Ecological Indicators 99 (2019) 294–298

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Short Note

# Improvements to the Wetland Extent Trends (WET) index as a tool for monitoring natural and human-made wetlands

Sarah E. Darrah[a], Yara Shennan-Farpón[a,b,h,*], Jonathan Loh[c], Nick C. Davidson[d,e], C. Max Finlayson[e], Royal C. Gardner[f], Matt J. Walpole[a,g]

[a] UN Environment World Conservation Monitoring Centre (UNEP-WCMC), 219 Huntingdon Road, Cambridge CB3 0DL, UK
[b] Institute of Zoology, Zoological Society of London, Regent's Park, London NW1 4RY, UK
[c] School of Anthropology and Conservation, University of Kent, Canterbury CT2 7NR, UK
[d] Nick Davidson Environmental, Queens House, Ford Street, Wigmore HR6 9UN, UK
[e] Institute for Land, Water and Society, Charles Sturt University, Elizabeth Mitchell Drive, PO Box 789, Albury, NSW 2640, Australia
[f] Stetson University College of Law, 1401 61st Street South, Gulfport, FL 33707, USA
[g] Fauna and Flora International (FFI), The David Attenborough Building, Pembroke St, Cambridge CB2 3QZ, UK
[h] Department of Anthropology, University College London, 14 Taviton St, London WC1H 0BW, UK

ARTICLE INFO

*Keywords:*
Wetlands
Wetland loss
Indicator
Aichi Targets
Ramsar Convention
SDG 6

ABSTRACT

Indicators of status and trends in wetland extent are essential for monitoring progress towards the environmental targets set by the Convention on Biological Diversity (CBD), the United Nations Sustainable Development Goals (SDGs) and the Ramsar Convention on Wetlands. Here, we test the value of the Wetland Extent Trends (WET) index as an updatable indicator of trends in wetland area and its application to global and regional scale assessments and national reporting. We expand the indicator to include a regional trend for Latin America and the Caribbean and a global human-made WET index. Based on a sample of over 2000 wetland records, natural wetland extent declined on average by 35% globally, at an increasing rate from 1970 to 2015. Human-made wetlands, however, increased by 233% from 1970 to 2014. The continuing decline in natural wetland extent suggests that global targets will not be achieved without significant further efforts.

## 1. Introduction

Indicators are essential in tracking progress towards global sustainable development and biodiversity targets (Tittensor et al., 2014; Mcowen et al., 2016), such as those set by the Convention on Biological Diversity (CBD) in its Strategic Plan for Biodiversity 2011–2020 and its Aichi Targets (COP 10 decision X/2, CBD, 2010), and the UN 2030 Sustainable Development Goals (SDGs) (UN, 2018a). In response to this Plan, a global Wetland Extent Trends (WET) index was created as a proof of concept to build a global picture of trends in wetland extent over time (Dixon et al., 2016). Despite regional data gaps, the indicator was adopted for use in key environmental assessments such as the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) Assessments (IPBES, 2016, 2018a, 2018b) the Ramsar Convention's Global Wetland Outlook (Ramsar Convention, 2018) and UN SDG 6 Synthesis Report (UN, 2018b). The indicator was also adopted into the Biodiversity Indicators Partnership (BIP, 2014).

Inland surface water ecosystems, including vegetated and open water systems cover at least 9–10% of global land area (Davidson et al., 2018; Davidson and Finlayson, 2018), support over 10% of all known species (Strayer and Dudgeon, 2010) and provide essential ecosystem services worldwide (MEA, 2005; Gardner et al., 2015). Coastal and near-shore marine wetlands cover a smaller area, about 1% of global land area, but are some of the most vulnerable ecosystems on Earth (Duffy, 2006; Burke et al., 2001). Their importance in supporting livelihoods is well known (MEA, 2005; Finlayson et al., 2013).

Wetland ecosystems are complex and dynamic, and despite progress in earth observation techniques (Fluet-Chouinard et al., 2015) and the development of global surface water maps (Pekel et al., 2016; Yamazaki et al., 2015), we lack consistent methods to monitor their extent and condition (Gallant, 2015). Global estimates of natural wetland extent remain variable and considered to underestimate actual coverage (Hu et al., 2017; Davidson et al., 2018; Davidson and Finlayson, 2018). The distinction between human-made or artificial wetlands and natural

* Corresponding author at: Institute of Zoology, Zoological Society of London, Regent's Park, London NW1 4RY, UK.
*E-mail addresses:* sarah.darrah@hotmail.com (S.E. Darrah), yara.shennanfarpon@ioz.ac.uk (Y. Shennan-Farpón), j.loh@kent.ac.uk (J. Loh), mfinlayson@csu.edu.au (C.M. Finlayson), gardner@law.stetson.edu (R.C. Gardner), matt.walpole@fauna-flora.org (M.J. Walpole).

https://doi.org/10.1016/j.ecolind.2018.12.032
Received 9 October 2018; Received in revised form 13 December 2018; Accepted 14 December 2018
Available online 26 December 2018
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wetlands remains a challenge when monitoring habitat loss (Davidson et al., 2018).

In this paper, we:

1) Extend and update global and regional wetland area trends from Dixon et al. (2016) using the WET index methodology.
2) Present global indices of change in natural and human-made wetlands from 1970 to 2015, using a scalable and updatable analysis sensitive to global and regional trends and rates of change.
3) Update the WET database to include data from Latin America and the Caribbean and present six regional indices of wetland change from 1970 to 2015.

## 2. Updating the analysis and improvements to the methods

### 2.1. The WET database

The updated WET database consists of 306 data sources, including scientific literature, grey literature, national wetland inventories, and four global datasets based on national-level data of mangroves, peatlands and rice paddies (Joosten, 2012; FAO, 2015, 2007; Hamilton and Casey, 2016). It contains 2130 individual time-series records of change in wetland area from local sites and aggregated national trends. 1000 records have been added to the first version of the database. Records are included for all six Ramsar Regions (Ramsar Convention, 2015) (Fig. 1): 23% from Africa; 23% from Asia; 20% from Europe; 11% from Latin America and the Caribbean; 16% from North America; and 8% from Oceania (Fig. 1; Fig. S1). No data were identified for Antarctica. The updated database contains information including the geographic location of time-series records, wetland type, year of data collection and wetland area measurements (see the Appendix for a full list of sources).

### 2.2. Data collection

The temporal and geographical update of the WET database involved a systematic literature review using a detailed search string in SciVerse's Scopus,[1] grey literature searches and a call for data from governments, research institutions and experts. A global search was performed in English, and a translated search string in Spanish and Portuguese was used to address previous data gaps for the Latin America and Caribbean region (Appendix Tables S1–S3). Criteria for the inclusion of new time-series data were kept consistent with the original method (Dixon et al., 2016).

### 2.3. Time-series analysis

The analysis follows Dixon et al. (2016), using an adaptation of the Living Planet Index (LPI) 'R' package 'rlpi' (Loh et al., 2005; Collen et al., 2009; McRae et al., 2017) to interpolate average change in extent over time using predictive linear regression (see Appendix for details on the script).

Time-series data were subdivided into six regions and 130 sub-regions, and 17 different wetland types based on the Ramsar Convention's wetland classification (Finlayson, 2018) (Appendix Tables S5–S7). Wetlands were classified into *inland*, *marine/coastal* and *human-made* (or artificial) categories.

We calculated four global WET indices: a "natural index" (combining inland and marine/coastal wetlands), a "natural marine/coastal index", a "natural inland index", a "human-made index"; and six regional natural indices. As temporal coverage of wetland time-series varies throughout the dataset, aggregated average rates of change in extent were calculated from 1970 to 2015 for the global natural WET index both annually and over a 5-year time interval to account for short-term fluctuations. To avoid misrepresentation of data due to differences in wetland type and coverage between regions, regional weightings were used to calculate the natural, marine/coastal and inland WET indices, based on area estimates from the Global Lakes and Wetlands Database (Lehner and Döll, 2004) (Appendix Table S8). Neither the global human-made, nor regional indices could be weighted due to a lack of available information on wetland distribution and extent (Davidson and Finlayson, 2018).

The global natural WET index was tested for bias by running it both with and without inclusion of the four global datasets. The WET methodology was previously tested for possible bias derived from faster rates of change in smaller wetlands by comparing the calculated rate of loss against remotely sensed data on Mediterranean wetlands from the European Space Agency and the Globwetland II project (http://www.globwetland.org/) (Dixon et al., 2016).

## 3. Results

Global and regional natural WET indices show a declining trend over time. The global WET index weighted by regions declined by 35% between 1970 and 2015 (95% CIs 32–37%) (Fig. 2A). The unweighted global index declined by 33% (CIs 30–36%). Global declines in coastal/marine wetlands are greater on average than inland wetlands (39% and 35% respectively), with faster rates of decline in inland wetlands seen in recent years (Fig. 2B). The global natural inland WET index is shown to 2013, as the lack of data points from 2014 and 2015 causes the index to fall outside CIs when calculated beyond this date (Fig. 2B). Over the time-period analysed, the average annual rate of decline in natural wetlands globally was $-0.95\%\ yr^{-1}$, with rates almost doubling in the most recent five years from $-0.85\%\ yr^{-1}$ for 2005–2010 to $-1.6\%\ yr^{-1}$ for 2010–2015 (Fig. 3). Although the human-made WET index is based on fewer data sources (59 data sources, 605 time-series records), it demonstrates a contrasting, positive trend with an increase of 233% (CIs 215–255%) from 1970 to 2014.

Exclusion of global datasets from the WET database did not have a significant impact on the analysis (36% decline, CIs 31–40%); these datasets are therefore included in all WET indices calculated. The regional WET indices all declined, varying from 59% in Latin America and the Caribbean to 12% in Oceania (Table 1).

## 4. Discussion

### 4.1. Large-scale patterns of wetland change

The WET index aims to address a key gap in our understanding of the state of aquatic habitats and allows the monitoring and reporting of average rates of wetland loss at all scales, given sufficient data. Here, we show rates of natural wetland loss are over three times faster than reported rates of forest loss ($-0.24\%\ y^{-1}$, 1990–2010) (FAO, 2015). Other global wetland studies have found similar rates of loss, between $-0.98\%$ and $-1.5\%\ y^{-1}$ (Talberth and Gray, 2012; Davidson, 2014). Despite the establishment of global targets to reduce natural habitat loss from 2000 onwards, in the period leading up to the CBD, 2010 Biodiversity Targets (2002–2010) the average rate of natural wetland loss was $-0.91\%\ y^{-1}$, increasing to $-1.60\%\ y^{-1}$ by 2015. These results imply that wetland targets will not be achieved under current implementation trajectories. This brings into question the effectiveness of international policy setting for wetlands, as raised in Finlayson et al. (2017), and as seen for other biodiversity targets in the 2011–2020 strategy (Shepherd et al., 2016; Leadley et al., 2014).

The human-made WET index suggests notable expansions in human-made wetlands over the sampled period, contributing to filling gaps in our knowledge of extent trends in artificial water bodies (Davidson and Finlayson, 2018). This data can help interpret results obtained from remote sensing methods and better understand the implications for biodiversity. While the increased rate of expansion of human-made

[1] SciVerse Scopus. http://www.scopus.com/.

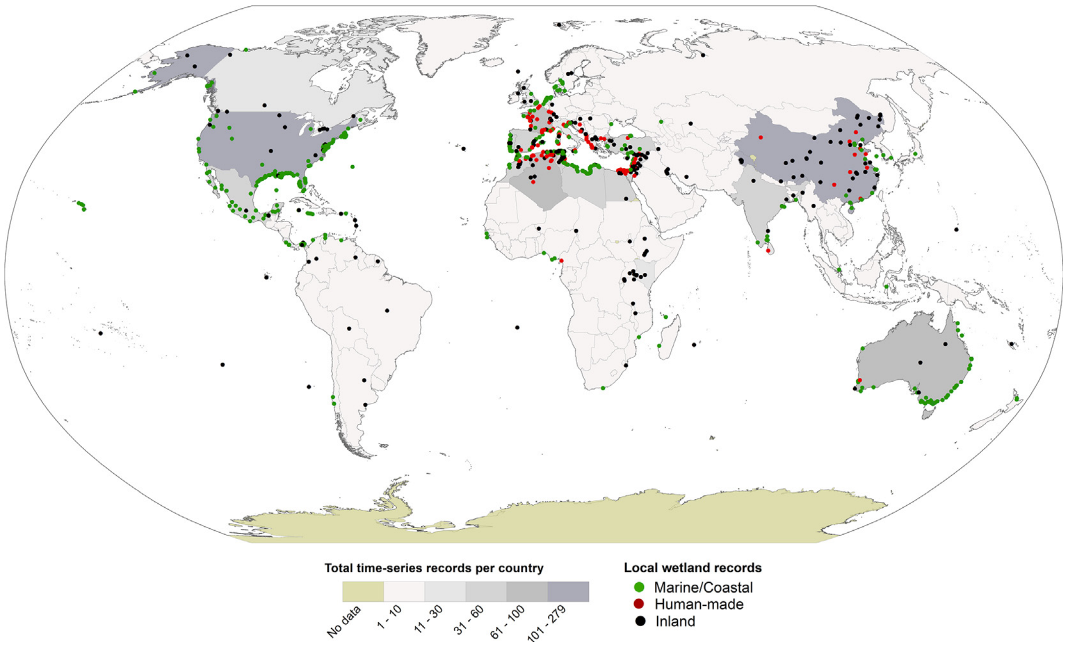


**Fig. 1.** Total number of time-series included in the updated WET database per country. Points show distribution of local time-series records (excluding national datasets) across Ramsar regions classified by wetland type (Finlayson, 2018).

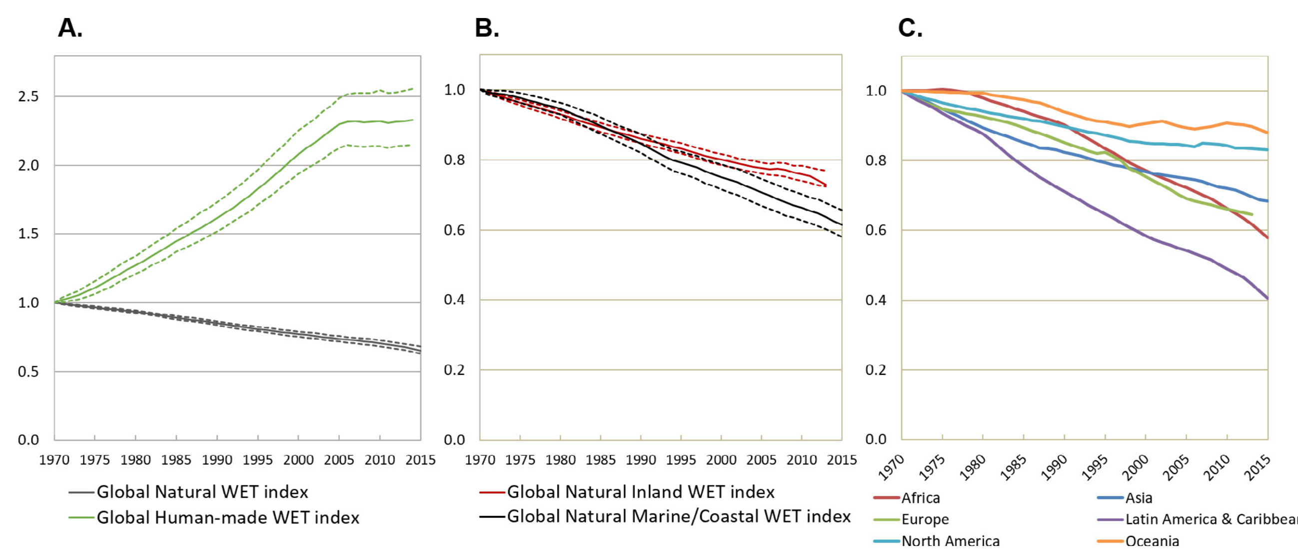


**Fig. 2.** Wetland Extent Trend (WET) index relative to 1970 for A) global natural and human-made wetlands, B) global marine/coastal and inland wetlands and C) natural wetlands in six regions. Natural regional wetland trends are reported from 1970 to 2015 except for Europe (1970–2013) due to data availability. Global natural trends are weighted by regional wetland area estimates whilst regional and human-made trends are unweighted. A decrease in the index means that wetland extent has declined on average while a flat index represents no overall change in wetland extent (gains and declines cancel each other out). Dashed lines show 95% confidence intervals.

wetlands could be due to improvements in wetland monitoring and reporting (Davidson et al., 2018), this trend is supported by global datasets of reservoirs and rice production area showing increases of 0.11 million $km^2$ and 0.30 million $km^2$ respectively over similar time-periods (Lehner et al., 2011b; IRRI, 2017; Davidson et al., 2018). The reported growth in human-made wetlands appears to level off between 2005 and 2014, despite more data from this period; this stabilisation matches a reduction in the rate of addition of large dams and reservoirs seen in the Global Reservoirs and Dams Database (Lehner et al., 2011a). It is unclear if the growth in artificial wetlands has compensated for biodiversity loss in natural wetlands (Ghermandi et al., 2010); we suggest further studies are required to accurately assess the state of artificial wetlands and the implications for biodiversity.

### *4.2. Application of the WET index in policy processes*

There is a need for national monitoring of wetland extent change to meet reporting requirements for global targets such as the SDGs (UN General Assembly, 2015), but national reporting can be incomplete, biased and difficult to update. Many countries lack national-level wetland information on which to base decision-making. Only 44% of Ramsar Contracting Parties report having completed national wetland inventories in 2018, although periodic reporting is now required (Ramsar Convention, 2018). Uptake of the WET index methodology at the national level could facilitate these monitoring requirements and support current reporting mechanisms, such as the national reporting cycle to the Ramsar Convention, which provides a systematic approach to the collation of nationally reported data, and the proposed

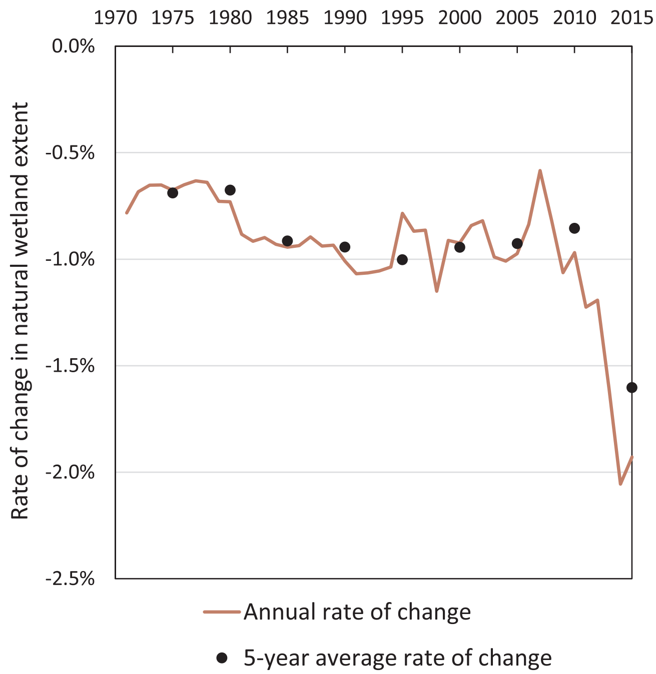


**Fig. 3.** Rate of change in natural wetland extent per year and as an average of each 5-year period.

**Table 1**
Percentage declines from 1970 to 2015 in the regional and global natural WET indices (I), 95% lower and upper confidence limits (LCL and UCL) and number of time-series in each index (N). NB. Europe index runs to 2013 due to data availability.

| | Natural | | | |
|---|---|---|---|---|
| | I | LCL | UCL | N |
| Africa | 42% | 36% | 49% | 322 |
| Asia | 32% | 28% | 36% | 316 |
| Europe | 35% | 31% | 41% | 268 |
| Latin America & Caribbean | 59% | 55% | 65% | 154 |
| North America | 17% | 13% | 21% | 324 |
| Oceania | 12% | 6% | 17% | 140 |
| Global (weighted) | **35%** | **32%** | **37%** | **1524** |

framework for data collection on water quality, volume and extent provided by SDG Indicator 6.6.1 (UN Water, 2018).

Whilst other monitoring approaches based on Earth observation exist, (Mueller et al., 2016; Yamazaki et al., 2015; SWOS, 2018), these are not yet fully operational or available for use by policy-makers and practitioners (Rebelo and Finlayson, 2018). Earth observation approaches to map surface water globally are advancing rapidly, but accurate estimates of natural wetland extent and distribution are still hard to achieve, with most analyses focusing on open or surface water systems only (Hu et al., 2017; Davidson et al., 2018; Davidson and Finlayson, 2018). In the absence of published time-series data obtained through Earth observation, the WET methodology complements existing surface water maps by incorporating *in situ* data and local studies to provide trends in change of all types of wetlands over time. The WET database allows for the comparison of relative loss in wetland area across regions. However, continuing data gaps mean absolute loss of wetland area over time cannot yet be accurately calculated. Collation of data using the WET index approach can identify and prioritise monitoring of data deficient wetland habitats (see Appendix Fig. S1 and Tables S5–7), assist in reporting on the state of the world's wetlands, and provide a robust method to assess change in extent of any habitat type.

## 5. Conclusion

As we move towards the post-2020 biodiversity agenda, practitioners and decision-makers need better environmental monitoring and reporting tools. Wetland ecosystems are important for biodiversity, poverty alleviation and human health (WWAP, 2015), and our results show that we are not on track to meet the habitat protection targets set in the 2020 Aichi Biodiversity Targets (CBD, 2010) and SDGs. The WET index is a useful policy tool which can help prioritise and apply conservation and habitat management practices in the absence of comprehensive national monitoring programmes for wetlands, as well as for other ecosystems.

## 6. Declarations of interest

None.

## Acknowledgements

We thank the Ramsar Convention on Wetlands for their role in developing this index. This work was supported by the Satellite-based Wetland Observation Service (SWOS) (grant agreement number 642088), the UN Environment World Conservation Monitoring Centre (UNEP-WCMC) and the Natural Environment Research Council (grant number NE/L002485/1). We also thank Matthew Dixon, Andy Arnell, Sarah Morris, Neil D. Burgess and Diego Juffe-Bignoli (UNEP-WCMC) for their contributions at various stages of this work, Louise McRae (ZSL) for her support with the 'rlpi' R package, Alex Häuser for georeferencing time-series records, and all the data providers, as listed in the Appendix.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ecolind.2018.12.032.

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