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1 **Title**

2 Protecting wetlands for people: Strategic policy action can help wetlands mitigate risks and
3 enhance resilience

4 **Author names and affiliations**

5 Joanna Endter-Wada[1]*, Karin M. Kettenring[2], and Ariana Sutton-Grier[3]

6 [1]Department of Environment and Society and Ecology Center, Utah State University

7 [2]Department of Watershed Sciences and Ecology Center, Utah State University

8 [3]Earth System Science Interdisciplinary Center, University of Maryland College Park

9 **Corresponding author***

10 Dr. Joanna Endter-Wada

11 Department of Environment and Society

12 Quinney College of Natural Resources

13 Utah State University

14 Logan, Utah 84322-5215 USA

15 Phone: 435-797-2487

16 Email: joanna.endter-wada@usu.edu

17 **Highlights**

18 • Wetlands can help protect human communities from consequences of extreme weather events

19 • Society has not valued the protective services of wetlands

20 • Coordinated and effective policy action is needed to protect wetlands to protect people

21 • We propose countries take policy action to create national wetland commissions

22 • Commissions would integrate wetland protective services with disaster planning, infrastructure

23 investment, and climate change adaptation strategies

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Abstract

We elevate the undervalued role of wetland protective services for mitigating disastrous consequences of unprecedented weather-related events for human communities. Scientific evidence increasingly reveals that wetlands play critical hydrologic roles in landscapes, helping to mitigate flood, drought, and, in some cases, fire risks. However, wetland protective services have not received sufficient policy action. We propose national wetland commissions, modeled after the concept of lake and river commissions, as one way to strategically link wetland protection to other societal objectives, including human disaster risk planning, infrastructure investments, and climate adaptation strategies. We offer an example applicable to the United States, describing an institutional design for a National Interagency Wetland Commission. We suggest it could be patterned after existing federal commissions statutorily created by Congress with delegated administrative and regulatory authority and designated independent agency status within the executive branch. It is time for bold and innovative policy action to incorporate wetland protective services into societies' defenses against extreme weather events.

Keywords

extreme weather events; wetland protective services; disaster risk planning; climate change adaptation; wetland policy

Manuscript text

1. Introduction

Extreme weather and climate events are becoming the norm—breaking records, dominating news, and creating cumulative impacts to regions suffering from recurrent events (Ummenhofer

and Meehl, 2017). A 2020 assessment of the global risk landscape rated extreme weather events second (2014–2016) or first (2017–2020) in terms of likelihood for the past seven years, and among the top four risks in terms of impact for the fourth year in a row. In 2020, for the first time in the annual report's history, all top five global risks in terms of likelihood and three of the top five risks in terms of impact are environmental in nature. Accompanying extreme weather events in the top five likely risks the world faces in 2020 are the closely related challenges of climate action failure, natural disasters, biodiversity loss, ecosystem collapse, and human-made environmental disasters (World Economic Forum, 2020).

Hurricanes, typhoons, cyclones, and monsoons are wreaking havoc across the globe (World Meteorological Organization, 2019). Tropical storms are slowing due to climate change, resulting in more fatalities and destruction, particularly in densely populated urbanized areas, mostly due to compound flooding from storm surges and heavy rainfall (Needham *et al.*, 2015; Kossin, 2018). Climate change is also causing tropical cyclones to have enhanced average and extreme rainfall (Patricola and Wehner, 2018). Mounting devastation has occurred just in the past three years. Most notably, 2019 saw hundreds of people killed and widespread devastations from Cyclone Idai in southeast Africa, the deadliest storm ever in the Southern Hemisphere, Typhoon Hagibis in Japan, Typhoon Lekima in China, and historic floods in the U.S. Midwest and South. In 2018, Super Typhoon Mangkhut ravaged parts of the Philippines and China, Hurricane Florence devastated several states in the United States (U.S.) Southeast, the Indian state of Kerala experienced the worst monsoon flooding in at least 100 years with over a million people displaced and 400 killed, and an overwhelming 125 cm of rain in 24 hours led to massive flooding and mudslides in Hawaii's island of Kauai. And in 2017, communities throughout the

Caribbean and southeastern U.S. suffered extensive losses from hurricanes Harvey, Irma, Jose, and Maria. The third largest U.S. city, Houston, was subjected to a 500-year flood, supposedly a rare event, for the third year in a row with billions of dollars in damages.

Meanwhile, Australia, Brazil, Canada, Greece, Portugal and the U.S. are among the growing number of places experiencing what has been called "the Age of Megafires," where "unprecedented" dangers from widespread, fast-moving, and intense fires have increased in areas subject to drought and often undergoing rapid landscape-scale change (Pyne, 2009; Attiwill and Binkley, 2013). Australia experienced one of its most calamitous summer fire seasons in 2019–2020 with widespread destruction resulting from millions of acres burned, thousands of homes destroyed and people displaced, and close to a billion animals and dozens of people killed (Morton, 2020). In 2018, California experienced its most deadly and destructive wildfire season on record, part of a trend where 75% of the largest, 75% of the most destructive, and 50% of the deadliest top 20 wildfires in the state's history have occurred since 2000 (Cal Fire, 2019). A recent study suggests that extreme swings from heavy precipitation to drought conditions are likely for California throughout the rest of the century (Swain *et al.*, 2018), supporting other evidence that climate change will further increase the frequency and impacts of extreme fire events (Flannigan *et al*., 2009).

The ecological, human, and economic consequences of catastrophic storm and drought events can, at times, be linked, directly or indirectly, to landscape-scale changes that have resulted in massive losses of wetlands. Yet, the protective services of wetlands—for preventing and mitigating weather-related disasters—are greatly undervalued by people and governments worldwide. We have failed to sufficiently protect wetlands to protect ourselves as well as the

89 wildlife that depend on them. It is time to take bold, effective, and coordinated policy action to
90 incorporate wetland protective services into societies' defenses against extreme weather events.
91 Here we lay out the scientific case for how wetlands provide protective services and why it is
92 important to link wetland management to disaster risk planning and climate adaptation strategies.
93 We then propose one policy alternative for better protecting and managing wetlands to help
94 people mitigate flood, drought, and fire risks and their devastating consequences: national-level
95 wetland commissions. This suggestion is based on the general success of the commission model
96 applied to rivers and lakes as an effective way to manage transboundary water resources and to
97 bring together diverse stakeholders interested in their protection. Finally, we present our
98 arguments with U.S. examples of opportunities for inter-agency cooperation and a proposed
99 structure for a U.S. National Interagency Wetland Commission. While the commission model
100 has been widely applied in water management and other problematic governance situations, its
101 adoption, purpose, and design to specifically help wetlands mitigate societal risks and enhance
102 resilience to extreme weather events is the strategic policy innovation that we offer here.

103 ***2. Recognizing and valuing wetland protective services***

104 *2.1 Wetlands provide essential ecosystem services and terrestrial-aquatic linkages*

105 Wetlands are some of the most productive ecosystems on earth and play critical roles in
106 hydrologic, nutrient, and carbon cycling while providing vital wildlife habitat (Zedler and
107 Kercher, 2005; Alexander *et al.*, 2018). Their habitat value has motivated wetland protection
108 through avenues such as wildlife refuges and spurred vast restoration efforts in response to
109 waterfowl population declines. Wetlands play critical hydrologic roles in landscapes through

storing and slowly releasing water downstream or recharging shallow groundwater, enabling them to mitigate flood risks during hurricanes or other extreme precipitation events while also delaying the onset and impacts of drought under some circumstances (Zedler and Kercher, 2005; Westbrook *et al.*, 2006; Alexander *et al.*, 2018; Fairfax and Small, 2018; Ameli and Creed, 2019). The dendritic landscape patterns of riparian networks can also lessen the impacts of wildfire (especially those that are beaver-dammed) by serving as a firebreak and providing refuge for wildlife (**Fig. 1**; Fairfax and Whittle, 2019; Wheaton *et al.*, 2019). Wetlands can also dissipate wave energy which reduces stream and coastal erosion and associated land loss, decreasing risks to growing cities and urbanized areas (Duarte *et al.*, 2013; Narayan *et al.*, 2017; Espeland and Kettenring, 2018; Narayan *et al.*, 2019). Because of these protective services of wetlands, there is growing interest in their role in risk and disaster reduction, but these protective services have not received sufficient policy action.

Fig. 1. Riparian wetlands associated with beaver dams can mitigate the impacts of wildfire. These so-called "emerald refuges" can serve as firebreaks and refuge for wildlife during fires (Pettit and Naiman, 2007; Rood *et al.*, 2007; Wheaton *et al.*, 2019). Beaver-dammed riparian areas create broad, diffuse floodplain habitat that are more resistant to burning and these habitats crisscross some landscapes with dendritic stream networks (Fairfax and Small, 2018; Fairfax and Whittle, 2019; Wheaton *et al.*, 2019). The presence of these riparian features is on the rise with increasing efforts to restore beaver and beaver-associated wetlands throughout the semi-arid West or, when beaver are not present, through the use of BDAs (beaver-dam analogues) (Pollock *et al.*, 2014; Charnley, 2018; Goldfarb, 2018; Wheaton *et al.,* 2019). (Photo credit: Joseph M. Wheaton).

Wetlands, by their very nature, are highly dynamic and provide essential linkages between terrestrial and aquatic ecosystems and between human-dominated and natural landscapes (Alexander *et al.*, 2018). Wetlands often constitute the critical landscape nexus between land and water on coasts, lakeshores, and river and stream banks where they buffer and stabilize these transition zones. Paradoxically, their locations at these nexuses make them highly

140 productive and simultaneously vulnerable. Many wetlands are threatened due to human
141 competition for land and water, lack of landscape-level planning, and lack of appreciation for the
142 integral functioning of wetlands within watersheds (Zedler and Kercher, 2005; Clare *et al.*, 2011;
143 Narayan *et al.*, 2017). The highest levels of competition for land often occur in the very places
144 where protective services of wetlands are most needed, surrounding and within human
145 communities (Narayan *et al.*, 2017), the largest of which are often located on coasts and rivers
146 (Li *et al*., 2015). Understanding their protective services and the important functions wetlands
147 play in different contexts requires a landscape perspective and greater scientific integration.

148 *2.2 Insufficient wetland protection has enormous societal costs*

149 Humanity has viewed wetlands as wastelands and vigorous national campaigns to drain
150 and fill them have been pursued over centuries (Vileisis, 1999; Zedler and Kercher, 2005;
151 Gardner, 2011). These 'marginal' lands have been deemed too costly to protect, given society's
152 insatiable appetite for ever-increasing land development, first for agricultural expansion and
153 more recently with (sub)urban sprawl. Wetland degradation and destruction have resulted in
154 radical landscape transformations with less natural wetland protection and more highly
155 engineered built water infrastructure that often gives society a false sense of security (Zedler and
156 Kercher, 2005; Creed *et al.*, 2017; Sutton-Grier *et al.* 2018). Hindsight has revealed the
157 cumulative effects of wetland loss. Failure to protect wetlands has not only led to extensive
158 ecological impacts but also resulted in enormous societal costs (Zedler and Kercher, 2005; Creed
159 *et al.*, 2017). Many countries face increased loss of life as well as rising costs of destroyed assets,
160 unsustainable insurances risks, and mounting government debt from weather-related disasters in
161 flood- and drought-prone areas (Deryugina, 2017; Smith, 2020). These financial burdens—often

the result of poor land-use planning—fall on citizens, and the political will of taxpayers and investors to compensate other people for short-sighted decisions is diminishing (Choe, 2020). Mounting societal costs provide an urgent and compelling rationale for policy action now to save lives and avoid public and private financial losses.

2.3 Need for more comprehensive approach to wetland protection

Our current approach to managing wetlands is fragmented and ineffective (e.g., Gardner, 2011; Strand and Rothschild, 2015). Since its 1971 inception, the Ramsar Convention on Wetlands International Importance especially as Waterfowl Habitat has focused on the principle of "wise use of wetlands," acknowledging the importance of their sustainable use to human communities, recognizing the need for national wetland policies, and encouraging wetland integration into national land and resource use planning and management (Finlayson *et al*., 2011). But few countries have specific and comprehensive wetland policies, and "many countries lack capacity or the cross-sectoral political will to ensure such landscape-scale collaborative implementation is undertaken" (Finlayson *et al*., 2011:197).

The full range of environmental and societal values provided by wetlands, and the diversity of wetland types critical in different landscape settings, remain unprotected in most countries (Sun *et al*., 2015, Turner *et al*., 2000; Kentula and Paulsen, 2019) and are subject to diverse anthropogenic disturbance and stressors related to agriculture, development, industry, and hydrologic and habitat modifications (Herlihy *et al*., 2019; Lomnicky *et al*., 2019). Because of their unique character and value in different contexts (Peimer *et al.*, 2017), and due to a general lack of specific wetland statutes and implementing agency authorities, many wetlands do

not receive adequate attention in national governments' policy landscapes. Most wetland protection occurs under more general environmental laws and is aimed at protecting wetland ecosystem services related to sustainable human uses or protecting biodiversity (Strand and Rothschild, 2015; Peimer *et al.*, 2017). The very concept of mitigation and the practice of wetland mitigation banking imply that some wetlands will be allowed to be degraded or destroyed (Clare *et al*., 2011). Restored or created wetlands take a long time to or never achieve the same level of functioning as natural wetlands (Moreno-Mateos *et al.*, 2012). Thus, the very approach of using wetland mitigation results in loss of function and a change in where within the landscape wetlands are located and how effectively they provide protective and other services (Zedler and Kercher, 2005; Clare *et al.*, 2011).

3. Proposal for National Wetland Commissions

3.1 Forging wetland policy in an interagency nexus for coordinated protection

Countries need a more comprehensive and integrated approach to wetland policy. Because wetlands are connected to landscape features and services that are generally under the administrative purview of different and often powerful government agencies, fostering interagency cooperation that would expand and coordinate instead of displace or challenge existing agency efforts is a more politically viable policy approach. Wetland protection could be enhanced if pursued in a governmental decision-making nexus that includes the water, land, human, and wildlife dimensions of wetlands and makes more explicit connections to human disaster preparedness and response, infrastructure investments, and national defense. A collective-action institutional strategy of this nature would enable a nation's relevant agencies to

jointly monitor wetland conditions, assess cumulative impacts and risks associated with wetland loss, and identify opportunities to realize mutual benefits wetlands can provide for achieving various societal objectives. This strategy would move countries in the direction of exercising greater foresight to increase the long-term resilience and sustainability of ecological and social systems to natural disasters and climate change.

3.2 Applying the river and lakes commission model to wetlands

We propose consideration of national-level interagency wetland commissions as institutional structures for coordinated wetland protection, management, and restoration. Such commissions could be modeled after joint river and lake commissions, which are generally created by international treaties or interstate compacts and charged with management of transboundary international or interstate watercourses (United Nations 2007; Rieu-Clarke *et al*., 2017; Caponera and Nanni, 2019). We note that the type of organization we suggest may not always be called a commission as there are a variety of river basin organizations with different types of autonomy, authorities, rules and incentives, and connections to existing institutions (Huitema and Meijerink, 2017). Nor is a commission the only policy option that could be selected to better manage wetlands. Robust assessment and debate are occurring within the environmental and water governance literatures over experiences with collaborative, landscape-scale environmental planning efforts (Blatter and Ingram, 2001; Layzer, 2008), how best to manage environmental risks and increase water security (Bakker and Morinville, 2013), and the politics and interactions of scales and networks (Bakker and Morinville, 2013; Lejano *et al*., 2013; Norman *et al*., 2015). These examinations reveal the importance of multiscalar institutional dynamics and decision-making processes in environmental problems and their

226 solutions. Devolution of governmental authority and decision making to local levels is often
227 thought to produce better environmental outcomes, but national-level institutions with legal
228 mandates, management authorities, technical and financial resources, and responsibilities to
229 wider publics remain important for organizing collective action on scales commensurate with the
230 2020 global risk landscape (Thomas, 2003; Heclo, 2008; Layzer, 2008; Rieu-Clarke et al., 2017;
231 World Economic Forum, 2020). Overarching policy challenges for addressing the global risks
232 society currently faces include finding ways for existing governmental agencies to work more
233 productively together in complex institutional landscapes and to engage more effectively with
234 non-governmental organizations and civil society.

235 We argue that applying the commission model to wetlands at a national scale would be
236 an excellent way to confront challenges involved in managing wetlands to help mitigate risks
237 from and enhance resilience to extreme weather events. We advocate this policy approach for
238 several reasons. First, commissions are often formed to work across national or more local-level
239 (e.g., regional or state) geographic boundaries to address problems that transcend the
240 management capacities of singular government scales or institutions (United Nations, 2007).
241 National wetland commissions could be involved in similar intergovernmental and institutional
242 boundary-spanning by working across a country's own wetland-relevant government agencies
243 and jurisdictions. Second, current wetland management tends to be polycentric with legal
244 authorities often dispersed across different agencies (Environmental Law Institute, 2008; Strand
245 and Rothschild, 2015). This situation likely makes a coordinated, interagency approach through
246 the commission model more politically feasible than the older environmental protection model of
247 passing a national law that a particular agency would then be charged with implementing. Third,

establishment through national-level action would recognize a country's collective responsibility for protecting wetlands and provide avenues for both diplomatic cooperation in various international fora and coordination within the country. National wetland commissions could be more influential in representing treaty countries that participate in the Ramsar Convention on Wetlands of International Importance especially as Waterfowl Habitat. Their national status would also enable them to work across different national agencies and sub-national governmental jurisdictions such as territories, regions, tribes, states, provinces, districts, and zones. Fourth, most countries nationalize their military defense and disaster response functions under compelling imperatives for mutual protection. Putting greater emphasis on the protective services of wetlands implies the same level of national commitment and effort.

The commission model has been an important way to facilitate cooperation and stakeholder engagement over rivers and lakes, as well as to bring both technical expertise and financial resources to bear on managing shared natural resources (United Nations 2007; Rieu-Clarke *et al*., 2017; Caponera and Nanni, 2019). In a similar way, wetland commissions could be an important innovation in terms of how wetlands are managed, bringing needed resources and partner organizations and communities together to identify the significance of different wetland types within their respective landscape contexts for providing multiple ecosystem services, including protective services. This approach would counter the piece-meal, one-at-a-time model that currently exists, which often narrowly focuses on a limited number of ecosystem service benefits wetlands provide (e.g., clean water). However, wetlands are not linear features like rivers or as clearly bounded as lakes; wetlands also are sometimes ephemeral and can change size depending on water inputs and precipitation patterns. These geomorphic distinctions imply

wetland commissions would need to be modified versions of river and lakes commission models in terms of geographic extent and context, incorporating institutional design differences to fit the dynamic nature of these resources. Such an approach is supported by policy theory that emphasizes the need for appropriate contextualization of a particular policy model to fit the circumstances of time and place in which it is applied, the nature of the problem it is designed to address, and societal objectives is it intended to achieve (Schneider and Ingram, 1997; Sabatier, 2007).

Below we describe generally some of the proposed work of national wetland commissions, recognizing that it is premature to be too prescriptive on the exact structure and function of such commissions and what they would be expected to accomplish since this will naturally vary to fit different national institutional contexts. Here we describe some of the aspects we see as critical components of national wetland commissions as a starting point for their design and development.

3.3 The work of national wetland commissions

The mandate of national wetland commissions would be to provide a comprehensive interagency approach to strategically protect wetlands for critical ecosystem services they provide in diverse landscape and watershed contexts. One of the first tasks for wetland commissions would be to establish science and policy objectives, as well as stakeholder engagement goals, and then to develop plans for how to meet those objectives and goals. These commissions ideally would seek ways to leverage member agencies' institutional resources and existing stakeholder networks, including private property and public sector interests, but they

would also need to navigate potentially contentious politics and build trust among agencies with varying power and access to resources. Commissions' responsibilities would include making recommendations on how to integrate information about key wetland functions and services into land-use and infrastructure decisions, including disaster management planning and response.

To be successful, national wetland commissions would need sufficient administrative independence and political power to work across existing agencies, integrate science with policy considerations, and avoid having disasters be politicized. Their work would require authority, funding, and flexibility to strategically fulfill their missions and purposes. Work of commissions would need to be supported by technical committees and staff. National wetland commissions would benefit from having a standing Scientific Committee and Policy Committee.

The Scientific Committee would be charged with addressing questions of effectiveness in protecting wetlands going well beyond trends reporting in wetland cover changes. It could be tasked to: (1) oversee a coordinated research agenda to develop a comprehensive spatially-explicit inventory of national wetlands (including guidance on frequency, scalability, metrics of wetland health, and key information on links between wetlands and human benefits including disaster risk reduction); (2) improve understanding of wetland functions related to type, condition, and landscape position; (3) further characterize how wetland protective services would reduce human vulnerability to extreme weather-related events; and, (4) develop better forecasts of the scope and scale of future threats from extreme weather events that wetlands could help mitigate.

The Policy Committee would be charged with addressing governance questions. Its tasks would include helping to: (1) coordinate and simplify compliance with wetland-related

regulatory and permitting processes often administered by different agencies; (2) develop policy guidance for interpretation and implementation of existing statutory and regulatory authorities of its participating agencies; (3) make and enforce decisions that bridge existing agency authorities (through means such as Memoranda of Agreement or Understanding) to facilitate consultation and coordination; and, (4) utilize member agencies' established networks and avenues for engaging private landowners and other stakeholders and working with regional and local governments to integrate wetlands into landscape-scale conservation efforts.

4. A National Interagency Wetland Commission for the United States

Policy shortcomings are obvious when it comes to explicit protection of wetlands in many countries, including the U.S. Many cultural and natural resources are protected and managed under treaties and laws titled for and focused on them. The U.S. has specific laws to protect air, coastal zones, forests, marine mammals, rangelands, rivers, endangered species, water, wilderness, and other resources (Fairfax and Russell, 2014). In sharp contrast, wetlands are minimally protected under laws primarily designed to accomplish other objectives or protect other features of landscapes and ecosystems (Gatz and Stubbs, 2017). As "wet land," wetlands do not fall neatly within larger U.S. governmental divisions of responsibility over land and water and split authority between states and the federal government (Environmental Law Institute, 2008; Clarke *et al.*, 2018). At the national level, wetlands are managed indirectly through a unique regulatory arrangement between the Army Corps of Engineers (charged with engineering harbors and rivers for navigability and enforcing section 404 of the Clean Water Act) and the Environmental Protection Agency (charged with overall implementation of the Clean Water

Act), through Fish and Wildlife Service refuges managed primarily for bird habitat, and through agricultural incentive programs aimed at stemming wetland loss and impairment on private lands (Gardner, 2011; Strand and Rothschild, 2015). Many tribal and state governments also have wetlands programs through which they exercise various regulatory, monitoring and assessment, restoration, and cooperative activities (Environmental Law Institute, 2008). However, insufficient regulatory protection through the Clean Water Act with constantly shifting definitions of 'Waters of the United States' (i.e., WOTUS) (Mulligan, 2019) and the fragmented institutional landscape for wetland protection leave the future of wetlands in the U.S. insecure (Gardner, 2011; Strand and Rothschild, 2015; Creed *et al.*, 2017; Gardner *et al*., 2019). Consequently, wetlands remain largely unprotected in regards to the diversity and full range of environmental and societal values they sustain including their protective services (Herlihy *et al*., 2019; Kentula and Paulsen, 2019; Lomnicky *et al*., 2019).

Some opportunities currently exist to coordinate interagency action, such as protecting both land and water that wetlands need in arid regions (e.g., Downard *et al.*, 2014), or incorporating wetland restoration and management into storm risk reduction strategies (**Box 1**) or drought risk reduction strategies (**Box 2**). However, even with these efforts, a U.S. National Interagency Wetland Commission (NIWC) is needed to provide a more comprehensive, coordinated and direct approach to wetland protection (**Fig. 2**). It is a strategic institutional design choice located at agency intersections in the national policy landscape that would mirror the intersections wetlands occupy in physical landscapes. A NIWC would specifically enable agencies to work across both jurisdictional and geographic boundaries to promote cooperation for wetland protection within the U.S., using existing federal agency networks and procedures

356 that involve working with tribal, state, and local governments (Clarke *et al*., 2018). A NIWC
357 would also promote stakeholder engagement to foster discussion and shared goal setting, and
358 would help federal agencies become more aware of the needs and interests of both the private
359 and public sectors affected by federal management decisions. If broadly structured to include and
360 promote the protective services of wetlands (Fig. 2), a NIWC would not be limited in its research
361 and discussions to only WOTUS-protected "jurisdictional" wetlands that fall under the current
362 Clean Water Act definition and the implementing authority of the Army Corps of Engineers and
363 Environmental Protection Agency. Multiple agencies and their private and public sector
364 stakeholders with different missions and cultures, broader perspectives, and varying interests,
365 could potentially help the U.S. significantly reframe and rescale its approach to wetland
366 management. The compelling and urgent challenge to mitigate the disastrous consequences of
367 unprecedented weather-related events for human communities, and the role that wetlands could
368 play in meeting that challenge, could unite and propel the NIWC to find opportunities to
369 strategically protect wetlands not only for their benefits to wildlife but to people as well.

Box 1. WETLANDS AND STORM RISK REDUCTION

Wetlands can help mitigate the effects of storms (**left**; photo credit: NOAA), such as the catastrophic flooding Houston experienced in 2018 (**right**; photo credit: NOAA). Historically, wetland protective services have been left out of disaster planning and management efforts. In the U.S., managing risks to human communities and infrastructure are responsibilities of several agencies that do not specifically include wetland management or protection in their missions. While water management likely will continue to use some engineered solutions—such as dams, reservoirs, levees, and seawalls—integrating wetlands, and more broadly all types of "natural" or "green infrastructure", into infrastructure planning and disaster risk reduction is a vital part of increasing community resilience to natural disasters and improving infrastructure investments (*Sutton-Grier et al.*, *2018*).

Opportunities to better integrate wetlands into U.S. disaster planning and response efforts currently exist. For example, the U.S. Federal Emergency Management Agency's "National Preparedness System" (NPS) guides the community process of preparing for disasters, particularly in its mitigation of disasters framework which recognizes wetlands can help "reduce loss of life and property by lessening the impact of disasters." Another opportunity at the local scale, where disaster planning generally occurs, is to incorporate wetland risk reduction benefits into implementation of the Coastal Zone Management Act (CZMA). Each coastal state has a CZM lead agency that could coordinate and provide guidance on how best to incorporate wetlands into that state's disaster planning. Leading communities around the U.S. could demonstrate how and why to include wetlands benefits into disaster planning and convince others to follow suit.

Another opportunity is the potential to include a focus on wetlands for disaster management into each state's wetland mitigation banks. A certain percentage (such as 25%) of the credits could be specified as "disaster risk reduction" mitigation credits. These credits would come from wetlands that had specifically been created or restored to reduce the risk of floods or droughts. Currently there are no such requirements. This change would mean that wetland protective services could be factored into considerations about landscape locations where loss and mitigation are taking place.

370

Box 2. WETLANDS AND DROUGHT RISK REDUCTION

Better use of wetlands can be a key aspect of preparedness for and mitigation of drought impacts (**left**; photo credit: K Kettenring). There is growing interest in the reintroduction of beavers (*Castor canadensis*) **(middle**: photo credit: R Donovan) for their engineering abilities to restore wetlands (**right**: photo credit: D Kimble, USFWS) as a means to capture winter precipitation above- and particularly below-ground, facilitate shallow aquifer recharge, and delay and slow the release of water throughout the growing season (Westbrook *et al*., 2006; Hood and Bayley, 2008; Gibson and Olden, 2014; Hafen, 2017; Holmes *et al*., 2017; Wheaton *et al*. 2019).

Similar to hard-engineering approaches taken in coastal environments, dealing with water shortages in drylands has relied on building dams and reservoirs to store water when it is plentiful (e.g., spring snowmelt in montane ecosystems) and release it when it is scarce (e.g., late irrigation season). This approach, however, has many risks, including costs of building and maintaining dams, dangers of dam failures (e.g., Oroville Dam in 2017), and ecological and economic impacts of vast flooding associated with reservoir sites and emergency releases.

Wetland restoration and creation, including through use of beaver reintroductions and beaver dam analogues, can promote the hydrologic protective functions of wetlands (Westbrook *et al*., 2006; Gibson and Olden, 2014). Opportunities exist in drought mitigation and climate adaptation activities to put greater emphasis on the role of green infrastructure, such as wetland networks. Other opportunities arise when replacing aging water infrastructure, where strategic wetland protection and restoration could become cost-effective alternatives to store and release snowmelt (Holmes *et al*., 2017; Macfarlane *et al*., 2017; Jones *et al*., 2018). In addition, use of mitigation banks with "disaster risk reduction credits" (See Box 1) could work for drought prevention equally as well as for flood mitigation.

Effectively and strategically relying on wetlands in the landscape for drought reduction requires deeper understanding of mechanisms by which wetlands influence hydrology and what wetland types, densities, areal coverage, and locations would have the greatest positive impacts (Gibson and Olden, 2014; Holmes *et al*., 2017; Macfarlane *et al*., 2017; Jones *et al*., 2018). NOAA's National Integrated Drought Information System (NIDIS) (https://www.drought.gov/drought/) provides opportunities to support such efforts through its "Coping with Drought" research initiative, support of Regional Integrated Sciences and Assessments (RISAs), and interagency coordination that can facilitate integrating wetlands into cross-agency planning and policies.

371

372 The U.S. NIWC ideally would be modeled after existing federal commissions statutorily

373 created by Congress that have delegated administrative and regulatory authority in a defined area

and are designated as independent agencies within the executive branch (Breger and Edles, 2000; Cole and Shedd, 2014), rather than after temporary commissions often appointed by Congress or the President to complete a specific investigative or advisory task (Egar, 2018; Straus and Egar, 2019). Examples of such independent agency commissions are the Consumer Product Safety Commission, Federal Communications Commission, Federal Election Commission, Federal Trade Commission, Interstate Commerce Commission, Nuclear Regulatory Commission, and the Securities and Exchange Commission (see https://www.usa.gov/independent-agencies). Design of U.S. NIWC would require considerable innovation, but the history of how and why U.S. commissions have been formed in the past, often in response to national emergencies, would provide valuable guidance (Breger and Edles, 2000).

The NIWC would have statutory independence to work in the policy space between agencies located in different executive departments, but be designed to function interdependently to connect key agencies having missions, authorities, or interests relevant to wetland protective services. The NIWC would explicitly link: 1) disaster management functions in the Department of Homeland Security (Federal Emergency Management Agency) and Department of Defense (Army Corps of Engineers); 2) the missions to provide communities with safe, reliable infrastructure of the Department of Transportation and the Department of Housing and Urban Development; and 3) ongoing land, water, and environmental management of agencies in the Departments of Agriculture, Commerce, Interior, and the independent Environmental Protection Agency (**Fig. 2**).

To more effectively link wetland science with wetland policy, top career officials of these agencies who have wetland expertise would be designated as commissioners and constitute the

primary executive body with formal decision-making powers. These officials should be people with authority to act on behalf of their agencies in coordinating internally, committing staff, directing resources, and dedicating funds to support joint interagency actions of the Commission. Formalized rules and procedures for meetings, communications, decision-making, conducting work, monitoring activities, involving stakeholders, and resolving conflicts would need to be established to institutionalize and foster the Commission's work.

Fig. 2. U.S. Interagency Wetland Commission to Promote Wetland Protective Ecosystem Services. An integrated, comprehensive approach to protect wetlands for people and wildlife in the U.S. We call for a National Interagency Wetland Commission authorized to protect wetlands within their larger watershed and landscape contexts, to sustain the full range of environmental and societal values they provide, and to elevate wetland protective services. These protective services have historically been under-valued and not given statutory, regulatory, or policy guidance protection. As recent current events have demonstrated, this oversight has left communities and wildlife subject to catastrophic damage. (Photo credit: NOAA)

A NIWC would finally give U.S. wetlands both the recognition these ecosystems deserve for the wide-range of important benefits they provide to society, and a mechanism for the nation

414 to manage and protect these valuable ecosystems across governmental geographic boundaries as
415 well as across institutional and bureaucratic boundaries.

416 ***5. Decisive policy action needed to reduce societal risks***

417 Policy innovation is urgently needed to deal with the devastating human consequences of
418 lost wetlands and harness their protective services to mitigate risks from and enhance resilience
419 to unprecedented disasters. Protecting wetlands can save lives and money, increase security of
420 urban communities and populations that are particularly vulnerable to extreme weather-related
421 events, and promote long-term sustainability. National wetland commissions could integrate
422 wetland science and policy to seek opportunities where wetland protection can be linked to other
423 societal objectives. Although we have proposed a blueprint for a U.S. National Interagency
424 Wetland Commission, it is not the only wetlands policy management option that could be
425 selected. But based on its application to rivers and lakes, the commissions model seems like a
426 viable alternative to foster collaboration across agencies, facilitate stakeholder engagement, and
427 bring technical and financial resources to bear on improving wetland management at the
428 landscape scale. In addition, this national wetland commission model could be appropriate in
429 other countries where similar management at the landscape scale is needed to protect people,
430 wildlife, and built infrastructure from extreme weather events. While creating national wetland
431 commissions would entail extensive effort, collaboration, and innovation, that pales in
432 comparison to societal risks we will continue to face in the absence of bold and forward-looking
433 policy action.

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441 **References**

442 Alexander, L.C., Fritz, K.M., Schofield, K.A., et al., 2018. Featured collection introduction:
443 Connectivity of streams and wetlands to downstream waters. J Am Water Resour As
444 (JAWRA) 54, 287-297. https://doi.org/10.1111/1752-1688.12630
445 Ameli, A.A. and Creed, I.F., 2019. Does wetland location matter when managing wetlands for
446 watershed-scale flood and drought resilience? JAWRA 55, 529-542.
447 https://doi.org/10.1111/1752-1688.12737
448 Attiwill, P. and Binkley, S., eds. 2013. The Mega-fire Reality: Proceedings of a Forest Ecology
449 and Management Conference. Forest Ecol Manag, Vol 294, 262 pg.
450 https://doi.org/10.1016/j.foreco.2012.12.025
451 Bakker, K., and Morinville, C., 2013. The governance dimensions of water security: a review.
452 Phil Trans R Soc A 371: 20130116.
453 https://royalsocietypublishing.org/doi/10.1098/rsta.2013.0116
454 Breger, M.J. and Edles, G.J., 2000. Established by Practice: The Theory and Operation of
455 Independent Federal Agencies. Admin L Rev 52:1111-1294.

456 Blatter, J. and Ingram, H., eds., 2001. Reflections on Water: New Approaches to Transboundary
457 Conflicts and Cooperation. Cambridge, MA, USA and London, England: MIT Press. ISBN:
458 0-262-52284-5.
459 Cal Fire. California Department of Forestry and Fire Protection. Statistics accessed 7/1/2019 at:
460 https://www.fire.ca.gov/stats-and-events/
461 Caponera, D.A. and Nanni, M., 2019. Principles of Water Law and Administration: National and
462 International, 3rd Edition. London and New York: Routledge, Taylor & Francis Group. ISBN:
463 978-1-138-61056-9
464 Charnley, S., 2018. Beavers, landowners, and watershed restoration: experimenting with beaver
465 dam analogues in the Scott River basin, California. *Res. Pap. PNW-RP-613. Portland, OR:*
466 *U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.*
467 https://www.fs.fed.us/pnw/pubs/pnw_rp613.pdf
468 Choe, S., 2020. BlackRock adjusts investments in light of climate change. San Francisco
469 Chronicle. Jan. 17. https://www.sfchronicle.com/business/article/BlackRock-adjusts-
470 investments-in-light-of-climate-14984997.php
471 Clare, S., Krogman, N., Foote, L., Lemphers, N., 2011. Where is the avoidance in the
472 implementation of wetland law and policy? Wetl. Ecol. Manag. 19, 165-182.
473 https://doi.org/10.1007/s11273-011-9209-3
474 Clarke, D., Fulton, S., Schempp, A., Koening, S., Ibrahim, C., and Pendergrass, J., 2018. The
475 MacBeth Report: Cooperative Federalism in the Modern Era. Washington, D.C.:
476 Environmental Law Institute. https://www.eli.org/research-report/macbeth-report-
477 cooperative-federalism-modern-era

478 Cole, J.P. and Shedd, D.T., 2014. Administrative Law Primer: Statutory Definitions of "Agency"
479 and Characteristics of Agency Independence. Congressional Research Service, R43562, May
480 22, 2014. https://fas.org/sgp/crs/misc/R43562.pdf
481 Creed, I.F., Lane, C.R., Serran, J.N., et al., 2017. Enhancing protection for vulnerable waters.
482 Nat. Geosci. 10, 809. https://doi.org/10.1038/ngeo3041
483 Deryugina, T., 2017. The fiscal cost of hurricanes: Disaster aid versus social insurance. Am.
484 Econ. J.: Econ. Policy 9, 168-198. https://doi.org/10.1257/pol.20140296
485 Downard, R., Endter-Wada, J., Kettenring, K.M., 2014. Adaptive wetland management in an
486 uncertain and changing arid environment. Ecol. Soc. 19, 23. http://dx.doi.org/10.5751/ES-
487 06412-190223
488 Duarte, C.M., Losada, I.J., Hendriks, I.E., Mazarrasa, I., and Marbà, N., 2013. The role of coastal
489 plant communities for climate change mitigation and adaptation. Nat Clim Change 3, 961-
490 968. https://www.nature.com/articles/nclimate1970
491 Egar, W.T., 2018. Designing Congressional Commissions: Background and Considerations for
492 Congress. Congressional Research Service, R45328, October 2, 2018. Washington. D.C.,
493 USA: Congressional Research Service. https://fas.org/sgp/crs/misc/R45328.pdf
494 Espeland, E.K. and Kettenring, K.M., 2018. Strategic plant choices can alleviate climate change
495 impacts. J Environ Manage. 222, 316-324. https://doi.org/10.1016/j.jenvman.2018.05.042
496 Environmental Law Institute, 2008. State Wetland Protection: Status, Trends &Model
497 Approaches. Washington, D.C.: Environmental Law Institute. https://www.eli.org/research-
498 report/state-wetland-protection-status-trends-model-approaches

499 Fairfax, E. and Small, E.E., 2018. Using remote sensing to assess the impact of beaver damming
500 on riparian evapotranspiration in an arid landscape. Ecohydrology 11, e1993.
501 https://onlinelibrary.wiley.com/doi/abs/10.1002/eco.1993
502 Fairfax, E. & Whittle, A.J., 2019. Smokey the Beaver: Can Beaver Dams Help Protect Riparian
503 Vegetation During Wildfire? American Geophysical Union, 11 December 2019. See:
504 https://agu.confex.com/agu/fm19/meetingapp.cgi/Paper/510755 and also
505 https://landsat.gsfc.nasa.gov/smokey-the-beaver-beaver-dams-and-wildfire/
506 Fairfax, S.K. and Russell, E., eds., 2014. U.S. Environmental Policy. Thousand Oaks, CA: CQ
507 Press, an imprint of Sage Publications Ltd. ISBN: 978-1-4522-7075-3
508 Finlayson, C.M., Davidson, N., Pritchard, D., Milton, G.R., and MacKay, H., 2011. The Ramsar
509 Convention and Ecosystem-Based Approaches to the Wise Use and Sustainable
510 Development of Wetlands. JIWLP 14(3-4):176-198. https://www-tandfonline-
511 com.dist.lib.usu.edu/doi/full/10.1080/13880292.2011.626704
512 Flannigan, M.D., Krawchuk, M.A., de Groot, W.J., et al., 2009. Implications of changing climate
513 for global wildland fire. Int J Wildland Fire 18, 483-507. https://doi.org/10.1071/WF08187
514 Gardner, R.C., 2011. Lawyers, Swamps, and Money: US Wetland Law, Policy and Politics.
515 Washington D.C.: Island Press. ISBN-13: 978-1-59726-814-1
516 Gardner, R.C., Okuno, E., Tai, S., Fennessy, M.S., Johnston, C.A., Otte, M.L., Palmer, M.,
517 Perry, J.E., Simenstad, C., Tanner, B.R., Tufford, D., Turner, R.E., Work, K., Yaich, S.C.,
518 Zedler, J.B., 2019. Advocating for Science: Amici Curiae Brief of Wetland and Water
519 Scientists in Support of the Clean Water Rule. Wetlands 39, 403.
520 https://doi.org/10.1007/s13157-019-01160-z

Gatz, L. and Stubbs, M., 2017. Wetlands: An Overview of Issues. Congressional Research Service, RL33483, Version 37, Updated, January 5. Washington. D.C., USA: Congressional Research Service. https://crsreports.congress.gov/product/pdf/RL/RL33483

Gibson, P.P. and Olden, J.S., 2014. Ecology, management, and conservation implications of North American beaver (Castor canadensis) in dryland streams. Aquat. Conserv. 24, 391-409. https://doi.org/10.1002/aqc.2432

Goldfarb, B., 2019. Beavers, rebooted. *Science* 360, 1058–1061. DOI: 10.1126/science.360.6393.1058

Hafen, K., 2017. To what extent might beaver dam building buffer water storage losses associated with a declining snowpack? Utah State University, Logan, UT. https://digitalcommons.usu.edu/etd/6503/

Heclo, H., 2008. On Thinking Institutionally. Oxford University Press. ISBN: 978-0-19-994600-6.

Herlihy, A.T., Sifneos, J.C., Lomnicky, G.A., Nahlik, A.M., Kentula, M.E., Magee, T.K., Weber, M.H., Trebitz, A.S., 2019. The response of wetland quality indicators to human disturbance indicators across the United States. Environ Monit Assess 191 (Suppl 1): 296. https://doi.org/10.1007/s10661-019-7323-5

Holmes, D., McEvoy, J., Dixon, J.L., and Payne, S., 2017. A geospatial approach for identifying and exploring potential natural water storage sites. Water 9, 585. https://doi.org/10.3390/w9080585

541 Hood, G.A. and Bayley, S.E., 2008. Beaver (Castor canadensis) mitigate the effects of climate on
542 the area of open water in boreal wetlands in western Canada. Biol. Conserv. 141, 556-567.
543 https://doi.org/10.1016/j.biocon.2007.12.003
544 Huitema, D. and Meijerink, S., 2014. The Politics of River Basin Organizations: Coalitions,
545 Institutional Design Choices and Consequences. Cheltenham, UK and Northampton, MA,
546 USA: Edward Elgar Publishing Limited. ISBN: 978-1-78254-921-5.
547 Jones, C.N., Evenson, G.R., McLaughlin, D.L., Vanderhoof, M.K., Lang, M.W., McCarty, G.W.,
548 Golden, H.E., Lane, C.R., and Alexander, L.C., 2018. Estimating restorable wetland water
549 storage at landscape scales. Hydrol. Process. 32, 305-313. https://doi.org/10.1002/hyp.11405
550 Kentula, M.E. and Paulsen, S.G., 2019. The 2011 National Wetland Condition Assessment:
551 overview and an invitation. Environ Monit Assess 191 (Suppl 1): 325.
552 https://doi.org/10.1007/s10661-019-7316-4
553 Kossin, J.P., 2018. A global slowdown of tropical-cyclone translation speed. Nature 558, no.
554 7708, 104. https://doi.org/10.1038/s41586-018-0158-3
555 Layzer, J.A., 2008. Natural Experiments: Ecosystem-Based Management and the Environment.
556 Cambridge, MA, USA and London, England: MIT Press. ISBN 978-0-262-12298-6.
557 Lejano, R., Ingram, M., Ingram, H. 2013. The Power of Narrative in Environmental Networks.
558 Cambridge, MA, USA and London, England: MIT Press. ISBN: 978-0-262-01937-8
559 Li, E., Endter-Wada, J., Li, S., 2015. Characterizing and Contextualizing the Water Challenges
560 of Megacities. J Am Water Resour As (JAWRA) 51(3), 589-613.
561 https://doi.org/10.1111/1752-1688.12310

562 Lomnicky, G.A., Herlihy, A.T., Kaufmann, P.R., 2019. Quantifying the extent of human
563 disturbance activities and anthropogenic stressors in wetlands across the conterminous
564 United States: results from the National Wetland Condition Assessment. Environ Monit
565 Assess 191 (Suppl 1): 324. https://doi.org/10.1007/s10661-019-7314-6
566 Macfarlane, W.W., Wheaton, J.M., Bouwes, N., Jensen, M.L., Gilbert, J.T., Hough-Snee, N., and
567 Shivik, J.A., 2017. Modeling the capacity of riverscapes to support beaver dams.
568 Geomorphology 277, 72-99. https://doi.org/10.1016/j.geomorph.2015.11.019
569 Moreno-Mateos, D., Power, M.E., Comín, F.A., Yockteng, R., 2012. Structural and functional
570 loss in restored wetland ecosystems. PLoS Biol 10(1): e1001247.
571 https://doi.org/10.1371/journal.pbio.1001247
572 Morton, A., 2019. Yes, Australia has always had bushfires: but 2019 is like nothing we've seen
573 before. The Guardian*, Australia Edition,* Dec. 25, 2019. Accessed at:
574 https://www.theguardian.com/australia-news/2019/dec/25/factcheck-why-australias-monster-
575 2019-bushfires-are-unprecedented.
576 Mulligan, S.P., 2019. Evolution of the Meaning of "Waters of the United States" in the Clean
577 Water Act. Congressional Research Service, R44585, Version 10, Updated, March 5.
578 Washington. D.C., USA: Congressional Research Service.
579 https://fas.org/sgp/crs/misc/R44585.pdf
580 Narayan, S., Beck, M.W., Wilson, P., et al., 2017. The Value of Coastal Wetlands for Flood
581 Damage Reduction in the Northeastern USA. Scientific Reports 7, 9463.
582 https://www.nature.com/articles/s41598-017-09269-z.pdf

583 Narayan, S., Thomas, C., Matthewman, J., et al., 2019. Valuing the Flood Risk Reduction
584 Benefits of Florida's Mangroves. http://www.conservationgateway.org/pages/Florida-
585 Mangroves.aspx
586 Needham, H.F., Keim, B.D., and Sathiaraj, D., 2015. A review of tropical cyclone-generated
587 storm surges: Global data sources, observations, and impacts. Rev Geophys 53, 545-591.
588 https://doi.org/10.1002/2014RG000477
589 Norman, E.S., Cook, C., and Cohen, A., eds., 2015. Negotiating Water Governance: Why the
590 Politics of Scale Matter. Farnham, Surrey, England and Burlington, VT, USA. ISBN: 978-1-
591 4094-6790-8.
592 Patricola, C.M. and Wehner, M.F., 2018. Anthropogenic influences on major tropical cycline
593 events. Nature 563, 339-346. https://www.nature.com/articles/s41586-018-0673-2
594 Peimer, A.W., Krzywicka, A.E., Cohen, D.B., Van den Bosch, K., Buxton, V.L., Stevenson,
595 N.A., Matthews, J.W., 2017. National-level Wetland Policy Specificity and Goals Vary
596 According to Political and Economic Indicators. Environ Manage 59, 141-153.
597 https://doi.org/10.1007/s00267-016-0766-3
598 Pettit, N.E., and Naiman, R.J., 2007. Fire in the riparian zone: characteristics and ecological
599 consequences. Ecosystems, 10(5), 673-687. https://doi.org/10.1007/s10021-007-9048-5
600 Pollock, M.M., Beechie, T.J., Wheaton, J.M., Jordan, C.E., *et al.*, 2014. Using Beaver Dams to
601 Restore Incised Stream Ecosystems. *BioScience* **64**, 279–290.
602 https://doi.org/10.1093/biosci/biu036
603 Pyne, S.J., 2009. The human geography of fire: A research agenda. Progr. Hum. Geogr. 33, 443-
604 446. https://doi.org/10.1177/0309132508101598

605 Rieu-Clarke, A., Allan, A., and Hendry, S., 2017. Routledge Handbook of Water Law and
606 Policy. London and New York: Routledge (Taylor & Francis Group). ISBN: 978-1-138-
607 12120-1.
608 Rood, S.B., Goater, L.A., Mahoney, J.M., Pearce, C.M. and Smith, D.G., 2007. Floods, fire, and
609 ice: disturbance ecology of riparian cottonwoods. Botany, 85(11), 1019-1032.
610 https://doi.org/10.1139/B07-073
611 Sabatier, P., ed. 2007. Theories of the Policy Process, Second Edition. Boulder, Colorado, USA:
612 Westview Press. ISBN-13: 978-0-8133-4359-4.
613 Schenider, A.L., and Ingram, H., 1997. Policy Design for Democracy. Lawrence, Kansas, USA:
614 University Press of Kansas. ISBN: 0-7006-0844-3.
615 Smith, A.B., 2020. 2010-2019: A landmark decade of U.S. billion-dollar weather and climate
616 disasters. NOAA ClimateWatch Magazine (Beyond the Data in News and Features), Jan. 8,
617 2020. Available at: https://www.climate.gov/news-features/blogs/beyond-data/2010-2019-
618 landmark-decade-us-billion-dollar-weather-and-climate
619 Strand, M. and Rothschild, L., 2015. Wetlands deskbook, 4th Edition. Washington DC:
620 Environmental Law Institute. ISBN: 978-1-58576-172-2
621 Strauss, J.R. and Egar, W.T., 2019. Congressional Commissions: Overview and Considerations
622 for Congress. Congressional Research Service, R40076, Version 22, Updated, November 22,
623 2019. Washington. D.C., USA: Congressional Research Service.
624 https://fas.org/sgp/crs/misc/R40076.pdf
625 Sun, Z., Sun, W., Tong, C., Zeng, C., Yu, X., Mou, X., 2015. China's coastal wetlands:
626 Conservation history, implementation efforts, existing issues and strategies for future

627 improvement. Environment International 79:25-41.
628 https://doi.org/10.1016/j.envint.2015.02.017
629 Sutton-Grier, A.E., Gittman, R.K., Arkema, K.K., et al., 2018. Investing in natural and nature-
630 based infrastructure: Building better along our coasts. Sustain. 10(2), 523.
631 https://doi.org/10.3390/su10020523
632 Swain, D.L., Langenbrunner, B., Neelin, J.D. and Hall, A., 2018. Increasing precipitation
633 volatility in twenty-first-century California. Nat. Clim. Change 8, 427-433.
634 https://www.nature.com/articles/s41558-018-0140-y
635 Thomas, C.W., 2003. Bureaucratic Landscapes: Interagency Cooperation and the Preservation of
636 Biodiversity. Cambridge, MA, USA and London, England: MIT Press. ISBN: 0-262-20141-0.
637 Turner, R.K., van den Bergh, J.C.J.M., Söderqvist, T., et al., 2000. Ecological-economic analysis
638 of wetlands: scientific integration for management and policy. Ecol Econ 35(1), 7-23.
639 https://doi.org/10.1016/S0921-8009(00)00164-6
640 Ummenhofer, C.C. and Meehl, G.A., 2017. Extreme weather and climate events with ecological
641 relevance: a review. Phil Trans R Soc B 372, 20160135.
642 https://doi.org/10.1098/rstb.2016.0135
643 United Nations, 2007. Our Waters: Joining Hands Across Borders: First Assessment of
644 Transboundary Rivers, Lakes and Goundwaters. United Nations: Economic Commission for
645 Europe. ISBN: 978-9211169720
646 Vileisis, A., 1999. Discovering the unknown landscape: a history of America's wetlands.
647 Washington, D.C.: Island Press. ISBN-10: 1559633158

Westbrook, C.J., Cooper, D.J., and Baker, B.W., 2006. Beaver dams and overbank floods influence groundwater–surface water interactions of a Rocky Mountain riparian area. Water Resour. Res. 42, W0604. https://doi.org/10.1029/2005WR004560

Wheaton, J.M., Bennett, S.N., Bouwes, N., Maestas, J.D. and Shahverdian, S.M., eds., 2019. Low-tech process-based restoration of riverscapes: Design manual. Version 1.0. Utah State University Restoration Consortium. Logan, UT, USA. DOI: 10.13140/RG.2.2.19590.63049/2

World Economic Forum, 2020. The Global Risks Report 2020, 15th Edition. Geneva, World Economic Forum. ISBN: 978-1-944835-15-6. https://www.weforum.org/reports/the-global-risks-report-2020

WMO (World Meteorological Organization), 2019. WMO Statement on the State of the Global Climate in 2018. WMO-No. 1233. Geneva Switzerland. ISBN: 978-92-63-11233-0

Zedler, J.B. and Kercher, S., 2005. Wetland resources: Status, trends, ecosystem services, and restorability. Annu. Rev. Environ. Resour. 30, 39-74. https://doi.org/10.1146/annurev.energy.30.050504.144248

Competing interests statement

Authors declare no competing interests.