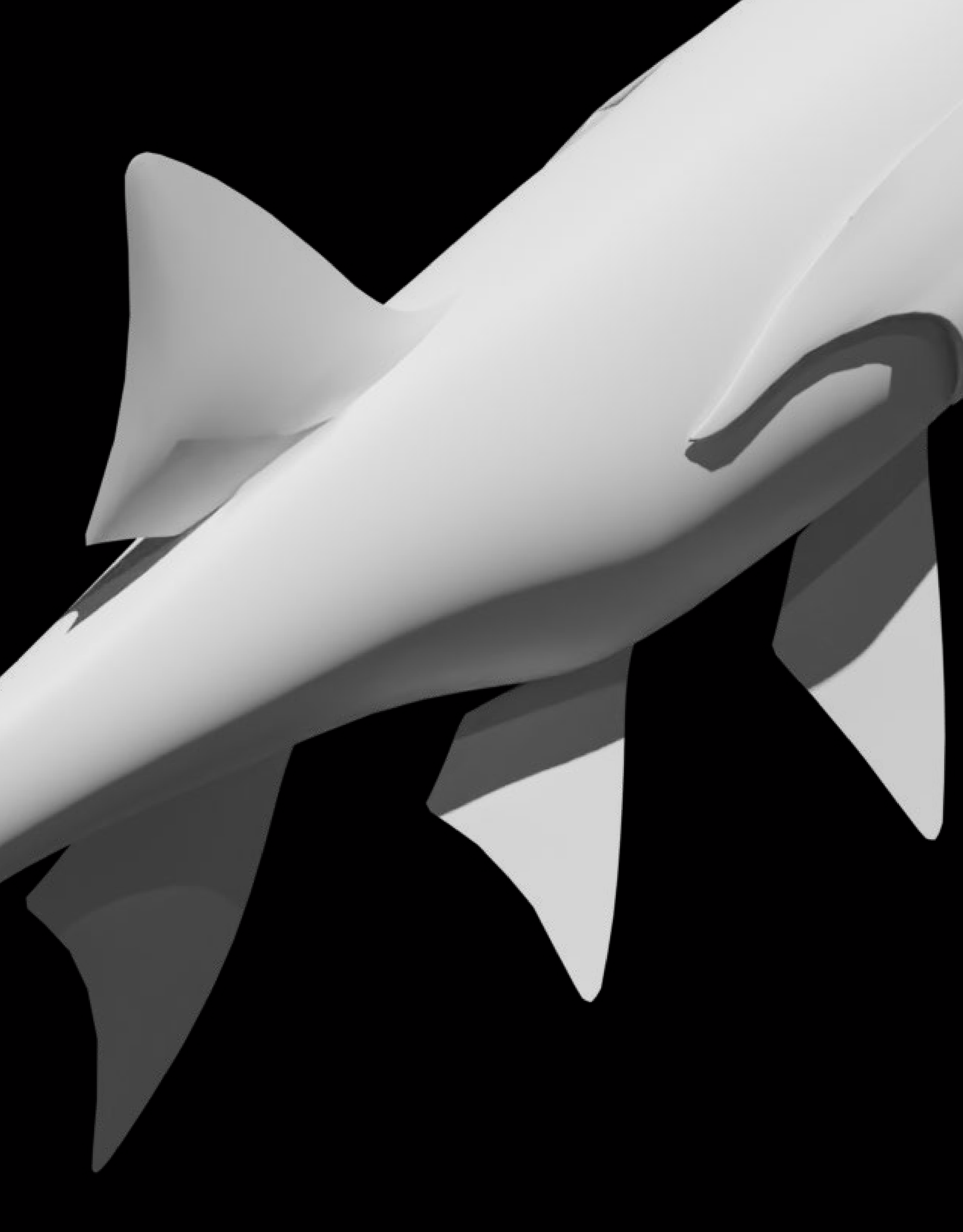

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