2. STATUS AND TRENDS

Ramsar tracks global wetland status and trends, which helps measure progress in Sustainable Development Goal 6. Natural wetlands have declined in inland, coastal and marine habitats; a small growth in artificial wetlands fails to compensate. Populations of wetland-dependent species are declining and many are threatened. Global water quality is still getting worse. Yet wetlands are critically important for their ecosystem services: food and water security, disaster risk reduction and carbon sequestration amongst others. Their economic and biodiversity value far outweighs many terrestrial ecosystems.

Ramsar tracks global status and trends in wetlands

Given the specific requirement for Ramsar Contracting Parties to maintain the "ecological character" of all wetlands through "wise use", the analysis of status and trends is structured around the Convention's definition of ecological character (Box 2.1). It therefore addresses the ecosystem components, processes and services that comprise the ecological character of wetlands, to the extent that information is available. Data on the ecological character of wetlands such as wetland extent are now being collected from Contracting Parties through wetland inventories, and from January 2018 countries include such data in National Reports to the Convention. As the Convention is co-custodian with UN Environment of the UN Sustainable Development Goal indicator 6.6.1 (*Change in the extent of water-related ecosystems over time*) these data will be used as a formal mechanism for reporting.

The Ramsar obligation to maintain the ecological character of wetlands includes the Convention on Biological Diversity's ecosystem approach.

BOX 2.1

ECOLOGICAL CHARACTER OF WETLANDS (RAMSAR CONVENTION 2005)

In 2005 the Convention redefined wetland "ecological character" as "*the combination of the ecosystem components, processes and benefits/services that characterize the wetland at a given point in time*" as shown in Figure 2.1.

Contracting Parties are now required to maintain the ecological character of all wetlands, not just those designated as Wetlands of International Importance ("Ramsar Sites") as was previously the case, following changes in 2005 to the definition of "wise use" (Finlayson et al. 2011). The Convention further requires Contracting Parties to report if the ecological character of a Ramsar Site "has changed, is changing or is likely to change as the result of technological developments, pollution or other human interference".

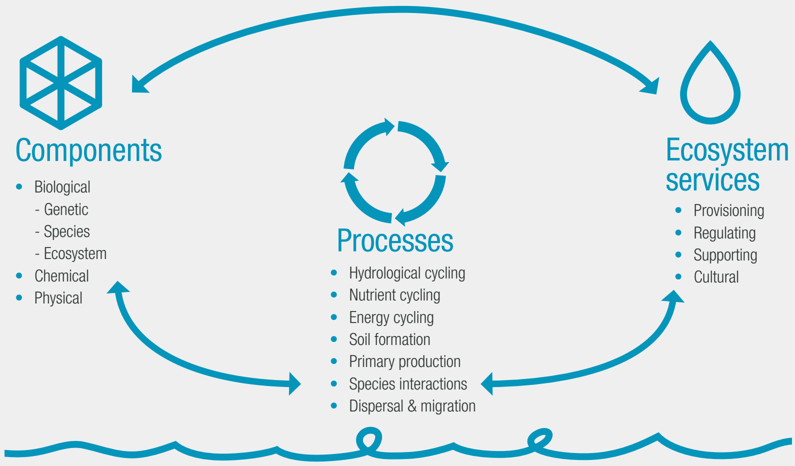


Figure 2.1
Conceptualization of ecological character as the components, processes and ecosystem services that characterize a wetland (from Finlayson et al. 2016)

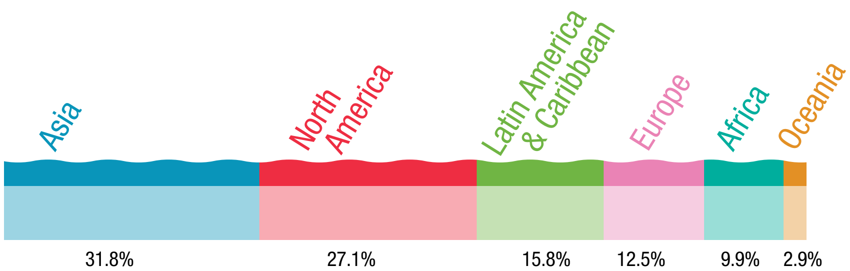
Accuracy of global wetland area data is increasing

The most recent estimate of global inland and coastal wetland area is in excess of 12.1 million km², an area almost as large as Greenland. Of this, 54% is permanently inundated and 46% seasonally inundated. An estimated further 5.2 million km² are intermittently or occasionally inundated, but this is believed to include areas of former converted wetlands affected by extreme storm events. Around 93% of wetlands are inland systems, with 7% being marine and coastal – although this coastal estimate does not include several wetland classes such as nearshore subtidal wetlands, which also fall into the Ramsar definition. Global areas of human-made wetlands are small in comparison: reservoirs cover an estimated 0.3 million km² and rice paddy 1.3 million km² (Davidson et al. 2018; Davidson & Finlayson 2018).

Estimates of global wetland extent have increased considerably since the 1980s, due largely to recent improvements in remote sensing and mapping methods; this is not a reflection of any real increase in the area of wetlands (Davidson et al. 2018).

The largest areas of wetlands (Figure 2.2) are in Asia (32% of the global area), North America (27%) and Latin America and the Caribbean (16%). Wetland areas in Europe (13%), Africa (10%) and Oceania (3%) are smaller (Davidson et al. 2018).

Figure 2.2
Regional distribution (%) of wetland area (from Davidson et al. 2018)



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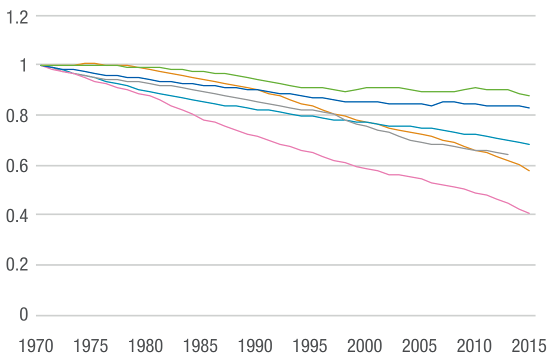
Natural wetlands have declined and artificial wetlands increased

Remaining natural wetlands cover only a fraction of their original area and have been progressively declining for centuries in most of the world, through drainage and conversion (see Box 2.2). Up to 87% of the global wetland resource has been lost since 1700 CE in places where data exist (this may not represent the global total), with rates of loss increasing in the late 20th century (Davidson 2014). However, recent assessments of trends in global water inundation area and global open water area (both natural and human-made wetlands) report both losses (Prigent et al. 2012; Schroeder et al. 2015) and gains (Pekel et al. 2016; Box 2.4) in net area over different time periods.

Since 2014, the Ramsar Convention has commissioned the UN Environment World Conservation Monitoring Centre to develop a Wetland Extent Trends (WET) Index (Dixon et al. 2016), based on a sample of wetlands. The WET Index collates over 2,000 time-series data from 1970 to 2015, subdivided by region and wetland classification. Average trends are aggregated and analysed.

In 2017, the analysis extended to all Ramsar regions and shows a continuing progressive decline (UN WCMC 2017). It suggests (Figure 2.3) a decline of about 35% in both marine/coastal and inland natural wetland areas studied between 1970 and 2015, with a decline in average wetland extent in all regions, which varies from 12% (Oceania) to 59% (Latin America, mainly data on the Caribbean excluding Orinoco and Amazon for the wetlands sampled).



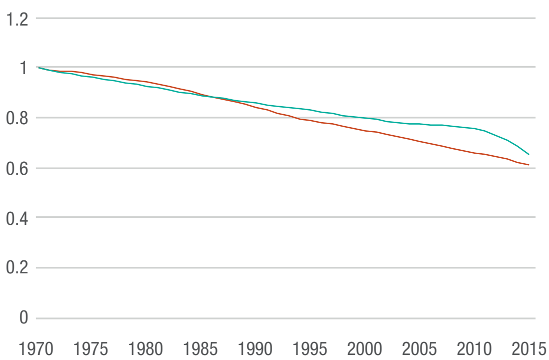


Figure 2.3
WET Index global and regional trends in natural wetland area since 1970. Source: UN WCMC (2017) Note that the WET Index analyses trends only in reported cases, and should not be taken as an indication of total wetland area change on a continental scale.

Natural WET Index by Region (top)
- Africa
- Asia
- Europe
- Latin America & Caribbean
- North America
- Oceania

Inland and Marine/ Coastal WET Index weighted by region (bottom)
- Global marine/ coastal weighted
- Global inland weighted

The average annual rate of natural wetland loss estimated by the WET Index is -0.78% a year; over three times faster than the average annual rate of loss of natural forests (-0.24% a year) between 1990 and 2015 (FAO 2016a). Rates of natural wetland loss have accelerated from -0.68 to -0.69% a year between 1970 and 1980 to -0.85 to -1.60% a year since 2000.

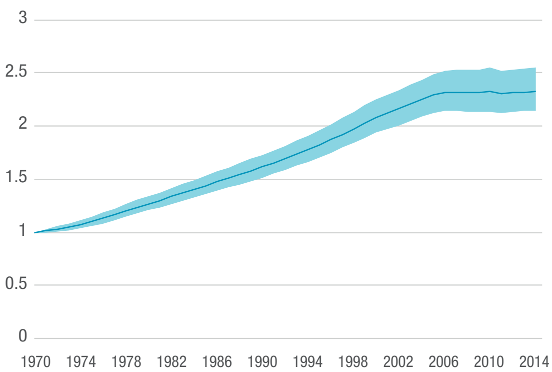


Figure 2.4
WET Index global trend in human-made wetland area since 1970. Source: UNEP-WCMC (2017)

Human-made WET Index with upper and lower confidence limits

In contrast, human-made wetlands have increased since the 1970s (and earlier), sometimes from conversion of natural wetlands. Reservoirs' extent has increased by about 30% and rice culture by about 20% (Davidson et al. 2018); see also below (page 24). The WET Index suggests a two-fold increase in human-made wetland area since 1970 for the areas studied (Figure 2.4), although areas are relatively small compared to natural wetlands (Davidson et al. 2018). Limited data availability means that regional trends could not be calculated.

Wetland change in Europe illustrates global trends

Land-use change in Europe over two thousand years has resulted in wide-scale wetland drainage, mainly for agriculture and urban development. Change has been acute in estuaries, claimed for agriculture, port and industrial development (Davidson et al. 1991), and in river valleys and floodplains. The ecological character of many wetlands has changed, including creation of reservoirs and other water storage: in Iberia dams have been constructed on all major rivers (Nicola et al. 1996). Habitat loss has damaged ecosystem functions and services, especially in shallow-water fisheries (Lotze et al. 2005; Lotze 2007), e.g., in the Wadden Sea (Eriksson et al. 2010), and the loss of most native oyster reefs (Airoldi & Beck, 2007). In the 1960s, Project Mar collated national inventories of Wetlands of International Importance (IUCN 1965) and found accelerated wetland loss since the 1940s: "*Every day between 1960 and 1965 a kilometre of European coast was developed*" (Airoldi & Beck 2007). Davidson (2014) reported major losses in coastal and inland European wetlands during the 20th and early 21st centuries. Conversely, new wetlands have been created by the filling of reservoirs, flooding quarries and gravel pits and restoration of drained wetlands (e.g., Hertzman & Larsson 1999). The WET Index suggests an overall loss of about 35% of European inland and coastal wetlands since 1970 (UN WCMC 2017).

Box 2.2

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WETLAND AREA TRENDS IN MEDITERRANEAN WETLANDS

The Wetland Extent Trends (WET) Index was calculated for c. 400 Mediterranean wetland sites and indicates a loss of 48% of natural wetlands from 1970-2013. This suggests that the region's wetlands have fared worse than those of the three surrounding continents (Africa 42% loss, Asia 32% and Europe 35%) (UN WCMC 2017). This is in contrast to previous calculations, which used only a subset of three-quarters of the 400 sites and found a loss of 9% of natural wetlands from 1975-2005. This smaller loss is in part due to only including sites which still had a good extent of wetland habitats, thus excluding those totally or largely lost by 2005. Conversely, literature reports for the other sites are likely to lead to overestimated loss, since sites with large wetland losses are more likely to be reported. These two opposite biases illustrate the influence of sampling on calculated regional wetland losses. Source: Mediterranean Wetland Observatory (2018)

Area of natural inland wetlands is changing and generally declining

Data on the extent, distribution and trends of wetland types are still incomplete, although national reporting on extent by Ramsar Contracting Parties to the thirteenth Ramsar Conference of Parties provides preliminary national data. Further reporting will soon provide national data that can be aggregated at regional and global levels as well as on Ramsar Classification of Wetlands, Inland, Marine and Coastal and Human Made Wetlands. Through this mechanism, national validated data on an accepted international definition of wetlands will be provided to measure SDG indicator 6.6.1 on extent of water related ecosystems. Multiple sources of information about different wetland types are presented from Davidson and Finlayson (2018); however separate information is not available for all 42 wetland types in the Ramsar classification. Generalized wetland classes are therefore used in the descriptions below (see Tables 2.1-2.3).

Inland natural (surface) wetlands are dominated by three broad classes: peatlands, marshes and swamps on alluvial soils, and natural lakes. Together these form about 80% of the global area of surface inland wetlands (Figure 2.5). Peatlands overall form over 30% of inland wetlands. Areas of rivers and streams, forested peatlands and swamp and flooded forests on alluvial soils are smaller. No information is available on areas of different types of groundwater-dependent wetlands, but underground wetlands may underlie much of the c. 19 million km² of carbonate rocks on the global land surface (Williams 2008) – a larger area than that of inland and coastal surface wetlands.

Most inland wetland classes for which there are data are declining in global area, with major declines in forested and tropical peatlands, although there was little overall change in global peatland area between 1990 and 2008, and a reported small increase in the area of non-forested peatlands (data from Joosten 2010) – possibly partly through conversion of forested peatlands (Table 2.1).

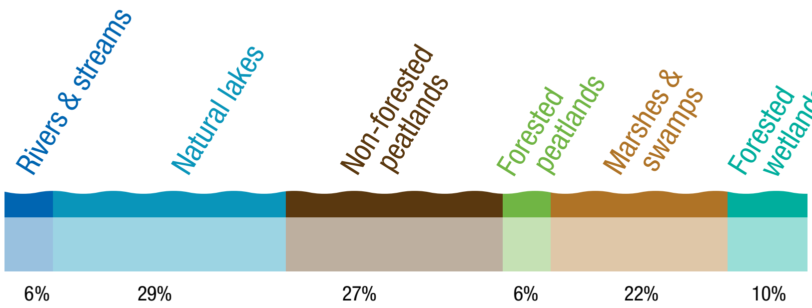

Figure 2.5
Relative areas (%) of natural inland wetland classes (from Table 2.1).

Box 2.3

TRENDS IN GLOBAL SURFACE WATER AREA

Between 1984 and 2015 there was an estimated loss of almost 0.09 million km² of permanent surface water (fresh and saline) (2% of global water area measured). This loss was offset by 0.21 million km² of new permanent water bodies, of which 0.03 million km² changed from seasonally to permanently flooded and 0.18 million km² of permanent water formed in areas previously devoid of surface water. All continental regions show a net increase in permanent water, except Oceania, which had a fractional (1%) net loss (Pekel et al. 2016). These data need to be interpreted in relation to the time period assessed, taking into account extreme events such as drought and floods.

Change in inland wetlands

Table 2.1
Extent and area change of natural inland wetland classes (Source: Davidson & Finlayson 2018). Light blue shading indicates no information available.

Qualitative area changes:
→ No change: (±5%)
↓ Decrease (-5-50%)
↑ Increase (+5-50%)

Inland natural wetlands	**Global area (million km^2)**			
	Wetland classes	**Wetland sub-classes[a]**	**Global area change (% change)[b]**	**Global area change (qualitative)[c]**
Rivers & streams	**0.624-0.662**			↓
Natural lakes	**3.232-4.200**			↓
Natural lakes (>10 ha)		2.670		↓
Natural pools (1-10 ha)		0.562		
Peatlands	**4.232**		**-0.97**	→
Non-forested peatlands (bogs, mires & fens)		3.118	**+6.80**	↑
Forested peatlands		0.696	**-25.32**	↓
Tropical peatlands		1.505	**-28**	↓
Temperate & boreal peatlands		3.380		
Marshes and swamps (on alluvial soils), including floodplains	**2.530**			↓
Tropical freshwater swamps (alluvial soils)		1.460		↓
Forested wetlands (on alluvial soils)	**1.170**			
Groundwater-dependent wetlands				
Karst & cave systems				
Springs & oases				
Other groundwater-dependent wetlands				

[a] Different wetland sub-classes are defined according to different criteria and do not necessarily add up to the total figure for the wetland class. The areas provided for temperate/boreal and tropical peatlands are not additive to those for non-forested and forested peatlands; rather, these are two different spatial dis-aggregations of all peatlands.
[b] Year-ranges for % area change vary between sources and wetland classes: peatlands, non-forested peatlands, forested peatlands 1990-2008, tropical peatlands 2007-2015.
[c] If no quantitative trend was available, a qualitative trend was interpreted from a range of published trends for smaller areas of the wetland category (from Davidson & Finlayson 2018).

Area of natural coastal/ marine wetland types is also declining over time

The largest areas of natural marine/ coastal wetlands are unvegetated tidal flats, saltmarshes and coral reefs, together forming almost 80% of the global total, with mangroves and seagrass beds having smaller areas (Figure 2.6). These figures do not include sand dunes, beaches and rocky shores, shellfish reefs, kelp forests and shallow subtidal systems, for which area information is lacking. Of these, shallow subtidal systems will be a large area, but shellfish reefs and kelp forests smaller.

Almost all coastal natural wetland classes have declined in global area (Table 2.2), many with considerable losses (coastal deltas, seagrass beds and shellfish reefs). The exception is kelp forests for which trends are highly variable, with declines in some parts of the world but increases in others.

Figure 2.6
Relative areas (%) of natural marine/ coastal wetlands (from Table 2.2)

- Unvegetated tidal flats
- Saltmarshes
- Coastal deltas
- Mangroves
- Seagrass beds
- Coral reefs (warm water systems)

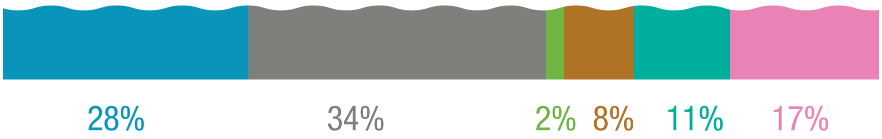

Table 2.2
Extent and area change of marine/ coastal natural wetlands (Sources: Davidson & Finlayson 2018; Global Mangrove Watch). Light blue shading indicates no data or information available.

Qualitative area changes:
- → No change: (±5%)
- ↓ Decrease (-5-50%)
- ↓↓ Decrease (>-50%)
- ↑ Increase (+5-50%)

	Global area (million km²)			
	Wetland classes	**Wetland sub-classes**[a]	**Global area change (%)**[b]	**Global area change (qualitative)**[c]
Estuaries	**0.660**			↓-↓↓
Unvegetated tidal flats		**0.458**		↓-↓↓
Saltmarshes		**0.550**		↓
Coastal deltas		**>0.030**	**-52.4**	↓↓
Mangroves	**0.143**		**-4.3%**	→
Seagrass beds	**0.177**		**-29**	↓
Coral reefs (warm water systems)	**0.284**		**-19**	↓
Shellfish reefs			**-85**	↓↓
Coastal lagoons				↓
Kelp forests			**–0.018**	→
Shallow subtidal marine systems				↓
Sand dunes/beaches/rocky shores				
Coastal karst & caves				

[a] Different wetland sub-classes are defined according to different criteria and do not necessarily add up to the total figure for the wetland category.

[b] Year-ranges for % area change vary between sources and wetland classes: coastal deltas 1986-2000; mangroves 1996-2016; seagrass beds 1879-2005; coral reefs historical to 2008; shellfish reefs historical to 2010; kelp forests 1952-2015.

[c] If no quantitative trend was available, a qualitative trend was interpreted from a range of published trends for smaller areas of the wetland class (from Davidson & Finlayson 2018).

Human-made wetland types have increased in area

As natural wetlands decline, those made by human agency continue to increase, often but not always replacing natural wetlands. Major areas of human-made wetlands are rice paddy and water storage bodies such as reservoirs, with much smaller areas of small ponds and tropical palm oil and pulpwood plantations on peat soils. Global areas of wet grasslands, saltpans, aquaculture ponds and wastewater treatment ponds are not available. Most classes of human-made wetlands have increased considerably in global area since the 1960s (Table 2.3) and may now form about 12% of the world's wetlands.

Table 2.3
Extent and area change of human-made wetlands (Source: Davidson & Finlayson 2018). Light blue shading indicates no data or information available.

[a] Year-ranges for % area change vary between sources and wetland classes: reservoirs 1970-2012; rice production area 1965-2014; palm oil plantations 1990-2015.

[b] If no quantitative trend was available, a qualitative trend was interpreted from a range of published trends for smaller areas of the wetland class (from Davidson & Finlayson 2018).

➔ No change: (±5%)
🡣 Decreases (-5-50%)
🡡 Increases (+5-50%)
🡡🡡 Increases (>+50%)

Human-made wetlands	Global area (million km²)	Global area change (% change)[a]	Global area change (qualitative)[b]
Water storage bodies			
Reservoirs	**0.443**	**+31.6**	🡡
Small (e.g., farm) ponds	**0.077**		🡡-🡡🡡
Agricultural wetlands			
Rice paddy	**1.290**	**+30.2**	🡡
Palm oil plantations	**0.002**	**+39**	🡡
Wet grasslands			🡣
Wastewater treatment/constructed wetlands			🡡
Saltpans (salines/salinas)			
Aquaculture ponds			
Human-made karst & caves			

Populations of many wetland-dependent species are declining

Recent assessments support earlier analyses suggesting that many populations of wetland-dependent species are in long-term decline and threatened with extinction.

The IUCN Red List assesses the level of threat of extinction of plant and animal species, and shows that:

- Of over 19,500 wetland-dependent species assessed globally, one-quarter (25%) are threatened with extinction;
- 25% of inland wetland-dependent species (of over 18,000 species surveyed) are globally threatened, with 6% being Critically Endangered;
  - Inland species dependent on rivers and streams are more globally threatened (34%) than those of marshes and lakes (20%);
  - Inland wetland-dependent species have a higher risk of extinction than their terrestrial counterparts (Collen et al. 2014);
- There is a similar level of global threat (23%) for the much smaller number (less than 1,500) of coastal and near-shore marine species assessed, with only 1% being Critically Endangered.

The Living Planet Index (LPI) calculates an average change in population abundance over time of populations of vertebrate species – the rate of change rather than absolute change in population size. It shows that:

- Since 1970, 81% of populations of freshwater species have declined globally (Figure 2.7): a much greater decline than those of species depending on any other ecosystem (WWF 2016);
- Between 1979 and 2008 there was an index increase for freshwater species of 36% in temperate regions – but an index decrease of 70% in tropical regions (WWF 2012);
- In contrast to the freshwater LPI, much of the 36% decline in the 2016 marine LPI occurred between 1970 and the late 1980s, after which the trend has stabilized (Figure 2.7), reflecting the global trend in fish catch which stabilized, but at much lower population levels, after 1988 (WWF 2016).

The Red List Index (RLI), derived from IUCN Red List data, assesses trends in the survival probability of groups of species (Butchart et al. 2007):

- RLI trends are negative for all four wetland-dependent taxonomic groups with available data (mammals, birds, amphibians and corals) (Figure 2.8), indicating that species are increasingly moving towards extinction;
- Declines have been fastest for corals (driven especially by bleaching events linked to ocean acidification and warming);
- RLI index values are lowest for amphibians, indicating that they are under greatest threat (in particular due to the chytrid fungus);
- Waterbirds have been in continuous decline since the late 1980s.

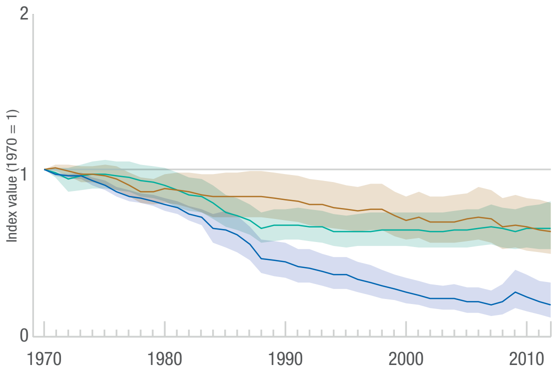

Figure 2.7
Living Planet Index 2016 for freshwater, marine and terrestrial biomes. Terrestrial biomes include tropical and temperate forests, grasslands, shrublands and deserts. Source: adapted from WWF (2016).

Living Planet Index
— Terrestrial
— Marine
— Freshwater

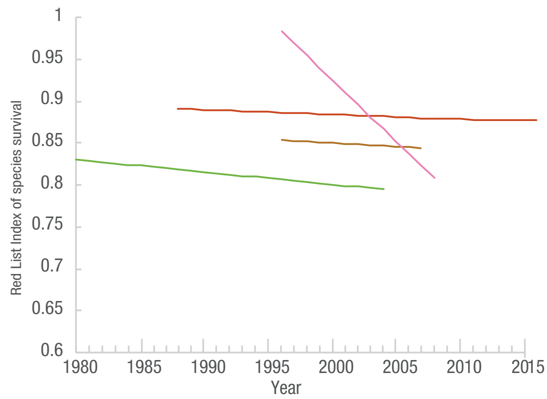

Figure 2.8
Trends in the Red List Index of species survival of different wetland-dependent species taxonomic groups. Source: BirdLife International (2015).

— Birds
— Mammals
— Amphibians
— Corals

Regional trends of wetland-dependent species show highest risks in the tropics

Regional status and trends of freshwater species and populations have been assessed from the IUCN Red List, but not for everywhere or every taxa. Percentages of globally threatened species are derived from extant species with an assessed threat level (i.e., excluding Extinct and Data Deficient species).

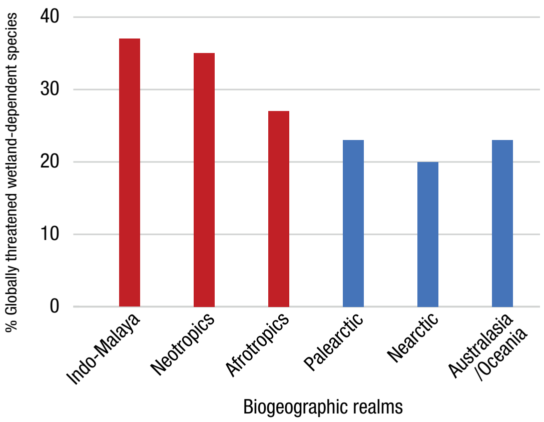

Figure 2.9
Percentages of globally threatened freshwater vertebrates and decapods (crabs and crayfish) in biogeographic realms (tropical realms: red; other realms: blue). Source: Collen et al. (2014).

Regionally, percentages of globally threatened freshwater taxa in different biogeographic realms (areas with a broadly similar evolutionary history) vary between 20% and 37% (Figure 2.9) (Collen et al. 2014), with the highest threats in the tropics. At a finer spatial scale, global threat levels of wetland-dependent species vary greatly across different regions (Table 2.4). Of regions assessed, Madagascar (43% wetland-dependent species globally threatened), New Zealand (41%), Europe (36%) and the Tropical Andes in Latin America (35%) have the worst species status, with serious problems also in Africa (25%), and the Arabian Peninsula (22%). Lower threat levels occur in parts of Asia (Indo-Burma, Eastern Himalaya and India: 10-19%), North America (20%), Eastern Mediterranean (19%) and Oceania Pacific islands (12% – freshwater fish only). Even here some taxa are at risk: crabs and mammals in Indo-Burma; amphibians and freshwater fish in India; freshwater shrimps in North America; and non-marine molluscs, decapods and freshwater fish in the Eastern Mediterranean.

Box 2.4
(see also Table 2.4)

STATUS OF FRESHWATER SPECIES IN SELECTED AREAS OF THE TROPICS

Continental Africa In Africa, of freshwater taxa assessed, the most globally threatened are molluscs (41%), followed by amphibians (31%), crabs (28%) and fish (27%) (Darwall et al. 2011).

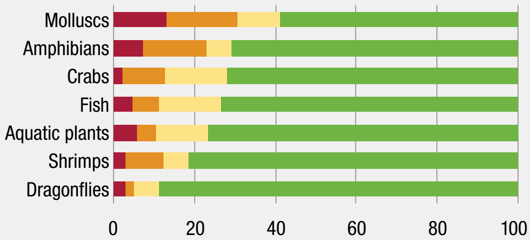

Figure 2.10
Status of African freshwater species (from Darwall et al. 2011)

- Critically endangered
- Endangered
- Vulnerable
- Near threatened & least concern

Indo-Burma, Eastern Himalaya and Western Ghats Numerous Indo-Burma species are globally threatened – including 77% of wetland-dependent mammals, along with crabs (34%), amphibians, fish and molluscs (each 17%). However, few (2%) are Critically Endangered. In the Eastern Himalaya and Western Ghats regions, threats to fish are high (18% and 37% respectively) and amphibians in the Western Ghats (41%), although other taxa are less threatened than in Europe and Africa. (Allen et al. 2010, 2012; Molur et al. 2011).

Madagascar & Indian Ocean Islands Many freshwater taxa are globally threatened, particularly aquatic plants (80%), crayfish (67%), amphibians (49%), fish (43%) and non-marine molluscs (30%). (Máiz-Tomé et al. 2018).

Tropical Andes Eighteen per cent of freshwater species present are globally threatened, with 4% Critically Endangered. Highest threats are to molluscs (38%: 15% Critically Endangered) and aquatic plants (33%: 8% Critically Endangered). (Tognelli et al. 2016).

Trends in wetland-dependent species

Table 2.4

Global threat status of inland wetland-dependent taxa in different regions. (Sources: IUCN Freshwater Red List publications & Red List database[1]).

- <10% globally threatened species
- 10-25%
- >25%
- taxon not assessed

		% globally threatened											
Region	**Sub-region**	**Lycopods & ferns**	**Freshwater vascular plants**	**Non-marine molluscs**	**Crabs**	**Crayfish**	**Freshwater shrimps**	**Dragonflies**	**Freshwater fish**	**Amphibians**	**Waterbirds****	**Wetland-dependent mammals**	**All assessed taxa**
Africa	Continental Africa		24	41	28		19	11	27	31			25
	Madagascar & Indian Ocean islands		80*	30	15	67	4	7	43	49			43
Asia	Arabian Peninsula		16	24	0			29	50				22
	Indo-Burma		2	17	34		0	4	17	17	12	77	13
	Eastern Himalaya			2			8	2	18				10
	India		9	12	11		4	3	37	41			19
Europe	Europe	40	8	59		67	41	16	40	23	15		36
	Eastern Mediterranean		3	45	44			7	41	33	5	38	19
Latin America & Caribbean	Tropical Andes		33	38				15	16				35
North America	North America					20	40		20	22			20
Oceania	New Zealand			47		0	0	0	49	75			41
	Pacific Islands of Oceania								12				12

1. Continental Africa: Darwall et al. 2011; Madagascar: Máiz-Tomé et al. 2018; Indo-Burma: Allen et al. 2012; Eastern Himalaya: Allen et al. 2010; India: Molur et al. 2011; Arabian Peninsula: Garcia et al. 2008; Tropical Andes: Tognelli et al. 2016; Europe: BirdLife International 2015a, Bilz et al. 2011, Cuttelod et al. 2011, Freyhof & Brooks 2011, Kalkman et al. 2010, Temple & Cox 2009, García Criado et al. 2017; Pacific Islands of Oceania: Pippard 2012; East Mediterranean: Smith et al. 2014; Others: Red List database 2017.3 (accessed 30 October 2017).

* endemic species only

** Red List assessment exists for many waterbirds, but this taxon was not covered by many of the sub-regional Red List freshwater assessments

Status of wetland-dependent species — taxonomic groups

Assessments of the status of different taxonomic groups have been undertaken, often for iconic species, including examples such as for flyways for migratory waterbirds. Table 2.5 provides a summary. Trends in global status are available for only a few taxa: seagrasses, corals, amphibians, marine turtles, waterbirds and mammals.

The results are given below. They show a depressing picture of loss, with threats to every group. In over half the taxa assessed, more than a quarter of species are globally threatened, rising to all species assessed in the case of marine turtles.

For almost all inland and coastal wetland-dependent taxa assessed from the IUCN Red List, global threat levels are high (with >10% of species being globally threatened):

- Highest levels of global extinction threat are for marine turtles (100% globally threatened), wetland-dependent megafauna (62%), freshwater reptiles (40%), non-marine molluscs (37%), amphibians (35%), corals (33%), and crabs and crayfish (32%).
- Of all taxa assessed, only coral reef-dependent parrotfish and surgeonfish (2% globally threatened) and dragonflies (8%) have a low threat status.

Status of wetland-dependent groups is summarized below (note that some draw on only partial data):

Ferns and lycopods

In Europe (the only region assessed) 36% of wetland-dependent species are globally threatened (Garcia Criado et al. 2017).

Table 2.5
Summary of the global threat status (IUCN Red List) of different wetland-dependent taxa.

- <10% globally threatened specie (green)
- 10-25% (orange)
- >25%. (red)

Global threat status of wetland-dependent taxa		
Wetland-dependent taxon	**% globally threatened[1]**	**% Critically Endangered**
Lycopods & ferns[2]	36	**unknown**
Freshwater vascular plants[3]	17	4
Seagrasses	16	0
Mangroves	17	3
Corals	33	1
Non-marine molluscs[3]	37	10
Crabs	32	5
Crayfish	32	10
Freshwater shrimps	28	4
Dragonflies	8	1
Fish		
Freshwater fish	29	5
Coral reef fish (parrotfish & surgeonfish only)	2	0
Amphibians	35	9
Reptiles		
Freshwater reptiles	40	11
Marine turtles	100	33
Waterbirds	18	3
Mammals	23	3
Wetland-dependent megafauna (fish, reptiles and mammals >30 kg)	62	27

[1] IUCN Red List status: Critically Endangered (CR); Endangered (EN); Vulnerable (VU).
[2] For Europe only.
[3] For some geographic regions only.

Freshwater vascular plants

Overall Red List threat status is relatively low (17% globally threatened), but varies considerably, from 2% (Indo-Burma) to 24% in Africa and 33% in the tropical Andes.

Seagrasses

Of 72 species, 31% are decreasing with only 7% increasing. Ten (16%) are at elevated risk of extinction, with three Endangered (Short et al. 2011).

Mangroves

Eleven (17%) of 66 species assessed are globally threatened (Polidoro et al. 2010). Particular areas of concern are the Atlantic and Pacific coasts of Central America, with up to 40% of species threatened with extinction.

Corals

33% of 704 species assessed are globally threatened (Carpenter et al. 2008). Regionally the Caribbean and the Coral Triangle (western Pacific) have the highest proportions of corals of high extinction risk. Global threat status worsened by -17.8% between 1996 and 2008 (BirdLife International 2015).

Non-marine molluscs

Global threat status is high, at 37%, rising to 59% in Europe, 45% in the Eastern Mediterranean, 41% in Africa and 38% in the tropical Andes (Cuttelod et al. 2011).

Crabs

32% are globally threatened, with 5% Critically Endangered (Collen et al. 2014). Threat levels are high in Africa and Indo-Burma.

Freshwater crayfish

32% are globally threatened, with 10% Critically Endangered (Richman et al. 2015).

Freshwater shrimps

28% of 479 species are globally threatened, with 4% Critically Endangered. The highest threat levels are in the Nearctic (46% globally threatened from only a small number of species), Palearctic (32%) and Indo-Malayan (30%) (De Grave et al. 2015). Regionally, European (41%) and North American (40%) shrimps have high threat status (Table 2.4).

Dragonflies

The only insect group whose global status has been assessed (Clausnitzer et al. 2009). Only 8% are threatened, a low level of threat compared to other wetland-dependent taxa. For 1,968 species assessed regionally there is also low average threat level (8%), with 1.5% Critically Endangered.

Freshwater fish

Of 8,389 species assessed, 29% are globally threatened, with 5% Critically Endangered. Threat levels are highest in the Arabian Peninsula (50%), New Zealand (49%), Madagascar (43%), the Eastern Mediterranean (41%) and Europe (40%).

Parrotfish and surgeonfish

Most of the 160 species of these coral reef fish are widespread and of Least Concern status, with only three (2%) being globally threatened (Comeros-Raynal et al. 2012).

Amphibians

Wetland-dependent amphibians are amongst the most globally threatened of the freshwater taxa assessed, due particularly to the impacts of chytrid fungus, with 35% globally threatened, of which 9% are Critically Endangered (Stuart et al. 2004; Red List database 2017). There are high levels of threat in New Zealand (75%), Madagascar (49%), India (41%) and Eastern Mediterranean (33%). Amphibians depending on rivers and streams are more globally threatened than those of static waters (Stuart et al. 2004). The global status has deteriorated by -4.3% between 1980 and 2004 (BirdLife International 2015).

Reptiles

Also one of the most threatened taxa, with 40% of species globally threatened, and 11% Critically Endangered (Collen et al. 2014). Of the seven marine turtle species all six assessed are globally threatened: two Vulnerable (Leatherback and Olive Ridley), two Endangered (Loggerhead and Green) and two Critically Endangered (Hawksbill and Kemp's Ridley) (IUCN-SSC Marine Turtle Specialist Group). Recent assessments indicate population increases in some populations of six of the seven species, but with continued decreasing trends in the western Pacific (Mazaris et al. 2017).

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Waterbirds

A relatively low global threat status at the species level, but still 18% globally threatened with 3% Critically Endangered (IUCN Red List database). Global threat status has deteriorated by -1.5% between 1988 and 2016 (BirdLife International 2018). Waterbird biogeographic populations were in a poor and deteriorating state globally in the 1970s; although overall status improved slightly between 1976 and 2005, 47% of populations were still decreasing or extinct (Wetlands International 2010).

- Only flamingos, oystercatchers, stilts and avocets, pelicans, gulls, terns and skimmers have more increasing than decreasing populations;
- The 13 other waterbird groups have all deteriorated in status, particularly rails and crakes, sandpipers, jacanas and painted snipes and storks;
- An estimated 1.8 million waterbirds/ seabirds are killed illegally every year in the Mediterranean, Northern and Central Europe and the Caucasus.

Long-distance migrant waterbirds continue to be in poor status. Although in the 2000s their status has improved on some flyways, it has deteriorated further on others (Wetlands International 2010; Davidson 2017):

- African-Eurasian flyways have been in steady decline since the 1960s with flyways covering eastern Europe, western Asia and eastern Africa having particularly poor status;
- Asia-Pacific flyways have poor status, but this has improved since the 1970s;
- Americas flyways have a relatively good and recently improved status.

There are also regional differences in status and trends of resident and short-distance migrant waterbirds:

- Populations depending on four regions (South America, Sub-Saharan Africa, Asia and Oceania) have a continuing poor status, with worst status in Asia and some recent improvements in Oceania;
- Resident populations in North America and Europe have a relatively better status, with status improving since the early 1990s.

Mammals

23% of inland wetland-dependent mammals are globally threatened, with 3% Critically Endangered (Collen et al. 2014). Global status deteriorated by -1.9% between 1996 and 2006 (BirdLife International 2015).

Freshwater megafauna

Wetland-dependent fish, reptiles and mammals weighing >30 kg) are particularly highly threatened with extinction: of 107 such species assessed, 62% are globally threatened with 27% Critically Endangered (Carrizo et al. 2017). South and Southeast Asia have a particularly high proportion of threatened freshwater megafauna species.

Water quality trends are mainly negative

Water quality is a key concern for human well-being (Horwitz et al. 2012), yet trends are mostly negative. Declining water quality degrades wetlands, although conversely wetlands also improve water quality through ecosystem regulating services (Russi et al. 2013). Major threats include untreated wastewater, industrial waste, agricultural runoff, erosion and changes in sediment (see drivers section). Since the 1990s, water pollution has worsened in almost all rivers in Latin America, Africa and Asia (WWAP 2017). Deterioration is expected to escalate as climate change, economic development, and agricultural expansion and intensification continue, generating increasing threats to human health, wetlands and sustainable development (Figure 2.11, Veolia & IFPRI 2015).

Industrial and municipal wastewater treatment generally reflects a country's income. On average, high-income countries treat 70% of wastewater, upper middle-income countries 38%, lower middle-income countries 28% and low-income countries only 8% (Sato et al. 2013). Globally over 80% of wastewater is released into wetlands without adequate treatment (WWAP 2012; UN-Water 2015).

Some 25 to 40 billion tonnes of topsoil erode every year, mainly from farmland. Erosion transports 23-42 million tonnes of nitrogen and 15-26 million tonnes of phosphorus (FAO and ITPS 2015). Globally, nutrient loading and eutrophication of wetlands remain the largest water quality challenges (Figure 2.12). In the North American Great Lakes, the increase in diffuse sources from agriculture and domestic lawns means that Lake Erie is becoming more eutrophic again (Michalak et al. 2013; Scavia et al. 2014). In Europe, eutrophication affects about 30% of water bodies in 17 Member States (European Commission 2012), particularly from diffuse pollution sources. Almost 15% of groundwater monitoring stations exceeds the World Health Organization standard for nitrates in drinking water (European Commission 2013). By 2050, an estimated one-fifth of the global population will face risks from eutrophication and one-third will be exposed to water with excessive nitrogen and phosphorous (WWAP 2017).

Too much sedimentation can damage aquatic biodiversity (e.g., Jones et al. 2012; Kemp et al. 2011), while conversely trapping sediments behind dams can reduce sediment loads to coastal and delta zones ("sediment starvation") resulting in land subsidence and wetland loss. The loss of wetlands and their storm and flood protection in the Mississippi Delta, due in part to dam construction, contributed significantly to increasing the impacts of Hurricane Katrina in 2005 (Batker et al. 2010).

Early findings from the global water quality monitoring programme show severe pathogen pollution (Figure 2.13) already affects one-third of all river stretches in Latin America, Africa and Asia (UNEP 2016). Despite some improvements in sanitation coverage (WHO/UNICEF 2015), for two decades loadings of faecal coliform bacteria have generally increased in these regions. Microbial contamination of wetlands is a serious health risk (Santo Domingo et al. 2007), responsible for diseases such as cholera and giardiasis (Horwitz et al. 2012).

Salinity is another key determinant of water quality. Clearing vegetation and irrigating salt-affected soils can leach salts as irrigation water percolates through the soil profile, increasing groundwater salinity (OECD 2012a). Rising water tables cause salinization of soils and wetlands. In coastal areas, both over-abstraction of groundwater, and sea level rise, contribute to saltwater intrusion (OECD 2015a; Werner et al. 2013). Groundwater salinity and soil salinization are largely irreversible (Bennett et al. 2009).

Control of sulphur pollutants from power plants has reduced the occurrence and impacts of acid deposition in OECD countries (OECD 2017). However, nitrogen oxides from fossil fuels and ammonia from agriculture still cause acid deposition to wetlands, and subsequent eutrophication. Acid mine drainage is a major pollutant in many countries (Simate & Ndlovu 2014), and mining can also be a significant source of dissolved heavy metals.

Thermal pollution of wetlands is commonly associated with power plants and industry. It decreases oxygen, alters food chains, reduces

A wide range of pollutants are impacting water quality

biodiversity and encourages invasions by thermophilic species (Chuang et al. 2009; Teixeira et al. 2009). The global extent and impacts of thermal pollution are not well studied (OECD 2017).

Increasing loads of plastic debris are being dispersed over long distances. At least 5.25 trillion plastic particles, weighing over 260,000 tonnes, are afloat in the world's oceans (Eriksen et al. 2014). Debris can persist for centuries (Derraik 2002). Plastic particles disrupt food chains, damage animals and release Persistent Organic Pollutants. About 88% of reported incidents between biota and marine debris are associated with plastics (GEF 2012); in the Mediterranean, plastic has been found in 18% of the stomachs of larger pelagic predatory fish (Romeo et al. 2015), and microplastic pollution is increasing in many inland systems such as the Great Lakes (Eriksen et al. 2013) and remote mountain wetlands (Free et al. 2014).

Agricultural intensification has increased chemical use worldwide, to approximately two million tonnes/year (De et al. 2014). Many chemicals can leach into water (Flury 1996), creating a global problem (Arias-Estévez et al. 2008; Bundschuh et al. 2012; EEA 2014; Luo et al. 2009). Impacts are largely unquantified, for example in soil organisms (Bünemann et al. 2006). In nearly half of OECD countries pesticide concentrations in surface and groundwater in agricultural areas exceed national recommended limits (OECD 2012b).

Contaminants of emerging concern – pharmaceuticals, hormones, industrial chemicals, personal care products and many others – are continually evolving and often detected at concentrations higher than expected (Sauvé & Desrosiers 2014).

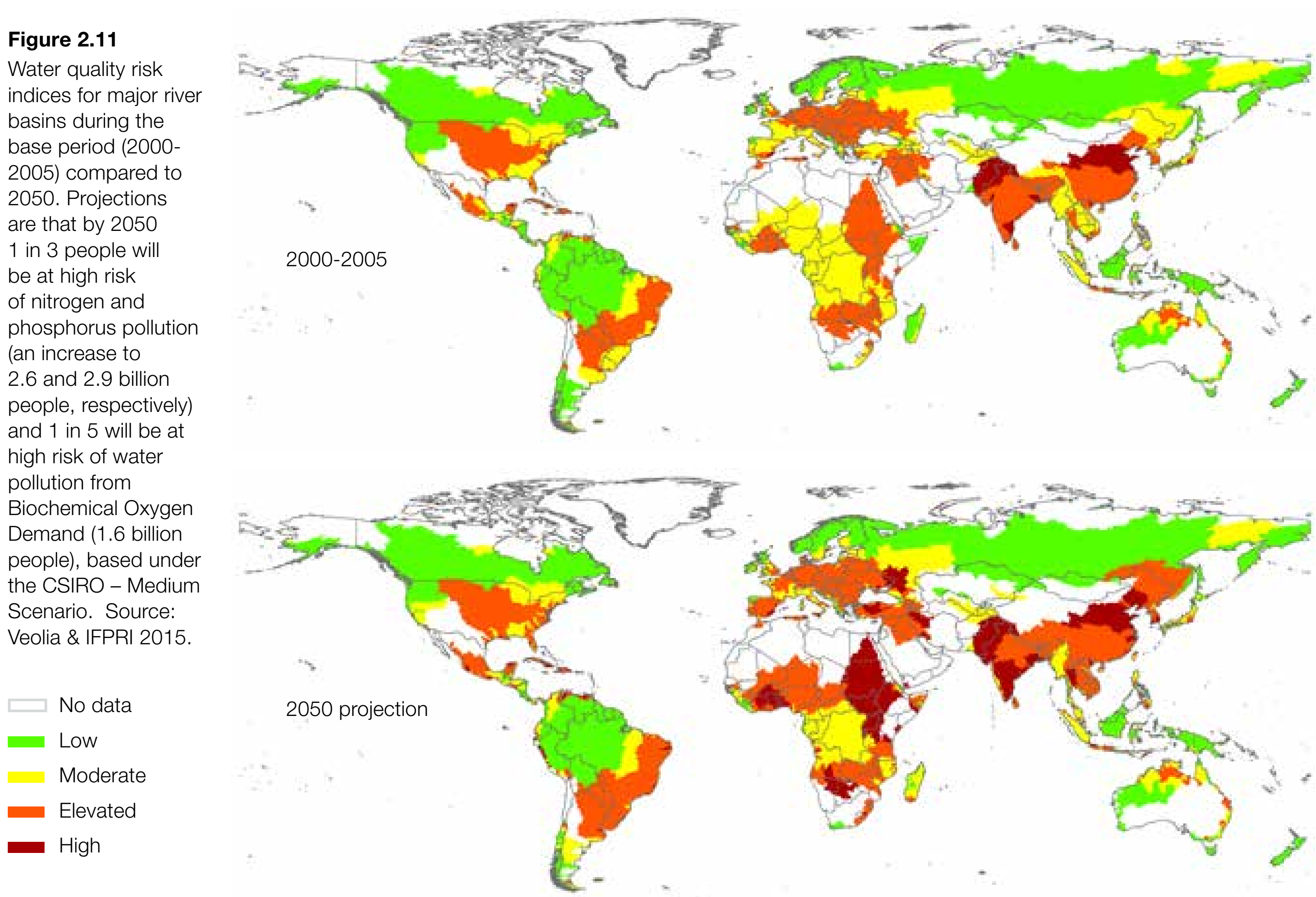
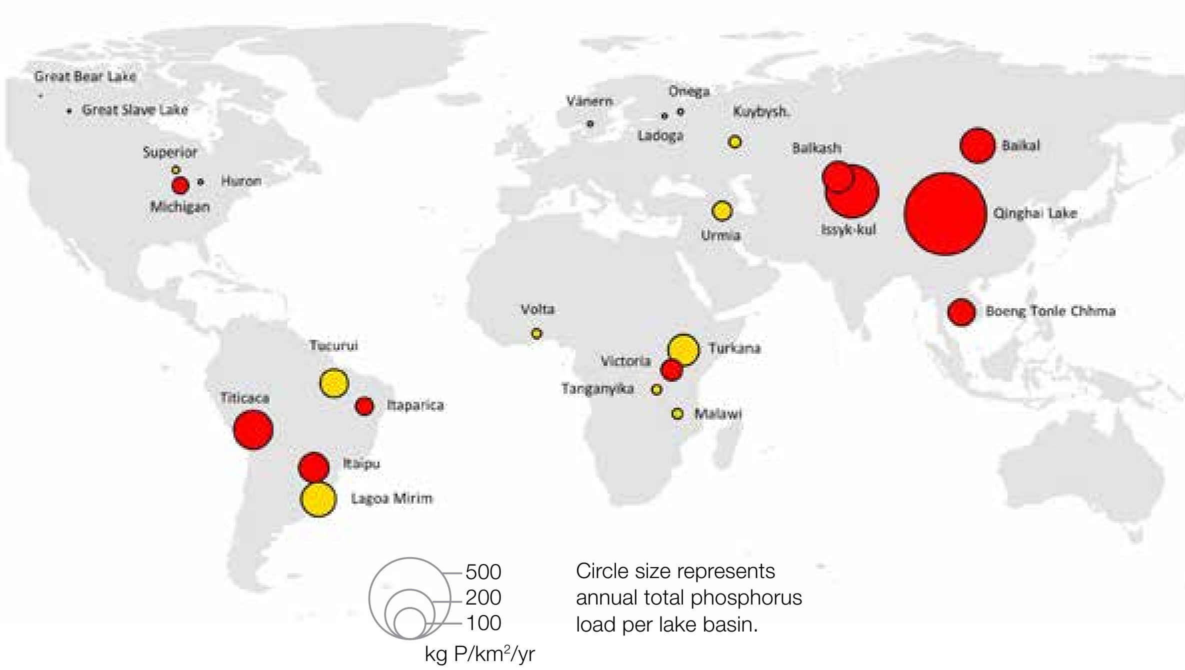


Figure 2.11
Water quality risk indices for major river basins during the base period (2000-2005) compared to 2050. Projections are that by 2050 1 in 3 people will be at high risk of nitrogen and phosphorus pollution (an increase to 2.6 and 2.9 billion people, respectively) and 1 in 5 will be at high risk of water pollution from Biochemical Oxygen Demand (1.6 billion people), based under the CSIRO – Medium Scenario. Source: Veolia & IFPRI 2015.

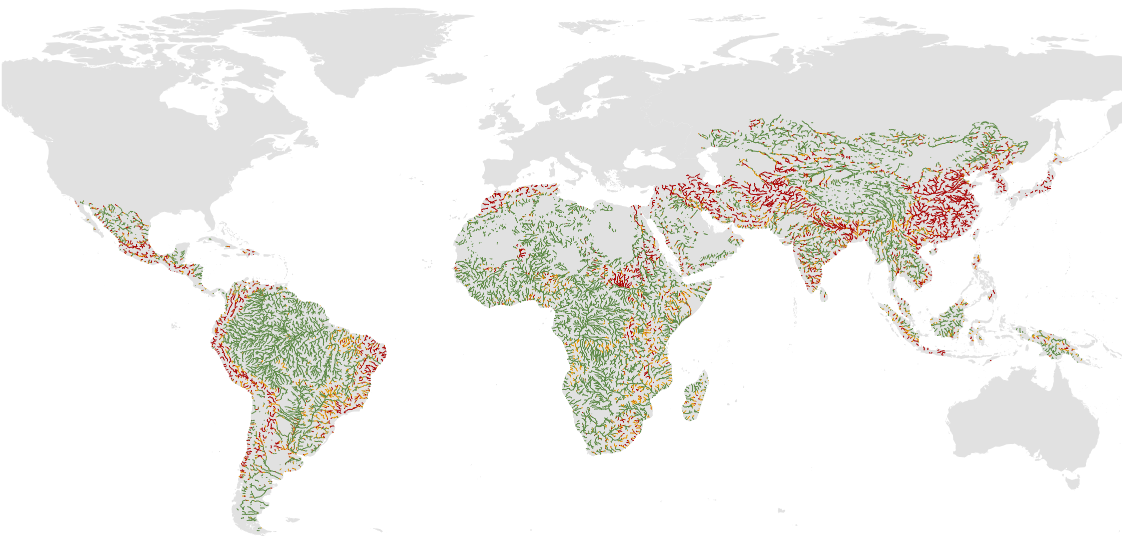
Figure 2.12
Average total phosphorus loads per lake basin area with an indication of the role of human activities for the 25 largest lakes, 2008-2010. Colour indicates whether the proportion of anthropogenic loadings exceeds 50% (yellow) or even 90% (red) or falls below 50% (blue). From UNEP (2016).

Annual total P loads:
Anthropogenic loadings are
- ≤50% or
- >50% and ≤90%
- >90% of total loadings



Circle size represents annual total phosphorus load per lake basin.

Figure 2.13
Estimated in-stream concentrations of faecal coliform bacteria (FC) for Africa, Asia and Latin America (February 2008-2010). Source: UNEP (2016).
© CESR, University of Kassel, April 2016, WaterGAP3.1



February 2008-2010
FC [cfu/100ml]
- Not computed
- Low pollution (=200) (suitable for primary contact)
- Moderate pollution (200<x<1000) (suitable for irrigaton)
- Severe pollution (>1000) (exceeds thresholds)

Wetlands maintain the global water cycle — hydrological processes

Ecosystem processes are the physical, chemical and biological interactions responsible for the dynamics and ecological functioning of wetlands; they also underpin many ecosystem services. The major processes addressed here can be categorized as: hydrological, biogeochemical, carbon sequestration and storage, and primary productivity and energy flow.

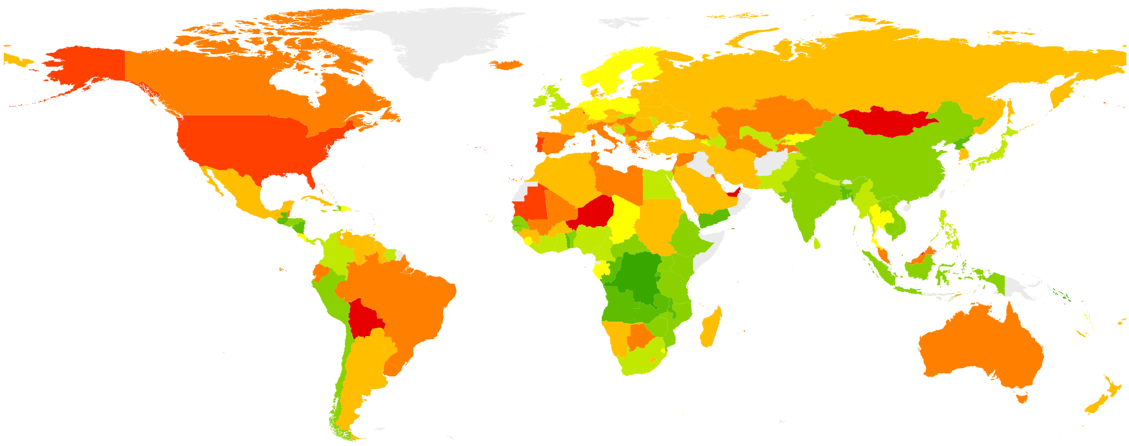
Wetlands play a major role in the water cycle by receiving, storing and releasing water over time, regulating water flows, and providing the water needed to support life. The hydrological regime is a measure of the levels, volume, timing and frequency of water flows into and out of wetlands. It helps determine wetland structure and function, influences biodiversity and primary production, and generates ecosystem services such as flood abatement and water quality improvement. Water management and sea level rise are changing hydrology in many regions, for example in the Mekong Delta where salinity and water levels are increasing, leading to shifts in wetland structure and function (Erwin 2009).

Changes to the water cycle influence wetland processes, reducing or increasing water, converting ephemeral or seasonal wetlands to near-permanent, or changing the seasonality of water flows. Changes in surface water and seasonality of flows have occurred in many river basins, including the Colorado, Yangtze, Murray-Darling and Nile (Gupta 2007). Over-pumping of groundwater has depleted the water available to wetlands in parts of the US (Froend et al. 2016), the North China Plain, the Northwest Sahara Aquifer System, the Guarani Aquifer in South America and aquifers beneath north-western India and the Middle East (Famiglietti 2014). Water management that reduces natural water level fluctuations also decreases habitat diversity (e.g., by changing wetland mosaics to channelized systems) and species abundance (e.g., by reducing plant seed germination) (Voldseth et al. 2007; Blann et al. 2009).

Trends in hydrologic processes are influenced by increasing human demands and changes in precipitation and evapotranspiration due to climate change, both creating competition for available water (Hipsey & Arheimer 2013). The supply of freshwater has been subject to increasing pressure from consumption and pollution as populations increase (Postel 2000). Water use can be represented by the total water footprint of a region (Figure 2.14), to inform water management. This provides a cumulative measure of pressure on water supplies by accounting for "blue" water (surface and groundwater used for irrigation, industrial or domestic purposes), "green" water (rainwater stored in the soil used by crops and lost by evapotranspiration) and "grey" water (the amount of freshwater required to assimilate pollutants). The global water footprint increased between 1996 and 2013, with agriculture accounting for 92% of this (Mekonnen & Hoekstra 2011), causing major disruptions to hydrologic processes.

Figure 2.14
Global water footprint as shown through National Water Footprint Accounts for the total of green, blue and grey water (from Mekonnen & Hoekstra 2011).

Total water footprint [m3/yr/cap]
- 550 - 750
- 750 - 1000
- 1000 - 1200
- 1200 - 1385
- 1385 - 1500
- 1500 - 2000
- 2000 - 2500
- 2500 - 3000
- > 3000
- No data



Complex biogeochemical processes maintain functional wetland ecosystems

Wetlands support a unique set of biogeochemical processes as a result of their hydrologic and soil characteristics. When saturated, wetland soils store, transform and export nutrients and other compounds. Ecosystem processes that lead to the uptake and retention of nutrients include: plant uptake and storage in tissues, microbial processing (particularly of carbon, nitrogen and sulphur), and the physical process of sediment deposition. Many biogeochemical processes are the foundation for ecosystem services such as water quality improvement, particularly the removal of nutrients from agricultural and urban runoff.

Nitrogen is a key nutrient needed for growth (Vitousek et al. 1997), but in excess it can run off from agricultural and urban lands to pollute surface and groundwater (Paerl et al. 2016; Rabalais et al. 2002). In waterlogged soils nitrate-nitrogen is transformed by microbes to nitrogen gas and returned to the atmosphere through the process of denitrification, (Groffman et al. 2009), which can remove up to 90% of the incoming nitrate loads (Zedler & Kercher 2005). Denitrification rates are closely correlated with the availability of organic matter and soil nitrate, both of which can be abundant in wetlands, making them denitrification "hot-spots" (Groffman et al. 2012). The increases in nitrate runoff associated with agricultural runoff lead to higher rates of denitrification (Zedler & Kercher 2005). Nitrogen is also deposited in wetlands through atmospheric processes.

Phosphorus is also a critical nutrient and at natural levels it is often limiting to plant growth. As many of its forms are insoluble, the bulk of phosphorus is attached to and transported by sediments. Agricultural intensification is increasing application of mineral phosphorus fertilizer and thence its loss to wetlands (Ockenden et al. 2017). Some sinks to the bottom and is absorbed into soil (Kadlec 2008) while some stimulates plant growth (Marton et al. 2015) and thus eutrophication. Climate change is projected to increase phosphorus loss to wetlands by 30% by 2050 (Ockenden et al. 2017).

Nutrients are exported from wetlands in several ways including in the form of organic matter. Nutrient uptake and temporary storage in plants can have the beneficial effect of desynchronizing nutrient movement in watersheds. For example, in temperate climates, phosphorus is taken up by plants in the spring and summer then released in the autumn as plants die back. This improves water quality during the critical growing season, reducing eutrophication (Mitsch & Gosselink 2015).

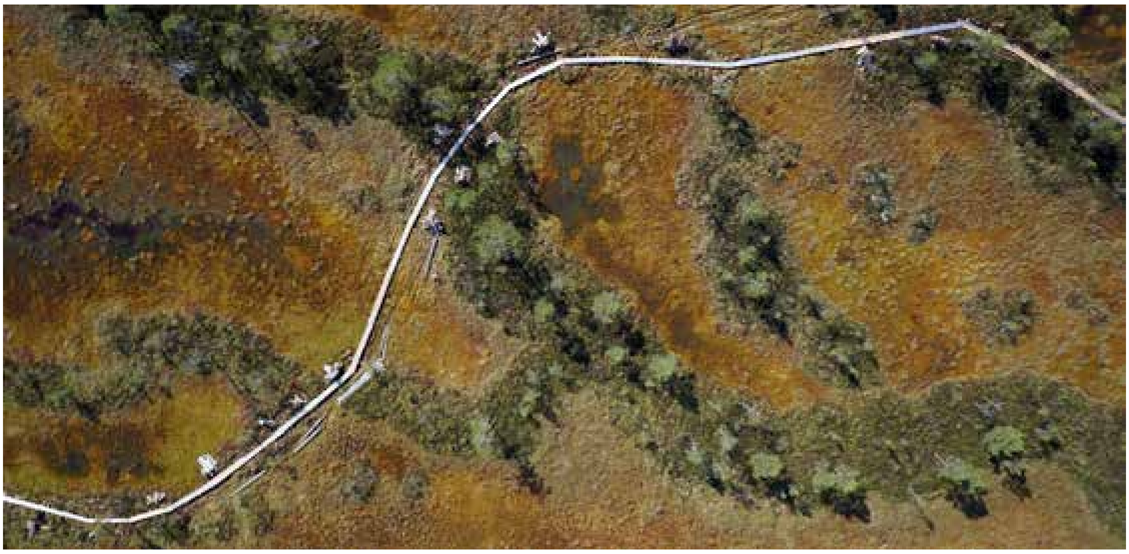
Wetlands are the world's largest carbon stores, but also release methane

The majority of the global soil carbon pool is held in wetlands. Carbon sequestration and storage results from the balance of primary production (taking in carbon dioxide for photosynthesis and producing organic matter) and respiration (or decomposition; generating carbon dioxide or methane from organic matter) (Joosten et al. 2016). Wetland conditions slow decomposition and when less than plant productivity, carbon accumulates (Moomaw et al. 2018). Changing temperature and precipitation regimes due to climate change can shift the balance of these processes, causing wetlands to become carbon sources. Peatlands are powerful carbon sinks, holding the largest, long-term store of any ecosystem. Peat accumulates at rates of 0.5–1.0 mm yr^{-1} building over thousands of years (Parish et al. 2008) making peatlands one of the largest global reserves, storing over 600 PgC (Gorham 1991). This is nearly three-quarters as much as is stored in the atmosphere (Moomaw et al. 2018) and, despite occupying only 3% of the land surface, they store twice as much carbon as the world's forest (Joosten et al. 2016).

Coastal and marine wetlands, including salt marshes, mangroves and seagrass beds, are also critical sites of carbon uptake and storage. Mangrove forests are some of the most "carbon dense" ecosystems in the world (Ewers Lewis et al. 2018). This "blue carbon" accumulates due to high primary production and sediment trapping, enabling carbon to accumulate over long time periods (perhaps thousands of years; McLeod et al. 2011). In river deltas, these processes may allow wetlands to keep pace with sea level rise. When sediment inputs are cut off, sediment starvation and subsidence of delta wetlands can occur (Giosan et al. 2014). Increasing human disturbance in coastal zones is linked to the loss of carbon from wetland soils (Macreadie et al. 2017).

However, the climate mitigation benefits of carbon storage in freshwater wetlands are partially counteracted by release of methane, a potent greenhouse gas. As part of the carbon cycle, wetlands can release the greenhouse gases carbon dioxide and methane, the latter by specialized bacteria known as methanogens. Wetlands produce an estimated 100 Tg of methane per year, 20-25% of total global methane emissions (Keddy 2010). Emissions vary widely: tending to be low in brackish to saltwater wetlands where high sulphate levels inhibit methane production (Poffenbarger et al. 2011), and higher in freshwater sites.

Higher temperatures under climate change are expected to increase greenhouse gas emissions from wetlands, particularly in permafrost regions where warming leads to permafrost melting, increasing the availability of oxygen and water in the soil. Subsequent microbial activity generates large amounts of carbon dioxide and/or methane that is released to the atmosphere (Moomaw et al. 2018).



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Wetlands are one of the most biologically productive ecosystems

Primary production is a measure of plant growth (i.e., the carbon fixed in photosynthesis by plants and algae), and the source of energy for all animals. It is also the foundation for many wetland ecosystem services, where high levels of productivity support many human communities (Bullock & Acreman 2003). Primary productivity varies with wetland type, plant species present, climate, soils, nutrient availability and hydrologic regime (Table 2.6; Bedford et al. 1999; Ehrenfeld 2003). High rates of primary production tend to support high animal diversity (Keddy et al. 2009), for example the highly productive Pantanal (in Brazil, Bolivia and Paraguay) has 260 species of fish, 650 species of birds, and many large animals (Zedler & Kercher 2005).

Trends in primary production are strongly influenced by trends in water quality, particularly nutrient loads, influenced for example from agricultural runoff. With nutrient enrichment, wetlands are subject to invasion by aggressive species with high growth rates, such as *Typha* spp., or depending on location, *Phragmites* spp. (Keenan & Lowe 2001). The dominance of highly productive plant species can represent a trade-off in other wetland functions, for example biodiversity typically declines, while organic matter and carbon accumulation in wetland soils increases (Craft & Richardson 1993). Continuous loading of phosphorus to the Florida Everglades has increased primary production as *Typha* invades at the expense of native plant communities (Noe et al. 2001). Higher atmospheric carbon dioxide concentrations can stimulate plant growth, although this effect differs by species and wetland type (Erickson et al. 2013).

Finally, wetlands are important sources of organic carbon, exporting leaf litter and dissolved organic carbon that supports downstream food webs (Elder et al. 2000). Organic carbon is also important because of its ability to attenuate light and absorb harmful UV-B radiation (Williamson et al. 1999), protecting amphibian and fish eggs from impacts such as DNA damage (Hader et al. 2007).

Table 2.6
Primary production, a measure of the accumulation of organic matter, for a range of wetland ecosystem types (Cronk & Fennessy 2001). Data for peatlands includes above and below ground (root) production.

Wetland Type	Net Primary Production g dry weight m^{-2} yr^{-1}
Salt Marsh	130 – 3700
Tidal Freshwater Marsh	780 – 2300
Freshwater Marsh	900 – 5500
Mangrove	1270 – 5400
Forested Northern Peatlands	260 – 2000
Non-forested Northern Peatlands	100 – 2000

Wetlands play a critical role in providing ecosystem services

Ecosystem services are a core component of the Ramsar Convention's conceptualization of ecological character, and of Ramsar Site values (Sharma et al. 2015; Wang et al. 2015). Wetlands play a greater role in providing ecosystem services than other ecosystems (Costanza et al. 2014; Russi et al. 2013). The *Ramsar Strategic Plan* calls for including wetland benefits in the strategies of sectors such as energy, mining, urban development and tourism, and promotes mainstreaming recognition of these benefits.

Values can be expressed in different ways, from monetary to aesthetic, spiritual or totemic, and quantitatively or qualitatively. Qualitative expressions may include: as a core belief (e.g., species' existence rights); assignment of importance (e.g., in disaster risk reduction); or as a preference (e.g., to support tourism). Multiple perspectives need to be taken into account.

An indicator in the *Ramsar Strategic Plan* requires assessment of the ecosystem services from Ramsar Sites. Data from 2018 National Reports suggest that there has been some progress, with 24% of reporting countries having carried out such an assessment. Box 2.5 provides an example.

Building on available assessments of ecosystem services, and on the Millennium Ecosystem Assessment (2005), a qualitative analysis of ecosystem services in wetlands is provided in Table 2.7. For inland wetlands the importance of food, fresh water, fibre and fuel is evident. Regulating services are important, particularly for climate, hydrological regimes, pollution control and detoxification, and natural hazards. Spiritual, inspirational, recreational and educational services are important in rivers, streams and lakes. Regulating services are underpinned by support for biodiversity, soil formation and nutrient cycling. A different pattern is seen in coastal/marine wetlands, with food being the dominant provisioning service, and climate regulation also important. Tidal flats, salt marshes and mangroves provide pollution control and detoxification, and, along with coral reefs, regulation of natural hazards.

Box 2.5

ICHKEUL ECOSYSTEM SERVICES

Ichkeul National Park in Tunisia is a Ramsar Site covering 12,600 ha of lake and marshes. Highly threatened in the 1990s due to water diversion and dam building; ecosystem collapse was avoided by a new management strategy and a series of wet years. The park is important for its waterbirds, and provides diverse ecosystem services to local and regional populations. These were quantified in 2015, amounting to c. US$3.2 million/year, or US$254/ha, with regulating services providing 73% of this value, provisioning services 18% and cultural services 9%. Protection against floods (34%), groundwater replenishment (23%) and sediment retention (12%) had the highest value, followed by grazing (10%), recreation/tourism (9%) and fisheries (7%). The value of services is almost ten times the management costs. The share benefitting the local population is comparatively low (11%), but the amount per household is not negligible and amounts on average to c. US$1,600/year for households located inside the park. These figures will be used to argue for water releases from dams to maintain the wetlands, and to communicate park values to local communities.
After Daly-Hassen (2017).

Wetland ecosystem services

Table 2.7
Consolidated list of wetland ecosystem services

Relative importance of ecosystem services derived from different types of wetland ecosystems (based on expert opinion and from the Millennium Ecosystem Assessment 2005). The information represents a global average; there will be local and regional differences in importance, and further services could be added as considered important and where adequate information is available.

H High
M Medium
L Low
? Not known
na Not applicable

Wetland types / Services	Inland wetlands					Coastal / marine wetlands							Human-made wetlands					
	River Stream	Lake	Peatland	Marsh Swamp	Underground	Salt Marsh	Mangrove	Seagrass	Coral Reef	Shellfish Reef	Lagoon	Kelp	Reservoir	Rice Paddy	Wet Grass	Waste Ponds	Salinas	Aqua Ponds
Provisioning services																		
Food	H	H	H	H	na	H	H	M	M	M	M	L	M	H	H	L	H	H
Fresh water	H	H	L	M	H	L	na	na	na	na	L	na	M	na	na	L	na	Na
Fibre & fuel	M	M	H	H	na	L	H	na	na	na	M	na	L	na	na	L	na	L
Biochemical products	L	?	?	L	?	L	L	?	L	?	?	L	?	na	?	?	L	?
Genetic materials	L	L	?	?	?	L	L	?	L	?	?	?	L	L	?	?	L	L
Regulating services																		
Climate	L	H	H	H	L	H	H	H	M	L	L	na	M	L	L	na	L	na
Hydrological	H	H	M	M	L	M	H	na	na	na	M	na	H	M	L	na	na	na
Pollution control	H	M	M	H	M	H	H	L	L	na	M	?	L	L	L		na	na
Erosion protection	M	M	M	M	H	M	H	L	M	M	L	L	L	M	M		M	na
Natural hazards	M	H	M	H	na	H	H	M	H	M	M	L	L	L	L	na	M	na
Cultural services																		
Spiritual & inspirational	M	H	M	M	L	?	L	?	H	na	M	na	M	L	L	na	M	na
Recreational	H	H	L	M	L	?	?	?	H	na	M		H	L	L	na	L	na
Aesthetic	M	M	L	M	L	M	M	na	H	na	M	na	H	M	M	na	M	na
Educational	H	H	M	M	L	L	L	L	L	L	L	L	H	L	L	L	M	L
Supporting services																		
Biodiversity	H	H	H	H	H	M	M	L	H	M	M	L	M	M	M	L	M	L
Soil formation	H	L	H	H	na	M	M	na	Na	na	na	na	L	M	L	L	L	na
Nutrient cycling	H	L	H	H	L	M	M	L	M	na	M	L	L	M	L	H	L	L
Pollination	L	L	L	L	na	L	M	M	Na	na	?	?	L	L	M	L	L	na

Types of ecosystem services provided by wetlands

Water

Wetlands play crucial roles in providing fresh water for domestic uses, irrigation and industry. Global renewable water resources from rivers and aquifers total ~ 42,000 km^3/year of which 3,900 km^3/year is extracted for human use (FAO 2011). Agriculture accounts for 70% of water withdrawals, industry 19% and the municipal sector 11%. Global irrigated agriculture area has doubled in 50 years. Europe withdraws 6% of water resources (29% for agriculture), Asia 20% (80% for irrigation), and the Middle East, Central Asia and North Africa withdraw 80-90% for irrigation (FAO 2011). Groundwater demand has rapidly increased, particularly in South Asia where 40% of irrigated agriculture relies on groundwater alone or in conjunction with surface water (FAO 2011). It is estimated that around 60% of human water withdrawals flow back to local hydrological systems, with the rest representing consumptive use (FAO 2011). Impacts on water services are similar in countries with very different levels of wealth (Dodds et al. 2013).

Food

Wetlands provide a wide diversity of food. Inland fisheries range from large-scale industrial operations to subsistence, with global annual harvest rising from 2 million tonnes in 1950 to over 11.6 million tonnes in 2012, likely even higher if small-scale subsistence fishing is included (FAO 2014). Bartley et al. (2015) report that 95% of the inland fisheries' catch occurred in developing countries, where it often plays a vital nutritional role, but represents only 6% of global fish production. Estuarine and coastal fisheries have declined by 33% since industrialization, with fishery nursery habitats (e.g., oyster reefs, seagrass beds and other wetlands) declining by 69% (Barbier et al. 2011; Worm et al. 2006). Global aquaculture increased from less than 1 million tonnes in 1950 to 52.5 million tonnes in 2008, comprising 45.7% of the world's food fish production. Rice fields are increasingly used for aquaculture (Edwards 2014). Aquaculture is commonest in Asia (especially China), significant in Europe and Africa, but still relatively low in the Americas (FAO 2011). Wetlands also provide grown and harvested wet crops, wildfowling and other hunting.

Water regulation

Wetlands retain, release and exchange water, influencing policies such as Natural Flood Management (Parliamentary Office of Science and Technology 2011). River channels, floodplains and large connected wetlands play significant roles in catchment hydrology, but the water-holding capacity of many "geographically isolated" wetlands can play important roles in hydrology (Marton et al. 2015) with effects on stream flows (Golden et al. 2016). Well-functioning wetlands can reduce disaster risk. Practical examples include the Charles River in Massachusetts, USA, where conservation of 3,800 ha of wetlands reduces flood damage by an estimated $17 million/year (Zedler & Kercher 2005). Conversely, wetland loss can increase flooding and storm damage (Barbier et al. 2011). There is a growing appreciation that maintaining wetland services is generally more economic than converting them to alternative uses (Garcia-Moreno et al. 2015).

Other natural hazards

Wetlands play key roles in other types of natural hazard regulation. Moist wetland habitats can serve as a brake on natural and anthropogenic pressures contributing to salinization of soils and wildfire spread. However, the relationships between the various factors modulating the impacts of extreme events are complex and often poorly understood (de Guenni et al. 2005).

Climate regulation

Storage and sequestration of carbon by wetlands plays an important role in regulation of the global climate. Peatlands and vegetated coastal wetlands contain large carbon sinks and sequester approximately as much carbon as do global forests, although freshwater wetlands also represent the largest natural source of methane (Moomaw et al. 2018). Salt marshes sequester millions of tonnes of carbon annually (Barbier et al. 2011), whilst deep tropical dams can be a substantial source of methane, offsetting or overwhelming the reported low-carbon benefits of hydropower generation (Lima et al. 2008). Natural processes in wetlands account for 25–30% of methane emissions, and wetlands are a significant contributor to the 90% of nitrous oxide emissions from ecosystems (House et

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al. 2005). Wetlands also provide microclimate regulation, for example in urban environments where they can break down "heat islands" (Grant 2012).

Cultural heritage

Natural features of wetlands and other ecosystems often embody cultural and spiritual importance, including regional identity. These can include both natural features, such as the sacred lakes of the Himalayas (WWF 2009), and human-constructed features such as the rice paddy that constitutes the principal source of income for about 100 million households in Asia and Africa (Umadevi et al. 2012). Cultural heritage includes traditional knowledge about the characteristics, social meaning and stewardship of wetland resources, as for example for Australia's First People (Department of the Environment 2016).

Recreation and tourism

Both natural and modified wetlands offer recreational possibilities and tourism benefits. Scuba diving in coral reefs provides a rationale for their protection but also adds potential pressures on ecosystems (Barker & Roberts 2004). In 2002, the earnings of about 100 dive operators in Hawaii were estimated at US$50–60 million/year (van Beukering & Cesar 2004). Coral reef diving earns gross revenue of US$10,500–45,540/year in the Bohol Marine Triangle, the Philippines (Samonte-Tan et al. 2007). The value of tourism on the Great Barrier Reef in Australia is more than AU$ 5.2 billion annually (Goldberg et al. 2016). Substantial losses in tourism revenue have been observed due to recent coral bleaching events (Barbier et al. 2011).

Wetland ecosystem services exceed terrestrial services in value

Reviews of wetland ecosystem services (e.g., by Brander et al. 2006; Brouwer et al. 1999; Ghermandi et al. 2010), show that the estimated values vary enormously across wetlands with different characteristics. De Groot et al. (2012) provided average Total Economic Value (TEV) of wetland ecosystem services based on 458 value-estimates (on 2007 Int$/ha/year): open ocean 490; coral reefs 350,000; coastal systems (including beaches) 29,000; coastal wetlands (including mangroves) 190,000; inland wetlands 25,000; rivers and lakes 4,300. Wetlands far exceeded terrestrial ecosystems; for example inland wetlands had a TEV almost five times higher than tropical forests, the most valuable terrestrial habitat. Costanza et al. (2014) analysed the loss of ecosystem services from 1997-2011 due to changes in the area of different biomes, including wetlands. They estimated losses of ecosystem services were US$7.2 trillion from tidal marshes and mangroves, US$2.7 trillion from swamps and floodplains, and US$11.9 trillion from coral reefs.

Numerous studies examine ecosystem services from specific wetlands, but few indicate trends. New Zealand provides an example of trends in wetland ecosystem services over two decades showing both importance and decline (Figure 2.15). In the absence of data for other wetlands it is reasonable to conclude that as wetland extent and status decline, so do ecosystem services.

Figure 2.15

Trends of ecosystem services from aquatic ecosystems in New Zealand over two decades (adapted from Dymond et al. 2014)

Importance for delivering services.

- High
- Medium high
- Medium low
- Low

Trend over last 20 years

- ↑ Improving
- ↗ Some improvement
- ↔ No net change
- ↘ Some deterioration
- ↓ Deterioration
- +/- Improvement and/or deterioration in different locations

Ecosystem service	Wetland	Estuary	Lake	River	Marine
Provisioning					
Crops					
Livestock					
Capture fisheries	Medium low ↘	Medium high ↔	High ↔	High ↔	High ↔
Aquaculture				High ↗	High ↗
Wild foods	High +/-	High +/-	High +/-	High +/-	
Timber					
Fibre	Medium low ↘				
Biomass fuel					
Thermal energy					
Freshwater	Medium low ↔		High ↔	High +/-	
Genetic resources	High ↘	High ↔	High ↔	High ↘	High ↔
Biochemicals, natural medications and pharmaceuticals					
Minerals					High ↗
Physical support for dwellings					
Regulating					
Air quality regulation					
Climate regulation	Low ↔	Low ↔	Low ↔	Low ↔	High ↘
Water regulation	Medium low ↔			High ↘	
Erosion regulation					
Water purification and waste treatment	Medium high ↘			High ↘	
Disease regulation					
Pest regulation	Medium high ↘	Medium high ↔	High ↘	High ↘	Medium high ↔
Pollination					
Natural hazard mitigation	Medium high				
Cultural					
Amenity value	Medium low ↘	High ↘	High ↘	High +/-	High +/-
Recreation	Medium low ↔	High ↔	High ↘	High ↔	High ↔
Tourism	Medium low ↔	Medium low ↔	High ↔	High ↔	High ↔
Sense of belonging		Medium high ↔	High ↔	High ↔	High ↔
Supporting					
Soil formation and maintenance					
Provision of natural habitat free of weeds and pests	High ↘	High ↘	High ↔	High ↘	High ↘

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These issues were highlighted by Green et al. (2015) who pointed out that nearly all global fresh water resources were compromised to some extent, with 82% of the global population exposed to a high level of threat to their upstream fresh water supply. Ricaurte et al. (2017) in a national analysis for Colombia, found that there were large differences in the vulnerability of different wetland types and their ecosystem services, with the most vulnerable being floodplain forests, riparian wetlands, freshwater lakes and rivers. They recommended that land use policies were needed to ensure restrictions on activities that were harmful to wetlands if these services were to be maintained.

Box 2.6

REDUCING NUTRIENT POLLUTION TO RESTORE SEAGRASS

Contemporary wetlands face many challenges. But wetland ecosystems are also resilient, and if care is taken to reduce pressures and introduce effective management, some of the problems can be halted or reversed.

The Tampa Bay Estuary Program (TBEP), established by federal law in Florida, USA, has successfully restored seagrass beds to their 1950s extent. The TBEP's approach recognizes that healthy seagrass populations are found in open waters with the lowest levels of nutrient pollution, which is a function of upstream land uses. Nitrogen loads are the most damaging nutrient entering the estuary.

After the federal government approved limits on nitrogen for Tampa Bay, the TBEP facilitated fair and equitable nitrogen load allocations through the Tampa Bay Nitrogen Management Consortium (NMC), a voluntary, ad-hoc public-private partnership. This has reduced both point and non-point sources of nitrogen. Members include the primary point source dischargers: public wastewater treatment facilities, an electric power plant, a port and phosphate facilities. The NMC includes local government, which regulates land use activities responsible for non-point source nutrient pollution. They have prohibited the sale and use of fertilizer during the rainy season and regulated coastal zone development. By 2015, 16,306 ha of seagrass occurred in Tampa Bay, exceeding the restoration goal of 15,400 ha set in 1995.

Source: Sherwood (2016)