North American Lake Management Society

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Nature-based Solutions in Urban Lakes and Watersheds

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Introduction

It is increasingly being realized that answers to solving many of our environmental and societal issues lie in nature. In the face of accelerating climate change, pervasive harmful algal blooms, concerning water quality declines, widespread biodiversity loss and habitat degradation, and other wicked problems, nature-based solutions (NbS) can serve as an important tool in significantly addressing and mitigating many of these concerns, while simultaneously yielding many other valuable benefits (Ossola & Lin, 2021).

Urban lakes and watersheds are under significant threat from such challenges, despite being valuable resources that provide many ecosystem services depended upon by residents. Urban lakes can provide a wide range of environmental, economic, recreational, aesthetic, cultural, and other social benefits (Schallenberg et al. 2013). They can drive many elements of public health such as food and water security, sanitation, air and water quality, urban heat island effects, flood abatement, and exposure to pathogens. Urban lakes are heavily used and impaired from human activities; they are subject to intensive human influences and are usually shallower (Costadone, 2021), making them more vulnerable to stressors than rural and non-urban lakes (Tiwari et al. 2021). Such disturbances can include excessive nutrient loading, stormwater runoff, and other forms of pollution and contamination; invasive species; habitat degradation; overexploitation and other unsustainable use; dams and other unnatural modifications to flow; and high sensitivity to climate change effects (Reid et al. 2018). Cumulatively, these disturbances are taking their toll on urban lakes, impacting the function of the benefits they provide to cities and regions. Freshwater ecosystems, which include urban lakes and watersheds, are considered the most degraded systems in the world, disproportionately suffering from human activities compared to terrestrial or marine ecosystems (World Wildlife Fund et al. 2021). Freshwater biodiversity loss is so severe, and can oftentimes be so difficult to detect, that it is referred to as an invisible tragedy, hidden under the surface of the water (Reid et al. 2018).

NbS can serve as an important management tool in addressing many of these staggering threats that urban lakes face, helping to secure the benefits they provide while also yielding others. NbS can help improve the overall human and environmental health of some of the most densely populated urban and suburban lakes and watersheds. This is becoming increasingly important in light of the worsening climate crisis and growing human population; not only are both water consumption and the extent of urban areas increasing, but urban areas are most likely to experience the worst impacts of climate change (Kabisch et al. 2017). Increasing urbanization and development, and exacerbating effects of climate change, are linked with decreased water quality of urban and suburban watersheds. NbS can play an important role in improving the health of urban lakes and watersheds while also building climate resilience in cities, and ultimately, globally. NALMS recommends higher prioritization of the implementation of NbS in urban lakes and watersheds to comprehensively address these present-day challenges. NbS, climate resilience, and greenhouse gas emission reduction must become more of a legislative and financial priority to avoid the worst impacts of climate change now and in the future.

What are Nature-based Solutions?

The Nature Conservancy (2021) aptly describes NbS as approaches that work with nature instead of against it to tackle a variety of societal challenges such as climate change, water and food security, biodiversity protection, human health, and disaster risk management. NbS mimic or harness the power of a natural process to solve a particular problem, often yielding other benefits in the process. NbS are a broad set of tools that can be practiced through various approaches, including pollution remediation, mitigation of natural hazards, water quality and quantity improvement, shoreline protection, habitat restoration and protection, recreational and green space implementation, energy conservation, and much more. Ideas include the use of green spaces to retain and clean water; the recovery of pollinator populations to improve food security; coastal habitat restoration to increase resiliency to storms and other climate change impacts or increase fishery harvests; the use of vegetation and green space in urban areas for their cooling effects and carbon sequestration; and more.

The term NbS is increasing in use as these approaches continue to gain traction. There are many similar terms that are sometimes used interchangeably, including: green infrastructure; low-impact development; sustainable urban drainage systems; ecosystem-based approaches; sustainable development; engineering with nature; and ecosystem services. These and like terms all encompass similar ideas, but NbS more specifically address projects and approaches that mimic natural processes to solve environmental and societal problems.

Why Nature-based Solutions: The Potential Benefits

In addition to tackling the issue of interest, many NbS also provide a variety of other important short and long-term benefits environmentally, socially, and economically, unlike their gray infrastructural alternatives (FEMA, 2021; Seddon et al. 2020). These can include improvements in air and water quality, savings in costs and/or maintenance, reduced or nonexistent natural disasters and hazards, decreased energy consumption, increased recreational spaces, and more (Table 1). While different NbS have the potential to provide a bounty of many significant benefits, it is important to assess a project's potential for each of these on a case-by-case basis. The efficacy of a NbS will depend on available resources and how thoughtfully the project or series of projects have been considered before implementation, as will be discussed later in the paper.

Table 1. The wide variety of benefits that can potentially be reaped from NbS. For more details on these benefits, refer to FEMA's guide for Building Community Resilience with NbS.

Environmental	Economic	Social
Pollution and nutrient removal	Increased property values	Provision of recreational and green space
Improved water quality and increased water quantity	Reduced or nonexistent gray infrastructure maintenance costs such as stormwater management, shoreline enhancement, etc.	Improved physical health from ecosystem services such as cleaner air and water
Groundwater recharge	Creation of green jobs	Increased food security through urban gardening opportunities
Provision of urban habitat for increased biodiversity	Energy conservation savings	Improved mental health and well-being
Mitigation of flooding, drought, erosion, storm surge, and other natural disasters	Increased tax revenue in some cases	Increased community engagement and involvement opportunities
Thermal and energy benefits: mitigation of urban heat island effects	Mitigation of property damage and other costly expenses from disaster, extreme weather, climate change	Opportunity to contribute to environmental justice

Climate resiliency and adaptation	Reduced water use and water treatment costs	
Carbon sequestration		
Improved air quality		

Limitations of NbS and potential disservices must also be considered in conjunction with the possible services identified in Table 1. Disadvantages could include higher taxes, increased mosquito or tick habitat, or green gentrification (further discussed later in the paper). Another possibility is that NbS that increase groundwater infiltration, such as those that aim to capture stormwater runoff, must account for higher amounts of water in an urban environment in areas with basements. These NbS must be designed in a way that protect underground dwellings from the increase in urban runoff as a result of the project. NbS can yield many benefits and public outreach campaigns should continue to increase awareness of their many advantages. However, too often the literature states that NbS are always a win-win situation. NbS can vary widely in application, along with their costs, benefits, and maintenance requirements. Going forward, practitioners must transparently acknowledge the disservices or unintended consequences that a project or series of projects could yield. This must be recognized about NbS approaches, in addition to their benefits, so that such consequences can be properly addressed or mitigated.

Nature-based Solutions for Urban Stormwater

These ideas of working with nature are in contrast to traditional "gray" infrastructure approaches of the built environment. Outdated gray infrastructure approaches, particularly those designed to handle stormwater runoff, are currently one of the biggest threats to water quality (Yang & Lusk, 2018). Historically, the idea underlying development was to channel all of the rainwater away via pipes, gutters, drains, and other conveyance infrastructure, with the goal of sending as much of it as possible away from the built environment. When an area gets developed, green spaces are replaced with impervious surfaces such as lots, roads, pavement, and rooftops. The rainfall runs off of these surfaces instead of staying onsite and recharging groundwater. This construction design is extremely harmful because it degrades water quality by conveying pollutants and nutrients directly to water bodies, in addition to causing other issues including increased erosion and reduced biodiversity. Excess nutrients favor certain species and allow them to thrive at the cost of most of the other organisms in an aquatic system. This includes harmful algal species that are normally kept in check to bloom out of control (Gaffield et al. 2003). Massive blooms can release harmful toxins and decaying algal cells can deplete the water's oxygen, causing die-offs of fish and other aquatic organisms (Brand & Compton, 2007).

In contrast to this short-term approach of carrying rainfall away from the site, stormwater is now being recognized as a tool that depends entirely on how it is managed. If managed well, stormwater runoff can provide many benefits. Stormwater-focused NbS aim to retain rainfall onsite, minimizing the volume of water and pollution discharged to water bodies from the built environment. Much of the country's gray stormwater infrastructure is aging, is costly to update and maintain, and often does not perform well under extreme storms or high-rainfall events (Davis & Naumann, 2017). Some gray stormwater infrastructure also currently contains lead. NbS can eliminate or mitigate many of these problems, especially by significantly reducing the frequency of floods and combined sewer overflows, which are increasingly occurring with traditional stormwater management (FEMA, 2021). These overflows result in untreated sewage leaking into water bodies, harming the environment and public health. NbS goals of reducing flood water volume will improve water quality by avoiding such overflows, and by slowing down both the flow and volume of stormwater runoff so that it can be filtered before reaching water bodies. Gray stormwater infrastructure often cannot handle high rainfall and extreme storm events that are increasing in frequency and intensity due to climate change (Oral et al. 2020), especially older infrastructure that was not built with current human population numbers or climate change in mind. NbS can help urban areas cope with the increasing volume of rainfall from extreme weather.

Stormwater treatment trains: A Case Study

Stormwater treatment trains can consist of a few or many NbS projects in a landscape or watershed. Practices can include, but are not limited to: stormwater ponds and parks; rain gardens; bioswales; cisterns; rain harvesters; green roofs and walls; permeable pavement; and tree trenches and plantings. There are also NbS specific to coastal environments and lake shorelines, called living shoreline techniques, that are used primarily to enhance shoreline stabilization and protection, and bring with them many other environmental, economic, recreational, and aesthetic benefits. These kinds of practices, which are usually smaller in scale, can also be combined with practices that are traditionally larger in scale such as terrestrial habitat preservation or restoration, and coastal, wetland, and river restoration techniques.

When Augustenborg, Sweden was regularly suffering from a series of devastating floods, it was clear that the city's conventional gray stormwater infrastructure was not adequate to handle current stormwater volume. The city took a stormwater treatment train approach by transitioning from combined sewer systems and other gray infrastructure to a new open rainfall management system. The new techniques included open channels, stormwater ponds, stormwater wetlands, and green roofs, replacing much impervious coverage with permeable surfaces, and cumulatively allowing for significant rainfall infiltration. As a result, flooding ceased to be an issue in the city. The performance of the combined sewer system that serves the surrounding area also improved by largely reducing the volume of runoff from high rainfall events for the watershed and region as a whole. Additionally, Augustenborg reaped many other benefits provided by increased green space such as improved wildlife habitat, recreational space, improved air and water quality, and much more (Mentens et al. 2006).

Nature-based Solutions for Urban Floods and Droughts

Flooding and Extreme Weather in Vermont: A Case Study

Floods, particularly those from increasing precipitation and intensifying extreme storms and weather, are one of the greatest challenges to society today. Floods can result in devastating property damages and economic costs, adverse environmental and public health impacts, injuries, and death, making them one of the most catastrophic events for society (Watson et al. 2016).

Tropical Storm Irene struck the Lake Champlain Basin of Vermont in 2011. It resulted in damage to more than 500 miles of roads and 200 bridges, releases of hazardous waste, combined sewer overflows, agricultural losses, and an estimated $175-250 million in damages (EPA, 2014). Watson et al. (2016) quantified the flood mitigation services that an affected area of Vermont was able to provide against this storm with NbS concepts of wetland preservation and the reconnecting of riverine floodplains. The Otter Creek region, which hosts a network of protected wetlands and a floodplain that is largely connected to its river, was shown to provide between $627,000 and $2 million in avoided damages to Irene and reduce downstream flood damages by 92%. The authors demonstrated that the flood abatement benefits alone cover at least a quarter of the cost of conserving the Otter Creek network of wetlands and floodplains.

This case study not only demonstrates the underappreciated economic value of wetland and floodplain conservation in a watershed, but also the need to take a preventative approach going forward instead of a reactive approach to disasters, extreme weather, and other environmental and societal challenges. A preventative approach through the use of NbS can play an important part in avoiding significant damages and losses that this Lake Champlain Basin of Vermont experienced, while also yielding many other valuable benefits.

Droughts and Heat Waves in the North American West: A Case Study

Conversely, in arid regions with little precipitation that are more prone to pressures from droughts and heat waves, NbS can also aid in storing and preserving water, reducing the reliance on irrigation (Oral et al. 2020), and mitigating urban heat island effects (Costadone, 2021). Xeriscaping, a landscaping approach that naturally requires little or no irrigation with the use of drought-tolerant vegetation and/or efficient irrigation methods, is increasing in use in these climates. This environmentally and financially efficient NbS principle can serve as an important tool in conserving water and energy, mitigating droughts, heat waves, and other impacts from climate change. This is particularly important in light of the unprecedented 2021 summer heat waves that have disproportionately impacted western America and Canada, bringing temperatures of 116 degrees Fahrenheit (about 46 Celsius) to Portland, Oregon; 108 degrees (about 42 Celsius) to Seattle, Washington; and 118 degrees (about 48 Celsius) to Lytton, British Columbia, the hottest temperature ever recorded anywhere in Canada, and ever recorded for all three of these cities (The Atlantic & Meyer, 2021). Considering such unusual heat waves, and that much of the American west has been experiencing a megadrought since the turn of the 21st century (Williams et al. 2020), xeriscaping and other NbS that address heat waves and droughts deserve increased attention.

Tucson, Arizona is a leading community in the state in xeriscaping implementation. The University of Arizona Pima County Master Gardener public demonstration gardens teach residents various gardening principles that enable them to live more in harmony with their arid desert environment instead of water-intensive, non-native lawns and gardens. The visiting centers and public gardens allow for Arizonans to observe examples of what they can do with their own landscapes. Tucson Water also hosts a rainwater harvesting rebate program, where residents or small businesses can receive up to $2,000 in rebates to install a rainwater harvesting system on site (FEMA, 2021). Many other municipalities in dry climates, such as Mesa, Arizona, and Denver, Colorado are similarly offering rebates and other financial incentives encouraging the removal of turfgrass and installation of xeriscape elements. This saves water and money on residential, municipal, and regional scales.

Another NbS that is practical in dry, arid environments, and similarly provides thermal and environmental benefits and cost savings, is the presence and conservation of urban lakes. Costadone (2021) demonstrated the energy use reduction and socioeconomic value that lakes and green spaces provide in mitigating heat waves and urban heat island effects. The author assessed three urban lake areas of the Phoenix Metropolitan Area of Arizona: the Lake of Tempe, the Dobson Lakes, and Biltmore Lake neighborhoods. At each site, the presence of the lake was found to significantly reduce energy consumption; the Lake of Tempe provided up to a 57% reduction in energy use overall, and up to a 74% reduction for properties within 50 meters of the lake. Each site exhibited significant energy consumption savings overall, with the highest savings being reaped by those within 50 meters of each lake. This study asserts that urban lakes are NbS in themselves, yielding many essential ecosystem services that are crucial to protect and invest in, especially in urban settings. In addition to providing important environmental, recreational, economic, and other social benefits, urban lakes provide significant cooling and thermal benefits. This is particularly important in arid regions like Phoenix and will continue to increase in relevance as extreme heat waves and droughts continue to occur in other non-desert climates due to climate change.

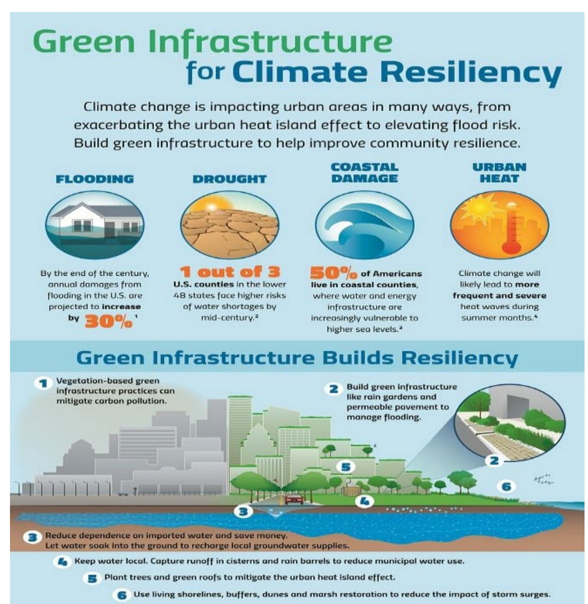
Urban Watershed Nature-based Solutions in Practice

Nature-based solutions are most effective if analyzed through a landscape or watershed-scale lens. This approach allows each project to work in tandem with other natural features and other NbS projects in the region for cumulative impacts in the watershed, as well as the consideration of human dimensions such as environmental justice and equitable distribution. This allows for identification of the most impactful and/or feasible areas of the watershed for such projects. Cohen-Shacham et al. (2019) encourage this approach to have a more complete awareness of the wider landscape context in addition to more wholly achieving goals such as increased green space and improved water quality and urban habitat. This also provides opportunity to assess the landscape of interest socio-economically to better understand the history of the region and its current state, including existing NbS projects or lack thereof, and which communities have been underserved or divested from.

NbS should also be implemented with the long-term thought processes of both adaptive management and climate resilience in mind. With NbS being a relatively young field, there is still much to learn about best management practices. Therefore, it is crucial to allow these projects and their management plans to be flexible enough to incorporate new knowledge, data, and considerations (DeAngelis et al. 2021). Similarly, it is important for researchers and practitioners to contribute new data and share lessons learned from their NbS projects so that this newer discipline can keep growing and improving.

The Role of Nature-based Solutions in Tackling Climate Change

Adaptive management and long-term thinking are particularly relevant as the effects of climate change escalate. The latest scientific findings conclude that we are fast approaching an irreversible turning point of climate change; the average temperature of the earth has already reached 1.2 degrees Celsius above pre-industrial levels, bringing us closer to the critical threshold of 1.5 degrees Celsius of post-industrial era warming that scientists have long been raising the alarm about ([World Meteorological Organization, 2021](#)). All NbS projects must not only consider how longer-term climate change impacts will affect their project, but also how the project can potentially mitigate such impacts or adapt to it. For example, it is crucial to identify climate hazard zones of the region, such as areas more prone to flooding from sea level rise and extreme storms. NbS focused on hazard mitigation, such as coastal habitat restoration and living shoreline projects, would be most wisely targeted in these areas (DeAngelis et al. 2021), instead of



installing rain gardens in such places that will most likely be flooded by storms or sea level rise in the near future. The two Environmental Protection Agency graphics below demonstrate how various NbS can tackle climate change and enhance resiliency in endless ways.

Economic Considerations

NbS can provide many economic benefits as detailed above, including increased property values or tax revenue, creation of green jobs, reduced water use and treatment expenses, and other various forms of long-term cost savings. NbS can prevent or altogether avoid the need for expensive upgrades or repairs to gray infrastructure, especially stormwater structures; mitigate or prevent harmful and costly disasters such as combined sewer overflows and/or floods, droughts, heat waves, landslides, and other extreme weather impacts from climate change; and provide thermal refuge via cooling effects to buildings and cities. Many NbS ultimately save money in the long term compared to their gray infrastructural alternative (Lafortezza et al. 2017), but this is largely dependent on the project and can vary. This is often true for stormwater NbS such as stormwater ponds, rain gardens, and green roofs (Clark et al. 2006), whose alternatives are costly to maintain and are aging in many places (Seddon et al. 2020).

However, stormwater NbS, like many kinds of NbS, also require regular maintenance that must be considered in planning; who will be responsible for maintenance? How much will it cost initially and in the long-term? Will long-term funding and resources be available in the future for continued maintenance? Too often, NbS are not maintained often enough or effectively, and their performance and efficacy suffer as a result (Erickson et al. 2018). Some NbS will not be effective at performing their intended services if not properly managed.

Funding Nature-based Solutions

Despite the increasing need for NbS, they remain poorly underfunded. Under 5% of climate budgeting is directed toward managing impacts of climate change, and under 1% is directed toward coastal protection, infrastructure and hazard mitigation (Seddon et al. 2020).

However, as the need to work with nature instead of against it becomes clearer, and as interest in and understanding of their utilization grows, more funding opportunities are becoming available for NbS. Since NbS provide such a wide array of benefits, they can potentially be funded through an increasingly diverse range of sources, including various public and private actors, general funds, bond proceeds, tax and fee revenues, and many different kinds of grants and financial assistance programs (FEMA, 2021). NbS practitioners should strive to apply to a variety of environmental, social, and economically focused financial assistance programs.

Using positive and negative financial incentives could generate additional funds for NbS in addition to potentially increasing awareness and helping to promote mindset or cultural shifts to living more in harmony with the environment. Positive incentives such as rebates, tax credits, or low-interest loans could help reward those who engage in NbS (FEMA, 2021), while negative incentives such as stormwater utility fees could help reinforce the idea that the less impervious surface on the property, the better. Public-private partnerships are also encouraged as an ideal way to increase collaboration and community engagement while also securing additional funding and resources (FEMA, 2021; Kabisch et al. 2017). For more detailed information on increased funding options for NbS, refer to FEMA's Guide for Local Officials on NbS (2021).

Other Important Considerations in Nature-based Solutions Implementation

Increased Interdisciplinary Communication

For the implementation of NbS to be effective, equitable, and comprehensive, it requires the involvement of many stakeholders and consideration of many factors. Too often, these projects are siloed and thought of as only including those in environmental and planning fields. However, NbS also include many legislative, social, economic, and community dimensions that must also be addressed early in the process to avoid future unforeseen consequences or conflicts. Nesshover et al. (2017) and DeAngelis et al. (2021) stress the need for increased transparency, community engagement, and interdisciplinary communication when planning these projects.

NbS projects that are added into a community without local involvement and input can potentially invite negative public perceptions and unforeseen conflicts and may be missing opportunities for wiser and more efficient project design based on knowledge of the area from locals. It is important to survey the local resident's concerns, desires, values, and viewpoints, as well as understand the basics of the community's culture and history if possible. Hypothetically, if a stormwater treatment park is being planned in a community that has suffered from a history of mosquito-borne illnesses, and the project proceeds forward without this knowledge due to lack of community engagement, the park's grand opening could be met with animosity from the public. Regardless of the project's intended benefits or the facts, residents may only perceive it as a mosquito breeding ground, in addition to viewing it as a secretive, top-down approach from outside the community. To avoid such a scenario, incorporate the community into the planning process, in which case measures can be included from the beginning to mitigate concerns such as mosquitoes. Public outreach campaigns and initiatives can play important roles in educating communities about the benefits of NbS and their goals, as well as inviting their input. For certain NbS, this could also occur in the form of volunteer events, which fulfill the goal of educating, in addition to assistance in completing some of the project. For example, the Tampa Bay Estuary Program of Florida hosts many volunteer events including sea grass plantings (Tampa Bay Estuary Program, 2017). Increased coverage of sea grass beds serves to improve water quality and resiliency to climate change, increase wildlife and fish habitat, and many more benefits, in addition to community engagement.

While proper community involvement is key to NbS project acceptance and success, comprehensive interdisciplinary collaboration and partnerships are vital. NbS implementation requires not only the involvement of environmental scientists and planners, but also engineers, policymakers, local municipalities officials or staff, relevant industries, nonprofits, local/regional organizations, and other community partners who will be affected or could play a role. FEMA (2021) recommends public-private partnerships when possible as a tool to increase the resources, and therefore possibilities, for NbS projects. Kabisch et al. (2017) similarly emphasizes the importance of varied partnerships in NbS projects in securing multiple sources of funding and in distributing responsibility for long-term maintenance and costs.

Environmental Justice

NbS projects have an important stake in concerns regarding equity and environmental justice: such projects can either mitigate or exacerbate racial and social inequity. Practitioners must ask various questions about the community or region targeted for NbS to understand the broader background and context that they are going into, such as:

- Who exactly will benefit from the NbS?
- Who exactly will pay for the costs of the NbS? Who might experience some other foreseeable disadvantages of the NbS such as mosquitoes?
- Which communities, today and historically, in the region have been the most invested in, the least invested in, and/or divested from?
- Does the area of interest have a history of racial profiling, gentrification, and/or displacement? Perhaps the project could be an opportunity to understand historical use of the land prior to white settlement.
- What is the median income and cost of living in the area?
- What are the average demographics and socioeconomic profile of the area?
- What are the biggest issues facing community members, including climate change impacts (flooding, heat waves, droughts, etc.)?
- By which communities and/or stakeholders are the problems mainly experienced?

These are just some of the critical questions to ask when considering a NbS in a community or region, as NbS can have a far-reaching, long-term ripple effect on an area and nearby communities in various ways. Green gentrification, which is the displacement of historical residents in response to NbS and green infrastructure projects, is not yet considered enough when working in underserved communities of lower income and minority backgrounds. NbS can often raise property values in an area, leading also to higher rents and costs of living; this leads to the progressive loss of the original community as longer-term, poorer residents leave to occupy more affordable areas, and wealthier residents and businesses take their place and move in (Taguchi et al. 2020). This is a complex and multi-faceted dynamic to consider; while targeting lower-income, underserved areas for NbS can potentially remediate environmental justice concerns in some ways, such as improving air and water quality and public health of a poorer area, it can also unintentionally lead to this outcome. Klein et al. (2020) provides a comprehensive tool kit for a wide array of NbS practitioners to consider in ensuring equitable distribution of benefits and avoiding green gentrification as best as possible in NbS implementation. Being aware of these possibilities, asking the right questions as outlined above and in Klein et al. (2020), and utilizing strategies as recommended by these authors such as rent control and affordable housing legislation, are all key to ensuring that benefits and costs of NbS are distributed as equitably as possible.

Continuing to Incorporate Nature-based Solutions into Legislation

NbS are revolutionizing how we handle and solve various environmental and societal issues. As NbS increase in extent and scope globally (Seddon et al. 2020), legislation must also continue to evolve with it. Legislative and political barriers of various scales, such as outdated land use and zoning ordinances that do not account for climate change, or strict homeowner's association requirements that prevent environmentally friendly landscaping, are just some examples of how NbS implementation can be hindered legislatively. Policies should be reanalyzed and updated when possible to not only allow for easier NbS implementation, but also encourage it (DeAngelis et al. 2021). The American Fisheries Society (2021), NALMS, and partners in the Consortium of Aquatic Science Societies (American Fisheries Society et al. 2021) also strongly encourage the Biden administration and Congress to make such updates and incentives through current and upcoming economic recovery and infrastructure legislation. NALMS supports this notion in that many of the current economic and infrastructural challenges that the Biden administration are tackling offer prime opportunities to get NbS, climate resilience, and watershed-scale conservation onto the federal agenda in an effective way that simultaneously yields many other vital societal benefits. Removing federal legislative barriers, implementing policies that incentivize and promote NbS, and increasing funding opportunities are all significant federal actions that can currently be taken that will help result in wider applications, while also trickling down to smaller regional, state, and municipal scales. NbS practitioners should work with policymakers to enact policies that promote or require NbS as the solution, or part of the solution, to urban lake and watershed issues.

Depending on the region and/or community, it may be appropriate to require a certain amount of NbS instead of gray infrastructure, especially in relation to stormwater. Requiring NbS in new developments or redevelopments could take the form of rain garden or green roof requirements on new buildings; the United Kingdom and Germany are two countries that have some laws in place that require this (Kabisch et al. 2017; Oberndorfer et al. 2007). Going forward, laws that require some extent of NbS in new developments and redevelopments are a good practice to consider in achieving environmental and NbS-specific goals. However, NbS legislative requirements are not appropriate everywhere, particularly poorer and lower-income regions who may not be able to afford the taxes or other upfront costs and/or long-term maintenance of implementing such projects. Proper community involvement, engagement, and socio-economic understanding must occur before requiring a community to implement NbS in order to avoid public rejection and animosity towards the project(s), green gentrification, and other negative consequences. NbS development requirements can work well in some cases but are highly context-dependent and should be heavily considered before being pursued.

Conclusion

The significant environmental, economic, and societal costs of neglecting environmental needs and taking a "business as usual" approach towards climate change is increasingly being observed, especially considering challenges like biodiversity loss, food and water insecurity, declining water quality, worsening natural hazards and disasters, and ecosystem collapse (Seddon et al. 2020). The time is now for urgent and immediate action on human-caused climate change; the wicked problems plaguing urban lakes, watersheds, aquatic resources, and society as a whole are only worsening (American Fisheries Society, 2020). There must be a shift from short-sighted goals to longer-term thinking and planning that accommodates the current impacts of climate change and those that will occur in the near and long-term future. NbS can be a meaningful part of this transition while also bringing along many other favorable societal and economic benefits, including resilience to extreme storms and natural hazards, improved water quality and quantity, increased food security, improved air quality, increased recreational space, energy conservation, maintenance cost savings, and much more.

NbS and climate resilience must become more of a legislative and financial priority to avoid the disastrous alternatives that will be more costly and will result in lost resources, biodiversity, properties, and human life, among many other catastrophic consequences. Going forward, NALMS supports the following for NbS:

- Reduced legislative barriers and increased funding must clear the way for wider implementation of NbS. NbS should be encouraged and financially incentivized in new legislation and required if and when appropriate.
- Transparent community engagement must occur during implementation to recognize concerns and mitigate possible disservices of a project.
- Using a watershed or landscape scale approach, stormwater treatment trains should be implemented, when possible, to address the significant issues associated with gray stormwater infrastructure, while xeriscaping principles should be used to mitigate droughts and heat waves while conserving limited water supplies.
- NbS must mitigate environmental justice concerns rather than exacerbate them. Green gentrification can be avoided by properly engaging the community, doing the right

socioeconomic and historical research, and employing effective tools as outlined in Klein et al. (2020).

- Increased interdisciplinary communication and collaboration must occur to effectively and equitably enact these projects, which involve many more actors than just environmental scientists and planners.
- This young discipline needs more data and research attention to better understand best management practices, further quantify services and disservices, and promote wider confidence in NbS implementation.

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