

Economic Impact of Invasive Species

Direct Costs Estimates and Economic Impacts for Washington State

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Washington State Noxious Weed Control Board
Washington State Recreation and Conservation Office Washington Invasive Species Council
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Executive Summary

Invasive Species in Washington

Washington is at risk from a wide variety of invasive species. These nonnative plants and animals have an adverse impact on Washington's landscapes, ecosystems, agriculture, commerce and recreation.

This report aims to help state agencies tasked with managing natural resources to quantify the potential economic damages of a select list of twenty-three invasive species on the overall Washington economy, coupled with a broader understanding as to how these damages translate into lost jobs, lost wages, and lost business sales (or output).

Total Costs of Invasive Species

Crops: Cropland has the potential to be quickly infested by invasive plants, which reduce overall yields and require resources for their control. Furthermore, crops are directly lost through invasive animal consumption. The direct impact of invasive species on crops grown in Washington is estimated to be **$239.5 million** per year.

Livestock: Invasive noxious weeds in pastures and rangeland displace desirable forage that help sustain livestock. In some cases, these plants are also toxic to livestock and horses and can be fatal. The direct economic impact of invasive species on the livestock industry is estimated to be **$120.1 million** annually.

Timber: Many invasive species can severely impact Washington's $1.68 billion timber and logging industry. Invasive noxious weed species such as Scotch broom can outcompete new saplings, which reduces future timber harvests. Insect species such as the gypsy moth have a more immediate impact on the timber industry by defoliating and stressing, resulting in mortality of adult trees. The direct economic impact of invasive species on the timber industry is estimated to be **$124.8 million**.

Recreation: Recreational activities such as hunting, fishing, and boating can all be adversely affected by invasive species. Many of the same species that impact a rancher's ability to range their cattle also reduce elk and deer populations. Aquatic invasive species can cause declines in fish populations and reduce access to popular fishing areas. Other aquatic species can clog up boat propellers and render public boat launches unusable. The direct economic impact to recreational activities from invasive species is estimated to be **$20.5 million** per year.

Most Costly Invasive Species

Plant Species

Rush skeletonweed has an extensive root system that allows it to outcompete native grasses and valuable crops for water. Major crops impacted include wheat and potatoes, both of which are major commodities in Washington. It has the potential to have a total economic impact of **$149.2 million**, putting **1,080 jobs** at risk if it were allowed to spread an additional 12% per year into susceptible land types.

Scotch broom quickly forms dense stands which quickly outcompete young trees and desirable forage plants. Furthermore, Scotch broom can be toxic to cattle. Scotch broom is widespread in western Washington and has the potential to cause a total of **$142.7 million** in lost sales and **660 job** losses in Washington per year if it were allowed to spread an additional 12% per year into susceptible land types.

Animal Species:

Apple maggots infest apple, pear and cherry orchards, rendering significant numbers of fruit unsuitable for sale. Since apple maggot is an invasive species, any orchard infested with apple maggot cannot export any of its fruit without undergoing treatment. The total economic impact from apple maggot is estimated to be **$392.5 million**, putting **2,900 jobs** at risk per year.

Zebra mussels are not currently found in Washington but do have the potential to infest numerous bodies of water in the Columbia River Basin. Zebra mussels can clog intake valves in dams as well as colonize public boat launches, rendering them unusable. If zebra mussels were to establish in Washington, the economic impact could be as large as **$100.1 million**. This translates into an estimated loss of **500 jobs**.

Information & Background

Project Background

Invasive species have an adverse impact on Washington's landscapes, ecosystems, agriculture, commerce, and recreation. These damages translate into costs borne by businesses and communities throughout the state economy, such as lost agricultural output and outdoor recreation-related sales.

The Washington State Department of Agriculture, in partnership with the State Noxious Weed Control Board and the Washington Invasive Species Council, requested a cost-effective study of the potential economic damages of a select list of 23 invasive species on the wider Washington economy and a broader understanding as to how these damages would translate to lost jobs, lost wages, and lost sales. The resulting analysis leveraged various ecological studies and economic impact studies done for other states on similar invasive species, particularly the recent report "Economic impact from selected noxious weeds in Oregon", which was released in December 2014 by the Oregon Department of Agriculture (The Research Group, 2014).

Research Questions

> What are the **direct economic impacts of invasive species** in terms of lost output across a range of natural resource activities, e.g., agriculture, timber, and aquaculture?

> What are the **total impacts of invasive species** in terms of lost business sales (including indirect and induced impacts), lost labor income and lost jobs to Washington?

> How do **invasive species affect recreational activities** in Washington?

> What are the possible scenarios that describe **the spread of invasive species** throughout Washington?

Key Terms and Concepts

This report broadly focuses on four distinct land types:

1. **Croplands:** Parcels of land that are designated as agriculture land by the Washington Department of Agriculture's 2015 Agriculture Land Use Survey that are growing a variety of agriculture products.
2. **Rangelands:** Designated rangeland is considered to be the sum of Grassland/Pasture and shrub land land areas as described by the National Agriculture Statistic Service's CropScape map for Washington. Rangeland impacts are considered only for livestock meant for slaughter.
3. **Timberland:** Lands that were designated as timber-producing areas were collected from The Washington State Forest Biomass Supply Assessment Database through the University of Washington.
4. **Wildlands:** Wildlands are broken into three unique recreation impacts; 1. Hunting, 2. Fishing, and 3. Boating. Hunting on Wildlands are considered to cover the same area as rangeland. However, fishing impacts are focused exclusively on rivers while and boating impacts are calculated for both rivers and lakes but not ocean bays. River data is collected through the Washington Department of Fish and Wildlife's SalmonScape database. Lake data is collected through the United States Geographic Survey National Hydrography Dataset.

Degradation Rates: The primary mechanism for calculating direct impacts of invasive plant species are the utilization of per-acre degradation rates tabulated in a Oregon Department of Agriculture report "Economic Impact From Selected Noxious Weeds in Oregon" (The Research Group, 2014). The degradation rate is the percentage of output lost per acre across all relevant land types for each considered species. These degradation rates are related exclusively with the productive capacity of the land an invasive species might be found on.

Acreages of Impact from Invasive Species: Acreages of impact for each invasive species and associated commodities are generally based on a percentage of probable spread for each land type studied this is also referred to as a "rate of infestation" or "rate of spread" in the report. Some species have drastically different rates of infestation or spread than others which in turn result in different levels of impact.

Explanation of Analytics

The analytics presented in this report provide a snapshot of total economic impact within a single year if no prevention or management activities occurred.

Methodology

Output Calculations by Commodity

Crops: The annual output of crops in Washington are taken from the National Agriculture Statistics Service for each commodity produced in Washington in 2015.

Livestock: Livestock's annual output is taken from the National Agriculture Statistics Services for Cattle, including calves but excluding inter-farm and inter-state sales. This value is discounted by the share of cattle that are fed exclusively on feed lots, as compared to the total head of cattle.

Timber: Output for the timber industry is represented as the gross business revenue for North American Industry Classification System code 113, which represents the forestry and logging industry. This data is provided by the Washington Department of Revenue.

Hunting: Values for hunting are specifically focused on the cost for big game and migratory bird licenses and represents the output of hunting.

Fishing: Fishing output is represented at a value of $100 per day per stream across four days of fishing per week as per the "Economic Impact from Selected Noxious Weeds in Oregon" report. For Washington, the total output of fishing is estimated to be $27.4 million in 2015.

Dams: The output value of dams is represented as the additional cost required for maintenance and repairs by invasive species. The cost for cleaning dams with entangled vegetation is expected to be $3,000 per dam facility as per the Colorado Department of Fish and Wildlife. The cost of removing invasive mussels from dams is estimated to be $48,000 per dam annually as per "Economic Risk of Zebra and Quagga Mussels in the Columbia River Basin." From the "Potential Economic Impacts of Zebra Mussels on the Hydropower Facilities in the Columbia River Basin" report, the cost of installing a preventive system for zebra mussels is estimated to be $1.8 million per dam.

Boating and Boat Launches: The output of recreational boating is calculated by using the methodology outlined in Chang and Jackson (2003) and the number of recreational boating days as outlined by the Oregon State Marine Board (2009). The output methodology described in Chang and Jackson (2003) is specifically applied to bays. This methodology is slightly altered to provide an output value for streams by looking at stream lengths instead of bay acreages.

Acreage Datasets and Analysis Used

Crops: Data on crop acreages for Washington was taken from the 2015 Washington State Department of Agriculture Agricultural Land Use. This provides estimates on acres by crop type and county in Washington state for impact estimates by invasive species. The geodatabase was connected to ArcGIS using directions provided by the Washington State Department of Agriculture.

Rangeland: The United State Department of Agriculture Crop Scape dataset provides estimates on rangeland acres by county in Washington state for impact estimates by invasive species. Specifically, the process is as follows: the grass/pasture (value 176) and shrub land (value 152) rasters are downloaded for Washington state; then using the Use Raster to Polygon tool in ArcGIS the raster converts pixels to a shapefile and merges the polygons together for one rangeland area estimate; the Use Erase tool in ArcGIS is used to remove area from rangeland that overlaps with any crop sections from the Washington State Department of Agriculture dataset; finally, the Use Split tool in ArcGIS is used with a detailed county line shapefile to get rangeland estimates by county.

Timber: Timber acreages are from the Washington State Forest Biomass Supply Assessment Database. This database provides estimates on timberland acres by county in Washington state for impact estimates by invasive species. Excluded are timberland polygons where centroids fall within crop sections and crop group is not "Commercial Tree (4)."

Rivers and Lakes: Rivers and lakes in Washington are taken from the National Hydrography Database maintained by the U.S. Geological Survey. This database provides estimates on river and lake acres by county in Washington state for impact estimates by aquatic invasive species. Rivers were buffered by one acre on each side of center line in ArcGIS.

Dams: Dam data is taken from the Washington Department of Ecology. This helps flag rivers and lakes by county in Washington state for the presence of dams, for estimates of dam maintenance needed as a result of damage caused by aquatic invasive species. Dams were spatially joined to rivers and lakes within 500 feet of the dam.

Boat Launches: Data on boat launches are from the Washington State Recreation and Conservation. This flags rivers and lakes by county in Washington state for the presence of boat launches, for estimates of aquatic invasive species spread by boats. Boat launches were spatially joined to rivers and lakes within 500 feet of the boat launch.

Direct Impacts from Invasive Species

The direct impacts from invasive species are generally categorized by their impacts to different commodities produced on select land types. These land types are Cropland, Timberland and Rangeland, which in turn correspond to the commodities that are produced on those lands (crop commodities on Croplands, timber on Timberlands and livestock and hunting on Rangelands). The degradation-per-acre for most invasive plant species are from the "Economic Impact from Selected Noxious Weeds in Oregon" report produced for the Oregon Department of Agriculture by The Research Group, LLC.

Impacts of invasive animal species per acre vary by commodity affected. In most cases, these per-acre impacts were found through consultation with Washington State Department of Agriculture and Washington State Department of Fish and Wildlife to arrive at a percent rate of damage per acre. Exceptions include gypsy moth and invasive mussels, which impact trees and dams respectively. Impacts for these two species are derived from "Estimating the Benefits of Gypsy Moth Control on Timberland" by Ganser and Herrick (1987) and "Economic Risk of Zebra and Quagga Mussels in the Columbia River Basin" produced by the Independent Economics Analysis Board (2013) supplemented by "Expansion of Dreissena into Offshore Waters of Lake Michigan and Potential Impacts on Fish Populations" by Bunnel et al. (2009).

Using the per-acre output values calculated per commodity, the individual invasive species impacts are applied to calculate the direct economic loss per commodity per invasive species. These direct economic losses are then summed across 52 macro economic sectors that are used to calculate induced and indirect economic impacts.

Induced and Indirect Economic Impacts

The primary tools for estimating the broader impacts of invasive species in Washington state are calculated from the Washington State Input-Output (I-O) Model for year 2007, published in 2012, and IMPLAN. The Washington State I-O Model provides a data-rich rendering of the state economy across 52 sectors. The transactions table, which underpins the I-O Model, provides estimates of intermediate purchases, sales, and final demand across all modeled sectors.

The complex analysis of the model, published online by the Washington State Office of Financial Management, allows analysts to model the impacts of economic activities when output, labor, wages, and first-round direct purchases/requirements are known. In order to apply the input-output model for multiple years of analysis, implicit price deflators were used to adjust previous year totals to 2014 (the most recent modeling year). Direct requirements for all affected sectors were calculated based on shares of purchases for each sector to each year of output, derived from the 2007 transactions table, as well as IMPLAN social accounting matrices, and interviews.

The economic impacts of invasive species in Washington include direct, indirect, and induced effects, the total impact being the sum of these impacts. Analysis begins with a transactions table, constructed from multiple data sources by Beyers and Lin. This table captures all transactions between and within industries and final demand, the latter including personal consumption expenditures (i.e., household consumption), domestic and foreign exports, investment, and federal, state, and local expenditures. Total output in an economy is thus the sum of inter- and intra-industry purchases, also referred to as intermediate transactions, and final demand. The input-output transactions table is governed by an important accounting identity requiring that all purchases in an economy must equal all output. Within the transactions matrix, the sum of each column represents all purchases by an industry or source of demand, and will equal the amount sales and output by that activity.

For example, in the latest transactions table, the input-output sector "Software Publishing and Internet Service Providers" in 2007 purchased nearly $5.3 billion in non-labor inputs from other industries in Washington. Added to this, the sector paid $9.7 billion in wage and salary outlays (including non-wage benefits), plus $8.3 billion in other value added activities (e.g., profits, dividend payments) and $10.1 billion in imported (domestic and foreign) inputs; these amounts total $33.4 billion, exactly equal to total sales, or output, by this industry in Washington.

Induced and Indirect Economic Impacts
(continued)

The columns of a transactions table thus represent production functions for each modeled industry. Direct requirements coefficients, also referred to as technical coefficients, are the share of total purchases for each input. For example, in 2007, again return to the Software Publishing and Internet Service Providers industries in Washington, firms belonging to this grouping purchased $240.4 million in goods and services from the industry category “Architectural and Engineering /Computer Systems Design and Related Services,” translating into a direct requirements coefficient of 0.0072, or 0.72% of all purchases made by Software Publishing and Internet Service Providers based in Washington State ($240.4 million / $33.4 billion).

Once a matrix of direct requirements is calculated, a series of equations are used to relate changes in demand in one sector of the economy to changes in gross output to across the entire economy. Inter-industry transactions, denoted “O,” is equal to a vector X of gross output per industry multiplied by the matrix of direct requirements, denoted “A.”

$$(1)\ O = AX$$

The vector of gross output per industry, X, is the sum of inter-industry output (transactions) and final demand. In the above example, $41.7 billion in total output in aerospace is equal to $842.8 million in inter-industry sales plus $40.8 billion in final demand.

$$(2)\ X = O + D$$

Combining equations (1) and (2) results in industry gross output equaling the sum of industry output multiplied by direct requirements plus final demand:

$$(3)\ X = AX + D$$

Rearranging this equation:

$$(4)\ D = (1-A)X, \text{ and}$$

$$(5)\ X = D(1-A)^{-1}, \text{ the } (1-A)^{-1}, \text{ which is also referred to as the “Leontief Inverse”}$$

Finally, input-output modeling is primarily used to assess economy-wide changes given a change in one or more activities, resulting in equation

$$(6) X = (1-A)^{-1}D$$

REFERENCES

Beyers, W, Lin, T. 2007. The 2007 Washington Input-Output Study. Olympia, WA: Washington Office of Financial Management. http://www.ofm.wa.gov/economy/io/2007/I-O_2007_report.pdf

Chang, W-H, Jackson, RS. (2003). Economic Impacts of Recreation Activities at Oregon Costal and River Ports. Washington D.C.: U.S. Army Corps of Engineers.

Gansner, DA, Herrick, OW. 1987. Estimating the benefits of gypsy moth control on timberland. US Dept. Agric. For. Serv. Res. Note. NE-337. https://www.fs.fed.us/ne/newtown_square/publications/research_notes/pdfs/scanned/OCR/ne_rn337.pdf

Oregon State Marine Board. 2009. Boating in Oregon, Triennial Survey Results - 2008. https://data.oregon.gov/Recreation/Waterbodies-In-Rank-Order/rqyv-cfng

Ruyle, G , Ogden, P. 1993. What is an A.U.M.? In: Arizona Ranchers' Management Guide. Gum, R, Ruyle, G, and R Rice, eds. Tucson, AZ: Arizona Cooperative Extension. pp. 1-4.

Systma, M, Rouhe, A. (2007). Feral Swine Action Plan for Oregon. Portland, Oregon: Portland State University. http://pdxscholar.library.pdx.edu/cgi/viewcontent.cgi?article=1013&context=centerforlakes_pub

The Research Group, LLC. 2014. Economic Impact From Selected Noxious Weeds in Oregon. Prepared for Oregon Department of Agriculture Noxious Weed Control Program. https://www.oregon.gov/ODA/shared/Documents/Publications/Weeds/ORNoxiousWeedEconomicImpact.pdf

United States Department of Agriculture. (2015). 2015 State Agriculture Overview, Washington. Retrieved from https://www.nass.usda.gov/Quick_Stats/Ag_Overview/stateOverview.php?state=WASHINGTON

United States Department of Agriculture. (2014). National Agricultural Statistics Service. Retrieved from https://quickstats.nass.usda.gov/.

Washington Department of Agriculture. 2015 Agriculture Land Use Data Layer. 2016. Published agriculture-specific datalayer [Online]. Available at https://www.arcgis.com/home/webmap/viewer.html?webmap=f6b595bf3a5f438e93bf678d2389b4ea (accessed [4/25/2016]; verified [4/25/2016]). WSDA, Olympia, WA.

Washington Department of Fish and Wildlife. 2015 SalmonScape. 2016. Published river-specific datalayer [Online]. Available at http://apps.wdfw.wa.gov/salmonscape/map.html (accessed [4/25/2016]; verified [4/25/2014]). WDFW, Olympia, WA.

Washington Department of Fish and Wildlife. (2016). Game Harvest Reports. Retrieved from http://wdfw.wa.gov/hunting/harvest/2015/reports/deer_sp_gmu_all.php

Summaries of Individual Invasive Species

HIMALAYAN BLACKBERRY *Rubus armeniacus*

Description of Species

Himalayan blackberry is a perennial shrub that produces long sprawling stems called canes that are covered with sharp, hooked spines and may reach a length of 40 feet. Himalayan blackberry has five-petaled white or pink flowers, which form aggregate fruits. The compound leaves have serrated edges and are alternately arranged. Root crowns of this Class C noxious weed can grow up to 8 inches in diameter and roots can reach 5 feet into the soil. Blackberry shrubs can grow up to 12 feet tall.

Distribution in Washington

Himalayan blackberry is found in 26 counties, with significant concentrations found in 19 counties in the western part of the state. It is less widespread but still problematic in parts of eastern Washington.

Impacts Considered

Cattle and livestock: Outcompetes native pasture plants and impacts quality of grazing lands.
Timber: Prevents growth of shade intolerant trees such as Douglas fir and ponderosa pine.
Croplands: Can infest croplands and requires control.

Other Considerations

Recreation: Himalayan blackberry produces dense thickets that restrict access to or limit the use of public lands and increase park management costs.
Cost of control: Birds and animals consume fruit and carry seed over a wide area. Any control program needs to be long term.
Host for berry pest: Himalayan blackberry is a host species to the spotted-wing fruit fly, *Drosophila suzukii*, a serious insect pest of berry and tree fruit crops in the Pacific Northwest.

Reference: http://www.nwcb.wa.gov/weeds/himalayan-blackberry and links therein.

Source: Washington State Noxious Weed Control Board

Direct Economic Impact of Species

If Himalayan blackberry spread an additional 12% in the 19 counties with significant infestations in Washington, it would translate to approximately 17,000 invaded acres of croplands, 284,000 acres of rangeland and wildland, 2.1 million acres of timberlands, and 1,605 miles of rivers and streams. Timber is the commodity affected the most by Himalayan blackberry, with a direct economic impact of almost $14 million worth of timberland. Impacts to timber account for 68% of the total estimated direct impacts from Himalayan blackberry.

Two of the counties most affected by Himalayan blackberry are Lewis County and Grays Harbor County, which have estimated direct impacts of $2.4 million and $2.1 million respectively.

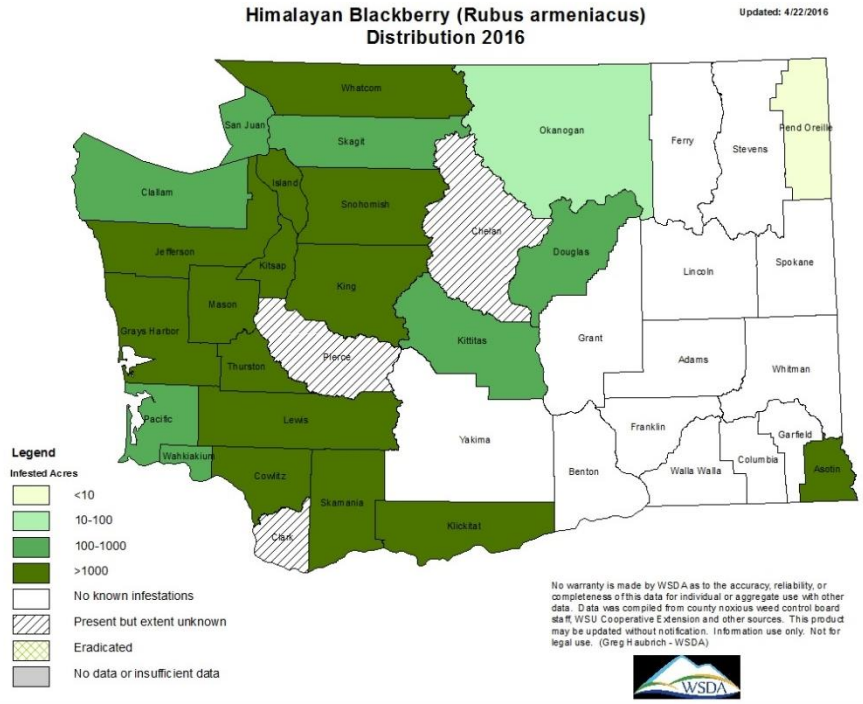
Himalayan Blackberry Direct Impacts	
Direct Impacts to Crops	**$1,369,500**
Blueberry	$323,000
Strawberry	$54,000
Other Berries	$2,500
Hay	$990,000
Direct Impacts to Livestock	**$4,025,000**
Direct Impacts to Timber	**$13,903,000**
Recreation in Wildlands	**$1,135,000**
Direct Impacts to Hunting	$247,000
Direct Impacts to Fishing	$888,000
Total	**$20,432,500**

Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

Looking at the broader Washington economy, Himalayan blackberry infestation could have a cumulative output impact of $48.7 million. This loss of output translates into a loss of 230 jobs in Washington and $12.7 million in lost labor income.

Total Himalayan Blackberry Impacts	
Output	**$48,786,000**
Jobs	**230**
Labor Income	**$12,773,000**



Description of Species

Yellow starthistle is an annual or biennial Class B noxious weed with long, winged stems covered in white wooly hairs, deeply lobed leaves, and yellow flowerheads. Bracts at the base of the flowerhead are covered with spines up to 1 inch long. It typically grows 2 to 3 feet tall when adequate moisture is present but can bloom when only 2 to 3 inches tall under extreme drought conditions. Most seeds have fine bristles that allow them to be wind-dispersed.

Distribution in Washington

Yellow starthistle occurs primarily in eastern Washington and is most abundant in the southeast part of the state. Twenty-one counties currently have some amount of yellow starthistle, 11 of which have a significant number of infested acres. Both King and Thurston Counties had introductions of yellow starthistle, which were eradicated.

Impacts Considered

Cattle, horses, and livestock: Yellow starthistle rapidly outcompetes desirable forage species in pastures, rangeland, and meadows. Horses consuming too much yellow starthistle, whether fresh or dried in hay, over 1 to 2 months may develop “chewing disease,” a fatal neurological disease with no cure. Cattle can consume the basal rosettes but the spines of the flowering plants can cause injury.
Wheat: Can infest wheat crops in areas where there is high competition for nutrients needed for new seed.

Other Considerations

Hunting: Hunters and their dogs can be injured by the sharp spines, and they may also help disperse the seeds into new areas. Infested hunting grounds should be avoided by hunters, hikers, and campers.
Environment: Yellow starthistle is a superior competitor for water than many native plants in arid regions.

Reference: http://www.nwcb.wa.gov/weeds/yellow-starthistle and links therein.

Source: Marty Hudson, Klickitat County Noxious Weed Control Board

Direct Economic Impact of Species

If yellow starthistle were to spread into an additional 12% of susceptible land types in the 11 counties with significant infestations, it would be equivalent to 320,000 acres of rangeland and wildland, along with an additional 596 miles of rivers and streams. The largest impact caused by yellow starthistle is to livestock, which accounts for more than $21.1 million in direct impacts.

Yakima County is affected the most by yellow starthistle, with a total of $8.5 million in potential economic loss. Yakima accounts for 38% of all the direct impacts associated with yellow starthistle in Washington. Other counties with significant economic impacts associated with yellow starthistle include Klickitat County and Ferry County.

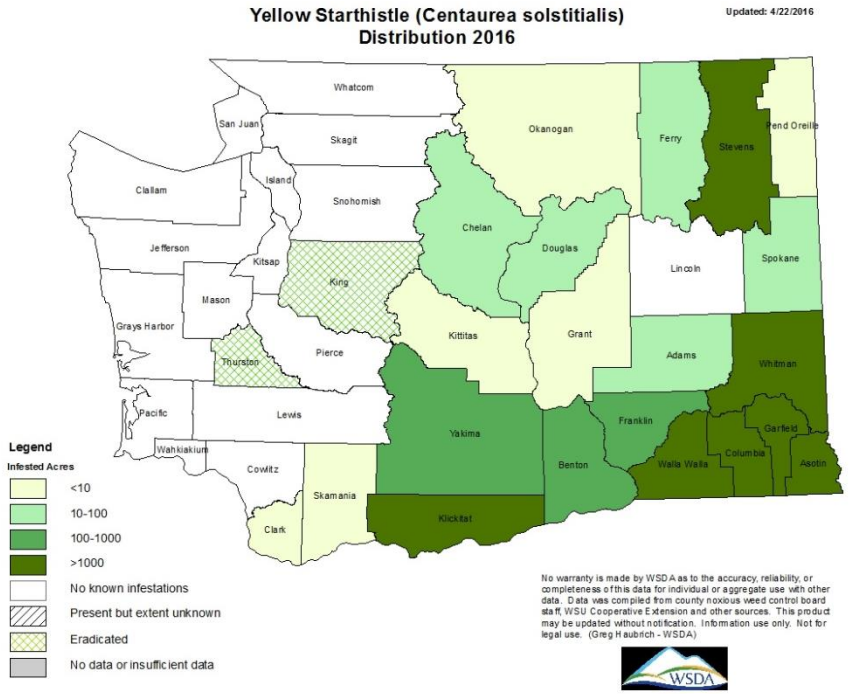
Yellow Starthistle Direct Impacts	
Direct Impacts to Livestock	**$21,162,000**
Recreation in Wildlands	**$1,215,000**
Direct Impacts to Hunting	$556,000
Direct Impacts to Fishing	$659,000
Total	**$22,377,000**

Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

Projecting the impact of yellow starthistle across the wider Washington economy indicates that the total value of economic output at risk is approximately $54.3 million. This output loss is associated with a loss of 290 jobs and $14.8 million in wage income.

Total Yellow Starthistle Impacts	
Output	**$54,326,000**
Jobs	**290**
Labor Income	**$14,893,000**



Description of Species

Diffuse knapweed is a biennial weed that forms basal rosettes in its first year of growth and then bolts and flowers from midsummer through fall. This Class B noxious weed is a single-stemmed plant with numerous branches, and it can grow to 3 feet tall. Flowerheads are slender and generally white, and bracts are lined with a distinctive fringe of fine spines. Diffuse knapweed reproduces primarily by seeds, which are dispersed by the tumbling of windblown mature plants and when they stick to the fur of animals. Moving water is also a major dispersal agent that helps spread this species over a wide area.

Distribution in Washington

Diffuse knapweed is found in 36 of the 39 counties of Washington, with only Jefferson, Pacific and Wahkiakum Counties having no known infestations at this time. It is most abundant in eastern Washington, and 25 counties are considered to be heavily infested with diffuse knapweed.

Impacts Considered

Cattle and livestock: Diffuse knapweed outcompetes desirable forage species in pastures, rangeland, and meadows.

Other Considerations

Wildfire hazard: Plants produce a high amount of dry biomass, which is flammable.
Increases soil erosion: Dense infestations of diffuse knapweed can lead to soil erosion.

Reference: http://www.nwcb.wa.gov/weeds/diffuse-knapweed and links therein.

Source: Sue Winterowd, Stevens County Noxious Weed Control Board

Direct Economic Impact of Species

Diffuse knapweed is a widespread noxious weed in Washington, with significant infestations found in 25 of the 39 counties. However, diffuse knapweed populations are often found in wastelands, roadsides, and lower-quality rangeland. Furthermore, diffuse knapweed is under an effective biocontrol program that helps curtail the plant's spread on valuable land. Based on these factors, the potential impact of diffuse knapweed was estimated as if it spread into just an additional 1% of the productive land types in those 25 counties. This is equivalent to approximately 70,000 acres of rangeland and wildland along with a further 210,000 of timberland.

Okanogan and Yakima are the two counties with the largest estimated impact from diffuse knapweed. Okanogan County is estimated to have a loss of $791,000 directly attributable to diffuse knapweed while Yakima County is estimated to experience $644,000 in direct costs.

It is important to point out that if diffuse knapweed has a greater spread rate than 1%, the potential costs grow rapidly. For example, if the spread rate increases to 5%, the total direct economic impacts associated grow to $23.9 million.

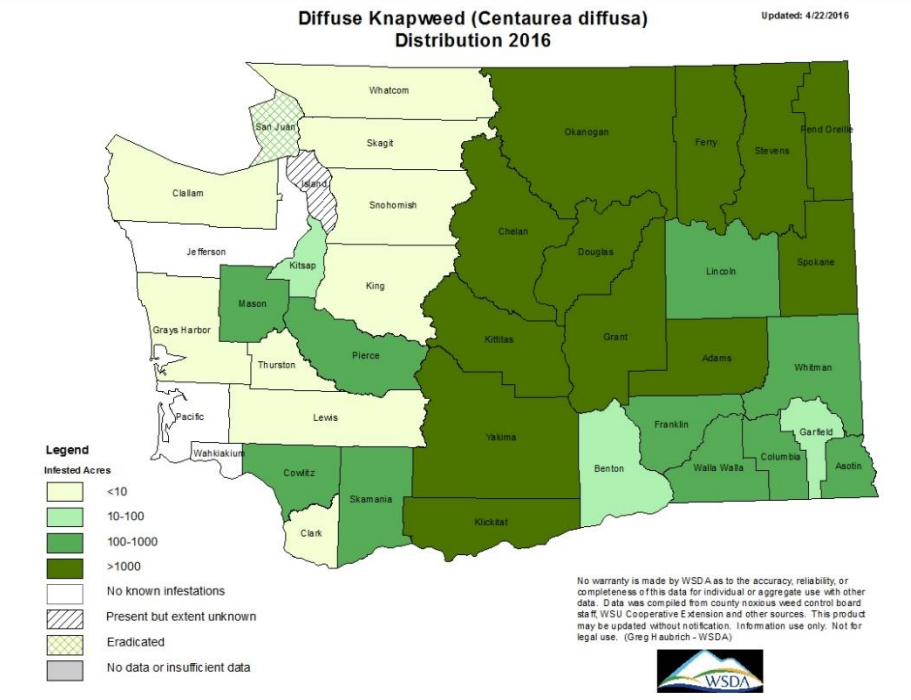
Diffuse Knapweed Direct Impacts	
Direct Impacts to Livestock	**$3,345,000**
Direct Impacts to Timber	**$1,373,000**
Direct Impacts to Hunting	**$61,000**
Total	**$4,779,000**

Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

At a 1% infestation rate, diffuse knapweed is expected to have a total impact of $11.5 million throughout the Washington economy. This loss of output is also associated with a loss of 60 jobs and a further loss of approximately $3 million in labor income.

Total Diffuse Knapweed Impacts	
Output	**$11,539,000**
Jobs	**60**
Labor Income	**$3,097,000**



MEADOW KNAPWEED *Centaurea x moncktonii*

Description of Species

Meadow knapweed is a hybrid between black and brown knapweed and may be difficult to distinguish from its parent species. The Class B noxious weed is a perennial, has a woody root, and can grow from 1 to 5 feet tall. Leaves are entire and up to 6 inches long. Stems are multi-branched. Flowerheads are solitary, about an inch in diameter, ranging from pink to a reddish-purple hue, and are typically oval or globe-shaped.

Distribution in Washington

Meadow knapweed is found across 25 counties in Washington, with eight counties considered to have significant infestations. Many of the 25 counties are found in western and central Washington.

Impacts Considered

Cattle and livestock: Meadow knapweed outcompetes desirable forage species in pastures, rangeland, and meadows.
Timber: Infestations can be found on tree farms with moist soils.

Other Considerations

Cost of control: Meadow knapweed can be controlled using Integrated Pest Management methods including selective herbicides, mechanical, cultural, and biocontrol agents, but it requires a long-term management plan.

Reference: http://www.nwcb.wa.gov/weeds/meadow-knapweed and links therein.

Source: Washington State Noxious Weed Control Board

Direct Economic Impact of Species

Significant meadow knapweed infestations are found in eight counties in Washington and if the species were to spread an additional 12% into productive land in those counties, an estimated 209,000 acres of rangeland and wildland along with a further 662,000 acres of timberland would be directly affected.

Kittitas, Klickitat and Skamania are the three counties most likely to be affected by meadow knapweed. Kittitas County alone has an estimated direct loss of $4.7 million, which is just over one-third of all the direct costs associated with meadow knapweed. Meadow knapweed in Klickitat and Skamania Counties is estimated to have an impact of $2.7 million and $2.5 million, respectively.

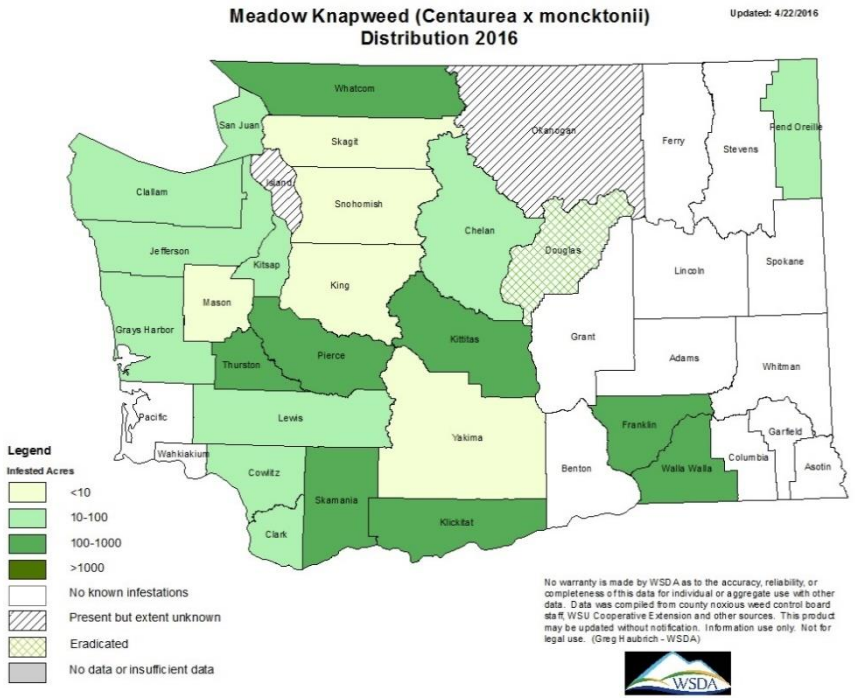
Meadow Knapweed Direct Impacts	
Direct Impacts to Livestock	**$9,860,000**
Direct Impacts to Timber	**$4,319,000**
Direct Impacts to Hunting	**$181,000**
Total	**$14,360,000**

Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

Looking beyond meadow knapweed's direct impact and studying its impact throughout the Washington economy reveals that total impacts to economic output could amount to $34.6 million. Approximately 180 jobs would be at risk in Washington along with a further $9.2 million in lost labor income.

Total Meadow Knapweed Impacts	
Ouput	**$34,656,000**
Jobs	**180**
Labor Income	**$9,290,000**



Description of Species

Spotted knapweed is a multi-stemmed perennial plant that can grow up to 5 feet tall. Its leaves are typically lobed on the lower part of the plant, unlobed toward the top of the plant, and have a greyish hue. This Class B noxious weed begins to flower in July continuing through the fall with purple, pink, or cream colored flowers. The bracts of the flower heads are typically tipped black, giving this species its common name. Spotted knapweed seed production is prolific, and the seeds are dispersed by wind, animals, and people. It produces a deep taproot, which draws moisture from deeper soils, allowing the plant to keep growing through the summer months. This deep taproot also makes removal of the weed extremely difficult.

Distribution in Washington

Spotted knapweed is widespread in Washington with infestations found in 37 of the 39 counties. Only Pacific and Wahkiakum Counties do not have any known infestations of spotted knapweed at this time.

Impacts Considered

Cattle and livestock: Spotted knapweed invades rangeland and is unpalatable to livestock. The plant releases chemicals from its roots that inhibit germination and slow the growth of native plants.

Other Considerations

Cost of control: Once spotted knapweed is well-established, control and restoration of rangeland may be more expensive than the potential production of the land.
Recreation: Spotted knapweed can cause long-lasting damage to native habitat. It is unpalatable to deer and elk, and can significantly reduce available forage.

Reference: http://www.nwcb.wa.gov/weeds/spotted-knapweed and links therein.

Source: Washington State Noxious Weed Control Board

Direct Economic Impact of Species

Current estimates of additional valuable land that could be impacted by spotted knapweed expansion total more than 2.6 million acres, if it were to spread into 12% of productive land. Approximately 588,000 of the affected acres are found in rangeland and wildland, with more than 2 million acres in timber. Despite the disparity in affected acres, the majority of estimated impacts from spotted knapweed come from the effects on livestock on rangeland, which accounts for more than two-thirds of all direct impacts associated with spotted knapweed.

Throughout the state, 15 counties have sizable spotted knapweed infestations. Of those counties, Okanogan County has the potential to be impacted the most from spotted knapweed, with a direct loss from spotted knapweed estimated to be $11.8 million. This figure accounts for more than 28.4% of the total direct loss in Washington.

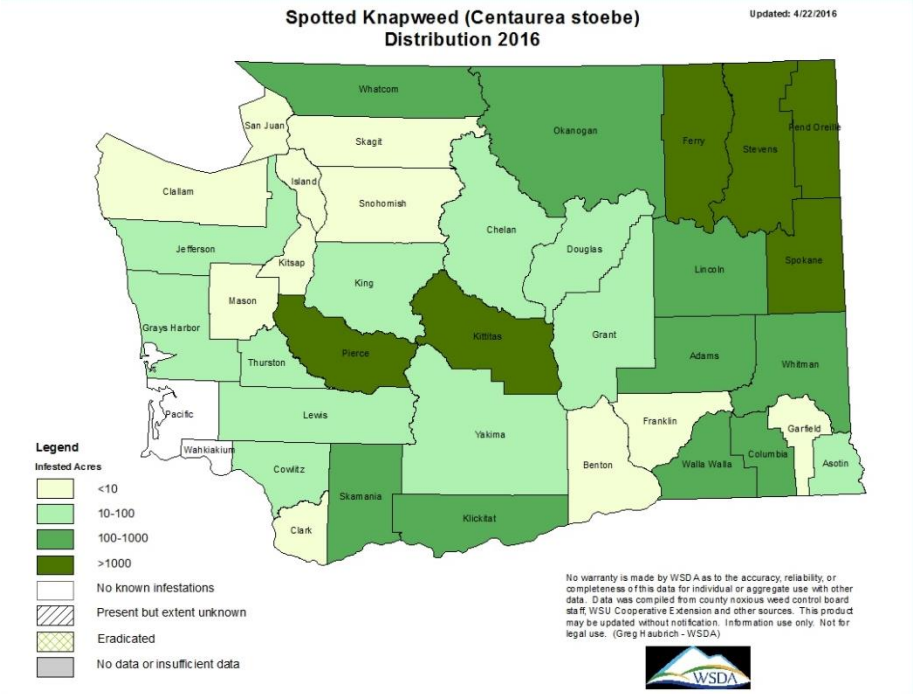
Spotted Knapweed Direct Impacts	
Direct Impacts to Livestock	**$27,795,000**
Direct Impacts to Timber	**$13,447,000**
Direct Impacts to Hunting	**$511,000**
Total	**$41,753,000**

Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

The risk spotted knapweed poses to the wider Washington economy is significant. With a 12% rate of spread, total economic output losses amount to more than $100 million. An additional 510 jobs are estimated to be lost, along with an associated $26.9 million in lost labor income.

Total Spotted Knapweed Impacts	
Ouput	**$100,713,000**
Jobs	**510**
Labor Income	**$26,944,000**



Description of Species

Leafy spurge is an aggressive Class B noxious weed that typically reaches 2 to 3 feet tall. The perennial plants have tough stems that contain a white latex sap that is poisonous when consumed and can cause skin irritation. The leaves are alternate, narrow, and are slightly wavy along the margins. Flowers are small and are borne in greenish-yellow clusters above yellow petal-like bracts. Leafy spurge's woody root system can extend down 20 feet below the soil surface. Seed capsules rupture, ejecting the seeds up to 10 feet from the parent plant.

Distribution in Washington

Leafy spurge is found in limited distribution in several counties, primarily in eastern Washington, and it is most abundant in Lincoln County. It has been detected and eradicated in a few counties in western Washington.

Impacts Considered

Cattle and livestock: Leafy spurge depletes soil of moisture and nutrients; rangeland invaded by leafy spurge does not readily convert back to productive grass and wildflower communities, even over long timespans. It is toxic to cattle and horses.

Other Considerations

Toxicity to humans: Leafy spurge contains a white latex sap that causes skin irritations and may cause permanent blindness if rubbed into the eye.

Reference: http://www.nwcb.wa.gov/weeds/leafy-spurge and links therein.

Source: Washington State Noxious Weed Control Board

Direct Economic Impact of Species

Leafy spurge is estimated to have a potential rate of spread of 12% across 10 counties in Washington. This correlates to 279,000 additional acres of rangeland and wildland throughout Washington. Of the 10 counties studied to have direct impacts from leafy spurge, Okanogan County was estimated to experience $13.2 million in direct costs from leafy spurge. This is equivalent to just under half of all estimated direct impacts.

Leafy spurge not only displaces native vegetation on rangeland but it is also toxic for livestock. As such, a portion of the losses accrued from livestock are from fatalities.

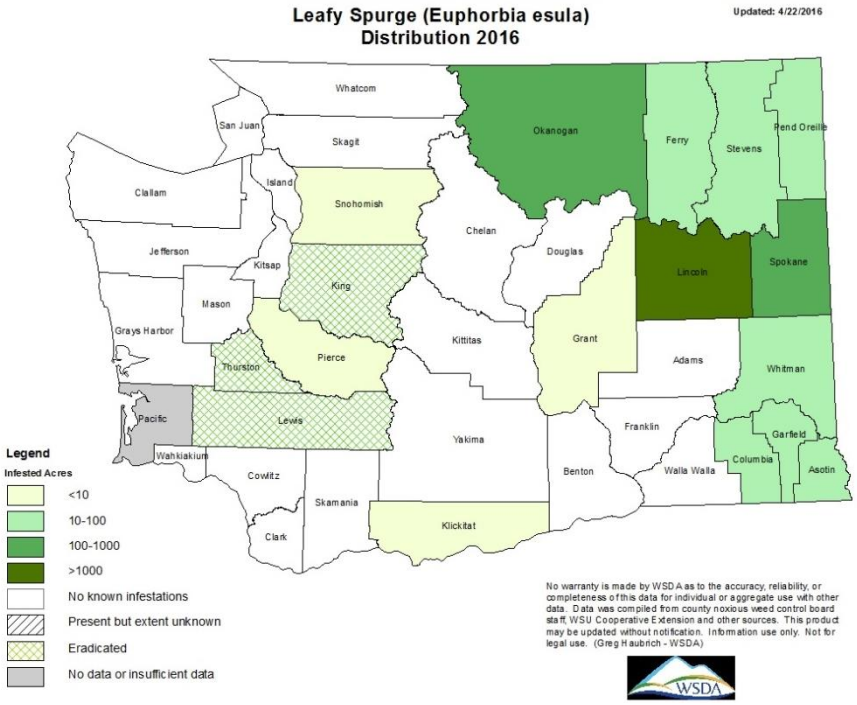
Leafy Spurge Direct Impacts	
Direct Impacts to Livestock	**$26,405,000**
Direct Impacts to Hunting	**$485,000**
Total	**$26,890,000**

Sources: The Research Group, 2014 *4; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

The total output at risk to leafy spurge infestation is estimated to be more than $65.3 million. A further 350 jobs are estimated to be at risk coupled with a loss of more than $18 million in wages.

Total Leafy Spurge Impacts	
Output	**$65,326,000**
Jobs	**350**
Labor Income	**$18,011,000**



Description of Species

Scotch broom is a perennial evergreen shrub with numerous dark green angled branches with small, simple or three-parted deciduous leaves. The Class B noxious weed grows up to 8 to 10 feet tall and is in bloom from April to June with numerous bright yellow, pea-shaped flowers. As its seeds mature inside black, ripened pods, they are ejected and thrown several feet away from the parent plant to start new plants. Scotch broom roots have nitrogen-fixing bacteria in nodules that help it thrive in nutrient-poor soils.

Distribution in Washington

Scotch broom is found in 32 Washington counties, but it is most widespread in the western part of the state and is spreading into areas just east of the Cascade Mountains.

Impacts Considered

Cattle and livestock: Scotch broom creates dense stands that displace desirable, forage species. It is toxic to livestock.
Timber: Dense stands prevent forest regeneration after clearing.
Field crops: Outcompetes crops for nutrients and water.
Elk: Scotch broom is toxic to elk and reportedly may have once poisoned elk on the Olympic Peninsula. Encroaching Scotch broom reduces forage for elk, potentially reducing hunting opportunities.

Other Considerations

Costs of control: Scotch broom shrubs can produce an average of almost 10,000 seeds per year, which can remain viable in the soil for more than 30 years. This means that any control measures must be extremely long term.
Recreation: Scotch broom can grow in a variety of areas including natural areas, parkland and even dunes. These all increase the cost of parkland management significantly.
Fire hazard: Stands of Scotch broom provide dry biomass that is flammable and can elevate fires to tree canopies.
Environment: Scotch broom can alter soil chemistry and composition, making native plant restoration difficult.
Ecosystems: Scotch broom threatens rare or vulnerable ecosystems such as prairies and Garry oak.

Source: Washington State Noxious Weed Control Board

Reference: http://www.nwcb.wa.gov/weeds/scotch-broom and links therein.

Direct Economic Impact of Species

Scotch broom is more abundant in western Washington and extremely difficult to eliminate due to its size, dense stands, and because seed can remain viable for at least 30 years. More than half the counties in Washington are considered to have a significant presence of Scotch broom. Because it is already so pervasive, the risk of increased spread is considered to be extremely high and scotch broom could invade 35% of productive lands in afflicted counties if landowners stopped controlling it.

More than 1.8 million acres of rangeland and wildland are estimated to be at risk for Scotch broom infestation. A further 6.5 million of timberland is also considered to be at risk of Scotch broom infestation. Kittitas, Lewis and Grays Harbor Counties are the three counties estimated to experience the largest share of impacts from Scotch broom. Kittitas County is estimated to experience roughly $6.5 million in direct losses from Scotch broom. Lewis County and Grays Harbor County are estimated to have $6.2 million and $5.9 million in direct losses from Scotch broom, respectively. Scotch broom impacts average around $2.9 million per infested county.

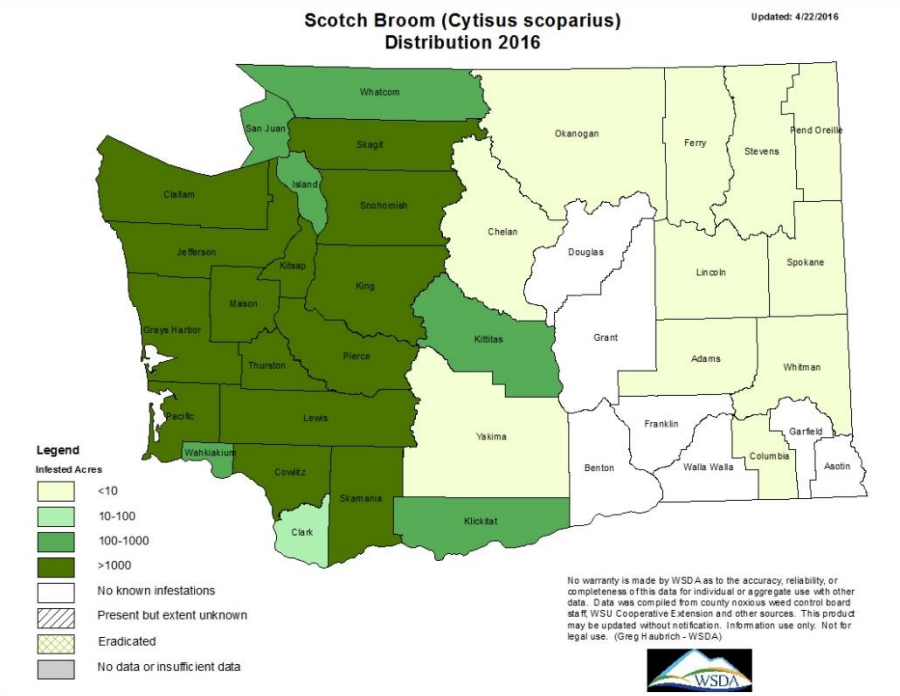
Scotch Broom Direct Impacts	
Direct Impacts to Livestock	**$15,859,000**
Direct Impacts to Timber	**$42,907,000**
Direct Impacts to Hunting	**$971,000**
Total	**$59,737,000**

Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

Given Scotch broom's pervasiveness and high average direct impact per county, the wider impacts throughout the Washington economy are similarly significant. An estimated $142.8 million in business activity is expected to be at risk across the Washington economy. This lost business activity is associated with a loss of 660 jobs and more than $36 million in lost wages.

Total Scotch Broom Impacts	
Ouput	**$142,771,000**
Jobs	**660**
Labor Income	**$36,753,000**



Description of Species

Rush skeletonweed has a few sparse leaves and wiry dark-green stems giving it a skeletal appearance. The Class B noxious weed is a perennial species with a taproot that can grow 7 feet deep to reach water. It has small yellow flowers that bloom from July to September. Each plant can produce up to 20,000 small, wind-dispersed seeds. Rush skeletonweed seeds are also spread through contaminated grains. Furthermore, cultivation of croplands infested with rush skeletonweed facilitates expansion of this noxious weed as machinery breaks up and then spreads propagating root fragments throughout fields.

Distribution in Washington

Rush skeletonweed is found in 28 counties and is most abundant in eastern Washington. Counties with more than 1,000 estimated acres of rush skeletonweed infestations include Adams, Columbia, Franklin, Klickitat, Spokane and Stevens.

Impacts Considered

Cattle and livestock: Rush skeletonweed outcompetes desirable forage species, thereby reducing grazing opportunities for livestock and wildlife.
Potatoes, wheat and small grains: Extensive root systems outcompete crops for nutrients and water.

Other Considerations

Damage to machinery: Rush skeletonweed produces a thick latex sap that can gum up crop harvesting machinery.

Reference: http://www.nwcb.wa.gov/weeds/rush-skeletonweed and links therein.

Source: Washington State Noxious Weed Control Board

Direct Economic Impact of Species

Rush skeletonweed is estimated to have significant populations in 13 counties in Washington. If rush skeletonweed is not controlled and spreads into 12% of productive land in those counties, then roughly 321,000 acres of cropland are considered to be directly at risk of rush skeletonweed infestation, of which 244,000 acres are wheat producing. Wheat and potato acreages account for more than 81% of the possible crop acres that see a direct impact. An additional 262,000 acres of rangeland and wildland are also projected to be directly affected by rush skeletonweed.

The county estimated to have the largest direct economic impact from rush skeletonweed is Grant County, with more than $12.7 million at risk. Other counties at risk from rush skeletonweed include Whitman County ($9.3 million) and Franklin County ($7.7 million).

Rush Skeletonweed Direct Impacts	
Direct Impacts to Crops	**$55,396,000**
Wheat	$16,707,000
Potato	$20,626,000
Legumes	$7,319,000
Hay	$10,744,000
Direct Impacts to Livestock	**$6,190,000**
Direct Impacts to Hunting	**$228,000**
Total	**$61,814,000**

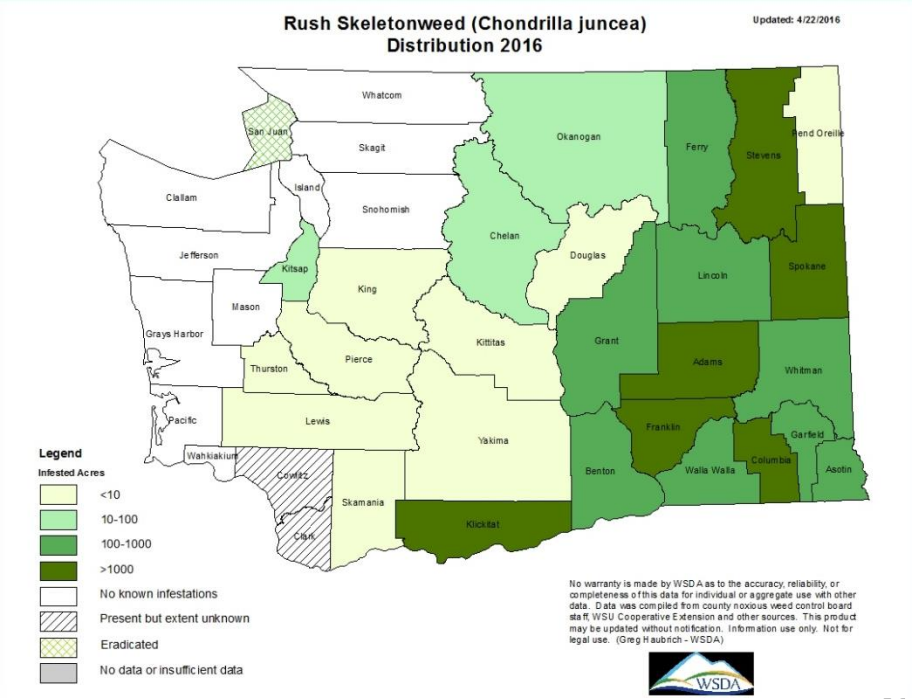
Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

Rush skeletonweed is primarily a threat to crops, specifically wheat, potatoes, and hay. Washington is a major producer of all three commodities; the wider impacts of rush skeletonweed could therefore be significant to Washington's economy.

Approximately $149 million in economic output in Washington is estimated to be at risk due to the spread of rush skeletonweed infestations. This translates into a loss of 1,080 jobs across Washington and an additional $46.9 million in labor income.

Total Rush Skeletonweed Impacts	
Output	**$149,243,000**
Jobs	**1,080**
Labor Income	**$46,984,000**



PURPLE LOOSESTRIFE *Lythrum salicaria*

Description of Species

Purple loosestrife is an herbaceous perennial Class B noxious weed commonly found in wetlands and riparian habitats. Plants can grow up to 10 feet tall, and stems are typically square-sided with four or six angles with lance-shaped, opposite leaves. Purple or magenta flowers typically have five to six petals and are arranged in dense spikes. Purple loosestrife seeds are very small and the species is a prodigious seed producer, with some large plants producing more than 1 million seeds.

Distribution in Washington

Purple loosestrife is found throughout Washington. Only Columbia, Garfield and Lincoln Counties have no known infestations of purple loosestrife at this time. Franklin, Grant and Grays Harbor are the three counties with the most significant acreages of purple loosestrife.

Impacts Considered

Recreational Fishing: Purple loosestrife displaces native plant species in riparian habitats. Once it forms dense stands, it restricts access to rivers.
Shellfish/Wetlands: Native plant species are displaced; wetland animals cannot use it for nesting or food; can lead to soil erosion and damage to floodplain habitat needed for shellfish production.

Other Considerations

Wetlands: Purple loosestrife is very invasive in wetland areas, where it displaces native wetland plants, significantly reducing food and nesting habitat for waterfowl and other animals. It can also alter the aquatic food web.
Irrigation Systems: Can restrict water flow in irrigation ditches.

Reference: http://www.nwcb.wa.gov/weeds/purple-loosestrife and links therein.

Source: Jennifer Andreas, Washington State University- Invasive Weed Management Project

Direct Economic Impact of Species

Purple loosestrife impacts are centered primarily around recreational activities such as impacts to hunting waterfowl, fishing and recreational boating. The weed is found in significant amounts in 20 counties across Washington and risks affecting more than 1,600 miles of rivers and streams along with 38,000 acres of boat-able lakes and rivers.

Purple loosestrife is estimated to potentially impact an additional 12% of riparian habitats if it is not controlled, with Grant and Chelan Counties expected have the largest share of impacts with $932,000 and $726,000 respectively. The average direct loss per county due to purple loosestrife is an estimated $308,000. These economic impacts do not reflect the degradation of valuable wetland habitat and function.

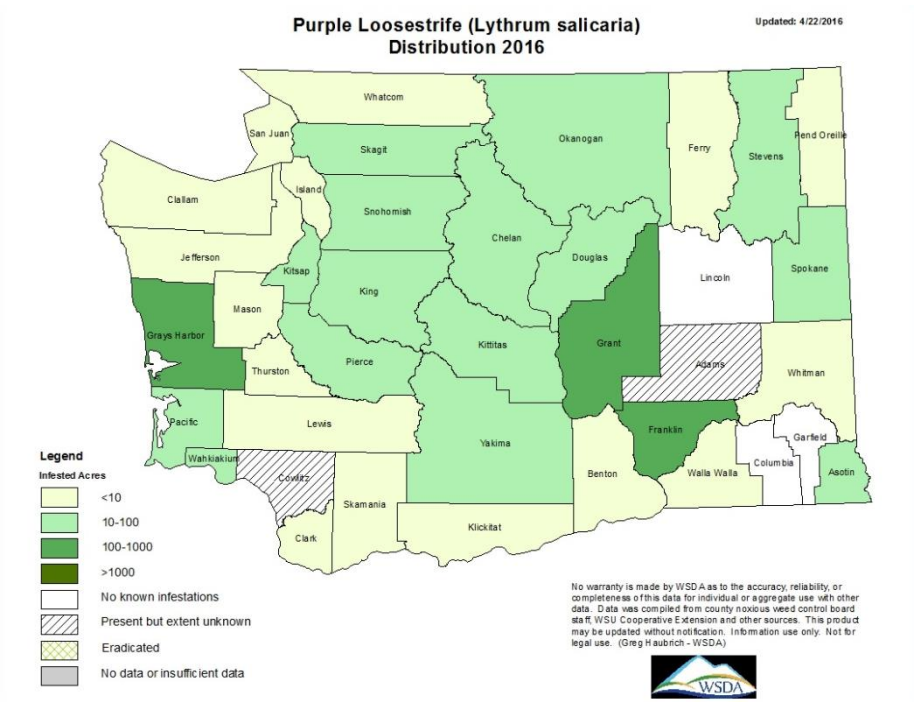
Purple Loosestrife Direct Impacts	
Recreation in Wildlands	**$6,156,000**
Direct Impacts to Hunting	$511,000
Direct Impacts to Fishing	$1,872,000
Direct Impacts to Boating	$3,773,000
Total	**$6,156,000**

Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

Purple loosestrife effects on recreation industry suggests that more than $20.8 million in economic output is at risk across the Washington economy. Furthermore, 150 jobs in Washington would be at risk along with $6.6 million in lost labor income.

Total Purple Loosestrife Impacts	
Output	**$20,817,000**
Jobs	**150**
Labor Income	**$6,693,000**



SMOOTH CORDGRASS *Spartina alterniflora*

Description of Species

Smooth cordgrass is a hardy estuarine grass with densely-arranged stems that grow to form a thick mat of roots. The grass has fine leaves with distinctive lime-green coloring. Smooth cordgrass is a perennial plant and a prolific seed producer. The species propagates through its dense root system and can further infest areas via vegetative fragments and rhizomatous clones. This particular *Spartina* species is found in intertidal salt marshes.

Distribution in Washington

Smooth cordgrass has been found throughout the Puget Sound, Neah Bay, Grays Harbor and Willapa Bay. Small populations have also been found near the mouth of the Columbia River. At its peak in 2003, smooth cordgrass colonized upwards of 9,000 solid acres in Washington but well-funded and coordinated eradication efforts have since reduced it to a projected 6 solid acres in 2016

Impacts Considered

Mollusks, crustaceans, wild and farmed fish: Smooth cordgrass transforms intertidal mudflats into steep and deep tidal channels, increasing waves, all of which restrict commercial and natural fisheries.
Salmon: Prevents mixing of freshwater and salt water in estuaries that can harm salmon populations.
Wetlands: Increases flooding potential by creating dense intertidal meadows.

Other Considerations

Recreation: Smooth cordgrass can clog popular waterways and prevent recreational boating.

Reference: http://www.nwcb.wa.gov/weeds/smooth-cordgrass and links therein.

Source: Chad Phillips, Washington State Department of Agriculture

Direct Economic Impact of Species

Smooth cordgrass control has been one of the top priorities of the Washington State Department of Agriculture, which has taken the lead in coordinating eradication efforts between private, federal, state, county, and tribal landowners. Smooth cordgrass has the potential to cripple the shellfish/aquaculture industry in Washington without proactive control of smooth cordgrass populations. Smooth cordgrass stands also limits nesting habitat for migratory waterfowl.

Smooth cordgrass could potentially reestablish itself in six counties in Washington at a growth rate of 20%, this is equivalent to approximately 37,000 acres of shellfish production. Of the six affected counties, Pacific County and Grays Harbor County are estimated to have the largest impacts from smooth cordgrass. Pacific County is estimated to have $6.7 million in direct economic losses, while Grays Harbor County is estimated to have a similar $6.3 million in direct economic loss.

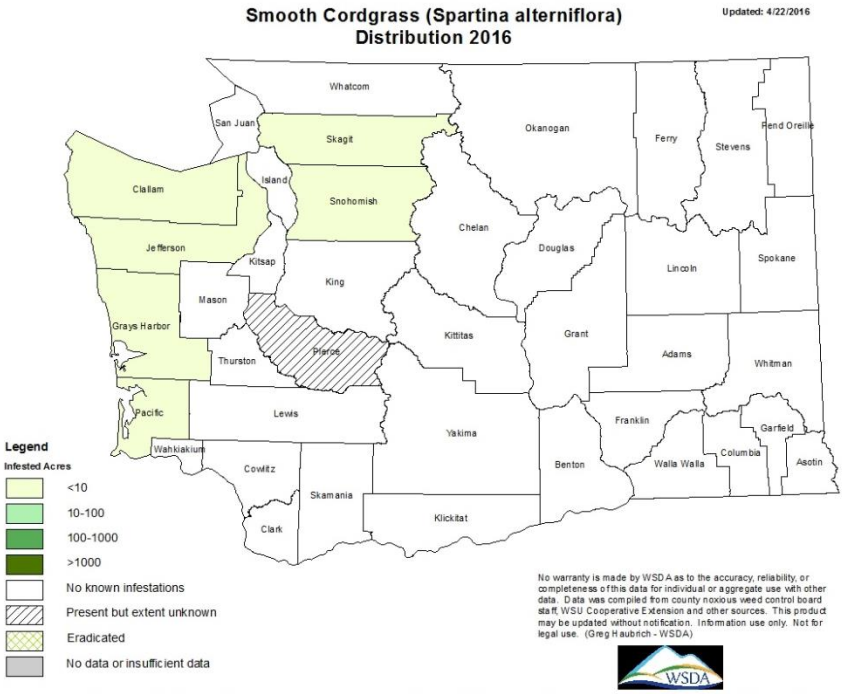
Smooth Cordgrass Direct Impacts	
Direct Impacts to Shellfish	**$20,258,000**
Direct Impacts to Hunting	**$224,000**
Total	**$20,482,000**

Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

The majority of direct impacts caused by smooth cordgrass are from losses incurred by the shellfish industry, which requires a significant amount of inputs from other industries across Washington. Studying the expanded impact of smooth cordgrass reveals that total economic output at risk is more than $48.6 million along with 360 jobs. An estimated $15.5 million in labor income would be lost if smooth cordgrass was able to significantly reestablish itself in Washington.

Total Smooth Cordgrass Impacts	
Output	**$48,866,000**
Jobs	**360**
Labor Income	**$15,589,000**



INVASIVE KNOTWEED *Polygonum sachalinense, P. polystachyum, P.cuspidatum, Polygonum x bohemicum*

Description of Species

The invasive knotweeds consist of giant, *Polygonum sachalinense;* Himalayan, *Polygonum polystachyum;* Japanese, *Polygonum cuspidatum;* and the hybrid Bohemian knotweed, *Polygonum x bohemicum*. These Class B noxious weeds all have bamboo-like, hollow green or red stems with swollen nodes and alternate, entire leaves. The invasive knotweeds have an extensive underground rhizome system. They bloom late in the season and produce small, creamy-white spikes of flowers from July to October. Knotweed plants can grow more than 12 feet tall in a single growing season. These knotweeds are considered some of the most invasive plants on Earth, and they are extremely difficult to control.

Distribution in Washington

Invasive knotweed species and hybrids are found throughout Washington's riparian habitats. Only Adams County does not appear to have any sizable population of knotweed at this time.

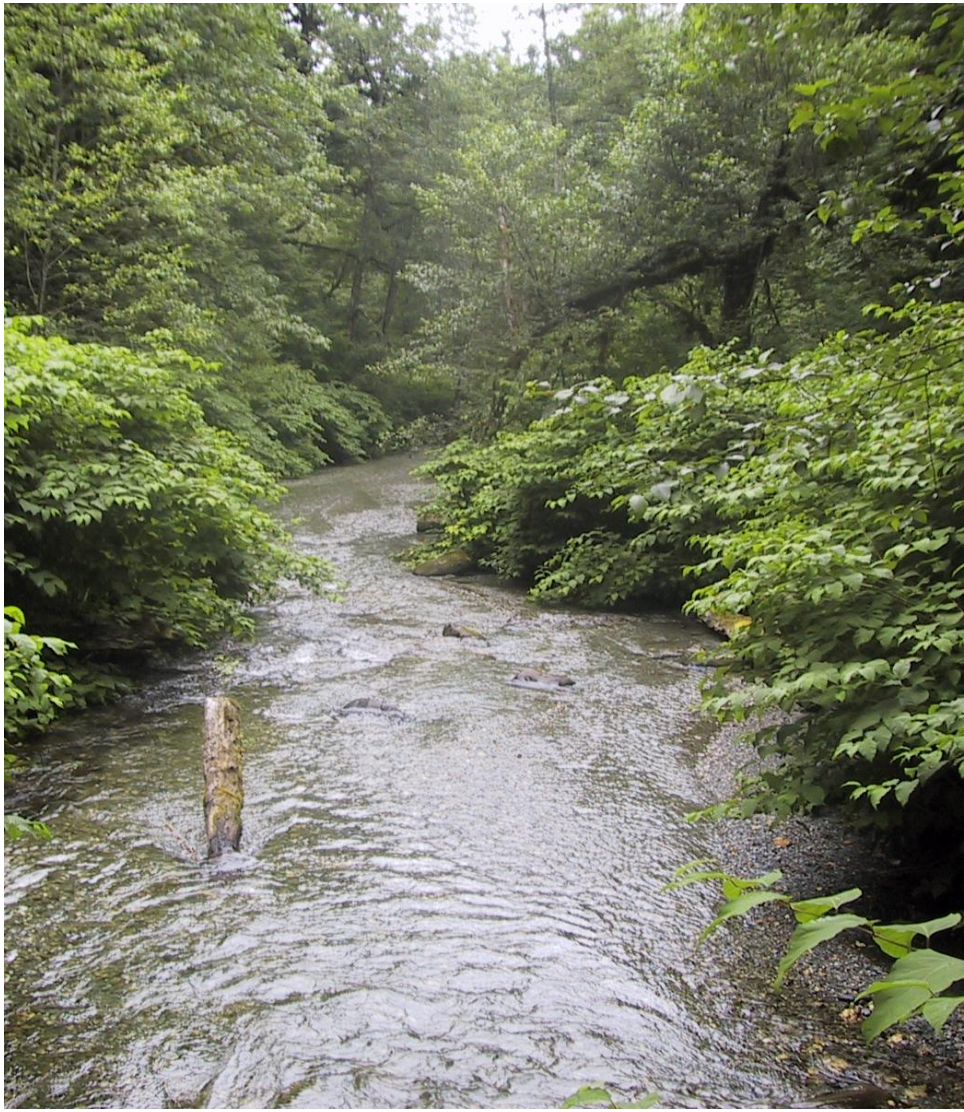
Impacts Considered

Environment: Invasive knotweeds can significantly alter riparian habitats, food webs, and native plant communities.
Rivers and Streams: Invasive knotweeds can rapidly dominate river embankments and cause severe soil erosion, impacting water quality and salmon habitat.

Other Considerations

Wildfire: Dry knotweed biomass can be a fire hazard.
Infrastructure: Knotweed rhizomes can damage septic systems and infrastructure such as roads and pipes.

References: http://www.nwcb.wa.gov/weeds/giant-knotweed, http://www.nwcb.wa.gov/weeds/himalayan-knotweed, http://www.nwcb.wa.gov/weeds/japanese-knotweed, http://www.nwcb.wa.gov/weeds/bohemian-knotweed and links therein.



Source: Laurel Baldwin, Whatcom County Noxious Weed Control Board

Direct Economic Impact of Species

Invasive knotweed has significant populations in 19 of Washington's 39 counties. However, it is mostly confined to riparian habitats, so economic impact estimates only reflect a 1% impact on rangeland, wildlands, streams and rivers. This is roughly equivalent to 24,000 acres of rangeland and wildland and a further 227 miles of stream banks and river banks. Impacts across counties are fairly similar, with the average direct impact per county estimated at $48,000.

Despite the current modest impacts per county, any increase in the rate of spread has a sizable effect on the direct impacts of invasive knotweeds because of how widespread it is. For example, if the rate of spread were estimated to be 5% of productive lands, total direct impacts from invasive knotweed jump to more than $9.3 million.

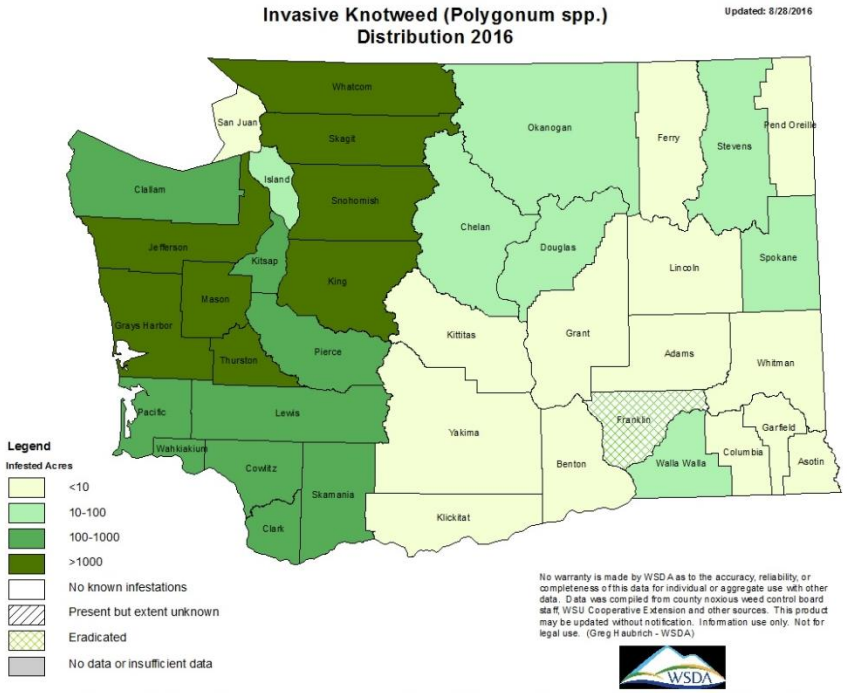
Invasive Knotweed Direct Impacts	
Direct Impacts to Livestock	**$1,565,000**
Recreation in Wildlands	**$306,000**
Direct Impacts to Hunting	$41,000
Direct Impacts to Fishing	$265,000
Total	**$1,871,000**

Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

Looking at the wider economic impacts of invasive knotweeds reveals that at a 1% rate of infestation, total economic output at risk across Washington is nearly $4.5 million. This represents 25 jobs at risk with an associated $1.2 million in lost labor income.

Total Invasive Knotweed Impacts	
Output	**$4,532,000**
Jobs	**25**
Labor Income	**$1,256,000**



Description of Species

Eurasian watermilfoil is a perennial, submerged aquatic Class B noxious weed that flourishes in nutrient-rich water bodies across a wide range of temperatures, depths and turbidity. It has finely dissected leaves occurring in whorls of four, with each leaf consisting of at least 12 pairs of leaflets. Stems sometimes have a reddish hue. This invasive plant forms dense, underwater stands and forms canopies that crowd or shade out native submerged plants. Eurasian watermilfoil can readily propagate via stem fragments and spread to new water bodies by clinging to boats or gear.

Geography in Washington

Eurasian watermilfoil populations are found in 34 of Washington's 39 counties. However, it has the potential to be found in lakes and rivers throughout Washington.

Impacts Considered

Waterways: Eurasian watermilfoil clogs public water treatment plants, power plants and dams.
Recreation: Prevents recreational boating by impeding navigation in bodies of water, getting tangled in propellers, restricting swimming areas, and reducing habitat for fish.

Other Considerations

Boating: Thick canopies of Eurasian watermilfoil can damage boat propellers and engines.
Reduction in housing prices: Lakeside homes with lakes infested with Eurasian watermilfoil show a depreciation in property values.
Lake habitat: Displaces native submerged aquatic plants and reduces quality of habitat.

Reference: http://www.nwcb.wa.gov/weeds/eurasian-watermilfoil and links therein.

Source: Julie Sanderson, Chelan County Noxious Weed Control Board

Direct Economic Impact of Species

Significant levels of Eurasian watermilfoil infestation are found in 23 counties across Washington. One scenario assumes Eurasian watermilfoil affects roughly 12% of the lakes and rivers in those 23 counties – this is equivalent to roughly 49,000 acres of lakes and rivers in Washington. A further 140 dams are estimated to be in contact with Eurasian watermilfoil, which requires routine cleaning at a cost of $3,000 per facility.

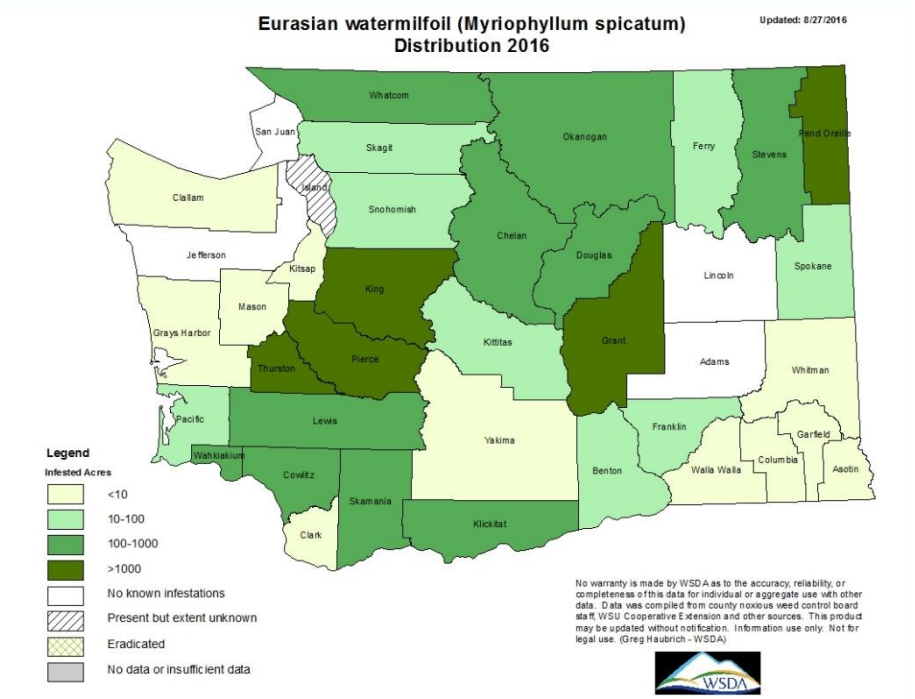
Eurasian Watermilfoil Direct Impacts	
Direct Impacts to Boating	**$5,140,000**
Direct Impacts to Dams	**$420,000**
Total	**$5,560,000**

Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; CDFW, 2015; WSDE, 2016; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

Projecting the impact of Eurasian watermilfoil across the Washington economy shows that an estimated $14.9 million in economic output could be lost when 12% of affected counties' waterways are at risk. This represents a loss of 120 jobs and $4.8 million in lost wages.

Total Eurasian Watermilfoil Impacts	
Output	**$14,858,000**
Jobs	**120**
Labor Income	**$4,895,000**



Description of Species

Invasive zebra and quagga mussels, *Dreissena polymorpha* and *D. bugensis*, are small mollusks that attach to any solid surface under water. Female invasive mussels can produce up to 500,000 new mussels per year. The eggs develop into microscopic larvae called veligers that move through the water column until they attach to a hard surface. Both invasive mussels were first introduced to the United States in the ballast water of ships. Within the United States, invasive mussels are primarily moved by recreational and commercial boaters.

Distribution in Washington

Zebra and quagga mussels are not established in Washington, thanks to cooperative efforts by neighboring states to prevent their introduction. They are a significant and costly problem in the Great Lakes complex, including the Mississippi River system. There is a well-established population in Lake Mead near Las Vegas, Nevada. In 2008, zebra mussels were discovered in the San Justo Reservoir in Hollister, California. Most recently, larvae of invasive mussels were detected in the Tiber Reservoir in Chester, Montana.

Impacts Considered

Salmon, trout, and shellfish: The mussels rapidly filter phytoplankton, the loss of which stimulates toxic algal blooms and reduces food for young, planktivorous fish. Mussel filter-feeding also reduces dissolved oxygen content in waterbodies.
Waterways: Live and dead mussels clog intake pipes within water treatment plants, irrigation systems, power plants, and dams.

Other Considerations

Boating: Invasive mussels attach to any hard surface. Adults foul boat hulls and engines, affecting efficiency and eventually damaging the equipment.
Recreation: Invasive mussel shells can cut swimmers, limiting recreational water recreation. The mussels can also accumulate toxins, becoming poisonous to animals that feed on them.

Source: Amy Benson, U.S. Geological Survey, Bugwood.org

Direct Economic Impact of Species

Invasive mussels require waterbodies containing calcium to build and harden their shells. Twenty-four lakes and five major rivers have calcium levels that could support the invasive mussels. In total, 23 dams and 227 public boat launches lie in bodies of water that could support invasive mussels. Furthermore, approximately 1,061 miles of rivers and streams are likely to be affected by invasive mussels.

The largest cost associated with invasive mussels is the installation of mussel mitigation systems, costing $1.8 million per dam facility. Furthermore, removal of invasive mussels costs an estimated $48,000 per facility. Removal of mussels from boat launches is estimated to cost $750 per boat launch.

These direct impacts reflect the total costs if no measures were in place to prevent the spread of invasive mussels. After the installation of preventive systems, the only yearly impacts would be to boat launches and recreational fishing.

Invasive Mussels Direct Impacts	
Direct Impacts to Dams	**$42,895,000**
Installation of mitigation systems	$41,791,000
Removal from dam installations	$1,104,000
Removal from Boat Launches	**$170,000**
Direct Impacts to Fishing	**$47,000**
Total	**$43,112,000**

Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; Rogers et al., 2015; IEAB, 2013; WSDE, 2016; WSRCO, 2015; Ruyle and Ogden, 1993; PSMFC, 2005; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

Invasive mussels can quickly reproduce and infest entire waterbodies that have calcium levels high enough to support shell development. As such, the total potential impacts throughout the Washington State economy is significant. Total impacts to economic output at risk is estimated to be $100.1 million with an associated 500 jobs potentially lost and $27.8 million in labor income.

Total Invasive Mussels Impacts	
Output	**$100,116,000**
Jobs	**500**
Labor Income	**$27,884,000**

Description of Species

Apple maggots are the larvae of the fruit fly, which is native to eastern North America. Female fruit flies lay eggs by making small incisions into the skin of the fruit, which causes dimpling. After three to seven days, eggs hatch and the maggots start to feed on the fruit. Quickly, the fruit becomes soft and will fall off the tree. Apple maggot larvae then pupate in the soil underneath the infected fruit tree and emerge as adult fruit flies in the spring.

Distribution in Washington

Apple maggots were first detected in Clark County. Apple maggots are found in 22 of Washington's 39 counties.

Impacts Considered

Apples, pears, sweet cherries: Apple maggot attacks early maturing fruit and renders it unfit for consumption, sale, and export.

Other Considerations

Exports: Crops that are infested with apple maggot cannot be sold for export in order to prevent the spread of apple maggot.
Quarantine areas: Infested areas are included in quarantine areas, prohibiting the movement of fruit to protect orchards that do not have this costly pest.

Source: Joseph Berger; insectimages.org

Direct Economic Impact of Species

Apple maggot primarily feeds on apples, but cherry and pear trees are also hosts. Seventeen counties in Washington are at risk for apple maggot introduction. An estimated rate of spread of 15% into susceptible cropland in these counties suggests that a total of 19,000 acres of apples, 5,000 acres of cherries and 2,000 acres of pears are at risk.

Trees infested with apple maggot are estimated to lose about half their fruit. However, any orchard infested with apple maggot cannot export any of their produce. As such, there are different valuations of non-commercial consumption of fruit versus the value of fruit for export.

Apple Maggot Direct Impacts	
***A* Direct Impacts to Crops (domestic)**	**$54,152,000**
Apple	$47,663,000
Cherry	$4,609,000
Pear	$1,880,000
***B* Direct Impacts to Crops (exports)**	**$108,305,000**
Apple	$95,327,000
Cherry	$9,219,000
Pear	$3,759,000
***A+B* Direct Impacts to Crops (total)**	**$162,457,000**
Apple	$142,990,000
Cherry	$13,828,000
Pear	$5,639,000

Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

Apple maggot impacts are unique due to the different valuations of domestic production and fruit destined for export. At a 15% rate of spread, the total economic impact of apple maggot is estimated to be nearly $392 million. Approximately $131 million is from fruit destined to be sold domestically and the remaining $261 million destined for export.

Total jobs at risk amount to approximately 2,900, of which 970 jobs are at risk due to shortfalls in domestic sales with a further 1,940 jobs at risk due to shortfalls in export sales. The potential job losses equate to a total potential loss of $125 million in lost wages.

Total Apple Maggot Impacts	
Output	**$391,988,000**
Jobs	**2,900**
Labor Income	**$125,182,000**

Description of Species

The caterpillars of Asian and European gypsy moths, *Lymantria dispar asiatica* and *L. dispar*, can have a massive impact on forests and landscaping trees and shrubs. Both species produce egg masses containing hundreds of eggs, and the emerging caterpillars quickly defoliate host trees, which can severely weaken or kill them.

Asian and European gypsy moths are both problematic, but the Asian species is considered worse. The female European gypsy moth is flightless and its spread through the eastern United States has been slow. In contrast, female Asian gypsy moths are strong fliers, and the Asian gypsy moth has quickly been spreading through the United States. Additionally, the Asian gypsy moth has a wider range of potential host trees, compared to the European gypsy moth, although both gypsy moth species can feed on more than 300 species of trees and shrubs.

Distribution in Washington

Gypsy moth has not yet established in Washington State. Some populations have been detected, but have been quickly eradicated through an extensive monitoring and eradication program administered by the Washington State Department of Agriculture.

Impacts Considered

Timber: Larvae can consume more than 300 different species of trees and shrubs. European gypsy moth prefers oak species. Asian gypsy moths will consume larch, oak, poplar, alder, willow and some evergreen species.

Other Considerations

Recreation: Gypsy moths can defoliate forests and wildlands, affecting scenic and recreational value.

Source: Bill McNee, Wisconsin Department of Natural Resources, Bugwood.org

Direct Economic Impact of Species

Gypsy moth has an estimated yearly radial spread of 13-14 miles, which is equivalent to 376,000 acres per year. In 2015, there were 18,975 gypsy moth traps placed in Washington. If an estimated 1% of those traps proved positive and gypsy moth were allowed to infest timberland at a 15% rate of spread, more than 7.5 million acres of timberland would be at risk of defoliation due to Gypsy moth.

Gypsy moth has the potential to infest at least 20 counties across Washington. King County is estimated to experience the largest impact, with around $8.5 million in direct costs. The average direct impact of gypsy moth per county is around $2.4 million.

Gypsy Moth Direct Impacts	
Direct Impacts to Timber	**$48,863,000**
Total	**$48,863,000**

Sources: ODA, 2014; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Gansner and Herrick, 1987; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016

Total Economic Activity at Risk

The projected impact of gypsy moth refers to the economic output, jobs and labor income at risk. If 1% of all gypsy moth traps tested positive and 15% of timberland near those traps were infested by gypsy moth caterpillars, the total economic impact at risk from gypsy moth across the Washington economy is estimated to be approximately $116 million. A further 500 jobs are considered to be at risk from gypsy moth and $29 million in lost labor income.

Total Gypsy Moth Impacts	
Output	**$116,086,000**
Jobs	**500**
Labor Income	**$29,012,000**

EMERALD ASH BORER *Agrilus planipennis*

Description of Species

Emerald ash borer is an invasive wood-boring beetle that is destructive to ash (*Fraxinus*) trees. Adult beetles are roughly 0.33 inches in length and are metallic green in color. Emerald ash borer larvae feed on the sapwood of the ash tree, disrupting the flow of water and nutrients of the tree trunk by girdling it. In the United States, more than 7.5 billion ash trees have been killed by emerald ash borer.

Distribution in Washington

Emerald ash borer is not present in Washington. However, Washington State actively monitors for new introductions in King, Lewis Pierce, and Thurston Counties.

Impacts Considered

Timber: Emerald ash borer larvae feed on the ash tree sapwood, disrupting a tree's ability to transport water and nutrients through its trunk.
Urban Forests: Ash trees are frequently planted in urban parks and on city streets. Larval impacts to urban ash trees would devastate Washington's urban and community forestry program.

Other Considerations

Recreation: Emerald ash borer infestations can defoliate forests and wildlands.
Riparian Forests: Ash tree defoliation and death in near-stream environments negatively impacts stream temperature and health.
Quarantine: In the event of introduction, a quarantine limiting intrastate or interstate movement of ash nursery trees, hardwood firewood, and other ash products will be placed on the affected counties.

Source: Leah Bauer, U.S. Department of Agriculture's Forest Service Northern Research Station, Bugwood.org

Direct Economic Impact of Species

Emerald ash borer exclusively impacts ash (*Fraxinus*) trees. In Washington, ash trees are found primarily in urban parks, neighborhoods, and green spaces. In commercial forestry, it has a relatively low value for harvest.

In 2015, a total of 88 emerald ash borer traps were placed across King, Lewis, Pierce and Thurston Counties. Using a 15% rate of infestation for those traps provides a direct impact of $1.5 million in loss to ash trees.

King County has the most significant urban park ash tree population with the highest appraised value of those ash trees. Estimated direct economic losses in King County total more than $1.1 million.

Emerald Ash Borer Direct Impacts	
Direct Impacts to Ash Trees	**$1,555,000**
Total	**$1,555,000**

Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

The economic impact of emerald ash borer does not include the cost of removing and destroying infested ash trees or restoration planting. The total economic output at risk from emerald ash borer is almost $4.2 million. This translates to 30 jobs at risk from emerald ash borer and $1.39 million in lost wages.

Total Emerald Ash Borer Impacts	
Output	**$4,199,000**
Jobs	**30**
Labor Income	**$1,398,000**

Description of Species

Nutria is a large semi-aquatic rodent native to South America. Nutria were first introduced in 1899 to the United States in California for the purposes of fur farming. During World War II, the fur farming industry in the United States collapsed, and nutria were released into the wild where they thrived with little natural predation. Nutria favor riparian and wetland areas, damaging wildlife habitat and estuaries.

Distribution in Washington

In Washington, nutria were first detected outside of captivity in 1943. Nutria have since spread in many areas of western Washington and are gaining a foothold in in central Washington.

Impacts Considered

Wetlands: Nutria consume estuary and marsh vegetation, causing bank erosion, degraded water quality, and wetland habitat loss.
Salmon: Destruction of vegetative cover on stream banks and in estuaries causes water quality issues, stream bank erosion and habitat loss.

Other Considerations

Recreation: Destruction of stream banks, lake shores, and wetlands reduces opportunities for outdoor and water recreation.
Habitat destruction: Nutria can disrupt ecosystem processes in critically-important areas.

Source: John and Karen Hollingsworth, U.S. Fish and Wildlife Service, Bugwood.org

Direct Economic Impact of Species

Nutria primarily live in riparian habitats near streams and rivers. The impact of nutria on crops primarily occurs on farmland adjacent to riparian habitat. At a 15% rate of spread, nutria are estimated to directly impact 23,000 acres of crops statewide. In total, 1,724 miles of rivers and streams are likely to be affected by nutria.

Nutria are found in 13 counties in Washington, with the largest impact occurring in Yakima County. Nutria in Yakima could cause more than $525,000 in direct damages. The average direct impact per affected county is estimated to be $199,000.

Nutria Direct Impacts	
Direct Impacts to Crops	**$298,000**
Grains	$40,000
Alfalfa Hay	$122,000
Corn	$136,000
Direct Impacts to Fishing	**$2,291,000**
Total	**$2,589,000**

Sources: The Research Group, 2014*; WSDA, 2015; USDA, 2015; WDFW, 2015; University of Washington, 2015; Ruyle and Ogden, 1993; Chang and Jackson, 2003; Oregon State Marine Board, 2009; OFM, 2016; Community Attributes Inc., 2016*

Total Economic Activity at Risk

While the direct impacts of nutria are limited, the potential impacts across Washington are significant. At a 15% rate of infestation along rivers in affected counties, total economic impacts across Washington could total approximately $6.4 million in lost output. This lost output would lead to a loss of 25 jobs and $1.7 million in wages.

While the total impact of nutria estimated in this report is relatively small, the unquantified impacts by nutria to Washington's environment and biodiversity will be significantly larger than the figures in this report suggest.

Total Nutria Impacts	
Output	**$6,104,000**
Jobs	**25**
Labor Income	**$1,779,000**

Description of Species

Feral swine are descendants from Eurasian wild boar or domestic pigs that escaped captivity and have reverted to wild characteristics. Adult feral swine are prodigious breeders and can weigh upwards of 400 pounds. Feral swine are omnivores and will generally eat anything that is available, including crops.

Distribution in Washington

There are no established populations of feral swine in Washington. There have been isolated occurrences on the Olympic Peninsula and in southeast and south central Washington. Feral swine have established populations in parts of northeast Oregon and southern Idaho.

Impacts Considered

Crops including potatoes, grapes, pears, apples and cherries: Rooting (digging with tusks and snouts) can destroy crops as well as till soil and open areas for noxious weed invasion. Because Washington does not have any established feral swine populations at this time, the existing economic models were not applicable. Therefore, economic impacts were not calculated for this species.

Hay, wheat, grain, hops: Rooting can destroy crops' roots. This can create areas for noxious weed introduction, further reducing yields.

Cattle and livestock: Feral swine are known to carry or transmit more than 30 diseases and parasites that can be transmitted to livestock, people, pets and wildlife.

Value of Potentially-Affected Crops and Animals

Commodity	Value (Millions)	Data Year
Cattle & Calves	$1,163.3	2015
Sheep & Other Livestock	$144.4	2015
Apples	$1,914.8	2014
Cherries	$507.4	2014
Peaches	$11.0	2014
Pears	$236.1	2014
Potatoes	$764.9	2014
Grapes, Wine	$304.8	2014
Barley	$16.1	2015
Hay	$623.5	2015
Hops	$280.0	2015
Wheat	$629.1	2015
Total	**$6,595.5**	

Sources: PSU, 2007; USDA, 2015; USDA, 2014.

Other Considerations

Habitat destruction: Feral swine typically occupy the same areas as deer and other native herbivores. In some instances, feral swine have been documented killing deer, turkeys, and young livestock.

Source: The Nature Conservancy, Bugwood.org

Prepared For

Washington State Department of Agriculture

Washington State Noxious Weed Control Board

Washington Invasive Species Council

Washington State Department of Ecology

Washington State Department of Fish and Wildlife

Washington State Department of Natural Resources

Washington State Department of Transportation

Washington State Parks

Washington State Parks and Recreation Commission

Prepared By
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Washington's native plants, such as balsamroot, are at risk from encroachment of invasive, noxious weeds.
Photo courtesy of Emily Stevenson, Skamania County NWCB