Coastal Communities

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Contributor: Liette Vasseur

Coastal communities are increasingly vulnerable to climate change and its effects may push coastal ecosystems to undergo irreversible changes. This is especially true for shorebirds with the loss of biodiversity and resource-rich habitats to rest, refuel, and breed. To protect these species, it is critical to conduct research related to nature-based Solutions (NbS).

Keywords: ecosystem-based adaptation ; nature-based solutions ; climate change

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1. Introduction

Human communities and wildlife located in the coastal zone are increasingly vulnerable to hazards and the impacts associated with climate change. Hazards—such as storm surges, ice storms, and heavy rainfall—increase water level fluctuations, which can lead to erosion and flooding [1][2]. In coastal communities, these multiple stressors may cause coastal ecosystems to undergo sudden, rapid, and irreversible changes [3]. This can result to habitat loss, land degradation, and the reduction or removal of species diversity as well as associated ecosystem functions and services [4][5]. Habitat loss is widely used as a measurement for the risk of extinction of species and is considered an important factor for the decline of shorebird populations [6]. The loss of these habitats results in a loss of resource rich habitats and an increase in shorebird population decline [7]. The long-term accumulation of impacts caused by climate change and loss of land are detrimental to the feeding and nesting ground generally available, resulting in a shift in many species' natural migration patterns. This accumulation of effects can cause a negative impact on population density and a shift in biodiversity [1][2][6].

Several changes in the natural behavior of shorebirds have also been documented—such as altitudinal shifts [8], earlier breeding [5], timing of migration [8], breeding performance (egg size, nesting success) [5], and population distributions [9]. Due to the increased stressors of climate change and human intrusion, shorebirds are among the bird groups of highest conservation concern in the world with three times as many species declining as increasing [10]. Climate change is predicted to cause approximately 400–550 bird species extinctions globally, and an additional 2150 species may be at risk of extinction by 2100 [11]. Most shorebirds must undertake energetically demanding migrations covering thousands of kilometers between breeding and non-breeding sites, and several species interrupt their journeys to rest and refuel at stopover sites along the way [12]. With the decline of many species, conservation is critical for maintaining healthy communities that consist of many diverse species as well as healthy ecosystems.

2. Ecosystem-Based Adaptation Strategies

The strategies and methods used in this scoping review led us to the results of four major groups of EbA strategies that were identified as potentially interesting and feasible for the Niagara Region: forest cover, living shorelines, managed retreat and realignment, and beach nourishment.

The first potential strategy was forest cover, which can be described as heavy forested areas to provide canopy cover and a barrier against weather events [13]. Forested area has been commonly used in riparian zones and along rivers in some areas of Canada to reduce flooding from ice melt [13][14]. This strategy was shown to be a beneficial option due to its ability to trap water, which reduces runoff rate and erosion, provides water filtration, increases habitat diversity, and can enhance tourism and recreation [15][13][16][17][18]. While the result showed many benefits to this strategy, it also revealed some challenges such as having extensive national regulations for buffer properties, often being heavily affected negatively by increasing population density, and potential tree falls that may affect resilience of shorelines [13][17][18][19]. The most interesting case studies include the use of forest cover along rivers to reduce flooding when a community experiences flooding due to ice jam [13] and the use for coastal and agricultural lands in India with highly populated areas to reduce impacts on humans as well as creating wildlife habitats [15].

Managed realignment and retreat represented the second EbA strategy showing promises as a sustainable strategy in many areas such as low development areas, beaches, and riparian areas [16][20]. Managed retreat or realignment is the partial or total removal of man-made or hard infrastructure strategies. This strategy was shown to be a beneficial option due to its ability to create or improve natural habitat, allow natural sand transport and is economically more feasible than continued defense [20][21][22]. It has been used to retore salt marshes, thus reducing exposure of humans to storms and increasing potential shorebird habitats [20]. This strategy was beneficial in low impact conditions where wave attenuation might not be as high and these realigned habitats, such as salt marshes, creating important biodiversity benefits for many shorebird species [20]. However, this option may not always be feasible especially in areas that are highly developed due to the difficulty of realigning or retreating heavy populations and dense concentrations of infrastructure [3]. It also presents challenges regarding proper disposal of previous defense infrastructures or buildings and can be a costly strategy to achieve or maintain [21][22]. For example, this strategy has been used in Norfolk, UK, to restore salt marshes [23] or in New York, USA, to increase piping plover habitats [24].

The third option was living shorelines. This EbA involves the restoration, enhancement or protection of ecosystems, such as marshes and coastal grasslands, which provide feeding ground for many migrating shorebirds due to greater vegetated habitats, while protecting human populations at the same time [25]. Living shorelines are categorized as a larger group of green infrastructure practices, which include a greater range of nature-based techniques for inland areas that address a variety of issues in place of hard infrastructure. This strategy was shown to be a beneficial option due to its potential to address erosion through restoration and protection, enhance existing habitats or create new natural habitats, reduce wave height and strength as well as sediment retention through root systems [3][15][23][25][26]. However, challenges arise if there is a lack of proper planning on incorporating these strategies as success depends on vegetation characteristics, design, and setting of the area [26][27][28]. Such an EbA has been proven to be more effective in North Carolina than grey infrastructure and more cost-efficient [27].

The fourth option was beach nourishment. Beach nourishment is the process of adding sand onto eroding beaches. Sand is brought in from offshore and pumped onto eroding beaches or brought from other location. It helps restore beaches while also protecting shoreline structures from erosion, wave action, and storm forces. This strategy was shown to be beneficial due to its potential to enhance natural processes and biodiversity, contribute to beach recreation and tourism, act as a buffer between water and land and was recorded to be the most promising long-term solution compared to alternative strategies [29][30][31][32]. This strategy also has challenges such as requiring constant maintenance, monitoring, and modeling, needing regular nourishment after storms and can have negative impacts on groundwater [32][33][34]. Beach nourishment has been done in several locations around the world where tourism is important; however, it has also been done in Georgia to provide more nesting habitat, attracting foraging activities, and reducing next predation [25]. In the example of Dollard coast of the Wadden Sea, a wide green dike pilot program was implemented as a flood protection system [32].

3. Analysis of Ecosystem-Based Adaptation Strategies with Nature-Based Solution Principles

The four EbA strategies were then assessed against the eight core NbS principles set out by Cohen-Shacham et al. [35] (pp. 25). The interpretation and implementation of the NbS concept is very context specific, depending on a variety of factors influencing the societal challenges being addressed. This being the case, it is only feasible to standardize the processes for the design and execution of NbS each time a solution is implemented [36]. For this individual study, each strategy was evaluated on a coastal ecosystem setting and overall, the strategies identified by the scoping review met on average 5.5 of the NbS principles.

Through evaluation of the case studies against the standards of NbS only living shorelines met all the eight core principles. This was mainly because the case studies showed that while it deals with societal challenges such as higher energy sites (Principle 2) [27], it helps promote nature conservation through the planting of vegetation and habitat formation for many species (Principle 1) [14][27]. It can integrate cultural aspects, bring societal benefits, and enhance biodiversity by both benefitting both natural environments as well as economic environments (Principles 3, 4, 5) [3][14][27]. Because of the capacity to be at a larger scale than the other EbA strategies, it can be applied at the landscape level (Principle 6) [14]. Case studies showed that trade-offs were possible ad thus integrated into policies at the local and regional levels (Principles 7, 8) [3][27].

According to the case studies examined, the forest cover strategy cover Principles 1 and 5 through the promotion of nature and biodiversity conservation by planting trees which create habitat and restore habitat for many species [17][25]. This strategy meets Principle 2 as it can either be implemented alone or as an integrated method with other green strategies [16]. Principles 4 and 6 were also met in this strategy through its capacity to be implemented at a larger landscape level scale as well as providing both environmental and economic benefits by creating buffers to protect human infrastructure and communities [17][25]. None of the articles mentioned the possibility of trade-offs regarding ecosystem services as it is mainly to maintain forested areas and the possibility to be integrated into overall policies to address specific challenges.

Beach nourishment met a total of five NbS principles. Through the widening of beaches on a landscape scale it promotes the enhancement of natural habitats coastal fauna and flora, this can also be used in combination with living shorelines for increased productivity (Principle 1, 2, 6) [23][25]. The planning and implementation of this strategy involves multiple stakeholders and provides benefits for both environmental and economic areas allowing for broad participation at all levels (Principles 4, 8) [23][37].

The strategy that met the least number of principles, only four principles, was managed retreat and managed realignment. Managed realignment and retreat allow for natural coastal erosion, sand transport, and reduce impact of storms at a landscape scale which allows for conservation of these areas (Principles 1, 6) [16][20]. This method is often used in combination with beach nourishment in order to complete the process of retreat (Principle 2) [20][25]. This strategy also recognizes and addresses the trade-offs between the production of a few immediate economic benefits for development through the promotion of tourism and protection of human infrastructure (Principle 7) [16].

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