Current and Potential Climate Change Impacts at First Landing State Park

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Photo by Chase Garrison

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I. Introduction

First Landing State Park (formerly known as Seashore State Park) was first opened to the public in 1936 at Cape Henry in northern Virginia Beach, Virginia. It provides multiple recreation opportunities including beach access, boat ramps, camping, hiking and biking trails, educational programs, etc. It is unique in its location within an urban-surrounded area, as well as its multiple state and globally rare natural communities and species. Within its 2888.5 acres, First Landing State Park contains a variety of rare and endangered species and accommodates the most annual visitors with over 1.7 million visitors each year (Park Ranger EDU, 2018). It is also the only place where the northern geographic limit of semi-tropical species and the southern geographic limit of temperate-zone species overlap and where both types of species thrive (Virginia Department of Game & Inland Fisheries, 2018b). It has a substantial economic impact on Virginia Beach and the state as a whole, providing 372 jobs, $2.3 million in state and local taxes, $25.9 million from visitor spending, and $17.9 million in total economic value added (Magnini, 2018). The management and protection of First Landing from climate change is important for both its biological and socioeconomic significance.

As anthropogenic climate change progresses, the impacts on First Landing will progress as well. For the purpose of this paper, the climate change impacts that were focused on include: changes in surface temperature and precipitation; biodiversity changes due to invasive species, migration of non-native species into the park, and possible extinctions of native species; and direct human impacts due to land use changes

caused by increases in the number of annual visitors and growth of the Virginia Beach population. These hazards and the park's vulnerabilities to the hazards are discussed, followed by possible future scenarios based on projections from IPCC (2015) and Weldon Cooper Center for Public Service (2017). Possible options for protection and maintenance of the park are then introduced, and recommendations are made for relevant groups and agencies involved in decision making.

II. Climate Change Hazards to First Landing

A. Changes in Surface Temperature and Precipitation

As anthropogenic CO_2 emissions have increased, the average surface temperature has increased as well. As surface temperature increases, changes in precipitation patterns also occur. Changes in surface temperature and precipitation patterns have, and will likely continue to have, impacts on both wildlife and recreation opportunities at First Landing.

One impact of these changes is a potential increase in the frequency of droughts. There are two different types of drought as described by NOAA (2018): meteorological drought, which refers to when an area is subject to drier weather patterns than is typical for its climate, and hydrological drought, which refers to when water supplies are low, which affect rivers, groundwater levels, etc. Future projections of these drought types use Standardized Precipitation Indices (SPIs) for meteorological drought and Palmer Drought Sensitivity Indices (PDSIs) for hydrological droughts (Strzepek et al., 2010). According to Strzepek et al. (2010), under an intermediate CO_2 emission scenario and using PDSIs it is likely that extreme

hydrological droughts are likely to become more frequent throughout Virginia. As many species within First Landing are dependent on things that water supply affects, such as groundwater, ponds, swamps, etc., this could negatively impact many species within the park.

Changes in heat wave frequencies and magnitude is also a potential hazard to First Landing. It is likely that as temperatures increase, heat waves will occur more often, for longer periods and with higher temperatures, although occasional cold temperature extremes may still occur (IPCC, 2015). Species in First Landing that are living near their physiological limits such as eelgrass will have to migrate to new areas within their physiological limits. However, temperatures may increase at such a fast rate that these species may not be able to migrate quickly enough and combined with more intense and longer heat waves beyond their limits, they may become either locally or biologically extinct (Najjar et al., 2009; IPCC, 2015).

Although drought frequency is likely to increase, extreme precipitation events are also likely to increase in both intensity and frequency (IPCC, 2015). In layman terms, this means that even if the number of days where it rains decrease, the days where it does rain will have higher amounts of rainfall and wind speeds. In addition, hurricanes are likely to increase in intensity regarding wind speed and amount of precipitation as well (Rahmstorf et al., 2018). There is also a poleward migration of where hurricanes are reaching their maximum intensity. This means that it is possible that more intense hurricanes may reach Virginia more frequently (Kossin et al., 2014). Both increases in extreme precipitation events and increasingly intense hurricanes could have negative effects on First Landing recreation and wildlife.

Higher amounts of rainfall could cause flooding which could impact plant seedlings and habitats for First Landing species. The threat of flooding combined with increased wind speeds is also likely to increase erosion rates. As a result, both flooding and erosion would impact recreation at the park by affecting hiking trails or flooding areas with cabins and campsites. In addition, there is a potential for more frequent park closures such as the closing in 2016 cause by Hurricane Matthew (Satchell, 2016). These impacts on recreation would likely cause a significant decrease in revenue from visitor spending, which the park, local, and state governments all benefit from.

B. Invasive Species and Migration of Non-Native Species

There are several invasive species which are currently found within First Landing State Park that have the potential to negatively impact native species. The following invasive species have been identified as being very likely to be able to proliferate within the park and thus disturbing ecological systems.

The first is Japanese Stilt Grass (*Microstegium vimineum*), which was introduced to North America from Asia and was first found in Tennessee in 1919 (Leicht et al., 2005). Japanese Stilt Grass is a highly prolific grass species that spreads very quickly by producing 100-1000 seeds each year which can be held in seed banks where they can be dormant for more than three years if conditions are not suitable for hatching. This large number of seeds can then be spread by humans, animals, water, or wind to new areas where it can live in a wide variety of habitats under various conditions such as intense light or shaded areas (Leicht et al., 2005). It can also exist in very high densities (3000-4000 plants/m^2), which can completely cover ground areas thus

suppressing native species and their seedlings causing areas to become completely overtaken by Japanese Stilt Grass (Leicht et al., 2005). Stilt Grass also appears to alter soil pH, making soils more acidic which can make these areas less suitable for native species, and generally outcompetes native species for resources as well (Virginia Department of Conservation & Recreation, 2016b).

The second is Red-eared sliders (*Trachemys scripta elegans*), which are native to the Mississippi River Valley of North America and have become one of the most invasive species globally primarily due to their popularity in the pet trade and irresponsible owners releasing them into the wild. They are highly adaptable and are able to survive in fresh or brackish waters. Like other invasive species, their primary threat is that they create more competition for resources with native turtle species such as food, nesting sites, habitat, etc. Pearson et al. (2015) predict that invasive Red-eared slider populations will negatively impact native turtle species through competition for food resources, particularly in areas where food resources are limited since they appear to use these resources more efficiently in terms of growth and development than native species. This is further supported by Polo-Covia et al. (2011), which concluded that when food resources are not limited enough to cause direct competition between different species the amount of food intake is similar between species, but when resources are limited and different species must compete for the same resources the Red-eared slider food intake was much higher. First Landing is home to many turtle species, including several that have been classified by the Virginia Wildlife Action plan as "High Conservation Need" or higher such as Spotted Turtles, Northern Diamond Backed Terrapins, and the state and globally rare

Eastern Chicken Turtle (*Deirochelys reticularia reticularia*) (Virginia Herpetological Society, 2018). If resources such as food, habitat, and nesting sites become more limited as climate change impacts First Landing, it is possible that these native turtle species could be overcome and replaced by Red-eared sliders.

In addition to introduce invasive species, it is possible that species which are currently non-native to First Landing may begin to migrate into First Landing State Park as their geographic range expands poleward due to warming temperatures. These species could possibly alter biodiversity and ecological systems in the same way that invasive species do through competition for resources. However, it is possible that these species may not all have negative effects on First Landing wildlife. Identifying which species may migrate to the park and their possible effects on species is a topic of research that should be pursued further to best prepare conservation efforts.

C. Land Use Changes

The public interest in outdoor recreation has been steadily increasing since the 1960s (Monz et al., 2010). Although increased interest in outdoor recreation has the potential to increase revenue for parks such as First Landing, an increase in visitors can negatively impact ecosystems within parks by affecting vegetation, changing soil quality and erosion rates, as well as degradation of habitat and water quality (Monz et al., 2010). Areas with hiking trails are usually developed in order to minimize these impacts as much as possible; however, people sometimes choose to go hike off the trails, disturbing habitats even further than anticipated (Marzano and Dandy, 2012). Since First Landing has such a large number of annual visitors with more coming each year, it makes sense to assume that these impacts will most likely continue to

increase. Therefore, a balance must be established between allowing visitors access to recreational activities while best preserving the unique ecosystems within First Landing.

In addition to impacts on the park caused by visitors within the park, there is also the potential for an increasing Virginia Beach population surrounding First Landing to create hazards as well. According to Weldon Cooper Center for Public Service (2017), the population of Virginia Beach is projected to continue growing through at least 2040. As the population in an area increases, the environment is generally subject to increases in air and water pollution (Mittal and Mittal, 2013). There may also be pressure for land to be taken from First Landing in order to accommodate the necessary housing or industry needs for a larger population. Continued protection of First Landing from being purchased for urban development is important for preservation of its unique environments and wildlife.

III. Vulnerabilities of First Landing to Climate Change

A. Changes in Surface Temperature and Precipitation

Due to both the soil composition of First Landing as well as Virginia Beach's susceptibility to droughts, the area is vulnerable to the hazards caused by changing temperatures and precipitation patterns.

A large portion of the soil in First Landing is composed of sandy soils, including trail areas (Division of State Parks, 2000). Sandy soils are highly susceptible to wind and water erosion due to their poor structure and tendency to lose moisture quicker than other soil types (Agriculture and Agri-Food Canada, 2014). As more intense

precipitation events and hurricanes occur more frequently and for longer durations in terms of rainfall amounts and wind speeds, the rates of erosion will most likely increase causing habitat degradation for wildlife and damage to recreation areas such as hiking trails, which are already vulnerable to erosion due to the high amount of usage in these areas.

First Landing is also particularly vulnerable to increasing drought frequency projected by Strzpek et al. (2010). In areas where drought frequencies are projected to increase, it is possible that some areas with a high water storage capacity (i.e. mountain regions in the western United States) may be able to offset the effects of droughts through effective management of stored water (Strzpek et al., 2010). Strzpek et al. (2010) assess an area's drought vulnerability by dividing total water storage by mean annual runoff (MAR), with a lower number representing an area is less vulnerable and a higher number representing an area with higher vulnerability. Virginia as a whole, and particularly the coast, has a very low water storage capacity to MAR ratio which means that management strategies for minimizing drought impacts will be limited.

Species in First Landing that are living near the southernmost border of their geographic ranges are also vulnerable to increasing temperatures projected by IPCC (2015). As discussed in Section IIA, these species will have to migrate to new areas within their physiological limits. However, at the rates at which temperatures are projected to increase it is likely that they will be unable to do so quickly enough. This vulnerability is also increased when considering that more frequent and longer heat waves are projected to occur as well (IPCC, 2015). More frequent and longer heat

waves could cause more immediate local or total extinctions through massive die-offs of species that are near their physiological limits such as the mass die-off of eelgrass in the summer of 2015 (Najjar et al., 2009). These local and/or global extinctions would change biodiversity within First Landing, which may cause imbalance within ecosystems, although research would have to be done to determine the extent of how these potential extinctions would affect ecosystems within the park.

B. Invasive Species/Migration of Non-native species

The threat of invasive species such as Japanese Stilt Grass and Red-eared sliders make native species vulnerable due to being out-competed for resources needed for survival causing native species to either be forced to migrate to new habitats or to become extinct either locally or globally.

Japanese Stilt Grass is shade-tolerant which allows it to overtake native species in the forest understory (Leicht et al., 2005). Since it also appears to lower soil pH, it may also create areas where, even if the Stilt Grass is eradicated, native species would not be able to survive in such soil conditions. This not only makes native plant species vulnerable to migration/extinction, it also affects the numerous species that rely on low-lying plant species for food, shade from heat, shelter, or other needs. This may weaken native species fitness, leaving them more vulnerable to climate change impacts.

Red-eared sliders have been shown to compete with native species for resources, generally out-competing native species when resources are limited (Pearson et al., 2015; Polo-Covia et al., 2011). In addition, they have been found to have greater fecundity and reach sexual maturity at an earlier age than a majority of other turtle

species, allowing them to grow their population faster than other native species (Perez-Santigosa et al., 2008). These factors will likely make native turtle species at First Landing vulnerable to climate change impacts, as having limited resources favors Red-eared sliders. If Red-eared slider population becomes too high, native species will have to find new habitats in order to survive. However, this may be difficult due to First Landing's location surrounded by urban development which reduces the possibility of finding suitable nesting sites as well as increasing storm and hurricane intensities causing erosion in potential nesting areas as well. If native species are unable to adapt to these difficulties cause by climate change and Red-eared sliders, it is possible that several native turtle species may become extinct without significant intervention.

IV. Foresight on Climate Change at First Landing

Foresight into possible futures of First Landing due to climate change can be developed using a scenario-based approach, considering different scenarios based on projections of future surface temperature and Virginia Beach population. Considering three possible projections and scenarios, potential impacts of these scenarios on First Landing wildlife and recreation are discussed. Projections and possible scenarios for future surface temperature are based on the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC AR5), and projections/possible scenarios for Virginia Beach population are based on Weldon Cooper Center for Public Service Population Projections (IPCC, 2015; Weldon Cooper Center for Public Service, 2017).

A. Surface Temperature

The IPCC AR5 uses Representative Concentration Pathways (RCPs) based on future CO_2 emissions to make projections of future surface temperatures by 2100. These RCPs represent different scenarios regarding future CO_2 emissions based on factors such as climate policy, land use, population, technology, etc. (IPCC, 2015).

RCP2.6 represents the stringent mitigation scenario where efforts are made to significantly reduce GHG emissions. Under this scenario, atmospheric CO_2 concentrations are projected to be no higher than 500 parts per million (ppm) with an increase in global mean surface temperature of 0.3-1.7 ^{o}C by 2100 compared to 2005 (IPCC, 2015). There are two intermediate mitigation scenarios, RCP4.5 and RCP6.0. These scenarios project atmospheric CO_2 concentrations between 500-700 ppm and an increase in global mean surface temperature of 1.1-3.1 ^{o}C by 2100 (IPCC, 2015). The "business-as-usual" scenario, RCP8.5, is based on no efforts being made to reduce CO_2 emissions. RCP8.5 projects atmospheric CO^2 concentrations to be as high as 1500 ppm, with an increase in global mean surface temperature of 2.6-4.8 ^{o}C by 2100 (IPCC, 2015).

Under all scenarios, the frequency and intensity of extreme precipitation events are projected to increase (IPCC, 2015). In addition, the hurricane intensities in both precipitation amounts and wind speeds is projected to increase although hurricane frequency is not expected to increase (Rahmstorf, 2018).

B. Virginia Beach Population

According to U.S. Census Bureau (2017), the population of Virginia Beach as of 2017 is approximately 450,435. The Weldon Cooper Center for Public Service

projected the possible future population through 2040 (Weldon Cooper Center for Public Service, 2017). By 2020, it is projected that the population will reach 467,134 (3.71% increase). The projected population by 2030 is 482,578 (3.31% increase), and by 2040 it is projected to reach 491,054 (1.76% increase) (Weldon Cooper Center for Public Service, 2017).

Based on the percent change in population every 10 years, the population is projected is projected to increase but a slower rate each decade. As these projections are not guaranteed to be exact since the future cannot be predicted, the following scenarios are proposed as more broad ranging possibilities to consider.

The first is the low scenario where the population projections are significantly lower than actual future population in terms of percent increase each decade, with the potential for population to decrease at some point. The middle scenario refers to if the population projections are relatively accurate in regards to percent increase each decade. The last scenario is the high scenario refers to if the population projections are well under the actual future populations. These scenarios provide simple possibilities to consider for decision making regarding how to alleviate hazards cause by an increasing (or possibly decreasing) Virginia Beach population.

C. Possible Impacts Considering Surface Temperature and Population Scenarios

1. Wildlife and Biodiversity Impacts

Under all scenarios for surface temperature, average temperatures are expected to increase by 2100. As such, species in First Landing which are near the southernmost border of their geographic range and living close to their physiological limit for temperature would have to migrate poleward in order to survive. Under the

intermediate and business-as-usual scenarios the rate of warming would likely be too quick for several species to adapt quickly enough and migrate to more suitable areas, particular plant and small mammal species (IPCC, 2015). These migrations and/or extinctions of native species would affect biodiversity within the park, potentially disrupting ecological processes such as food webs.

Changes in ecological processes could be further exacerbated by drought, migration of non-native species into First Landing, and potential proliferation of invasive species. Strzpek et al. (2010) also projects that hydrological drought frequencies and durations are expected to increase on the coast of Virginia, which may also negatively impact plant species in particular. It is plausible to believe that currently non-native species may begin to migrate into First Landing as a result of rising temperatures as well, just native species will have to migrate out. In addition, introduced invasive species may be better suited or more adaptable to climate change factors than native species which could accelerate extinctions of native species.

It is impossible to predict how these potential biodiversity changes will impact wildlife at First Landing State Park. Therefore, it is important that research is conducted regularly to determine the extent of the impacts. Research could be a guiding force in decision making by answering questions such as what mitigation and adaptation measures could be taken to protect native species, which native species are most important to protect, or identifying which non-native species are beneficial or detrimental to the park.

2. Recreation and Socioeconomic Impacts

Increases in the population of Virginia Beach will likely create more local visitors coming to Virginia Beach. Combined with out of town visitors and overall more visitors coming to First Landing each year, it is logical to believe that impacts on recreational areas will be more heavily impacted. More foot traffic in trail areas would make trails more vulnerable to damage from erosion, which may already become impacted due to increasing extreme precipitation events (Monz et al., 2010; IPCC, 2015). Trails cause erosion and disturb habitats, and areas where people choose to hike off-trail cause more damage than anticipated compared to designated trails (Marzano and Dandy, 2012). As more annual visitors come to First Landing, it is possible that a higher number of hikers will choose to hike off-trail which would create significant damage to surrounding habitats.

If hurricane intensities increase and the areas where they reach their peak intensity move poleward (Rahmstorf et al., 2018; Kossin et al., 2014), it is probable that stronger hurricanes will impact First Landing more often. If more frequent extreme precipitation events and more intense hurricanes reach First Landing, these storms could damage all areas of the park through wind damage and possible flooding. They could also cause more frequent closures of the park such as the closure in 2016 due to flooding caused by Hurricane Matthew (Satchell, 2016). The campsites and cabins at First Landing generate approximately $10,000 in revenue each weekend alone (Satchell, 2016). In addition to loss of parking fees from hikers and beach-goers, partial or complete closures of the park would cause significant loss of revenue.

V. Decision Making: Stakeholders, Agencies, and Legislation

The following are relevant stakeholders, government agencies, and legislation which should be considered in regards to making decisions, are able to conduct research to aid in decision making, and/or have the ability to put these decisions into action through groundwork or funding.

Two different state agencies have identified as important to decision making as a source of expert knowledge and in facilitating research: The Virginia Department of Conservation and Recreation (DCR) and the Virginia Department of Game & Inland Fisheries (DGIF). The Virginia DCR is the primary government agency involved in protection and maintenance Virginia's state parks as well as the primary leader in recreational planning. They allow for visitors to enjoy recreational opportunities while maintaining soil and water quality as well as conserving protected lands and wildlife within these lands and state parks as a whole, as well as provide tools for conservation of natural resources (Commonwealth of Virginia, 2018). In addition, they have the following goals and responsibilities: provide funding for recreational opportunities; publish and distribute Virginia Outdoors Plans (Virginia's statewide plan for conservation and recreation) every 5 years; and update existing State Park Master Plans every ten years (Virginia Department of Conservation & Recreation, 2016a). The Virginia DGIF is responsible for managing and conservation of inland fisheries, wildlife and habitats throughout Virginia while also allowing activities such as hunting, fishing, boating, education, etc. (Virginia Department of Game & Inland Fisheries, 2018a).

Management at First Landing State Park is one of the primary stakeholders that should be considered in making decisions, as they will likely be the main group that will be fulfilling decisions made. The local Virginia Beach Community is also an important stakeholder as decisions made and actions may impact their lives; therefore, communication with decision makers and the community is important for their continued support of the park. There is also potential for the local community to be a vital resource for fulfilling decisions made and overall maintenance of the park through volunteer efforts in cooperation with First Landing management, as well as possibly funding through donations. The local community should also be urged to participate in public input meetings held by the Virginia DCR to have input into future editions of Virginia Outdoors Plans.

The Virginia State government and Virginia Beach Local Government may be influential in decision making and will most likely be important organizations in providing funds to the Virginia DCR to fulfill conservation goals.

All decisions made must be done so in accordance with Virginia Code of Law, Title 10.1. Conservation, Chapter 2.Parks and Recreation, § 10.1-200.1. State park master planning.

VI. Options for Preserving First Landing Wildlife and Recreation

There are several options to protect and maintain wildlife and recreational opportunities at First Landing from the threats of climate change. The following options have been identified as possible options that could be either easily accomplished, are relatively inexpensive, or will be important to further

understanding of the effects of climate change to best equip those involved in conservation efforts.

1. Limiting Trail Erosion

Planning actions to limit or reduce trail erosion in an economically responsible way requires information on the usage of trails. Currently, there is only one trail that accounts for how many people use the trail; the Cape Henry trail, which is the longest at approximately 6 miles. This leaves approximately 13 miles of trail area where there is no monitoring of how many visitors are using the trails, which trails are being used, or of visitor activities on the trails. Wolf et al. (2012) states that for adequate research to be done on the impacts of trails on surrounding wildlife, it is usually necessary for visitor data to be collected (although this should not be the sole variable in determining trail impacts). Wolf et al. (2012) identifies possible monitoring systems and examines both the advantages and disadvantages in terms of cost, ease of use, and sensitivity towards short-term fluctuations in visitors for each: direct observation of visitors by staff members; visitor surveys/questionnaires on their usage; and GPS tracking. Establishing one of these monitoring systems or a combination would provide visitor data that is required for adequate research on the impacts of trails as well as to identify which trails are the most vulnerable to damage and should be prioritized in management decisions.

2. Establish New Management Techniques to Minimize Recreational Impacts

Since much of the trail areas at First Landing are composed of sandy soils and according to Agriculture and Agri-Food Canada (2014) sandy soils are most vulnerable to erosion, protecting these areas will be important to sustain recreational

opportunities. For example, the use of mulched rip lines could be used to reduce water erosion by reducing slope length to prevent runoff from gaining significant speed (Tasmanian Government, 2014). Another example would be to reduce the slopes of all trails to well under 7%, which is recommended by the National Park Service to best prevent erosion; however, all trails must have at least some slope to allow for water drainage to prevent flooding (National Park Service, 2018). These are only two possibilities to combat erosion, and other methods could be researched and implemented if they are found to be more practical, cost efficient, or effective.

3. Research on Ecological Impacts of Invasive and Non-Native Species

Research on the impacts of invasive species and non-native species that may potentially establish populations at First Landing will aid decision makers to identify things such as which species are a threat to conserving native species, which species will have little no impact, or which may have potential benefits. For example, identifying these species will better direct efforts in eradicating problematic species and prevent resources from being wasted controlling species which may not cause any ecological damage. Further understanding of these species could also provide information that could help develop more efficient methods of removing problematic species.

4. Develop Citizen Science Program

Since it would be nearly impossible for the staff or researchers at First Landing to account for all signs of climate change, the more people looking for these signs the better. Developing a citizen science program that informs the local community and/or First Landing visitors of warning signs or evidence of climate change impacts would

help stakeholders in gathering information needed to make informed decisions. In addition, the program will also raise awareness on the threats of climate change at First Landing and help to promote the importance of conservation and management of the park from these threats.

VII. Recommendations for Preservation

The threat of climate change is likely to have severe impacts on the wildlife and recreational opportunities at First Landing. Due to its ecological and socioeconomic importance to Virginia Beach, Hampton Roads, and the state of Virginia, it is imperative that adaptive measures are taken in order to ensure its preservation. In order to make appropriate, effective, and well-informed decisions, additional data must be collected and new knowledge created to best equip those responsible for its preservation to take actions towards adaptation and mitigation strategies to minimize climate change impacts. Therefore, the following recommendations are made based on the previously stated options.

1. Collect Data on Trail Usage Via GPS Tracking

Use of GPS tracking to monitor trail usage will provide more accurate counts of the number of visitors using trails, which trails they use, and their activity on the trails. Wolf et al. (2012) found that of the methods to collect data on the usage of trails, GPS tracking provided three advantages compared to visitor surveys/questionnaires and direct monitoring by staff: 1) it is unbiased; 2) provides the most data; and 3) allows for multiple sites to be track activity on the trails. Visitor

surveys were found to be unreliable as not everyone can be surveyed and the accuracy of survey answers could be biased or inaccurate due to memory. Direct monitoring by staff would require at least one, if not several employees to monitor all trails to provide the most accurate results. Even so, the amount and types of data may be limited (such as whether hikers ran or walked, how many hiked off-trail, etc.) and counts from staff could also be inaccurate. Therefore, GPS tracking would provide a variety of accurate types of data that would best equip those involved to develop adaptation and mitigation strategies to maintain the trails at First Landing.

2. Research on Potential Effects of Invasive and Non-Native Species

   Thorough understanding of invasive species in the park and identifying species which may establish themselves at First Landing is essential to best focus conservation efforts towards controlling species that may cause the most damage, as well as identifying which native species are most at risk from threats of invasive/non-native species. Therefore, resources should be committed to researching the potential ecological effects of invasive species, along with identifying non-native species that may soon be established in First Landing and their potential impacts as well. This will provide a solid foundation of knowledge and data on which appropriate decisions and actions can be based upon in regards to minimizing ecological damage of these species.

3. Develop Citizen Science Program on Climate Change Impacts

   Development of a citizen science program to educate the public about climate change impacts, how to monitor these impacts, and allow them to report findings to First Landing personnel. This program would provide a relatively inexpensive yet

effective way to aid stakeholders in gathering research data, educating the public on climate change threats, and promoting the importance of conserving recreational opportunities and wildlife at First Landing.

Although the threat of climate change will almost inevitably impact First Landing recreation and wildlife, implementing these recommendations provide a solid starting point for those involved in protection and maintenance of First Landing to begin the mitigation and adaptation process against climate change while providing essential information on which future decisions can be made.

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