CSIRO PUBLISHING

Marine and Freshwater Research, 2014, **65**, 934–941
http://dx.doi.org/10.1071/MF14173

Short communication

How much wetland has the world lost? Long-term and recent trends in global wetland area

Nick C. Davidson

Institute for Land, Water and Society, Charles Sturt University, Albury, NSW, Australia; and Chemin des Jordils 18, 1261 Le Vaud, Switzerland. Email: arenaria.interpres@gmail.com

Abstract. It has been frequently stated, but without provision of supporting evidence, that the world has lost 50% of its wetlands (or 50% since 1900 AD). This review of 189 reports of change in wetland area finds that the reported long-term loss of natural wetlands averages between 54–57% but loss may have been as high as 87% since 1700 AD. There has been a much (3.7 times) faster rate of wetland loss during the 20th and early 21st centuries, with a loss of 64–71% of wetlands since 1900 AD. Losses have been larger and faster for inland than coastal natural wetlands. Although the rate of wetland loss in Europe has slowed, and in North America has remained low since the 1980s, the rate has remained high in Asia, where large-scale and rapid conversion of coastal and inland natural wetlands is continuing. It is unclear whether the investment by national governments in the Ramsar Convention on Wetlands has influenced these rates of loss. There is a need to improve the knowledge of change in wetland areas worldwide, particularly for Africa, the Neotropics and Oceania, and to improve the consistency of data on change in wetland areas in published papers and reports.

Additional keywords: coastal, conversion, inland, loss, Ramsar Convention.

Received 25 June 2014, accepted 25 July 2014, published online 23 September 2014

Introduction

Humankind has been draining, in-filling and converting both coastal and inland wetlands for many centuries: for example since at least Roman times in Europe (Davidson *et al.* 1991); at least the 17th century in North America (Dahl 1990) and southern Africa (Kotze *et al.* 1995); and for at least 2000 years in China (An *et al.* 2007). This conversion and degradation of wetlands continues, with the underlying drivers being economic and human population growth, and proximate causes being conversion at first to extensive and then intensive agriculture (croplands), changes in water use and availability (including the downstream effects of water abstraction and major hydro-engineering schemes), increasing urbanisation and infrastructure development, disease control (especially for mosquitoes), spread of invasive species and, on the coast, sea defences, port and industrial developments, and aquaculture (Finlayson *et al.* 2005; van Asselen *et al.* 2013).

Widespread (although mostly not quantified) inland and coastal wetland drainage and conversion, and particularly its impact on hunted waterfowl populations, has been increasingly reported and raised as a concern since the 1920s in North America (see Schmidt 2006) and from the early 1960s in Europe (Swift 1964; Hoffmann 1964). Hoffmann (1964) concluded that 'in temperate regions drainage of wetlands is proceeding at an increased rate and without reference to their diverse values', and recommended the establishment of an international convention on wetlands. This led, in 1971, to the global in scope establishment of the 'Ramsar Convention on Wetlands' (Carp 1972), which recognised the great value of wetlands, 'the loss of which would be irreparable', to people, and which has the desire to 'stem the loss and degradation of wetlands now and in the future', through the wise use of all wetlands, the designation and management of Wetlands of International Importance ('Ramsar Sites') and international cooperation (see Matthews 1993; de Klemm 1995; Ramsar Convention Secretariat 2011; for the history of the Convention). The Convention now has 168 governmental Contracting Parties, which have designated 2185 Ramsar Sites covering over 208 million hectares of wetlands and associated habitats (see www.ramsar.org, accessed 23 June 2014).

It has been widely reported that 50% (or at least 50%) of the world's wetlands have been lost (or lost since 1900), but the provenance of this figure is obscure. Its origin appears to date back to reports in the USA in the mid 1950s. Shaw and Fredine (1956) calculated that for seven US states the loss of marshes and swamps (only), mostly through drainage and conversion for agriculture and flood protection, was 45.7% between 1850 and 1953, but noted that this figure was only from those states that were particularly active in wetland conversion. Weller (1981), citing Shaw and Fredine (1956), USDA (1980) and loss of prairie pothole wetlands from Schrader (1955), reported to a wildlife conference in Minnesota, USA, that '*precise data on wetland losses due to drainage are lacking, but large wetland regions* [*in the USA*] *have suffered as much as 50 to 96% loss from the time of first settlement*'. At the same conference Harmon (1981), stated that '*wetland losses exceed 50% in many waterfowl habitats – prairie pothole region and bottomland* *hardwoods*, *for example*', based on losses in the Prairie Pothole region (Harmon 1980) and bottomland hardwoods in the Mississippi Delta (USFWS 1978). Both authors were writing in the context of the USA only.

Winkler and DeWitt (1985), in a paper on impacts of peat mining and citing only Harmon (1981) and Weller (1981), then stated that '*the biggest changes in land-use since 1900 have been a 50% decrease in wetlands globally*', introducing unsubstantiated global and temporal elements to the earlier statements. This has subsequently, in various forms, been restated: Maltby (1986), citing Winkler and DeWitt (1985): '*According to some experts*, *the world may have lost half its wetlands since 1900*'; Dugan (1993, 2005): '*The loss of wetlands worldwide*, *which some specialists estimate as being in the order of 50 per cent of those that once existed* ...'; OECD (1996): '*Some estimates show that the world may have lost 50 per cent of the wetlands that existed worldwide since 1900*'; and Maltby and Acreman (2011): '*This is probably about half of the extent that existed before human modifications during historical times*'. Finlayson and Davidson (1999) noted that '*The loss of wetlands worldwide has been estimated at 50% of those that existed in 1900 – a figure that includes inland wetlands and possibly mangroves*, *but not large estuaries and marine wetlands such as reefs and seagrasses*', and Perennou *et al.* (2012) citing Finlayson and Davidson (1999) noted that '*worldwide loss over the same period* [*20th century*] *has* [.] *been estimated at 50%*'. Finlayson and D'Cruz (2005) and Finlayson (2012), drawing on a collation of information on the extent of wetlands globally (Finlayson *et al.* 1999), cautioned that '*there is insufficient information on the extent of specific wetland types to substantiate the commonly reported 50% wetland loss globally*'.

The statements of 50% wetland loss seem to have become widely received wisdom, despite originating from very limited data from the USA only for the mid 20th century. In the mid 1980s, this was then restated as a global figure of loss since 1900 AD, and since then has been repeated in various forms.

Here I make a first global assessment of the published evidence for temporal and geographical trends in the extent of wetlands, and rates of change in wetland area. This was done to determine whether or not there is evidence to support the statements that the world has lost 50% of its wetlands, since historical times or since 1900 AD. With wetland losses known to have continued during the last quarter of the 20th century and beyond, could such a figure also be an underestimate of overall 20th century wetland loss? Further, is there evidence that the loss of wetlands has been stemmed in the more than 40 years since the establishment of the Ramsar Convention in 1971?

Methods

I analysed changes in wetland extent, and rates of change in extent, from 189 reports in published scientific journal papers and reports. These cover a wide range of spatial scales, from a single wetland to national, regional and global scales; and widely different time periods, from a few years to many centuries. All analyses are of change in the area of wetlands, and not change in the number of wetlands.

For analysis, records were allocated to one of five time periods: 'long-term', before 1900 AD; 1900 to 1944; 1945 to 1974; 1975 to 1989; or 1990 and later. For some analyses, long-term records were further allocated to one of three time periods: pre-18th century; 18th century; or 19th century. As many records provided only a percentage change and not a wetland area for a start or end year, trends could not be corrected for any bias arising from the different size of the wetland areas assessed in different time periods.

Each record was categorised as being for natural inland, natural coastal, unspecified natural wetland type(s) or human-made wetlands. While recognising that probably no wetland in the world is now wholly 'natural', for this analysis a natural wetland is one whose habitat types have not been wholly altered to a different land-cover type or to a human-made wetland type *sensu* the Ramsar Convention's classification of wetland types (http://www.ramsar.org/cda/en/ramsar-documents-info-information-sheet-on/main/ramsar/1-31-59%5E21253_4000_0__#type, accessed 10 July 2014).

Each record was assigned to one of six geographical regions (*sensu* the regional categorisation under the Ramsar Convention on Wetlands): Africa, Asia, Europe, Neotropics (Central and South America and the Caribbean), North America or Oceania (which includes Australasia). A few records were reported at only a global or multi-regional scale.

Each record is of the overall 'net change' in wetland area reported, and so can include any areas of wetland that may have been restored or created within the reported area during the time period. It is likely that for some records there may have been conversion of part or all of the natural wetland to a human-made wetland type (e.g. through conversion to aquaculture ponds or the damming of rivers and floodplains to create reservoirs), but information as to which habitat types or other land-cover a wetland was converted was seldom reported.

Not all records provided sufficient year-period information from which to calculate a rate of change, and very few records provide any intermediate data points between a start and end year. Therefore, for consistency, annual percentage rates of change in wetland area were calculated as the arithmetic mean change between the start and end year of each record. Statistical tests were conducted using Vassarstat (www.vassarstats.net, accessed 12 June 2014) and Handbook of Biological Statistics (http://www.biostathandbook.com/, accessed 25 May 2014). Details of records and their sources are provided as Supplementary Material.

Results

Spatial coverage of wetland area change

The published evidence for change in wetland area is patchy and limited, especially for Africa, the Neotropics and Oceania (see Supplementary Material). There are few parts of the world with comprehensive assessments of change in wetland area, notable exceptions being the USA (Dahl 2006, 2011), China (An *et al.* 2007; Niu *et al.* 2012; Zheng *et al.* 2012) and Europe (EEA 2010).

In total, 64 long-term (63 for natural and one for human-made wetlands) and 125 20th–early 21st century records (117 for natural and eight for human-made wetlands) were identified. Most records were for Europe (51% of the total), Asia (20%) and North America (11%). There were fewer records for Africa (7%), the Neotropics (3%) and Oceania (5%). 24% of records were at the single wetland site scale, 28% for sub-national regions, 34% at national (country) scale, 11% at supra-national scale and 3% at global scale. Most records were for natural wetlands: 46% for inland wetlands; 40% for coastal wetlands; 9% for unspecified wetland type(s); and 5% for human-made wetlands.

The overall frequency of records at different spatial scales for natural wetlands was similar for long-term and 20th–early 21st century records ($\chi^2 = 5.44$; d.f. 3; $P = 0.142$) (see Supplementary Material). However, the spatial scale frequency of records for inland and coastal natural wetlands was different for both long-term records ($\chi^2 = 11.10$; d.f. 3; $P = 0.011$) and 20th–early 21st century records ($\chi^2 = 15.30$; d.f. 3; $P = 0.002$). For long-term records, there were relatively more coastal records at wetland site scale and relatively more inland records at sub-national region and national scales. For 20th–early 21st century records there were relatively more coastal records at wetland site and national scales, and relatively more inland records at sub-national region scale.

The influence of spatial scale on the extent of reported wetland area change

For 20th–early 21st century records of natural wetlands, both percentage change and rate of change were significantly related to the spatial scale of the record: for percentage change, Spearman's rho −0.342; d.f. 115; $P = 0.0002$; and for rate of change, Spearman's rho −0.343; d.f. 115; $P = 0.0002$ (Fig. 1). Reported rates of change in area were fastest for site-scale records and slowest for supranational and global scale records. For long-term records, there were no significant differences between records of different spatial scales or between site-scale and larger-scale records, for rate of change in wetland area or percentage change in area.

The biggest difference for 20th–early 21st century records was between site-scale records and those at larger spatial scales: a 1.9 times faster rate of change in area (Mann–Whitney U = 876; z = 2.52; $P = 0.0117$), and a 1.4 times higher percentage change in area (M–W U = 853.5; z = 2.53; $P = 0.0114$). The values given below include, where appropriate, site-scale records.

Long-term wetland area change

All records of long-term change of natural wetlands report a loss of wetland area. The global average long-term loss reported was 53.5% ($n = 63$) (Table 1), with more loss of inland natural wetlands (average 60.8%; $n = 25$) than coastal wetlands (average 46.4%; $n = 31$). Excluding site-scale records, the global average loss was 56.9% ($n = 48$), with 59.2% ($n = 24$) for inland and 49.8% ($n = 18$) for coastal natural wetlands.

The long-term rate of loss for all types of natural wetland averaged −0.296%.y^{-1} (Table 1). The rate of loss was 1.75 times, and significantly, faster for inland wetlands than for coastal wetlands (M–W U-test (two-sided): U = 77; z = 2.417; $P = 0.016$) (Table 2). Excluding site-scale records, the average rate of loss was −0.258%.y^{-1} ($n = 35$), and was 1.15 times faster for inland natural wetlands (−0.342%.y^{-1}; $n = 14$) than coastal natural wetlands (−0.298%.y^{-1}; $n = 9$) but the difference was not statistically significant (M–W U test (two-sided): U = 83; z = −1.23; $P = 0.219$).

Rates of loss of natural wetlands have increased progressively over the centuries, with the lowest average rate being for

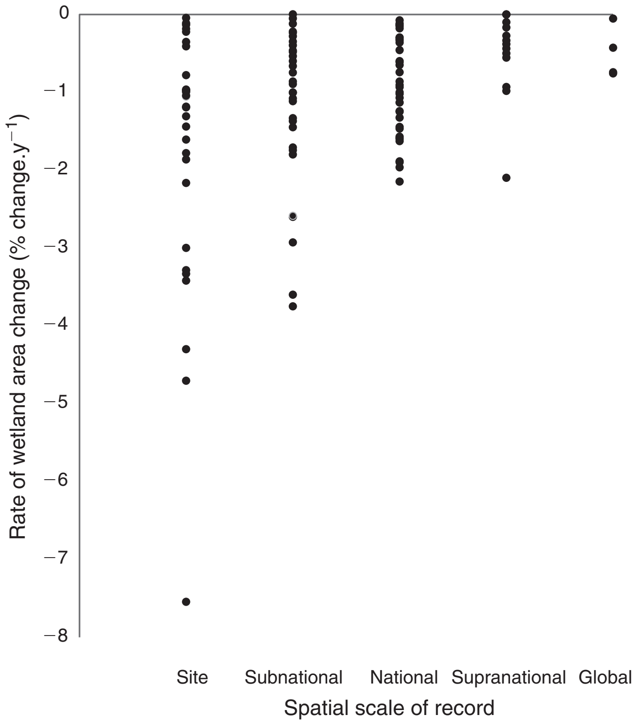

Fig. 1. Annual rates of change (%.y^{-1}) of natural wetlands recorded at different spatial scales for records for the 20th and early 21st century. Each global-scale data point is for a different wetland type: peatlands; inland open waters; mangroves; and deltas.

records starting earlier than the 18th century (Table 1). The average rate for 19th century records was significantly faster than for earlier records ((M–W U test (two-sided): U = 310; z = −2.96; $P = 0.0031$), but significantly slower than that for the first half of the 20th century ((M–W U test (two-sided): U = 377; z = −2.59; $P = 0.0096$).

Long-term loss of wetlands has been reported from all regions of the world. The largest overall losses were for Europe and North America, with regional average losses by region being Africa: 43.0% ($n = 3$); Asia: 45.1% ($n = 7$); Europe: 56.3% ($n = 38$); North America: 56.0% ($n = 7$); and Oceania: 44.3% ($n = 6$). Average long-term rates of loss were 1.8 times faster in Europe (mean = −0.323%.y^{-1} ± 0.316 s.d.; $n = 26$) than in North America (mean = −0.181%.y^{-1} ± 0.052 s.d.; $n = 7$). There were insufficient records to calculate long-term rates of loss for other regions.

Long-term rates of natural wetland loss varied considerably, but most were in the range −0.1%.y^{-1} to −0.4%.y^{-1}. The fastest long-term rates (above −0.5%.y^{-1}) were reported for lowland raised bogs (peatlands) in parts of the United Kingdom, floodplains in parts of Germany and the USA, and freshwater marshes, coastal marshes and saltmarshes in parts of Italy (see Supplementary Material).

Wetland area change in the 20th and early 21st centuries

The rate of loss of all natural wetland types during the 20th and early 21st centuries averaged −1.085%.y^{-1} (Table 1), significantly faster than the long-term loss rate (M–W U-test

Table 1. Changes in the area of all types of natural wetlands over different time periods
n = the number of records for each time period. s.d. = Standard Deviation

Period	n	Average no. of years	Average area change (%)	Average rate of change (%.y^{-1})	s.d.	No. & percentage of reports with average change >−1%.y^{-1}
Long-term:						
up to and including the 20th century (start year):						
Pre-18th century	14[A]	n/a[B]	−55.4	−0.113	0.079	0
18th century	6	224.3	−56.9	−0.239	0.081	0
19th century	20	137.6	−48.9	−0.422	0.312	2 (10%)
all long-term	63	n/a[B]	−53.5	−0.296[C]	0.278	2 (5%)
20th and early 21st century (start year):						
1900–1944	23	77.7	−55.8	−0.782	0.475	7 (30%)
1945–1974	38	37.9	−49.3	−1.363	1.446	23 (61%)
1975–1989	28	20.0	−27.8	−1.308	1.261	12 (43%)
1990 or later	17	13.0	−6.5	−0.565	0.803	4 (24%)
all 20th–early 21st century	117	38.6	−38.5	−1.085	1.163	49 (42%)

[A]Not all reports of long-term change provided a start year from which to calculate a rate of area change.
[B]Time periods vary greatly between records, from over a millennium (e.g. since Roman times in Italy), several hundred years (e.g. pre-colonial times in North America, New Zealand and South Africa) to since the 19th century, and not all provide a year from which the record began.
[C]n = 40: not all reports of long-term change provided a start year from which to calculate a rate of area change.

Table 2. Rates of change in the area of natural inland and natural coastal wetlands over different time periods
n = the number of records for each time period; s.d. = standard deviation

Period	Inland wetlands n	Inland wetlands Average rate of change (%.y^{-1})	Inland wetlands s.d.	Coastal wetlands n	Coastal wetlands Average rate of change (%.y^{-1})	Coastal wetlands s.d.
Long-term:						
up to and including the 20th century	15	−0.391	0.319	20	−0.228	0.241
20th and early 21st century (start year):						
1900–1944	10	−0.853	0.393	8	−0.721	0.590
1945–1974	25	−1.483	1.728	10	−0.930	0.555
1975–1989	11	−1.625	1.435	17	−1.103	1.134
1990 or later	13	−0.479	0.851	3	−0.924	0.761
all 20th–early 21st century	59	−1.180	1.423	38	−0.949	0.804

(two-sided): U = 1024.5; z = −5.297; P = <0.0001). Excluding site-scale records, the average rate of loss was −0.901%.y^{-1} (n = 88), also significantly faster than the equivalent long-term rate (M–W U-test (two-sided): U = 876; z = 2.52; P = 0.0117). Rates of loss were significantly faster than the long-term rates of loss for both inland natural wetlands (M–W U-test (two-sided): U = 642; z = −2.28; P = 0.0226) and coastal natural wetlands (M–W U-test (two-sided): U = 792.5; z = −4.86; P = <0.0001) (Table 2).

Comparing the rate of loss in the 20th–early 21st century with long-term rates of loss (Table 1), natural wetlands have been lost during the last 100 years at a 3.7 times faster rate than in the long term. Although in the 20th–early 21st century the rate of loss of coastal natural wetlands was still slightly lower than that of inland natural wetlands (Table 2), the relative increase in their rate of loss was greater, such that coastal wetlands were being lost 4.2 times faster and inland wetlands 3.0 times faster than in the long term.

Rates of loss of all natural wetlands in each of the time periods of the 20th and early 21st centuries were considerably faster than long-term rates (Table 1, Fig. 2): between 1.9 times (for 1990 onwards) and 4.6 times (for 1945 onwards). The average rate of loss was highest (−1.363%.y^{-1}) in the third quarter of the 20th century, when there was also the highest percentage (61%) of reported losses occurring at a high (>−1.0%.y^{-1}) average annual rate of loss (Table 1). Average loss rates continued to be almost as fast (−1.308%.y^{-1}) in the last quarter of the century (1975 onwards), but slowed after 1990 (−0.565%.y^{-1}) (Table 1). Rates of loss were consistently higher for natural inland than natural coastal wetlands for the periods from 1900 through to the 1980s, but whereas the average rate of loss of inland wetlands then slowed considerably, a rapid rate of loss continued for coastal wetlands (Table 2, Fig. 2).

Wetland losses have occurred during the 20th and early 21st centuries in all regions of the world (Table 3). Rates of loss of all natural wetlands differed significantly between regions

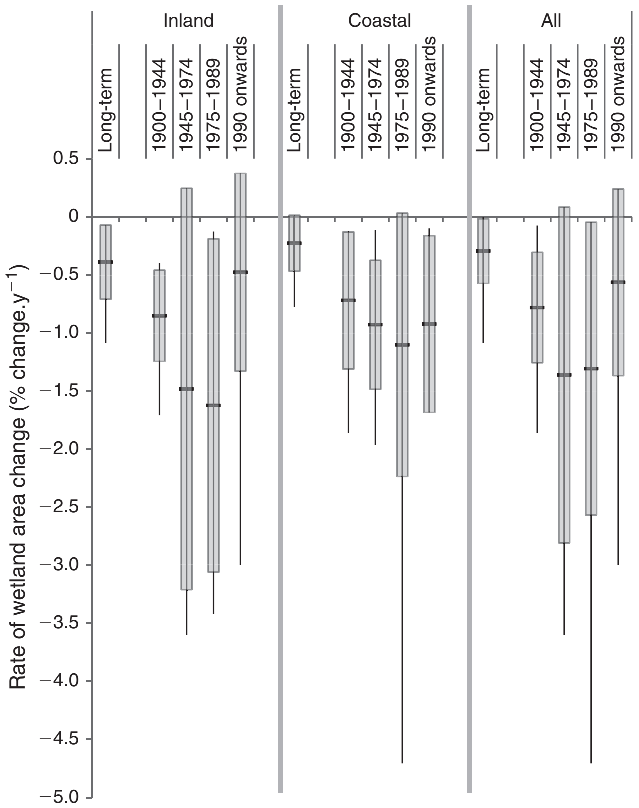

Fig. 2. Annual rates of change (%.y^{-1}) of natural wetland types during different parts of the 20th and early 21st century, compared with earlier long-term rates. The 'all wetlands' category includes inland, coastal and unspecified natural wetland types. Horizontal bar: mean; shaded box: Standard Deviation; vertical line: range.

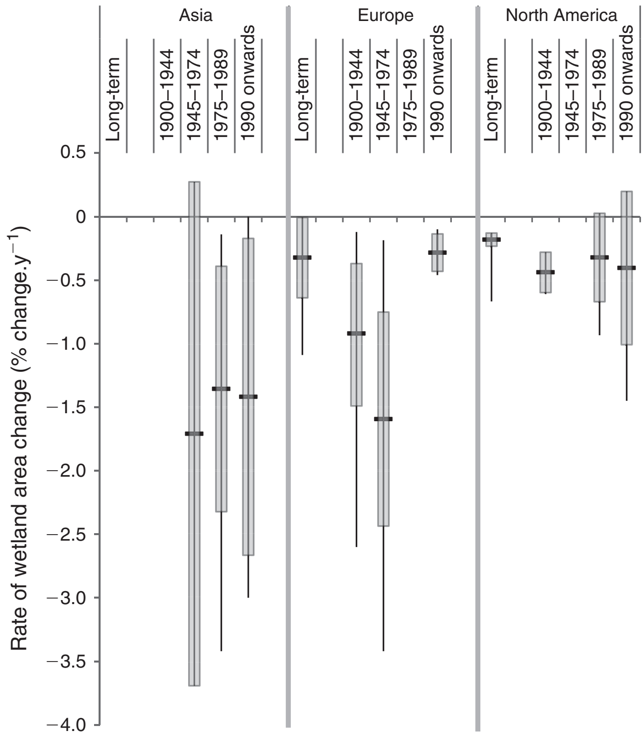

Fig. 3. Annual rates of change (%.y^{-1}) of natural wetlands for different regions during different periods of the 20th and early 21st century, compared with earlier long-term rates of change. There were too few records for other time periods or other regions (Africa, the Neotropics, Oceania) to calculate comparable rates of change. Horizontal bar: mean; shaded box: Standard Deviation; vertical line: range.

Table 3. Rates of change in the area of natural wetlands in different regions during the 20th and early 21st centuries
n = the number of records; s.d. = Standard Deviation

Region	*n*	Average rate of change (%.y^{-1})	s.d.
Africa:			
All wetlands	10	−0.927	1.260
Asia:			
Inland wetlands	16	−1.885	1.872
Coastal wetlands	12	−1.102	0.488
All wetlands	28	−1.515	1.494
Europe:			
Inland wetlands	26	−1.027	0.912
Coastal wetlands	17	−0.986	0.625
All wetlands	50	−1.057	0.767
Neotropics (Caribbean, Central and South America):			
All wetlands	7	−1.956	1.639
North America:			
Inland wetlands	7	−0.347	0.504
Coastal wetlands	7	−0.508	0.368
All wetlands	14	−0.428	0.432
Oceania (incl. Australasia):			
All wetlands	4	−1.062	1.799

(Kruskal–Wallis one-way analysis of variance: K = 5; H = 15.94; d.f. = 4; $P = 0.0031$). Rates of loss were slowest in North America and fastest in the Neotropics and Asia. Regional differences in rates of loss were also significant for inland natural wetlands (Africa, Asia, Europe and North America only): K = 4, H = 9.81; d.f. 3; $P = 0.0203$ (with slowest rates in North America and fastest in Africa and Asia), but not quite significant for coastal natural wetlands (between Asia, Europe and North America): K = 3; H = 5.44; d.f. 2; $P = 0.0659$.

The temporal pattern of rates of loss through the 20th and early 21st centuries varied regionally (Fig. 3). In Europe rates differed significantly (K = 3, H = 16.49, d.f. 2, $P = 0.0003$), with particularly high rates in the period from 1945 onward but much slower for the 1990s onward. In North America, rates were consistently lower than in Asia and Europe, and did not vary significantly during the 20th century (K = 3, H = 1.83, d.f. 2, $P = 0.4005$). Rates of loss in Asia have been consistently high (and not significantly different: K = 3, H = 0.01, d.f. 2, $P = 0.995$) across the different time periods of the 20th and early 21st centuries.

Particularly high rates of loss (>1.5%.y^{-1}) since 1975 have been reported for both inland and coastal wetlands in China, tropical peatswamp forest in Borneo and inland wetlands in part of New Zealand.

Most reports of losses of natural wetlands for the 20th–early 21st centuries were for less than the full time period (Table 1). Extrapolating from the average rates of wetland loss for the different time periods of the 20th century (from Table 1), suggests that only 29.4% of wetlands present in 1900 AD may have remained by the end of the century – a loss of 70.6%, with a loss of 63.0% of coastal natural wetlands and 75.0% for inland natural wetlands. The extent of loss has varied between regions, with extrapolated losses of 83.7% for Asia (66.7% since 1945), 71.0% for Europe and 36.5% for North America.

The figures are similar but slightly lower when site-scale records are excluded: an average natural wetland loss of 34.9% ($n = 86$) for an average period of 39.2 years; and a 20th century 64.0% loss extrapolated from average rates of loss in each time period (62.0% for coastal wetlands and 68.8% for inland wetlands).

These continuing losses of natural inland and coastal wetlands contrast with increases in human-made (artificial) wetlands (as also noted earlier in Swift 1964) (see Supplementary Material). In Europe, open waters increased by 4.4% between 1990 and 2006, attributed mostly to the creation of reservoirs and other artificial water bodies (EEA 2010). In China, in the 30 years between 1978 and 2008, while natural inland wetlands decreased in area by 33%, artificial inland wetlands increased by 122% (Niu *et al.* 2012); in the USA, the area of restored and created ponds increased by 12% between 1985 and 2004 (Dahl 2006); and the global area of rice paddy harvested increased by 41.5% between 1961 and 2012 (FAOSTAT http://faostat.fao.org, accessed 10 July 2014).

Overall natural wetland loss since the start of the 18th century

Reported long-term loss of natural wetlands averaged 54–57%, but overall losses may have been much greater than these values. Extrapolation from the average rates of wetland loss since the start of the 18th century (from Table 1) suggests that of the wetland area existing in 1700 AD, 76.3% remained in 1800 AD and 44.1% in 1900 AD, but only 13.0% at the end of the 20th century (Fig. 4) – an overall loss of 87.0% since 1700 AD.

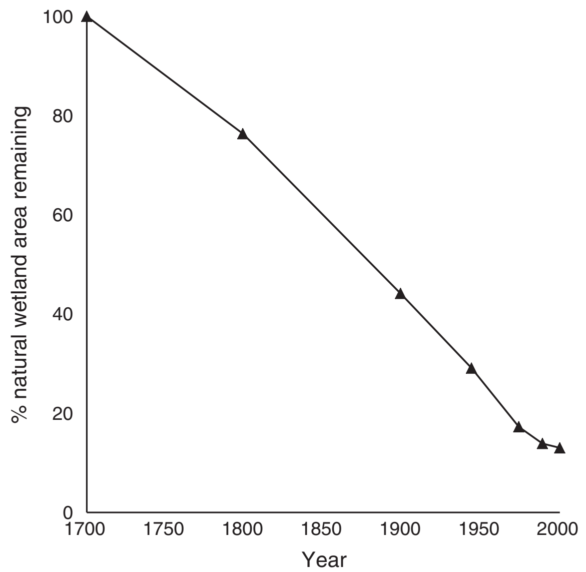

Fig. 4. The percentage remaining of the natural wetland area at the start of the 18th century (1700 AD). Values are extrapolated from the average rates of wetland loss in Table 1.

A similar extrapolation for wetland area at the start of the 19th century suggests that only 16.9% remained at the end of the 20th century – a loss of 83.1% since 1800 AD.

Discussion

This assessment of the extent of global wetland losses confirms that conversion and loss of natural wetlands has been long-term and widespread, and is continuing in all parts of the world (excluding Antarctica, for which the only record located was for peatlands and reported little change (Joosten 2009)). Historical (long-term) reports indicate a loss of 54–57% of the world's wetlands – exceeding the widely stated but unsubstantiated figure of 50% – but may have been much greater than this, with a loss of 87% of natural wetland area since the start of the 18th century.

The rate of loss of natural wetlands accelerated progressively from before the 18th century to a peak in the second half of the 20th century. Similarly, a progressively accelerating rate of loss of intertidal estuarine wetlands in the United Kingdom between the 16th and 20th centuries was reported by Davidson (2013). Natural wetland conversion and loss in the 20th and early 21st centuries has happened at a much faster rate (3.7 times) than previously, with the overall loss of wetlands since 1900 AD being considerably more than the unsubstantiated '50% loss since 1900'. From this study, 20th century losses have been 64–71% of the wetland area present in 1900 AD, and for some regions, notably Asia, even higher.

Losses of natural inland wetlands have been consistently greater, and at faster rates, than of natural coastal wetlands. For such inland wetlands, losses were 57–61% in the long term and 69–75% for the 20th century. This compares with 46–50% long-term and 62–63% 20th century losses of coastal natural wetlands.

While the rate of loss of natural inland wetlands has slowed since the 1980s, the rate of loss of natural coastal wetlands has remained high, with the overall relative rate of loss of coastal wetlands during the 20th and early 21st centuries being 4.2 times faster than in the long term, compared with 3.0 times faster for inland wetlands.

Whereas these figures show a major loss of natural wetland area, some conversion of natural wetlands will have been to other, human-made, types of wetlands such as rice paddies, aquaculture ponds and reservoirs, so that global losses of all types of wetland will be lower than reported here. However, the extent of conversion to human-made wetlands is hard to assess given the available information.

The precise extents and rates of wetland losses reported here are influenced by the spatial scale of the data in published reports, with larger extents and faster rates of loss from reports from specific wetland sites than those from assessments of larger areas. The reasons why are not clear, but studies at large spatial scales are more likely to include both wetlands that have been converted and those that have not. It is also possible that researchers have focussed their attention, at least in publications, on those wetlands that are known to have been partially or wholly converted and lost, and/or are under threat of further conversion, rather than those wetlands that have remained unchanged.

The figures presented here are also likely be affected by geographical bias in the numbers of published reports found for different regions of the world, with most being from Asia, Europe and North America. There is a dearth of published reports of wetland area change for Africa, the Neotropics and Oceania, as has been found in other studies of wetland baseline inventory and change (Finlayson and Davidson 1999; Burke *et al.* 2000; van Asselen *et al.* 2013).

There is an urgent need for further attention to be paid to wetland inventories and analyses of change in wetland areas, particularly in Africa, the Neotropics and Oceania. Also, some types of wetland are not well represented in the dataset sourced for the present study: there is little information (of even baseline area from global wetland inventories and mapping) on ephemeral or intermittently flooded wetlands, such as wet meadows and arid and semiarid zone shallow depressions. There is also a lack of data for areas, and especially for trends, for some of the world's major flooded forest areas, such as those in the Amazon and Congo (see e.g. Finlayson *et al.* 1999; Maltchik 2003; Keddy *et al.* 2009).

It is regrettable that other publications could not be included in this analysis as they did not state the years covered by the assessment, or had only incomplete figures for change in area. In others, the existence of data on change in wetland area was not identifiable from their titles, keywords or abstract. It is recommended that future reports on changes in wetland area include the following information: keywords such as 'wetland area change', 'wetland loss', or 'wetland conversion'; a precise start and end year of the assessment; the wetland type(s) assessed; the wetland area at the start and end year of the record and/or the percentage change; and information about the types of habitat or land use to which the wetland has been converted.

The present study has only looked at changes in the area of remaining wetlands, and not at the state of those that remain. Many remaining wetlands continue to face severe pressures, despite the many benefits of high value they provide to people (Finlayson *et al.* 2005; Carpenter *et al.* 2011; Russi *et al.* 2013; Costanza *et al.* 2014). Although there is no assessment of the state of health of the world's remaining wetlands, many are recognised as having deteriorated in status and to be currently degraded. In 2012, 28% of 127 national governments reporting to the Ramsar Convention indicated that the overall status of their wetlands had deteriorated in recent years, compared with 19% reporting an improvement (Ramsar Convention 2012).

The patterns of wetland area change reported here raise questions about whether the governments that are Parties to the Ramsar Convention are effectively addressing the Convention's 1971 desire to 'stem the loss and degradation of wetlands'. The high rates of wetland loss reported for some regions, such as Asia and Europe, in the second half of the 20th century suggest that the concerns that led to the creation of the Convention were well founded. However, widespread wetland conversion and loss has continued. Although the continuing low rate of loss in North America and the considerably reduced rate of loss in Europe are encouraging signs, the continuing very high rates of loss of both inland and coastal natural wetlands in Asia are of particular concern (see MacKinnon *et al.* 2012). Finlayson (2012) presented this as a paradox whereby although there had been a substantial investment in wetland policy and information through the Convention, this had not stopped or reversed the global loss and/or degradation of wetlands: a situation that raised questions about the extent or effectiveness of national implementation of the Convention.

The present study has revealed that: wetland conversion and loss in the long term was in excess of 50% and as much as 87% since the beginning of the 18th century; wetland loss was almost four times faster in the 20th century than previously, with losses of up to 70% of wetlands existing in 1900 AD; conversion of coastal natural wetlands accelerated more than that of inland natural wetlands in the 20th century; and conversion and loss is continuing in all parts of the world, and particularly rapidly in Asia. The fate of the world's remaining wetlands is very uncertain.

Acknowledgements

I am most grateful to Maria Grazia Bellio, David Coates, Nicola Crockford, Linda Davidson, Matthew Dixon, C. Max Finlayson, Jonathon Loh, Ed Maltby, Randy Milton, Crawford Prentice, David Stroud, Denis Whigham and two anonymous referees for invaluable help, information, comments and advice on earlier drafts of this paper.

References

An, S., Li, H., Guan, B., Zhou, C., Wang, Z., Deng, Z., Zhi, Y., Liu, Y., Xu, C., Fang, S., Jiang, J., and Li, H. (2007). China's Natural Wetlands: Past Problems, Current Status, and Future Challenges. *Ambio* **36**, 335–342. doi:10.1579/0044-7447(2007)36[335:CNWPPC]2.0.CO;2

Burke, L. A., Kura, Y., Kassem, K., Revenga, C., Spalding, M., and McAllister, D. (2000). Pilot Analysis of Global Ecosystems. Coastal Ecosystems. World Resources Institute, Washington D.C. Available from: http://www.costabalearsostenible.es/PDFs/AMYKey%20References_Indicators/PAGE_WRI.pdf [accessed 21 June 2014]

Carp, E. (ed.) (1972). Proceedings of the International Conference on the Conservation of wetlands and Waterfowl. Ramsar, Iran, 30 January – 3 February 1971. (IWRB: Slimbridge, UK.)

Carpenter, S. J., Stanley, E. H., and Vander Zanden, M. J. (2011). State of the World's Freshwater Ecosystems: Physical, Chemical, and Biological Changes. *Annual Review of Environment and Resources* **36**, 75–99. doi:10.1146/ANNUREV-ENVIRON-021810-094524

Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S. J., Kubiszewski, I., Farber, S., and Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change* **26**, 152–158. doi:10.1016/J.GLOENVCHA.2014.04.002

Dahl, T. E. (1990). Wetland losses in the United States 1780's to 1980's. (U.S. Department of the Interior, Fish and Wildlife Service: Washington, DC.).

Dahl, T. E. (2006). Status and trends of wetlands in the coterminous United States 1998 to 2004. (U.S. Department of the Interior, Fish and Wildlife Service: Washington, D.C.).

Dahl, T. E. (2011). Status and trends of wetlands in the coterminous United States 2004 to 2009. (U.S. Department of the Interior, Fish and Wildlife Service: Washington, D.C.).

Davidson, N. C., Laffoley, Dd'A, Doody, J. P., Way, L. S., Gordon, J., Key, R., Drake, C. M., Pienkowski, M. W., Mitchell, R. M., and Duff, K. L. (1991). Nature conservation and estuaries in Great Britain. (Nature Conservancy Council: Peterborough, UK).

Davidson, N. (2013). Loss of intertidal habitat through landclaim in Asia. In 'The State of the World's Birds 2013'. p 14. (BirdLife International: Cambridge, UK).

de Klemm, C. (1995). The Legal Development of the Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat (2 February 1971). (Ramsar Convention Bureau, Gland, Switzerland) Available from: http://www.ramsar.org/cda/en/ramsar-pubs-books-legal-development-of/main/ramsar/1-30-101%5E23880_4000_0__ [accessed 20 June 2014]

Dugan, P. (ed.) (1993). Wetlands in Danger. (Mitchell Beazley: Auckland.)

Dugan, P. J. (ed.) (2005). Philip's Guide to Wetlands. (Philip's: London.)

EEA (2010). The European environment: state and outlook 2010. (European Environment Agency: Copenhagen.)

Finlayson, C. M. (2012). Forty years of wetland conservation and wise use. *Aquatic Conservation: Marine and Freshwater Ecosystems* **22**, 139–143. doi:10.1002/AQC.2233

Finlayson, C. M., and D'Cruz, R. (2005). Inland water systems. In 'Ecosystems and Human Well-being: Current State and Trends: Findings of the Condition and Trends Working Group'. (Eds R. Hassan, R. Scholes and N. Ash.) pp. 551–583. (Island Press: Washington, D.C.)

Finlayson, C. M., and Davidson, N. C. 1999. Summary report. In 'Global review of wetland resources and priorities for wetland inventory'. (Eds C.M. Finlayson and A.G. Spiers.) pp. 1–15. Supervising Scientist Report 144/Wetlands International Publication 53. (Supervising Scientist: Canberra, Australia.)

Finlayson, C. M., Davidson, N. C., Spiers, A. G., and Stevenson, N. J. (1999). Global wetland inventory – current status and future priorities. *Marine and Freshwater Research* **50**, 717–727. doi:10.1071/MF99098

Finlayson, C. M., D'Cruz, R., and Davidson, N. (2005). 'Ecosystems and human well-being: Wetlands and Water. Synthesis.' (Millennium Ecosystem Assessment. World Resources Institute: Washington D.C.)

US Fish & Wildlife Service (1978). Bottomland hardwood preservation program lower Mississippi River delta – habitat category 7. (US Fish & Wildlife Service: Atlanta Regional Office, USA).

Harmon, K. W. (1980). Prairie potholes. *National Parks & Conservation Magazine* **45**, 25–28.

Harmon, K. W. (1981). Impacts of wetland losses on wildlife. In 'Selected Proceedings of the Midwest Conference on Wetland Values and Management'. (Ed. B. Richardson.) pp. 347–353. (Minnesota Water Planning Board: St. Paul, MN, USA.)

Hoffmann, L. (compiler) (1964). Proceedings of the MAR Conference organised by IUCN, ICBP and IWRB. Stes-Maries-de-la-Mer, France, 12–16 November 1962. IUCN Publications New Series 3. (IUCN: Morges, Switzerland.)

Joosten, H. (2009). The Global Peatland CO2 Picture. Peatland status and drainage related emissions in all countries of the world. (Wetlands International: Ede, The Netherlands.)

Keddy, P. A. (2009). Wet and wonderful: the world's largest wetlands are conservation priorities. *Bioscience* **59**, 39–51. doi:10.1525/BIO.2009.59.1.8

Kotze, D. C., Breen, C. M., and Quinn, N. (1995). Wetland losses in South Africa. In 'Wetlands of South Africa'. (Ed. G.I. Cowan) pp. 263–272. (Department of Environmental Affairs and Tourism: Pretoria.)

MacKinnon, J., Verkeuil, Y. I., and Murray, N. (2012). IUCN situation analysis on East and Southeastern Asian intertidal wetlands, with particular reference to the Yellow Sea (including the Bohai Sea). Occasional paper of the IUCN Species Survival Commission No. 47. (IUCN: Gland, Switzerland.)

Maltby, E. (1986). 'Waterlogged wealth. Why waste the world's wet places?'(Earthscan.IEED: London.)

Maltby, E., and Acreman, M. C. (2011). Ecosystem services of wetlands: pathfinder for a new paradigm. *Hydrological Sciences Journal* **56**, 1341–1359. doi:10.1080/02626667.2011.631014

Maltchik, L. (2003). Three new wetlands inventories in Brazil. *Interciencia* **28**(7), 421–423.

Matthews, G. V. T. (1993). 'The Ramsar Convention on Wetlands: its History and Development.' (Ramsar Convention Bureau: Gland, Switzerland.)

Niu, Z. G., Zhang, H. Y., Wang, X. W., Yao, W. B., Zhou, D. M., Zhao, K. Y., Zhao, H., Li, N. N., Huang, H. B., Li, C. C., Yang, J., Liu, C. X., Liu, S., Wang, L., Li, Z., Yang, Z. Z., Qiao, F., Zheng, Y. M., Chen, Y. L., Sheng, Y. W., Gao, X. H., Zhu, W. H., Wang, W. Q., Wang, H., Weng, Y. L., Zhuang, D. F., Liu, J. Y., Luo, Z. C., Cheng, X., Guo, Z. Q., and Gong, P. (2012). Mapping wetland changes in China between 1978 and 2008. *Chinese Science Bulletin*. doi:10.1007/S11434-012-5093-3

OECD (1996). Guidelines for aid agencies for improved conservation and sustainable use of tropical and subtropical wetlands. DAC Guidelines on Aid and Environment No. 9. (OECD: Paris.)

Perennou, C., Beltrame, C., Guelmami, A., Tomas Vives, P., and Caessteker, P. (2012). Existing areas and past changes of wetland extent in the Mediterranean region: an overview. *Ecologia Mediterranea* **38**, 53–66.

Ramsar Convention (2012). Report of the Secretary General on the implementation of the Convention at the global level. Ramsar COP11 DOC. 7. Available from: http://www.ramsar.org/pdf/cop11/doc/cop11-doc07-e-sg.pdf [Accessed 10 November 2013].

Ramsar Convention Secretariat (2011). Ramsar's Liquid Assets. 40 years of the Convention on Wetlands. Available from: http://www.ramsar.org/pdf/Ramsar40_booklet/Ramsar_LiquidAssets_E.pdf [accessed 15 April 2014]

Russi, D., ten Brink, P., Farmer, A., Badura, T., Coates, D., Förster, J., Kumar, R., and Davidson, N. (2013). 'The Economics of Ecosystems and Biodiversity for Water and Wetlands.' (IEEP: London.)

Schmidt, P. R. (2006). North American Flyway Management: a century of experience in the United States. pp. 60–62 in 'Waterbirds around the World'. Eds. G.C. Boere, C.A. Galbraith and D.A. Stroud. (The Stationery Office: Edinburgh, UK.)

Schrader, T. A. (1955). Waterfowl and the potholes of the North Central States. In 'Yearbook of Agriculture, 1955.' pp. 596–604. (US Department of Agriculture: Washington, DC.)

Shaw, S. P., and Fredine, C. G. (1956). 'Wetlands of the United States: their extent and their value to waterfowl and other wildlife.' U.S. Circular 39. Northern Prairie Wildlife Research Center Online. (Department of the Interior: Washington, DC.) Available from: http://www.npwrc.usgs.gov/resource/wetlands/uswetlan/index.htm [Accessed 12 December 2013].

Swift, J. J. (1964). Proceedings of the First European Meeting on Wildfowl Conservation. St. Andrews, Scotland, 16–18 October 1963. (Ed. J.J. Swift). (The Nature Conservancy: Londone.)

US Department of Agriculture (1980). 'Appraisal 1980 – Soil and Water Resources Conservation Act.' (US Department of Agriculture: Washington, DC.)

van Asselen, S., Verburg, P. H., Vermaat, J. E., and Janse, J. H. (2013). Drivers of Wetland Conversion: a Global Meta-Analysis. *PLoS ONE* **8**(11), e81292. doi:10.1371/JOURNAL.PONE.0081292

Weller, M. W. (1981). Estimating wildlife and wetland losses due to drainage and other perturbations. In 'Selected Proceedings of the Midwest Conference on Wetland Values and Management'. (Ed. B. Richardson.) pp. 337–346. (Minnesota Water Planning Board: St. Paul, MN, USA.)

Winkler, M. G., and DeWitt, C. B. (1985). Environmental impacts of peat mining: documentation for wetland conservation. *Environmental Conservation* **12**, 317–330. doi:10.1017/S0376892900034433

Zheng, Y., Zhang, H., Niu, Z., and Gong, P. (2012). Protection efficacy of national wetland reserves in China. *Chinese Science Bulletin* **57**, 1116–1134. doi:10.1007/S11434-011-4942-9