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TECHNOLOGY AND ENVIRONMENT

An Interactive Qualifying Project Report
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by

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Abstract:

The aggressive spread of invasive non-native species poses a serious threat to the native plant and animal species of North America. Billions of dollars are wasted due to the economic and agricultural impact of these plants. The non-native plants also play a significant role in altering the ecosystem functions such as wildfire occurrences, its frequency and nutrient cycling. This project investigated different exotic plants found on the Colorado Plateau. Six different plant species were considered, and we analyzed their effects on native plants, animals, humans and the environment. The impacts of these plants on agriculture and economy are explored in detail and the control measures that can be used to prevent the invasion of these species are also discussed.

Introduction:

Every action has an equal and opposite reaction. This is true for just about everything including the exotic species found in many regions of the United States. Some of these plants were brought to America accidentally, or for ornamental or economic purposes. Exotic plants are valuable to us in the sense that they provide food for humans, forage and shelter for animals and many of these plants have very pretty flowers which can be used for ornamental purposes. For example farmers use cheatgrass as source of forage for livestock and the toadflax was brought over for ornamental purposes. Even though these exotic plants can be useful; some of these plants are harmful to the native plants and the animals.

Billions of dollars are spent each year to prevent and control the spread of these exotic plants in the United States. One might ask, what is the big deal in letting some of these exotic plants grow in the wilderness? The purpose of this project is to look into the

effects of these plants to the surrounding nature, plants, animal and humans. Furthermore, this project looks into some of the specific exotic plants found in the Colorado plateau and explores its characteristics. We first start by defining the problem. The figure 1 below shows the area in which we are researching our six plants.

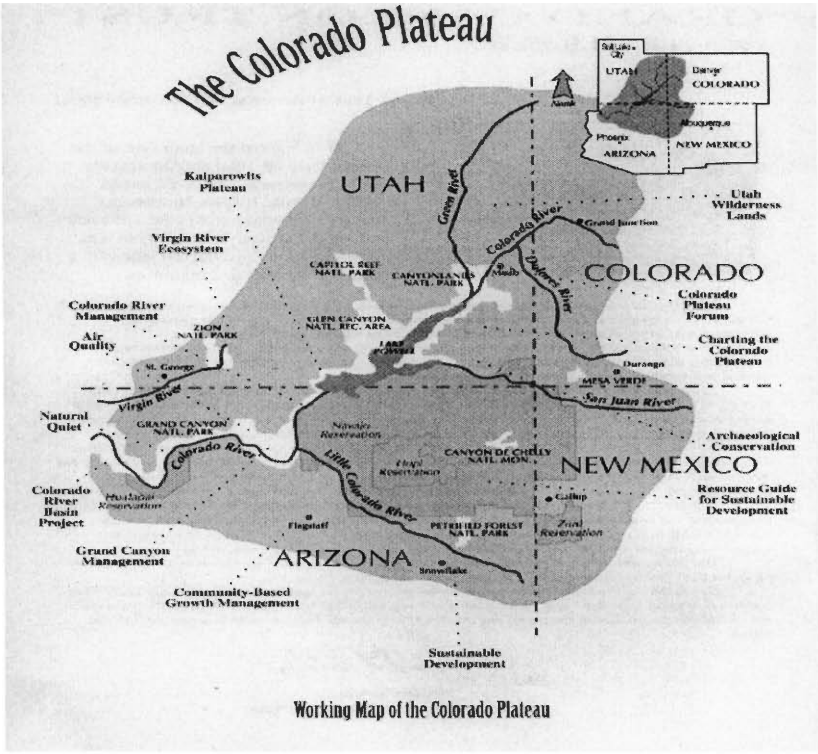

Figure 1: Colorado Plateau

Defining the Problem:

Exotic plants have major impact on the native plants and animals, it upsets the biological balance, the economic and agricultural losses causes by these plants mounts up to billions of dollars, and in addition to all of this, it also interferes with the human social activities. The paragraphs below gives a birds eye view of the problems caused by invasive plants.

Birdseye View of the Problem

The purpose of this project was to study the effect of invasive plants on the native plants, environment, and economy. From the project description given to us, we were able to learn that invasive plants cause serious trouble to the ecosystem and the environment. Our task was to focus into the effect of these plants on the western parts of the United States specifically Colorado.

When we started looking into different non-native plants, we found that there are more than 50 different exotic invasive plants just in Colorado. It is almost impossible to study the effect of all the non-native plants found in Colorado in a short period of time. Therefore our next step was to take a general look into the effect of invasive species and then choose 6 of the most threatening plants and do more research about them.

General Effect of Invasive Plants:

Water is a very precious natural resource. It is needed for daily life activities, industrial purposes and for agricultural uses. Rainfall is scarce in the western part of United States and major source of water are obtained from rivers such as Colorado. Invasive plants like Russian Olives are found growing next to river banks. Using their extensive roots system they literally suck up all the water which would have been otherwise used for irrigation purposes. For example, the O.C Fisher reservoir which was built during the 1950's has never reached the expected water level because of the invasive plants absorbing all the water from the river.

Several western states have conducted research on the harmful effect of invasive plants. One of the researches was conducted by the upper Colorado River Authority. Their studies revealed that more than 25% of once perennial streams of Colorado and

Concho River have stopped flowing due to the invasion of noxious weeds such as salt cedar, mesquite, and juniper. Furthermore, the research stated that if intense and dramatic brush control methods are not put into practice, with in the next two decades rural and metropolitan areas of Texas would not have sufficient water to meet the municipal, industrial and agricultural uses.

Invasive plants have a direct impact on agriculture as well. The main crop plants cultivated in Colorado includes wheat, barley, spring wheat, corn, sorghum, alfalfa, sugarbeets, dry beans, potatoes, onions, sunflowers, and vegetable crops. It cost about 1 billion dollars to cultivate and maintain these crops. Out of 1 billion dollars, 10% or $100,000,000 is wasted just to control and prevent weeds from invading farms. These figures are obtained after using the best prevention method technologies; without the use of these technologies, the annual crop loss would be 2 or 3 times higher.

In addition to reducing crop yield, these plants also reduce the crop quality. Volunteer rye and jointed goat grass present in the wheat harvest reduce the market quality of winter wheat stock; the presence of green weeds in harvest affects the drying and storage of small grains and sugar beets. The presence of weed seeds in the crop seeds is a serious drawback in the commercial market where sale of crop seeds are made.

Without any doubt, the effect of these plants on water and agriculture affects the economy as well. The spread of invasive weeds reduces the land value, because people don't want to buy land infected land. The modern weed control programs used in agriculture, and projects to eliminate the non-native plants found growing next to the river banks all cost millions of dollars. Invasive plants reduce the presence of native plants and animals which negatively affects the tourism. All these factors taken together

into account causes millions of dollars go to waste which could have been otherwise utilized for useful purposes. Having taken a general look into the effect of invasive plants, we now consider the in-depth effect of these plants on the sections below.

In-depth view of the problem

Role of Exotic plants in creating loss of biodiversity and upsetting the biological balance:

Invasive plants play a major role in creating loss of biodiversity. These plants are better adapted to absorb more moisture and nutrients from the soil. The result is that these plants grow without control and crowd out the native plants. Non-native plants also have the advantage that their natural competitors are absent in the newly introduced area. The figure shown below (Fig 2) illustrates the fast growth rate of dalmation toadflax, a non-native plant brought to the United States from the Mediterranean region. By examining the graph, one can see that in just 10 years the area of land infested by damnation toadflax raised from 4 acres to 900 acres and in next three years those plants were able to more than double its infestation from 900 to 2000 acres.

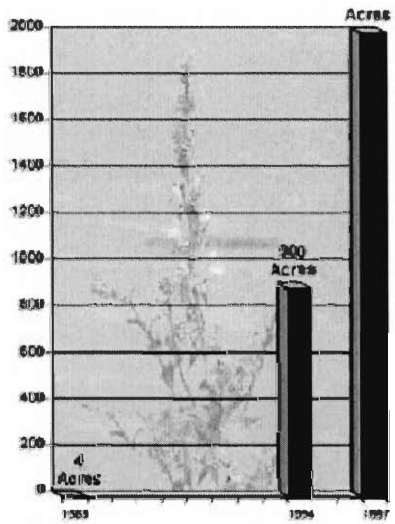

Figure 2: Dalmation Toadflax Infestation in Shoshone River.

The uncontrolled growth of these plants results in the loss of biodiversity of plants and animals. Due to the loss of native plants, animals lose their niches which cause a decrease in population of wildlife. According to studies conducted in Colorado, it was found that 10% of the 1300 native plant species in Colorado have been replaced by exotic plants.

Focusing our attention to the impact of these plants on society and economy of the western part of the United States, we can see that the impact created is very devastating. Agriculture is major source of income to the west. In-order to cultivate land efficiently, it has to be properly irrigated and the fields have to be kept out of weeds. But due to spread of the invasive plants, the amount of water resources available has decreased severely. The paragraphs given below look into the effect of non-native plants on water resources, agriculture, economy and society.

Effect of Invasive plants on water:

"Here is a land where life is written in water."

Here is a land where life is written in Water
the West is where the Water was and is
Father and Son of old Mother and Daughter
Following Rivers up immensities
Of Range and Desert thirsting the Sundown ever
Crossing a hill to climb a hill still Drier
Naming tonight a City by some River
A different Name from last night's camping Fire.

Look to the Green within the Mountain cup
Look to the Prairie parched for Water lack
Look to the Sun that pulls the Oceans up
Look to the Cloud that gives the oceans back
Look to your Heart and may your Wisdom grow
To power of Lightning and to peace of Snow.

Thomas Hornsby Ferril

Above is a poem written by Colorado's late Poet Thomas Hornsby Ferril; it implies the value of water to western states. Approximately one twentieth of the land in Colorado is used under irrigation, a proportion which is higher than any other states in America. If one were to consider irrigation by surface water only, Colorado has half again as much land in irrigation as any other state(1). As a result of this vast usage of water, it is one of the top priorities of Colorado to protect its water resources.

In western regions like Colorado and Texas, rainfall is scarce and most of the water for these areas is provided by rivers like Concho and Colorado. Recent studies done in Colorado and Texas have shown that the water provided by these rivers is reducing. West Texas landowners, water supply professionals and range scientist have long suspected that the introduction of the non-native plants plays a major role in depleting the amount of water resources available. The low water level of the O.C.Fisher Reservoir is just one of the dramatic examples which illustrate this point. The O.C Fisher reservoir was built during the early 1950's, and since its completion, the reservoir has never reached the water level predicted by its designers.

It has been determined from the existing records that this disappointing performance is due to the dramatic shift in the hydrologic characteristics which has negatively affected the watershed. Further studies were conducted in this field and according to the "North Concho River Watershed Brush Control Planning, Assessment and Feasibility Study, 1998", researches were able to conclude that by controlling the non-native brushes the total watershed could be restored from 8000 acre feet per year to 38,000 acre feet per year.

In research conducted by the Upper Colorado River Authority on "Concho River & Upper Colorado River Basin Brush Control Feasibility Study" the report states that unless intense and dramatic brush control programs are put into practice within the next two decades, specific communities of West Texas including rural and some metropolitan areas will not have sufficient water to meet the municipal, industrial and agricultural uses. The evidence for this statement is overwhelming. After the drought that occurred during the 1950's, more than 25% of once perennial streams of Colorado and Concho River have stopped flowing after noxious weeds like salt cedar, mesquite, and juniper began to dominate the area.

Two research companies namely Blackland research and Texas A&M produced a computer model of how much water could be saved annually by the control of brushes like mesquite, juniper and salt cedar. The result obtained was shocking. It showed that the entire Colorado and Concho river basin could gain a total of 249,584 acre feet of water annually. With such a huge amount of water going to waste, there is no need to argue that measures should be taken to prevent the spread of noxious invaders to save water.

Effect of Invasive Plants on Agriculture:

Invasive plants pose a serious threat to agricultural productivity as well. In Colorado alone planters spend over $100.000, 000 a year for weed control and for nuisance caused by weeds. Weeds have a negative impact on agriculture and by reducing crop production, causing low quality crop, interfering with mechanical harvesting and by reducing land value.

Colorado's main row crops include wheat, barley, spring wheat, corn, sorghum, alfalfa, sugarbeets, dry beans, potatoes, onions, sunflowers, and vegetable crops. It cost

about 1 billion dollars a year to cultivate and maintain these plants. Out of that 1 billion dollars, 10% of or $100,000,000 is wasted on the prevention and control of weeds. The wheat producers of Colorado alone suffer over $20,000,000 in losses due to the harmful effects of cheatgrass, jointed goatgrass, and volunteer rye. The figures stated above are losses obtained after using best weed management technology. If one were to cultivate the land without these technologies, the annual crop loss would be 2 or 3 times higher.

The losses in crop yield by weeds are caused by competing for light, moisture, and soil fertility. Detailed study done by the Colorado Noxious Weed management team showed that weeds competing with row crops were quickly able to reduce the yield by 10 to 15%. In places where the weed densities are high, the yields were reduced from 25 to 50%. Further studies done on corn and wheat plants by researchers confirmed that 60 to 75 % of the crop can be lost due to weed infection.

Loss of crop yield is not the only harmful effect of weed on agriculture; it also reduces the quality of the crop. Weeds such as Volunteer rye and jointed goat grass reduce the market quality of food stock winter wheat. Poisonous weeds reduce the hay palpability of livestock's and the excess amount of green weeds present in the harvest affects the drying and the storage of plants such as small grains and sugarbeets. In addition to all of this, weeds can also cause rejection of seeds for commercial seed purposes. For example, certain weed seeds are banned from being present in certified seeds offered for sale. Scouting can detect the presence of these seeds. If these weed seeds are found in the crop seeds, then the farmers are not allowed to sell their crop seeds from that farm in the commercial market. Furthermore the presence of weed seeds can affect the reputation and value of crop seeds from a particular region as well.

Documented absence of weed seeds standout as an important aspect of the commercial seed trade. Therefore it is very important that measures are taken in-order to prevent the spread of noxious weeds on agricultural lands.

Economic Impact of Invasive Plants:

Economic loss is another downside created by the non-native plants. The basic value of any income producing investment is based on the projected income flow the investment will produce (2). This is true for stocks, bonds, buildings cars etc. If the income stream increases, the price of the product also increases. On the other hand if the income stream decreases the price of the product decreases.

When invasive plants invade a new land area, it decreases the carrying capacity of the land by crowding out the usable forage plants. Since the income stream decreases, the value of the land decreases as well. 70 million acres of land in the west are infested by weeds. One can just imagine the tremendous amount of land values lost due to the spread of these plants. The table shown below shows the annual grazing land impact (Table 1) and wildland impact (Table 2) in the state of North Dakota.

Grazing Acres	$11,426,000
Infested Acres	625,900
% Infested Acres	5.48%
Lost Animal Unit Months (AUMs) of Grazing	459,000
Value Lost AUMs	$ 6,876,000
Lost Expenses & Returns	$17,317,000
Direct Economic Impact	$24,193,000
Secondary Economic Impact	$53,989,000
Combined Economic Impact	$78,182,000

Table 1: Annual Grazing Land Impact in North Dakota

Wildland Acres	4,899,000
Infested Acres	350,300
% Infested	7.15%
Reduction Soil Water Conservation	$ 514,100
Reduction Wildlife Recreation	$2,111,600
Direct Economic Impact	$2,625,700
Secondary Economic Impact	$5,291,000
Total Economic Impact	$9,790,000

Table II: Annual Wildland Impacts in North Dakota

Adding the total economic impacts caused by grazing and wildland, we get $87,972,000 lost each year just in North Dakota. Its really mind disturbing to think that such a huge amount of money is gone to waste due to invasive plants.

Reducing the land value is not the only economic impact of these plants. In the section "Effect of Invasive plants on water"; the amount of water lost due to invasive plants is discussed. In-order to save the available water resources, strong measures have to be taken immediately. A study done by the Upper Colorado River Authority(UCRA) calculated that water in the Colorado and Concho river can be saved at the cost of about $74.63 per acre foot of water. UCRA is recommending that approximately 1.4 million acres of watersheds should be targeted which will result in a final cost of $72.5 million.

Non-native plants also adversely affect the economy by interfering with the recreation and tourism activities.

Effect of Invasive Plants on Tourism:

Tourism is another major source of income of the west. One might wonder why people would go to the west for tourism. The answer is that many places there are considered wild and unspoiled. It's a place where the native ecosystem and natural occurrences still dominate the landscape (2). People go there to enjoy the nature, watch wildlife and to have good hunting. But due to the rapid spread of invasive plants the

natural species are being replaced and are being pushed more into the wilderness, places which cannot be accessed by the public.

Wildlife appreciation can be classified into to two categorizes such a consumptive wildlife appreciation and non-consumptive wild life appreciation. Consumptive wildlife appreciations consist of hunting while the other consists of watchable wild life activities and photography. The expenditure for these activities includes sales of gun, ammunition, license, gasoline, lodging, good and services. Non-consumptive wildlife appreciation expenditure includes the fees required for the guides, lodging, camping and photographic equipment, public or private land use fees and park trips.

The total annual expenditure for consumptive and non-consumptive wildlife related activities is calculated to be about $217,000,000 a year. Due to the spread of spotted knapweed alone, the direct economic impact is calculated to be about $1,177,000 a year. The direct economic impacts of these weeds have secondary impacts such as reduction in employment opportunities and income. Adding the primary and secondary impacts together, we get a total loss of $2,641,000 each year.

From the facts given above, it can be clearly seen that the non-native plants have a negative impact on the environment, on humans, and that they even have the ability to change the structure and function of the ecosystem resulting in large scale transformation of environmental condition of that area. Therefore time must be taken to study the effect of these newly introduced plants.

For the purpose of our project we looked into six different types of invasive species that are found in Colorado. The six species are Leafy spurge, Yellow starthistle, Cheat grass, Russian Knapweed, Toadflax and Salt cedar. For each of the plant species,

there is a brief description of their origin, structure, effects on other plants and animals, usage of water, effects on the environment, and the prevention measures that could be taken to preclude the further spread of these non-native species.

Six Major Invasive Plants of Colorado:

1) Bromus tectorum (Cheatgrass)

Cheatgrass is an exotic plant which was bought to the United States from Eurasia. This plant was introduced to the Colorado plateau during the 1890's through contaminated seeds. By 1920, cheatgrass were able to invade most of the semi arid area of the Colorado plateau. Figure 3 and figure 4 show pictures of Cheatgrass.

Figure 3: Semi-dry Cheat grass

Figure 4: Cheat grass

Classification and Physical Structure:

Cheatgrass can grow from 6 inches to 2 feet tall. The leaves which are 1/8 to ¼ inch wide are covered with fine soft hair. This plant is categorized as an annual plant,

which means that it grows from the dispersed seeds, produces seeds and dies by the end of the year. Furthermore, it can be classified as a winter annual because the plant germinates during fall, survives the winter and disperses the seed by summer and ends it lifecycle.

Method of Invasion:

Cheatgrass acts both as an early serial invader and as a climax dominant plant on sites where perennial grass and forb understories are found. Cheatgrass invades a new region mainly by help of wildfire. As stated above, cheatgrass is a winter annual plant; therefore it completes its life cycle by spring and dries by the time summer weather begins. The dry fine structure of the plant serves as an excellent fuel for fire. Naturally wild fires occur at a frequency of one in every 60 – 100 years. With the presence of cheatgrass, wildfires occur once in every 3-5 years. At this frequency, the native species are simply not able to recover after a cycle of two or three wildfires. As a result, the cheatgrass monoculture forms and this further increases the frequency of wildfires making cheatgrass the dominant species in an area.

Effect on plants and environment:

Creating serious threat to the environment as a fire hazard, reducing the nitrogen content of the soil, depleting minerals and water are some of the harmful effects of the cheatgrass. Table 1.1 outlines some of the characteristics of cheatgrass which makes it a fire hazard and figure 5 shows a devastating wildfire caused by cheatgrass.

1) It produces large quantities of seed that usually develop into dense stands.
2) It can provide continuous fuel between grass land and forest stands.
3) It grows in 6 to 22 inch precipitation zone, area with severe fire weather.
4) It cures early in the fire season
5) Its finely divided stems and flowering stem ignite readily when dry
6) It responds easily to any change in moisture conditions because of its structure

Table III: Characteristics of Cheatgrass which makes it fire hazard.

Reducing the nitrogen content of the soil is another undesired result of cheatgrass. Research conducted by Professor Raymond D. Evans and his colleagues from University of Arkansas found out that the nitrogen content of the soil decreases dramatically where cheatgrass are found. This lack of nitrogen in the soil can potentially choke the native plants of the dessert.

The reason why the nitrogen content of the soil decreases is because when cheatgrass invades an area, it grows in thick blanket thereby blocking the sunlight to the soil. The microorganisms, primarily cyanobacteria which fix the nitrogen in the soil need sunlight to help replenish the nitrogen. Therefore by blocking the sunlight, cheatgrass are preventing the bacteria's from nitrogen fixation. In addition to this, the wildfire caused by the plant causes the nitrogen trapped in plants to literally go up in the smoke.

Figure 5: Wildfire caused by cheatgrass.

The lifecycle of the cheatgrass enables it to adapt in a better way to the environment so that it can absorb more minerals and nutrients. The roots system of the Cheatgrass grows during the winter. Therefore by spring time when all the other native plants are just growing their root system, cheatgrass already has extensively built roots which help it to extract higher level of soil moisture and nutrition.

Effect of Cheatgrass on Animals:

As most of the nonnative plant, cheatgrass also has negative impact on the native animals. The wildfire caused by cheatgrass makes it impossible for the native sagebrushes to grow. Shrub-steppe animals depend upon these shrubs for food, shelter and nesting. Therefore the decline in the presence of sagebrush caused by cheatgrass adversely affects the population of native species of the Colorado. Most of the native grass fields are also replaced due to the spread of cheatgrass. Livestock's of that area depend on these grasses for food. Table 4 shows the palatability of cheatgrass for various livestock's.

	CO	MT	ND	UT	WY
Cattle	Fair	Fair	Fair	Good	Fair
Sheep	Fair	fair	Fair	Fair	Fair
Horses	Fair	fair	Fair	Good	fair
Pronghorn	---	Good	Poor	---	---
Elk	Fair	Poor	---	Good	---
Mule Deer	Poor	Poor	Poor	Good	---
Small Mammal's	Good	Poor	---	Good	---
Small Non-game birds	---	Poor	Poor	Good	---
Upland game birds	---	---	---	fair	---
Waterfowl	---	---	---	Fair	---

Table V: Palpability of Cheatgrass

From the table we can see that for most of the animals, the palpability is just fair. Nevertheless cheatgrass can provide good nutritional value for livestock's during the

spring, but once the grass matures, its nutritive value decreases rapidly. If the cheatgrass are consumed by cattle during late spring and summer, it could harm the cattle because the mature seeds contain long stiff awn that often punctures the mouth and throat tissues of the cattle. The barbed fruits can also pierce into the eyes of the livestock causing serious injury. Sometimes the intestines are pierced resulting in the death of the cattle.

The native plants not only provide food to the native animals, but it also provides cover from its enemies. Shown below on table 5 is the wildlife cover given by cheatgrass to different fauna of the western states.

	UT	CO	MT
Elk	Poor	---	---
Pronghorn	Poor	---	---
Upland game birds	Fair	---	---
Waterfowl	Fair	---	Good
Small Non-game bird	Good	---	Poor
Small Mammals	Good	Good	Poor

Table VI: Wildlife cover by cheatgrass

Effect of Cheatgrass on humans:

According to research, the presence of about 105 cheatgrass plants every square yard reduces the wheat yield by an average of 27%. In addition to this, it takes millions of dollars for the restoration and reconstruction of facilities destroyed by wildfires caused by cheatgrass. The loss of land due to the spread of cheatgrass is also devastating. According to the Bureau of Land Management, roughly 4,600 acres of federal lands in the West are lost each day to weed infestations. Once infested, most lands cannot be reclaimed with our current technical and economic capabilities, resulting in significant or total loss of economic and environmental land values. It can be said that heavily infested lands are essentially national sacrifice areas.

Control Measures:

From the discussions above, one can see the adverse effects of cheatgrass. In order to protect the native plants and animals, it is extremely important that control measures are taken to prevent the invasion. A combination of controlled fire, mowing the grass, and using chemicals are needed to control the spread of cheatgrass. First the plant has to be burned during early spring before it has dispersed its seed. For the following two years, the area has to be mowed to get rid of grasses which have emerged from the existing seed bank. Native plants should also be planted repopulate the area with the native species. This is the only method which has shown some effect over the control over invasiveness of the cheatgrass.

2) Toadflaxes (Dalmation and Yellow Toadflax):

The Dalmation Toadflax and the yellow toadflax is another invasive weed found throughout Colorado. These plants have its origin from the Mediterranean region. It was bought to the United States for ornamental purposes and has been cultivated as an ornamental for at least 400 years. The toadflaxes were meant to be brought up in cultivated environments such as home gardens, but they escaped into the wilds and were able to become an invasive species. Figures 6 and 7 provide the pictures of Dalmation toadflax.

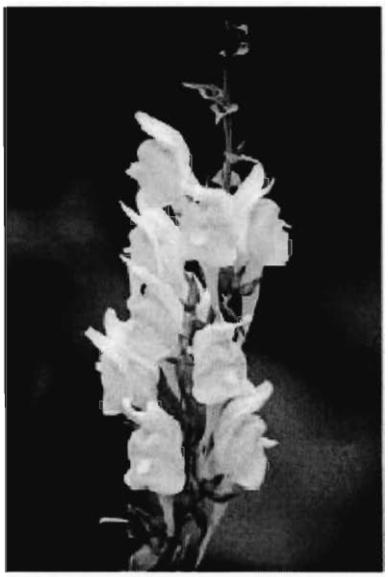

Figure 6: Dalmation Toadflax

Figure 7: Yellow Toadflax

Classification and physical Structure:

The Dalmation toadflaxes are herbaceous short lived perennials that emerge during April or May. Dalmation toadflaxes have stems which are 3 to 4 feet tall. Their leaves are board and covered with wax. The seeds produced are irregular in shape and are flattened. Figure 8 shows the detailed description of the plant. Yellow toadflax on the other hand grows shorter, have smooth erect leafy stems. They often grow to be 1 to 2.5 feet tall. The fruit produced is brown in color, globe shaped capsule containing many seeds within. The seeds itself are small, round and rough. Figure 8 shows the detailed picture of the plant with stems, roots, flowers and fruits.

Figure 8: Dalmation Toadflax

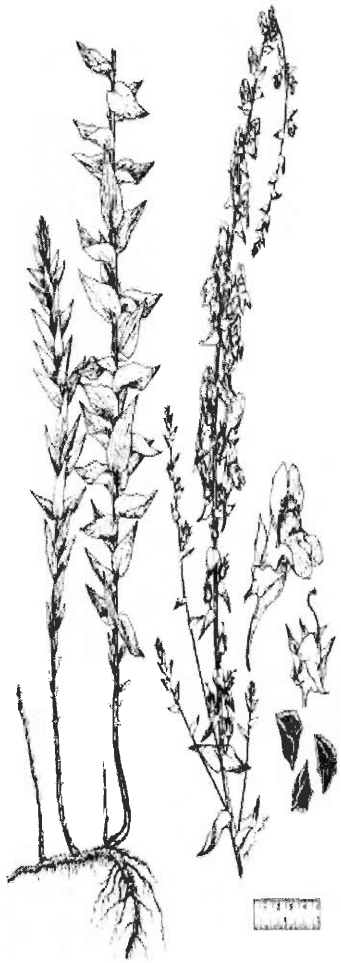

Figure 9: Yellow Toadflax

Methods of Invasion:

The toadflax species have high genetic variability which enables them to thrive through a variety of climatic conditions. These plants are usually found in disturbed open habitats. A single dalmation toadflax can produce up to 500,000 seeds while the yellow toadflax produces up to 30,000 seeds a year. And these seeds can germinate up to 20 once it has entered the soil. Using wind as the primary source of disposal these plants have been able to spread throughout Colorado.

The ability of the toadflax to generate extensive roots system helps it to invade a wide range of area effectively. During the first year the plant is established, it can

produce 90 to 100 secondary shoots from the roots. Lateral roots of Dalmation toadflax spread out from the base of the plant approximately one to four inches below the surface of the soil. Sinker roots extend from the lateral roots four to ten feet deep. Vegetative buds are generally produced on lateral roots two to eight inches below the soil surface. These buds grow new plants especially if the mother plant is disturbed (trampled, grazed or mowed), the soil is tilled, or more moisture becomes available.

Ecological and Environmental Impacts:

The toadflaxes are aggressive and highly competitive weeds. As a result, these plants can effectively replace the native plants as well as the animals associated with it. The displacement of bunch grass communities by toadflax increases soil erosion and surface runoff. The toadflaxes also have poisonous glycoside present in them which can be harmful to livestock if consumed in large amount.

Economic Impacts:

The spread of the toadflaxes has greatly reduced the cattle-carrying capacity of the pasture lands in Colorado. Studies indicate that presence of these plants in fields reduce the palpable grass as much by 2 or 3 times than its natural carrying capacity. Toadflaxes are also poisonous to animals; if these plants are consumed in large amount death of cattle's could result.

Even though economic data specific to Dalmation toadflax are scarce, it was recorded that the direct management cost averaged $40 per acre in 1992 on a Montana ranch of which 30% of the 1064 acres were infected.

Control Measures:

Both the Dalmation toadflax and the yellow toadflax are aggressive growers and are extremely hard to control. Prevention is the best method to keep the spread of these plants under control. Using herbicides is one way to reduce the population of these plants, but this process requires constant treatments at highly expensive rates. Biological control is another effective way of controlling the spread of these plants. There are eight different insects that can be used for the purpose, namely 1) *Brachypterolus pulicarius,* 2) *Calophasia lunula,* 3) *Eteobalea intermediella,* 4) *Eatable serratella,* 5) *Gymnetron antirrhini,* 6) *Gymnetron netum,* 7) *Gymnetron linariae,* and 8) *Mecinus janthinus.* Burning these plants is not effective in controlling them because the fire is seldom able to destroy the roots and seeds buried inside the ground.

3) Centaurea solstitialis L (Yellow Starthistle)

History:

Yellow starthistle(figure 11), also known as *Centaurea solstitialis L,* is an exotic plant that currently exists in many areas of the United States including the Colorado Plateau. Yellow starthistle is native to Eurasia and is believed to have been introduced in the western United States in mid 1800's. It is believed that the yellow starthistle was first brought over by European and Chinese settlers in California through contaminated grain or Chilean grown alfalfa seed and the primary use of these plants was for beekeeping and honey making.

Classification and Characteristics:

Yellow Starthistle is a member of the sunflower family, Asteraceae. Yellow starthistle is a gray-green to blue-green plant that produces yellow thistle like flower with

3/8-3/4 inch yellowish spines arranged in position like a star located at the base of the flower head as shown in figure 10. They can grow in heights varying from 6 inches to 5 feet and it has rigid, winged and covered stems that branch from the base and has a taproot which extends deep and these taproots compete for moisture and nutrients with other plants. The lower leaves of this plant are deeply loped with a length of about 2 to 3 inches and the upper leaves are short, sharp and narrow with a length of about 0.5 to 1 inch. Both the stem and the leaves are covered with cottony wool hairs and are of dull green color with a whitish appearance. The outer seed of the flower is dark brown without any bristles, while the inner seed is light brown with white bristles about 1/8 inches long.

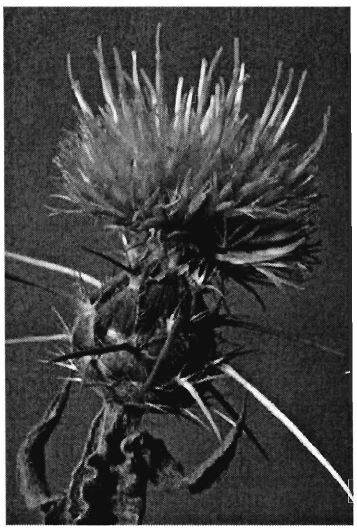

Figure 10: Spiny Flower

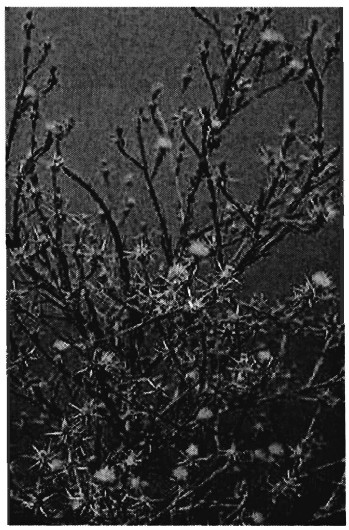

Figure 11: Yellow Starthistle

Life Cycle:

Yellow starthistle has a very long life cycle and it germinates from fall through spring. The taproot allows them to store moisture and nutrients for the growth and flowering well in to the summer, long after other native species have died off. These plants are a winter annual and it sometimes behaves as a biennial, depending on the

climate conditions. They begin the growth cycle in the fall from seeds that germinate when the temperature is in sixties and when the moisture conditions improve. The plant begins to bolt from May to July and produces bright flower heads that are spiny. From June through August the flowering takes place, this is when the bright yellow flowers open up. In August the plants begin to dry off and they can be easily identified by their silvery gray with a white cottony flowerhead as shown in figure 13. The changing of colors from bright yellow to silvery gray indicates that the seeds have matured. The flowering and seed production times will vary according to the climate. There are two types of seeds produced through this process. The two types are plumed seed and plumeless seeds. The plumed seeds are produced by the florets in the center of the head and the plumeless seeds are produced by the outer circle of the florets. The plumed seeds are light colored seeds that quickly disappear after it matures. The plumeless seeds are dark colored seeds that remain in the head until it falls apart by wind, frost or other disturbances. The seeds fallen, germinate around the parent plant within a distance of 2 feet. The seeds begin to germinate with the fall rain and the growth cycle repeats. Because of varying conditions, the distribution and maturation rates, some seeds may germinate at any time of year. In general, the plants mature by late august, and from September through October, the plants dry out, loose leaves and turn silvery grey with whitish heads. In some places, depending on the climate

Figure 12: Branches

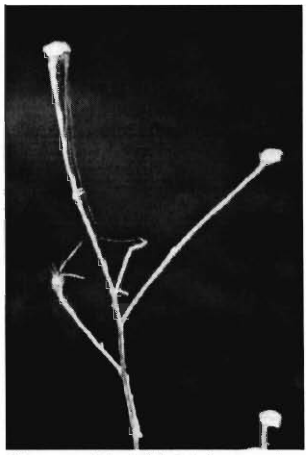

Figure 13: Whitish heads

conditions, yellow starthistle can survive over the winter, re-grow in the spring and dry out by early June.

Temperature also plays a major role in the growth of the yellow starthistle. In mild winter climates, plants can act as biennials, meaning the plant could live up to about 2 years. In colder climates, mature plants hardly survive the winter, while the seedling can survive extended frost periods.

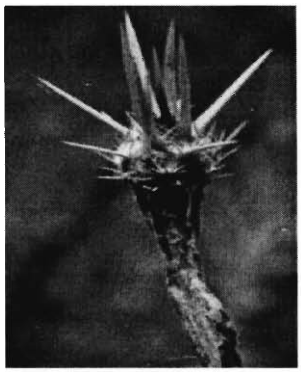

Figure 14: In bud

Figure 15: Juvenile starthistle

Effects on Water and Native plants:

Recent studies on the yellow starthistle show that these plants take up significant amounts of water and this threatens both human economic interest as well as native plant ecosystems. Yellow starthistle takes as much as 50% of annual stored soil moisture and

reserves it in its roots to depth greater then six feet. They also have a great impact on the native species such as blue oak, *Quercus douglasii*, and Purple needlegrass, *Nassella pulchra*. For growth and survival, these two native plants depend on the summer soil moisture. However, having yellow starthistle in the same area as these plants affect their survival rates, since, the yellow starthistle reserves deep soil moisture much earlier then the native plants disabling them from reserving the amount of moisture needed for their survival. Even with normal rainfall, the native species can experience drought conditions if the yellow starthistle infestations are high. If we can somehow control the further spread of weeds and completely get rid of the existing weeds, we could conserve great amounts of water. Thus, helping the human economic interests as well as the native plant ecosystems.

Habitat:

Yellow starthistle is found in areas with hot, dry summers and well-drained soils, especially in areas where fire, over-grazing, road construction or other causes have seriously disturbed vegetation. They can also be found in vineyards, abandoned croplands, alfalfa and small grain fields and roadsides and are also able to grow in various types of soils. These plants reproduce through seeds. Yellow starthistle can produce about 150,000 seeds per plant per season. The seeds can be spread through wind, contaminated commercial seeds, alfalfa seeds, hay, vehicles, construction and maintenance equipment, farming equipment, motor rail vehicles, animals, man and birds, especially birds with finches.

Figure 16: Setting Seed

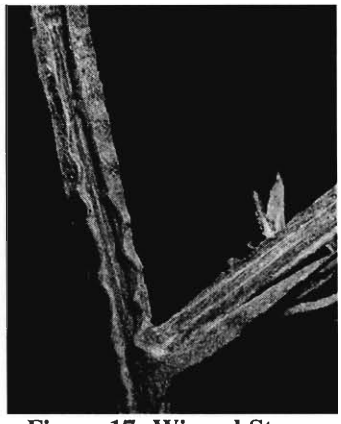

Figure 17: Winged Stems

Effects of Invasion:

Yellow starthistle is known to kill horses and poses a danger to the wildlife and agriculture in the Colorado plateau. Yellow starthistle is toxic to horses and if they come in to contact with the plant, they may be poisoned and can develop disease such as the chewing disease, if they consume large quantities over one or two months. The toxin is created when the chemical substances in the yellow starthistle are somehow altered in the processes of digestion and metabolism, which causes death of nerve centers in the brain controlling normal eating and drinking mechanisms. The disease can be recognized with the first symptoms of poisoning. Lacking in ingestion of food or drink, muscles of the lips, face, and tongue become stiff and swollen, giving the horse a fixed expression are usually the first signs of poisoning. Poisoning from these plants ultimately results in permanent brain damage, and severely affected animals eventually die of thirst and starvation, since they are unable to consume any food or water. Sheep, cows, and other livestock are unaffected by this plant. So far no cure has been found to treat the animals poisoned by the yellow starthistle.

Yellow starthistle has been found to be releasing some types of chemical compounds that might affect the native plants from growing. The process through which

these chemical compounds come in contact with the native plants is known as the allelopathy. Allelopathic compounds escape from degrading plant residue or from the moisture of the roots and the chemicals are released through glands or duct on the stem or foliage.

Control Measures:

There are many control methods, through which existing yellow starthistle and the further spread of these plants could be controlled. These methods include, mowing, grazing, control with grasses, burning, re-vegetation, chemical control, mechanical control, biological control, and total prevention methods.

For mowing to work efficiently in order to reduce the number of yellow starthistle, appropriate mowing methods should be used. If an appropriate method is not used, it may increase the number of plants rather then reducing it. The proper mowing method would be mowing after the annual grasses have dried off, seed is shattering and most important is when the yellow starthistle is not mature. If the plant is mowed after all the flowers have bloom or if the plant has not started budding, this would increase the amount of yellow starthistle. Blades should be set low in order to remove the flowering tops and buds, but it shouldn't be so low, because if it is too low the cutter will not be able to cut it after its re-growth. Second mowing should always be done within four to six weeks of the first mowing. Third mowing will not be required unless there is enough moisture in the soil and the temperature is still hot. This procedure will not completely get rid of the yellow starthistle, but it will help to reduce the growth of these plants.

Another method which could be used is grazing. Through studies, it has been found that this is an effective method for the control of yellow starthistle if it is used

properly. First and the most important thing to remember when grazing is that horses should be allowed to graze on the yellow starthistle, since this plant has been proved to be poisonous to horses. Sheep, goats, or cattle can be used for the grazing of yellow starthistle. Grazing should be done at least one to three times at about two weeks interval, and grazing should be done in the months of May through June at an earlier growth stage of the yellow starthistle. However, the growth rate will increase if grazing is done in the early rosette stage, since this is the leaf stage that comes before the budding stage. Overall, this method will help decrease the reproduction rate, the plant height and the size.

Another method that could be used is the burning method. It is best when the burning of these plants is done when the flowers first appear at the end of the rainy season. Burning should occur when the yellow starthistle is green and other grasses have dried off, the foliage from these grasses will serve as a fuel source to allow a more complete burn. In order for this method to work, burning should be done for at least two or more consecutive years. This method will help control the yellow starthistle and reduce seed spreading.

Re-vegetation can also be used for the control of the yellow starthistle plants. The methods that we looked at earlier can only be used to reduce these plants but with no other competitors to compete with they will re-establish themselves in the area. With re-vegetation, certain plants could be planted in the area where the yellow starthistle plants are found and we can use these plants to prevent the germination or growth of the yellow starthistle plants. The plants chosen should be well adapted to the environment so that it

would be unlikely for them to become invasive plants and it is best to choose plants that could grow faster and better.

Using grasses such as Zorro annual fescue and perennial ryegrass can help reduce the growth of the yellow starthistle. Also, through research it has been found that wild oats are capable of completely removing the yellow starthistle plants, without the fear of it being reestablished. It is found that the grasses provide shades, which play a major role in the reduction of the yellow starthistle.

Chemical control can also be used to control the yellow starthistle. Herbicide treatment is most commonly used method since this method is considered to be the most economic and effective. Several herbicides such as clopyralid, 2-4-D, Dicamba, Triclopyr, Glyphosate can be used while the plant is in the rosette stage. These herbicides are known as the post-emergent herbicide treatments that generally work on seedlings. Post-emergent herbicides can be used around the home, for pastures, rangeland, along roadsides and other non crop areas. Another type of herbicide treatment is the pre-emergent herbicide treatment, which should be applied before the seeds germinate in order for it to work effectively. Pre-emergent herbicides such as chlorsulfuron and sulfometuron are used along roadside and for other noncrop uses. Best control of yellow starthistle is achieved when these pre-emergent herbicides are used before the weeds emerge. These should not be used in pastures, rangeland or around the home. Overall, herbicides can be most commonly used for the control of the yellow starthistle for both agricultural and non-crop environments.

Another method used for the control of the yellow starthistle plants is the mechanical method. When using this method, the irrigation should occur before the

autumn rains to induce early germination. In order to bring the buried seeds on to the surface, deep tilling or disking will be required. When the autumn rains begin to fall, the new re-sprouted seedlings should be disked again so that desired grasses could be planted. This method can be used in spring as well, but for it to work effectively the tillage must be deep because by this time the yellow starthistle forms deep tap roots and it will be difficult to take out. By doing this, it will bring the buried seeds to the surface which will result in new germination which must be disked under as well. This should be done several times before planting any types of grasses.

Biological control is believed to be the best method for broad, general control of the yellow starthistle plants. Insect species that feed on various parts of the plant or seed are used on the yellow starthistle pants. Recent studies have shown that insects such as weevils and flies are most beneficial. The two weevils that are commonly used are the *Bangasternus orientalis* and the *Eustenopus villosus* and the three flies that are commonly used are the *Urophora sirunaseva*, *Chaetorellia australis*, and *Chaetorellia succinea*. All five of these species attack the yellow starthistle's only mean of reproduction and spread of the weed, which is the flower/seed head and they directly or indirectly reduce the seed production. The way these insects work is that they lay their eggs in or on the flower/seed heads and the larvae eat up most of the maturing seeds before they can spread. These insect species do no attack any valuable crops or any of the native plants. Most recently, it has been found that the *Eustenopus villosus* and *Chaetorellia succinea* have been proven to be most effective in reducing the spread of yellow starthistle plants. This control method is viewed used as the best long-term strategy for managing the weed. However, it is believed that this method alone cannot

control the spread of the yellow starthistle plants. Combination of herbicides and biological controls might prove more effective then using any of these methods alone.

Total prevention is however impossible, since the yellow starthistle plants are spread over a wide range of North American continent. Even though we cannot completely remove these plants, we can help the further spread of these species. Some measures that could be used are that, people driving vehicles should not drive through thistle zone in to a thistle free zone. Always check hay or straw before feeding the animals. Re-seed the ground with desired species and mulch when it is necessary to do so. Also try and avoid soil compaction. These were some of the measure people might use to help stop the further spread of these species.

People have been researching on the yellow starthistle plant to try and find a way to remove these plants. Currently an entomologist at the Exotic and Invasive weeds research unit is conducting a research on the yellow starthistle's seed production in the United States and in one of the native countries, Turkey. The yellow starthistle does not spread as much over in Turkey as it does here in United States. His current objective is to find out the conditions in Turkey that keep the yellow starthistle from spreading more and create those conditions here.

Yellow starthistle is not entirely bad, since it provides nitrogen to enhance the soil, erosion protection, and also provides food and cover for some forms of wildlife. It provides forage for the cattle when it is in its early growing stage. Bees also use these plants for the production of honey. However it also poisons horses, annoying to people and produces chemicals that inhibits the growth of other plant species.

4) Centaurea repens (Russian Knapweed)

History:

Russian knapweed, most commonly known as *Centaurea repens* or *Acroptilon repens* is a member of the Asteraceae (sunflower) family. Russian Knapweed is a native of Mongolia, western Turkistan, Iran, Turkish Armenia, and Asia Minor. It is known that Russian knapweed has invaded most of the continent except for Antarctica. It was introduced in the United States through the Turkistan alfalfa seed and possibly sugar beet seed. It was first introduced in California in the early 1900's and soon became widespread through out the United States.

Figure 18: Russian Knapweed

Figure 19: Leaves

Classification and Characteristics:

Russian knapweed is a perennial herbaceous plant that is characterized by its extensive root system, low seed production and persistence. It is silvery green in color and it can grow up to 3 feet tall. Shoots or stems are erect and branched openly ranging from 18 inches to about 36 inches tall with many branches. When young, the stems of this plant are short, wooly and whitish in color and the leaves are covered with soft, short, gray hair. Stems of the older plant are dark brown to black in color. Lower leaves of this

plant are 2 to 4 inches in length and are deeply lobed, while the upper leaves are very narrow, oblong, and toothed with smooth margins (figure 19). The roots of these plants are called "black root", since they are black or dark brown in color and has small alternately arranged scale leaves which supports buds in their axils (figure 24). These buds then develop in to adventitious shoots, enabling the plant to spread rapidly and form dense colonies. The roots of the Russian knapweed are arranged in horizon and vertical positions in the ground. The roots can be from 6 to 27 roots per square foot and they can grow to a depth of about 23 feet. The root is the major means of propagation and spreading. The flowers of the Russian knapweed are pink to lavender in color and they grow in solitary heads at the tips of leafy branches. They are cone shaped with the head ranges from ¼ to ½ inches in diameter. The bracts, located under the flower heads are of a broad papery tip and are greenish in color. The flowers have a thistle like texture that is lavender to white in color and are 1/3 to ¼ in diameter. The seed of this plant as shown in figure 21 is called the Achenes. Achenes are 2-3 mm long, 2 mm broad, 1 mm thick and are of ivory color with long white bristles.

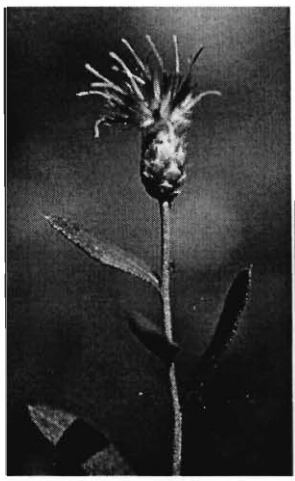

Figure 20: A Flower

Figure 21: Seeds (Achenes)

Habitat:

Russian knapweed can be found along roadsides, riverbanks, irrigation ditches, pastures, waste places and croplands. This plant is common on the heavier, often saline soils of bottom lands as well as sub-irrigated slopes and flats. Russian knapweed is known to invade disturbed areas, forming dense single-species stands and it does not readily establish in healthy, natural habitats. Russian knapweed is mostly commonly found in riparian communities such as the Freemont cottonwood and the skunkbrush community. This plant is not restricted to any particular soil but it grows particularly well in clay soil. According to a study conducted, infestations of this plants seems to increase in dry locations but the infestations were known to decrease in moist locations due to the presence of perennial grasses. Also another study, conducted by Dall'Armellina and Zimdahl in 1988 showed that the Russian knapweed would not be able to compete well under a heavy canopy and it is more suited to open areas. Also, the Russian knapweed is able to survive in almost any crop and it is sensitive to decreased amounts of sunlight.

Life Cycle:

Russian knapweed is long-lived, perennial (living up to two years or more) and persistent weed species. In Colorado, the Russian knapweed emerges in late April or early May. The young plants can be recognized by their silvery green color, hairy leaves and shoots. The plant starts to bolt and forms rosettes in late May to mid-June. The lavender cone shaped flowers bloom from June to October producing ivory-white seeds with a feather like plume. These plants, approximately, produces 50 to 500 seeds per shoot and are viable for two to eight years in soil in the Colorado region. This plant

emerges earlier then other noxious weeds, since it is usually full grown by June. The early growth of this plant gives them a great competitive advantage over spring-planted and low-growing crops. These plants transfer nutrients such as carbohydrates to the root system after the bloom and into the fall. These nutrients help form the root buds which will produce new shoots in spring.

Figure 22: A Seed head

Figure 23: Dense Infestations

Reproduction:

Russian knapweed reproduces through seeds and vegetative root buds. This plant does not reproduce entirely through seed dispersal and the plant is able to produce up to 1,200 seeds per year. Seeds of Russian knapweed germinate over a wide range of temperatures ranging from 20-30 degree Celsius. Light is not essential for germination but altering the light and darkness seems to improve germination and white light has been known to stimulate the germination process of these plants. Since the seeds are too heavy to be carried by the wind the seeds are not spread that easily. They are usually transported

through contaminated hay or seed lots. Primary means of reproduction for these plants is through vegetative buds. The root system consists of the original root, taproot, one to many horizontal roots and their vertical extensions. Horizontal roots form shoots that can later grow in to newly independent plants. The roots can extend horizontally up to 7 meters with 2-2.5 meters of growth in the first year and 5-7 meters of grown in the second year. Stands of these plants can grow to densities of 100-300 shoots/meters squared, which can completely crowd out the competing plant species and the stands are known to survive for more than 75 years. This plant is found to have allelopathic effect that inhibits the growth of crops and other plants in the area. This allelopathic effect, combined with the vegetative reproduction, allows the Russian knapweed to colonize and dominate new sites quickly.

Effects of Invasion:

There have been many known impacts of Russian knapweed on other species, since Russian knapweed can easily form very dense colonies and its root can extend up to great lengths. This plant invades many disturbed western grassland and shrub land communities and also the riparian forests. Once they are established in to the area, they can easily dominate the area reducing the desirable vegetation such as the perennial grasses. Russian knapweed is known to threaten the stability of ranching operations on rangeland. Presence of Russian knapweed reduces forage for livestock and biodiversity for wildlife habitat. Animals are should not be allowed to graze on the Russian knapweed, since the taste of this plant is bitter and it is known to be poisonous to horses as it can cause a neurological disorder called the "chewing disease." The symptoms of this disease, resembles to the Parkinson's disease in humans and the symptoms are

generally that the animals will be incapable of consuming any food or water. So far this disease has only been found in horses. Cattle, sheep and goats are unaffected by this plant. The presence of the plant in hay decreases its feed and market value. Russian knapweed on agricultural land may cause serious reductions in yields, crop value and may even significantly devalue the land itself.

Food Source:

Russian knapweed is known to be used by white-tailed deer in north central Montana as a source for food in the summer and winter months. It is also considered to be important forage for bighorn sheep found in the Rocky Mountains and the seeds of this plant are a food source for some birds and rodents.

Figure 24: Roots

Figure 25: Russian Knapweed

Control Measures:

The keys of controlling the Russian knapweed are stress the weed and cause it to expend nutrient stores in its root system, eliminate new seed production and control its vegetative spread. There are several methods that can be used for the control of the Russian knapweed species. Such controls include burning, cutting, grazing, mowing, pulling, biological control, cultural control, and chemical control.

There is no information on the Russian knapweed regarding fire adaptations. This plant is known to be deep-seated with extensive perennial root system that will likely allow it to live even after a severe fire. Fire probably would kill the plant but the root system will be unharmed. It could most likely re-establish itself from root buds after the fire or through seed dispersal or though people, animals or vehicles. It is also capable of re-establishing itself from seed, however the tolerance of the seeds to heating is not known and any dispersal of seeds over a distance larger then the height of the plant requires a dispersal agent to carry the seed. In order to prevent infestation, re-establish vegetation on the bare ground as soon as possible after the fire. While doing so, be sure to use only the seeds that are certified as weed-free seeds. Monitor the burn site regularly after the fire, especially the following spring since that is when the week would try and re-establish itself. Control the entry of human, animals, and livestock in to the areas at risk for weed invasion until the desired vegetation has grown and recovered sufficiently to resist weed invasion.

Cutting the plant will help in eliminating seed production but will not be able to kill Russian knapweed completely since cutting will only remove the above ground portion of the plant reducing its growth. Cutting couple of times in a year will force the plants to use the nutrients stored in the roots to re-establish it self and the plant that re-emerges will usually be smaller in size and lower in vigor. If the cutting method is used, it should be continued annually, failure to do so may increase the population of the plant if even a year is missed in between.

Grazing of animals on the field where Russian knapweed exists should be avoided, since the consumption of these plants is considered to be toxic to horses.

Mowing method is kind of similar to that of cutting. Mowing will remove the top portion above the ground and helps eliminate seed production. Same condition goes with this, mowing should be done couple of times a year annually. Failure to do so may increase the plant population. However, mowing can harm the surrounding plants if it is not done carefully.

Discing or plowing can be used on agricultural land, and this process should be repeated for at least three years at a minimum depth of 30cm.

Pulling is also and effective method used to control the Russian knapweed. However, it does not eliminate the plant, although after couple years of pulling, the plants seem to grow smaller in size and lower in vigor. When pulling, it is best to remove as much roots as possible in order to create the greatest amount of stress on the plant. In order to control the infestation, pulling of the plant should be done at least three times a year: spring, summer and fall.

Several herbicides have been found and proved effecting against the Russian knapweed. Picloram is a synthetic-auxin type herbicide that disrupts the growth of the plant. And the plants often die because of the disorganized and out-of-control growth that could occur through this herbicide. This herbicide does not harm most grasses and monocots. Clopyralid is another herbicide that is used during bud-growth stage and during the fall to control the Russian knapweed. This is also a synthetic-auxin type herbicide but is more selective then picloram since it kills only a certain types of broad-leaved plants. Glyphosate is most commonly used to control the top growth of the Russian knapweed. It is an amino acid inhibitor. It is a non-selective compound and is used to control broad-leaved weeds and grasses. It may kill all of the plants it comes in

contact with. Damage can be minimized by applying the herbicide with a wick or carefully spraying it with a handheld application directly to the leaves of the plants. Russian knapweed cannot be controlled by herbicides alone. Use of chemical controls has proven to be more difficult with Russian knapweed then with any other knapweed species. However, using herbicides may stress the plant enough to give the native plants a competitive advantage. Also, while using chemical control, avoid injuring the grasses around the plant since this may cause the competition with native plants to reduce.

Cultural method can be used to control the Russian knapweed. After the weed has been controlled, grow desirable plant species in its place. Smooth brome is known to compete with the Russian knapweed. Sod-forming perennial grasses like stream-bank or thick-spike wheat grasses are known to prevent re-invasion of the knapweed species. Grass growth should be increased by irrigation around the stands of the Russian knapweed, this will increase grass competition with knapweed and keep the weed under continual stress.

Biological controls can also be used to put additional stress on the Russian knapweed. Two species have been released in the United States to control the spread of these plants. These two species are *Subanguina picridis* and *Aceria acroptiloni*. Subanguina picridis is a gall forming nematode, native to Asia. This species is worm like and about 1.5mm long in length. It induces the production of galls on the stems, leaves, and root collar reducing plant growth and the seed productions. Larvae of this species feed, mature and reproduce within the galls. Two or more generations are completed during the growing season. However, they cannot travel far from the host plant. Human intervention is needed for the nematode to travel. Aceria acroptiloni is a gall forming

mite native to Eurasia. These mites can be found in the flower heads, they form galls in the flower heads and feed on the inner bracts, the receptacles of the flowers and the deformed structures of the flowers. Females lay eggs in the receptacle of the flower and the inner bracts. In a single season, two or more generations are formed. Plants that have been infested by these species are underdeveloped and noticeably small. These species can be used to cease the formation of new shoots and stalls the seed production.

Prevention of Russian knapweed can be done by maintaining healthy natural communities and by monitoring the infested sites at least 3 times each year. First monitoring should be done in spring from late May to mid-June, when plants start bolting. Next monitoring should be done in summer in the month of July to find any missed plants that have flowered and are easily recognizable. Third monitoring should be done in fall from late August to early September, to find any late-blooming plants that might have re-grown from the root system that had been pulled during earlier search.

There is no single way to remove the Russian knapweed. However, a combination of the controls such as the one's described above, proper land management and vegetative suppression can help reduce the Russian knapweed plant species. An effective method of eliminating the Russian knapweed is to first control the growth of the species and then re-vegetate the ground with native species.

5) Euphorbia esula L. (Leafy Spurge)

Leafy spurge is native to Europe and Asia. They were brought over to America in the 19th century. It was first recorded in Massachusetts in 1827 and then it spread quickly and reached the other eastern areas of the United States. By early 1900's Leafy spurge started spreading from east to the west of the United States. Leafy spurge also known as

Euphorbia esula L are the members of the Euphorbiaceae family and are deep rooted into the ground. Leafy spurge is creeping, herbaceous perennial weed that reproduces from seed and vegetative root buds.

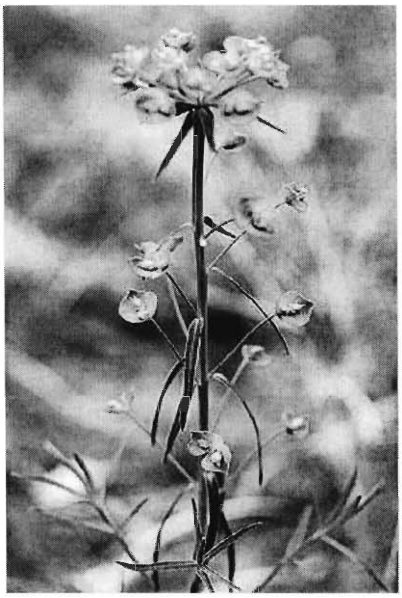

Figure 26: Leafy Spurge

Description of the parts of Leafy spurge:

Roots:

The root is the main part of Leafy spurge as it helps the plant to spread more effectively through its extensive root system forming 300 buds. The root of Leafy spurge is woody, tough and is covered with thick bark. It can grow up to 15 feet deep or more and laterally spread up to 35 feet. The root contains nutrients which helps the plant to sustain life for longer period of time and also allows the weed to recover from stress, including the control efforts. The roots have buds which are pink in color and are capable of producing new shoots and this is the main factor in the spread and persistence of weed. Therefore even if the foliage of the plant is destroyed, due to the pink buds, the new shoots regenerate and help in producing new plants. The root of Leafy spurge contains milky white latex which is harmful to the cattle and to the human skin.

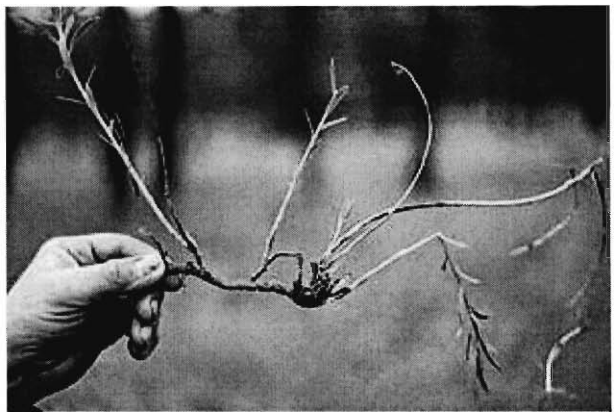

Figure 27: Creeping Root

Stem:

The stem of Leafy spurge is erect and the stem is hairless. The buds found in roots produce more new stems and this happens in April and by mid May the stem starts growing. The stem too contains the white latex. When the stem of Leafy spurge is wounded then the latex flows from the injury and seals the wound.

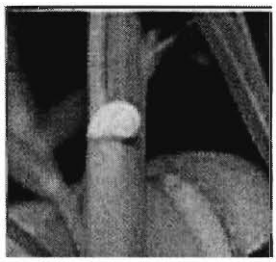

Figure 28: Stem with white latex

Leaves:

The leaves of Leafy spurge are bluish green in color with smooth margins. The leaves are 0.25inch to 0.5 inch wide and are 1 inch to 4 inches long. The leaves surface is hairless and contains the white milky latex too. The leaves are always in a bending position.

Figure 29: Leaves of Leafy Spurge

Flowers:

Leafy spurge is a bushy plant arranged in clusters with yellow pedals and green bracts. They are borne in umbrella like clusters and look more like small leaves than usual flowers. The yellow bracts appear in late May and early June but the real flower however appears in mid June. The flower is unisexual and each flower is above 1/8 inch high and 1.5 to 3 millimeters long. The flowering is usually completed by mid July. Seed continues to develop for several more weeks until the female flower appears.

Figure 30: Flowers of leafy spurge

Seed:

Seeds are round to oblong in shape and are about 1/12 inch long. The seed is gray or mottled brown in color with dark line on the side. Seeds are contained in capsules and there are 1-10 seeds produced per stem. Seed development continues for up to six weeks. When the capsule dries up, they explode and expel the seeds up to 15 feet away from the mother plant. The seeds live in the soil up to eight years and the seedling start developing vegetative buds within 10-12 days of emergence.

The seed of Leafy spurge has high germination rate which starts in late April to early May and the plant reproduces and spreads rapidly through vegetative reproduction.

Reproduction/Spread:

Leafy spurge reproduces by seeds and from spreading roots. The infestation is usually initiated by the seed and the expansion of the number of plants in mostly done by vegetative reproduction. The reproduction by seed starts with the dispersal of seeds from the parent plant. Leafy spurge starts flowering in May to early June, where each flower produces an average of 140 seeds that develop in those three capsules. When the female flower appears, the seed starts maturing and then after 30 days the capsule gets dried, which causes the capsule to explode, dispersing the seeds up to 15 feet away from the mother plant. These seeds after dispersal reach different areas by water, birds, animals and human beings. They even float easily in water and the waterways turn out to be good sources for new infestation. The eighty percent of the seeds die but the once that live act very competitive to the native plants within the four months of dispersal. Leafy spurge seeds can travel through the digestive tracts of animals and survive well in the resulting dung of those animals.

The seeds which survive live more than eight years in the soil and most of these seeds start germinating within the first two years. The portion of Leafy spurge which is above the ground is around three feet and the one that remains under the ground is the main part of the plant.

The seeds help in the germination but the root acts as the main part for the success of reproduction. The root system of Leafy spurge is very extensive and aggressive. The root system has a huge nutrient reserve which supports the plant through long period, years of drought, grazing stress and herbicide damage. The root along with the hundreds of buds present produces new and independent plants. If the plant is removed by hand or damaged by the herbicides treatment, grazing or fire, due to the buds present on the roots the new shoots would be produced and quickly produce new plants which would be more aggressive and competitive.

Habitat:

The plant occurs primarily in non-cropland and non-cultivated areas. Leafy spurge can tolerate wide range of soil moisture, from damp to very dry soil. The plant usually prefers the sunny conditions but can also grow in savanna habitats area. The plants are more aggressive in very dry areas where competition from native plants is less intense. These areas are more sensitive to this type of plant: roadsides, prairies and woodland.

Effects of Invasion:

Leafy spurge can be dangerous to grassland for both economic and ecological reasons. Leafy spurge is the first plant that grows in spring and it uses all the moisture and nutrients available, leaving very less for the native plants. This has reduced the

production of the native plants. Leafy spurge has reduced the productivity of grazing land by 50 to 75 percent and currently has taken over about three million acres of land in United States.

Leafy spurge plant contains a toxic substance which is white latex and this is harmful to the animals excluding some (angora goat). This substance if taken by cattle or other wild animals causes scours, weakness and even death in cattle. This plant also causes some irritation to their mouth and their stomach.

Control Measures:

Leafy spurge is a non native plant that is aggressive in nature and its perennial nature allows it to live for more then two years and can effectively compete with the native plants taking up all of their natural resources. The control of this species is necessary in order for the native plants to exist in the area. There are several control methods that can be used to prevent the further spread of the Leafy Spurge species. These measures much like the other plants include mechanical control, chemical control and biological controls along with controls using fire, grazing, and using native species to compete with the leafy spurge.

One of the methods used to control the leafy spurge is the biological method. Insects are being used for the control of the leafy spurge, some of these species that have been used in Colorado include copper spurge flea beetle also known as *Aphtona flava*, Brown dot leafy spurge flea beetle known as *Aphtona cyparissiae*, and Black dot leafy spurge flea beetle also known as *Aphtona nigriscutis*. The way these beetles destroy the leafy spurge is that the larvae of these species feed on the root hairs and roots and the adult beetles feed on stems, leaves and flowers. However, the success of these beetles is

depended on the environmental conditions. These beetles are helpful in reducing the spurge species but they cannot stop the new shoots from emerging. Beetles that are currently being researched on come from regions in Europe and western Asia, where these natural predators have kept leafy spurge under control. In addition to these beetles, current research is being done on disease organisms which attack specific spurge species. It is also known that using sheep grazing along with these beetles can significantly reduce the leafy spurge population. Sheep will not get rid of the leafy spurge but they limit its growth. If grazing is done, it should be done early in the spring when the plant is in its early stage. Goats are also used for the control of this weed. Sheep mostly grazes the flowering plants while the goats consume shrubs. Research suggests that using goats is better then sheep since goats are readily available to graze the plant while the sheep require a two to three week adjustment period to begin grazing. However, the goats are difficult to manage then the sheep, therefore it depends on the landowner which animal they want to use. Biological control is still in its experimental stage therefore it is not expected to completely control the leafy spurge.

Another control method that can be used is the mechanical method. There are two types of tillage programs that have been proven to be useful methods of control. They are intensive tillage throughout the growing season and the fall only cultivation. However the cultivation should be consistent because if it is not the leafy spurge is more likely to recover quickly from rootstock, and pieces of roots that produce new shoots. Hand pulling of these weeds can be difficult at times but it is useful in areas where it has not been widely infested. This can prove to be a good method only if the entire root system is pulled, however if it is not entirely pulled the weed population is more likely to

increase the number of leafy spurge plants rather then decreasing them. Mowing can also be used to reduce the seed production and to prevent new infestations. If mowing method is used, mowing should occur every two to four weeks. This will reduce the seed production and will prevent the further spread of the species.

Chemical control can also be used to prevent the spread of leafy spurge. While applying the chemical herbicides it is important to apply the right amount, because too much of an herbicide can injure the surrounding plants and applying too small of a quantity can encourage the growth of the weed. Using herbicide control just once will not provide long term control, re-treatment would be necessary for several years. Two herbicides that are most effective in early summer or fall when the spurge plants are flowering or re-growing are Dicamba and 2, 4-D herbicides. The most effective herbicide for the control of the leafy spurge is Picloram. However picloram should not be used on high quality natural areas. This herbicide is known to effect woody species and care should be taken in its application since it can move through the soil and can be absorbed by the roots of the neighboring plants up to 30ft away. So far, from the research conducted it has been found that picloram is most effective and can be applied at 1 quart/A for three to four consecutive years for it to be successful in removing the leafy spurge. Glyphosate can also be used for the prevention of leafy spurge during the summer months of June, July and August when the plants start seeding. This herbicide is non selective and is capable of injuring or killing any vegetation it comes in to contact with. At this time, chemical control has been proven to be the quickest and most effective method for the control of the leafy spurge. However, herbicide use is very costly and if not maintained on a yearly basis and can result in complete and rapid infestation.

Fire can also be a control measure, but it has not generally been successful for controlling leafy spurge since after a fire this weed can regenerate very rapidly. On the other hand, fire can also be beneficial in some ways. It can remove litter and dead stems and is also capable of stimulating bunchgrass growth, which may improve its competitive ability with the leafy spurge plants.

Native plants species can also be used for the control of the leafy spurge. Native plants should be chosen according to their competitive behavior with the leafy spurge species. Through research, it has been found that competitive native plants such as Russian wildrye, pubescent wheatgrass, smooth brome, western wheatgrass and Dahurian wildrye are competitive with the leafy spurge. These plants can be used as desirable replacements for the leafy spurge species.

Best defense again the leafy spurge species is to prevent infestation. Infestation is best prevented when combinations of controls are used. Infestations should be controlled while the leafy spurge is in small patches, if the infestations become larger, control can be very difficult and costly. Success can be achieved with this plant in reducing and eliminating this weed, but only with commitment, time and persistence.

6) Tamarix Ramosissima (Salt Cedar)

Introduction:

Figure 31: Salt Cedar

Salt Cedar or Tamarisk is often commonly referred to as Tamarix ramosissima and T. parviflora. The name tamarisk is based on the genus name Tamarix but it is still not clear from where this name came. People assume it might have been derived from the Tambre River in Spain or the Tamaro River in Nepal. Salt cedar means plants fine cedar like foliage and the ability to survive in saline or alkaline soils. The genus tamarix is native to southern Europe and North Africa through the Middle East and south Asia to China and Japan. The way salt cedar was introduced in US was through nurserymen of the east coast in 1823. It was brought to the west coast through eastern nurseries. In the western US they planted the plant as an ornamental but later is escaped the cultivation. And by 1920's it started becoming a problem. Now we can find salt cedar in many moist spots in the desert regions of the western US. It was between the 1890's and 1920's that the salt cedar invaded many riverine systems. The abundant increase during 1930 through 1950, it occupied most of the available and suitable habitant in central North America. During 1960, the nationwide estimate of acreage infested was 900,000 acres.

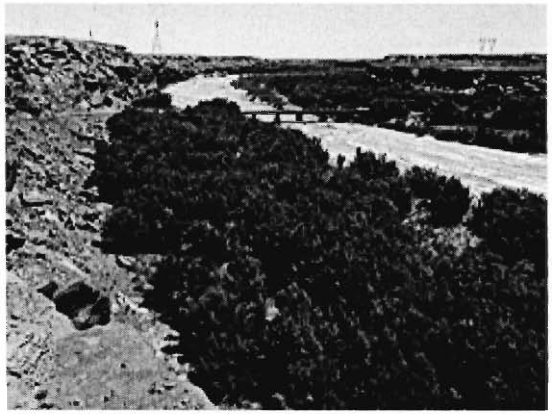

Figure 32: Tamarisk Grown along the Colorado River

Description of the Plant:

Tamarix plants are generally shrubs or small trees of deserts, sandy or saline areas, shores, river banks, mountain streams and dunes. These plants grow usually 15 to

20 feet high. Tamarisk is a deciduous tree which is an advantage during the stress conditions like drought. In this condition the plant reduces its surface area and reduces the amount of transpiration loss. These plants have extensive root systems with adventitious roots from buried branches. The leaves are herbaceous, alternate, and small, punctuate, and scale like with secreting glands. These are generated on photosynthesis cladophylls. The flowers are small but aggregated into panicles or spikes that make the display beautiful. The capsules contain numerous small seeds with long hair that helps in dispersal.

Biology and Ecology of Salt Cedar:

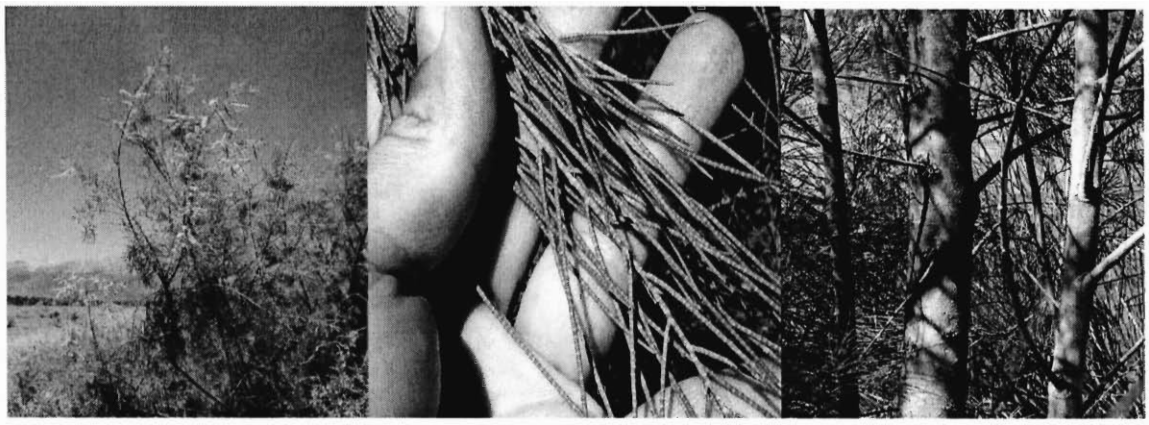

Figure 33: Tamarisk Flower **Figure 34: Tamarisk Stem** **Figure 35: Tamarisk Trunk**

Salt Cedar is a facultative phreatophytic shrub or small tree which grows in dense disturbed areas along the lakeshores and streams. The flowers of these plants are arranged densely along the stems and are mostly pink or white. They bloom mostly from June to September. Tamarisk flower produces small amount of nectar and attract a large number and variety of insects including the honeybees. This happens only in the fall when other native species are not flowering and are pollinated only by insects. At higher elevations the tamarisk has been found to have 2 flower producing cycles, once in the spring and another in late summer but at lower elevations it has only one cycle. The tree of this plant

grows very rapidly and it especially grows in its first years and produces approximately 600,000 small wind and water transported seeds. Seeds are very small and have hair which makes them easily transported. They generate in large numbers and germinated within twelve hours after being wet. Seeds that are not germinated do not survive. The germination can occur in the light or dark. There are some conditions that are required such as saturated soil for two to four weeks, open sunny ground and no competition from other seeds. The seedlings become established in dense stands of wet silt bars after floodwaters recede. The leaves contain glands that excrete salts which help the plant to grow in saline soil and with a saline ground water supply. In a three year old plant, the roots grow up to nineteen feet laterally. The older the plant is, it is more tolerant to inundation by floodwaters. Younger plants are less tolerant and may be controlled by flooding.

Displacement and Degradation of Native Plant Communities:

The effect of salt cedar invasion is the displacement of native plant communities and the degradation of habitat for most species of birds and mammals is the most obvious and the most destructive. In most part of US native riparian plant communities have been displaced on a very large scale. The salt cedar has the ability to absorb salts from deep soils and ground water and transport the salt all the way up to its leaves, where it is secreted. The falling leaves contaminate the soil at the base of the shrub and that creates a zone where none of the other plants can grow except for the salt tolerant tamarisk. This plant is phreatophyte and uses the water available to other vegetation. This plant is also has high evapotranspiration rate as the roots grow 30 meters vertically and 50 meters horizontally. Tamarisk extracts up to 200 gallons of water per day. Native plants have

difficulty competing with the tamarisk for water; the tamarisk has an extensive roots system that absorbs water from deep underground and leave very less amount of water for the native plants. The fire also cannot harm the plant as the root system of the plant grows vertically up to thirty meter and when the upper portion of the plant is burnt the lower part re-grows and it grows up to a height of 6 – 10 feet in the first year itself. Salt cedar has a specialized physiology that can close stomata and results in transpiration rates being below potential during the hottest part of the day. This makes tamarisk tolerant of heat.

Control Measures:

To manage this kind of exotic plant it requires a long term commitment. A lot of different kinds of method have been used to manage salt cedar. They can be managed mechanically, chemically and biologically. The most effective is the one when we use all these methods combined. Mechanical method includes hand pulling the weeds, digging them out or root cutting them. Removal by hand is generally recommended for small infestations of saplings under one inch diameter. Root cutting and bulldozers are more effective them just digging and pulling out the weeds by hand. But this can be more expensive and along with it, it's not good for the soil and will lead to resprouting. Since salt cedar's have the ability to re-sprout from roots, mechanical methods are largely unsuccessful. If we set fire on the plant then only the upper portion of the plant will be destroyed and within a year a new plant will be produced due to the roots. Even if we use this method to control tamarisk then it is advised to use in the summer when there is less water available due to the heat. This method can only control the plant for the smaller

period of time and will destroy the other native plants. Therefore it's not advisable to use this method.

Chemical control has been the most effective method. If we use the herbicides cautiously to restore the area infested by the salt cedar then there can be a repopulation of native plant species. System herbicides which kill the plants from the roots up are recommended for salt cedar management. This included the foliar sprays, cut stump treatments, basal bark treatments and aerial sprays. The biological method means finding out the insects that would only harm tamarisk not the native plants. Scientists have been busy finding out the insects which actually do this and they found out that mealybug from Israel and leaf beetle from China are harmful to tamarisk. The mealybug fed on the twigs and the leaf beetle deforiated tamarisk in the greenhouse test. These insects are harmful to tamarisk up to 85 % and will take three to five years to control tamarisk in small sites and five to ten years in places where tamarisk is found densely. Other insects are also being investigated as potential biological control agents. Five other insects are being tested within the United States and other additional eight species are being tested overseas.

It is more effective to combine the controls and use it. If we burn down the area affected by tamarisk and then after burning down the stems and the braches of this plant, use an herbicide which will kill the re-sprout. This method has been used mostly in the areas where salt cedar has densely occupied. The use the herbicide after the basal bark treatment is also effective but the only downfall of this treatment is that it's very expensive. The basal bark treatment does prelude us from cutting down the plants and saves labor charges but a lot of herbicides has to be used which turns out to be expensive.

Use of herbicides after cutting down the tree can be useful too. After cutting tamarisk there would be less water consumption and use of herbicide would be more effective.

Further Actions:

The readings above dealt with the negative impacts caused by invasive plants. This project only analyzed six plants; still the effect they have on the environment and economy is devastating. There are several other invasive plants present in Colorado and in the western parts of the United States which needs to be studied. Doctors often say that prevention is better than cure. We can apply the same principle in the study and spread of invasive plants. Many home gardeners are not aware of the harmful effects of these plants. Plants like dalmation toadflax may seem perfect for home gardening, and people may plant them on their backyard without knowing their harmful effects. Therefore measures should be taken to educate the public about these plants.

An informed public can make a difference; the following example proves this point. Pampas is an invasive grass found in California. Stores like Wal-Mart, Home Depot and Orchard Supply Hardware used to sell the seeds for these grasses. Carloyn Martus, a member of the Cal-EPPC was dismayed to see Wal-Mart selling these seeds to customers. She expressed her concerns to the customer service and through appropriate personals, the sale of pampas seeds were pulled off the shelves. Home Depot and Orchard Supply following the example of Wal-Mart also pulled off their sale of pampas seed. This is just one example of how the informed public made a difference in the case of invasive plants.

So what measures should be taken to inform the public? The first one could be distributing information handout about these plants in flower or garden shops. The

handout should contain the pictures of the plants, flowers and seed; their method of invasion. It should also contain details about how to control and prevent the spread of these plants if they are actually present in the yards.

The dispersal of invasive seeds may also be caused by human ignorance as well. Hikers, campers and hunters could cause the spread of invasive plants by transporting the plant seeds on their boots or clothes. In-fact the source of many weed infestation has been traced back to roads, trails, railroads and travel corridors. People who drive their vehicles through an infested area can carry the seeds in the thread of the tires, the winch or in any other cracks found in the vehicle. Figure 36 shows a picture of how invasive plants can be spread by travelers. Once again the best way to prevent this type of introduction is by informing the people. Stores that carry hiking and hunting accessories should pass along information about these plants. They should be advised to ensure that their clothes and other outfits are properly clean before moving from one area to another.

Figure 36: Spread of invasive plants caused by travelers

Perhaps even the internet is another way by which people can be educated about the effects of these plants. While doing research, we were able to find a program called Alien Plant Ranking System from the website: www.npwrc.usgs.gov/resource/2000/aprs/aprs.htm, which upon entering data will produce a graph which can be easily understood by people. The graph accurately tells the

amount of impact and degree of harm that can be caused by a specific plant and figure 37 shows a sample graph obtained by using the program.

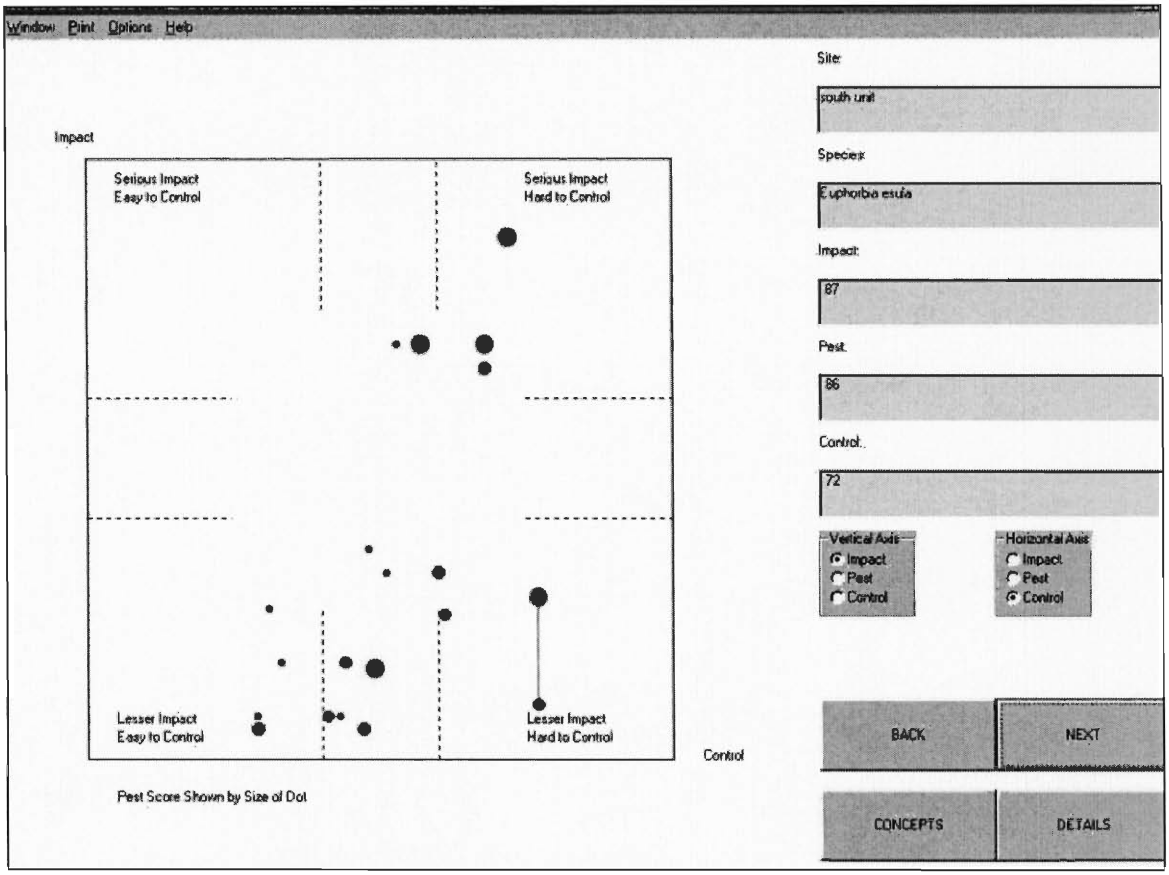

Figure 37: Sample output of APRS

The graph can be divided into four sections namely plants that cause serious impact but which are easy to control; plants that have lesser impact and are easy to control, plants that have serious impact and are very hard to control; and finally plants with lesser impact but harder to control. The X-axis of the graph stands for Impact and the Y-axis of the graph stands for Control. The output graph is obtained by answering a set of data sheet. An example of the data sheet is shown in figure 38.

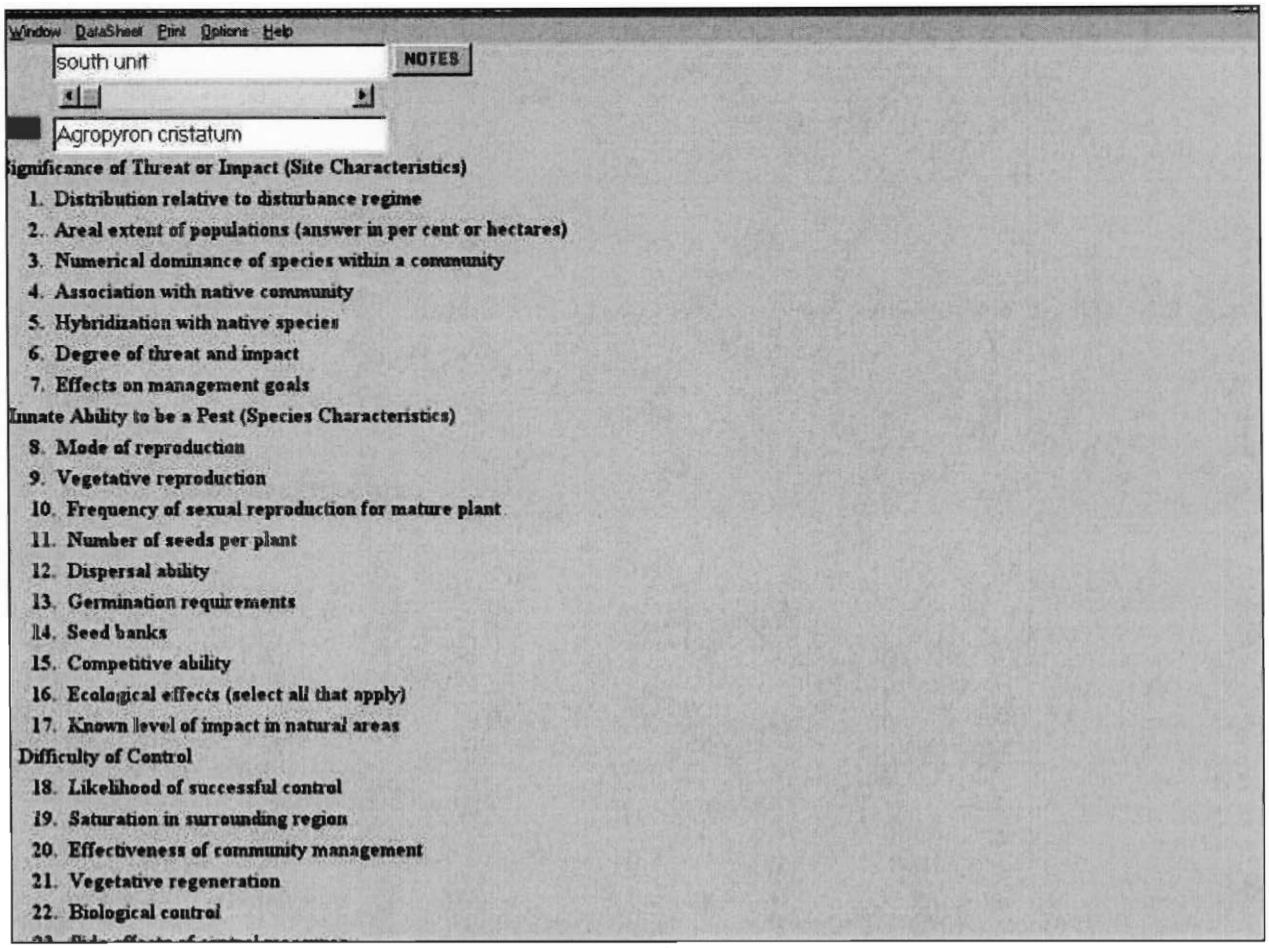

Figure 38: Data Sheet for APRS

Further Studies:

As one might notice, in order to make the Alien Plant Ranking System work properly, the data entered has to be accurate as possible. Therefore for further studies, students could work on collecting data on different alien species, producing graphs and putting them on a website that will help public as well as land managers to have a better idea of different alien plants.

This paper only dealt with the environmental, ecological and economical effects of invasive plants. Further studies could be done on native animal species such as the Mexican spotted owl, apache trout fish and Southwestern Willow Flycatcher which are endangered due to the presence of non-native plants. The spotted owl uses seral forest

and rocky canyonlands for nesting, roosting and hunting. One of the reasons why the populations of these birds are decreasing is because of the catastrophic wildfires. Since we already know that cheatgrass has a great influence on the rapid occurrence of wildfires, further research can be conducted to see whether or not the spread of cheatgrass has a direct effect in reducing the population of Mexican spotted owls, and how the reduction in population of these birds affect the ecosystem.

By changing the ecosystem, the non-native plants open new homes for non-native animals and birds. Studies could be done to see what species are doing better in the new environment and what their impact would be. Research could be also done to see if any of the non-native plants in Colorado attracts harmful pests or micro-bacteria's. Since pesticides, insecticides, and chemicals used to control the spread of invasive species, their effect on land, water and humans can also be studied.

Conclusion:

This project dealt with the effects of invasive plants found in the western part of the United States. We first took a general look into the role of these plants in upsetting the biological balance of an area, how they negatively impact the water resources, and how damage is done to the economy by affecting factors such as agriculture and tourism. The key highlights of this research were

- Approximately 138 billion dollars in economic damages are caused do to the spread of invasive plants.
- Out of the total money spent on agriculture, 10% is spent by farmers for weed control and prevention

- Due to the excessive presence of invasive plants with highly developed root system next to stream banks, many streams are drying out and if immediate actions are not taken, then places like Texas might not have sufficient water in the future years for municipal, industrial and agricultural functions.
- The spread of invasive weeds has had a major impact in reducing the land value of many lands in Colorado and Texas.

Once we had a general look into the effect of the invasive plants, we started to concentrate on the impact of six specific plants found in Colorado region. We discussed how each plant affects the ecology, economy and the environment. The section on plants also dealt with the control measures that can be taken to prevent the spread of these plants.

The final step of the project was to discuss further studies and actions that can be done in the field of invasive plants. This section talked about the importance of why public should be well aware exotic plants and the measures that can be taken to accomplish this. It also talked about software called Alien Plant Rankin System, which might prove very useful in further years. The essence of this paper boils down to one simple statement, invasive plants no matter how harmless or attractive they might look, can cause serious damage to the environment and people therefore one should take every measure to prevent them from spreading.

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