The PACFISH/INFISH Biological Opinion (PIBO) Effectiveness Monitoring Program and Invasive Plant Species Detection: A Retrospective Summary 2003-2011.

Eric Archer[a]
Nate Hough-Snee[b]
Andrew Van Wagenen
Ryan Lokteff
Brett B. Roper

USDA Forest Service
PACFISH/INFISH Biological Opinion

[a] PIBO project leader: earcher@fs.fed.us, [b] Primary and corresponding author: nwhoughsnee@fs.fed.us

Abstract: Invasive species pose a serious threat to aquatic and riparian habitats around the world. Inherently, invasive species detection and monitoring are an integral part of a robust riparian monitoring program. Within the Interior Columbia River and Upper Missouri River Basins, invasive species have the potential to alter and degrade riparian areas within steelhead (*Oncorhynchus mykiss*) and bull trout (*Salvelinus confluentus*) habitat. The USDA Forest Service's PACFISH/INFISH Biological Opinion Effectiveness Monitoring program (PIBO) is tasked with assessing the integrity of riparian and in-stream habitat that supports these and other fish. We report the PIBO vegetation program's biological invasion detections for study years 2003-2011 to highlight current and potential threats to riparian resources. We compiled stream locations with at least one invasive weed occurrence and assessed invasion richness and intensity. We report the proportion of reaches invaded based on their management classification (reference, managed for natural resources or designated grazing monitoring areas), and mapped invasive plant richness within each PIBO reach. We conclude that current riparian condition and vegetation communities within the Columbia and Missouri River Basins have been altered by biological invasions and that these invasions may threaten long-term ecosystem integrity within the PIBO study area.

Keywords: aquatic monitoring, Columbia River Basin, exotic species, invasive species, Missouri River Basin, PIBO, riparian condition, riparian vegetation, weeds

Introduction

Invasive plants have the potential to degrade riparian and aquatic habitats (Richardson et al. 2007), displace native flora and fauna (Urgenson et al. 2009), reduce the quality and amount of native prey and forage available to endangered fishes and terrestrial animals (DiTomaso 2000; Pejchar and Mooney 2009) and change the physical, hydrologic and geomorphic properties of streams and riparian corridors (Tickner et al. 2001). Within the U.S., all invasive plant and animal species combined have been estimated to exert negative economic effects valued at as much as $120 billion per year and threaten 42% of species currently listed as *Threatened* or *Endangered* through the Endangered Species Act (Pimental et al. 2005). Given the diverse and cumulative impacts biological invasions have on ecosystem integrity and forest stakeholders such as ranchers, farmers, the forest products industry, and outdoor recreationists, invasive species have garnered significant attention as a management concern (Harrington and Reichard 2007; Adams et al. 2009). Specifically, invasive plants threaten aquatic and streamside lands managed by the USDA Forest Service (herein the Forest Service or USFS) and USDI Bureau of Land Management (BLM). These lands have great economic and ecological value for fish and wildlife habitat, rangeland water and forage, recreation, and aesthetics (Hooper et al 2005; Naiman and Décamps 1997).

Riparian zones – the transition zone between upland and aquatic environments – occupy a disproportionately small area on the landscape, but confer disproportionately abundant ecosystem services and are at particular risk to degradation by biological invasions (Naiman and Décamps 1997; Hood and Naiman 2000; Stohlgren et al. 1999). Within the Forest Service's mandates to sustainably manage forests, rangelands and aquatic resources, invasive species have been identified as a threat to aquatic endangered species and their habitats on Forest Service lands and beyond (Harrington and Reichard 2007; Adams et al. 2009). The federal government presently classifies a species as invasive if it meets two criteria: it is nonnative to the ecosystem under consideration and its introduction causes or is likely to cause economic or environmental harm or harm to human health (Executive Order No. 13112, 1999).

In the Pacific Northwest, the Forest Service currently surveys for biological invasions along stream courses through two in-stream habitat monitoring programs: the Aquatic and Riparian Effectiveness Monitoring Program (AREMP; Lanigan et al 2012) and PACFISH – INFISH Biological Opinion Effectiveness Monitoring program (PIBO) (USDA/USDI 1995; USDA 1995; Kershner et al 2004). These programs provide information on changing riparian and aquatic conditions within the range of the northern spotted owl (AREMP) and the Interior Columbia River and Upper Missouri River Basins (PIBO).

The PIBO program has a dedicated vegetation monitoring component that collects riparian plant composition data at federally managed headwater stream reaches across the Interior Columbia and Upper

Missouri River Basins. By measuring vegetation composition, thorough inventories of the plant species at each study reach may be generated over time, allowing for early invasion detection and floristic quality assessments.

Within this report we use PIBO's vegetation data to outline the presence of invasive vascular plants within the PIBO study area. This report has three primary objectives:

1. to map detections of state listed invasive species within the Interior Columbia and Upper Missouri River Basins.

2. to summarize the frequency of detection of each invasive species, across PIBO sites.

3. to categorize watersheds by severity of biological invasion based on overall invasive plant species richness and to correlate invasive species richness and land management activities.

Management activities such as grazing, road maintenance, and timber operations are the primary vectors for biological invasion DeLoach 1991; DiTomaso 2000. Federal land managers can however adaptively alter their management to control existing invasions and prevent new biological invasions from occurring. In this report we focus on the differences between reference, managed and designated grazing monitoring areas to understand how land management practices may be influencing invasive species infestations.

Study Area and Design

PIBO samples stream reaches within 6th-field subwatersheds with a gradient < 4% because these reaches are highly responsive to the cumulative upstream effects of upstream land management (Montgomery and MacDonald 2002; Kershner et al. 2004). To be included in the study, at least 50% of the upstream watershed must be federally owned (USFS, BLM or USDI National Park Service). In select subwatersheds where grazing occurs, PIBO also monitors specific sites known as Designated Monitoring Areas (DMAs). At DMAs, relationships between grazing management activities and in-stream and riparian condition are evaluated. Because DMAs are disturbed to various degrees by rangeland actions, they may exhibit higher numbers of non-native plant invasions than unmanaged reaches. DMAs may also recover quickly from degradation when management actions are revised to improve forest and rangeland condition. PIBO sites either occur within reference watersheds, those with no legacies of logging, grazing, hard rock mining or road building or managed watersheds. Managed watersheds are subject to some level of a combination of forest uses including, grazing, road maintenance are but are not specifically monitored for their grazing effects like DMAs,

Vegetation Data and Analysis

We used vegetation data from 4,762 PIBO reach visits to 3,195 unique sites between 2003 and 2011 to identify stream reaches that contained at least one invasive plant species. Because PIBO samples on a rotating panel design, most reaches are revisited every fifth year. Accordingly, sampling intensity varies by how many sampling visits a site has received.

PIBO field crews collect vegetation data at stream reaches as they are sampled for stream habitat throughout the growing season. Crews sample plant composition at both the stream's first line of vegetation (greenline) and across the riparian area (cross-sections). Numerous cross-section and greenline sample plots are used at each reach to identify species and estimate vascular plant cover for all species with ≥5% cover.

We used the United States Department of Agriculture Plants Database (USDA 2012) to identify plant species listed by state noxious weed control boards in Washington, Oregon, Idaho and Montana (Table 1; Appendix 2), and we considered a species invasive if it was listed as a noxious weed or invasive species by at least one state weed control board or equivalent state agency. These states' non-native species definitions parallel the federal definition of having the potential to cause economic and/or ecological harm (Appendix 2). Depending on a species' classification, states require some level of action to report, control or prevent the spread of that species (Table 2).

Table 1. Invasive plant species identified within PIBO reaches between 2003 and 2011 and their state noxious weed priority levels. Species in **Bold** are noxious weeds that have at least one state in the PIBO study area that requires control or eradication. Weed statuses are listed by state priority levels, which are summarized in Table 2 and fully spelled out in Appendix 1. (--) indicates a weed that is not regulated by a given state. State noxious weed boards, whose contact information is listed in Appendix 2, can be reached directly for more information on each state's weed control and mapping efforts (Table 1 continues on the following page).

Common Name	Species Name	Priority			
		ID	MT	OR	WA
Absinthium	*Artemisia absinthium*	--	--	--	C
Annual ragweed	*Ambrosia artemisiifolia*	--	--	B Quarantine	Monitor
Baby's breath	*Gypsophila paniculata*	--	--	--	C
Bighead knapweed	***Centaurea macrocephala***	--	IIB	--	A
Bull thistle	*Cirsium vulgare*	--	--	B Quarantine	C
Burningbush	*Bassia scoparia*	--	--	Quarantine	B
Butter and eggs	*Linaria vulgaris*	Contain	IIB	B Quarantine	C
Camelthorn	*Alhagi maurorum*	--	--	--	B
Canada thistle	*Cirsium arvense*	Contain	IIB	B Quarantine	C
Common gorse	*Ulex Europaeus*	--	--	B Quarantine	B
Common St. Johnswort	*Hypericum perforatum*	--	IIB	B	C
Common tansy	*Tanacetum vulgare*	--	IIB	--	C
Common viper's bugloss	***Echium vulgare***	Control	IIA	--	B
Cultivated knotweed	***Polygonum polystachyum***	Control	--	B Quarantine	B
Dalmatian toadflax	*Linaria dalmatica*	Contain	IIB	B Quarantine	B
Desert false indigo	*Amorpha fruticosa*	--	--	--	B
Diffuse knapweed	*Centaurea diffusa*	Contain	IIB	B Quarantine	B
Field bindweed	*Convolvulus arvensis*		IIB	B Quarantine	C
Field sowthistle	***Sonchus arvensis***	Control	--	--	B
Five-stamen tamarisk	*Tamarix chinensis*	Contain	IIB	--	B
French broom	*Genista monspessulana*	--	--	B Quarantine	B
Giant horsetail	*Equisetum telmateia*	--	--	B Quarantine	--
Gypsy flower	*Cynoglossum officinale*	Contain	IIB	B Quarantine	B
Hardheads	***Acroptilon repens***	Control	IIB	B Quarantine	B
Herb Robert	*Geranium robertianum*	--	--	--	B
Himalayan blackberry	*Rubus armeniacus*			Quarantine	C
Japanese knotweed	***Polygonum cuspidatum***	Control	--	B Quarantine	B
Jointed goatgrass	*Aegilops cylindrical*	Contain	--	B Quarantine	C
Leafy spurge	*Euphorbia esula*	Contain	IIB	B Quarantine	B
Mat sandbur	*Cenchrus longispinus*	--	--	--	B
Meadow hawkweed	***Hieracium caespitosum***	Control	IIA	--	B
Medusahead	*Taeniatherum caput-medusae*	--	--	B Quarantine	--
Nodding plumeless thistle	***Carduus nutans***	Control	--	B Quarantine	B
Orange hawkweed	***Hieracium aurantiacum***	Control	IIA	A Quarantine	B
Oxeye daisy	*Leucanthemum vulgare*	Contain	--	--	B
Poison hemlock	*Conium maculatum*	Contain	--	B Quarantine	B

Table 1. (Continued from page 5):

Common Name	Species Name	Priority			
		ID	MT	OR	WA
Proso millet	*Panicum miliaceum*	--	--	B Quarantine	--
Puncturevine	*Tribulus terrestris*	Contain	--	B Quarantine	B
Quackgrass	*Elymus repens*	--	--	Quarantine	--
Queen Anne's lace	*Daucus carota*	--	--	--	B
Ram's horn	*Proboscidea louisianica*	--	--	--	Monitor
Reed canarygrass	*Phalaris arundinacea*	--	--	--	C
Rush skeletonweed	*Chondrilla juncea*	Contain	IB	B Quarantine	B
Scotch cottonthistle	*Onopordum acanthium*	Contain	--	B Quarantine	B
Spiny cocklebur	*Xanthium spinosum*	--	--	B Quarantine	C
Spotted water hemlock	*Cicuta maculate*	--	--	--	B
Spring milletgrass	*Milium vernale*	Contain	IIB	--	--
Tansy ragwort	***Senecio jacobaea***	Contain	IIA	B Quarantine	B
Striated broom	*Cytisus striatus*	--	--	B Quarantine	--
Sulphur cinquefoil	*Potentilla recta*	--	IIB	B Quarantine	B
Tall buttercup	***Ranunculus acris***	--	IIA	--	--
Velvetleaf	***Abutilon theophrasti***	--	--	B Quarantine	A
Whitetop	*Cardaria draba*	Contain	IIB	B Quarantine	C
Wild chervil	*Anthriscus sylvestris*	--	--	--	B
Yellow star-thistle	***Centaurea solstitialis***	Contain	I	B Quarantine	B

Table 2. Standardized invasive species management requirements for each state noxious weed classification used within the PIBO study area. These state classifications correspond to those in Table 1. Note that some state classifications are listed in multiple columns because they require dual landowner actions, primarily reporting invasions in addition to eradication efforts.

State	Management Requirement							
	Eradicate upon detection				Prevent spread and contain existing invasions		Report to state upon detection	
ID	EDRR		Control		Contain		EDRR	
MT	IA	IIA	IB		IIB		IA	IB
OR	A		T		B		A	
WA	Quarantine		A		B	C	Monitor	A

We calculated the proportion of sites that were invaded for each sampling year and summarized them by watershed management type: reference, managed for grazing, timber or roads or DMA. For invaded reaches, we summarized total invasive plant species richness at each individual stream reach. We used invasive plant species richness because it illustrates nearby vegetation changes or proximity to

common weed dispersal vectors such as roads, utility right-of ways, or livestock trailing areas. We totaled the number of detected invasive plant species at each reach to calculate reach-level invasive species richness. We also calculated average reach-level invasive species richness by year and land management type.

We normalized these results by using a scaled severity index (herein, severity index) to classify invasive species richness within 5^{th}-order watersheds (Equations 1a and 1b). This index scales between 0 and 1 with 0 indicating an area where invasive species have not been detected and higher values indicating that multiple invasive species are present and/or a high invasive species cover. (Table 3).

$$\text{Scaled severity index} = \frac{\text{Observed watershed richness} - \text{Minimum watershed richness}}{\text{Maximum watershed richness} - \text{Minimum watershed richness}}$$

Equation 1a. The scaled severity index that was applied to the invasive species richness data for each 5th-order watershed within the PIBO study region. The minimum and maximum watershed richness values were 0 and 5 respectively.

Table 3: Summary of the scaled severity index used in the mapping of invasions within 5th-order watersheds.

Severity Index	Mapped color	Level of Severity	Summary
0	Green	None	No invasion present at any reaches
0.01-0.25	Yellow	Moderate	One or more invasive species present within some or all sampled riparian zones.
0.251-0.50	Orange	High	One to many invasive species present within some or all sampled riparian zones.
> 0.50	Red	Extreme	Multiple invasive species present within some or all sampled riparian zones.

To classify invasion intensity at a finer resolution, we created an invasive species richness map of individual study reaches (Figure 1). We also provide distribution maps for the five most common invasive species (Figures 5-9). For thirteen noxious weeds that require control and eradication by at least one state within the PIBO study area, we provide individual maps for the five most common of these, and a combined map of the remaining eight species (Figures 10-12).

Findings and Discussion

We identified 55 invasive species in 1,453 visits to 1,019 unique reaches (Table 2). The most common species detected were Canadian thistle (*Cirsium arvense*, 637 occurrences), reed canarygrass (*Phalaris arundinacea*, 475 occurrences), Oxeye daisy (*Leucanthemum vulgare*, 198 occurrences), spear thistle (*Cirsium vulgare*, 135 occurrences), and St. John's wort (*Hypericum perforatum*, 120 occurrences). These five species comprised 72% of the invasive species detected across the PIBO study area (Figures 5-9).

Table 4. Invasive species found within the PIBO study area between 2003 and 2011, including the frequency of each species and the proportion of the total invasion that each species comprises. Species in **Bold** correspond to mandated control or eradication efforts within at least one state in the PIBO study area (Table 2).

Common Name	Frequency			Common Name	Frequency		
	Percent of total invasion occurrences	Count	Rank		Percent of total invasion occurrences	Count	Rank
Canada thistle	29.61	637	1	Field bindweed	0.14	3	28t
Reed canarygrass	22.08	475	2	**Japanese knotweed**	0.14	3	28t
Oxeye daisy	9.21	198	3	Common gorse	0.14	3	28t
Bull thistle	6.28	135	4	Wild chervil	0.09	2	32t
Common St. Johnswort	5.58	120	5	Diffuse knapweed	0.09	2	32t
Quackgrass	4.37	94	6	**Yellow star-thistle**	0.09	2	32t
Gypsyflower	4.09	88	7	Spotted water hemlock	0.09	2	32t
Tall buttercup	3.86	83	8	Queen Anne's lace	0.09	2	32t
Common tansy	3.67	79	9	Robert geranium	0.09	2	32t
Orange hawkweed	1.53	33	10	Baby's breath	0.09	2	32t
Sulphur cinquefoil	1.12	24	11	Spring milletgrass	0.09	2	32t
Nodding plumeless thistle	0.93	20	12	Puncturevine	0.09	2	32t
Himalayan blackberry	0.88	19	13	**Velvetleaf**	0.05	1	41t
Field sowthistle	0.79	17	14	Camelthorn	0.05	1	41t
Spiny cocklebur	0.56	12	15	Annual ragweed	0.05	1	41t
Dalmatian toadflax	0.42	9	16	Desert false indigo	0.05	1	41t
Jointed goatgrass	0.33	7	17t	Burningbush	0.05	1	41t
Bighead knapweed	0.33	7	17t	Mat sandbur	0.05	1	41t
Leafy spurge	0.33	7	17t	Rush skeletonweed	0.05	1	41t
Butter and eggs	0.33	7	17t	Striated broom	0.05	1	41t
Absinthium	0.28	6	21t	**Common viper's bugloss**	0.05	1	41t
Cultivated knotweed	0.28	6	21t	Giant horsetail	0.05	1	41t
Hardheads	0.23	5	23t	French broom	0.05	1	41t
Poison hemlock	0.23	5	23t	Proso millet	0.05	1	41t
Meadow hawkweed	0.23	5	23t	Ram's horn	0.05	1	41t
Scotch cottonthistle	0.19	4	26t	**Stinking Willie**	0.05	1	41t
Medusahead	0.19	4	26t	Five-stamen tamarisk	0.05	1	41t
Whitetop	0.14	3	28t				

We detected 13 state-listed noxious weeds – species that merit early detection and rapid responses to prevent serious infestations (Tables 1, 2 and 4). These weeds were infrequent in occurrence - likely a product of existing eradication and control efforts or limited presence within the study area - but were more likely to occupy a higher percent cover at each reach where they occurred. These species are ideal candidates for early eradication based on their respective state management requirements and their low present frequency within the Columbia and Missouri River Basins (Tables 1 and 4, Figures 10-15).

Land management had a significant effect on whether reaches had invasive plants at detectable levels within all study years. Reference sites were invaded at a much lower rate (17-27% of sites annually; 22% of sites on average) than managed sites (31-47% of sites annually; 37% of sites on average). Managed site invasion rates were comparable to or lower than those of DMA sites (30-61% of sites annually; 42% of sites on average). Invasions were most common across eastern Oregon and Idaho. We report site invasion by land management category and year in Table 5 and Figure 1.

Table 5. Total number of sites sampled, total number of invaded sites and the proportion of total sites invaded for each year calculated by each land management type. The bottom row is the raw totals for all sample years, 2003-2011, and averages across these years.

Year	DMA			Managed			Reference		
	Total sites sampled	**Invaded sites**	**Proportion of sites invaded**	**Total sites sampled**	**Invaded sites**	**Proportion of sites invaded**	**Total sites sampled**	**Invaded sites**	**Proportion of sites invaded**
2003	75	30	0.40	263	110	0.42	54	12	0.22
2004	71	25	0.35	236	76	0.32	77	14	0.18
2005	56	23	0.41	318	98	0.31	44	15	0.34
2006	97	59	0.61	326	117	0.36	81	22	0.27
2007	70	40	0.57	288	136	0.47	65	12	0.18
2008	99	37	0.37	311	112	0.36	58	10	0.17
2009	61	27	0.44	324	125	0.39	83	14	0.17
2010	105	32	0.30	345	134	0.39	62	14	0.23
2011	105	40	0.38	282	96	0.34	67	18	0.27
Average	**82**	**35**	**0.43**	**299**	**112**	**0.37**	**66**	**15**	**0.23**

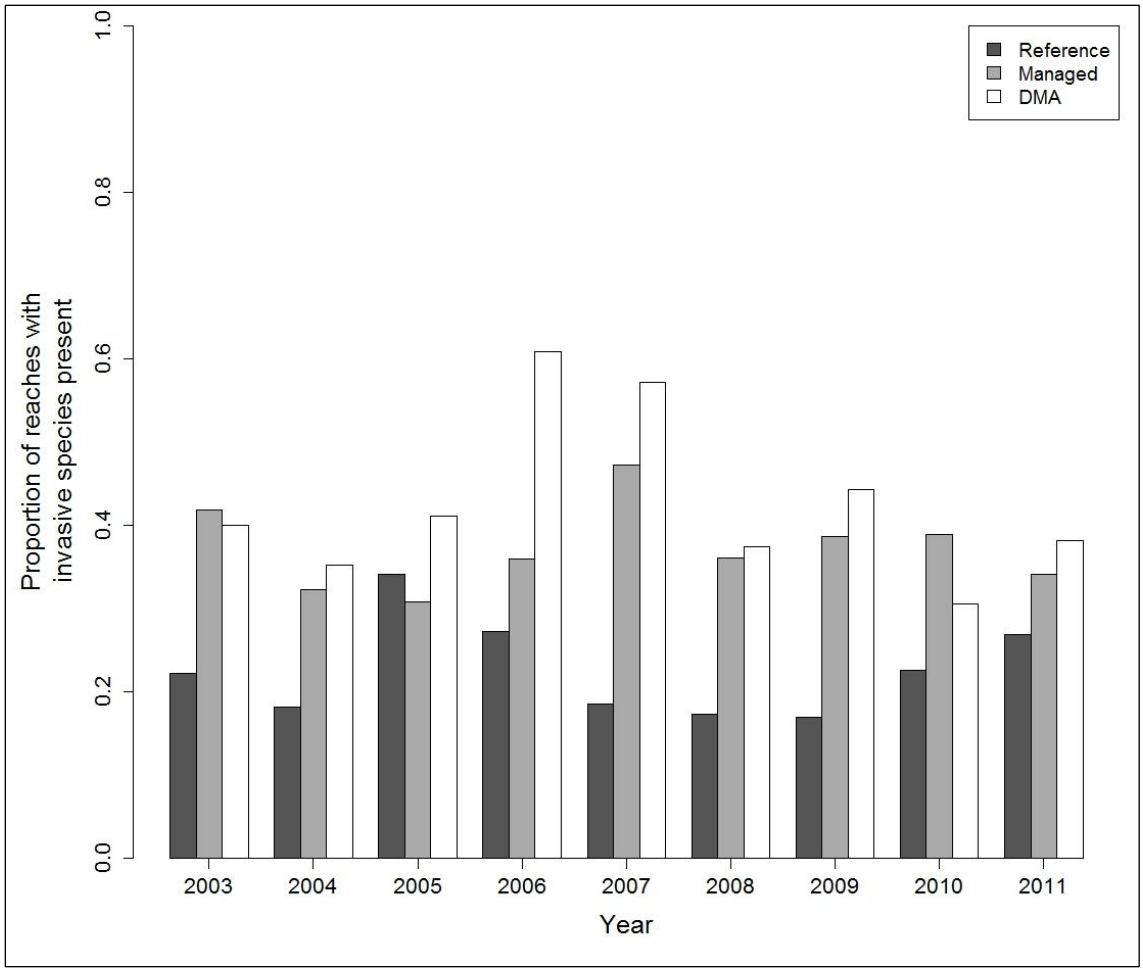

Figure 1. The proportion of reaches within the reference, managed and DMA classifications that were observed to have at least one invasive vascular plant species, graphed by year. Summary statistics for differences between groups within each year are presented in Table 5.

Invasive species richness, like the proportion of sites that were invaded, was correlated to the different management uses of each watershed. Of those reaches that were invaded, reference sites, those with no management activity exhibited lower invasive species richness than both managed and DMA reaches. DMA sites, those with the highest grazing intensity exhibited the highest invasive species richness (Figure 2). These results parallel our invasion proportion results, indicating that watershed management, while collinear with each site's geographic location, corresponds not only to invasion potential, but also the diversity of those invasions.

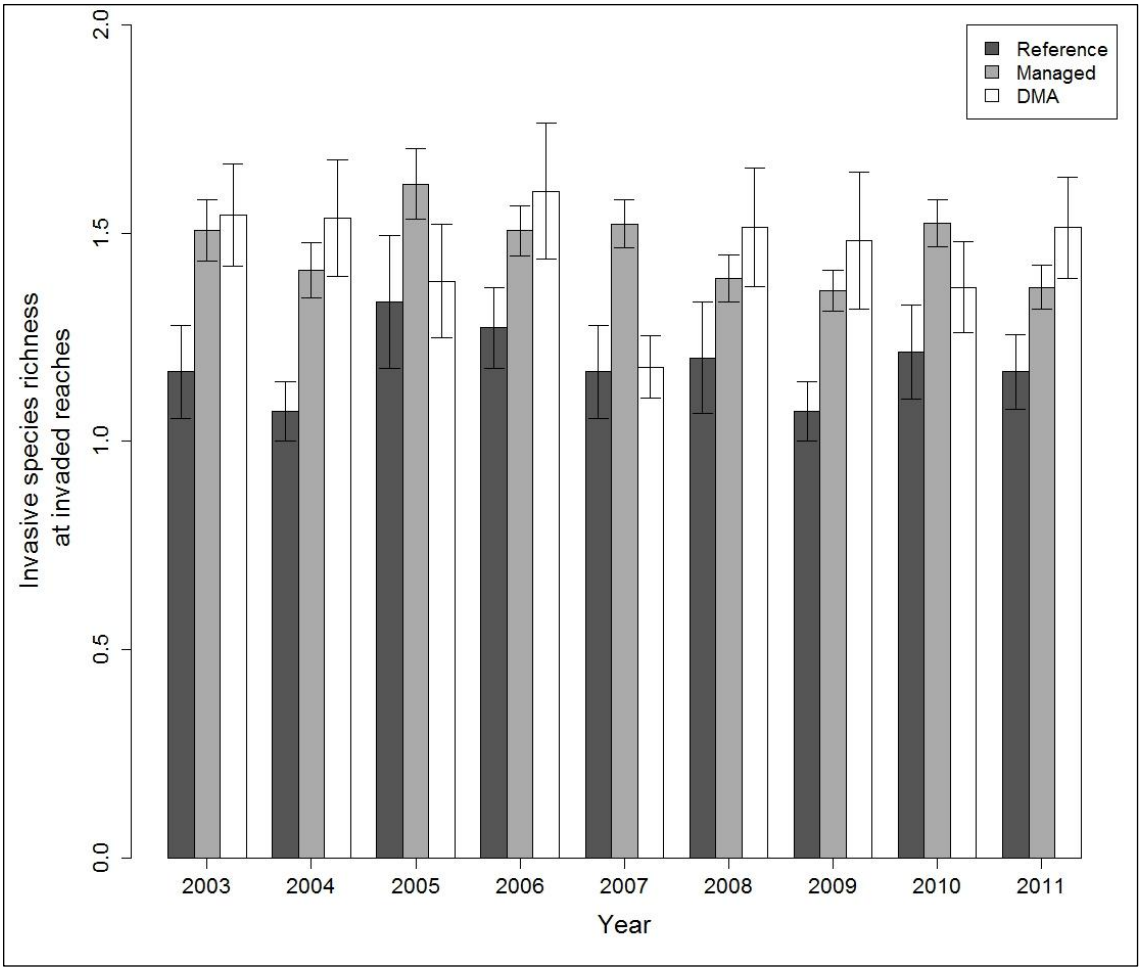

Figure 2. Average invasive species richness within the reference, managed and DMA reach classifications, graphed by year. Bars are ± standard error of the mean.

After applying the scaled severity index to all invaded reaches within each 5th-order HUC watershed, we found that 13 watersheds fell into the most extreme category for invasive species richness (Figure 4). There were also 16 watersheds that ranked as extreme and 57 watersheds that ranked as high severity. The extreme and high severity watersheds were distributed across the study area, but largely occurred in portions of Idaho and Oregon (Figure 3). More severely invaded watersheds were also more likely to occur at low elevations, on managed sites, near roads and in areas with high stream densities, observations that are supported elsewhere in the literature (Parendes and Jones 2001; Becker et al 2005; Hansen and Clevenger 2005).

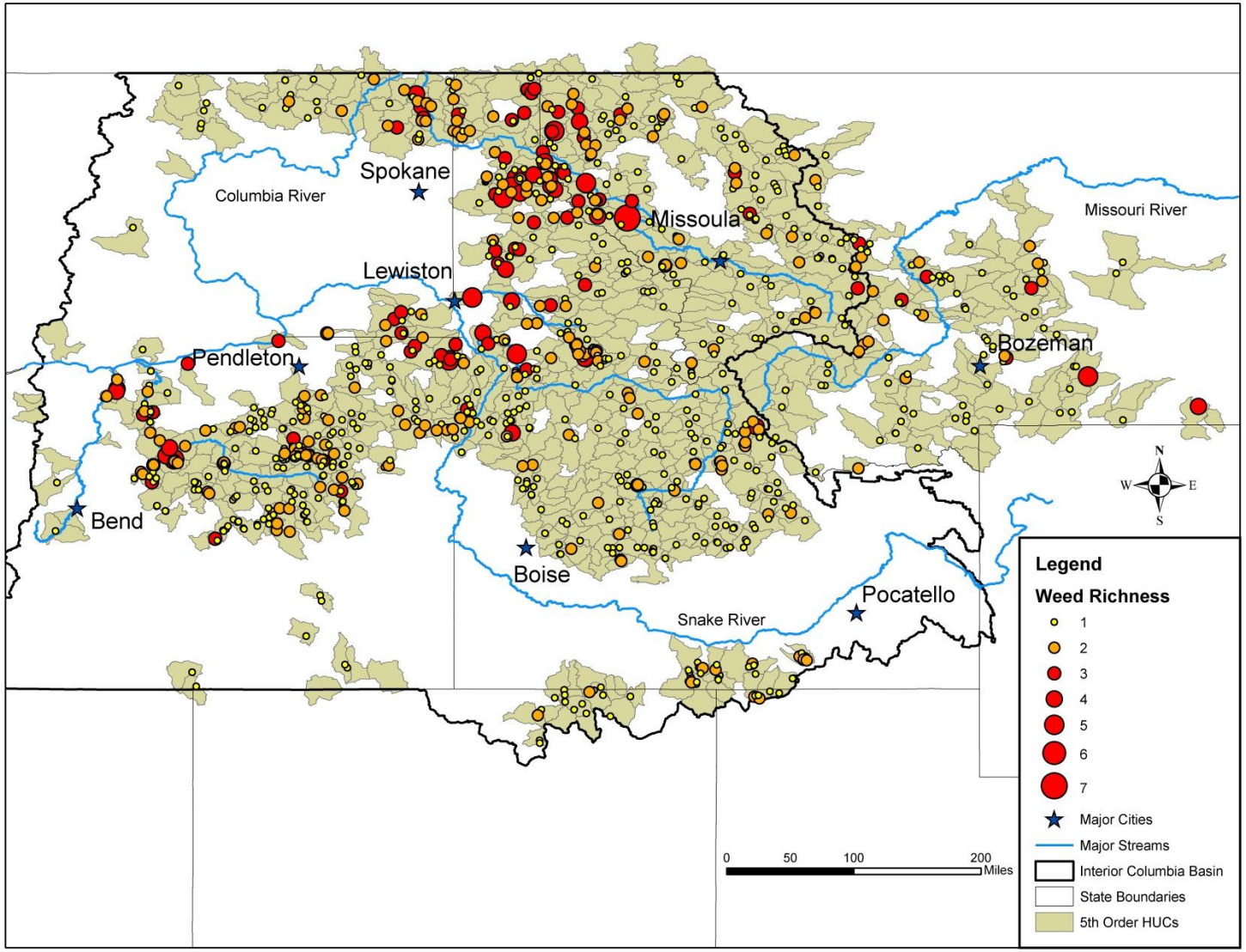

Figure 3. Invasive species richness at sampled PIBO reaches within the interior Columbia and upper Missouri River basins.

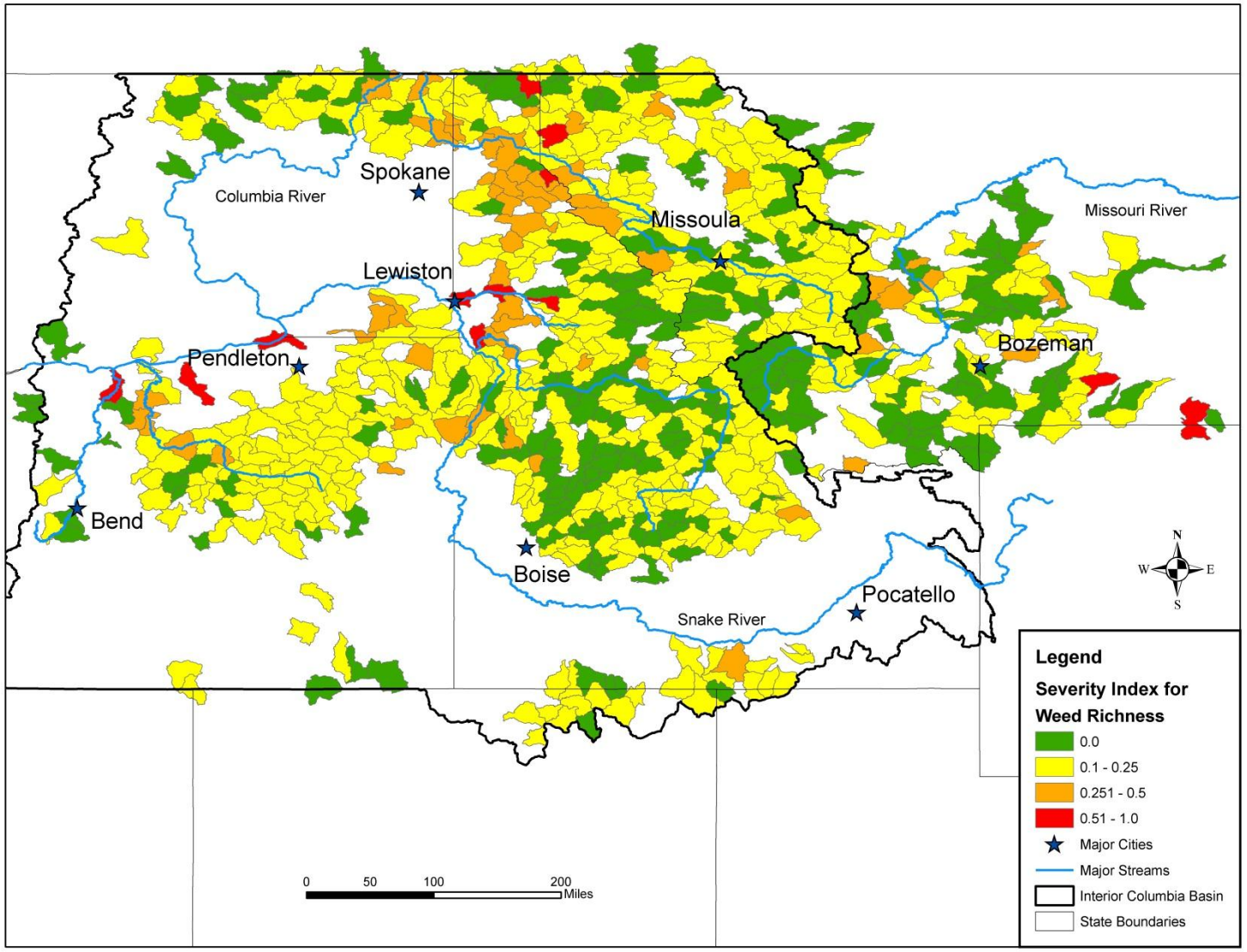

Figure 4. Scaled severity index for invasive species richness within 5th-order watersheds across the interior Columbia and upper Missouri River basins. Severity index was calculated using the formula in Equation 1.

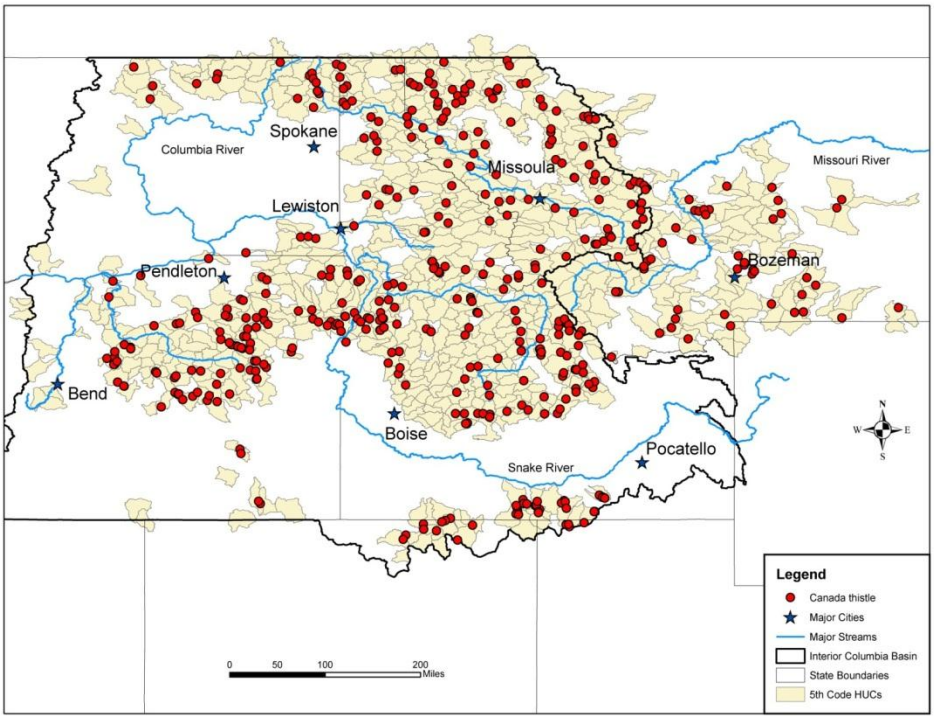

Figure 5. Canada thistle (*Cirsium arvense*) presence at sampled PIBO reaches across the interior Columbia and upper Missouri River basins. Canada thistle is the most common invasive species in the PIBO study area (637 reach visits) and is listed as invasive in WA, OR, ID and MT.

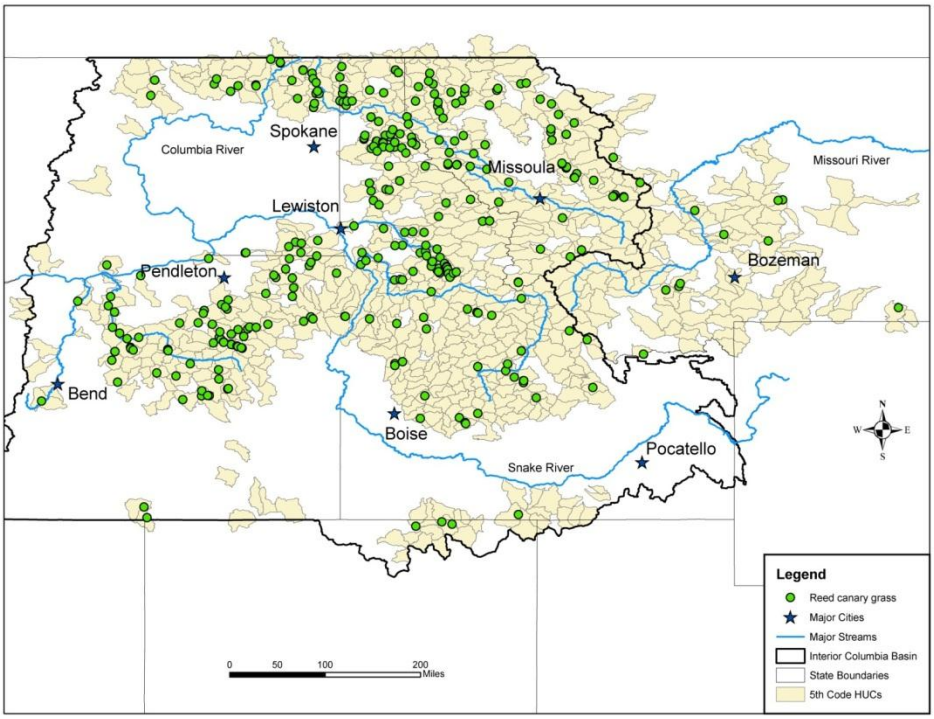

Figure 6. Reed canarygrass (*Phalaris arundinacea*) presence at sampled PIBO reaches across the interior Columbia and upper Missouri River basins. Reed canarygrass is the 2nd most common invasive species in the PIBO study area (475 reach visits) and is listed as invasive in WA.

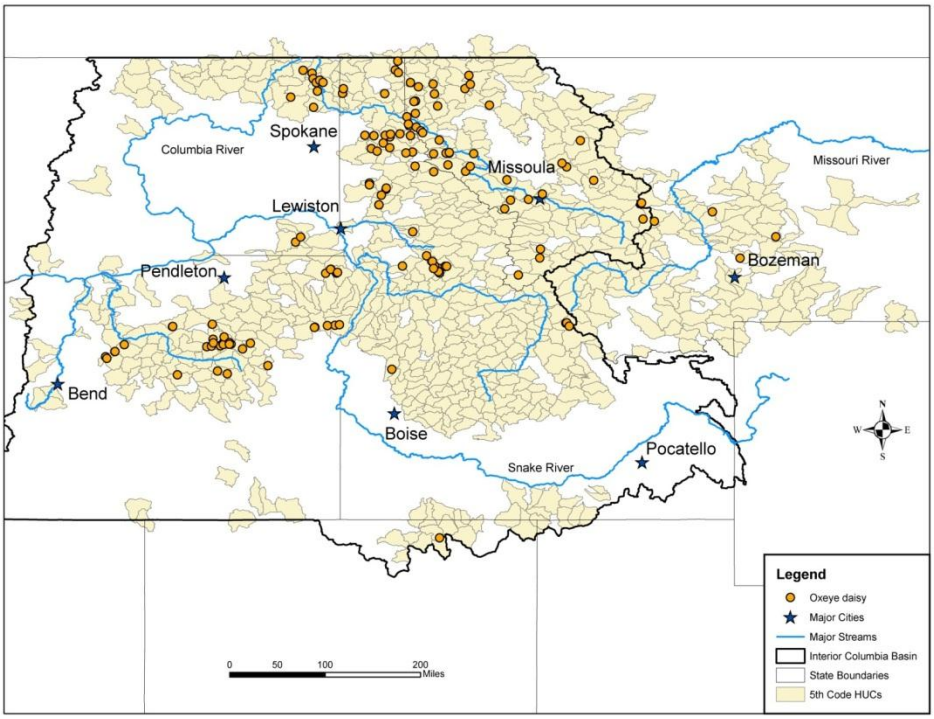

Figure 7. Oxeye daisy (*Leucanthemum vulgare*) presence at sampled PIBO reaches across the interior Columbia and upper Missouri River basins. Oxeye daisy is the 3rd most common invasive species in the PIBO study area (198 reaches) and is listed as invasive in ID and WA.

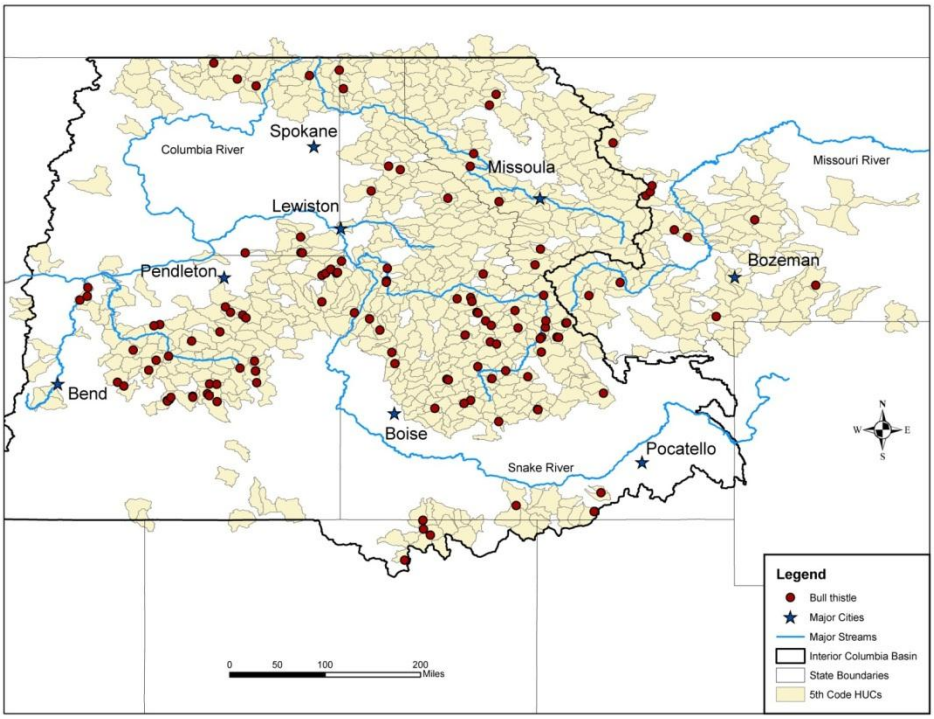

Figure 8. Bull thistle (*Cirsium vulgare*) presence at sampled PIBO reaches across the interior Columbia and upper Missouri River basins. Bull thistle is the 4th most common invasive species in the PIBO study area (135 reach visits) and is listed as invasive in WA and OR.

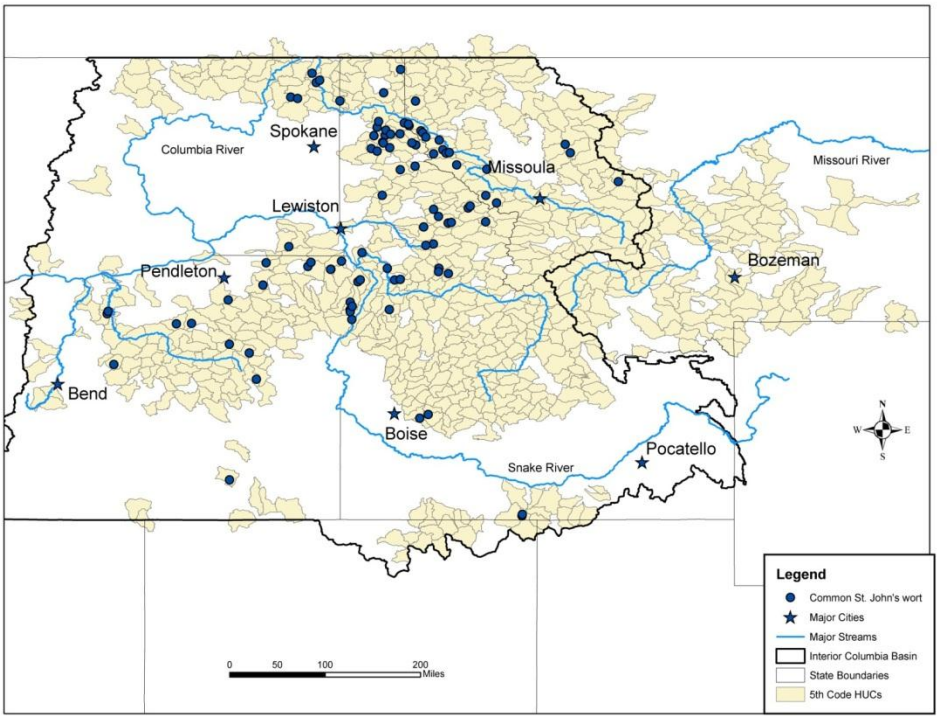

Figure 9. Common St. John's wort (*Hypericum perforatum*) presence at sampled PIBO reaches across the interior Columbia and upper Missouri River basins. St. John's wort is the 5th most common weed in the PIBO study area (120 reach visits) and is listed as invasive in WA, OR and MT.

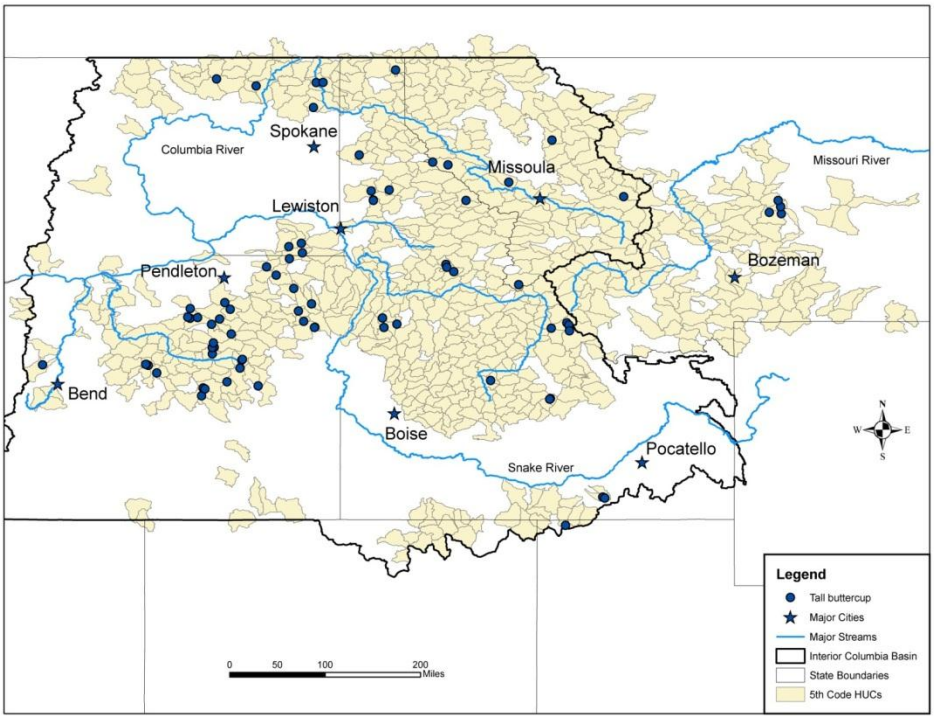

Figure 10. Tall buttercup (*Ranunculus acris*) presence at sampled PIBO reaches across the interior Columbia and upper Missouri River basins. Tall buttercup is the most common noxious weed within the PIBO study area (83 reach visits).

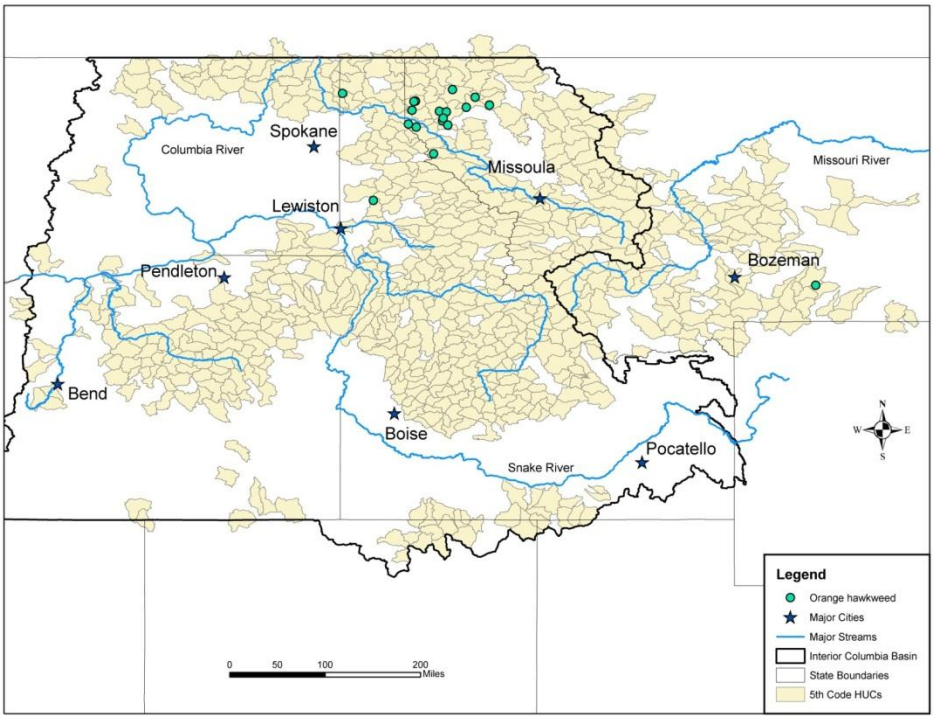

Figure 11. Orange hawkweed (*Hieracium aurantiacum*) presence at sampled PIBO reaches across the interior Columbia and upper Missouri River basins. Orange Hawkweed is the 2nd most common noxious weed within the PIBO study area (33 reach visits).

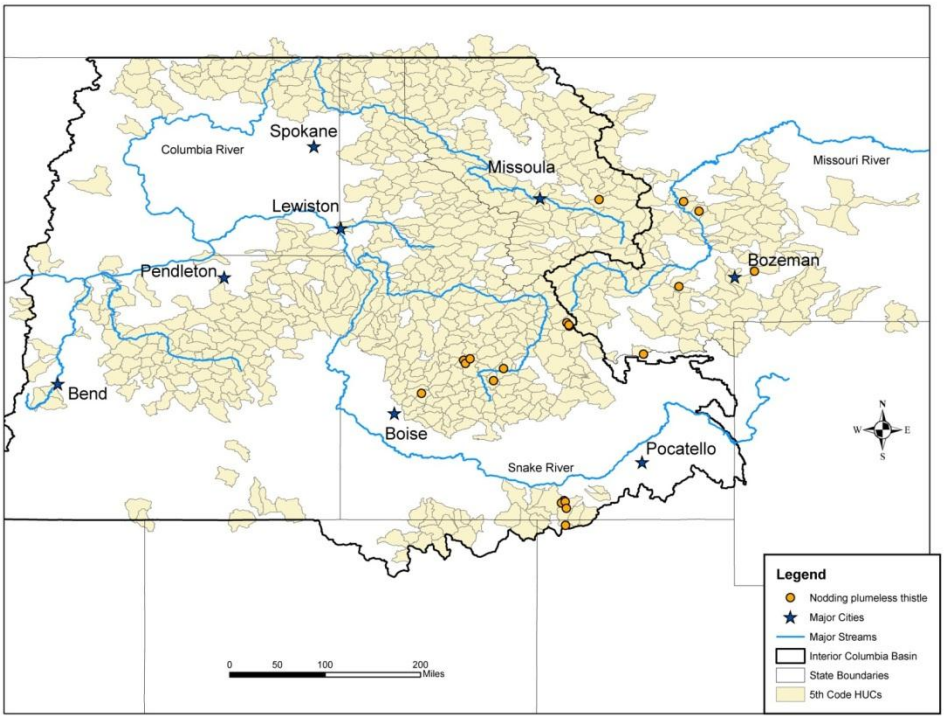

Figure 12. Nodding plumeless thistle (*Carduus nutans*) presence at sampled PIBO reaches across the interior Columbia and upper Missouri River basins. Nodding plumeless thistle is the 3rd most common noxious weed within the PIBO study area (20 reach visits).

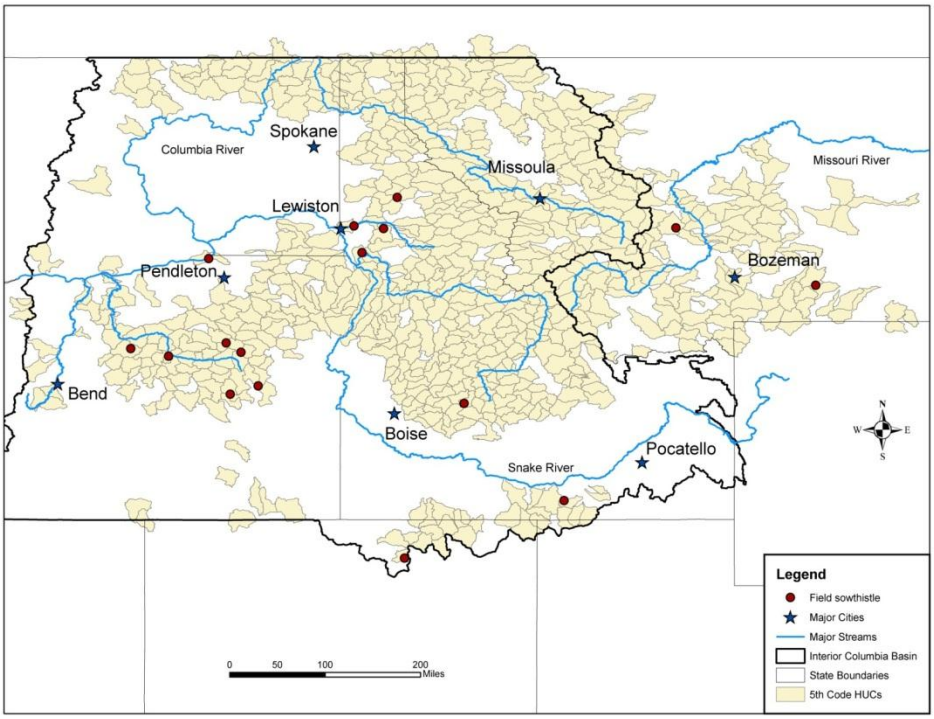

Figure 13. Field sowthistle (*Sonchus arvensis*) presence at sampled PIBO reaches across the interior Columbia and upper Missouri River basins. Field sowthistle is the 4th most common noxious within the PIBO study area (17 reach visits).

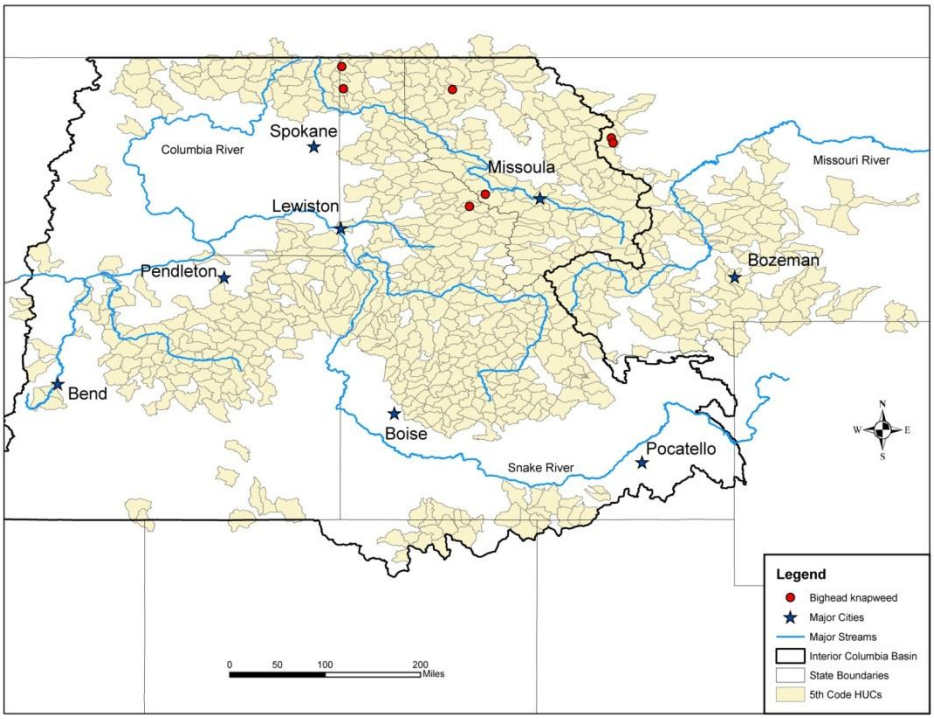

Figure 14. Bighead knapweed (*Centaurea macrocephala*) presence at sampled PIBO reaches across the interior Columbia and upper Missouri River basins. Bighead knapweed is the 5th most common noxious weed within the PIBO study area (seven reach visits).

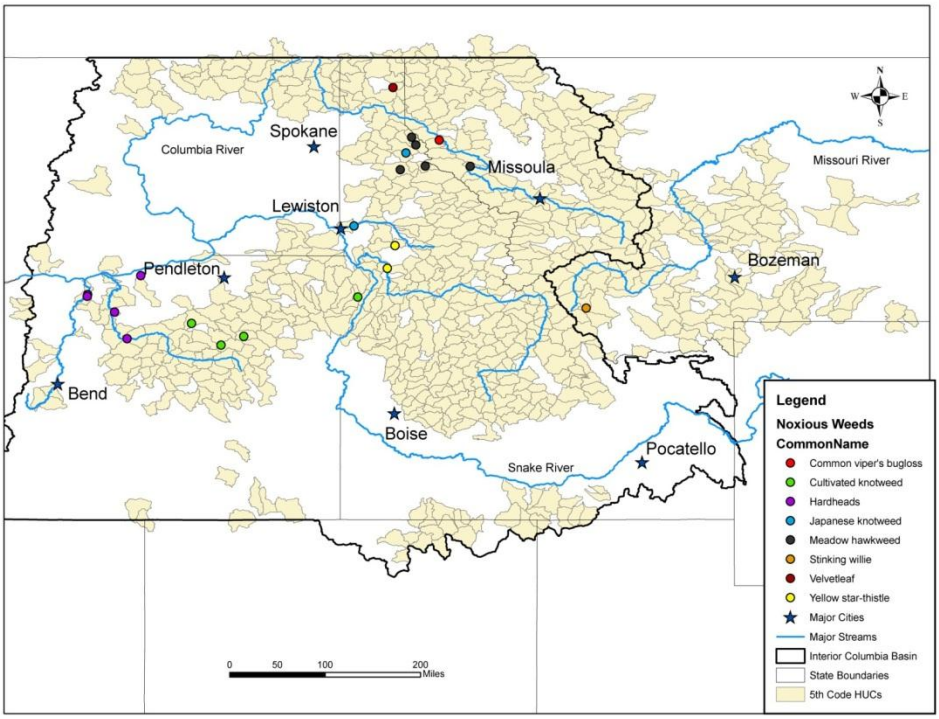

Figure 15. Presence of the eight remaining noxious weeds at sampled PIBO reaches across the interior Columbia and upper Missouri River basins.

Summary

We found that invasive plant species are common and widespread across the interior Columbia River and Missouri River basins and that biological invasion frequency is tied to land management classification types (reference, managed, DMA) within each watershed. Of those invasive species detected, most occurred at only a few sites. Even though they were uncommon these species could potentially contribute to riparian degradation by invading a greater portion of watershed in which they were found. Invasions occurred at a range of intensities across the study area but some seem to be in early stages at which control or eradication efforts may be effective. From these invasion detections, we provide a general overview of where invasions currently exist so that land management agencies can begin planning for invasion control based on their existing strategies and local requirements for handling noxious invasive species.

To meet state noxious weed guidelines, we suggest invasion control be prioritized based on state/forest program requirements (Tables 1 and 2, Appendices 1 and 2) and then on sites that are invaded by multiple species of high concern. The additive effects of several invasive species within a reach or subwatershed may prove more difficult to manage than single species invasions, as certain plant life history strategies and control methods may be incompatible. In addition, invasive plants may be of special concern in streams with ESA-listed fishes.

Those reaches that are currently invaded at low intensity (few species at low abundance) can be prioritized as an equal priority for control, because invasion control may be more successful in recently detected, small, isolated cases (Mehta et al. 2007).

While there are numerous biological and environmental drivers of invasions, some of these factors, such as temperature and elevation, are not under the control of local land managers. Therefore, invasive species management should be based not only on the seriousness of the species at hand, but also on vectors that can be directly controlled (e.g. grazing, timber harvest, road building, recreation and non-timber vegetation management) and the proximity of invasions to at-risk resources. When weed suppression is the preferred strategy, local units can take advantage of interagency partnerships to manage invasions. These partnerships involve local, county and state noxious weed agencies (Appendix 2) and can be effective in mixed-ownership watersheds with local, private and federal landowners and stakeholders.

Riparian health is heavily tied to upland and streamside vegetation processes (Naiman and Décamps 1997) and frequent or high-intensity biological invasions may have an adverse effect on riparian and in-stream resources including fish, forage, wildlife, and the quality and quantity of water available to downstream users (Hooper et al. 2005). In addition to conservation concerns, invasive species can cause economic harm to cattle and timber operations, landowners, and local communities. We hope that this report helps land management agencies identify riparian invasions and encourages control or eradication of weeds that impair riparian and aquatic health.

Acknowledgements
We thank Cynthia Tait for thorough comments on previous drafts of this report and past PIBO staff and field technicians for their collection and management of the program's vegetation data.

References

Adams, S.B., Burnett, K.M., Bisson, P., Harvey, B., Nislow, K.H., Rieman, B.E., Rinne, J. 2010. The role of the Forest Service in aquatic invasive species research. In: Dix, Mary Ellen; Britton, Kerry, editors. A dynamic invasive species research vision: Opportunities and priorities 2009-29. Gen. Tech. Rep. WO-79/83. Washington, DC: U.S. Department of Agriculture, Forest Service, Research and Development. p. 55-66.

Becker, T, H., Dietz, R. Billeter, H. Buschmann, and P.J. Edwards. 2005. Altitudinal distribution of alien plant species in the Swiss Alps. *Perspectives in Plant Ecology, Evolution and Systematics* 7: 173-183.

DeLoach, C.J. 1991. Past successes and current prospects in biological control of weeds in the United States and Canada. *Natural Areas Journal*, 11: 129-142.

DiTomaso, J.M. 2000. Invasive weeds in rangelands: species impacts and management. *Weed Science* 48: 255-265.

Executive Order No. 13112, 64 F.R. 6183. February 8, 1999. Available online at: http://www.invasivespeciesinfo.gov/laws/execorder.shtml

Hansen, M.J. and A.P. Clevenger. 2005. The influence of disturbance and habitat on the presence of non-native plant species along transport corridors. *Biological Conservation* 125: 249-259.

Harrington, T.B and S.H. Reichard. 2007. Meeting the challenge: invasive plants in Pacific Northwest ecosystems. Gen. Tech. Rep. PNW-GTR-694. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 166 p.

Hood, W.G. and R.J. Naiman. 2000. Vulnerability of riparian zones to invasion by exotic vascular plants. *Plant Ecology* 148: 105-114.

Hooper, D.U., F.S. Chapin, J.J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J.H. Lawton, D.M. Lodge, M. Loreau, S. Naeem, B. Schmid, H. Setala, A.J. Symstad, J. Vandermeer and D.A. Wardle. 2005. Effects of biodiversity on ecosystem functioning: a consensus of current knowledge. *Ecological Monographs* 75, 3-35.

Kershner, J.L., E.K. Archer, M.C. Coles-Ritchie, E.R. Cowley, R.C. Henderson, K. Kratz, C.M. Quimby, D.L. Turner, D.L. Ulmer, and M.R. Vinson. 2004. Guide to effective monitoring of aquatic and riparian resources. Gen. Tech. Rep. RMRS-GTR-121. Ft. Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 57 p.

Kershner, J.L. and B.B. Roper. 2010. An evaluation of management objectives used to assess stream habitat conditions on federal lands within the interior Columbia River Basin. *Fisheries* 35: 269-278.

Lanigan, S.H., S.N. Gordon, P. Eldred, M. Isley, S. Wilcox, C. Moyer and H. Andersen. 2012. Northwest Forest Plan – the first 15 years (1994-2008): Watershed condition status and trend. Gen. Tech. Rep. PNW-GTR-856. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 155p.

Mehta, S.V., R.G. Haight, F.R. Homans, S. Polasky and R.C. Venette. 2007. Optimal detection and control strategies for invasive species management. *Ecological Economics* 61: 237-245.

Montgomery, D.R. and L.H. MacDonald. 2002. Diagnostic approach to stream channel assessment and monitoring. *Journal of the American Water Resources Association* 38: 1-16.

Naiman, R. J. and H. Décamps. 1997. The ecology of interfaces: riparian zones. *Annual Review of Ecology and Systematics* 28: 621–658.

Parendes, L.A. and J.A. Jones. 2000. Role of light availability and dispersal in exotic plant invasion along roads and streams in the H.J. Andrews Experimental Forest, Oregon. *Conservation Biology* 14: 64-75.

Pejchar, L. and H.A. Mooney. 2009. Invasive species, ecosystem services and human well-being.

Trends in Ecology and Evolution 24: 497-504.

Pimental, D., R. Zuniga and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52: 273-288.

Richardson, D.M., P.M. Holmes, K.J. Esler, S.M. Galtowitsch, J.C. Stromberg, S.P. Kirkman, P. Pysek and R.J. Hobbs. 2007 Riparian vegetation: degradation, alien plant invasions and restoration prospects. *Diversity and Distributions* 13:126-139.

Stohlgren, T.J., D. Binkley, G.W. Chong, M.A. Kalkhan, L.D. Schell, K.A. Bull, Y. Otsuki, G. Newman, M. Bashkin and Y. Son. 1999. Exotic plant species invade hot spots of native plant diversity. *Ecological Monographs* 69: 25-46.

Tickner, D.P., P.G. Angold, A.M. Gurnell, and J.O. Mountford. 2001. Riparian plant invasions: hydrogeomorphological control and ecological impacts. *Progress in Physical Geography* 25: 22-52.

Urgenson, L.S., S.H. Reichard and C.B. Halpern. 2009. Community and ecosystem consequences of giant knotweed (*Polygonum sachalinense*) invasion into riparian forests of western Washington, USA. *Biological Conservation* 7: 1536-1541.

USDA/USDI (U.S. Department of Agriculture and U.S. Department of Interior). 1995. Decision Notice and Finding of No Significant Impact; Environmental Assessment for the interim strategies for managing anadromous fish producing waters in eastern Oregon and Washington, Idaho, and portions of California (PACFISH). Available at: www.fs.fed.us/r6/fi sh/9502-pacfi sh.pdf

USDA (U.S. Department of Agriculture). 1995. Decision Notice and Finding of No Significant Impact; Environmental Assessment for the Inland Native Fish Strategy (INFISH).

USDA, NRCS(U.S. Department of Agriculture Natural Resource Conservation Service).

2012. The PLANTS Database (http://plants.usda.gov, 10 JUNE 2012). National Plant Data Team, Greensboro, NC 27401-4901 USA.

Appendix 1: List of noxious weed classifications within the PIBO study area by individual state noxious weed agencies. The definitions to the invasive species classification nomenclature are provided directly by state noxious weed boards, etc, and are linked in Appendix II. Definitions annotated by * indicate an unofficial definition because no official state definition was provided.

State	Nomenclature	Standardized level of priority	Management Requirement	Definition from state agency
ID	Control	Very High	Eradicate upon detection	Noxious weeds that should be controlled upon discovery using mechanical, herbicide or other approved methods*.
	Contain	High	Prevent spread; contain existing invasions	Noxious weeds that should be contained to prevent their spread to new areas. These species may already be somewhat common*.
	EDRR	Extreme	Eradicate upon detection; Report to state upon finding	Early detection and rapid response species: those whose detection would merit immediate containment or control*.
MT	IA and IB	Extreme	Eradicate upon detection; Report to state upon finding	These weeds are not present or currently have a limited presence in Montana. Management criteria will require eradication or containment and education.
	IIA	Very High	Eradicate upon detection	These weeds are common in isolated areas of Montana. Management criteria will require eradication or containment where less abundant.
	IIB	High	Prevent spread; contain existing invasions	These weeds are abundant in Montana and widespread in many counties. Management criteria will require eradication or containment where less abundant.
OR	A	Very High	Eradicate upon detection; Report to state upon finding	A weed of known economic importance which occurs in the state in small enough infestations to make eradication or containment possible; or is not known to occur, but its presence in neighboring states make future occurrence in Oregon seem imminent.
	B	High	Prevent spread; contain existing invasions	A weed of economic importance which is regionally abundant, but which may have limited distribution in some counties.
	T	Extreme	Eradicate upon detection	A priority noxious weed designated by the Oregon State Weed Board as a target for which the ODA will develop and implement a statewide management plan. “T” designated noxious weeds are species selected from either the “A” or “B” list.

Appendix 1: Continued from page A1.

State	Nomenclature	Standardized level of priority	Management Requirement	Definition from state agency
WA	A	Extreme	Eradicate upon detection; Report to state upon finding	Non-native species that are limited in distribution in Washington State. State law requires that these weeds be eradicated.
	B	Very High	Prevent spread; contain existing invasions	Non-native species that are either absent from or limited in distribution in some portions of the state but very abundant in other areas. The goals are to **contain** the plants where they are already widespread and **prevent** their spread into new areas.
	C	Moderate to High	Prevent spread; contain existing invasions	Non-native plants that are already widespread in Washington State. Counties can choose to enforce control, or they can educate residents about controlling these noxious weeds.
	Quarantine	Extreme	Eradicate upon detection	The Washington State Department of Agriculture maintains a quarantine list of plants, also called the prohibited plants list, whose sale or distribution is prohibited in the state. All Class A noxious weeds are on this list. There are also plants on the list to prevent them from being imported and spread into Washington State
	Monitor	NA	Report to state upon finding	The purpose of the monitor list is to gather more information on suspect weeds, as well as monitor for occurrence or spread. Information collected may be used to justify future inclusion on the state noxious weed list. There is no legal or regulatory aspect to this list

Appendix 2: Links to state weed control programs and documentation for individual species classification series found in Appendix 1.

Idaho:s
State weed control board:
http://www.agri.idaho.gov/Categories/PlantsInsects/NoxiousWeeds/indexnoxweedmain.php
http://www.idahoweedawareness.net/

Montana:
State weed control board:
http://agr.mt.gov/agr/Producer/Weeds/index.html

Oregon:
State weed control board:
http://www.oregon.gov/ODA/PLANT/WEEDS/Pages/index.aspx
Noxious Weed Policy and Classification System 2012:
http://www.oregon.gov/ODA/PLANT/WEEDS/docs/weed_policy.pdf

Washington:
State weed control board:
http://www.nwcb.wa.gov/
State law governing weeds:
http://www.nwcb.wa.gov/ab_weedlaws.htm

All data used for this report are available at the PIBO Region 4 intranet:

http://fsweb.r4.fs.fed.us/unit/nr/pibo/index.shtml