



Global Wetland Outlook: Technical Note on Status and Trends

The Status and Trends section of the Global Wetland Outlook (GWO) provides the context for the report by examining the distribution and condition of wetlands globally. This Technical Note provides further information on the area of wetlands globally. This is provided in support of the information on wetland area that has been summarised and included in the GWO. Further information on other measures used to describe the ecological character of wetlands is presented in the GWO and is not considered further in this Technical Note.

Specifically, data from the Supplementary Material (<https://doi.org/10.1071/MF17377>) compiled by Davidson & Finlayson (2018) are presented here (with permission from CSIRO Publishing) to provide more detailed information on the extent of 22 individual wetland classes; the relationships between these and the Ramsar wetland typology are shown in the Appendix provided by Davidson & Finlayson (2018).

The information that is provided here shows that inland natural surface wetlands are dominated by non-forested peatlands, marshes and swamps on alluvial soils, with peatlands forming approximately 33% of these wetlands. The area of marine or coastal wetlands is dominated by unvegetated tidal flats and saltmarshes. The total global wetland area estimated from these individual wetland classes is between 15.2×10^6 and 16.2×10^6 km², which is greater than that obtained from recent global estimates derived largely from remote sensing (Davidson & Finlayson 2018). Given considerable data gaps for some wetland classes included in the Ramsar wetland typology, these figures are seen as underestimating the area of global wetlands.

Background

The GWO, which is the Ramsar Convention's flagship publication, reports on the status and trends of the world's wetlands. The Contracting Parties requested the GWO in Ramsar Resolution XII.5, which called upon the Convention's Scientific and Technical Review Panel (STRP) to update and expand upon Ramsar Briefing Note 7, State of the World's Wetlands and their Services to People: A compilation of recent analyses. The Standing Committee subsequently identified this task as among the STRP's highest priorities.

Purpose

Technical notes are complementary to the GWO. They consist of technical information to explain the methodology or analysis supporting findings published in the GWO. They also provide supplemental details and references.

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Wetland types: A. Paramos lake, Colombia; B. Floodplain, Chile; C. Marsh, Brazil; D. High altitude peatlands, China; E. High altitude lake, India; F. River, UK; G. Reed swamp, Romania; H. Salt marsh, France; I. Coastal salt lake, Puerto Rico; J. Freshwater lake, Minnesota, USA; K. Mangroves, USA; L. Soda lake, Kenya; M. Water fall, USA; N. Swamp, Sri Lanka; O. Cave, Slovenia (Photographs © CM Finlayson)

Assessment of data and information for individual wetland classes

An assessment of the data and information on the area of individual wetland classes is provided below. It draws on the supplementary material provided in Davidson & Finlayson (2018). Information on the global extent of wetland classes is provided in Davidson et al. (2018). General information on the ecology and conservation of individual wetland classes and sites is not presented here, but can be found in papers in numerous compilations, including the 170 papers most recently included in the compendium published by Finlayson et al. (2018).

The following text is divided into the three categories used in the higher level of the Ramsar typology of wetlands, namely:

- Inland natural wetlands – rivers and streams; lakes; peatlands; marshes and swamps; and groundwater-dependent wetlands.
- Marine and coastal wetlands – estuaries; tidal flats and saltmarshes; coastal deltas; mangroves; seagrasses; coral reefs; shellfish reefs; coastal lagoons; kelp forests; and shallow subtidal marine systems.
- Human-made wetlands – reservoirs; small ponds; rice paddy; oil palm plantation; agricultural wet grasslands; wastewater treatment ponds; salt production ponds; and aquaculture ponds.

For further information on the range of wetland types and their classification, the reader is directed to a recent review by Gerbeaux et al. (2018).

The global area of wetlands provided by the combined estimates for individual wetland classes considered by Davidson & Finlayson (2018) amounted to 15.2 to 16.2 × 10⁶ km². This estimate for global wetland area is higher than the 12.1 × 10⁶ km² obtained from recent global wetland area estimates of permanently and seasonally inundated wetlands derived from remote sensing (Davidson et al. 2018); however, given the considerable data gaps for individual wetland classes, these estimates are both likely to be underestimates.

Inland natural wetlands

Rivers and streams

The surface area of rivers and streams is hard to measure and probably makes little sense, particularly over large geographical scales, as they are largely narrow, linear features, and flooding, particularly in tropical areas, can increase the areal extent of rivers 100–1000-fold (Melack et al. 2009). These changes suggest that it could be difficult to consistently determine the area of rivers and streams. Nevertheless, global area estimates have been made and vary, with Raymond et al. (2013) most recently providing an estimate of 0.624 × 10⁶ km², slightly smaller than the 0.662 × 10⁶ km² of Downing et al. (2012), but larger than the 0.360 × 10⁶ km² of Lehner & Döll (2004). Allen & Pavelsky (2018) in a new analysis show that global river and stream surface area (at mean annual discharge) is 0.773 × 10⁶ km², an area larger than previous estimates. Area estimates for most regions are not available, except for North America with 0.124 × 10⁶ km² (Allen & Pavelsky 2015).

Lakes

Lakes are water-filled depressions located in a basin and surrounded by land, varying in size (see below). The frequency of flooding and filling varies greatly, with some remaining dry for extended periods of time. The most recent global estimates of the area of natural lakes are 4.200 × 10⁶ km² for lakes >0.1 ha (Downing et al. 2006) and 3.232 × 10⁶ km² for lakes >1 ha (Messenger et al. 2016), with the former including more than 277 × 10⁶ very small lakes (0.1 to 1 ha), with a global area estimate of 0.693 × 10⁶ km², 16.5% of the estimated area of all lakes. Both estimates are higher than a previous estimate of 2.43 × 10⁶ km² (Lehner & Döll 2004). However, the latter is, by inference, for permanent freshwater lakes only since they also provide separate figures for ‘pan, brackish/saline

wetland', which includes salt and soda (alkaline) lakes, and 'intermittent lake/wetland', which includes intermittent lakes.

Messenger et al. (2016) provided an estimate of 2.670×10^6 km², for lakes >10 ha, similar to the 2.905×10^6 km² of Downing et al. (2006). By subtraction, the global area of lakes of 1-10 ha area from Messenger et al. (2016) is 0.562×10^6 km², which is not greatly different from the 0.602×10^6 km² estimate from Downing et al. (2006).

Natural lakes >10 ha are widely distributed across all continents, with the largest areas in North America (including Central America and the Caribbean): 1.23×10^6 km² (46% of global area); and Europe, including Russia: 0.78×10^6 km² (29%), with much smaller total lake areas in Asia (10%), Africa (9%), South America (4%) and Oceania (2%) (Messenger et al. 2016). Countries with the most lakes and the largest areas of lakes are Canada (880; 0.86×10^6 km²), Russia (201; 0.67×10^6 km²) and the USA (103; 0.34×10^6 km²). By surface area, by far the largest natural lake is the Caspian Sea (0.34×10^6 km²) followed by Lake Victoria (0.07×10^6 km²) and three of the North American Great Lakes – Superior, Huron and Michigan (Messenger et al. 2016).

Changes in the area of lakes indicate differences in area change between regions and lakes (Pekel et al. 2016; UNEP 2007). An exception occurs on the Tibetan Plateau where many of the endorheic lakes (lakes in closed drainage basins) are expanding and new lakes are forming due to increased run-off from accelerated snow and glacier melt, leading to a 20% increase in area, 0.008×10^6 km² (Pekel et al. 2016).

Peatlands

Peatlands have been defined by Joosten & Clarke (2002) as areas of land with a naturally accumulated layer of peat, formed from carbon-rich dead and decaying plant material under waterlogged and low oxygen conditions, generally comprising at least 30% dry mass of dead organic material and greater than 30 cm deep. They can develop under a wide range of vegetation types in fresh and saline water (Finlayson & Milton 2018).

Freshwater peatlands, including both forested and non-forested inland peatlands, are estimated as covering 4.232×10^6 km² (Xu et al. 2018), a larger area than an earlier estimate of 3.814×10^6 km² (Joosten 2010). Regionally, the largest areas are in Asia (38%), North America (33%), Europe (12%) and Latin America and the Caribbean (11%), with much smaller areas in Africa (4%) and Oceania (2%) (Xu et al. 2018). They also occur in the Antarctic and sub-Antarctic islands, but their area is very small (<1% of the global peatland area). Eighty-two percent of global peatland area is non-forested mires (bogs, fens and freshwater marshes) (3.118×10^6 km²), with the largest areas in Asia (48% of this area), North America (35%) and Europe (11%) (Joosten 2010). Forested peatlands are estimated to cover 0.696×10^6 km² (Joosten 2010), with the largest areas in North America (38%), Europe (24%) and Latin America and the Caribbean (19%).

Tropical and subtropical peatland area has been estimated as 1.505×10^6 km² (Gumbricht et al. 2017), a considerably larger area than the 0.385×10^6 km² estimated by Page et al. (2011). In part this is because much larger areas of tropical peatland have now been identified in Latin America (Amazon Basin) and in Africa (Congo Basin) (see e.g., Lähteenoja et al. 2012; Dargie et al. 2017). These areas had previously been recognised as wetlands (e.g., Lehner & Döll 2004), but not as peatlands. A much larger proportion of the area of tropical peatlands are now known to be in Latin America and the Caribbean (46%), with smaller proportions in Asia (34%) and Africa (18%) and ~2% in Oceania (Gumbricht et al. 2017). The largest areas of temperate peatlands are in Russia (1.241×10^6 km²) and Canada (1.133×10^6 km²) (Xu et al. 2018).

Between 1990 and 2008 there was a small decrease in the extent of all peatlands (−0.97%), based on the areal estimates provided by Joosten (2010). The largest decrease was in Europe (−4%). Area change in all other regions was \pm <1%. These figures mask major differences in trends between non-forested and forested peatlands. The global area of non-forested peatlands increased by +7%, possibly due to the conversion of forested peatlands, with the largest increases in Oceania (+16%) and Asia (+16%) (Joosten 2010). Area change in other regions was much smaller (\pm <3%). In contrast, forested peatlands decreased globally by −25%, with by far the largest percentage decrease in Asia (−80%), with smaller decreases in Oceania (−11%) and Europe (−10%). In south-east Asia

(Peninsular Malaysia, Sumatra and Borneo), $\sim 0.018 \times 10^6 \text{ km}^2$ of peat swamp forest was lost between 2007 and 2015, an area decrease of -28% , largely through their conversion to oil palm and pulpwood plantations (Miettinen et al. 2016). In part of south-east Asia (Malay Peninsula, Borneo, Sumatra, and Java), between 2000 and 2010, peat swamp forests experienced a much higher rate of deforestation ($-3.7\% \text{ year}^{-1}$) than did lowland forests ($-1.6\% \text{ year}^{-1}$) or montane forests ($-0.1\% \text{ year}^{-1}$), and are being lost most quickly in Sumatra ($-5.2\% \text{ year}^{-1}$) followed by Borneo ($-2.8\% \text{ year}^{-1}$) (Wilcove et al. 2013).

Historical losses of peatlands have been considerable, although the ability to record such changes has been limited until the second half of the 20th century. European bogs, fens and mires decreased by -3.5% from 1990 to 2000. A total of 90% of raised bogs in the Netherlands were destroyed in the 20th century, and in Scotland 44% of lowland mires and 21% of blanket mires were lost between 1947 and 1988 (Mackey et al. 1998), and 15% of Flow Country blanket mires between 1970 and 1987 (Stroud et al. 1988). Initiations of restoration processes of bog habitat are now taking place in North America and Northern Europe, but not at a sufficient scale as to influence global figures.

Marshes and swamps

Freshwater marshes and swamps comprise a large variety of non-tidal forested and non-forested wetlands. They have hydric soils and do not accumulate large amounts of peat. Swamps are dominated by trees and marshes by emergent herbaceous plants. The terms, however, have not been used consistently, and many wetlands may contain both treed and non-treed components (Finlayson 2018a).

The global extent of marshes and swamps on alluvial soils is not well established. Lehner & Döll (2004) estimated the global area of freshwater marshes and floodplains as $2.53 \times 10^6 \text{ km}^2$, $\sim 25\text{--}31\%$ of their global wetland area. Tropical freshwater swamps on alluvial soils, some of which are forested, occur mostly on floodplains, with a total estimated area of $1.46 \times 10^6 \text{ km}^2$, 38% occurring in Africa, 33% in South America, 24% in Asia, and 5% in Australasia (Giesen 2018).

Swamp and flooded forests on alluvial soils have been estimated as covering $1.17 \times 10^6 \text{ km}^2$ (Lehner & Döll 2004). This may be an underestimate as areas of some major seasonally flooded forest systems such as in the Amazon and Congo Basins are considered to be generally underestimated in global wetland assessments. For the Amazon Basin, wetland area has been estimated as $0.480 \times 10^6 \text{ km}^2$, with the main-stem Amazon floodplain forests covering $0.098 \times 10^6 \text{ km}^2$ (Junk et al. 2014). However, $1.17 \times 10^6 \text{ km}^2$ may be an overestimate, given that some large areas of tropical forested wetlands have recently been recognised as forested peatlands in the Amazon and Congo Basins (Lähteenoja et al. 2012; Dargie et al. 2017).

A global area trend for swamps and marshes is not available, but there have been decreases in many regions. In Asia, freshwater swamps in China decreased by 23% and the area of natural marshland in north-east China by 55% from 1950 to 2000 through their conversion to agricultural land, and on the West Songnen Plain, 74% of marshes were converted between 1954 and 2008 (An et al. 2007; Huang et al. 2010; Wang et al. 2011). The Mesopotamian Marshes (Iraq) were massively drained between the 1970s and 2000s, but since then there have been major re-flooding and restoration efforts leading to reinstatement of marshes and swamps over a substantial area, with almost 60% of the marsh area present in the mid-1970s having been at least partially restored by the late 2000s – but owing to reduced river water flows, the marsh area is currently shrinking again (Becker 2014).

In North America, there was a small (+1%) overall increase in area of marshes and swamps in the USA in 2004–2009, largely a consequence of wetland restoration and creation activities (Dahl 2011), but in the prairie pothole Dakota region of the USA, 28–35% of natural pothole wetland area was converted to agriculture between 2001 and 2011 (Johnston 2013). In addition, almost 23,000 ha of wetlands have been created to remove and store nutrients before discharging into the Everglades (<https://www.sfwmd.gov/our-work/wq-stas>). On the Canadian shoreline of Lake Ontario by the late 1970s, some 43% of marshes may have been lost since the 18th century, and 70% of prairie wetlands (Whillans 1982). In Mexico some $1.758 \times 10^3 \text{ ha}$ of wetlands have been lost in the Central Plain of the Gulf of Mexico (Landgrave & Moreno-Casasola 2012).

In Europe, in the Po Delta, Italy, an estimated 98% of freshwater marshes have been converted since the start of the 20th century, 94% of Macedonian (Greece) marshes between 1930 and the mid-1980s (Jones & Hughes 1993), and 76% of Estonian floodplains between 1950s and 1990s (Kimmel et al. 2010). Overall, European inland vegetated wetlands decreased by 3% from 1990 to 2006 (EEA 2010). Some restoration projects have been undertaken (e.g., Germany, Denmark, Sweden, UK) although not yet to a sufficient extent as to influence these overall trends.

In other regions, 13% of the freshwater marshes of the Kafue Flats (Zambia) were converted from 1984 to 1994 (Munyati 2000); 88% of wetlands in the Cauca River Valley (Colombia) were drained from the 1950s–1989 (Naranjo 1993), as were 15% of New Zealand North Island freshwater wetlands between 1979 and 1983 (Ministry of the Environment 1997).

Groundwater-dependent wetlands

Areas of underground wetlands, notably in karst and cave systems, are difficult to measure. Over thirteen percent of the global land surface is formed of carbonate rock outcrops, under which underground cave wetlands will occur widely, including in the Middle East and Central Asia, Europe, Russia and North America (Beltram 2018). Carbonate rocks with underground karst groundwater circulation may cover 19×10^6 km² of global land surface (Williams 2008). Given that such systems are largely surface-porous, there may be little spatial overlap with surface water systems and so they will likely form a major component of inland natural wetland area, but areal estimates specifically for these underground wetlands are not available.

Springs are widespread around the world, as are oases in arid and semi-arid zones. Although no area estimates are available, their global areas are likely to be small. Many other wetlands are groundwater-dependent, either wholly or partly, permanently or seasonally (Eamus & Froend 2006), but there are no estimates of the area or proportion of inland wetlands which are groundwater-dependent.

Marine and coastal wetlands

Estuaries

Estuaries are often seen as semi-enclosed bodies of water that have a connection with the open sea and within which sea water is diluted with fresh water derived from the surrounding and upstream land. This includes a number of coastal environments, such as river mouths, deltas, lagoons, fjords, bays, and straits (Daborn & Redden 2018).

Lehner & Döll (2004) give a global area of 0.660×10^6 km² for ‘coastal wetlands’, which includes ‘lagoon, delta, mangrove, estuary, coastal wetland and tidal wetland’ classes from their sources. The global area of 1200 major estuaries has been estimated as approx. 0.500×10^6 km² (UNEP-WCMC 2003; Agardy & Alder 2005). This is likely to include areas of saltmarshes and unvegetated tidal flats, but it is not clear if it also includes mangroves. Regional distribution data is not available, but major estuaries occur in all regions of the world (except the Antarctic), with relatively fewer in Africa (Agardy & Alder 2005).

Tidal flats and saltmarshes

Tidal flats are gently inclined non-vegetated coastal wetlands that occur in estuaries or along low energy marine environments with regular exposure and flooding by tides (Finlayson et al. 2018). The global area of unvegetated tidal flats has been estimated as 0.458×10^6 km² (Schuyt & Brander 2004). Regionally, the largest areas of unvegetated tidal flats are in North America (37%), Latin America and the Caribbean (20%) and Asia (18%), together forming 75% of the global total (Schuyt & Brander 2004).

Saltmarshes are the main type of vegetated wetland in the coastal intertidal zone in high latitudes, the major areas being largely in temperate zones, particularly in regions with high tidal ranges such as around the North Atlantic.

The global extent and distribution of coastal tidal saltmarshes has not been comprehensively assessed. The most recent estimate of global area is a minimum of 0.550×10^6 km², from 43 of the 99 countries in which saltmarsh is known to occur (UNEP-WCMC 2017). Regionally, the largest areas of saltmarsh are in North America (41%), Oceania (Australia) (25%) and Europe (including the Russian Federation) (21%), together forming 87% of the global resource (Mcowen et al. 2017).

In Asia, there have been major losses of tidal flats and marshes: 28% of tidal flats existing in the 1980s in the Yellow Sea (China, Republic of Korea, Democratic Republic of Korea) had been lost by the late 2000s (at a rate of –1.2% annually), and from historical maps up to 65% of tidal flats have been lost over the past five decades (since the mid-1950s) (Murray et al. 2012, 2014). In China, coastal wetland losses have been variously reported as –16% (1990–2000), –40% (1978–2008) and –51% (1950–2000) at annual rates of between –1.0 and –1.6% per year, with the fastest rate over the most recent time period (An et al. 2007; Gong et al. 2010; Niu et al. 2012). In the Republic of Korea, at least 20% of intertidal wetlands were converted between 1987 and 2005 (Republic of Korea 2009).

In North America, 24% of USA estuarine intertidal area was lost between 1922 and 2004, and losses in some regions of the USA even greater: for example, 50% of saltmarshes in the Mississippi Delta between 1956 and 2004. More recently, losses have been much smaller: saltmarshes decreased by only –0.7% between 1998 and 2004 (Bernier et al. 2006). In the USA between 2004 and 2009, non-vegetated estuarine area increased by 2.2%, but saltmarshes decreased by a further 2.8% – attributed largely to impacts of coastal processes including sea-level rise rather than land claims (Dahl 2011). In Canada, losses by 1985 included 65% of the Atlantic coastal salt marshes, 70% of Pacific estuarine marshes and 80% of the Fraser River Delta, British Columbia (Government of Canada 1991).

In Europe, there have been long-term and widespread losses of coastal wetlands, exceeding 50% losses by the end of the 20th century on many parts of the coast (Airoldi & Beck 2007). Between 1990 and 2000, European coastal habitats decreased in area by about –1% (EEA 2007). On just 18 of Britain's 155 estuaries, a total of at least 890 km² had been claimed by the 1990s: 37% of their former area and an almost 25% loss of the overall British estuarine resource (Davidson et al. 1991). In south-east England, 25% of saltmarsh is estimated to have been lost in the last quarter of the 20th century through erosion and conversion, with losses continuing (Davidson et al. 1991). Wadden Sea saltmarshes decreased by –33% between 1950 and 1984, largely through conversion to farmland, and 56.5% of Rhone delta saltmarshes were lost between 1942 and 1984 (European Commission 1995). Such losses are now being partially counterbalanced by saltmarsh restoration through an increasing number of 'managed realignment' schemes in north-west Europe (Wolters et al. 2005), but overall areas are small.

Coastal deltas

Coastal deltas are fan-shaped and formed by the deposition of alluvial sediments at the mouth of a river. Of 52 major coastal deltas globally, Coleman et al. (2008) estimate the area of 14 of these as 0.030×10^6 km². All 14 major deltas assessed have decreased in area (Coleman et al. 2008). Some wetland loss was through coastal erosion converting coastal vegetated wetlands to open water (5104 km²), but a much larger area (10,786 km²) was lost through human conversion, an overall loss of –52.4% over just 14 years (1986–2000). The largest reported losses have occurred in the Shatt al Arab (6699 km²), Ganges-Brahmaputra (4290 km²), Indus (1595 km²) and Yukon (1100 km²) deltas. Only small losses (<100 km²) were reported from the Danube, Mackenzie, Mahanadi, Niger and Nile deltas. Other reported delta area losses include: Don delta (–22%: 1980s–1990s), Kuban delta (–48%: 1930s–1970s), Camargue (–31%: 1942–1974) (Tamisier 1992). Most of the world's medium and large sized coastal deltas are currently receiving less sediment than they need to grow to keep pace with rising sea levels. Hence their areas are generally decreasing (Giosan et al. 2014).

Mangroves

Mangroves are trees or shrubs that are generally found in the intertidal zone along deltaic coasts, lagoons, and estuarine shorelines in the tropics and subtropics (Finlayson 2018b). Global mangrove area in 2000 was estimated as 0.137×10^6 km² in 118 countries and territories in the tropical and subtropical regions of the world (UNEP-

WCMC 2011; Giri et al. 2011). The largest extent of mangroves is in Asia (42%), followed by Africa (20%), North and Central America (15%), Oceania (12%) and South America (11%). Approximately 75% of the world's mangroves are found in just 15 countries, the largest areas being in Indonesia ($0.031 \times 10^6 \text{ km}^2$), Australia ($0.009 \times 10^6 \text{ km}^2$) and Brazil ($0.009 \times 10^6 \text{ km}^2$) (2000 estimates; Giri et al. 2011).

Global mangrove area was estimated by FAO (2007) to have decreased by 19% between 1980 and 2005, with the largest area loss being in Asia (–25%). More recent analyses through the Global Mangrove Watch (Lucas et al. 2014) will provide more detailed regional and national analyses (see <https://www.globalmangrovetwatch.org/>), with initial data showing a global area for 2016 of $0.137 \times 10^6 \text{ km}^2$ with a 4.3% loss from 1996–2016.

Seagrasses

Seagrasses are marine angiosperms that form extensive meadows in clear, shallow estuaries and coastal waters where they propagate both sexually and vegetatively (Short et al. 2018). They are widely distributed around temperate and tropical shores, occurring both intertidally and particularly in the shallow subtidal zone. They are most diverse in south-east Asia (UNEP-WCMC 2005; Short et al. 2007). The global extent is estimated as $0.177 \times 10^6 \text{ km}^2$ (Spalding et al. 2003; Short et al. 2018). The global area of seagrass beds has been decreasing in all parts of the world, temperate and tropical, since at least the 1890s (Waycott et al. 2009). Overall, the measured area of seagrass loss was 3370 km^2 between 1879 and 2006, representing 29% of the maximum area measured. The rate of decline in seagrass meadows has accelerated over the past eight decades, from $-1\% \text{ year}^{-1}$ before 1940 to $-5\% \text{ year}^{-1}$ after 1980. The largest losses have occurred between 1980 and 2006: in total, a loss of 35% of seagrass area. Overall, 58% of sites assessed declined, 25% increased, and 17% exhibited no detectable change. Sites with area increases are in Western Europe and part of the Atlantic coast of the USA, but their areas are small.

Coral reefs

Coral reefs are an underwater marine ecosystem formed by reef-building corals that are held together by calcium carbonate. Warm water coral reefs are widely distributed in subtropical and tropical latitude seas between 30°N and 30°S (Spalding et al. 2001). By far the largest coral reef areas, totalling 80% of global area, are in Asia (41%) and Oceania (39%) and in particular in Indonesia (18% of the global area) and Australia (17%). Cold water coral reefs have been discovered to be more widespread than previously thought (Freiwald et al. 2004), mostly from high latitudes where they occur in deep water, but also as in the tropics where they thrive at even greater depths. Their area is not known, but recent studies suggest that global coverage could equal, or even exceed, that of warm water reefs.

A global area change for warm water coral reefs is not available, but coral cover has been decreasing worldwide (Wilkinson 2008). As hard structures, the overall area of coral reefs does not change substantially except where, for example, physical dredging or infilling occurs. Coral reef change assessments largely concern changes in the percentage of live coral cover in reefs. By 2008, there had been an effective loss of 19% of the original global area cover of coral reefs; a further 15% are seriously threatened with loss within the next 10–20 years; and a further 20% are under threat of loss in the next 20–40 years (Wilkinson 2008). However, 46% of the world's reefs are still regarded as being relatively healthy and not under any immediate threats of destruction. These reefs are generally either well managed or are remote from large land masses and human disturbances (e.g., in the Red Sea, the Maldives, Seychelles and Chagos archipelago in the Indian Ocean, and Papua New Guinea and many small atolls and islands in the Pacific Ocean) (Jackson et al. 2014).

In the Caribbean, although the rate of coral loss has slowed in the 1990s–2000s compared to the 1980s, significant declines are continuing. Average coral cover for 88 locations with coral data in the Caribbean declined from 34.8% in 1970–1983 to 16.3% in 1999–2011 (Jackson et al. 2014). In Mexico, the area of coral reefs around Veracruz Port decreased by 41% between 1907 and 2007 through landfill and development of port infrastructure (Valadez-Rocha & Ortiz-Lozano 2013). The extent of coral degradation due to bleaching is also of increasing concern (Hughes et al. 2017).

Shellfish reefs

Shellfish reefs are made of oysters and bivalves, are widespread in temperate coastal regions and also occur tropically and sub-tropically in Latin America and the Caribbean and southern North America. They remain widespread in the intertidal and shallow subtidal coastal regions of the world, despite ~85% of historical oyster reefs having been completely destroyed (Beck et al. 2011). Many remaining reefs are in poor condition. A global assessment of the condition of oyster reefs across 144 bays and 44 ecoregions found that, in comparison with past abundance, more than 90% of reef area has been lost in 70% of bays and 63% of ecoregions (Beck et al. 2011). In many bays, more than 99% of oyster reefs have been lost and are functionally extinct. Overall, 85% of oyster reefs have been lost globally since records began (Beck et al. 2011). Regions with functionally extinct oyster reefs are particularly Australia, the North Sea and Atlantic coast of Europe and the Pacific coast of North America. Remaining reefs in fair to good condition are mostly in the Gulf of Mexico and Caribbean, Latin America and New Zealand (Zu Ermgassen et al. 2012).

In Europe, native oyster reefs were ecologically extinct by the 1950s along most European coastlines and in many bays well before then due to over-exploitation (Airoldi & Beck 2007). In the USA, since the start of the 20th century, there has been a 64% decline in the spatial extent of oyster habitat and an 88% decline in oyster biomass over time, suggesting that many remaining reefs are in degraded condition (Airoldi & Beck 2007).

Coastal lagoons

Coastal lagoons are shallow coastal water bodies that vary from brackish to hypersaline conditions and generally contain submerged macrophytes. They occur along nearly 15% of the world's shorelines, with lagoons largely backing barrier coasts (Kusky 2005). The global area of coastal lagoons is not known. The largest proportions of coastlines which are barrier coasts are in Africa (18%) and also in North America, with 14% in Asia, 12% in Latin America and the Caribbean, 11% in Australia and only 5% in Europe. In the USA, lagoons are found along more than 75% of its eastern and Gulf coasts. In the Mediterranean region, there are ~400 coastal lagoons, covering a surface of over $0.006 \times 10^6 \text{ km}^2$ (Cataudella et al. 2014). In Mexico, coastal lagoons cover $1.567 \times 10^6 \text{ ha}$ in the Gulf of Mexico (Contreras & Castaneda 2004).

Kelp forests

Kelp forests are underwater marine areas with a high density of the brown macroalgae kelps. They are distributed widely around northern and southern temperate coasts, in the north Pacific and north Atlantic, along the Pacific and southern Atlantic coasts of Latin America, southern Africa and Australia and New Zealand. No global or regional area estimates are available. A recent first global assessment identified a small global average area decline (at $-0.018\% \text{ year}^{-1}$) between 1952 and 2015, but this trend masks great regional variation, with declines in 38% of the regions for which there are data (-0.015 to $-0.18\% \text{ year}^{-1}$), but increases in 27% of ecoregions (0.015 to $0.11\% \text{ year}^{-1}$), and no detectable change in 35% of ecoregions (Krumhansl et al. 2016). There are no clear geographical patterns in these trends in area changes, with increasing and decreasing area changes in adjacent ecoregions in most parts of the world. In Europe, 20th century losses, sometimes leading to virtual local disappearance, of kelp and other macroalgae beds have been widespread including in Iceland, Norway, Britain and Ireland, Sweden, Denmark, Finland, Germany, Lithuania, Italy, France, Spain, Croatia and Romania (Airoldi & Beck 2007).

Shallow subtidal marine systems

These areas, defined by the Ramsar Convention (1971) as being those of up to 6 m of permanent inundation by marine waters, can be expected to form a major component of coastal and nearshore marine wetlands. However, these areas have not been measured, except for the Mediterranean Basin: $0.042 \times 10^6 \text{ km}^2$ (Mediterranean Wetland Observatory 2018). No global or regional areas are available.

Human-made wetlands

Reservoirs

Reservoirs are water storage bodies generally formed by an enlarged natural or artificial lake, storage pond or impoundment created using a dam or lock to store water. It is estimated that globally there are $\sim 2.8 \times 10^6$ reservoirs or impoundments larger than 0.1 ha worldwide, and 16.7×10^6 when including those larger than 0.01 ha (Lehner et al. 2011). Their combined area is estimated at $0.443 \times 10^6 \text{ km}^2$ (GRAnD database, see <http://www.gwsp.org/products/grand-database.html>, accessed 15 September 2017). The largest numbers of dams are in North America (particularly USA), Asia (particularly China) and Europe. There are now in excess of 30,000 large dams globally, compared with ~ 5000 in 1950. While the number of large dams constructed worldwide has increased greatly since the 1950s, in all parts of the world, the rate of increase appears to have slowed since 2000 (Steffen et al. 2015).

As for the number of dams constructed, the global area of reservoirs has progressively increased: particularly rapidly from the 1950s to the 1980s, and recently more slowly. Global reservoir area increased by $0.289 \times 10^6 \text{ km}^2$ (188% increase) between 1950 and 2010, with $0.106 \times 10^6 \text{ km}^2$ (32% increase) being between 1970 and 2010 (GRAnD database; Lehner et al. 2011). It is not clear if these estimates include such impoundments as gas oil field lakes and mine tailings ponds.

Small (e.g., farm) ponds

Downing et al. (2006) estimated the global area of farm ponds as $0.077 \times 10^6 \text{ km}^2$ and also reported that the area of farm ponds is increasing in many parts of the world, particularly in semi-arid areas, and at average rates of $0.7\% \text{ year}^{-1}$ in Great Britain and $1\text{--}2\% \text{ year}^{-1}$ in parts of the USA.

Rice paddy

A rice paddy is a flooded parcel of arable land used for growing semiaquatic rice. Rice paddy area is estimated as $1.282 \times 10^6 \text{ km}^2$, of which $0.66 \times 10^6 \text{ km}^2$ (51%) is irrigated paddy and $0.63 \times 10^6 \text{ km}^2$ (49%) is rain-fed paddy (Salmon et al. 2015). The most recent estimate of global area of rice production (which includes rice paddy but also upland dry rice areas) is $1.635 \times 10^6 \text{ km}^2$ (see <http://ricestat.irri.org:8080/wrsv3/entrypoint.htm>, accessed 20 July 2017), of which rice paddy forms 79%. A total of 88% of the global area of rice production is in Asia, stretching from India and Nepal in the west to Japan, South Korea, and Taiwan in the east, from China in the north to Timor-Leste in the south. Proportionally much smaller rice areas occur in other regions.

Since 1965, rice production area has increased by $0.38 \times 10^6 \text{ km}^2$, a 30.2% increase from 1965 to 2014, although the change varies between regions with an increase of 26% in Asia, and larger increases in the smaller areas in Europe (36%) and particularly Africa (270%), but small area declines in Latin America and Caribbean (–9%), North America (41%) and Oceania (134%). These average regional changes mask different change directions in different countries: for example, in Asia, although rice production area has increased in most countries, it has decreased in others such as Japan and Taiwan (see <http://ricestat.irri.org:8080/wrsv3/entrypoint.htm>, accessed 20 July 2017).

Oil palm plantations

Oil palm plantations, planted on drained wetlands (peatlands), in parts of South-east Asia (Peninsular Malaysia, Sumatra and Borneo) have increased since 1990, and in 2015 managed land cover types (industrial plantations and smallholder-dominated areas) covered 50% ($7.8 \times 10^6 \text{ ha}$) of all peatlands, in this region, increasing from 11% in 1990 and 33% in 2007. Industrial (mostly oil palm) plantations have nearly doubled their extent on peatlands since 2007 and now cover 27% of peatlands (Miettinen et al. 2016) in the region. Plantations are also reported as increasing in Africa and Latin America, but areas are not available.

Agricultural wet grasslands

In Europe and some other parts of the world, areas of floodplain wetland and sloping fens have for millennia been managed as agricultural wet grasslands for stock grazing and fodder cropping. Similar grasslands have developed coastally, behind the artificial embankment of estuaries. Global and regional areas are not known, but many areas are now much smaller than previously through their conversion to intensive agriculture and urban and industrial developments, for example in south-east England (Thornton & Kite 1990).

Wastewater treatment wetlands

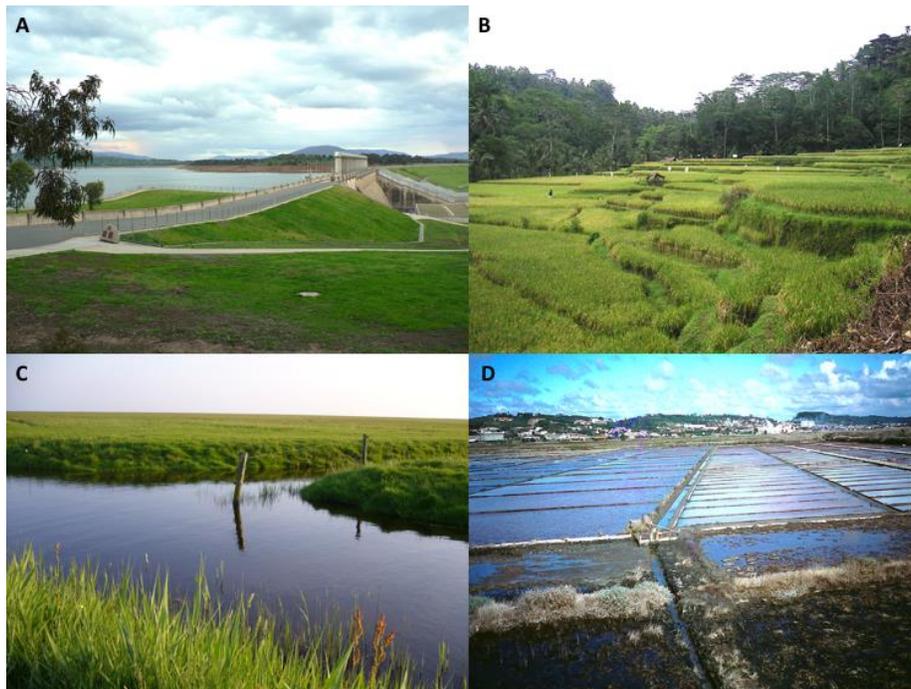
Many, mostly small, wastewater treatment wetlands have been constructed, with others created for other purposes such as amenity and mitigation of wetland losses. No global area estimates are available. In the USA, there are almost 150,000 ha of industrial ponds and a further over 326,000 ha of urban ponds: a total area of $0.004 \times 10^6 \text{ km}^2$ (Dahl 2011). There are also an increasing number (at least 223 by 2008) of wastewater treatment wetlands (of up to 1 ha area) in China (Liu et al. 2008).

Salt production pans

Salinas (salt production pans) are widespread in parts of the world where the climate is warm enough for rapid saline water evaporation. No global or regional area estimates are available, but in the Mediterranean in the 1990s, there were 165 salinas (90 of which were still producing salt) and a total area of 750 km^2 (Perennou et al. 2012).

Aquaculture ponds

Aquaculture ponds for commercial fish and shellfish production are also widespread and most frequent in China, India, Viet Nam, Bangladesh, and Egypt, and also well developed in France, Greece, the Czech Republic, Austria and Hungary in Europe, and the Lao People's Democratic Republic and Nepal in Asia (FAO 2016). No global or regional area estimates are available.



Human-made wetlands. A: reservoir, Australia; B: rice paddy, Bali; C: wet grasslands, UK; D: salt production pans (Salinas), Portugal. (Photographs © Nick Davidson)

Conclusions - data and information for individual wetland classes

Although there are some data and information available for the area of most inland wetland classes, there are still gaps for many marine and coastal wetland classes, in particular for shellfish reefs, coastal deltas, coastal lagoons, kelp forests and shallow subtidal systems. There is a dearth of information on the human-made wetland classes, including for wet grasslands, wastewater treatment or constructed wetlands, saltpans and aquaculture ponds (both inland and coastal). Obtaining information to fill these gaps is seen as a priority for wetland managers and could possibly be done effectively using Earth Observation approaches, as recognised by the Ramsar Convention (Rebelo & Finlayson 2018).

The above assessments confirm the findings of other assessments that the areal extent of both inland and marine/coastal wetlands is in decline (Davidson 2014; Gardner et al. 2015; Dixon et al. 2016) and that while human-made wetlands are increasing, they do not compensate for the declines (Davidson 2014; Davidson et al. 2018).

Further, these assessments confirm that estimates of the global area of wetlands derived from 'top-down' remote sensing and mapping have only recently equalled or exceeded estimates derived from 'bottom-up' site-based estimates. As there are gaps in the data available for many wetland classes, these are themselves underestimates. Hence, the estimates of between 15.2×10^6 and 16.2×10^6 km² are greater than the 12.5 to 14.4×10^6 km² derived by Milton & Finlayson (2018), and in the upper range of the 12.1 to 17.3×10^6 km² global wetland area derived by recent remote-sensing investigations (Fluet-Chouinard et al. 2015; Davidson et al. 2018).

These results support calls for more attention to be directed towards resolving the limitations of remote sensing-based assessments as well as directing more attention towards assessments of the different classes of wetlands for which there are current information gaps (Davidson & Finlayson 2018).



Yellow Water, Kakadu NP Ramsar Site, Australia. (Photograph © Nick Davidson)

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