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ALIEN TAXA IN THE NORTH AMERICAN SHRUB-STEPPE FOUR DECADES AFTER CESSATION OF LIVESTOCK GRAZING AND CULTIVATION AGRICULTURE

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Abstract

Because of its use as a nuclear materials production area, the 800-km² sagebrush steppe of the Columbia River Plain in Washington State has functioned as a quasi-natural area protected from livestock grazing and agricultural development since 1944. Alien vegetation and animals have invaded the eastern Washington region in the past century and are currently represented in the Columbia River Plain. Investigations were undertaken to evaluate the distribution of alien species, particularly vegetation, and their relationships to other flora and fauna in this region.

Recently disturbed areas were dominated by the alien annuals Russian thistle Salsola kali, *tumble mustard* Sisymbrium altissimum, *prickly lettuce* Lactuca serriola, *and bur ragweed* Ambrosia acanthicarpa. *Old-field habitats were composed almost entirely of the alien annual cheatgrass* Bromus tectorum. *Alien vegetation also comprised a portion of the flora in habitats that had not been disturbed or grazed by cattle in the past. Cheatgrass and spring whitlow-grass* Draba verna *were able to set seed in undisturbed habitats, whereas Russian thistle and tumble mustard seldom did. These two species continue as components of undisturbed habitat primarily through seed dispersal from disturbed sites.*

Old-field habitats support a depauperate fauna compared to undisturbed sagebrush steppe vegetation. Shrub-nesting birds such as the sage sparrow Amphispiza belli *were absent from old fields, and even ground-nesting species were found in abnormally low densities. Old fields supported relatively few mammal species, in part as a result of poor food supplies. Alien birds, the rock dove* Columba livia *and the European starling* Sturnus vulgaris, *visited undisturbed habitat, but did not nest there.*

No alien mammals were found in undisturbed sagebrush steppe vegetation; the only alien mammals found in the area, the house mouse Mus musculus *and Norway rat* Rattus norvegicus, *being limited to riparian areas and the vicinity of buildings.*

Alien taxa are likely to remain a component of any quasi-natural area in the sagebrush steppe ecoregion. Human disturbance need not be spatially extensive to maintain alien plants within undisturbed communities. Successional patterns after land disturbance produce conditions unfavorable for native fauna, but have not enhanced the distribution of alien fauna.

Keywords: North America, cheatgrass, biological invasion, grazing, natural areas.

INTRODUCTION

Natural vegetation in the intermountain valleys throughout the shrub-steppe ecoregion of eastern Washington has been greatly fragmented and altered by the activities of neo-European people that entered the region beginning 200 years ago. Alien plants were introduced with the advent of livestock grazing in the mid-1800s, and their spread was accelerated by cultivation agriculture and urbanization later in the century (Mack, 1981).

The Columbia River Plain, a broad, low-elevation valley located on the US Department of Energy's Hanford Site in southcentral Washington, was relieved of livestock grazing and cultivation agriculture in 1943 when the land was acquired by the federal government as a site for nuclear materials production. Since 1944, there has been no resident human population, and the idle land has functioned as a quasi-natural area (Gray & Rickard, 1989).

This paper examines the relationship between human-induced soil and plant disturbances and the occurrences of alien vascular plants, birds, and mammals on the Columbia River Plain. Particular attention is paid to alien plants, their occurrence in stands with little or no human-initiated disturbances for the past 47 years, and their effects on the abundance and distribution of native birds and mammals.

The Columbia River Plain consists of approximately 800 km² of gently undulating land located between the Rattlesnake Hills and the western shoreline of the Columbia River (Fig. 1). Elevations range from 130 m near the river to 260 m along the bases of the adjoining steep basalt ridges. The soils are derived from alluvium

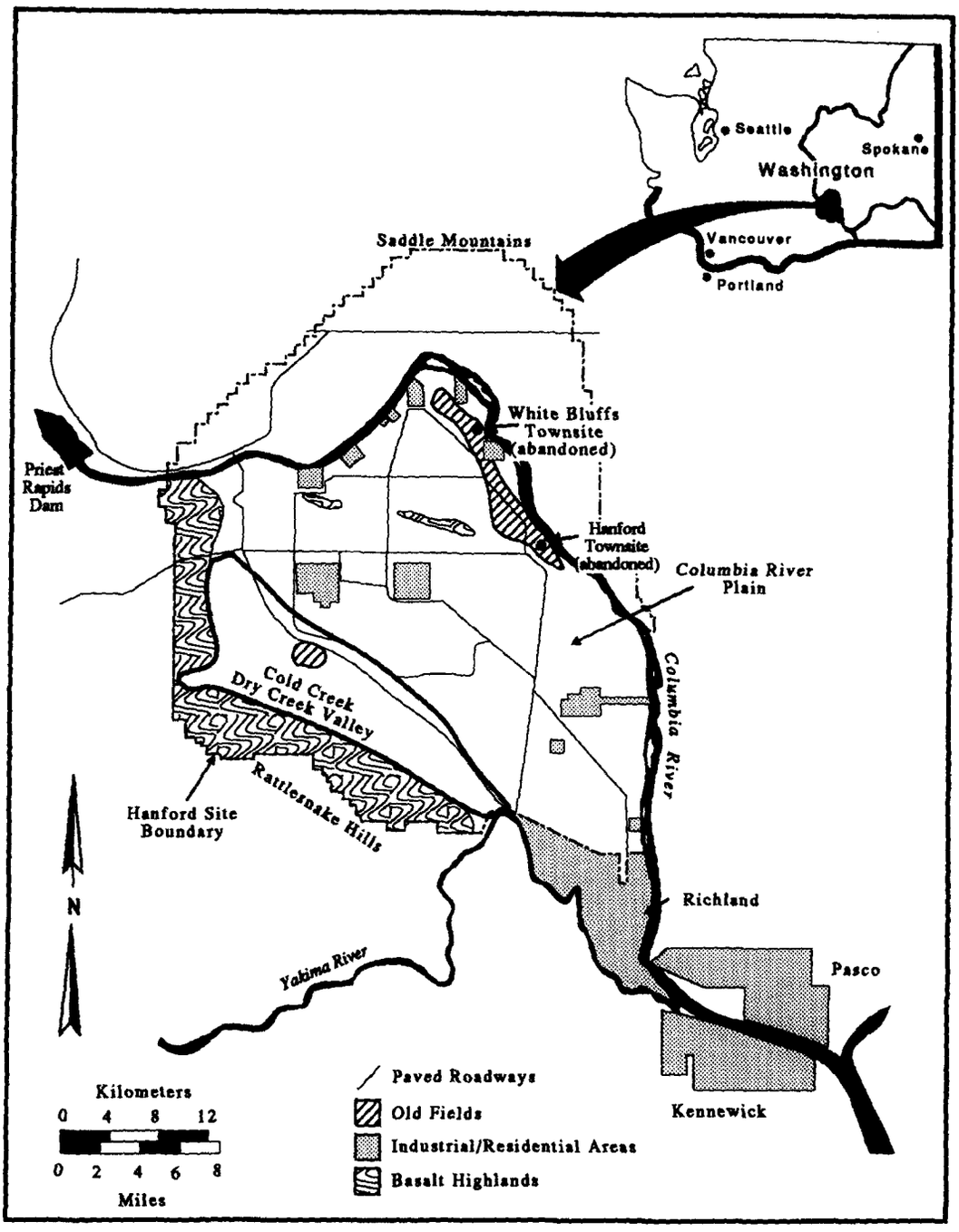

Fig. 1. Map of the US Department of Energy's Hanford Site in Southcentral Washington.

deposited by glaciofluvial floods during the Pleistocene era (Fecht *et al.*, 1987). Soils along the elevated margins of the plain are medium-textured silt-loams, while the interior is composed of coarser textured materials. A large area of active sand dunes occurs along the western shore of the Columbia River. The dunes move with the prevailing westerly winds and spill into the river.

The plain's climate is dry, with annual precipitation averaging only 16 cm (Stone *et al.*, 1983). Most of the precipitation falls in autumn and winter, while summers are characteristically hot and dry. Two small intermittent streams, Dry Creek and Cold Creek, spill onto the plain from the highlands to the west and northwest (Fig. 1).

In the early 1800s, the vegetation of the Columbia River Plain likely consisted of vast stands representative of the big sagebrush *Artemisia tridentata*/Sandberg's bluegrass *Poa sandbergii* or bitterbrush *Purshia tridentata*/needle-and-thread grass *Stipa comata* associations described by Daubenmire (1970). The former occupied the fine-textured soils at higher elevations along the edges of the plain, and the latter the low-elevation sandy soils toward the Columbia River.

Livestock grazing on the plain was well established by the 1850s (Chatters, 1989) and was more or less continuous until 1943. The impacts of grazing livestock on the vegetation were probably most intense near the Columbia River, which served as a water source in a landscape with few other sources of drinking water. Irrigation began on the Hanford Site in the early 1890s using Columbia River water. By 1940, hundreds of

acres were under cultivation, which provided the economic base for the small towns of White Bluffs and Hanford (Fig. 1).

In 1943, the entire resident human population on the Columbia River Plain was relocated, and self-revegetation of the abandoned fields has been under way since then (Rickard & Sauer, 1982). The dominant plants on these fields today are Eurasian annuals, especially cheatgrass *Bromus tectorum*, tumble mustard *Sisymbrium altissimum*, and jagged chickweed *Holosteum umbellatum*. Native taxa are slow to invade abandoned fields (Daubenmire, 1975).

Wildfires ignited by lightning and human accidents have been recurring events. In the summer of 1984, a fire burned across the entire southern half of the Columbia River Plain, resulting in the destruction of many shrubs.

Eurasian species have been a part of the plain's flora for more than a century. Most originated in the semi-arid regions of Eurasia, where they had been subjected to millennia of various intensities of anthropogenic disturbance (Mack, 1981). Consequently, the degree of success of Eurasian plants in the North American flora is generally attributed to the intensity of human-initiated disturbances (Harper, 1965). The major human-induced vegetation disturbances on the Columbia River Plain during this time have been localized mechanical disturbances and herbicide applications associated with construction sites, roadways, powerlines, buried waterlines, and hundreds of groundwater monitoring wells.

METHODS

Plant taxa were identified on 33 plots, each 10 × 10 m in size (Brandt *et al.*, 1990). The plots were located using a stratified sampling scheme based on random sampling of major vegetation types. All undisturbed plots were free from obvious mechanical disturbance (e.g. vehicle tracks). However, some locations had recently been burned. Plant taxa were also evaluated on 35 plots within areas disturbed between two and 50 years privious to the evaluation. Sampling methods were the same as for the undisturbed plots. Plots were searched early and late in the spring to locate specimens in bloom to aid in plant identification.

Avifaunal data were obtained by walking along two transects, 5.3 and 3.4 km long (Schuler *et al.*, 1988). All birds observed within 80 m on either side of the transect between stations 160 m apart were recorded. These transects sampled three bird habitats: unburned big sagebrush/cheatgrass, spiny hopsage *Atriplex spinosa*/ Sandberg's bluegrass, and burned habitats dominated by cheatgrass without shrubs. The transects were walked in the early morning twice weekly between March and June 1987.

Small mammals were trapped on grids established in six places during five consecutive trapping sessions between May and August 1987 (Marr *et al.*, 1988). Captured animals were marked and released.

RESULTS AND DISCUSSION

Plants

Fifty-five vascular plant taxa were identified to the species level on the plots, with two additional taxa identified to the genus level. Twenty-three taxa were annuals or biennials, 21 were perennial forbs, seven were perennial grasses, five were desert shrubs, and one was a cactus (Fig. 2). Six taxa, all annuals, were of Eurasian origin. Cheatgrass, an alien, was by far the most abundant and ubiquitous of the annuals; it occurred on 32 of the 33 plots. The most ubiquitous of the native annuals was tansy mustard *Descurainia pinnata*, which occurred on 19 plots. Sandberg's bluegrass was the most abundant and ubiquitous of the native perennial grasses, occurring on 26 of the plots. Bottlebrush squirreltail *Sitanion hystrix*, although nearly as widespread as Sandberg's bluegrass, was much less abundant. Big sagebrush was, by far, the most abundant and ubiquitous shrub, occurring on 26 of the plots. Perennial forbs were neither abundant nor ubiquitous.

Associations of alien and native taxa were examined by tabulating taxon co-occurrences of those taxa that occurred in more than 10% of the plots. Observed co-occurrences were compared to expected values using χ^2 tests with α-levels set at 0.01 for the overall test for each species, and 0.005 for the individual taxa-by-taxa comparisons. Several alien taxa did not occur at random with respect to native taxa. The occurrence of cheatgrass was independent of other taxa, as was that of yellow salsify *Tragopogon dubius* and Russian thistle *Salsola kali* (Table 1). However, spring whitlow-grass *Draba verna* occurred more often than expected in association with big sagebrush and Sandberg's bluegrass, and significantly less often than expected with pink microsteris *Microsteris gracilis*. Jagged chickweed occurred more often than expected with long-leafed phlox *Phlox longifolia* and white plectritis *Plectritis macrocera*, species more common in rocky substrates. Although tumble mustard was not distributed at random with respect to the other common taxa, no specific associations were significant at the protected α-level of 0.005.

Surveys of places where the soil surface had been mechanically disturbed within the recent past (five years) generally identified plant communities comprising mainly alien annuals (Table 2). These early succession communities are dominated by the alien annuals Russian thistle, tumble mustard, prickly lettuce, and bur ragweed, with lesser amounts of cheatgrass. Plant communities along gravelled roadsides continue to retain extensive stands of pale evening-primrose *Oenothera pallida*, jagged chickweed, and spring whitlow-grass. Late-succession (47 year) communities in old-field soils are dominated by two alien annuals: cheatgrass and tumble mustard (Table 3).

Of the nine alien species common to recently disturbed portions of the Columbia River Plain, six remain as persistent elements of native plant communities

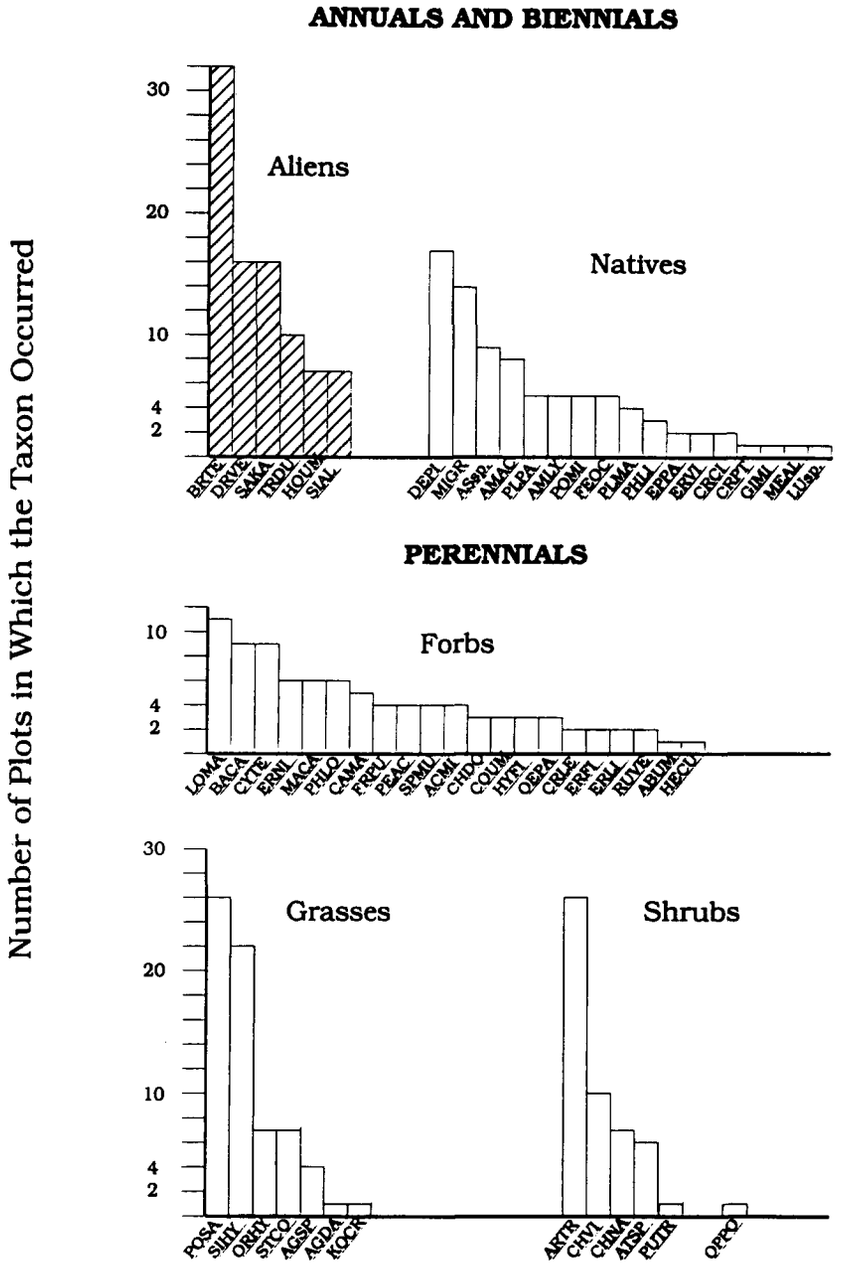

Fig. 2. Occurrences of vascular plants on 33 undisturbed study plots on the Columbia River Plain, Washington. Key: ABUM=*Abronia umbellata*, ACMI=*Achillea millefolium*, AGSP=*Agropyron spicatum*, AGDA=*Agropyron dasystachyum*, AMAC=*Ambrosia acanthicarpa*, AMLY=*Amsinckia lycopsoides*, ARTR=*Artemisia tridentata*, ASsp= *Astragalus* spp., ATSP=*Atriplex spinosa*, BACA=*Balsamorhiza caryana*, BRTE=*Bromus tectorum*, CAMA=*Calochortus macrocarpus*, CHDO=*Cheanactis douglasii*, CHNA=*Chrysothamnus nauseosus*, CHVI=*Chrysothamnus viscidiflorus*, COUM=*Commandra umbellata*, CRCI=*Cryptantha circumscissa*, CRPT=*Cryptantha pterocarya*, CRLE=*Cryptantha leucophaea*, CYTE=*Cymopterus terebinthinus*, DEPI=*Descurainia pinnata*, DRVE=*Draba verna*, EPPA=*Epilobium paniculatum*, ERFI=*Erigeron filifolius*, ERLI=*Erigeron linearis*, ERNI=*Eriogonum niveum*, ERVI=*Eriogonum vimineum*, FEOC=*Festuca octoflora*, FRPU=*Fritillaria pudica*, GIMI=*Gilia minutiflora*, HECU=*Helianthus cusickii*, HOUM=*Holosteum umbellatum*, HYFI=*Hymenopappus filifolius*, KOCR=*Koelaria cristata*, LOMA=*Lomatium macrocarpum*, LUsp=*Lupinus* spp., MACA=*Machaeranthera canescens*, MEAL=*Mentzelia albicaulis*, MIGR=*Microsteris gracilis*, OEPA=*Oenothera pallida*, OPPO=*Opuntia polyacantha*, ORHY= *Oryzopsis hymenoides*, PEAC=*Penstemon acuminatus*, PHLI=*Phacelia linearis*, PHLO=*Phlox longifolia*, PLPA=*Plantago patagonica*, PLMA=*Plectritis macrocera*, POMI=*Polemonium micranthum*, POSA=*Poa sandbergii*, PUTR=*Purshia tridentata*, RUVE=*Rumex venosus*, SAKA=*Salsola kali*, SIAL=*Sisymbrium altissimum*, SIHY=*Sitanion hystrix*, SPMU=*Sphaeralcea munroana*, STCO=*Stipa comata*, TRDU=*Tragopogon dubius*.

even after nearly 50 years without direct human disturbance. Clearly, disturbance need not be spatially extensive or temporally continuous to maintain the presence of alien plant taxa in the shrub-steppe region. Although much of the present human disturbance on the Hanford Site is limited to a few industrial areas, a network of small-scale disturbances extends over the Site associated with rights-of-way for roads, railways, powerlines, and waterlines.

The dominant alien plant species in the undisturbed habitat were cheatgrass, Russian thistle, and spring whitlow-grass. Cheatgrass was by far the most widespread species in all habitats. The demographic and phenologic characteristics allowing this dominance

Table 1. Co-occurrence frequencies of alien species with species commonly found (>10%) in undisturbed plots on the Hanford Site[a]

	ACMI	AGSP	AMAC	AMLY	ARTR	ASsp	ATSP	BACA	BRTE	CAMA	CHNA	CHVI	CYTE	DEPI	DRVE	ERNI	ERVI	FEOC	FRPU
Observed occurrence																			
BRTE	4	4	8	5	26	9	6	9	32	4	7	9	9	16	16	8	4	4	4
DRVE	2	4	1	2	16	2	3	6	16	3	1	3	1	8	16	6	4	0	2
HOUM	2	1	0	2	5	1	1	3	7	0	1	0	0	4	5	2	2	0	0
SAKA	2	2	8	2	9	6	2	4	14	2	3	5	5	9	6	3	1	2	2
SIAL	2	2	2	2	7	3	3	3	6	3	0	1	1	4	5	2	3	0	1
TRDU	1	2	3	2	7	1	1	1	10	1	2	2	2	3	6	3	2	0	1
Expected occurrence																			
BRTE	3·9	3·9	7·8	4·8	25·2	8·7	5·8	8·7		4·8	6·8	9·7	8·7	16·5	15·5	7·8	3·9	3·9	3·9
DRVE	1·9	1·9	3·9	2·4	12·6	4·4	2·9	4·4	15·5	2·4	3·4	4·8	4·4	8·2		3·9	1·9	1·9	1·9
HOUM	0·8	0·8	1·7	1·1	5·5	1·9	1·3	1·9	6·8	1·1	1·5	2·1	1·9	3·6	3·4	1·7	0·8	0·8	0·8
SAKA	1·9	1·9	3·9	2·4	12·6	4·4	2·9	4·4	15·5	2·4	3·4	4·8	4·4	8·2	7·8	3·9	1·9	1·9	1·9
SIAL	0·8	0·8	1·7	1·1	5·5	1·9	1·3	1·9	6·8	1·1	1·5	2·1	1·9	3·6	3·4	1·7	0·8	0·8	0·8
TRDU	1·2	1·2	2·4	1·5	7·9	2·7	1·8	2·7	9·7	1·5	2·1	3·0	2·7	5·2	4·8	2·4	1·2	1·2	1·2
Chisquare																			
BRTE	0·142	0·142	0·330	0·184	3·380	0·387	0·229	0·387		5·775	0·278	2·372	0·387	0·971	0·971	0·330	0·142	0·142	0·142
DRVE	0·004	4·836	5·475	0·170	8·362	3·417	0·007	1·638	0·971	0·313	4·160	1·963	6·920	0·029		2·972	4·836	4·284	0·004
HOUM	2·257	0·039	2·843	1·245	0·288	0·755	0·091	1·088	0·278	1·587	0·255	3·383	3·332	0·113	1·873	0·091	2·257	1·225	1·225
SAKA	0·004	0·004	11·220†	0·170	9·440†	1·638	0·674	0·081	9·478†	0·170	0·113	0·013	0·248	0·279	1·500	0·510	1·005	0·004	0·004
SIAL	2·257	2·257	0·091	1·245	2·392	1·088	3·636	1·088	3·830	5·305	2·392	1·079	0·755	0·113	1·873	0·091	7·880	1·225	0·039
TRDU	0·061	0·836	0·259	0·262	0·663	2·158	0·646	2·158	0·448	0·296	0·013	0·721	0·383	2·659	0·762	0·259	0·836	1·979	0·061

	HOUM	LOMA	MACA	MIGR	ORHY	PEAC	PHLO	PLMA	PLPA	POMI	POSA	SAKA	SIAL	SIHY	SPMU	STCO	TRDU	Chi^2
Observed occurrence																		
BRTE	7	11	6	14	7	4	6	4	5	5	26	14	6	21	4	7	10	
DRVE	5	9	1	11	1	0	6	4	5	4	16	6	5	12	0	3	6	
HOUM	7	2	1	6	0	0	4	3	3	3	7	4	3	4	1	1	5	
SAKA	4	4	3	7	5	4	3	1	1	2	13	16	3	10	3	4	6	
SIAL	3	5	0	4	1	0	3	2	3	1	7	3	7	7	1	1	3	
TRDU	5	4	2	6	1	0	2	2	3	2	9	6	3	8	2	1	10	
Expected occurrence																		
BRTE	6·8	10·7	5·8	13·6	6·8	3·9	5·8	3·9	4·8	4·8	25·2	15·5	6·8	21·3	3·9	6·8	9·7	
DRVE	3·4	5·3	2·9	6·8	3·4	1·9	2·9	1·9	2·4	2·4	12·6	7·8	3·4	10·7	1·9	3·4	4·8	
HOUM		2·3	1·3	3·0	1·5	0·8	1·3	0·8	1·1	1·1	5·5	3·4	1·5	4·7	0·8	1·5	2·1	
SAKA	3·3	5·3	2·9	6·8	3·4	1·9	2·9	1·9	2·4	2·4	12·6		3·4	10·7	1·9	3·4	4·8	
SIAL	1·5	2·3	1·3	3·0	1·5	0·8	1·3	0·8	1·1	1·1	5·5	3·4		4·7	0·8	1·5	2·1	
TRDU	2·1	3·3	1·8	4·2	2·1	1·2	1·8	1·2	1·5	1·5	7·9	4·8	2·1	6·7	1·2	2·1		
Chi square																		
BRTE	0·278	0·516	0·229	0·760	0·278	0·142	0·229	0·142	0·184	0·184	3·830	9·478†	3·830	0·516	0·142	0·278	0·448	38·606
DRVE	1·873	7·340	2·972	8·812†	4·160	4·284	7·792	4·836	6·261	2·343	8·362†	1·500	1·873	0·971	4·284	0·113	0·762	118·899*
HOUM		0·091	0·091	6·816	2·392	1·225	9·066†	7·880†	5·305	5·305	2·392	0·267	2·491	0·363	0·039	0·255	7·115	75·795*
SAKA	0·267	0·971	0·007	0·022	1·873	4·836	0·007	1·005	1·914	0·170	0·113		0·113	0·243	1·281	0·267	0·762	50·404
SIAL	2·491	5·802	1·974	0·788	0·255	1·225	3·636	2·257	5·305	0·005	2·392	0·113		4·442	0·039	0·255	0·663	70·279*
TRDU	7·115	0·287	0·032	1·815	1·079	1·979	0·032	0·836	2·461	0·262	1·079	0·762	0·663	1·148	0·836	1·079		36·924

[a] See Fig. 2 for four-letter code key. * $P < 0·01$. † $P < 0·005$.

Table 2. Plants occurring on recently disturbed areas of non-riparian flatlands of the Columbia River Plain

Species	Common name
Alien annual herbs	
Bromus tectorum	Cheatgrass
Chorispora tenella	Blue mustard
Draba verna	Spring whitlow-grass
Erodium cicutarum	Filaree
Holosteum umbellatum	Jagged chickweed
Lactuca serriola	Prickly lettuce
Salsola kali	Russian thistle
Sisymbrium altissimum	Tumble mustard
Tragopogon dubius	Yellow salsify
Native annual herbs	
Ambrosia acanthiaarpa	Bur ragweed
Amsinckia lycopsoides	Tarweed fiddleneck
Conyza canadensis	Horseweed
Descurainia pinnata	Tansy mustard
Microsteris gracilis	Pink microsteris
Polemonium micranthum	Littlebells polemonium
Native perennial herbs	
Machaeranthera canescens	Hoary aster
Oenothera pallida	Pale evening-primrose

have been extensively described (Young & Evans, 1985). Cheatgrass germination is enhanced by litter cover (Evans & Young, 1970), which is relatively high in undisturbed communities, and a broken soil surface (Evans & Young, 1972), a common feature of anthropogenically disturbed sites. Cheatgrass is a formidable competitor and nearly always sets viable seed in all habitats. The combination of medium seed dispersal and very strong competitive capabilities results in a species whose continued success on the Hanford Site is apparently independent of the presence of disturbed sites.

Although relatively widespread, occurring in just over half the undisturbed plots, Russian thistle seldom reaches maturity in undisturbed habitats. It is usually the first plant to appear on newly disturbed ground, but is soon displaced as the dominant by cheatgrass. Because seeds germinate in the spring, sometimes as late as four months after germination of cheatgrass and Sandberg's bluegrass (Young & Evans, 1978), the seedlings of Russian thistle are at a considerable competitive disadvantage for scarce soil moisture. The occurrence of Russian thistle in undisturbed habitat is likely a result of its exceptional seed-dispersal capability from seed sources on the network of disturbed habitats throughout the Hanford Site. Thus, even though the total amount of newly disturbed areas on the Columbia River Plain is small, its distribution among undisturbed sites has a significant influence on the species composition in those areas.

Table 3. Percentage cover of plants occurring on old fields abandoned in 1944 on the Hanford Site (modified from Rickard & Sauer 1982)

Species	Common name	Percent cover
Alien annual herbs		
Bromus tectorum	Cheatgrass	84·2
Holosteum umbellatum	Jagged chickweed	0·5
Sisymbrium altissimum	Tumble mustard	5·0
Tragopogon dubius	Yellow salsify	1·7
Native annual herbs		
Amsinckia lycopsoides	Tarweed fiddleneck	0·1
Descurainia pinnata	Tansy mustard	0·4
Native perennial herbs		
Poa sandbergii	Sandberg's bluegrass	0·9
Lupinus sp.	Lupine	0·6
Microseris lanciniata	Cut-leaved microseris	2·4

Spring whitlow-grass is as widespread as Russian thistle, yet this small-statured species has an extremely limited seed-dispersal mechanism. It is, however, able to set seed in nearly all habitats. Spring whitlow-grass flowers in March and sets seed by April; consequently, it benefits from ameliorated temperature and moisture at the soil surface during this time. It is generally displaced by cheatgrass on disturbed sites, but continues as an ephemeral species in early secondary succession and as a persistent component of undisturbed communities, as demonstrated by its significant association with big sagebrush and Sandberg's bluegrass. Clearly, the persistence of spring whitlow-grass on the Columbia River Plain is independent of recurring anthropogenic disturbances.

The alien herbs yellow salsify, jagged chickweed, and tumble mustard occurred in 20–30% of the undisturbed plots. Yellow salsify was a statistically random component of the plant community. Its seeds are wind-borne with a good dispersal capability. Jagged chickweed has poor seed-dispersal capability and is often associated with cheatgrass on 40-year-old abandoned cultivated fields. Tumble mustard, like Russian thistle, has very strong seed-dispersal capabilities, although fewer plants are established than for Russian thistle. Yellow salsify, jagged chickweed, and tumble mustard occasionally set seed in undisturbed habitats, and all remain as components of disturbed ground for many years. Whether or not these species can persist in the undisturbed portions of the Columbia River Plain without continued seed inputs from newly disturbed ground is equivocal.

Of the remaining alien herbs found in disturbed sites, prickly lettuce was not found in the undisturbed plots or the plots burned as recently as 1984. Although this plant has an effective seed-dispersal capability (seeds are wind-carried), it is apparently not effective at germinating in the undisturbed community. Blue mustard *Chorispora tenella* and filaree *Erodium cicutarium* have relatively weak seed-dispersal mechanisms and consequently are rarely found far from severely disturbed habitats on the Hanford Site. All species are replaced by cheatgrass during old-field succession.

Birds

Eighteen species of birds nested within 1 km of the two transect lines (Table 4). Only two, the rock dove and the European starling, were aliens. Both nested on a nearby inactive well-drilling rig and were seen along the transect while foraging in the surrounding shrub-steppe

Table 4. Frequency of occurrence (%F) of nesting birds along transect lines on the Columbia River Plain, characteristic nest placement, and residency period

Species	%F	Nest placement	Residency period
Passerines			
Western meadowlark *Sturnella neglecta*	100	Ground	Year-round
Sage sparrow *Amphispiza belli*	100	Desert shrub	Summer
European starling *Sturnus vulgaris*[a]	93	Artificial structure	Round
Horned lark *Eremophila alpestris*	64	Ground	Year-round
Common raven *Corvus corax*	50	Artificial structure	Year-round
Loggerhead shrike *Lanius ludovicianus*	21	Desert shrub	Summer
Black-billed magpie *Pica pica*	18	Deciduous tree	Year-round
Lark sparrow *Chondestes grammacus*	14	Ground	Summer
Brown-headed cowbird *Molothrus ater*	14	Parasitic	Summer
Western kingbird *Tyrannus verticalis*	7	Deciduous tree	Summer
Sage thrasher *Oreoscoptes montanus*	7	Desert shrub	Summer
Northern oriole *Icterus galbula*	4	Deciduous tree	Summer
Others			
Burrowing owl *Athene cunicularia*	68	Ground	Summer
Long-billed curlew *Numenius americanus*	57	Ground	Summer
Mourning dove *Zenaida macroura*	32	Ground	Summer
Rock dove *Columba livia*[a]	32	Artificial structure	Year-round
Common nighthawk *Chordeiles minor*	11	Ground	Summer
Swainson's hawk *Buteo swainsoni*	4	Deciduous tree	Summer

[a] Eurasian introduction.

vegetation (Schuler *et al.*, 1988). In the absence of artificial structures, these birds would not be nesting along the transects. However, rock doves do nest on natural cliffs along the edge of plains, and so can be considered established residents of the Columbia River Plain.

Human disturbance of the native vegetation has had some beneficial effects on the native bird fauna in that some native birds would not be nesting on the plain except for the presence of a few, small, isolated groves of planted exotic trees, mostly black locust *Robinia pseudoacacia* and Siberian elm *Ulmus pumila*. The few black-billed magpies, western kingbirds, northern orioles, and Swainson's hawks that were observed on the transects (Table 4) nested in trees that had been planted nearby. These same birds also nest in native trees scattered along the shoreline of the Columbia River and along the spring streams in the Rattlesnake Hills.

The native shrub-steppe vegetation is utilized as nesting habitat only by native birds. The sage sparrow, sage thrasher, and loggerhead shrike characteristically place their nests in the branches of sagebrush shrubs (Reynolds, 1981). The burrowing owl, horned lark, western meadowlark, common nighthawk, lark sparrow, long-billed curlew, and mourning dove place their nests on the ground. In this way, the ground-nesting species are not so easily displaced by burns that kill the shrubs.

Alien plants, especially cheatgrass, may have detrimental effects on those native birds that nest in shrubs in that cheatgrass may exclude shrubs from disturbed sites or areas where burns frequently occur. Bird species abundance was higher in habitats with a shrub component than in areas supporting mainly cheatgrass (Fig. 3). Horned larks were much more common in spiny hopsage/Sandberg's bluegrass habitat than elsewhere, while sage sparrows were most common in areas with big sagebrush and least common in burned habitats. No species was more common in cheatgrass than in shrub-grass habitats. Plant succession on old fields or other disturbed sites consequently produces conditions less favorable to birds than the structurally more diverse communities of native plants.

Although abandoned cultivated fields occur extensively on the Columbia River Plain in the vicinity of the abandoned townsites of Hanford and White Bluffs, their importance as habitat for nesting birds or small mammals has not been systematically studied. It seems reasonable to expect that ground-nesting birds, like the western meadowlark and horned lark, would nest in old fields or disturbed areas dominated by cheatgrass, but this has not been quantified. Horned larks show a preference for nesting in grasslands (Wiens *et al.*, 1987), but on the Columbia River Plain they were not abundant in recent fire scars dominated by cheatgrass (Fig. 3).

Horned larks were especially abundant on the lower slopes of the Rattlesnake Hills in fire scars dominated by native perennial grasses. Only horned larks, meadowlarks, and savannah sparrows *Passerculus sandwichensis* nested in old-field cheatgrass stands in the Rattlesnake Hills (Rogers *et al.*, 1988). Allen (1980) noted that long-billed curlews nested in abandoned cultivated fields on the Columbia River Plain, especially those with relatively sparse stands of grass.

Mammals

No alien mammals were trapped on the Columbia River Plain during our study. The most numerous small mammal was the Great Basin pocket mouse *Perognathus parvus*, followed in abundance by the deer mouse *Peromyscus maniculatus*. Both species reached

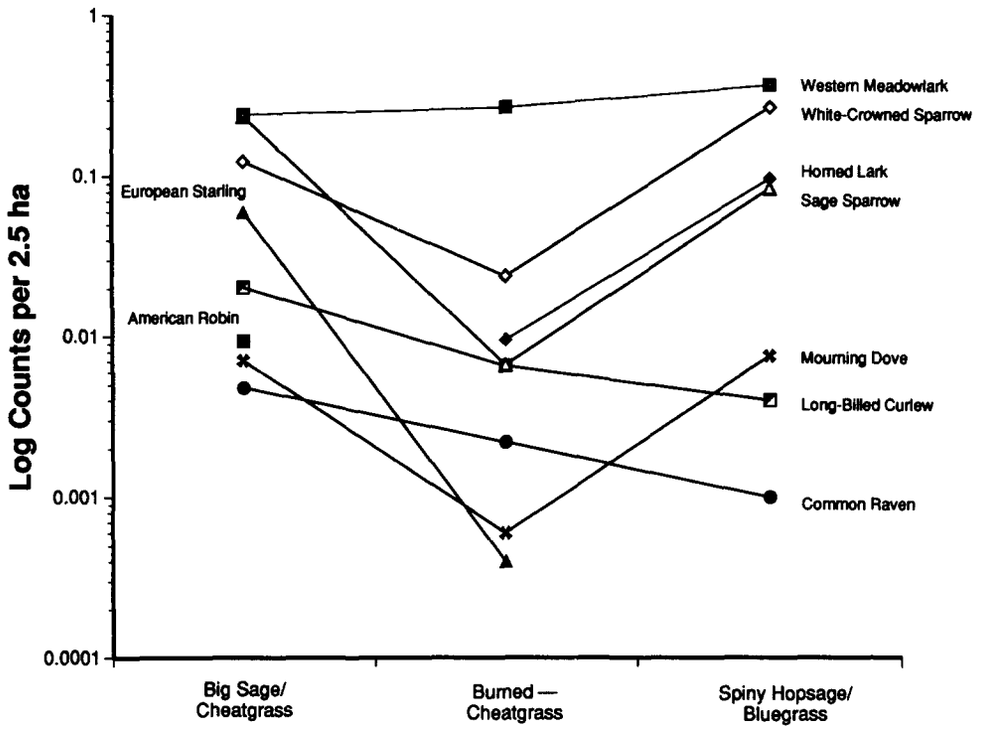

Fig. 3. Average counts of birds along transects in three plant communities on the Columbia River Plain.

their highest densities in the bitterbrush-Indian ricegrass *Oryzopsis hymenoides* habitat (Fig. 4). Relative densities of both species were higher in shrub-grass habitats where native grasses were more prevalent than cheatgrass. Both mammals have higher survival rates in shrub stands than they do in cheatgrass stands (Gano & Rickard, 1982).

The western harvest mouse *Reithrodontomys megalotis* was the third most abundant small mammal caught on the trapping grids. O'Farrell *et al.* (1975) thought harvest mice typical only of riparian vegetation, though later studies found them to be the second most abundant small mammal in cheatgrass-dominated old fields (Gano *et al.*, 1983). Consistent with the latter finding, the present study found harvest mice only in burned (cheatgrass) habitats and in spiny hopsage-Sandberg's bluegrass habitats (see Fig. 4). Other species that occurred on the plots, but in small numbers, were the montane vole *Microtus montanus*, northern grasshopper mouse *Onychomys leucogaster*, and the northern pocket gopher *Thomomys talpoides*.

Other small mammals inhabiting the Columbia River

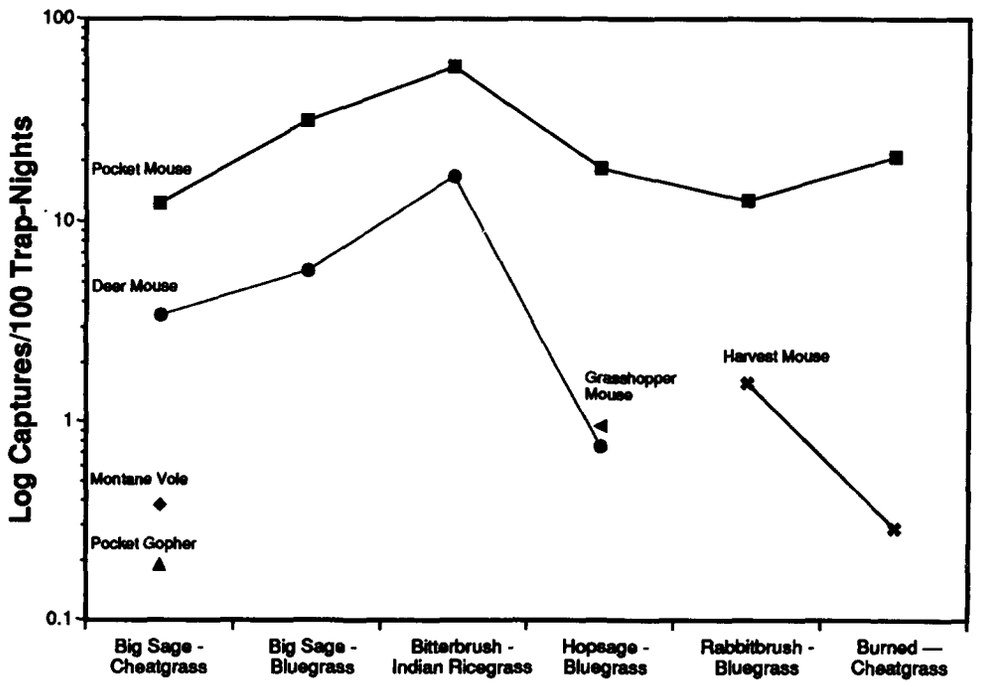

Fig. 4. Average captures of small mammals in six plant communities on the Columbia River Plain.

Table 5. Total small mammal captures on old-field cheatgrass and adjacent sagebrush-bluegrass communities on the Hanford Site, November 1978 to August 1980 (8,000 trap-nights per community)[a]

Habitat	Pocket mouse	Deer mouse	Harvest mouse	House mouse	Montane vole	Merriam's shrew *Sorex merriani*	Total
Old-field	67	2	12	1	1	3	86
Big-sage/ cheatgrass	231	29	15	0	3	2	280

[a] Rogers *et al.* (1988).

Plain, but rarely captured on the trapping grids, were the Townsend's ground squirrel *Spermophilus townsendii*, which can be locally abundant, and the sagebrush vole *Lagurus curtatus*, which is present in very low numbers (O'Farrell, 1972). Townsend's ground squirrels are active from March to June (Hedlund & Rickard, 1981). These were not active above ground during the main portion of our trapping period, but other studies have shown them to be the most abundant small mammal in terms of biomass in big sagebrush–bluebunch wheatgrass *Agropyron spicatum* habitats on the slopes above the Columbia River Plain (Rogers *et al.*, 1988). Foraging preferences based on fecal analyses identified Sandberg's bluegrass, tansy mustard, and lupine *Lupinus* sp. as preferred food of ground squirrels (Rogers *et al.*, 1988). Cheatgrass was avoided as a food.

Additional studies of small mammal abundance were conducted in abandoned cultivated fields dominated by cheatgrass and adjacent undisturbed sagebrush–bluebunch wheatgrass habitats (Rogers *et al.*, 1988). Although all species of small mammals, except the house mouse, were captured in both habitats, the undisturbed habitat had three times the trap catch as did the old fields (Table 5). Pocket mice eat cheatgrass seeds (Schreiber, 1973), thus food supplies should not be limiting the population density on the old fields. The comparatively low mouse catch in the old fields may be attributed to a combination of few plant species and structural simplicity of the plant community (Rosenzweig, 1973).

Cheatgrass seeds are used as food by the great basin pocket mouse (Schreiber, 1973), which is by far the most abundant mammal on the Columbia River Plain. It is not known if the success of cheatgrass on the Columbia River Plain has promoted an increase of pocket mice by increasing food availability. If cheatgrass has actually increased the population of pocket mice, it would be reasonable to expect an increase in pocket mouse predators such as the burrowing owl. This hypothesis, in the absence of data showing the abundance of burrowing owls in the decades before the invasion of cheatgrass, is difficult to test.

In other trapping studies conducted on the Hanford Site since 1965, the alien house mouse *Mus musculus* and Norway rat *Rattus norvegicus* were not captured outside of riparian zones and the vicinity of buildings, indicating that they are not capable of maintaining populations in the shrub-steppe ecoregion without the presence of resident people. None of the mid- to large-sized mammals inhabiting the Columbia River Plain are aliens (Rickard & Poole, 1989; Rogers *et al.*, 1988).

The spread of alien vegetation may have adverse effects on some of the medium-sized mammals native to the Columbia River Plain. Black-tailed hares *Lepus californicus* are found all across the plain, except in cheatgrass stands (Rickard *et al.*, 1974). Density is apparently positively correlated with shrub cover (Uresk, 1978). Diet analysis of hares showed that, although cheatgrass was the most abundant plant in the habitat, it did not occur in the hare diet. Yarrow *Achillea millefolium*, turpentine cymopterus *Cymopterus terebinthinus*, *Erigeron* sp., and grey rabbitbrush *Chrysothamnus nauseosus* were the taxa most often found in the hare's diet (Uresk, 1978).

Two large herbivorous mammals, mule deer *Odocoileus hemionus* and Rocky Mountain elk *Cervus elaphus*, inhabit the Columbia River Plain. Mule deer are distributed throughout the Plain, although their numbers are greatest along the riparian zones of the Columbia River. Fecal analyses showed that mule deer forage primarily on bitterbrush, though the alien Russian thistle may be utilized when other vegetation has senesced and is of low forage value (Uresk & Uresk, 1980). Rocky Mountain elk were introduced to the forested mountains of eastern Washington at the turn of the century. In 1972, a few animals travelled to the Hanford Site from the distant Cascade Mountains to the west and have now established year-round residency (McCorquodale *et al.*, 1986). In some ways, elk can be considered as aliens to the Columbia River Plain (Rickard *et al.*, 1977).

CONCLUSION

The shrub-steppe ecoregion of eastern Washington has few remnant natural areas, especially places located on valley topography (WDNR, 1989). Most of the few remnant stands are on steep slopes and/or rocky soils. The Columbia River Plain itself is not represented by a reserve.

Within the next few years, there will likely be no shrub-steppe sites on valley topography that qualify as natural area reserves. It is generally recognized worldwide that many of the established natural areas are too small to sustain viable populations of the larger

mammals and birds. Some scientists believe that conservation science will need to orient itself more toward multiple-use management and less towards the establishment of large preserves to sustain remnant habitats for use by wildlife (Verner *et al.*, 1986).

The Columbia River Plain functions as a refugium for native shrub-steppe plants and animals and also as an outdoor laboratory useful for conducting research aimed at restoration of disturbed shrub-steppe landscapes and wildlife populations.

Should natural reserve areas be established in Washington's shrub-steppe ecoregion in the future, these will also probably tolerate at least some alien taxa to conserve the remnant populations of the native flora and fauna. Our observations indicate that human disturbance need not be spatially extensive to maintain alien plants within undisturbed communities. The primary adverse effect of alien species in native habitat on the Columbia River Plain appears to be an increase in fire frequency and intensity, with resultant losses of shrubs and subsequent decreases in bird and small mammal abundance. Alien plant species are intruders into established arid-land nature reserves elsewhere in the United States, where they are seen as detractors to reserve 'naturalness' (Loope *et al.*, 1988). As pointed out by Usher (1988), after 1 000 years or so it is difficult to distinguish between native and introduced plant species.

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