7 The Sanaga River, an Example of Biophysical and Socio-Cultural Integration in Cameroon, Central Africa

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Summary

The Sanaga River is the largest in Cameroon and one of the main resources for the economic development of the country. A lack of electricity is one of the primary setbacks for the Cameroonian economy, and the national authorities plan to at least double, from 2,000 MW, the nation's hydropower electricity supply by 2035. Representing more than 75% of the estimated total hydro potential of Cameroon, the Sanaga River has one of the greatest hydropower potentials in Africa. As well as being a vital asset for the national economy, it possesses exceptional natural features such as waterfalls, biodiversity hotspots with endemic and rare wildlife (e.g., the West African manatee, hippopotamus, chimpanzee and forest elephant), and very high cultural diversity, with numerous ethnic groups represented. There are many human activities along the river (use of water resources for food security and irrigated agriculture, inland fisheries, intensive aquaculture, sand extraction and hydropower production) that are increasing, and with visibly detrimental effects. The construction of dams has forced the local population to move from one livelihood activity to another. The unique cultural heritage and biodiversity are hence under pressure, due to over-fishing, logging, hunting, agrochemical pollution and habitat destruction. Unfortunately, the management actions necessary for remediation of these detrimental impacts are not well captured in basin development plans. It is therefore considered urgent to implement more sustainable human activities, including the development of alternative economic resources, such as ecotourism.

7.1 Introduction

The Government of Cameroon has adopted ambitious development goals and its vision for 2035 sees Cameroon becoming a middle-income, industrialized country with poverty levels below 10% by 2035 (Nations Unies, NU, Cameroon 2018). In the context of the Government of Cameroon's development plan towards becoming an emerging economy by 2035, the lack of electricity is one of the five most important constraints identified by, among others, the private sector. The country is mainly reliant on hydropower for electricity generation, with 73% of total electricity generation in 2014 comprising hydro (Muh et al. 2018). However, the nation's renewable energy sources are not considered to have been properly harnessed, and there are persistent power outages throughout Cameroon, particularly in the dry seasons when water levels are low (Muh et al. 2018). A shortage in

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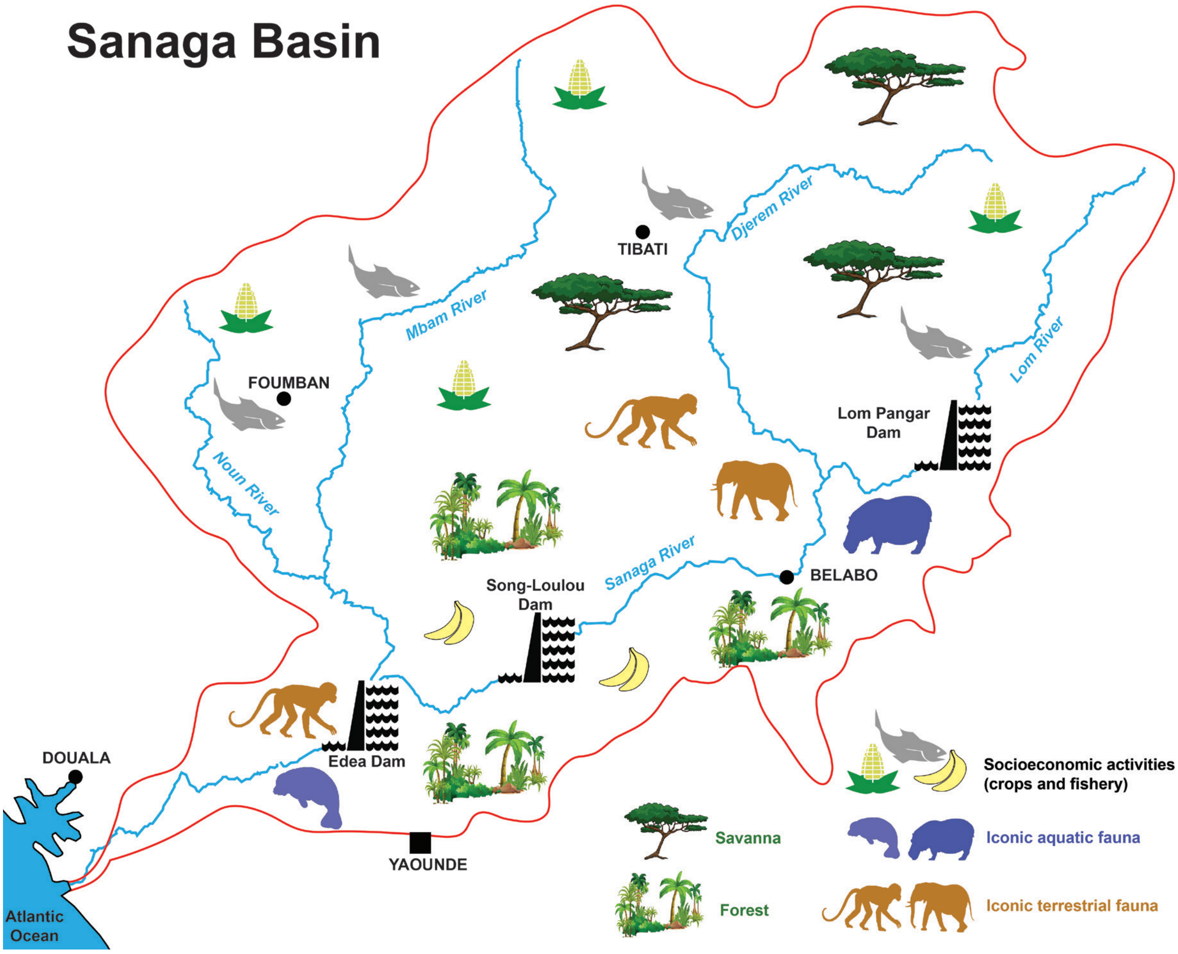

Fig. 7.1 Graphical abstract: The Sanaga Basin illustrating the distribution of the main iconic fauna and economic activities. Graph: Christophe Piscard

the production of electric power has already led to a decrease in financial benefits and is considered to be the main reason for the decline in the economic sector observed in Cameroon since 2000 (Republic of Cameroon 2010). To improve this situation, the Cameroonian authorities proposed a 2035 Strategy Development Plan for the Energy sector (Plan de Développement à long terme du Secteur de l'Électricité Horizon 2030, PDSE) (MINEE 2006). In the plan, the Government stated the goals to reach an electricity production capacity of at least 3,000 MW by 2020 and 6,000 MW by 2030, and to increase the rate of electricity access from the current level of around 55% to 75% by 2020; access is far lower in rural than in urban areas, at around 14% (Muh et al. 2018). To reach these twin goals, several steps have been proposed, one of which is to focus on increasing energy production within the Sanaga River Basin, where half of the potential is concentrated and it is proposed to concentrate most of the planned power plants (The World Bank 2018).

Unfortunately, for the Sanaga River, as in other places in the world, environmental protection was not accorded the attention it required in the development plan (Hugon 2005). Intended economic growth and benefits have been the principal considerations in the conception and proposed execution of new projects, with the assessment of impacts such as flow alteration, environmental pollution, decrease in wildlife resources, and the long term and transgenerational effects of economic activities neglected (Hugon 2005). The Sanaga River and its basin cover almost 25% of the total surface area of the country and its biodiversity, especially in the lower part of the basin, is among the most important in Africa (Darwall et al. 2011). The basin encompasses several biodiversity hotspots, including the Cross-Sanaga-Bioko Coastal Forests ecoregion, the Douala-Edea Forest Reserve, and the Lake Ossa complex. These areas comprise lowland, coastal forests as well as mangroves, with very high faunal biodiversity and regional endemism (Thieme et al. 2005, Kamdem Toham 2006). For example, the basin comprises the ecoregions 518 and 519, defined by Abbel et al. (2008) for freshwater fishes, which are characterized by a high diversity and rate of endemism. Regardless of

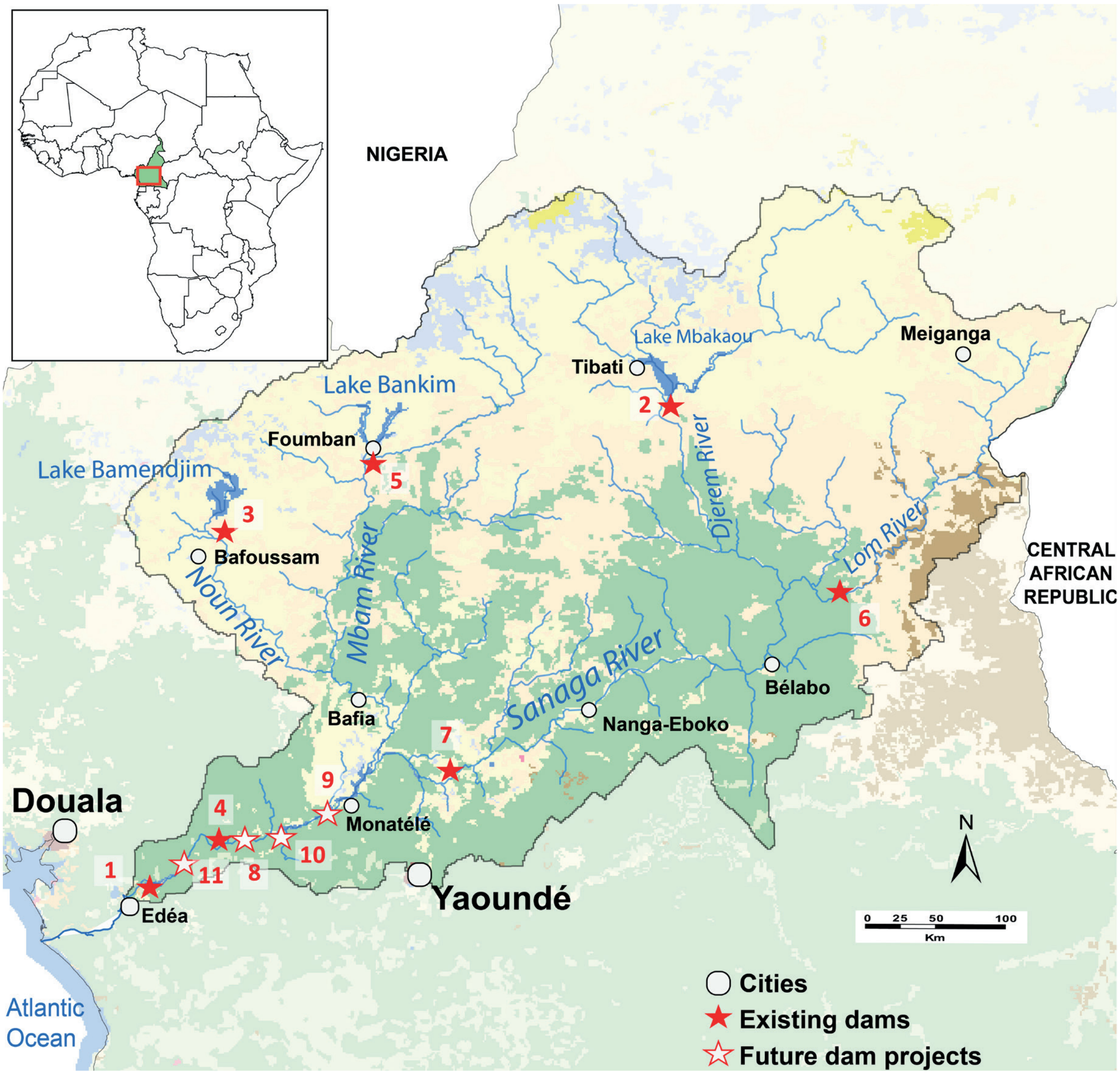

Fig. 7.2 Map of the Sanaga River Basin with the location of existing and proposed dams. Existing dams (*red stars*) are ranged from the oldest to the newest: 1. Edea Dam; 2. M'Bakaou Dam; 3. Bamendjing; 4. Song-Loulou Dam; 5. Mape Dam; 6. Lom Pangar Dam; and 7. Nachtigal Dam. Future dam projects (*white stars*) are ranged according to their projected year of construction: 8. Song Mbengué (2024); 9. Kikot (2026); 10. Grand Eweng/Ngodi (2028); and 11. Song Dong (2030). Map: Serge H. Zebaze Togouet

their recognised ecological importance, most of these areas are under pressure, due to over-fishing, logging, hunting and habitat destruction. Changes in the flow regime of the river have detrimentally affected the downstream habitats, important for threatened birds and protected manatees, both IUCN red list species ,and the overall ecological health and processes of the river system. There appear to be relatively few strongly developed cultural associations between different ethnic groups and the Sanaga River, but this may reflect the limited extent of readily available knowledge on this subject.

Despite environmental and social issues of major concern in the Sanaga River Basin, our review of the literature reveals a lack of scientific studies on past, ongoing, and future human impacts on the Sanaga River, as well as of joint consideration of ecological and sociocultural issues, such ethical and aesthetic considerations. However, scientific and other stakeholders, including local people, government authorities, NGOs, and industry need to build a common initiative for the sustainable use of the natural resources of the Sanaga River.

7.2 Geophysical setting

The Sanaga River is the largest river in Cameroon. Its drainage basin covers almost a fourth of the country, at about 140,000 km^2 (Republic of Cameroon 2009) (fig. 7.2, table 7.1). It flows for 918 km from its source on the Adamawa Plateau

Table 7.1 Main characteristics of the Sanaga River Basin

Sanaga River	
Countries in the catchment	Cameroon
Catchment size (km^2)	140, 000
Length (km)	918
Mean (min/max) annual discharge (m^3 s^{-1})	2,070 (234/6950) at Edéa Dam
Hydrological pattern	Hydrology is related to rainfall; perennial flow regime, with a short wet season (Sep. to Nov.) and a protracted dry season low flow period, from Dec. to Jun. The three sections of the catchment have distinctly different types of flow regime according to their climate conditions and topography.
Degree of naturalness	Near-natural in the lower section, but disturbed by dams in the middle and the upper sections. Agricultural activity is present throughout but is not intensive. Banks are natural.
Natural landscape types	Savanna floodplains in the upper river section, followed by a river corridor intersected by narrow canyons and waterfalls in the middle section, and a forested floodplain and braided channel in the lower section
Impact types	The main impacts are related to the 7 existing dams in the Sanaga Catchment (with 4 others already planned), the largest of which is located at Song-Loulou (35 m wall height) (see table 7.2 for dam characteristics).
Largest cities (inhabitants)	Edéa, with around 125,000
Urbanization	Very few, only small cities and towns
Protected areas (km^2)	Less than 5% of the catchment is under some form of protection. The main areas are the Mbam Djerem (4,200) and Mpem Djim (975) national parks, and Douala-Edéa Wildlife Reserve (1,600).
Prevailing land use form in the catchment	Forestry, food crops, cattle farming, palm oil production (lower section of the basin)
Famous elements of biodiversity	West African manatee, hippopotamus, chimpanzee, dwarf crocodile, many birds and fishes (table 7.3 gives details)
Famous elements of culture	Fishing, hunting of basin wildlife, tremendous ethnic diversity, with more than 50 ethnic groups

to its mouth at the Atlantic Ocean just south of Douala. Its mean annual discharge is 2,070 m^3 s^{-1} (measured at Edéa Dam).

The Sanaga River is formed by the confluence of the Djérem and Lom rivers. The river originates as the Djérem River, near the town of Garba in the administrative department of Mbéré, at an altitude of 1,150 m. From its source, the Sanaga flows from North-East to South-West Cameroon, through six of the 10 provinces of the country, namely the Adamawa, North-West, West, East, Central and Littoral Provinces. The river has a maximum width of 320 m above the confluence with its major tributary, the Mbam River, and terminates in a 600 m-wide estuary 67 km downstream of the city of Edéa, in the Gulf of Guinea. While the capital city of Yaoundé is not situated within the catchment of the Sanaga, it is located very close to the boundary.

The Sanaga River is divided into three sections defined by basin topography and climate (Olivry 1986), as discussed further in section 7.4 (fig. 7.2).

The Upper Sanaga (400 km long) corresponds to the Djérem-Sanaga River and its major tributary in this part of the basin, the Lom River, in the Adamawa Region. This part of the basin

Table 7.2 Existing dams on the Sanaga River Basin

Dam Name	Year of Construction	Function(s)	Volume/Capacity
Edea Dam	1954	Hydropower	Unknown storage volume/276.4 megawatts (MW)
M'Bakaou Dam	1969	Water regulation (i.e. water storage and flood control)	2,600 km^3
Bamendjing Dam	1975	Water regulation	1,850 km^3
Song-Loulou Dam	1976	Hydropower	5,000 km^3/384 MW
Mape Dam	1988	Water regulation	3,300 km^3
Lom Pangar Dam	2015	Hydropower and water regulation	6,000 km^3/120 MW
Nachtigal Dam	2022 (construction ongoing since 2019)	Hydropower	6,100 km^3/420 MW

has a humid tropical climate, with a dry season of five months and a rainy season lasting seven months. This part of the basin has an average altitude of 1150 m asl, with annual rainfall ranging between 1,500 and 2,000 mm y^{-1}.

The Middle Sanaga (450 km long) extends from the city of Goyoum to the city of Edéa, upstream of the littoral plain, and the main tributary is the Mbam River; Annual rainfall in this part of the basin ranges between 1,500 and 2,000 mm y^{-1}, which falls in two distinct rainy seasons, a short wet season from March–April and a second, with higher rainfall, from September to October. This river section varies in altitude from 950 to 400 m asl.

The Lower Sanaga (67 km) extends from downstream of the Edéa Waterfall to the coastal mouth of the estuary (10–15 km long). Rainfall within this coastal area is amongst the highest in the world and exceeds 4,000 mm y^{-1}. The average basin altitude of this river section is 396 m asl.

The present-day hydrology of the Sanaga River Basin is strongly influenced by seven existing dams, among which three were built for water regulation during the dry season (table 7.2).

7.3 Historical introduction

Prehistoric times are poorly known in this part of Africa and the origins of people are not clearly established (see review in Delneuf et al. 1998). However, archeological investigations testify to a human presence in North Cameroon since at least 46,000 BC; the oldest skeleton found in Cameroon is dated at 7700 BC and was discovered in the western part of Cameroon, near the city of Bamenda (fig. 7.2). The skeleton exhibited 'bantoid' traits. The Bantu people started to colonize the Sanaga Basin in around 3000 BC, from mountain areas between Nigeria and Cameroon, and the mountains around Yaoundé around 1000 BC. Between 3000 and 1300 BC, a second colonization event occurred to colonize the northeastern part of the Sanaga Basin, from the Central African Republic. For the Pygmies, the other old African ethnic group, their establishment in the southwestern part of Cameroon could be more recent, at 400 years ago.

More information is available after 1850, following the exploration of this area by German colonialists (Alexandre 1965). Consequently, we focussed our survey on the literature of the colonization of the Sanaga River Basin since the 18th century by the Pahuin (or Beti) people, the dominant ethnic group in the catchment (fig. 7.3). The Pahuin are divided into three main subgroups: the Beti, the Fang and the Bulu. Each group is further divided into smaller groups, in total representing around 20 different ethnic groups. The Pahuin are themselves a member of the Bantu group, which is widespread in Cameroon, Congo, Gabon and Equatorial Guinea (Yakan 1999). Pahuins started to colonize the Sanaga River around 1840, to escape attacks by the Bamun and Tikar peoples. The dispersal of the Pahuin was rapid. This was likely facilitated by the low numbers of local people inhabiting the rainforest, except for Pygmies and possibly descendants of the Fan (the Mvumbo and Mäkaa ethnic groups) who became established in Gabon perhaps as early as the 14th or 15th century (Alexandre 1965, Delneuf et al. 1998).

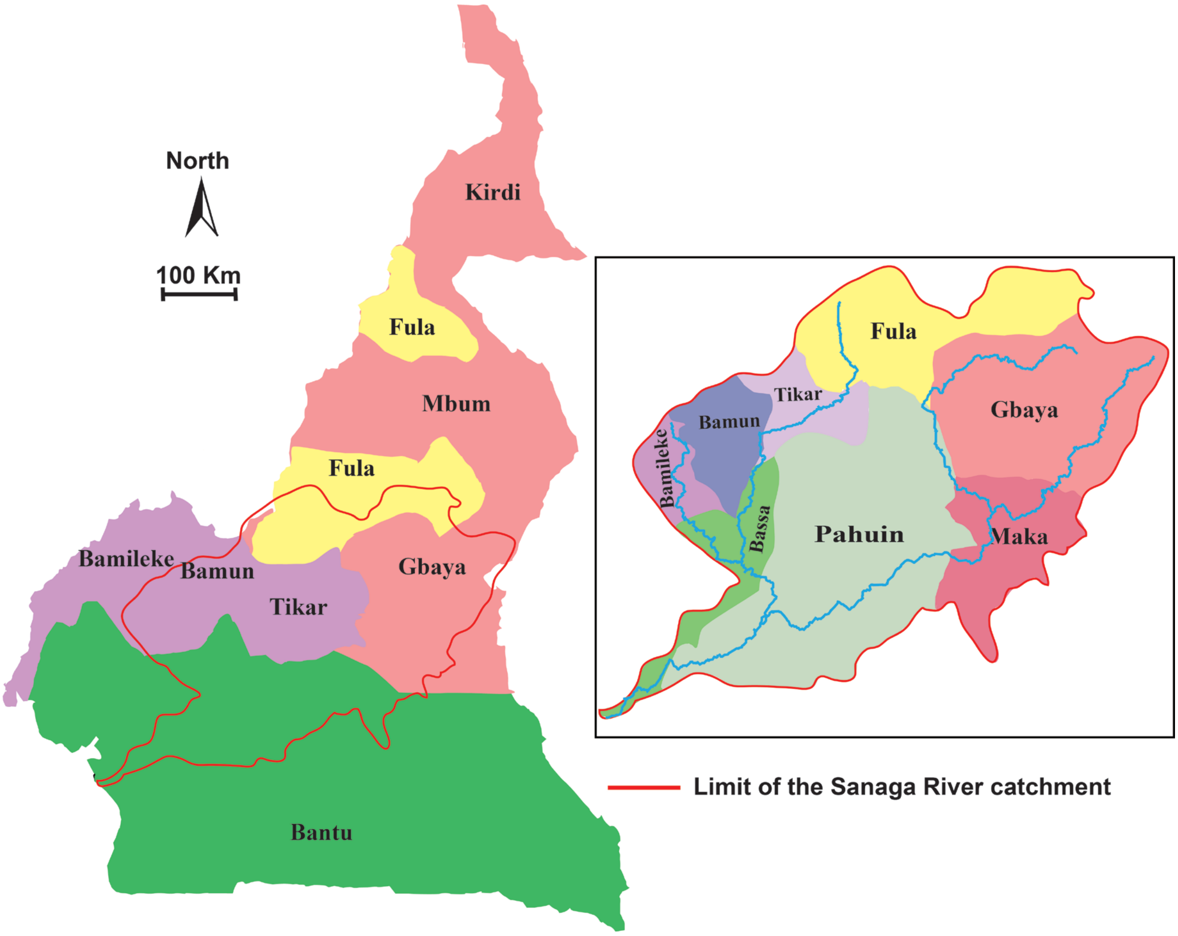

Fig. 7.3 Distribution of the main ethnic groups in Cameroon (*left*) and the Sanaga River Basin (*right*). Map: Serge H. Zebaze Togouet, based on Yakan (1999)

The economy of the Pahuins was mainly dominated by metal work, food agriculture (coffee, cocoa, cassava, corn, and banana) and hunting (bushmeat). The Pahuins and the other ethnic groups did not develop a specific relationship with the Sanaga River and have mainly lived on hilltops, to avoid unhealthy conditions in the wet lowlands. However, fishing represents one of the most important sources of food for people. Archeological investigations testify to the use of canoes and the consumption of fish since at least 1000 BC in this area (Mbida 1998). In Cameroon, freshwater fish is one of the main sources of protein, representing 40% of animal protein and 9.5% of the total food needs (Ministry of Livestock, Fisheries and Livestock/Animal Industries, MINEPIA 2009). Each ethnic group has developed its customary fishing methods that have led to the development of numerous varied fishing techniques, including traditional methods, such as using nets, creels (baskets), and dams for fish and crustaceans (Dounias 2015).

Fishing is also associated with the reservoirs of the dams, with the fishing culture having changed in part as a result of settlement by foreigners. More than 350 fishers were estimated to be located around and dependent on the fishery created by the Lom Pangar Reservoir (Global Water Partnership 2009). Officially, since its impoundment in 2015, over 6,000 fishermen have been reported to be active in the reservoir waters of Lom Pangar Dam, but they have been mostly supplying fish distribution networks outside the country. According to the Minister of Livestock, Fisheries, and Animal Industries, industrial fishing in the reservoirs of the various dams in operation is planned, to help close the significant gap between the supply and demand for fish in the country, and thereby, reduce imports (Business in Cameroon 2021).

7.4 Key elements of biotic diversity

From source to estuary, the Sanaga River crosses the Soudanian and the Guineo-Congolian domains, each characterized by specific environmental factors, such as soil and vegetation type, climate and water resources (fig. 7.5). Unfortunately, data on the distribution of plants and animals in Cameroon are limited and most of the available information is restricted to national parks and wildlife reserves (Global Water Partnership 2009, Darwall et al. 2011).

The upper section of the Sanaga River (i.e., the Djérem-Sanaga River) is characterized by Savanna vegetation growing on ferralitic brown and red soils, mixed with hydromorphic soils with an intermediate ability to store water (Olivry 1986). This section of the Sanaga River Basin is characterized by alternating dry and wet seasons throughout the year, which allow the development of plant characteristics of the Soudanian domain and more precisely the Soudano Guinean part (Yonkeu 1993). The plant community is dominated by *Triplochiton scleroxylon*, *Terminalia superba*, many Sterculiaceae, *Daniella oliveri*, *Lophira lanceolata*, *Annona senengalensis*, *Khaya* spp., and *Xylopia oethiopica* (Stohlgren et al. 1999). The downstream-most local catchment of the upper river is an ecotone between the tropical forest and the savannah. This area presents a great diversity of habitats and harbors fauna and flora characteristic of both evergreen forest and savanna. At least 60 species of mammals belonging to 10 orders and 26 families are recorded (Nchanji and Bechem 2001, Wilkie et al. 2006). The great mammals are well represented by elephant (*Loxodonta africana africana*), buffalo (*Syncerus cafer nanus*), and the river-dwelling hippopotamus (*Hippopotamus amphibious*) (Nchanji and Bechem 2001). Other iconic water-associated species include the giant otter shrew (*Potamogale velox*) and water chevrotain (*Hyemoschus aquaticus*) (Nchanji and Bechem 2001). The basin's rich avifauna of 362 birds within 53 families (Bobo et al. 2006) is characterized by 18 of the 45 bird species of the Soudano-Guinean savannas and 112 of the 215 species of the Guineo Congolian forest in Cameroon. As for mammals, the bird community is composed of species representing both forest and savannah. Two rare and threatened bird species are present: the Bamenda apalis (*Apalis bamendae*) and white-collared starling (*Grafisia torquata*) (Bobo et al. 2006). Preliminary investigations also revealed 65 species of reptiles with 14 families. Amphibians remain poorly known. The fish community of between 200 and 260 species includes 24 species endemic to the Sanaga River, some of which are critically endangered on the IUCN red list (Dajet and Despierre 1980, Bitja Nyom et al. 2016). These species are 12 species of *Aplocheilidae* and 13 species of *Cyprinidae*, of which three are endemic to the Sanaga River (*Aphyosemion bamilekorum*, *Aphyosemion franzwerneri* and *Barbus bourdariei*); 10 species of *Cichlidae* (*Hemichromis elongatus*, *Oreochromis niloticus*, *Tilapia camerounensis* and *T. guinnensis*) have been reported (The World Bank 2011). There are also seven native species of Clariidae from the Sanaga Basin that are widely used in fish farming (including *Clarias camerunensis*, *C. gariepinus*, *C. jaensis* and *C. pachynema*).

In the middle and lower sections of the Sanaga River, moist seasonal tropical forests occur whereas, along the lower reaches of the Sanaga River, the rainforest is dominated by Lophira alata and Saccoglottis gabonensis (Fomete and Tchanou 1998). Among dominant plant species are certain Oleaceae (*Coula edulis*), Ebenaceae (*Diospyros* spp.), Cesalpinaceae and Guttiferae (*Garcinia* spp.), and in the wetlands, members of the Euphorbiaceae (*Protomegabaria stapfiana*, *Dichostemma glaucescens*, and *Anthonotha aubryanum*). We also found the rare endemic aquatic plant, *Ledermanniella sanagaensis*, for which the only one known locality, the Nachtigall Falls, is threatened by the ongoing construction of the Nachtigall Dam. Several other types of vegetation according to drainage, elevation and type of soils were also identified (Newbery and Gartlan 1996). This part of the basin harbors many species, including threatened terrestrial species such as the African forest elephant (*Loxodonta africana cyclotis*), bushpig (*Potamochoerus larvatus*), and many primates and antelopes, and the aquatic West African manatee (*Trichechus senegalensis*). Thirty-five bird species and 22 families with two protected species: the Hartlaub's duck (*Pteronetta hartlaubii*) and the Grey Parrot (*Psittacus erithacus*) (Van der Waarde 2007) were reported. The fish community is dominated by catfishes (*Arius* sp.), African brown snapper (*Lutjanus endecanthus*), and *Scomberromorus* spp. The Lom Pangar Dam social and environmental impact study suggested the introduction of a fish community comprising mainly native species into the reservoir (Watershed Task Group 2008). The herpetofauna includes the Nile crocodile (*Crocodylus niloticus*), dwarf crocodile (*Tetraspis ostelamus*), monitor lizards (*Varanus* spp.), snakes, freshwater turtles and tortoises (Cameroon Wildlife Conservation Society 2001).

There are few data on the conservation status of biodiversity in this part of Cameroon. However, recent surveys between 2014 and 2016 in the eastern part of the country highlighted that 70% of elephants have disappeared during the last 15 years (N'Goran Kouame et al. 2017). Although the study did not include the Sanaga River Basin, some populations of elephants and apes are present in the Sanaga and suffering the same threats as in the adjacent areas.

The freshwater manatee populations seem to have been stable over the last decade, but the species remains threatened, mainly by fishing practices and habitat degradation due to high water pollution levels.

7.4.1 Conservation efforts for the African manatee

The most successful example of wildlife conservation in the basin is that of the West African manatee, *Trichechus senegalensis*. The West African manatee is protected in Cameroon (Section 69, Class A of the Regulation of Forestry, Wildlife and Fisheries). It is not permitted to be hunted, and its exploitation is subject to obtaining a capture permit, issued by the Department of Forest, Wildlife and Fisheries. However, in areas near the country borders (Korup and Mamfe regions, and Nigeria, the Ntem River in Kribi region, and Equatorial Guinea) the exploitation of manatees by Nigerians fishing in Cameroon is still common (Grigione 1996). Being a large animal, a manatee catch is invariably highly prized by local fishermen. The meat is widely considered delicious, whilst many other parts of the animal are consumed and used for traditional medicine, including the oil, skin and bones. Across most of its regional distribution, the West African Manatee though to have therapeutic properties for various ethnic groups. In Cameroon, this is not the case in the Sanaga River Basin, however, where local people do not like the smell and taste of manatee meat (Grigione 1996). Furthermore, the medicinal use of manatee body parts is almost unknown of in the study area (Mayaka et al. 2013). In terms of their diversity and sophistication, none of the assortment of hunting methods and tools used locally is strong enough to accidentally catch manatees, in contrast with lakes where commercial fishing is concentrated and where the accidental catches are threefold greater than in rivers (Mayaka et al. 2013). Additionally, the low density of inhabitants in the lower part of the Sanaga River contributes to the conservation of manatees. Indeed, the low number of people means there is a low amount of waste dumping in water bodies, in comparison with other reaches of the Sanaga River. However, industrial and subsistence farms surround water bodies, often extending right into the shorelines. This situation poses a major risk of pollution from agricultural fertilizers and pesticides. In particular, discarded waste may cause digestive blockage due to the ingestion of foreign objects, whilst a variety of pathogens and contaminants can cause several illnesses to manatees (Bonde et al. 2004).

7.5 Key elements of cultural diversity

Surprisingly, the Sanaga Basin lacks big riparian human settlements. Except for Edéa (125,000 inhabitants), there is no large city within the catchment. The other important places for ethnic groups within the basin (e.g., Bafoussam, Ngaoundéré, and Foumban) (fig. 7.2), are located along tributaries of the Sanaga River. However and as for Edéa's inhabitants, people of living in these cities did not develop strong cultural relationships with the rivers. More generally in Cameroon, only a few water-related ethnic groups have developed a cultural relationship with water (e.g., the Douala ethnic group who celebrate the Wouri River every year) but they are located along the Atlantic Coast far from the Sanaga River. The relationships between different groups of people and the Sanaga River mainly involve the exploitation of natural resources provided by the river (fig. 7.5), as discussed further below.

7.5.1 Crop agriculture, fisheries and water resources

The water resources of the river are used for irrigation by agro-industries in the Sanaga River Basin, such as sugar cane, tobacco, rice, vegetables and cattle rearing, as well as by local farmers to improve crop yields. There has been a progressive increase in the use of pesticides over time in the upper Sanaga Catchment. Irrigation agriculture has been widely developed, in the upper and middle parts of the basin, and is used for rice production, for example, in the Ndop Valley (Bime et al. 2015). The Bamendjing Dam (table 7.1) was not constructed with irrigation in mind, however, and the rice fields upstream make the reservoir poorly sized as a source of irrigation water.

The water levels in the other reservoirs are also managed for hydropower needs without clear integrated uses (e.g., for crop irrigation) and probably leave room for increased water use efficiency. As the reservoirs have evolved for multiple purposes since their construction, they have increasingly become important sources for commercial uses and cultural objects. An integrated approach allowing all usages (water supply, hydropower, fisheries, crops, biodiversity and tourism) would improve the management of the water resources (see 7.7).

The Cameroon water utility company diverts water from the Sanaga River, treats it, and then supplies it to the population of Yaoundé; the river thus represents a major water source for the city (located outside the basin).

The consumption of fish is very important for people, even for people living far from the

Table 7.3 Key elements of biodiversity in the Sanaga River Basin

Key element	Link to the natural flow regime	Ecosystem services	Human use and threats
Savanna	Plant growing during the wet season and fertilization of soil during flood events	Habitat for many species	Cattle farming, crop production, hunting
Mangroves	Growing on river bank and in wetlands and are dependent on flood events to convey freshwater, sediments and nutrients	Nursery for many species, biodiversity	Fishing, purification of water, food and wood production
Tropical rainforest	Flooding events eradicate pests, fertilize soils and disperse seeds (hydrochory)	Habitat for a high biodiversity, purification of air	Carbon sequestration, wood production, hunting
Ledermanniella sanagaensis	Endemic plant of the Nachtigall Falls	Habitat and food	Tourism
Primates (*Pan troglodytes*, *Cercopitecus* spp.)	Wetlands are a habitat for these species and a protection against hunting (for bushmeat).	Biodiversity	Tourism, food
Forest Elephant (*Loxodonta cyclotis*)	Wetlands are a habitat for these species and a protection against poaching.	Biodiversity, 'ecosystem engineers'	Tourism, hunting
Hippopotamus (*Hippopotamus amphibius*)	Amphibious and dependent on aquatic habitats e.g., deep pools, and grazing in riparian zone	Biodiversity	Tourism
West African Manatee (*Trichechus senegalensis*)	Lives in aquatic environment and reliant on habitat connectivity between the Sanaga River and adjacent lake systems, and of these areas	Biodiversity, 'ecosystem cleaner', important species helping drive wider conservation efforts	Tourism, traditional rites
Hartlaub's duck (*Pteronetta hartlaubii*)	Lives in aquatic environment	Biodiversity	Tourism
Elephant fish (*Marcusenius sanagaensis*)	Endemic living in aquatic environment	Biodiversity	Fishing for food
Bamileke killifish (*Aphyosemion bamilekorum*)	Lives in aquatic environment	Biodiversity	Aquarium trade
Barbus bourdariei (fish)	Lives in aquatic environment	Biodiversity	Fishing, aquaculture
Nile crocodile (*Crocodylus niloticus*)	Lives in aquatic environment	Top predator, regulating the population of other predators	Tourism, food
Dwarf crocodile (*Tetraspis ostelamus*)	Lives in aquatic environment and reproduces in riparian areas	Top predator	Tourism, food

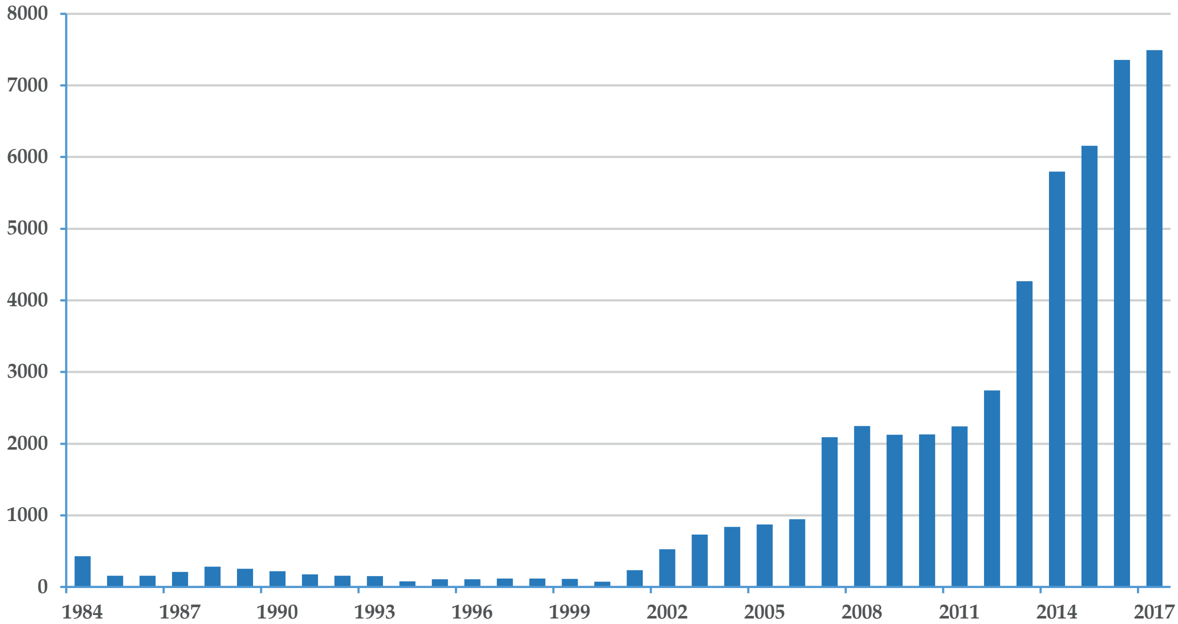

Fig. 7.4 Annual fish aquaculture production (in tons) in Cameroon. Graph: Christophe Piscart, based on data by FAO FishStat (2019)

sea. A lot of people prefer fish to meat and they catch freshwater fish from rivers and streams using varied fishing techniques (nets, creels, etc.). Many villages also organize collective fishing events, by creating small temporal dams on small streams with a mix of branches, mud and clay. Women and children use small nets to catch all of the fishes trapped in these small reservoirs. This collective fishing happens one or two times a year and the fish catches are shared among participants; the dams are destroyed immediately after the fishing event. Several reservoirs (Lom Pangar, Bamendjing, Song Loulou, and Mapé, table 7.1) are also important fishing places for the local population. Moreover, they are also often used by fishermen originating from other parts of the country and the neighboring countries of Ghana and Nigeria (pers. obs.).

Large areas of Cameroon, including the entire Sanaga Basin, experience drought during the dry season, and as a result of the increasing impact of climate change (Dzana et al. 2011). Furthermore, the situation is liable to worsen in the future (Grijsen and Patel 2014). In the headwaters of the Sanaga Basin, local authorities already buy water and trucks distribute water to drought-affected villages. Water shortages are made worse by poor land management and unsuitable farming methods, notably poor irrigation practices, tree felling and burning of forests for cropland. The potential for increased (agro) industrial development (e.g., palm oil and cotton production) exists and river management will need to take into account their effects in the future.

7.5.2 Fish farming

In 1948, freshwater fish farming (low intensity aquaculture) was introduced in Cameroon, in a small reservoir near Yaoundé (Tangou 2009). After several failures from uncontrolled individual initiatives, the government established hatcheries in 1978 to develop fish farming for three native species (viz. *Clarias gariepinus* (North African catfish), *Heterotis niloticus* (African bonytongue) and *Cyprinus carpio* (common carp)) and two species introduced from the Nile River in the 1950s (*Oreochromis niloticus*, Nile tilapia, and *Heterobranchus longifilis*). The development of the national aquaculture strategy in 1978, which was revised in 2003 and in 2009 included an action plan, has led to a significant increase in fish production (fig. 7.4); as a result, between 15,000 and 30,000 direct jobs have been created. In 2005, the total production of inland fisheries and aquaculture was estimated at around 68,750 tons (Pouomogne and Pemsl 2008). However, production remains weak in comparison with the national need, which is estimated at around 250,000 tons (Mkong et al. 2018).

7.5.3 Sand extraction

The riverbed in the middle Sanaga River contains a large amount of fine sand, which is widely used for the construction of buildings both locally and throughout Cameroon. River sand extraction is done manually, by thousands of local adults and children, or foreigners (mainly Malians and Nigerians). Sand extraction is a legal but uncontrolled activity, and the most financially lucrative activity in the Sanaga Basin. Most of the people who extract sand can be seen daily

Table 7.4 Key elements of cultural diversity in the Sanaga River Basin

Key element	Link to the natural flow regime	Ecosystem services	Threats and recovery
Water resources	Runoff management is used to store the higher volumes of water generated in the upper catchment. Creation of diversion channels connected to retention dams to regulate the flow rate in the Sanaga River and for irrigation	These people need the river and its associated wetlands for domestic water use, for fish, and as a source of fertilization for their lands during floods.	Flow regime alteration due to dams; over abstraction of water to supply urban centers outside the catchment
Farming	In the upper section of the Sanaga River Basin, the population is mostly rural and uses water mainly for irrigated farming. In this section, rural smallholder agriculture linked to the river flow regime (e.g., flood pulse) is an existing practice and provides many benefits to people.	Men and women have a division of labor in terms of some of the activities supported by the river, e.g. fishing and sand extraction are done by men and the fetching of domestic water by women. Other activities, such as crop farming, are done by both genders.	Most of the younger generation do not want to live like their parents and are moving towards modernity and urban areas. Consequently, most of the local population are elderly The lower river section harbors forest villages with hunting populations.
Fisheries and aquaculture	The consumption of fish is very important for people. People generally fish for their own consumption and collective fishing events are also organized by communities, 1–2 times a year. Only a few groups practice fishing in the river and on its floodplain, in wetlands, and in mangrove and estuary areas. 90% of the fish ponds (which are mainly located on the floodplain) used for fish production are connected to a river or stream by a bypass channel. There is no aquaculture in reservoirs or irrigation canals.	One of the main sources of food and protein for nutrition; local income sources	Fishing is mainly done by people from other countries (e.g., Ghana, Nigeria). Hydropower/other dams in the lower basin have encouraged the establishment of a local community of reservoir fishers Most aquaculture sites are small structures, but large foreign companies may replace the small production units.
Sand extraction	Sand is produced the upper part of the river and stored in the intermediate section where it is extracted manually by local people. The sand is used for construction everywhere in Cameroon.	Sand extraction provides lucrative informal work for mainly young men, and attracts migrant laborers from neighboring countries.	This economic activity, presently artisanal and with wholesalers only for transportation, could be replaced by large private companies.

diving at locations all along the river, driving canoes laden with sand, or loading lorries. Many hundreds of lorries are loaded daily on the river's banks to be used locally or in other regions such as Yaoundé. Both adults and children take part in this activity. Sand extraction is more difficult and dangerous during the rainy season, due to the increased river levels, water velocities, and depths. Therefore, far more sand is extracted during the low flows characteristic of the dry season. An association of sand extractors exists that helps to better organize this activity, as well as to keep the price of sand as cheap as possible for wholesalers. However, there are far more extractors than members in this association, and the actual number of extractors and the quantity of sand extracted remain unknown.

7.5.4 Risk avoidance strategies for flood and drought

Since there is no government plan to prevent flooding, the local populations have developed several individual strategies in response to flood events. In most cases, during the flood in the rainy season, people temporarily leave their homes. However, several control methods have been developed to counter floods, even if these additional costs are restricted to the richest people. Some houses built in flooded areas are now equipped with hard foundations and trenches are dug around houses. In cities, people build dikes and barriers, generally using bags stuffed with earth, walls of trees, ramparts of stones aligned along the banks, or walls of old sheets. In bigger cities, some sections of river channels are widened and woody debris is removed to avoid log jams. Finally, some wetlands are dried out using Eucalyptus plantations, to reduce flood risk (and also mosquitoes as vectors of many diseases). There is little adaptation to drought, except in areas where reservoirs support crop irrigation. In areas affected by drought, farmers typically cultivate plants adapted to such conditions, while crops with high water demands are cultivated near wetlands.

7.6 Current trends

7.6.1 Cultural dynamics

The lack of strong historical and spiritual-cultural links between local people and the Sanaga River, beyond the use of natural resources, is likely one of the most significant obstacles to the river protection. Basin economic development is considered by most stakeholders to be far more important than environmental protection. Importantly, this is amplified by the mixing of people of different ethnicities that is occurring, especially in the northern part of the catchment. The main ethnic groups of this region used to be the Képéré, Gbaya and Bobilis (Oreade-Breche 2011). However, the total number, and the diversity of ethnicities, of people living in the northern Sanaga Basin has strongly increased over the last decades, from 360,000 inhabitants in 1976 to around one million inhabitants in 2010 (MINEE 2006). At the same time, the local agriculture practices have changed from subsistence agriculture to uncontrolled and more extensive practices (e.g., irrigation and slash-and-burn cultivation) to fed new inhabitants. There is also increasing pressure from the cotton industry in the northern catchment. This northern part of the catchment represents 40% of the national livestock numbers but, over time, the area available for pasture has diminished (a consequence of the expansion of agricultural activities and of the overlap of protected areas with suitable rangelands). As a result, the basin experiences conflicts over the use of space for different uses and overgrazing is on the rise. The observed transhumance of cattle from the North of the country and neighboring countries into the Sanaga Basin, during the rainy season from April to November, has led to an increasing overexploitation of resources (water, fish and wood). Population increase has also led to an increase in the generation and indiscriminate disposal of waste, with detrimental consequences for river health and instream biota.

7.6.2 Estimations about losses in cultural and biological diversities

A roughly estimated 60% of cultural diversity has disappeared since the beginning of the 20th century. As a result of the construction of the hydropower dams in the Sanaga River Basin (Edéa, Song Loulou, Mbakaou, Bamendjing, Mapé, and Lom-Pangar), in particular, there has been a high influx of people to these areas for jobs from neighboring countries, such as Nigeria, Central African Republic, and Chad, as well as from other towns and villages in Cameroon (Oreade-Breche 2011). This has generated conflicts between economic activities and between people. For example, fishers from Nigeria tend to use larger boats with engines and larger nets, and hence catch more fish than the local people who rely on small canoes and angling or trap methods; as a consequence, inter-ethnic conflicts have increased. Networks also exist between foreigners that promote the installation of newcomers at the expense of local ethnic groups.

The percentage of cultural diversity lost since 1970 is estimated to be about 20%. This is due to the movement of many people from rural areas to cities and abroad to look for greener pastures over the years. Between 1976 and 2010, the proportion of Cameroonian people living in cities grew from 28.5 to 52.0% (Rapport National Habitat III, 2015). Most of the local ethnic people it hat were involved in the kinds of artisanal and subsistence activities mentioned are nowadays too elderly to be part of the labor force or are deceased. Another reason for the loss of cultural diversity from the basin was the limnic eruption of Lake Monoun, which lies in the Oku Volcanic Field in the northwest, on the 15th of August 1984. It resulted in the release of a large amount of carbon dioxide gas that led to the death of 37 people (Global Water Partnership 2009). This caused panic and many people fled from this part of the basin to other areas for safety, and most of them did not return. In 2003, a venting pipe was inserted into Lake Monoun to degas it, in an effort to prevent the disaster from recurring (Olivry 1986).

7.6.3 Water resources

Access to safe potable water for domestic use has become a major challenge for African societies, especially in the context of a growing global population. In Cameroon, less than 50% of the population has access to potable water (Nola et al. 1998). Consequently, many people use groundwater for their needs, but without taking into account its quality (Nola et al. 1998). Therefore, many people depend on various water sources of poor quality. Unsafe water is often contaminated with fecal material, domestic and industrial wastes. Bad quality drinking water is common in Cameroon, even in the capital Yaoundé, where the water is usually unsafe for human consumption regardless of the source (private standpipes, public taps, wells, or springs) (Nguendo Yongsi 2010). To respond to rising urban water demands for Yaoundé, a major project plan (Project PAEPYS) has been proposed to provide 400,000 $m^3 d^{-1}$ from the Sanaga River by 2020 (and which is 81% completed to date).

Irrigation agriculture is still sparsely developed and water consumption in this sector is highly likely to increase (Ministry of Water Resources and Energy 2006). Large areas of the basin experience natural drought during the dry season, likely amplified by climate change. Water shortages are made worse by poor land management and farming methods like irrigation. There are few industries located in the Sanaga River, except the sugar industry. However, there exists the potential for increased agro-industrial development and river management of the Sanaga should take into account its implications for the future.

7.6.4 Fish farming

Although 90% of the ponds used for aquaculture are not connected directly to the river floodplain, they pose the risk of high volume nutrient inputs into the river system, significantly increasing the potential for eutrophication (Nzieleu Tchapgnouo et al. 2012, Nhu et al. 2016). The consequences of eutrophication (e.g., increases in phytoplankton, replacement of diatoms with cyanobacteria, large-scale macrophytes blooms and water column deoxygenation) pose risks for the survival of fish and other aquatic life. There is also a risk of cyanobacterial blooms, especially in the warm waters (naturally typically above 26°C), which may produce secondary metabolites that are toxic to humans and animals (Zebaze Togouet 2011).

Another concern is the introduction of non-native species for aquaculture and reservoir fisheries, with potential negative impacts on the indigenous fish fauna, as already reported throughout most of inter-tropical Africa (Canonico et al. 2005). There are two introduced fish species introduced some 70 years ago. Until now, however, there has been no documented case of an invasion in the natural environment (although this does not mean that exotics are absent from the river).

7.6.5 Sand extraction

The high and growing demand for sand in Yaoundé has resulted in the intensification of sand extraction at sites along the Sanaga River. Hydropower dams have already been reported to affect the sediment flux in the lower Sanaga River (Ngoupayou et al. 2016). Rising sand extraction may amplify such geomorphological change by increasing riverbed incision, as already observed in the Niger River (Ferry et al. 2012). Consequences may include the deforestation of riparian areas, reductions in species populations, and possibly the local disappearance of animal and plant species, even if such cases have not as yet been reported. Bank soil erosion and water pollution are noticeable detrimental impacts associated with the engine waste oil (Ekengoue et al. 2018).

7.6.6 Hydropower production

To increase the production of energy in Cameroon, several hydropower dams have been constructed on the Sanaga River (table 7.2). The first one was built in the middle section of the river near Edéa in 1954, with a generation capacity of 264 megawatts (MW). The second and the biggest was built at Song Loulou in 1988, 50 km upstream and generates 335 MW. The most recent dam was built at Lom Pangar in 2016, on the upper river, generating 30 MW. At the same time, large reservoirs were built at Mbakaou (1969), Bamendjing (1974) and Mape (1981) for flow regulation, water storage and flood control.

The negative impacts of such constructions were numerous. For instance, the Lom Pangar Dam necessitated the clearing of 210 ha of for-

West African manatee. Photo: Eland Giant, with permission

Fisherman. Photo: Narcisse Nyamsi Tchatcho

Hippopotamus. Photo: Christophe Piscart

Sand fisherman. Photo: Christophe Piscart

Dwarf crocodile. Photo: Eland Giant, with permission

Flooded savanna. Photo: Christophe Piscart

Fig. 7.5 Left column: iconic examples of biological diversity, right column: iconic examples of cultural diversity

Nachtigal Dam. Photo: World Bank, with permission

Cultural meet with pygmies. Photo: Christophe Piscart

Palm plantation near Edéa. Photo: Christophe Piscart

Lobe's Waterfalls near Kribi. Photo: Christophe Piscart

Water pollution. Photo: Christophe Piscart

Wells for irrigation and drinking water near Edéa. Photo: Christophe Piscart

Fig. 7.5 (continued) Left column: iconic examples of threats, right column: iconic examples of sustainable management est land (Banque Africaine de Développement 2011) and the embankment induced modification of soil structure and increased erosion, that in turn increased the turbidity of the river water downstream (Massabé 2016). The impacts of the dams on the aquatic ecosystems could be attributed to changes in connectivity locally and at the catchment scale (Ward and Stanford 1995). In areas of Africa where water temperatures are naturally high, such as Cameroon, for instance, the water temperature increases in reservoirs and promotes eutrophication (Zebaze Togouet 2011) with reduced oxygen content downstream (Nyamsi Tchatcho 2018). The alteration to the pattern and timing of flows, the reduction in current velocity and the homogenization of habitat are also likely to have had strong detrimental impacts on biodiversity (Dudgeon et al. 2006), many as yet appearing undocumented in the case of the Sanaga River.

Large dams also generally induce forced resettlement and its subsequent socio-economic impacts. The displacement of the population always results in material losses, under-compensation and social disruption of local communities. For example, the construction of the Bamendjin Dam in the Sanaga Basin immediately affected over 307,757 people, forcefully displacing about 8,582 inhabitants as 3,178 houses were submerged. The adversely affected population increased over the years, despite the development of rice production and other agricultural activities, such as the growing of corn and groundnuts. The majority of the population still lack clean drinking water, electricity and agricultural land (Mbih et al. 2014). Moreover, in sub-Saharan Africa, dams contribute significantly to malaria risk, particularly in areas of unstable transmission (Kibret et al. 2015), a concern in the context of the water infrastructure of the Sanaga Basin.

The continued increase in energy demand in Cameroon, where only 47% of people have access to electricity, creates significant and mounting pressure on its aquatic ecosystems. Cameroon has the third-highest hydropower potential in sub-Saharan Africa after the Democratic Republic of Congo and Ethiopia (International Hydropower Association 2019). In order to satisfy 70% of the power need of the country, the Cameroonian authorities have planned for the construction of seven new large dams on the Sanaga River (including the ongoing Nachtigal project, and the Grand Eweng project that has just started). The construction of these dams will significantly change the flow regime and morphological dynamics of the Sanaga River and deeply change ecosystem functioning, with likely major detrimental impacts on biodiversity, especially in the lower section of the river.

The hydropower reservoirs have also changed human activities. A study conducted on the Lom-Pangar Reservoir highlighted an important change in the fish community with a strong increase in biomass of some species within the reservoir (*Oreochromis* sp., *Tilapia*, *Labeo*, *Brycinus macrolepidotus*, *Hepsetus odeo*, *Lates niloticus*, *Hydrocynus* sp. and *Heterobranchus longifilis*) (Magnet and Pouomogne 2005). This increase in fisheries productivity resulted in the development of more intensive fishing activity within the reservoir, but a decrease in fish biomass downstream, associated with lowered instream nutrient levels. Consequently, the local population living along the downstream river reaches had to move upstream to fish or to change their cultural activities (pers. comm. with local authorities).

Prior to 1970, the local population living near the Sanaga River used mainly terrestrial resources, with fishing dedicated to subsistence use and non-commercial/local income generation. However, the more recent intensive exploitation of aquatic resources (fish, water and sand) has led to immigration, strongly modifying the ethnic composition of riparian inhabitants. This ethno-demographic mixing has resulted in deep cultural change locally as the proportion of new ethnic groups of different cultures increases. While increasing the economic development of this poor and isolated part of the country, it has tended to increase conflicts (as previously mentioned).

7.7 Management suggestions

As illustrated in the previous sections, the Sanaga River Basin is threatened by many human activities and suffers from the lack of an integrated river basin management plan. However, regardless of this limitation and the high economic pressure on the basin, there remain interesting opportunities to mitigate anthropogenic impacts on its aquatic ecosystems.

The catchment still possesses very high biodiversity, with many emblematic species, as well as exceptional natural scenery, such as waterfalls (fig. 7.5), all of which are part of the overall attraction of the basin. The presence of several umbrella species, such as forest elephants, monkeys, hippopotamus and manatee in the national parks of the Sanaga River Basin has resulted in the presence of many conservation NGOs and strong attention to wildlife conservation decision-making. There is hence a high potential for coming generations to generate revenue through tourism, and even occasional wildlife sightings might encourage visitors to spend time in particular areas. While the basin's dams have had clear negative impacts on the aquatic environment, they have promotes an increase in infrastructure and the development of local towns with electricity supply and roads. This has improved tourist access to isolated areas. The potential for tourism is still underexploited (Massabé 2016) though, and supporting data are scarce.

However, the growing water demands, combined with droughts and changes in climatic patterns, have produced increasingly widespread water scarcity in many world regions (Kennen et al. 2018) and especially in Africa (Mahé et al. 2013). These problems are exacerbated by climate change and the human drive to achieve water security under increasingly modified environmental conditions and social-economic constraints (Acreman et al. 2014). Recent advances in environmental flow science and water management include methods for managing the quantity, timing, and quality of water flows required to sustain freshwater and estuarine ecosystems, including the human livelihoods and well-being that depend on these ecosystems (Poff et al. 2017, Arthington et al. 2018a, b). To ensure more sustainable resources management in the basin, the following steps should be implemented:

The critical limits on the amount of water available to support human and ecological requirements need to be defined for the Sanaga River system, which requires the environment to become recognized as a legitimate user of water in Cameroon (Kennen et al. 2018).

Integrative, strategic water and energy planning should be applied at the basin scale, with the goal of finding a balance between tapping hydropower potential and sustaining key natural resources. New analytical methods should be developed to account for the cumulative impacts at the basin scale of multiple dams on hydrology, sediment dynamics, ecosystem productivity and biodiversity, fisheries, and rural livelihoods. Institutions that permit and finance (for Cameroon at this time these are mainly international institutions) hydropower development must require basin-scale assessments that account for cumulative impacts and climate change. Such common-sense adjustments to assessment procedures would ensure that societal objectives for energy production are met, while avoiding the most socially and environmentally damaging projects (Winemiller et al. 2016).

Further study of the heritage value and cultural importance of water is needed, especially for indigenous populations. This is particularly important in Cameroon where environmental water is critical to support basic human needs and the multifaceted dependence of Indigenous peoples on aquatic ecosystems, as well to maintain biodiversity. A positive feature of the new generation approaches to environmental water is the emergence of holistic frameworks (e.g., decision support systems) that more directly incorporate ecosystem services and the cultural values important for local communities (Poff et al. 2017).

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