Problem Statement of Invasive Species

The city of Easton has recently seen itself in what many would call an environmental conundrum. Having defoliated the banks along the Delaware River in Riverside and Scott parks (see Figure 1), not only have they removed all the vegetation, but drastically changed that ecosystem. In an attempt to rid these banks of a mixed collection of both native and invasive shrubs, weeds and small trees and of the invasive species Knotweed and Hopvine, the use of AquaNeat, a strong herbicide, has lead not only to an uproar from the town’s people, but also to the loss of growth. With the riddance of all plant life along these banks, both Riverside and Scott Parks are susceptible to not only the regrowth of Hopvine and Knotweed but also to things like erosion, and the growth of other non-native plant species. By involuntary introduction, invasive species out-compete the plants that tend to live in certain areas and are characterized as being able to tolerate wide ranges of environmental conditions. Such species can thrive under various circumstances and hardships. The new situation that stands is the riparian zone that has come in contact with semi toxic glyphosate herbicides and has lost all plants life. What remains now is barren land with an unclear future.

The introduction of herbicide use as a method to deal with the management of the vegetation along Riverside and Scott Parks came after some of the Easton residents complained about its overgrowth. In accordance with “Easton residents decry herbicide use on Delaware River Banks,” typically removed by hand, the management of these parks’ plant growths was something done by hand, which besides being labor intensive, became increasingly expensive.
As city officials received complaints from citizens including fishermen who were struggling to get to the fish because of the vegetation, they found it necessary to strategically find something economical and efficient that would help them maintain it. A disagreement arose about the strategy employed to control the growth and the invasive. Herbicides are commonly used to kill unwanted plants. With unknown environmental and health effects, there is a risk when using them. Different herbicides have different effects on certain plants. In the case of the city of Easton, a prolonged application of herbicides inevitably caused all of the plant life, both native and invasive to be removed. The fear that this caused was for many the idea that their water quality may be at risk was not something they were okay with allowing.

Figure 1: As shown in this map of Easton, PA both Riverside and Scott Parks lie along the Delaware River. The fear is that the chemicals used along these banks can contaminate the water and are easy targets during floods.
The main issue with handling invasive species is trying to find a way to get rid of them without causing any further harm to the residing environment. In the case of the invasive species along the banks of Easton, the Japanese Knotweed and Hopvine both easily reproduce and drastically drain the surrounding ecosystem of its resources and make it increasingly harder for anything else or the indigenous species to thrive again. The Japanese Knotweed in particular reproduces in such a way that it forms solid colonies and by doing so restricts available land and depletes resources that would otherwise be available to other plants.

As previously seen, the use of pesticides and herbicides is something that has more than just zonal effects. Herbicides are created with the purpose of getting rid of something. Zonal herbicides not only affect the areas sprayed, but also negatively impact water quality and the downstream ecosystem. Specifically, AquaNeat, a 53.8% Glyphosate product that is a water soluble and non-selective aquatic herbicide and weed killer, was used in the Easton riverbank riparian zone, and could potentially negatively affect human health.

Japanese knotweed (shown in Figure 2), was brought to America in 1825 from the United Kingdom where it was used as a decoration; it was brought to the United States for similar purposes. Japanese knotweed has been considered a threat to the ecosystem because it is such a hardy plant; they are very hard to kill and as they grow, can cause a lot of damage. As shown in figure 3, one of the main threats posed by the Knotweed is that is can interfere with infrastructure. Japanese knotweed has been cited as the cause of damage in tarmac areas, wall structures, flood defense structures, building foundations and a reduction in biodiversity throughout-shading native plants (it grows a thick canopy as to not allow light into shorter plants and vegetation). It causes this damage to structures because it has a semi-woody root structure which grows deep and apparently can damage materials as hard as concrete by means of finding
weak points when expanding their root system. The Japanese Knotweed also grows from its roots, so to kill it you must kill the roots which grow very deep and are very sturdy. Aside from strength of the growth, the system can grow very quickly from only a portion of its whole, known as its rhizome network. Back in Japan, the plant is controlled naturally by a combination of fungus and insects, however in the United States there is no natural enemy, so the plant thrives uncontrollably. Importing the insects and fungus to help control the plant would most likely cause a bigger problem because those species also have no natural predator here in America.

The Japanese Hopvine, shown in figure 4 below, was also imported to the U.S. in the late 1800s for ornamental use and is causing problems in similar ways as the knotweed. Though the hopvine doesn’t have the destructive roots of knotweed, it may pose a bigger threat on the ecosystem because of how it grows. The hopvine grows by twining up tree trunks to the canopy and ultimately covering the whole tree with its leaves. The leaves absorb all the sunlight leaving none for the tree itself; it essentially chokes the tree to death. One of the reasons Japanese Hopvine is so hard to control is because in order to completely eradicate it, it need to be removed from its rhizomes. If the rhizomes remain the Knotweed will continue to flourish.
Both can be very destructive to the local ecosystem, and because of their location on the bank of the Delaware they have potential to spread downstream and disrupt other ecosystems.

**Key Terms**

**Invasive Species** – A species that does not naturally occur in a specific area that can interfere with other species and aspects of the environment

**Japanese knotweed** (Fallopia Japonica) – highly invasive species of plant that forms solid colonies which choke out other plants, displacing native species, and altering hydrological processes.

**Riparian** – the area of land between a river and land, river bank and interface between land and a river or stream. “Significant in ecology, environmental management, and civil engineering because of their role in soil conservation, their habitat biodiversity, and the influence they have on fauna and aquatic ecosystems”

**Native Species** – naturally occurring species that inhabit an area and fit into an ecological niche or chain.

**Herbicide** – A chemical substance used to destroy or inhibit the growth of plants, especially weeds.

**Germination** - The beginning of growth, as of a seed, spores, or buds
Alleopathy – beneficial or harmful effects that one plant has on another by release of chemicals from plant parts.

Ecosystem – a community of living organisms in conjunction with non-living components of their environment.

Rhizomes – underground network of roots of a plant.

Causes

The city of Easton had not repaired its riverside retaining walls in quite some time. As a result, the city felt it was necessary to inspect the walls, and deem if it was necessary or not to fix the walls. In order to do this, the city allocated workers to get rid of the plants that limited view of the wall. In order to do this the city cut then sprayed the area in a time span of over a year. Upon completion of cutting back the foliage, the wall was bare and ready for inspection. However, two separate instances occurred at this point. One, the local townspeople saw the bare walls and assumed incorrectly that the riverside had eroded away. Before, the plants made it seem as though the bank was much higher up than it now seemed without the plants. Aside from that, various people spoke out against the possibility that the walls, now unsupported by the plant life, would fall over. The walls were originally built without the intention of plant life playing a role in the structural integrity of the wall. This means the public opinions that rose from the cutting back of the plants were unfounded, misinformed, and unjustified.

The second sequence of events that unfolded due to the cutting back of the foliage was that the wall repair people were not properly communicating with the workers that cut back the plants. The riverbank maintenance crew was told to keep the retaining walls clear until they were repaired, while the wall repair crew was busy or not able to immediately respond to such a request. Because of this, the plants along the walls were continuously cut and sprayed on two
occasions. One of the main problems to this system that played has played a significant role in the current situation was that there was a time between the cutting and spraying of the plants, and the actual starting on the wall repair. As they waited for the actual wall to be fixed, which occurred approximately one year after the initial cutting, they needed to keep the wall clear and kept cutting. With each time they cut or on the occasions where they sprayed, they wore out the soil and now that is seen in the fact that nothing has grown back.

Essentially what was created was a prolonged period of time of expensive and excessive process along the river banks that eventually lead to the (practically) complete removal plant life.

**Quantifying aspects of the problem**

In order to truly analyze the problem, quantification of the situational aspects that make this a worrisome issue is necessary. One of the biggest factors to consider when analyzing this predicament is finding out ways to calculate the cost of damage done to the riparian area and surrounding infrastructure. Causes of the problem initially were damage to the surrounding wall, the existing plants were unruly to many and made it hard for fishermen to reach the river. Also the fact that invasives were beginning to appear was worrisome. Quantifying the previous cost versus cost of an herbicidal spray treatment can give us insight to whether or not the current method is sufficient and economically feasible. In doing so, we can make an agenda of alternative methods based on feasibility. Conducting a study on the percent of species in the riparian area over a certain amount of time to identify population change, growth and effect of chemicals is important to seeing how drastic the change has been and in doing so can be influential information to identifying future outlook. Essentially quantifying impacts of invasive species can make it clearer of how important this problem is.
Who is Affected

One of the main concerns with this problem is taking in consideration all the external parties that can possibly end up being affected by the actions of the city. One of the main fears of the citizens of Easton is that the use of herbicides near their source of water poses a threat to everyone’s safety. Through water runoff you can contaminate the drinking water for those in the surrounding areas and potentially everyone downstream. Anything that occurs in Easton can have negative affects in other communities because the Delaware continues to move downstream carrying with it whatever is in its path. This can also lead to an even greater spread of invasive species at other riverbanks.

One surrounding area that is not excluded from the occurrences at Riverside and Scott parks is the ecosystem in the water. By putting pesticides on land you can potentially contaminate the water, as stated before, and with that contaminate the fish and any other living organism within the water. The fish if contaminated can, in logical food chain manner, affect anything that consumes it.

The water quality of the Delaware is crucial to life all around it and anything that negatively affects it can be detrimental and because to much was not initially taken into consideration before the spraying, further research on the behaviors of the used herbicides would be necessary.

Economic Factors

The appearance and presence of the invasive species could affect public opinion and property values. From an economic standpoint the city of Easton can publicly become conotated by this event, decreasing its attraction value by many. With the potential affects that the knotweed and hopvine can have on infrastructure the city might also potentially see expensive
expenditures in their future to re-eradicated these plants and fix any damages caused by them. The cost of replacing or repairing the supports along the river, for matter of safety, would outweigh the cost of invasive species management meaning that action now rather than later is preferable. The cost of replacing the native species of plant may prevent the growth of invasive species, and not require much maintenance cost if they were to assimilate back to the natural ecosystem. Failure to take any action now can lead to a increase in the problems signifying an increase in cost to the city.

**Policy Alternatives**

Easton’s action of defoliating Riverside and Scott Parks has created an environmental change with, so far, no solution. Initially trying to deal with a vegetation overgrowth problem that made it hard to fix surrounding infrastructure, they cut and sprayed the riverbanks along the Delaware River with pesticides, leaving behind an empty riparian area that may be susceptible to invasive species. Determining a way to maintain a healthy environment and establish a new method of maintenance is now the problem we need to solve.

Lacking credible information on what was done to both Riverside and Scott parks, various misleading online sources stated that management to this riparian zone was done through various yet different steps. Through direct communication with the city we were able to establish that four different materials were sprayed along the riverbanks. A prolonged riddance process occurring between November 2011 to July 2012 involved the cutting of vegetation and two occasions of spraying along these areas. Understanding the effects of these materials along the riverbanks is key to coming up with a plan on minimizing their negative effects but at this point in time, according to Mark Fiely at Ernst Conservation Seeds and Steve Leonard at Jobsite
Products, re-stabilization of the riverbanks is one of the most important issues that needs to be dealt with as soon as possible.

**Dealing with erosion**

The fear of potential erosion due to the lack of plant life has been something that has worried many of the citizens. Through National Weather Service we were able to observe that the Delaware River in many occasions has caused flooding along the Easton area. When dealing with riverbanks, the occurrence of flooding, poses a threat to any attempts to protect that environment. Through flooding you have a larger chance of erosion which can ultimately lead to extreme water contamination and continued ecosystem destruction. Already taking into account the fact that there is no longer anything keeping the soil along these banks in place, the city of Easton has implemented a straw like matting with an under layer of seeds to re-stabilize these areas. Looking at the “Alternative Techniques of riprap Bank Stabilization” from the Federal Emergency Management Agency we have been able to find alternative methods that have been used in situations where a riparian area is at risk of eroding.

**Do Nothing**

One of the main reasons that the city of Easton initially decided to defoliate these riverbanks was “due to complaints about how it looked” (Malone, 2012). In accordance with The Morning Calls’s “Easton admits faults in defoliating riverbank, plans future use of chemicals,” Mayor Sal Panto states that Dave Hopkins, director of public works relayed this information to him and stated that in the end some parties will remain unhappy. In a response to this, one of our policies is to do nothing. As we analyzed the reasons for why this riparian zone was defoliated, we felt that complaints regarding the aesthetics of the parks did not justify their actions.
reviewing the negatives that this method of vegetation management has done on the ecosystem we concluded that the city of Easton would have been better off leaving the problem alone. The do nothing policy surrounds this idea.

This policy would be categorized as education in a form of persuasion. By educating the citizens about the nature and the importance of this ecosystem, you can persuade those who complained about the overgrowth into dealing with their dislike. With slight change to this ecosystem you risk changing the ecology of the surrounding areas and through education, by the mediums of flyers, newsletters, and park signs that state that this riparian zone is the home to various species, you can get people to agree with leaving these areas alone.

With our do nothing policy taking some kind of initial action is necessary. In order to avoid the prevailing issue of erosion restabilization of these parks is needed. At this point both Scott and Riverside Parks remain barren with little to no plant growth, which besides being surprising is also risky. Through manual planting of initially native species you begin the process of getting this ecosystem stable and growing again. From that point on, you do nothing. You allow the environment to flourish in a way natural to it, without the cities interference. This method allows city officials time to research alternative methods and time to see whether the problems that have once existed have changed, and from that point make the needed decisions. By restabilizing these parks, there is a possibility for invasive species to return but as mentioned before, allowing the ecosystem to naturally re stabilize itself, with a little help from the city, is important.

**Planting Native Species to Control Japanese Knotweed**

In a several year study performed by R. Howard Skinner, Martin van der Grinten, and Art E. Gover, the ability of native species to prevent the prolific establishment of Japanese knotweed
was tested. In the experiment, six separate mixtures of native species were introduced at varying locations along a plot of land where Japanese knotweed was prevalent. The study took place almost two miles northwest of Mansfield, Pennsylvania in the floodplain of the Tioga River. This floodplain forms the storm water retention basin for the Tioga Reservoir (Skinner, van der Grinten, and Gover, 2012). The plain shows no change in land elevation, but has significant water levels depending on the time of year and weather conditions. The study site has a high water table, and storms cause severe flooding within the plain, completely covering the plot for up to a week in certain circumstances. In the summer, water levels are around five feet deep, and in winter, about two and a half. The soil contained within the experimentation area is a fluventic endoaquept (Skinner, van der Grinten, Gover), meaning it is a fine granular compilation of sand and clay, well mixed, active, and non-acidic.

The experimental procedure taken consisted of mowing existing knotweed and application of herbicide, specifically a glyphosate compound. Glyphosate was used because of its non-persistent tendencies and approval near water. On top of this, “glyphosate treatments averaged between 97-98% canopy reduction and reduced biomass by 90-99% when evaluated 1 yr following treatment applications” . Originally, a 30 feet by 900 feet plot was mowed to as near the dirt as possible, and an application of about 2,300 liters per square mile of glyphosate was performed in August of 2006. The same area was sprayed again in May 2007 with about 1,200 liters per square mile of glyphosate. Up until this point, the entire plot area was treated in the same manner. Starting on June 1, 2007, the study area was broken into two groups. Half of the plot was sowed with six different mixtures of native plant species (2007 group), while the other half continued treatment (2008 group). This treatment consisted of a third spraying of glyphosate in early September 2007 at 1,200 liters per square mile followed by a mowing in late September.
A final glyphosate spraying occurred on May 28, 2008 at 1,200 liters per square mile, and then finally the six native species mixtures were planted afterwards. No further measures were taken to control the weeds in either case. (Skinner, eta).

Evaluations of the two plots were performed independently, but concurrently in late October 2007, early October 2008, early October 2009, early July 2010, and mid-July 2011. Initially, the treatments seemed effective in both groups. Although the 2007 group saw a consistent decrease in percent cover of the native species over the plot throughout the 37 month period after sowing (approximately 60% to less than 10%), the average plant height increased roughly linearly for the first two years, but saw a drop off in the third year. After just four months after sowing in the 2008 group, all but two native species mixtures were observed, because the other mixtures were significantly lagging behind in percent coverage and average height. The two mixtures that stuck out, literally and figuratively, in both the 2007 and 2008 groups (although less significantly in the 2007 group), were the PCWR (prairie cordgrass (Spartina pectinata) and Virginia wildrye (Elymus virginicus)) and RBM (riparian buffer mixture; see Table 1 in the recommendations for list of the 27 species) mixtures. The percent coverage of the RBM increased moderately after the first year in the 2008 group (about 70% to just over 80%), but then continued to drop off the following two years (down to 50%), whereas the PCWR mixture dramatically increased after the first year from about 40% to 80%, remained consistent the next year, and dropped off slightly the third year (ended at 70%).

In the 2007 group, the Japanese knotweed and other weeds increased in percent coverage over all three years as the native species diminished, starting at about 25% coverage and ending at over 80%. In the same group, the Japanese knotweed and other weeds increased in average height slightly in the first year and then approximately doubled in average height the second year.
It remained at this staggering size through the third year. The 2008 group, which saw prolonged glyphosate application and mowing as compared to the 2007 group, had far significantly less percent coverage by the knotweed and other weeds. The average percent cover for all weeds was only 13% four months after sowing, and decreased to 12% within the year and remained there for the following year. However, there was a jump in the percent coverage after 37 months to just under 40%. The average heights of the Japanese knotweed and other weeds in the 2008 group increased in the first year a moderate amount, and continued to grow into the second year. The heights leveled off after the third year.

Although the experiment took place in a different location with different specifics, this policy alternative shares many similar qualities with the situation here in Easton, which makes it a viable solution. Both Pennsylvanian areas have like soils and are alongside rivers. The climate between the two locations is not dissimilar. The collection of native species that were included in the experiment could be used here on the sides of the Delaware River. Although the elevation is more sloped along the Delaware and even more so locally from bank to water level, both the invasive species and the native species will be equally disadvantaged from it. This policy alternative may take a great deal of vigor and persistence, but it may be the only way to deal with the unstoppable invasive force that is Japanese knotweed.

This policy has elements of regulation and spending, as well as education. Although glyphosates pose threats, using them properly can minimize the negative side effects. While herbicide use is typically regulated, glyphosates are among the group that is accepted for use near water, making it a good selection for use alongside the riverbank. Aside from this, proper glyphosate application will minimize the amount of herbicides being used and can make the spraying more effective in removing invasive species. This will save time and money. The
education comes in with what is meant by proper glyphosate application. Although there is no perfect way to apply the herbicide, the experiment described above a fairly effective way to do so. This method can be tweaked and changed as needed to meet the specific requirements of the task here in Easton. A combination of mowing and applying glyphosate, accompanied with the timely sowing of predominant native species, can control and eventually eliminate invasive species, such as Japanese knotweed.

**Bronx River Riparian Plant Management Plan**

Before they were pests in the United States, the knotweed and hopvine were invading Europe; The United Kingdom has much more experience dealing with these plants than the United States, however, they have not made a substantial amount of progress finding a solution to the problem. The United Kingdom’s lack of success has forced it to consider more extreme approaches to the problem. The CABI is considering using some Japanese natural predators to fight it. In Japan, the knotweed population is controlled by more than 200 other Japanese species. The chrysomelid beetle and its larvae along with a rust fungus (Puccinia Spp.) have shown promise as control agents for the problem in the United Kingdom. While this could be a potential solution to the problem there, many issues arise when considering using other alien species as a solution to the problem along the Delaware. Introducing these species to the Delaware riparian area has the potential to create a problem similar to the one we are trying to solve. The beetle may find a more favorable native species to feed on and the fungi may interrupt even more native life.

As part of the 2012 Bronx River Riparian Plant Management Plan, the New York City Department of Parks and Recreation designed a treatment plan for many invasive species of plants. Japanese knotweed, covering over 50% in some areas, is the most prevalent invasive
species in the Bronx forest. The NYC Department of Parks and Recreation considered mechanical, herbicidal, and a combination of treatments for both isolated single patches as well as large patches of Japanese Knotweed. A mechanical method of removal would call for a digging and bagging of plant material two times a year during the months of June, August, and September for single patches, and a three time per year cut and removal of larger patches. The herbicidal control method uses 3-5% glyphosate spray during the summer. The combination method is composed of a two time a year cutting of plants with a six to eight week waiting time before spraying of 3-5% glyphosate. A control study done on Japanese Knotweed showed that there is an insignificant change in density of plants between cutting treatments of plots and control treatments where nothing is done to plots of knotweed. According to this study, the combination treatment would be a much more effective method than a mechanical treatment alone.

Our policy alternatives with the purpose of controlling invasive species in the riparian zone along the Delaware river in Easton include consistent Glyphosate herbicide treatment, manual mowing and uprooting of rhizomes, a combination method, doing nothing, or unconventional methods (introducing natural exotic predators). With each method we would have to consider allowing native plants to grow back on their own or manually revegetating the riparian area.

**Evaluative Criteria**

Criteria for evaluating our policies are something that will inevitably make or break the actions that we think can be successful and useful if implemented. Efficiency, effectiveness, feasibility, and social acceptance are what we think are the most important criterion for evaluating these policy alternatives. Each measure the future of a policy and in some way is essential when considering the future outcome of any policy put into action. The success and
suitability of these policies can be analyzed and ranked. Essentially, these criteria help establish whether we can efficiently reach our goal and measure how each policy helps reach that goal.

As seen before, one of the main influences to how policies are made or whether they are enacted is the public’s opinion on these policies. As previously observed, the action of spraying these riverbanks was not something that was taken lightly by the citizens of Easton. It evidently went against the city code that bans “people from clear-cutting riparian zones” (Malone, 2012) and threatened many aspects of their everyday lives. If the public disagrees with a policy then the time and money gone to researching the problem and developing the management of the problem are essentially gone. If a policy has no support, which can be measured by polls, surveys and public commenting, then you end up with the same problem and yet no solution. In our situation social acceptance will vary based on the policy alternatives and their effect on the citizens, continued usage of chemicals, harm to the environment, and many other things the public considers important or crucial.

The effectiveness of our policy is of utmost importance. We want to exterminate invasive species, restore native vegetation, and minimize any of the negative effect that the initial actions taken by the government officials of Easton may have had as a whole. It is pertinent that we act within a closed time frame to stop irreversible erosion. In order to do so, we must control and eradicate the invasive species that would cause erosion. And finally, we would like to restore the riparian zones to their natural state with native vegetation. If we fail to preserve the areas, our policies are not worth implementing.

The efficiency and overall benefit from our costs is very important when spending taxpayer’s money. Ideally every policy implemented would minimize cost however, such a policy may not achieve the goal as effectively, or in as timely of a manner. Taking the cost into
account is important because if a policy alternative is too costly, then it will not be able to be put into place because the city will not be able to afford it. There are many ways to test whether a policy alternative is efficient or not. One way is to use a cost-benefit analysis. A cost-benefit analysis is when you just simply weigh the costs of a particular policy alternative against its benefits. Its steps are to first identify all of the important costs and benefits. Then, to measure those costs and benefits in dollar terms. Lastly, sum up all of the costs and all of the benefits and see if the costs outweigh the benefits. Some other ways of testing the efficiency of a policy alternative is to do a risk assessment or a cost-effectiveness analysis.

Being one of the factors to prompt a new policy, social acceptability of certain treatments as opposed to others will impact our decision making. While herbicides may be more effective, negative externalities, or even negative beliefs, associated with chemical usage will influence public opinion. No matter how effective, efficient, and feasible a policy alternative is, the city will not be able to implement the policy if it doesn’t have social acceptance.

**Policies already in place**

The city of Easton has already tried to deal with the problem of vegetation management by spraying pesticides on the plants during the summer. In all, four chemicals were used: Doing this got rid of the Japanese Knotweed, but also killed off all of the indigenous plants as well. The Japanese Knotweed will grow back, but the other plants won’t. The spraying of pesticides ultimately made the situation worse, instead of better. Now, the city is looking for solutions that do not involve the use of chemical

Regular cutting and pulling of the weed will exhaust the rhizome and kill the plant off eventually, but it will take a number of years to do so. If this is done, the pulled stems need to be
properly disposed of to prevent the knotweed from growing back because they can do so from very small fragments. Cutting and mowing the weeds have been tried, but have proved to not only be inefficient, but also to promote the spread of the plant. Therefore, this is probably not the best option to use for dealing with the plants.

To get rid of the knotweed using herbicides, it is most effective to spray the chemicals during the late summer because it is more damaging to the underground rhizome system than if you apply the herbicides in the spring. According to site trials, it is more effective to use both digging and herbicide treatment instead of just using herbicides. A drawback to large-scale excavation projects using herbicides is that it is more costly than the other options. The cost of chemical use varies but a Knotweed Control Program in Washington State that has been running since 2004 has spent $4.3 million to chemically control the plant. The three most common types of herbicides used to control Japanese Knotweed are glyphosate, imazapyr, and synthetic auxins. Glyphosate is the herbicide most frequently recommended to control Japanese Knotweed because it is no persistent and therefore approved for use near water. A pure form of glyphosate will also have the least negative effects to the surrounding animals.

Table 1:

<table>
<thead>
<tr>
<th>Species</th>
<th>Common Name ‘cultivar’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Panicum dandestinum</td>
<td>Deer tongue 'Tioga'</td>
</tr>
<tr>
<td>Schizachyrium scoparium</td>
<td>Little bluestem 'PA ecotype'</td>
</tr>
<tr>
<td>Chamaecrista fasciculata</td>
<td>Partridge pea 'PA ecotype'</td>
</tr>
<tr>
<td>Scientific Name</td>
<td>Common Name</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>Elymus riparius</td>
<td>Riverbank wildrye</td>
</tr>
<tr>
<td>Elymus virginicus</td>
<td>Virginia wildrye</td>
</tr>
<tr>
<td>Verbena hastata</td>
<td>Blue vervain</td>
</tr>
<tr>
<td>Carex vuipinoidea</td>
<td>Fox sedge</td>
</tr>
<tr>
<td>Heliopsis helianthoides</td>
<td>Smooth ox ey</td>
</tr>
<tr>
<td>Sambucus nigra</td>
<td>Elderberry</td>
</tr>
<tr>
<td>Panicum virgatum</td>
<td>Switchgrass 'Shelter'</td>
</tr>
<tr>
<td>Sorghastrum nutans</td>
<td>Indiangrass 'PA ecotype'</td>
</tr>
<tr>
<td>Cicercia stria ta</td>
<td>Fowl mannagrass 'PA ecotype'</td>
</tr>
<tr>
<td>Andropogon gerardii</td>
<td>Big bluestem 'Niagara'</td>
</tr>
<tr>
<td>Desmodium canadense</td>
<td>Showy ticktrefoil</td>
</tr>
<tr>
<td>Viburnum dentatum</td>
<td>Arrow wood</td>
</tr>
<tr>
<td>Rhus typhina</td>
<td>Staghorn sumac</td>
</tr>
<tr>
<td>Rudbeckia hirta</td>
<td>Blackeyed Susan 'NC ecotype'</td>
</tr>
<tr>
<td>Monarda fistuiosa</td>
<td>Wild bergamot</td>
</tr>
<tr>
<td>Penstemon digitalis</td>
<td>Tall white beard tongue</td>
</tr>
</tbody>
</table>
Table 1: List of the 27 different species plotted in the Skinner, van der Grinten, Gover

Assessment and evaluations

To try and solve Easton’s current problem with the vegetation after last summer’s activities, we have come up with 5 alternative policies and 4 measures of criteria to rate the policies with. We have scored each policy according to each criterion on a scale of 1-10. One being the and ten being the best . These are the results.
<table>
<thead>
<tr>
<th></th>
<th>Policy 1</th>
<th>Policy 2</th>
<th>Policy 3</th>
<th>Policy 4</th>
<th>Policy 5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Efficiency</strong></td>
<td>3</td>
<td>3</td>
<td>7</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td><strong>Effectiveness</strong></td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td><strong>Feasibility</strong></td>
<td>10</td>
<td>3</td>
<td>7</td>
<td>7</td>
<td>7</td>
</tr>
<tr>
<td><strong>Social Acceptance</strong></td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>18</td>
<td>11</td>
<td>22</td>
<td>25</td>
<td>29</td>
</tr>
</tbody>
</table>

**Policy 1: Doing Nothing**

In terms of the environment we have seen that sometimes people’s wants do not correspond with the needs and workings of the environment, resulting in negative change. In the case of Easton, aesthetic appeal, natural processes, and difficulty to reach a resource, made both riverside and Scott parks targeted locations. In the end we know that the effect outweighed the reasons for defoliation which tells us that these areas would have been better off if left alone. One of our policies is centered on this idea. One of the policy alternatives that we can potentially see implemented in the city of Easton, as previously mentioned, is doing nothing. By doing nothing we mean doing something, as in re-stabilizing the riparian zones of these parks through manual planting of the previously native plant species and from then on doing nothing to the plants other than the maintenance that is normally done. Right now as already mentioned, leaving these parks barren would just be adding to the problem as there is no guarantee that these plants will ever grow back. By re-planting native plants you not only decrease the chance of
erosion occurring but you also take a step in returning this ecosystem back to its original healthy state. We would also like to educate the citizens of Easton in the form of flyers, newsletters, and park signs that teaches the citizens about the various species living in the ecosystem and teaches them how to not harm the area, mostly by leaving it alone.

We scored this first policy with a 3 for efficiency because we do not think this policy will be very efficient. We scored this policy with a 1 for effectiveness because since we are not actually doing anything it shouldn’t be very effective at all. After we replant the species, there is a good chance that Japanese Knotweed will flourish and become a problem. This policy would not do anything about the Knotweed and therefore would not effectively solve the problem of invasive species in the riverbank.

We scored this policy with a 10 for feasibility because this policy is 100% feasible. Since this policy does not require the use of any technology or manual labor, there is no reason why this policy couldn’t be done. We would just have to get native plant seeds to replant the native population.

We scored this policy with a 4 for social acceptability because we feel that the public wouldn’t be outraged because of this policy, but they wouldn’t be that excited about it either. When, there is a problem, people like to feel as if something is being done about it. This policy, even though it might work, won’t sit well with the public because they won’t get that feeling that something is being done about the problem.

**Policy 2: Introduction of Natural Predators**

Should the situation arise that these invasive species start to populate the currently desolate riparian area we may need a drastic answer to the problem, considering how bad the
problem can get. One of our more drastic and less popular policy alternatives is introducing a natural predator. The Japanese HopVine has three natural predators, a fungus: Pseudocercospora humuli and two moths: chytonix segregata and epirhoe sepergressa. The Japanese KnotWeed has plenty of natural predators in Japan which is why it isn’t a problem there, however, the problem arises when trying to figure out which natural predators would be suitable to combat the problem in Easton. The United Kingdom has plenty of experience dealing with Japanese KnotWeed and has already considered bringing a natural predator to deal with the problem and for a good reason; the Japanese KnotWeed causes an average of £150 million in damage annually. After years of research, scientists at Cabi (a non-profit agricultural research organization) determined that a psyllid called Aphalara itadori was the best solution to the problem. Mycosphaerella leafspot fungus is another popular predator that Cabi is considering for release into the U.K.

While there are obvious risks associated with using the natural predator method, it may be worth it to try. Natural predators know how to handle the invasive species and provide a solution that gets rid of the problem the natural way without the use of harmful chemicals that may affect native species or manual methods that require clearing entire sections of land. The method, however, is not extensively tested yet; this year will be the first year the U.K. tries to combat Japanese Knotweed with its psyllid predator. Perhaps Easton should wait until the United Kingdom sees some success before considering using natural predators.

Using natural predators to combat the invasive species problem was the least popular during our evaluations for a number of reasons, the most prevalent of which is the risks associated with introducing another exotic species. The public will want to see the eradication of the invasive species, not the introduction of another one. There are too many “what ifs”
associated with this solution. The predator may find a native species it favors more than the target invasive plant, then we will have a whole new problem to deal with. We must also consider what will happen if the predator does its job too well; after its main source of food is gone, it will have no choice but to move on to another plant, most likely a native one. We must also take into consideration that this is the extremely sensitive riparian zone we would be treating and the likelihood of the predator spreading downstream where it may not be needed is too high.

The Hopvine isn't as hard to control as the knotweed so introducing any of its predators would likely not be practical, and the only Knotweed predator suitable to be released into the wild here in Easton would be the psyllid simply because the fungus would definitely discriminate less between the native and invasive species. In the United Kingdom their situation is dire enough for them to consider using radical solutions like this, however, in Easton it hasn’t become that much of a issue.

The natural predator option scored the lowest during our policy evaluations with a pitiful 11 out 40. This policy scored a low 3 out of 10 in efficiency, efficiency is defined as “achieving maximum productivity with minimum wasted effort or expense”. This method definitely has potential to waste a lot of resources and money and even has the risk of making the problem it's trying to solve even worse. As for effectiveness, as a group we agreed on a 2 out of 10, however, it could also be expressed as a range. The range would take into consideration the worse possible outcome (the predator completely ignoring the invasive plant in favor of a tastier native plant) and the best possible outcome (the predator doing what its supposed to do and eradicating the invasive species) therefore the range would be 0-8. It wouldn’t earn a perfect 10 even if it would eradicate the invaders because we would have to then deal with the predator. This policy earned the lowest score out of all the policies in the feasibility section because the city of Easton already
has a limited budget to spend on this problem and importing more exotic species isn't very feasible when considering the budget or when considering the negative impact another exotic species could have in the sensitive riparian zone. Social acceptability, we predict, would also be relatively low. The general public would be outraged with the thought of bringing more exotic species with the possibility to destabilize an already unstable riparian buffer zone. In conclusion, this policy alternative scored the lowest out of all policy alternatives because it’s too risky; the window of success is too small and margin of error too large for it to be considered as a possible solution. There is a low chance of social acceptance; it’s not very efficient and not feasible especially considering our current nonexistent situation.

**Policy 3: Herbicides/Pesticides**

The third policy alternative that we chose involves only the use of pesticides/herbicides to deal with the Japanese Knotweed. Currently, there is no vegetation in the area. Therefore, for all of our alternatives the first thing that we will do is replant the native vegetation. So, if we implement this policy, we would first replant all of the native species and if the growth of Japanese knotweed becomes a problem we would spray glyphosate periodically on all of the Knotweed. The city of Easton had originally tried to spray pesticides on the vegetation in the area, causing the problem we are trying to solve now. But, they sprayed four different chemicals on the plants, with this policy, we would only spray one. We would use glyphosate instead of imazapyr or synthetic auxins because glyphosate is the pesticide that is most recommended to use to get rid of Japanese Knotweed because it is nonpersistent and therefore approved for use near water.
When we assessed this policy according to our well thought out evaluative criteria, efficiency, effectiveness, feasibility, and social acceptance, we scored this policy with a 7 or efficiency, a 6 for effectiveness, a 7 or feasibility, and a 2 for social acceptance.

We scored this policy with a 6 for effectiveness because we considered this policy to be fairly effective. The use of pesticides has a relatively high chance of actually doing what we want to do, which is to get rid of Japanese Knotweed as compared to the other alternatives. But, the reason why we gave this policy a 6 instead of an 8 or a 9 is because this policy won’t be very effective in restoring the native vegetation or minimizing negatives effects that have already taken place. This is because, when the pesticides are sprayed, even though we would try our best to only spray the knotweed, there is a high chance that the surrounding plants kill also be killed of as well. Because of that, and the chemicals that will still be lingering in the air that could get in the water, the ecosystem will be negatively affected l we implement this policy.

We scored this policy with a 7 for efficiency because we felt that this policy would be efficient. It would not cost as much to spray pesticides on the area than it would to hire manual labor to cut it down every day. This policy did not receive a 9 or 10 because it does cost money to use pesticides and we are not 100% sure that the use of pesticides will only kill the Knotweed and not end up killing everything. The cost of using pesticides varies, but there are cases in which areas have spent around $4 to $5 million on pesticides to control them for a few years.

We scored this policy with a 7 or feasibility because we do think that it would be feasible to implement this policy. The only thing we would need to do to make this policy work is to get our hands on the right amount of pesticides to kill off the knotweed. Since the pesticides we need are easily accessible, getting them shouldn’t be a problem. Easton did not have a problem
We scored this policy with a 2 for social acceptance. This is because even though this policy would get rid of the Japanese Knotweed, it would also kill off all the native plants in the area and negatively affect the surrounding ecosystem. The public would not only not accept this policy being put into place but they would probably also be outraged. They would not want their taxes to be going towards a policy that would destroy all plant life in the area. The problem that Easton is facing right now exists because pesticides were sprayed on a retaining wall that killed off all the plants and caused them not to grow back. If we replant everything and then spray pesticides on the area when Japanese Knotweed starts to flourish, the area will soon be back to looking like it does now, which is a barren wasteland. Therefore, we would be back to square one. The public realizes this and therefore would not accept this policy.

The total score that this policy received is a 22. Since, we has two other policies score higher than this one, we would not recommend that the city of Easton implement this policy. Even though different chemicals would be used, this policy is very similar to what was done to cause the city to have this problem in the first place.

**Policy 4: Mechanical Removal of Invasive Species**

Our policy alternative number four is the manual/mechanical removal of the invasive species. Mechanical removal of plants may or may not include the mowing, plowing, cutting or hand removal of large patches of Japanese Knotweed. The sources of labor potentially may be volunteers from the area or private contractors depending on the availability of resources and tax budget. This policy would have a lot of public approval because it does not use any herbicides or pesticides. Ultimately this alternative has a lot of positive attributes that would make it a great policy choice.
We would recommend that Easton implement a mechanical treatment of Japanese Knotweed that would call for cutting/mowing of large patches and manual removal by hand for small patches. By having such an hands on approach, we will be able to isolate and maintain native species of plants, while only getting rid of the invasive species. Cutting and plowing of large patches will not permanently keep invasive species from growing back, however, over time it will allow native species to compete with the rapid growth of Japanese Knotweed. Due to the complicated network of roots that the knotweed has, hand removal of the plants may not be able to completely uproot the plants. At the least, a thorough job will remove invasive plants without harming native ones, giving them a chance to repopulate. We highly suggest that Easton require whoever will be working to eliminate Japanese Knotweed along the riparian zones to be able to identify and discriminate native species from invasive species, and preserve native growth and vegetation.

As a source of labor, it would be better if private contractors and specialists were used to mechanically remove the invasive species because they would be much more adept at adhering to specifications of the township and ultimately do the most effective job. Easton may also use volunteers or activists from the area that may require service hours or just may feel strongly about preserving the environment. Volunteers could be high school students looking to build their resume, adult and college philanthropists, or prisoners and people on probation looking to serve time while making a difference. The use of volunteers would be very cost effective, but may lack the same quality of work as the use of private contractors due to their potential lack of expertise and adherence to the specifications, specifications which call for differentiating between native and invasive species. It would be most ideal if all volunteers were local activists.
who have the same incentives we have for restoring the riparian section back to its natural state, for its aesthetics as well as importance as an integral part of the surrounding area.

As part of mechanical removal of the plants, the cut portions of plant growth will have to be disposed of properly. This may be a cost we would have incur despite the use of volunteers, however, private contractors would be paid for the waste disposal as well. It would be ideal if Easton waste disposal companies could join in on the effort to restore the banks and donate time and effort to the collecting and disposing of plant waste and materials.

For all the hard work and manual labor put into mechanically removing invasive species from the riparian zones, great benefits are earned from not using an herbicidal treatment. Public approval of this policy will be very high, and citizens will not have to be concerned over the negative effects of the use of toxic chemicals may have on the environment, drinking water, and animals.

For our evaluation of policy four, mechanical removal of invasive species, we scored it with a 5 out of 10 efficiency. By not using herbicides, we are not effectively destroying the Japanese Knotweed down to the root, therefore will potentially have to treat the area mechanically many more times. The cost of labor and removal of waste, depending on how charitable our sources of labor are, will most likely be greater than the cost of using herbicides twice a year. However, many people may believe that there is a positive externality associated with not exposing the environment to destructive chemicals which cannot be quantified. Also, if manually removing plants allows native species to grow successfully on their own, then we can potentially avoid the cost of restoring and maintaining these native species.

For the evaluation criteria of effectiveness, policy four also scored a 5 out of 10. Although manually removing invasive species plants would be much more effective than relying on natural
predators to attack them, and more effective than doing nothing at all, research has shown that herbicidal treatments have been effective at completely destroying invasive plants down to the roots after only a few exposures to the chemicals. Mechanical removal may never completely stop invasive plants such as Japanese Knotweed from regrowing.

Like some of our other policies, mechanical treatment is very feasible. Our only uncertainty lies in the availability of labor and possibility of charitable gestures. For this reasoning it has scored a 7 of 10 for the evaluative criteria of feasibility.

Policy four scores the highest in social acceptability. By not exposing the environment to potentially harmful levels of chemicals, or introducing new predators which may cause a new nuisance, mechanically and manually treating invasive species avoids the public outcry which the occur from the other alternatives. The use of volunteers in the area will also spread awareness of the importance of environmental maintenance. An environmental movement by locals in the town will create individuals who take pride in the infrastructure and natural aesthetics of Easton.

**Policy 5: Mechanical Removal and Herbicide Spraying**

The fifth policy alternative we selected was the combination method of policies three and four. Since the riverbank is devoid of any plant life, native and invasive, a policy that includes both mechanical removal and herbicide spraying can be utilized for any situation in the upcoming germination period. As we cannot be sure exactly what will happen when the plants begin to grow, it is imperative to be prepared for any circumstance. An assortment of different native species should be planted along the banks of the river. These species could include any or all of the various mixtures described previously in this paper, and listed above in the table. Japanese knotweed tends to regrow in late winter and early spring, which means it will either
coincide or start earlier than the native species it will be competing with. Because of this fact, inspections of the river bank in late winter should be performed to assess the level of knotweed growth. Before the native species begin to sprout, the invasive species should be cut to the root, and a treatment of glyphosate should be directly applied to hinder their ability to grow, while limiting the negative impacts on the surrounding plant life. Once the native species begin to grow, herbicide treatments will only be used in severe circumstances where knotweed has overtaken a large area of the riverside. Hopefully, the original application will limit its growth, and this will not be necessary. Manual cutting and removal will take the lead role in controlling the knotweed at this point in order to make sure the knotweed does not overshadow the other plants. This will prevent the knotweed from growing too large and too numerous, and does not require herbicides, which harms both the invasive species and native plants. Intermittent inspections along the banks will need to be performed, and if the knotweed is starting to overgrow beyond its surrounding plants, a team of workers will trim and remove whatever knotweed they can. This is all in attempt to limit the invasive species growth so that the native species can have a chance to grow and establish itself along the riverbank.

Our Recommendation

Based on our evaluations of all our policy alternatives, given our evaluative criteria, we recommend policy 5, the combination treatment. The combination treatment includes a mechanical method of invasive plant removal, as well as an herbicidal treatment. The use of both treatment methods will optimize the effectiveness of invasive species control.

As the state of the riparian zones at the moment, no immediate treatment with the intention of destroying plant life is necessary because has been no vegetation since the last herbicidal
treatment. However, given the risk and potential cost that may arise from erosion, we would recommend short term action be considered to control erosion which may include the replanting of native species, or the use of mats designed to contain the problem. As seen after hurricane sandy, the riverbank is vulnerable to erosion and should be assessed before costly damages do occur.

Our treatment in preparation of invasive species plant growth will consist of dealing with small patches of knotweed, large patches of knotweed, as well as knotweed near native species of plants.

Japanese knotweed, being the expected species of invasive plant, in large patches shall be mechanically mowed or cut close to the bottom of the stems as possible. Once this is done, within three weeks after, the large area of knotweed should be sprayed with 100% glyphosate.

Smaller patches of invasive species shall be cut or removed by hand depending on size of the patch. The stems and roots of the plants should be treated with 3-5% glyphosate within 3 weeks of the mechanical treatment.

Patches of invasive species that grow near native species shall be carefully cut as to keep the native species intact. If an invasive species is directly adjacent to a native species, it should be uprooted by hand. If the patch of invasive species, large or small, does not appear to be close enough to the native species to be touching roots, then they should be safe enough to treat with glyphosate using caution.

Despite the importance, and potential costs, associated with our restoration project, discretionary tax spending may be difficult to put aside especially after the damages that occurred to the city after hurricane sandy. However, volunteers and activists may be recruited for a relief effort which in the process restores the riparian zone, which is relevant because the area
did erode during the storm. Volunteers and activists would be the best source of free labor given their commitment and loyalty to the city, and would adhere to our specifications within the limits of their abilities. Other sources of free labor may include high school students looking to build their resume, college students and philanthropists looking for community service hours, and religious groups that want to help the community. If the city is desperate for free labor, then prisoners, and people on probation may be used to help clear the riparian zone of invasive species. All of these groups would be only be used for the mechanical removal of the plants as they are not qualified to use chemical herbicides. If the city is able to recruit groups of free laborers, it must provide equipment and disposal services as well. Mowers and hedge cutters are usually already owned by cities for trimming grass and plant growth along roads and in parks. The disposal of invasive plant waste can often be very costly; however it may be possible to find a waste removal company in Easton willing to donate labor and time to the bagging, transportation and disposal of plant waste. If not, then this will be another cost for the city.

The use of toxic herbicides can be very dangerous and as a result requires certain authorizations. Therefore, the city of Easton must hire a private company to treat the invasive plants with the specifications for small and large patches of plants.

While isolating small patches, large patches, and patches near native plants may give native plants a chance to grow back on their own, we should be ready to restore the area and physically plant appropriate species. Despite the progress of invasive species removal, this may be done at the same time if necessary. If so, we must be careful to not expose these plants to our mechanical and our herbicidal treatment. We believe that planting species should be utilized along with our combination treatment given the state of erosion. If this landscaping is to happen,
then we might as well design the area to be accessible for assessing damages to the cement wall, as well as for fisherman.

Given the benefits of the thorough method of policy 5, we highly recommend the combination treatment. This will allow us to differentiate between invasive species and native species of plants, and let us target the plants we wish to remove. We believe that these actions be implemented timely because of the risk of erosion, and that we should restore the area by manually planting native species of plants. This process will save money in the long run, and will be worth it to have a safe, self-sufficient, and aesthetically pleasing riparian zone.
Figure 5: Using ArcGIS we mapped out the concerning area in Easton Pennsylvania. The green represents the flooding zone and emphasizes the importance of restabilizatins.
Citations


2. experiment


18.