Strategies for controlling invasive species while also allowing for, and facilitating ecosystem adaptation to changing environmental conditions.

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1.0 Executive Summary

Under the conservation leadership program, case studies are selected an applied to certain natural areas to try and benefit stakeholders facing wicked problems revolving around climate change. Paradise Creek Nature Park is a natural park found in urban Portsmouth, Virginia. Due to the area being once a landfill and therefore a disturbed habitat, invasive plant species have moved into the area. Combining the problems of invasive species specifically privet with the future consequences of climate change leads to an overall wicked problem of balancing and maintaining the park successfully. Certain key aspects will be looked at specifically defining the wicked problem, hazards, vulnerabilities, stakeholders, foresight, and an overview of interventions and suggested recommendations. Stakeholders include the Elizabeth River Project and the City of Portsmouth. Vulnerabilities location of park, history of the park (disturbed habitat) and the vulnerabilities of wildlife and plants at Paradise Creek Nature Park. Hazards include sea level rise, temperature rise, precipitation changes, privet, and resource limitations. The future of the park will be looked at through foresight scenarios looking at both privets future as well as high and low emission scenarios determining the rate of climate change. Finally, interventions and suggested recommendations will be given highlighting specific reasonable possible actions the park can make. These recommendations include methods of privet removal as well as the use of continued research at the park and citizen scientists.

2.0 Introduction

Paradise Creek Nature Park is a 40 acre nature park found in south-eastern Virginia in Portsmouth along the Elizabeth River. This park was created as a natural area for the public in a very urban area. The park was originally a landfill and was renovated into a natural area and is a model for urban river/wetland restoration. A large area of the park has been converted to natural wetlands bring back species that have not been seen for decades. The park is still relatively new, many projects have improved the natural areas health and more projects continue to this day. Paradise Creek Nature Park (PCNP) is a park under the non-profit organization known as the Elizabeth River Project. The organization tries to restore the Elizabeth river and the surrounding areas through restoration projects (Elizabeth River Project, 2020). Other programs include river star homes which is a group of homes that abide by certain practices that do not lead to the deterioration of the Elizabeth River (Elizabeth River Project, 2020). Besides restoring the park to a more natural state as well as the river through projects, the organizations other focus is on education. This education can be in the form of field trips, planting, or the learning barge that teaches kids about the Elizabeth river (Elizabeth River Project, 2020. However, the park is also controlled under the city of Portsmouth for general maintenance such as mowing.

This case study looks at the effects of invasive shrub species on an urban natural area and how the park will be affected in the future by the plant as well by climate change. This study also looks at how climate change and other anthropogenic activities will affect the park and the future of privet species at the park. This is a wicked problem because there is a massive trade off being addressed between adapting to natural changes (such as plant growth, sea level rise, and temperature rise) and the management of invasive plants such as privet at the park. On one hand the park must be able to grow and adapt to natural events. At the same time, the question must be asked as when does management become involved and what should or should not be done by the stakeholder parties.

One of the main challenges facing the park is the fact that it was an old landfill and once this area was disturbed, it made invasion easier for undesirable non-native plants (González-Moreno et al., 2015; Wang et al., 2012). Invasive species (such as privet) are a

group of plants that are non-native to the selected areas and is considered detrimental towards the natural area. Since these foreign species are not evolved into the area, there is a decreased chance of predation on these species for a food source (USDA, 2002). The species also has the ability to grow faster than native species or outcompete native plants leading to harmful ecological effects (USDA, 2002). Since one of the main goals of the park is to restore it to a preindustrial environment, invasive species are a major concern. One more numerous invasive species at the park is a shrub known as privet. This species is non-native and is not beneficial to the overall habitat.

Besides the effects of invasive species at Paradise Creek Nature Park, climate change and its effects on the natural environment is another issue for the wellbeing of the park in the future. Due to the wetlands at the park and its proximity to the Elizabeth river, sea level rise is one of the largest concerns when looking at all the effects climate change entails. Climate change will directly affect the structure of the park and its habitat but will also affect invasive species such as privet.

It is important to know the dangers of climate change and the relation it has to invasive species to understand what the future of the park will look like. If more information is known, choices can be made to shift the park in the best possible direction. Privet's interaction with the natural environment may shift especially due to climate change related issues.

3.0 Decision Making

Decision making is in the hands of the stakeholders that have a vested interest and investment into the area. In order to create any viable option proposed to benefit the system, the ideas, attitudes, and goals of the societal agents must be understood. Stakeholders will affect the system but are also affected by its outcomes as well. It is important to know who holds what powers in order to create a future with a desired outcome. There are two main

stakeholders who have a vested interest and have the authority to make positive interventions. These two stakeholders are the Elizabeth River Project and the city of Portsmouth. These are the most important groups that have the ability to create change at Paradise Creek Nature Park.

3.1 Elizabeth River Project

As described previously, the Elizabeth River Project is a non-profit organization that is focused on the Elizabeth River and the surrounding area. The Elizabeth River Project is the number one stakeholder that will be able to create change in order to affect the system in question. It Is important to understand the driving force behind the organization as well as goals. These goals include creating a restored natural area to a point similar an undisturbed habitat before humans manipulated the area. This goal coexists with the idea of removing invasive plant species such as privet in order to create a more productive ecosystem as it once originally was. However as described in the introduction, the Elizabeth River Project is a nonprofit organization, which can limit certain capabilities especially on larger projects. large amounts of work at the park is done by a few individuals (usually two) but volunteers are also an important resource. These volunteers help the park doing certain projects and they also become more connected to their natural area which is surrounded by industrialization. However, these volunteer groups are not proficient enough to complete all tasks at the park. Volunteers are also restricted from certain management activities due to liability issues. This can again hinder the park with already limited human resources. The organization also holds certain standards and rules to what can be done to manage the park. For example, certain methods are preferred over others

3.2 City of Portsmouth

While the City of Portsmouth does not affect day to day management of the park, the city still has some power. One of the main duties that is accomplished by the city of Portsmouth is general maintenance limited to just mowing grass at the park. They also benefit the park by maintaining paths and using heavy machinery. However, the city does cut, water,

prune, or assist the park in any other ways. However certain interventions implemented at the park may need to be processed through the city rather than the Elizabeth River Project. This is especially true if the interventions change major characteristics of the park or has the ability to affect other areas.

3.3 Goal Statements

The Elizabeth River Project compared to the city of Portsmouth has a more invested interest in the biological and habitat issues related to the park itself. The city of Portsmouth while does have an interest is more directed towards the human interaction with the park and general maintenance. While on the other hand, the Elizabeth River Project looks at how the public interacts with the park as well as with the natural environment and allows them to be more educated on environmental causes. The Elizabeth River Project was created to restore the Elizabeth river and therefore the park is an extension of that. The organization's goal is to bring back habitats to what they once were originally. As this being the case, the paper is directed towards the Elizabeth River Project especially concerning the explanation of the wicked problem as well as interventions/recommendations.

4.0 Wicked Problem of invasive Plants

In order to develop a meaningful management strategy for the park, it is important to create a consensus on how the park should be maintained over the next few decades considering the potential impacts of invasive species, climate change and sea level rise. Managing the park with the overall goal of managing invasive plants such as privet while allowing for natural ecological and climate related affects is a wicked problem. The solution that is desired by the stakeholders will shape what the wicked problem is. How they observe the park and the future hazards as well as using foresight will shape how the problem is addressed. As the name implies these problems are very difficult to solve or even solve at all. There are many moving parts and entities involved in the system, some of which cannot be changed. There is a set of ten characteristics that define what a wicked problem is described below.

There is no definite formulation or definition of a wicked problem, it depends how the problem is looked at from the viewer on how solutions will be determined. This is the case for PCNP, the problems facing PCNP may be different than other natural areas with similar circumstances. Wicked problems also do not have a stopping rules, natural growth and climate change are continually changing entities that do not stop. The solutions to answer the wicked problem at PCNP is not wrong or right but is deemed better or worse by the decision maker/stakeholders. Also, these solutions cannot be tested, and the solution chosen will affect the system and cannot be reversed. If a herbicide is used as a possible solution and turns to be harmful to native species, it cannot be reversed. Each solution put into place must be thought out carefully and each attempt counts dramatically to the overall system. Even though there may be other natural areas with a similar problem, each wicked problem is unique, and the circumstances will always be different leading to different outcomes. For example, there might be privet at another natural area however the location, stakeholders, and severity may all be different. Wicked problems have origins from other wicked problems like a chain reaction. Due to increased human dependence and use of fossil fuels there is an increase in CO2 which increases the rate that the climate changes for example global temperature shifts. Finally, the creator and implementer of the plan has no right to be wrong, if a choice is made and has negative effects, they are solely responsible. Another way of understanding the system is to use a conceptual map as shown in **Figure 1**. This map allows the viewer to see how each entity and part of the system interconnects with one another. While this map is rudimentary it can show the interactions of climate change on the park specifically the plants, both native and invasive species.

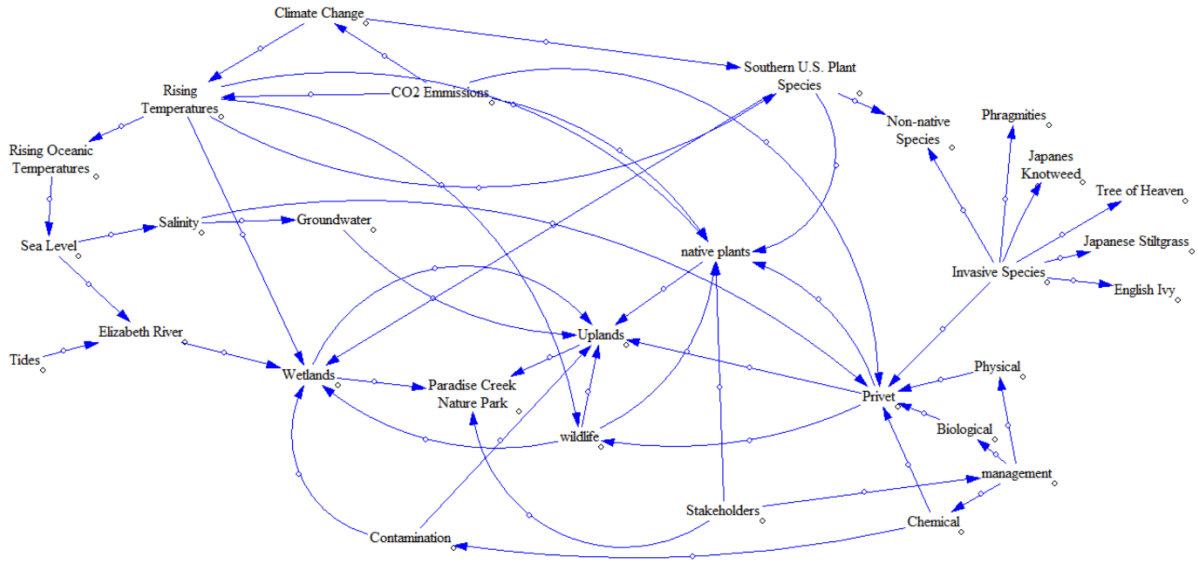

Figure 1 Conceptual Model

4.1 Invasive Species

As described previously above, invasive species are a species that is harmful towards the natural area found at PCNP. The wicked problem concerning privet is the eradication and removal of the plant. With the overall wicked problem being managing invasive privet while allowing ecosystem adaptation to climate change. There are many different reasons why invasive species are hard to eradicate and is also compounded by constraints at the park itself. Privet is also not the only invasive species found at PCNP. Other invasive plant species include tree of heaven, phragmites, English ivy, Japanese knotweed, and Japanese stilt grass to name a few. Although this paper will focus solely on privet due to its higher abundance compared to other invasives.

There is not just one reason why privet is difficult to eradicate at PCNP. First of all, due to how the plant grows, cutting the shrub at the stub will only lead to continuous growth and not kill it (USDA, 2002). Other methods of removal include pulling, herbicide, and theoretical biological controls (USDA, 2002). However, these methods all have their own costs/rewards to consider. Resources and consideration of the organization's goals and ideals shift what can be

done at the park itself. Since the Elizabeth River Project is a non-profit organization their budget does not allow for extensive spending on projects such as these. The city of Portsmouth does also not assist in removing invasive species as well and is therefore ERP is responsible. The parks goals are also eco-friendly focused and therefore practices for removing privet in other areas cannot be used here. Wetlands are also nearby which have been carefully restored and certain methods such as chemicals may be detrimental.

Besides the problems of removing the plant from the ecosystem, privet also affects the native plants and wildlife which it inhabits (Hanula et al., 2011). Since this natural area was recently created, it is hard to see what the ecosystem was like without privet and how the species naturally interacted with one another. However, since the area was disturbed and invasive species have moved in, only educated guesses can be made to see what plants may have been in the area. While other natural areas can give guidance, each area is different in their own ways. For example, if the hydrology of the area is changed it will affect what plants may be suitable which is found at PCNP.

Even though privet is being looked at here other invasive species are still of concern. It is also important to understand and distinguish what an invasive species is. The definition being used for this specific case study encompasses plants that were brought into an area on purpose and then proliferated. Plant movement due to climate change related hazards will not be considered an invasive species even if they are not formally a native species. If species were to move it would be at a slower rate than say privet invasion.

4.2 Climate Change

While invasive species like privet will affect the natural system at Paradise Creek Nature Park, climate change will have a larger overarching impact. Climate change will not only impact the natural system or ecosystem of the park but also the park as a whole. Due to the complexities of climate change, it cannot be addressed directly by the stakeholders. The stakeholders involved cannot stop rising CO2 levels and is therefore stuck with future projection of the climate. Certain climate change induced problems such as sea level rise will have the largest impact due to the proximity to the river. Obviously, the park cannot move its

location or reduce their risk to this hazard through mitigation. The lack of knowledge involving climate interactions on the park can be another challenge. If stakeholders are not aware of how climate change will affect the park it will be a problem for its continual operation as an example of a rehabilitated natural area.

5.0 Vulnerabilities

While hazards and threats are very important in understanding the system as a whole, it is important why these are considered hazards by looking at the vulnerabilities of the system. These vulnerabilities or fragilities of the PCNP system are inherit to the system and unlike the hazards or threats, these cannot be mitigated or adapted to. The vulnerabilities of the system must be known entirely to create and implement a positive plan towards the system in question. These vulnerabilities include location of the park, the parks disturbed habitat, groundwater, and the native species themselves. A table of vulnerabilities can be shown in **Table 1** highlighting three major vulnerability concerns.

One of the most important things in considering interventions or adaptations to the system is to understand that some interventions affect the system as a whole. This means that the possible solution will not just affect the invasive species that are desired but also the native species and ecosystem as a whole. The ecosystem itself is the vulnerability of the system, the ecosystem is interconnected, and any change will have lasting effects. This is what makes this scenario such a wicked problem. The question must be asked whether or not the intervention is an overall positive force or a negative force action on the park. The only way to try and overcome this is to model certain interventions and see what could happen to the system.

The location of the park as described previously is also a major vulnerability. If the area in question was farther inland and at a higher sea level, then sea level rise would not have affect on the system. However, the heart of the park is 11 acres of wetlands and is surrounded by upland forest. No amount of adaptation can be made reasonably to stop the impact sea level rise will have. This vulnerability is shown through flooding or through permanent inundation. While the park is not as vulnerable as some other lower lying areas, this area is especially of concern. Other vulnerabilities that are based off the location is the location of

groundwater at park. The groundwater table is not deep inside the Earth making it incredibly vulnerable to the threat of sea level rise. Also increased climate change will affect surface runoff in coastal areas by raising the water table and in turn affecting the natural ecosystem (Nuttle et al.,1990). The only possible way to try and adapt the system to the vulnerability is to affect the hydrology of the park. This would mean implementing large scale movement of material making the park a higher above the surrounding sea level, or create barriers. This would be incredibly expensive costing millions of dollars the ERP does not have. Even if possible, sea level rise would eventually catch up. On the other hand, the only way to diminish the impact on the vulnerability is to mitigate the hazard. Which as described earlier is not a reasonable possibility.

The natural environment including both plants and animals are also a vulnerability. As most invasive species are not adapted or evolved within the system, they are able to exploit the system. Privet is able to compete with and displace native species found at the park because of the rapid maturation and manner of seed producing (USDA, 2002). The problem is also compounded by the fact that the park was once a landfill and was a disturbed habitat once rehabilitation started to take place. Disturbed habitats have a higher rate of invasion to invasive species compared to undisturbed habitats (González-Moreno et al., 2015; Wang et al., 2012). This is not to say that invasive species cannot invade a none disturbed habitat, but it may be more difficult to start out in. If there is an area that has a disturbed habitat, the species will colonize that area in the early stages of invasion and then move to non-disturbed areas (González-Moreno et al., 2015).

The native plant species including invasive privet species are also vulnerable to changes in soil saturation. When sea level rise reaches a certain point, the groundwater will contain more saltwater coming from the wetlands. The plant species in the upland forest of the park are not adapted for this type of salinity. The rise in salinity of the soil will also affect privet which is considered a moderately sensitive plant to saltwater (Blaylock et al., 1994). Even a moderately sensitive plant species can still experience plant suppression (Blaylock et al., 1994). Even though this seems like a positive affect, other plant species at the park will suffer as well (Blaylock et al., 1994).

Vulnerabilities of Paradise Creek Nature Park			
Name of Vulnerability	Location of Park	Park History	Native Plants/Wildlife
Details of Vulnerability	• Water table level • Proximity to river • Sea level	• Disturbed habitat (leading to invasive invasion)	• Habitat restraints • Not resistant to invasive species • Survivability restraints (salinity, shad tolerance etc..)

Table 1 Vulnerabilities of PCNP

6.0 Hazards and Threats

Paradise Creek Nature Park has reshaped and changed the area that it once was from a landfill to a nature park. While improvements have been made as well as being made to create a productive natural area, certain hazards and threats will affect the park over time. Some of these threats are already present while some threats are not present yet. The threats affecting the park can be broken down into natural climate change related hazards, privet, and human threats. More specifically the main challenges with climate change at the park is in the form of temperature, sea level rise, and shifts in precipitation. These threats affect one another and compounds the wicked problem facing the system. As climate changes rapidly, there will be an effect on the natural system. The hazards listed below provides information to better explain future hazard scenarios that will happen and then will be used in the following foresight section to paint a picture of possible futures.

6.1 Sea level Rise

Paradise Creek Nature Park due to its location along a large tidal river and wetland will experience sea level rise as one of the largest climate change related factors. Due to the large scale of the threat/hazard, there is no way for the park to mitigate sea level rise. The other option is therefore adaptation. Even adaptation may not be feasible in the conventional sense due to monetary restrictions. The park as well as the area surrounding the park already faces some exposure to flooding during strong storms, rain, and hurricanes. There is an overall increase in number of flood events due to a growing number of extreme tides causing excessive problems (Carter et al., 2018). No matter what level of sea level will occur by the year 2100 or even as early as 2050, the effects of a higher and lower scenario will be similar. The impact on PCNP due to sea level rise will still affect species composition, soil salinity levels, and available habitat. The only thing that will be different is the severity of the scenario being used.

Eleven acres of the roughly forty-acre park is tidal wetlands that contain numerous amounts of native species that benefit wildlife. The wetland area has brought back many species that were once extirpated from the area. It is important to know the topography and elevation of the area being questioned when looking at sea level rise. The wetland area is surrounded like a bowl like mound where the water is almost recessed in the ground, this can be seen in **Figure 2**. While this bowl shape is beneficial towards the higher upland areas, the wetlands may suffer due to decrease ability to migrate to higher areas. This bowl shape therefore allows the park to have the ability to not face sea level rise consequences as quickly as other areas nearby. However, an increase in sea level rise will still affect the wetland area and shift distribution of certain plant species.

Figure 2 Wetlands Area Showing Bowl Shape Hydrology (Elizabeth River Project, 2020)

Sea level rise will also affect plant species that are not inhabiting the wetlands as well. Increased sea level will affect groundwater intrusion by the Elizabeth River's salt water. This saltwater will "contaminate" the aquifer used by the species found in the higher elevated parts of the park.

6.2 Regional Temperature Shifts

Due to an increase in CO2 emissions, there has been an increase in global temperatures, which will directly affect the southeast as well. It is important to know that the southeast (especially the area being looked at) has a variety of different habitats and ecosystems (Carter et al., 2018). While this paper is focused on the invasive shrub species privet, temperature changes know no limits in what it will affect. Changes in temperature will influence both invasive species such as privet but also native species as well. This change in temperature will affect the survivability of species and can shift inter-species competition. There will be a change seasonally both in the summer as well as in the winter.

There will be an increase in heat waves compared to anywhere else in the country (Carter et al., 2018). While there has been a decrease in days over 95°F (35°C), the number of nights above 75°F (24°C) have doubled since the early 1900's (Carter et al., 2018). Even with a

decrease in days over 95°F (35°C), there will be an increase of extreme drought due to heat events (Carter et al., 2018). This increased occurrence of droughts has a direct impact on the plants and can even affect wetland ecosystems (Carter et al., 2018; Brock et al., 2003). These wetland ecosystems such as salt marshes also have the ability to transform ecologically due to drought conditions (Carter., 2018; McKee et al., 2004).

Besides increases in heat waves, there will still be an overall increase in temperature over time. This of course is dependent on lower and higher emission models that predict CO2 compared to temperature (Carter et al., 2014). These temperature changes can be both observed for the year 2050 as well as 2100 as shown in **Figure 3** (Carter et al., 2014). This change in temperature will have an effect on both natural and invasive plant species inhabiting PCNP. These increased temperatures will lead to summer heat waves as describe above but is not limited to summer.

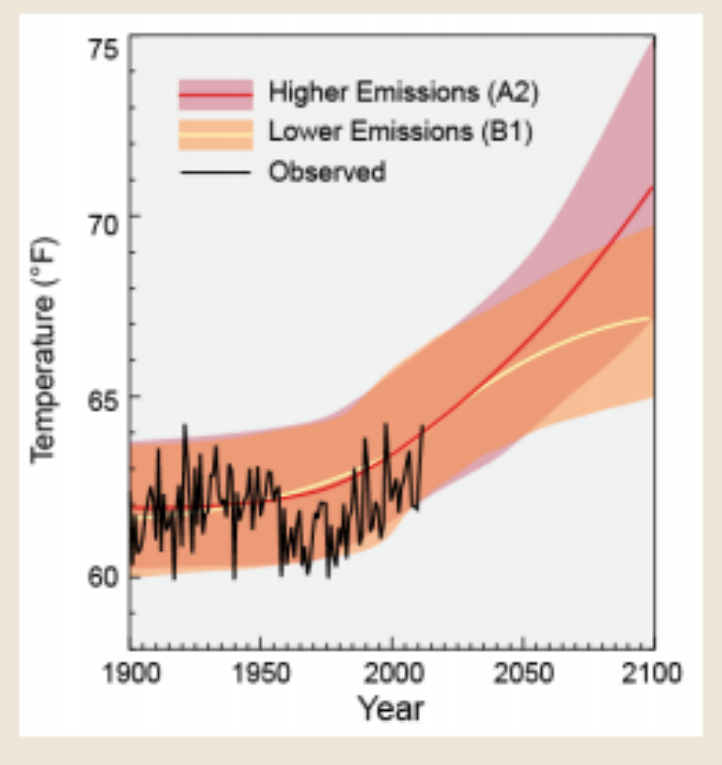

Figure 3 Observed and Projected Temperatures for the Southeastern U.S. (Carter 2014).

Winter temperatures like summer will also experience extreme temperature extremes. Due to climate change, the number and intensity of winter weather will decrease leading to warmer winters (Carter et al., 2018). This shift in winter weather will lead to a prolonged freeze-free season as well (Carter et al., 2018). These changing winter conditions leads to a change in which plants and animals are able to live in a certain area. This can be identified using plant hardiness zones which shows that as winter weather warms, southern species can migrate to warmer areas (Carter et al., 2018). This can be expressed in a plant hardiness zone map showing the ability for plants to survive in new environments shown in **Figure 4** (Carter et al., 2018). This change in winter temperatures can have an impact on the survival of certain plant species found at paradise creek nature park and may allow certain invasive such as privet to thrive. Or on the other hand this increased winter scenario can harm survival of privet, studies of this specific topic were not found and therefore hypothetical.

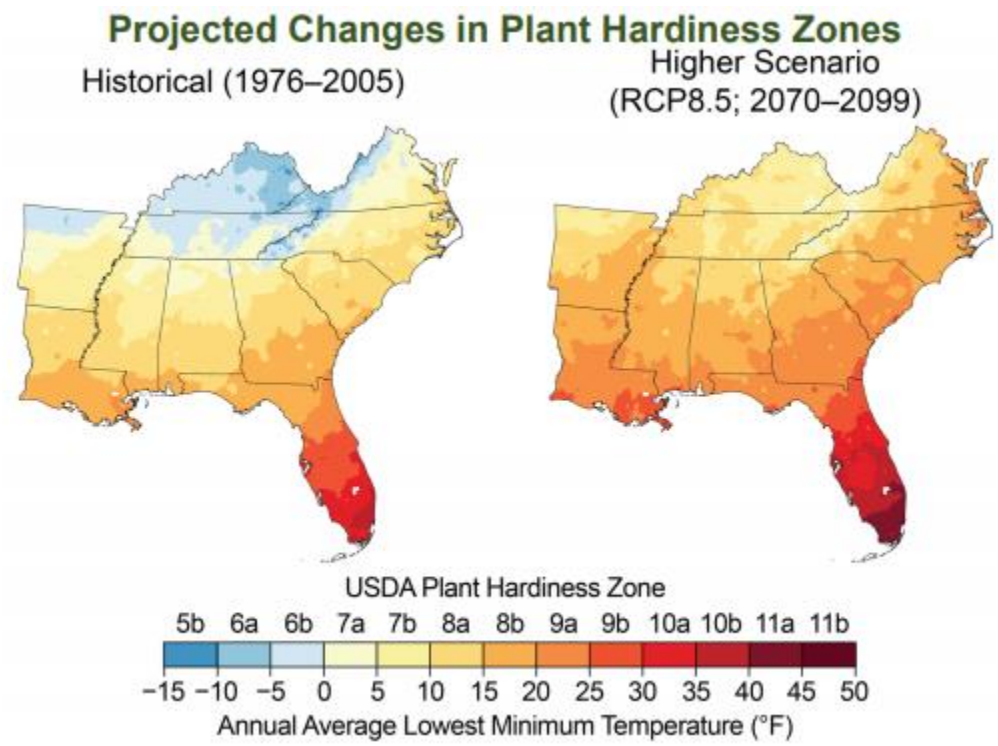

Figure 4 Projected Plant Hardiness Zones of Southeastern U.S. (Carter 2018)

6.3 Precipitation Changes

Compared to the other climate change related factors, future precipitation changes are more difficult to interpret. However, it is predicted that climate change will increase the intensity of the hydrologic cycle in the southeast region of the United States (Carter et al., 2018). This means more intense rainfall events which have been more numerous since 2014 even reaching levels of occurrence which was once only every 500 years (Carter et al., 2018). This increase in heavy precipitation can be shown in **Figure 5** which "shows percent increases in the amount

of precipitation falling in very heavy events (defined as the heaviest 1% of all daily events) from 1958 to 2012" (Walsh et al., 2014). There has also been an increase in the number of days that exceed three inches of rainfall shown in **Figure 6** (Carter et al., 2018). This increase in rainfall affects the number and intensity of flood events previously described in the section above.

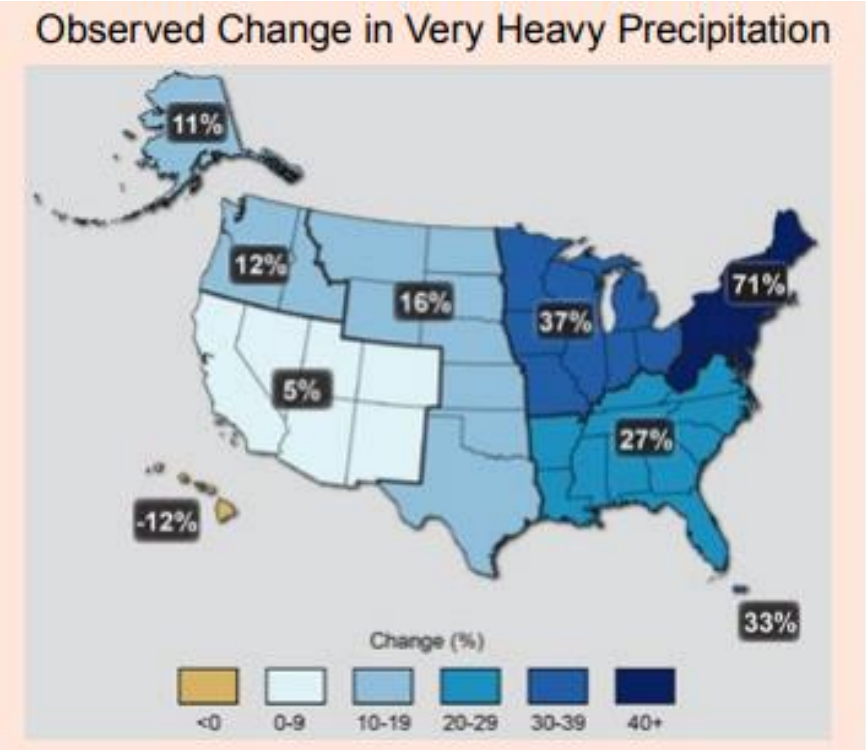

Figure 5 Observed changes in Intensity of Rainfall Events in U.S. (Walsh 2014)

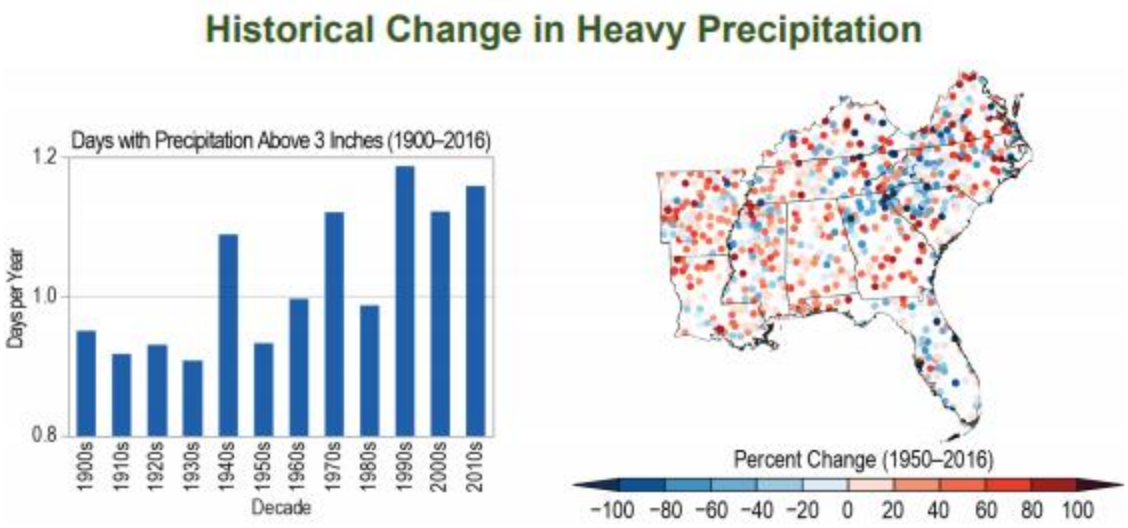

Figure 6 Events of Rainfall Over Three Inches and Heavy Precipitation in Southeastern U.S. (Carter, 2018)

6.4 Invasive Privet

The invasive shrub species privet is the largest invasive species in quantity found at Paradise Creek Nature Park. As described in the wicked problem, privet is a major concern and problem found at the park. There are two main types of privet found at PCNP Chinese privet and common/European privet. While these species have some differences, Chinese privet will be more focused on. However, while both are abundant at the park, more research and information is given about Chinese privet. Therefore, sources will be primarily directed towards Chinese privet, however comparisons can be made with the other privet species.

Chinese privet as the name implies is a native species to china and was brought to America in the mid 1800's as an ornamental plant but escaped from nurseries and parks in Louisiana in the 1930's and is still spreading rapidly to this day as shown I **Figure 7** (USDA,

2002).

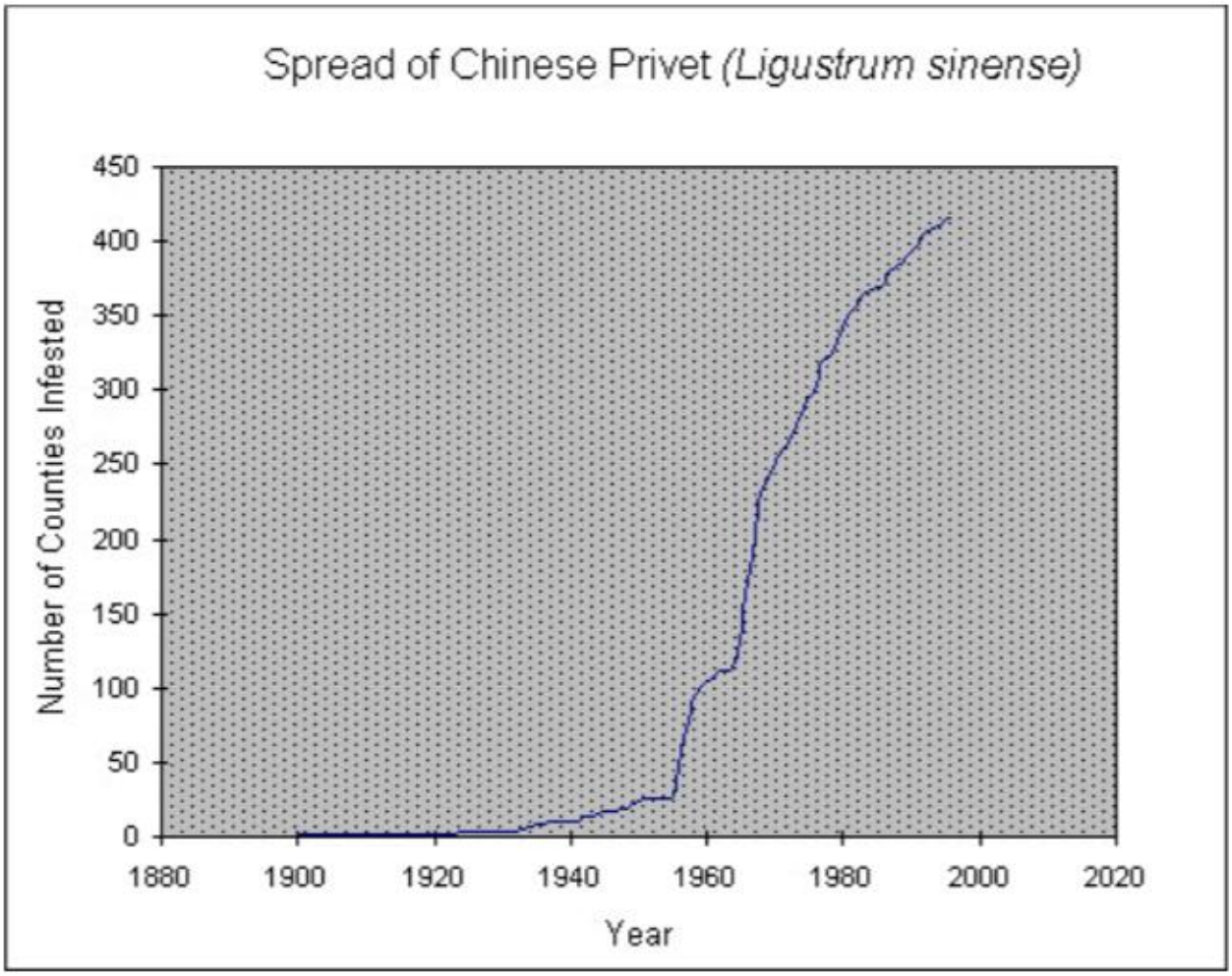

Figure 7 Spread of Chinese Privet Across U.S. (USDA, 2002).

Invasive species are harmful towards the natural habitat they inhabit due to the fact that they are not evolved within the ecosystem. These species are a threat to the natural landscape they inhabit and can even cause health problems in people (USDA, 2002). Privet also has the ability to outcompete plant species that are of particular concern or push a species to extinction in certain cases (USDA, 2002). Privet affects native species by competing for resources and changing decomposition rates as well as affecting nutrient cycling (Mitchell et al., 2011). Privet is problematic due the few restrictions it has in invading a natural area. Privet can be suitable for a wide range of soil types and light conditions (USDA, 2002). While privet

prefers large amounts of sunlight, it can still invade and occupy more shaded areas, especially shaded areas that contain moister soil which the park has (Merriam et al., 2002). Due to the combination of suitable characteristics, areas that have an abundance of privet have a sharp decrease in the number of seedlings of both herbs and trees (Merriam et al., 2002). There is also an overall reduction in number of species found of trees and other seedlings in areas occupied by privet (Merriam et al., 2002). Animal species can also be affected by invasion of privet due to the inadequate food or habitat they supply compared to native species they evolved with (Merriam., 2002).

6.5 Other Threats/Hazards

There are other concerns that will negatively affect the park as well besides climate and invasive threats. This includes the availability of resources and ability to manage the park itself. If resources are cut either through management or monetary resources, this will affect the park and make the other treats even harder to manage. The goals and Ideals of the park can also be hazardous to the system. If the stakeholders do not have a vested interest in the wicked problem, then the park will not receive proper care and no interventions can be made.

7.0 Foresight

In order to understand what will happen to the future of Paradise Creek Nature Park, there must be an examination of the causes that led the system to be exposed. The most obvious cause that led the system to be exposed to threats was that there was a disturbed habitat which lead invasion to occur. This is also coupled with the fact that invasive species were already in the vicinity of the park making invasion easier as well. The wicked problem being looked at can also be attributed to other larger wicked problems mainly anthropogenic threats. The problems facing the park are also not limited biologically but include climate change related events due to a huge increase in CO2 production. Even creating positive habitats such as the making of the 11 acres of wetland could be argued as a negative in some respects. For instance, now this created habitat is now subject to the threats of sea level rise and other climate change related hazards. The most destructive of the hazards including climate change are large-scale or global processes while the threat of privet is a local process.

However, climate change from global processes will be experienced differently based on certain local processes. The hydrology, height, and tides of an area will shape how the global processes is expressed.

After a detailed and highly understood look at both the threats/hazards and the vulnerabilities it is possible to create future scenarios using foresight. Combining both vulnerabilities with the hazards/threats can show a wide range of futures. The most effective way of imagining these futures is using a scenario-based approach. This does not mean that this scenario will happen, or these are the only scenarios that will occur. However, the scenarios created will give a baseline for some of the future threats and challenges that will arise. These futures are key for the stakeholders because they can look at these scenarios and create different interventions for the same future.

Some of the threats explained earlier have already been acted upon to move the system towards a desirable future. The invasive shrub privet has been eradicated in some areas and has had some success. However, there is still prolific stands and areas dominated by this plant. The future of the park can learn from the outcomes of each of these experiments. Another important management technique that has already been enacted is the landscape of the park itself. As described in the threats/hazard section sea level rise, the park is in the shape of a bowl that is raised higher than the wetlands and therefore above sea level. This implementation of landscape is one of the best natural tools to slow the effect sea level on the upland area of the park. While sea level rise will still have profound impacts on PCNP, it may not show as severe compared to other areas on the Elizabeth river. If this is true, then the importance of this natural area for wildlife will be compounded. Each of these experiments however cannot be undone and the affects can be permanent to the park itself.

The following sections will contain numerous possible scenarios in order to get some understanding of future challenges. It is important to know that not all scenarios can be listed or even thought of and these are a simple outline of some of the important concepts. This includes a general perspective of what invasive species like privet will look like in the future. The other important concept is looking at the range of severity for climate related threats most

importantly sea level rise. There is no doubt that climate change will have a profound impact upon this area, it is just the matter of intensity that is up for debate based of climate assessments and emission scenarios. The projections on future climate can best be examined using Representative Concentration Pathways (RCP) which contain a wide range of scenarios. The two RCP scenarios that will be used is a higher scenario and a lower scenario (USGCRP, 2018). Even under the lower possible scenarios, there will still be profound effects on the climate. The scenarios listed below will be discussed without the intervention of possible solutions in order to create a purer image of the future. Then interventions can be made in the following section explaining possible solutions.

7.1 No-Action

One of the simpler scenarios to envision is the no-action policy, this is not to be confused with a business as usual scenario. A business as usual scenario still has management and intervention at some level while no-action as the name implies means the system is let to run itself without intervention. If the Paradise Creek Nature Park system were to run naturally, the natural system would deteriorate. Invasive species such as privet would spread and outcompete native species. Privet growths would overtake all the areas cultivated for natural plants and deteriorate the habitat that had been created. This would decrease habitat and quality for wildlife in the area. However, it is important that not all wildlife would be affected and that sometimes the native plant species are more affected than wildlife. A study in a southeastern nature preserve even when large stands of privet were found, bird population was not affected (Wilcox et al., 2007). These bird species though not affected will still shape the park by eating and spreading privet berries making privet a larger percentage of the park. However important pollinators such as bees have been linked to decrease species richness and abundance in areas dominated by privet (Hanula et al., 2011). An increase in atmospheric CO2 levels due to human increase in emissions has been shown as a positive factor in the growth of Chinese privet (Smith et al., 2008). This was shown in an increase in both biomass in number of branches from the shrub (Smith et al., 2008). This means that Chinese privet will be harder to manage and a stronger competitor with other native species in the future. Climate change

factors such as temperature rise, precipitation, and most importantly sea level rise will occur. These climate threat scenario's will be explained in the following future scenarios.

7.2 Business as Usual

The business as usual scenario will be somewhat similar to the no action scenario. The threats have not changed and are still a serious problem. Chinese privet will still become better acclimated to an environment with a higher CO2 concentration both under lower and higher emission scenarios. However, the difference between no-action and business as usual is the current management plan. The park does manage invasive species such as privet to a certain level however, resources are not plentiful enough to focus on this large task. Volunteers and employees do manage some stands of privet. Without careful removal and watching the area, invasion will occur again if left untreated.

7.3 Lower Emission Scenario

The first climate-based scenario is the lower scenario based on lower CO2 emissions, lower human population growth, and an increase is CO2 reducing technology (USGCRP, 2018). Two dates are most commonly used to predict future scenario's; the year 2050 and the year 2100. While temperature shifts can both been seen as soon as 2050 and definitely at the year 2100, sea level rise is different. Therefore, sea level projections will be based off the year 2100 while temperature is given more freedom. Under the low scenario based upon RCP4.5 sea level will rise anywhere between 1-4 feet or (0.3-1.2 meters) by the year 2100 shown in **figure 9** (Hayhoe et al., 2018).Even a small change in sea level rise will have an impact on the park and can be shown using software such as the NOAA sea level rise viewer found in **figure 8.**

Figure 8 Sea Level Rise at 0,1,2,4,6, and 8 Feet from Left to Right at PCNP and surrounding area (NOAA, 20)

This figure while looks promising may not be accurate for such a small or specific area. The bowl shape of the wetlands area provides a strong defense against sea level rise to an extent. Species composition will change in the lower lying areas of the park. Wetland plant species will expand their range from its original area at the park. Increased sea level may increase the salinity of soils which privet inhabits. As described earlier privet is mildly sensitive to salinity, this may lead to a decrease in survivability or competitiveness with native species but also will affect native species as well (Blaylock et al., 1994). As explained in the section

above, an increase in CO2 will positively affect privet, even under lower scenarios such as RCP4.5. It is unknown however whether salinity changes or changes in CO2 levels will affect the species more.

Average annual temperatures will also increase even under lower scenario ranges based again on RCP4.5. Even without looking at future temperature scenarios, temperature will still be projected to increase by "2.2°F (1.2°C) relative to 1986–2015" (Hayhoe et al., 2018). Large increases in temperature are projected both under lower and higher scenarios by the end of the century. Under the lower projection RCP4.5 temperature is predicted to increase by 2.3°–6.7°F (1.3°–3.7°C) and can be shown in **Figure 10** (Hayhoe et al., 2018). This change even under the lower scenario still has the ability to impact they system. An increase in mean average temperature has been shown to increase invasion of privet throughout forested habitat in the southern United States (Wang et al., 2012). Therefore, an increase in temperature will increase the spread of the species. This combined with the other climate forcing will make privet harder to manage in the future.

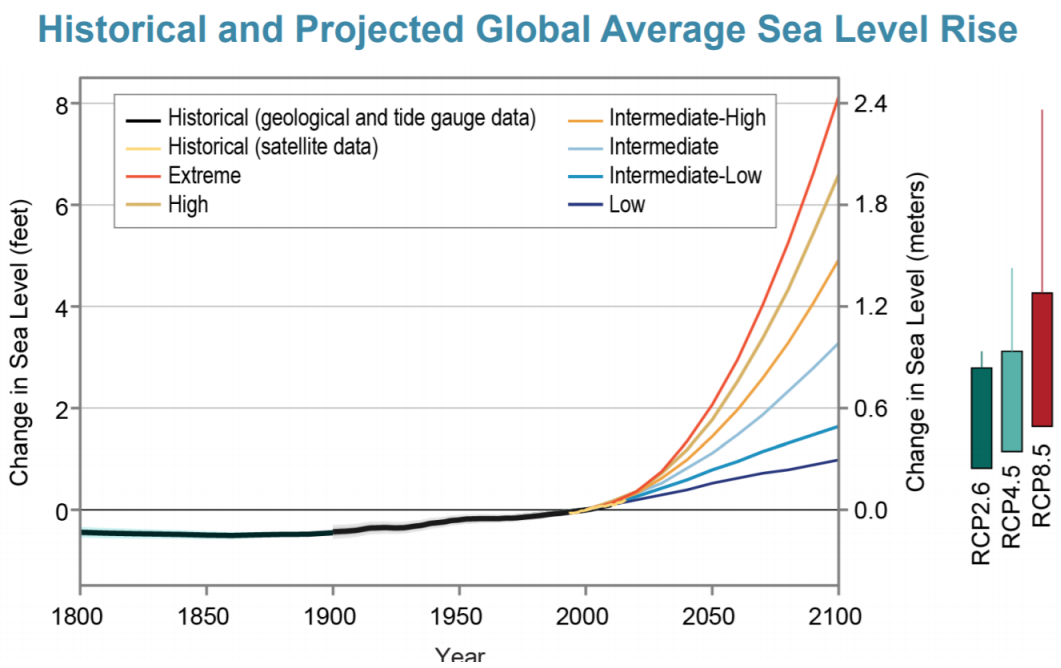

Figure 9 Future Possible Sea Level Rise Scenario's for U.S. (USGCRP, 2018)

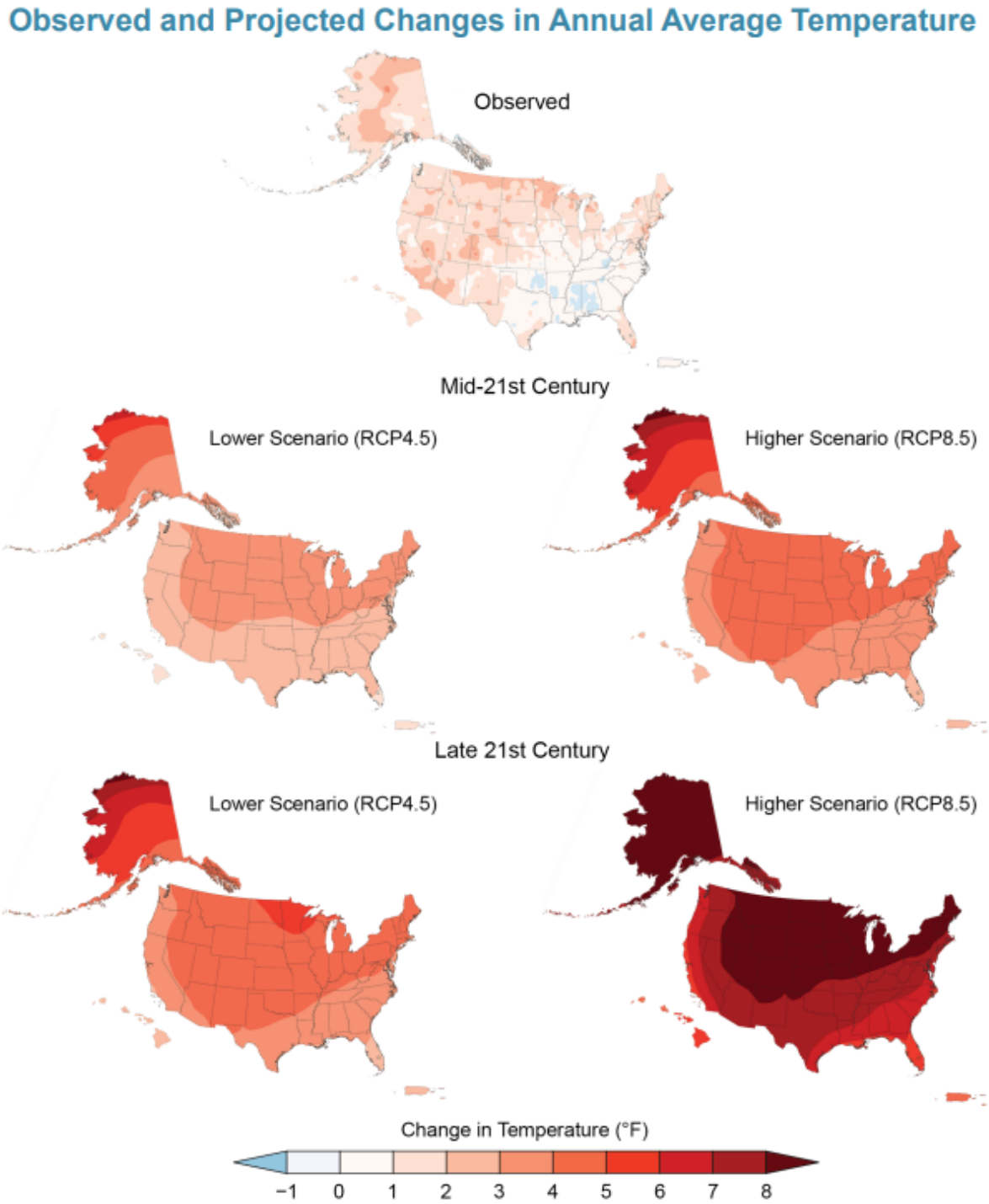

Figure 10 Projected Temperature Change Across the U.S. (Hayhoe, 2012)

7.4 Higher Emission Scenario

The second climate-based scenario is the higher scenario based on higher population growth, decrease in beneficial technology, and an increase in CO2 emissions (USGCRP, 2018). Based on the higher scenario RCP8.5, sea level rise would be much higher in the range of 4 to possibly even 8 feet or (1.2-2.4 meters) by the year 2100 shown in **figure 9** (Hayhoe et al., 2018). While the graph gives a partial insight into the sea level rise in the area it may not be as nicely depicted. As described in the lower scenario, the NOAA sea level tool may not be accurate for such a specific area. Increased sea level under the higher scenario will increase widespread flooding in the area especially surrounding the park at 8 feet or 2.4 meters shown in **Figure 8**. This will most defiantly affect the species composition on a much higher level than under the lower scenario. Sea water will infect the groundwater sources affecting both native and privet, privet will be affected by this level of salinity, but the severity can only be stipulated. Due to the high level of CO2 in the higher scenario privet will also increase in biomass and spread throughout the park. Even though the park may seem to be not as devastated as other areas, the park will become more important for migrating wildlife such as birds. Increased sea level rise will decrease other habitat in the surrounding area making PCNP more important and useful for food and living habitat.

Average annual temperatures in the United States will be even more severe in the higher scenario RCP8.5 than compared to the lower scenario RCP4.5. Under the higher scenario RCP8.5 the average annual temperature predicted by the end of the century is projected to be 5.4°–11.0°F (3.0°–6.1°C) shown in **Figure** 10 (Hayhoe et al., 2018). This greatly increased average temperature will increase the invasion of privet to a higher level compared to the lower scenario (Wang et al., 2012). This increase in temperature will lead to more periods of droughts and heatwaves during the summer, straining both native and non-native species. These increased temperatures will also affect winter months and shifting plant hardiness zones as described previously in section 4.2. This increase in days without freezing in winter and general warmer days will affect wildlife and plants as well. The paper is not focused

on the invasive species of fire ants, however warmer non-freezing winters benefits the fire ants at the park making them harder to manage.

The ecosystem itself regardless of privets abundance or presence has the strong possibility to change. Both plant and animal species as temperatures rise may move northward and possibly into PCNP (Carter et al., 2018). Salt marshes are especially vulnerable towards shifts in sea level rise and temperature changes (Carter et al., 2018). Mangrove forests in the southeast are expected to move northwards as winter temperatures become more favorable. If the ecosystem is to change or new species enter, a new problem emerges. If these species hypothetically move into the system are, they considered native or non-native? How do these species affect the ecosystem that is now currently present? Letting these southern plant and animal specifies inhabit the park is a reality that must be prepared for.

8.0 Interventions

Based on the scenario-based futures described above, possible solutions can be created into interventions that would benefit the system. It is important to know final interventions or possible solutions must co-inside with the goals and ideals of the main stakeholders. The interventions must also be somewhat possible for the park to accomplish. For instance, climate change related threats and hazards cannot be mitigated by the park due to the global scale of the problem. Even adapting to certain climate change related threats is unrealistic such as sea level rise. The park is already adapted to a certain extent to sea level rise due to the landscape and hydrology of the park near the wetlands. However, since this is a wicked problem there is no set solution that will fix the problem entirely. The solution can only be based from better or worse options, and again must satisfy the decision makers/ societal agents involved. One of the largest non-climate related challenges is addressing invasive species such as privet. It may be difficult or even impossible to create a system that is resilient to these species. Even if the species were eradicated from the park in some manner, how would future invasion be stopped.

8.1 Complete Eradication

One possible solution to create a more natural habitat is to completely eradicate privet form Paradise Creek Nature Park. This would require pulling privet pants from their roots, cut and spray with a herbicide specifically for privet, or a basal bark spray. All of these techniques are very effective of killing privet species with limited to no harm to other native plant species if used correctly. Since the park is roughly 40 acres and less of that contains privet, it may be theoretically possible to eradicate the plant from the park. This complete eradication would allow native species to reclaim areas that were once unavailable to inhabit and proliferate. This would have to incorporate the future foresight scenarios previously discussed. Since CO2 levels positively affect privet, more aggressive management may be necessary. However, this solution while ideal would be extremely time intensive, require huge amounts of resources, as well as countless workers dedicated to the project for weeks if not months.

8.2 Partial Removal

Compared to complete eradication, partial removal would follow the same principles of removing privet from the park. However due to the nature and persistence of the plant even complete removal does not stop future invasion. Therefore, certain areas of the park that are deemed most important should be given higher priority and managed intensively. After removal in these certain areas, native species can be planted and hopefully stop or stunt future invasions afterwards. After planting of native species in areas once inhabited by privet, intense management must be implemented in the area to prevent future invasion or encroachment. While this method still allows privet to grow and proliferate in some areas of the park, it may be the only feasible option in the future.

8.3 Bio Control

Due to the nature of the organization that PCNP is run under (Elizabeth River Project) certain control methods may not co-inside with ideals that are held by the park. While chemical control methods can be advantageous and a strong determent in dealing with privet it has its drawbacks. Due to the location of the park to the Elizabeth River, it may be unsafe to use strong chemicals closer to wetland areas. Since the organization prides itself on protecting,

conserving, and restoring the river it may be best to not to use said chemicals. The other methods include hand-pulling and mechanical methods however this is much more intensive and harder to accomplish. Finally, there is a third method that has been used on other invasive species, biological control. Biological control is the use of an organism commonly an insect that greatly affects and decreases abundance of a certain plant species. Studies have shown that insects such as the lace bug that is native to North America can be used as a possible control method for Chinese privet (Kalina et al., 2017). However, this bug species may have negative effects towards other plants or wildlife such as competing insects. Climate change may affect this species to make the area not preferred by the specific species.

8.4 Spray and Cut

While some use of chemical herbicides has been used for spraying of smaller cut areas. Larger areas infested with privet may be harder to manage by cutting all privet down to ground level and then spraying. The other method of killing privet that may be too large to cut down by a single person or too many privet shrubs is the cut and spray method. This requires the person to cut a single ring around the shrub with a saw and then spray the cut ring with the correct herbicide. If done correctly it will not have negative effects on other native plants and this method is used by the U.S. Fish and Wildlife System. This may be more advantageous that spraying directly on cut stumps on the ground. Due to minimized herbicide saturation of soil and decreases time and effort into removing large privet infested areas. The drawback to this method is that the privet shrub will still be standing for a while even while dead and still may shade out other native plants.

8.5 Adapting to Sea Level Rise Biologically

No matter the level of which sea level will rise, it will still be a problem that will affect Paradise Creek Nature Park. As previously stated, any options to create a plausible solution must take in mind adaptation rather than mitigation due to the global nature of the problem. Planting of new plant species may be necessary for the future of the park. Especially plants that are more salt tolerant when instances such as flooding, sea level rise, or saltwater intrusion of groundwater occurs. Future boundaries of wetlands may also need to be reconsidered and see

what upland areas will be left by the year 2100 based under certain scenarios. Since the park and organization has a strong tie with education, this could be used to benefit the park. The Park could possibly have a lesson or plan either with kids or solely staff that determines what each sea level scenario would look like in the wetlands area and create a map. This map can be used to further understand what areas are higher of concern and can be used as a rudimentary model.

However, this case study did not find or identify plant species found in the southeast that may be better at the future climate or salinity levels of future soils. It is therefore imperative for research to be done to jumpstart the ecosystem to a compatible level compared to future climate change related forces. Even without human involvement, species movement may still occur and should not be deemed as an invasive species but rather a naturalized species moved due to climate change.

While salt marshes are already in place and currently in above suitable conditions, sea level rise may drown out and inundate the lower lying areas of the park. The movement and migration of these salt marshes may be hindered by the bowl-shaped landscape surrounding the wetland area. Either the current saltwater marsh grasses migrate to the new sea level or new salt marsh plants dominate the new sea level. Any intervention to fight against this problem would be difficult due to the science of migrating wetlands in relation to steep topography.

8.6 Adapting to Sea Level Rise Physically

Again, the nature of the bowl-shaped wetlands surrounding the wetlands area is one of the best defenses currently used at PCNP against sea level rise. There are however other physical management solutions possible such as implementing allocation of water resources. Due to sea level rise there is a risk for soil to contain an increased level of salinity from instances of flooding, sea level in general, and groundwater intrusion. It may be necessary to try and reshape the hydrology of certain areas that utilize rainwater or other sources of water that is freshwater. This may be difficult to do or resources needed for such a task may be

unavailable. Also, farther into the future climate change related forces will make this option most likely obsolete and therefore this is only a temporary solution on a larger scale.

9.0 Discussion and Conclusion

Overall, this case study focused on privet and its relationship with Paradise Creek Nature Park as well as the future challenges of climate change affecting privet as well as the park in general. The future of Paradise Creek Nature Park will have many challenges and hopefully this case study highlighted some of the key ideas that are most important. Again, the problems facing PCNP is considered a wicked problem where there is no simple solution and the nature of the problem cannot be stopped or eliminated. The impact of privet has already affected the ecosystem even if it is not clearly seen. Privet will only get worse due to climate change factors such as increased CO2 concentrations; however increased water salinity can decrease survivability of privet but also natives as well. Other climate change factors such as increased annual temperatures including warming winter temperatures and summer heat waves will affect survivability and resilience of plants. Sea level rise is the number one threat that will face Paradise Creek Nature Park and cannot be mitigated to lessen its affects. Sea level rise combined with rising temperatures has the ability to transform ecosystems and change species composition and competition between natives and invasive species such as privet. Due to the nature of the problem, the system is vulnerable to adaptations being made. Even if the adaptation is desired to only affect privet, it may harm native plant species as well and negatively affect the system even worse than without adaptation. Any solution/ adaptation implemented will have lasting effects on the park.

Foresight is one of the most important tools in order to conceptualize any sort of future for the park. The main points that should be most important when looking at any future is privet, sea level rise, and temperature. Privet will most likely continue to spread and takeover areas of the park if left untreated due to its positive relationship with CO2 concentration increases. While it is mildly sensitive to salinity in soil moisture, this may not be enough to hamper its survivability. Temperature rise as well as sea level rise are all dependent on CO2

emissions and this paper particularly looked at scenarios based of the year 2100 rather than 2050. The year 2050 while still relevant may discount the future after that. The year 2050 will come and go relatively quickly and it may be more useful to create solutions based off the year 2100. Lower and higher scenarios both entail the same concerns just at a different level of severity. Under the lower scenario temperatures will rise between 2.2°F (1.2°C) and 5.4°–11.0°F (3.0°–6.1°C) under the higher scenario (Hayhoe et al., 2018). Sea level will rise between 1-4 feet or (0.3-1.2 meters) under the lower scenario and 4-8 feet (1.2-2.4 meters) based on the higher scenario (Hayhoe et al., 2018).

The main options for creating a solution to put the system on a positive tract will be focused solely on adaptation when applied to climate but mitigation as well as adaptation can be used when looking at privet specifically. The first solution and second solution is directed at the what level of aggressiveness will be used to manage privet. There is either complete or partial removal of the species, complete removal will be incredibly difficult while partial may be more understandable. Even a partial removal or privet in certain key areas may benefit the ecosystem to some extent. The way of removal however could be changed either to a newer cut and spray method or even possible through biological methods such as the lace bug mentioned earlier. The solutions however for facing climate change and how it will interact with the park including natives and privet is much more complicated. These solutions include the implementation of new species found farther south that may be better adjusted for future climates. Or the creation or movement of water or upland wetlands area to create a better source of freshwater due to possible saltwater intrusion. Then finally there may be a need to implement studies or activities that seek to understand where exactly will the park be affected the most due to sea level rise.

10.0 Recommendations

Due to the nature of this wicked problem which other wicked problems share, there is no one solution that is “right” but only better or worse than other solutions/options. The problems facing Paradise Creek Nature Park will be long lasting and cannot be stopped. The only way to assist the system is to adapt it to its future challenges of invasive species such as

privet, temperature rise, and sea level rise. It is important to recognize that climate change is going to accelerate sea level rise as well as increase air temperatures as well. This increased sea level rise will increase flooding, inundation, and decrease critical habitat for certain species of plants and wildlife. It is important to recognize that climate change especially sea level rise will affect the park and cannot be easily dismissed and taken less serious. Sea level rise will have much larger impacts on the park than privet. It is also crucial to acknowledge that climate change will affect privets interaction with the natural environment especially privet.

It is recommended that the solutions and given recommendations below will be carried out by Paradise Creek Nature Park/ Elizabeth river Project. The Elizabeth River projects overall organization is directed towards these type of endeavors. They have the greatest knowledge base as well as have the largest interest in the wellbeing of the park. However, if possible, resources from the City of Portsmouth would be appreciated for management projects. A few interventions were stated earlier however a combination of certain ideas from each possible solution may be needed for positive results. The park must manage privet only in certain areas of higher risk where important natives are living by any means necessary either by “cut and spray” or strictly mechanical. Privet will most likely not be able to be completely eradicated but management is still needed at some level. Privet even under increased climate related forces will most likely proliferate and adapting the park is not possible in that sense. Privet must be carefully monitored and possibly mapped by another student researcher or citizen scientist in order to focus management in certain areas. When addressing climate related issues, the park should create a program or initiative where citizen scientists or another intern/volunteer looks at and measures the wetland area. These measurements can be used and combined with predicted sea level rise and create rudimentary models of what the park may look like in the future. These models can then be used to see what areas will need the most management or work. These type of interactive science based activities are already implemented in the park and this could be added as a possible option. Overall, there is also no stopping climate change and its effects on the ecosystem. If new plants arrive and proliferate form the southern U.S. they should be allowed to exist because it is not invasive but natural movement.

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