WASHINGTON NATURAL HERITAGE PROGRAM

Conservation Strategy for Washington State Inland Sand Dunes

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Prepared by
Lisa A. Hallock
Ryan D. Haugo and
Rex Crawford, Ph.D.

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TABLE OF CONTENTS

Disclaimer

This Conservation Assessment was prepared for the Bureau of Land Management by the Washington Natural Heritage Program in order to compile information on Washington State inland sand dunes. This assessment does not represent a management decision by the U.S. Bureau of Land Management. Although the best available scientific information was used in preparation of this document, it is expected that new information will arise. In the interest of adaptive management and scientific inquiry, any additional or new information that will assist in conservation of Washington State inland sand dunes, should be provided to the Bureau of Land Management and Washington Natural Heritage Program.

Executive Summary

This report follows the May 2006 draft "Conservation Strategy Format" at the request of the Bureau of Land Management. This format applies to species and populations and was adapted here to apply to an ecological system. Individual format section headings were modified to apply to ecological systems rather than species.

Classification
Washington inland sand dunes are classified as the *Inter-Mountain Basins Active and Stabilized Dune* ecological system in the IESC (NatureServe 2006). A terrestrial ecological system is a group of plant communities (associations) that tend to co-occur within landscapes with similar ecological processes, substrates, and/or environmental gradients (Comer 2003).

Management Status
Ecological systems are not designated for protection under any federal legislation. However, a number of federal and state listed species are provided habitat by the *Inter-Mountain Basins Active and Stabilized Dune* ecological system in Washington. These species are discussed in this document.

The 2005 *State of Washington Natural Heritage Plan* identifies the Pacific Northwest Inland Sand Dune Ecological System as a Priority 1 feature for inclusion in the statewide system of natural areas (http://www.dnr.wa.gov/nhp/refdesk/plan/index.html). Nine plant and four animal species that are dune system-associated are listed as priority species.

One plant species (Northern wormwood) and one animal species (Washington ground squirrel) are candidates for listing under the federal Endangered Species Act. Two animal species have been identified by the USFWS as species of concern. Six animal species associated with dune habitats have been listed as Washington Candidate species (WDFW 2006) because of rarity or declining populations.

Two plant associations within Washington's inland sand dune systems are recognized by NatureServe: Ponderosa pine/antelope bitterbrush/Indian rice grass (G1: globally critically imperiled) and sand lyme-grass association (G2: globally imperiled).

Range and Distribution of Washington State Inland Sand Dunes
The *Inter-Mountain Basins Active and Stabilized Dune* ecological system is described from Colorado, Idaho, Nevada, Oregon, Montana, and Wyoming. In Washington, inland dune systems are currently found in 13 counties across the Columbia Plateau in eastern Washington with a total extent of 106,953 acres.

Threats
The total extent of Washington inland sand dune systems has declined approximately 76% from the early 1970s, primarily due to agricultural conversion, reservoir flooding and dune stabilization. Currently, the major threats to the sand dune ecological system in Washington are stabilization by invasive species, agricultural conversion including

effects from adjacent irrigation, off-road vehicle (ORVs) use, intentional sand dune stabilization, conversion to residential lots, mining activities and livestock grazing.

Management

Eight areas are recognized as having significant conservation value: Hanford Central Dunes (USFWS), Juniper Dunes Wilderness (BLM), Delight Dunes**,** Wanapum and Wanapum North Dunes (BOR), Wahluke Dunes (USFWS), Hanford Black Sand Dunes (USDOE), Sentinel Butte Dunes (BLM), and Wakefield Dunes. These areas warrant special management attention to protect and retain their conservation values. Management should promote a range of dune functional stages to maintain species diversity. Long-term management must address the projected trajectory and rate of migration of individual dune systems and the effects of surrounding landscape conditions and dune use. Short-term management must address exotic plant species invasion and on-site activities, such as ORV use, that influence whole system functioning and alter/destroy rare species habitat.

Research, Inventory, and Monitoring Opportunities

Research Priorities:

1. Invasive species impact and control
2. Restoration of dune systems
3. Rare species demographics, especially distribution
4. Complete floristic sampling of plant communities and their seral and environmental relationships to complete International Vegetation Classification descriptions.
5. The range of fire effects in sand dune systems, particularly addressing the response of annual exotic plant abundance, sand movement and stabilization

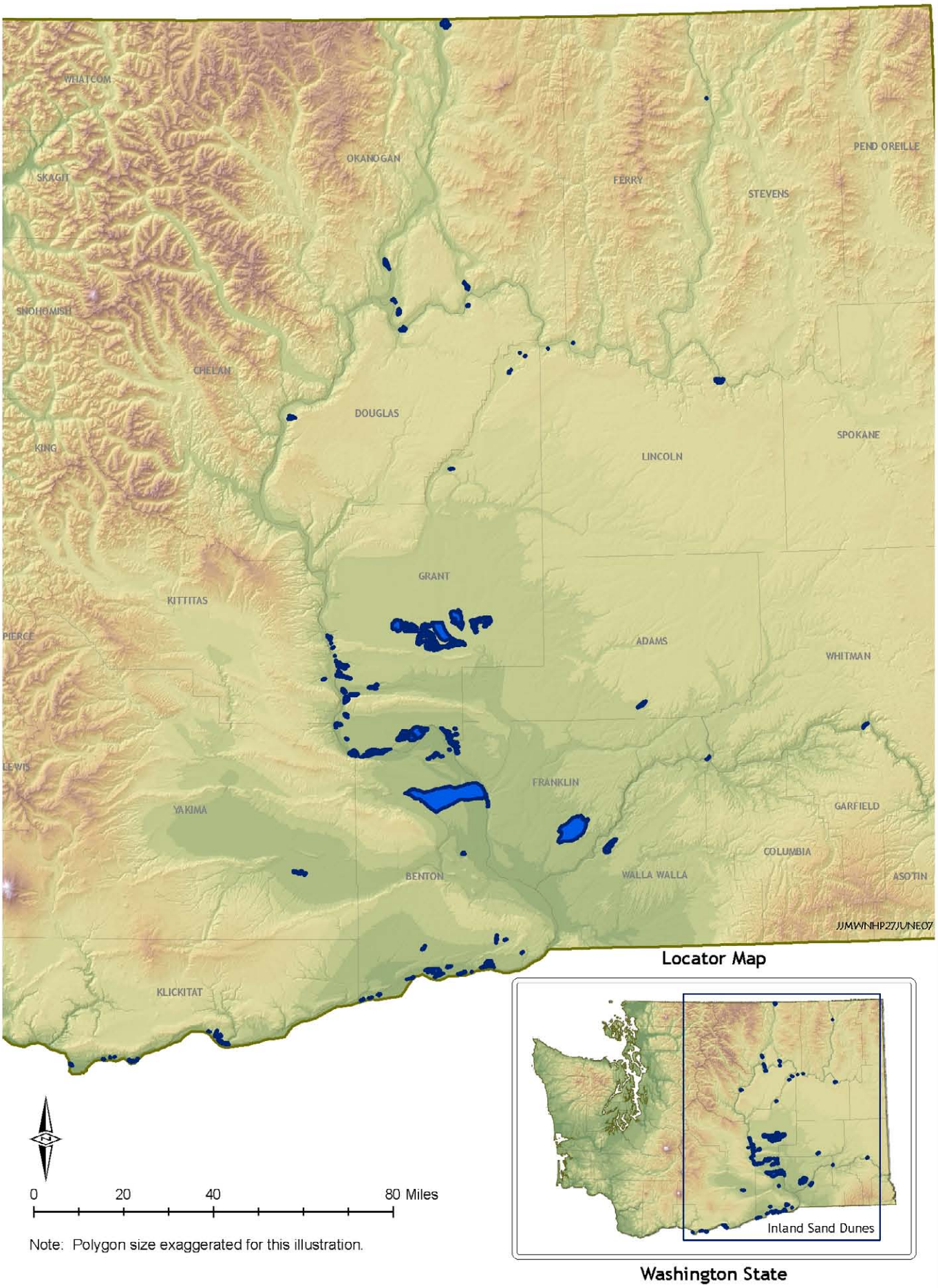
Inventory – Insects and rare plants have been identified as high priority for inventory. Information on small mammals would also be beneficial. The sand dune systems listed in the Management Areas section are the highest priority for inventory. An inventory on the Hanford Central Dunes and Juniper Dunes is needed to verify classification of the sand lyme-grass association, CEGL001563, (*Leymus flavescens*) and to determine its extent.

Monitoring Opportunities – Sand dunes are considered sensitive indicators of climate change because they reflect overall moisture balance, degree of vegetation cover, and wind patterns. Establishing a monitoring system for sand dune field rate of movement and stabilization/destabilization with climate change will inform management of dune species and whole dune systems. Dune systems are a confined, limited resource and are targeted for recreational use. Monitoring of recreational impacts, use levels, and public demand for recreational dune “resources” is needed.

List of Figures

The following figures are contained in Appendix I

List of Tables



Locator Map

Washington State

Figure 1. Current Extent of Inland Sand Dunes

I. Introduction

A. Goal

The goals of this Conservation Strategy are (1) to summarize existing and new information regarding the ecology of inland sand dune systems in Washington, including threats to this habitat and its associated species, and (2) to identify management strategies for the conservation of these systems. The majority of dune systems that once occurred in eastern Washington have been converted to agriculture, urban development and/or been inundated by water. The remaining sand dunes are vulnerable to conversion and/or stabilization by exotic annual species that alter the unique flora and fauna associated with this habitat. Additionally, damming of the Columbia River has ended the natural process of sand deposition that results in dune formation and perpetuation. If conservation actions are not taken, Washington's inland dune ecological systems and their associated species may be lost in the foreseeable future.

B. Scope

The geographic scope of this strategy is dune systems in the Columbia Plateau Ecoregion of Washington State (Fig. 1). This strategy may have application to dune areas in other portions of the Columbia Plateau. This report addresses only eolian dunes, that is, sands worked by wind. Gravel bars and coarse alluvial sand deposits, such as those at Crescent Bar in Kitittas County, which superficially resemble eolian sand dune systems but function differently and support different plant associations and associated species, are not covered by this report. We are confident that all significant extant eolian sand dune systems, that is, individual or portions of historical dune fields, are captured in this report. Small isolated sand dunes, especially those that have been stabilized by vegetation, may have been missed by our methods.

Dune systems were located using geology maps (Schuster et al. 1997, Stoffel et al. 1991), Washington County Soil Survey Information (US Dept. of Agriculture Soil Conservation Service), USGS 7.5 minute topographic maps, Department of Natural Resources orthophotos, and personal observations. For ease of reference, each sand dune system was given a name (Fig. 2). Knowledge compiled from all of Washington's inland sand dune systems is included in this report for comparison purposes and to present a range of conservation opportunities for dune habitats and associated species.

This strategy summarizes existing knowledge about sand dune systems in eastern Washington. Literature on the ecology of North American inland sand dunes is limited (Chadwick and Dalke 1965, Bowers 1982, Smith 1982) and often focused on specific areas such as the White Sands National Monument, New Mexico and Great Sand Dunes National Park, Colorado. Within Washington, the literature on inland dunes focuses primarily on the geomorphology and origin of individual dune systems (Gaylord and Stetler 1994, Gaylord et al. 1991, 1997, 1998, 2001, Petrone 1970, Bandfield et al. 2002) or mentions dunes as isolated features on the landscape (Washington County Soil Surveys). Daubenmire (1970) provides a brief, generalized overview of the ecology of

eastern Washington sand dunes. Much of the information included in this report has been generated by the Washington Department of Natural Resources' Natural Heritage Program (WNHP) biologists and is unique to this report. To fully understand this system, additional floral and faunal surveys are necessary. Threats identified in this report are based upon the field observations of Natural Heritage field personnel. Additional threats may be identified with time and additional surveys. This report includes site-specific management recommendations, as well as statewide concerns. Uncertainty and inference are acknowledged where appropriate.

C. Management Status

The 2005 *State of Washington Natural Heritage Plan* identifies the Pacific Northwest Inland Sand Dune Ecological System as a Priority 1 feature for inclusion in the statewide system of natural areas (http://www.dnr.wa.gov/nhp/refdesk/plan/index.html). Nine plant and four animal species that are dune associated are listed as priority species (Tables 1 & 2). The Washington Department of Fish and Wildlife (WDFW) has also expressed interest in designating inland sand dunes as a Priority Habitat.

Tables 1 and 2 identify the federal status, global and state rank, Natural Heritage Plan priority, and state status for each of the species of concern. The tables also indicate whether each is a sand dune or sandy soil obligate or facultative species. Of the plant and animal species included in Tables 1 and 2, note that one plant species (Northern wormwood) and one animal species (Washington ground squirrel) are candidates for listing under the federal Endangered Species Act. Two animal species have been identified by the USFWS as species of concern. Six animal species associated with dune habitats have been listed as Washington Candidate species (2006 listing) because of rarity or declining populations.

It is also important to note that new discoveries continue to take place in these habitats. Insect species, new to science, continue to be described from the Hanford Central and Wahluke dune systems (Soll 1999, Zack et al. 2003).

There are also two plant associations recognized in the International Vegetation Classification (IVC) that are of conservation concern within Washington's inland sand dune systems. The Ponderosa pine/antelope bitterbrush/Indian rice grass (*Pinus ponderosa* / Purshia *tridenata / Achnatherum hymenoides*) association, ranked as critically imperiled globally (G1), is found in a single location in Washington. The sand lyme-grass association (*Leymus flavescens*), ranked as globally imperiled (G2), is tentatively recognized in Washington at the Hanford Central Dunes and perhaps at Juniper Dunes.

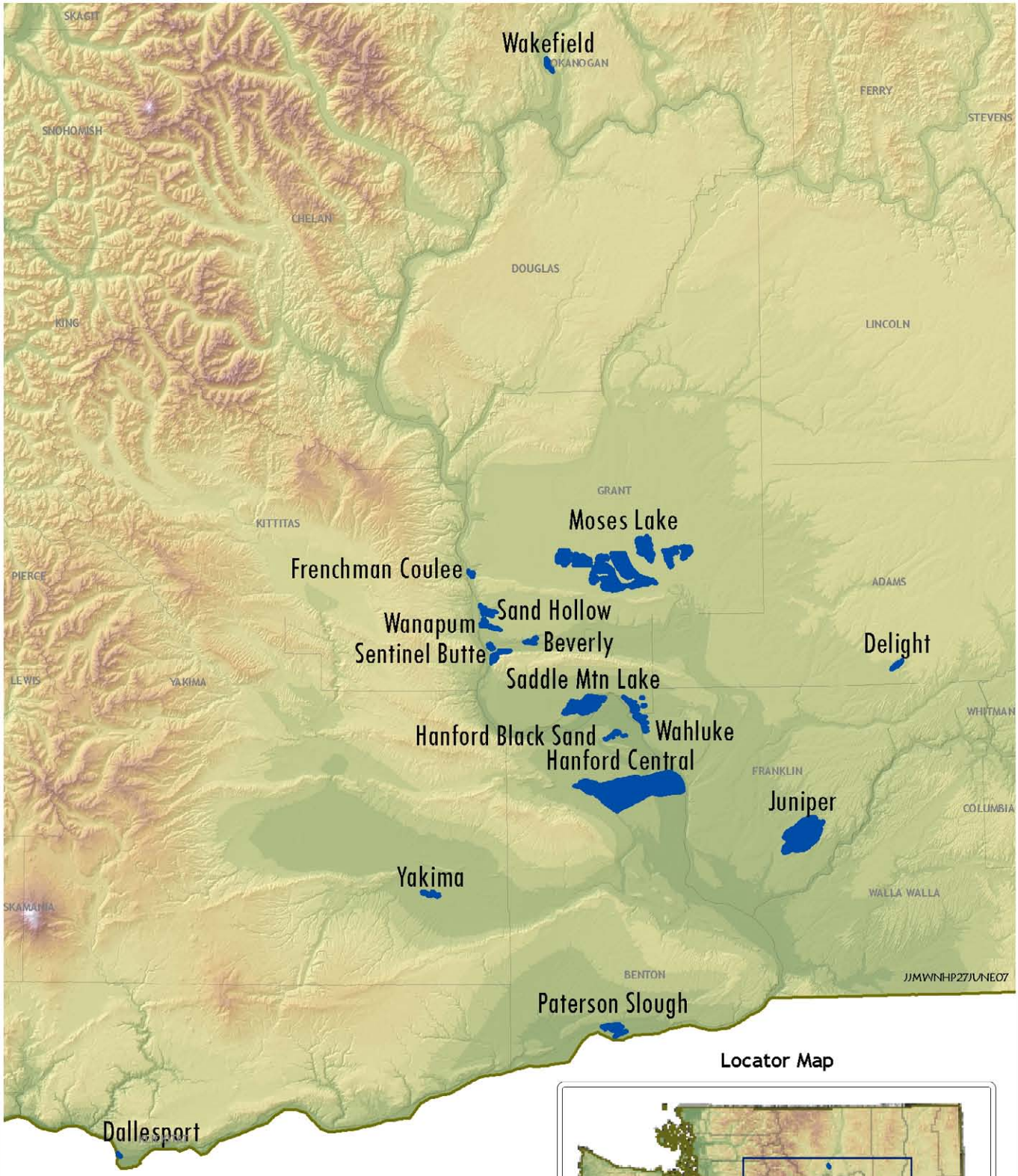


Figure 2. Sand Dune Site Names Featured in Report

Table 1. Rare plant species associated with Washington sand dune habitats.

Plant Species	Common Name	Federal Status	NH Rank	NH Plan Priority (2005)	State Status	Active sand dunes	Sandy soil
Artemisia borealis var. *wormskioldii*	Northern wormwood	Candidate	G5T1S1	1	Endangered	Facultative	Facultative
Astragalus geyeri	Geyer's milk-vetch		G4S1	2	Threatened	Obligate	Obligate
Astragalus kentrophyta var. *douglasii*	Thistle milk-vetch	Species of Concern	G5TXSX	Possibly extirpated	Possibly extirpated	Facultative	Obligate
Calyptridium roseum	Rosy pussypaws		G5S1	2	Threatened		Obligate
Camissonia scapoidea	Naked-stemmed evening primrose		G5S1	3	Sensitive		Obligate?
Corispermum pallidum	Pale bugseed		GHSH	Possibly extirpated	Possibly extirpated	Facultative	Obligate
Cryptantha leucophaea	Gray cryptantha		G2G3S2S3	3	Sensitive	Obligate	Obligate
Eriogonum maculatum	Spotted buckwheat		G5SX	Possibly extirpated	Possibly extirpated		Facultative
Gilia leptomeria (=*Aliciella leptmeria*)	Great Basin gilia		G5S1	2	Threatened		Facultative
Loeflingia squarrosa var. *squarrosa*	Loeflingia		G5T4?	2	Threatened		Facultative
Mimulus suksdorfii	Suksdorf's monkey flower		G4S2	3	Sensitive		Facultative
Nicotiana attenuata	Coyote tobacco		G4S2	3	Sensitive		Obligate

Table 2. Rare or declining animal species associated with Washington sand dune habitats.

Animal Species	Common Name	Federal Status	NH Rank	NH Plan Priority (2005)	State Status	Sandy habitat use
Cicindela columbica	Columbia River Tiger Beetle		G2SH		Candidate	Obligate
Bufo woodhousii	Woodhouse's Toad		G5S3	3	Monitor	Facultative
Sceloporus graciosus	Sagebrush Lizard	SC	G5S3	3	Candidate	Sand dune obligate
Dipodomys ordii	Ord's Kangaroo Rat		G5S4		Monitor	Obligate
Lemmiscus curtatus	Sagebrush Vole		G5S3	3	Monitor	Facultative
Onychomys leucogaster	Grasshopper Mouse		G5S3		Monitor	Obligate
Spermophilus townsendi townsendi	Townsend's Ground Squirrel	SC	G4S3		Candidate	Facultative
Spermophilus washingtoni	Washington Ground Squirrel	C	G2S2	1	Candidate	Facultative
Lepus californicus	Black-tailed Jackrabbit		G5S2S3		Candidate	Facultative
Lepus townsendii	White-tailed Jackrabbit		G5S2S3		Candidate	Facultative

II. Classification and Description

A. Sand dune geomorphology and origin

Formation of sand dunes requires a supply of well-sorted fine or medium grained (0.125-0.5 mm) sand and wind (eolian) transport. The wind moves the sand grains by saltation (bouncing) along the surface. Sand accumulates when wind passes from a rough surface to a smooth one (e.g., sand patch), flows over a depression and/or encounters a permeable obstacle such as a shrub. Dunes accumulate (accrete) sand during strong winds and lose sand during gentle winds until they reach a critical size. Once this size is attained, sand is trapped under all wind conditions due to aerodynamic factors that result in sand being dropped at the leeward margin of the dune instead of being carried off the dune (Smith 1982).

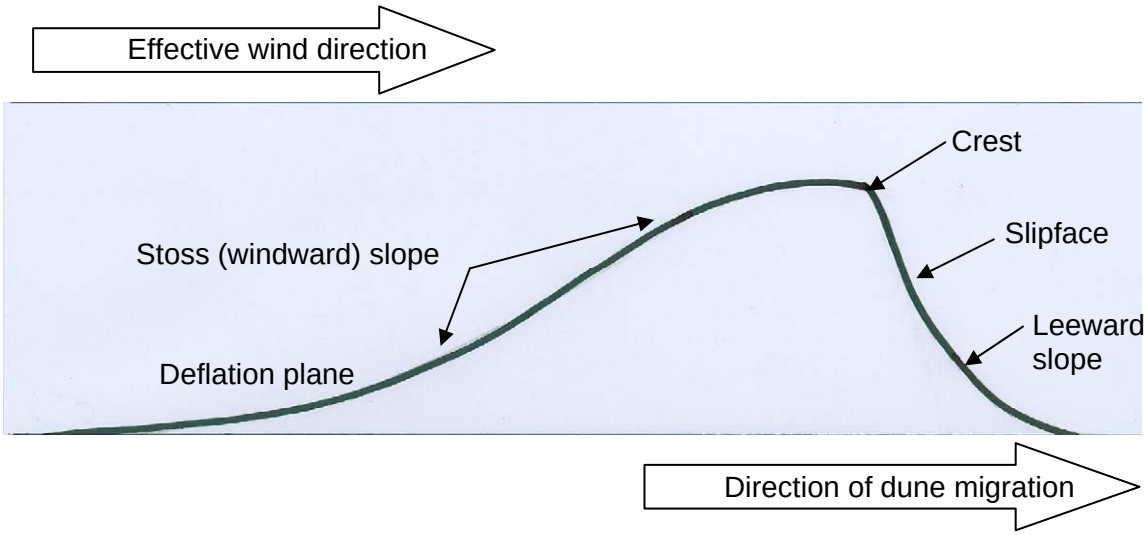
Sand dunes in sub-arid to semi-arid regions support vegetation if wind stress is not too great. The vegetation cover is related to the amount of annual rainfall and rate of evapo-transpiration. The amount of vegetation cover responds dramatically to climate related changes (Gaylord and Stetler 1994, Helm 2003). The mobility of sand dunes is related to the power of the wind and inversely related to the amount of vegetation cover (Hacks 1941). Long periods of increased precipitation and persistent presence of vegetation may lead to covering of the sand surface with litter and/or microphytic crust, soil formation and partial to complete stabilization of the dunes. In contrast, periods of drought will result in conditions unfavorable to vegetation and can reinitiate the mobility of the sands (Lancaster 1988).

Four simple dune types have been observed in Washington. The following descriptions are from Smith (1982) using Hacks' (1941) scheme that defines dune-form as a function of three variables: wind, sand supply and vegetation. Dune terminology is presented in Figure 3. Longitudinal dunes form when there is a small to moderate supply of sand, much wind and little vegetation (Fig. 4). These dunes are long in proportion to width and symmetrical in cross section. Transverse dunes form when there is a copious sand supply, little to moderate wind and little vegetation. Barchans are a subset of this dune type limited to areas with hard surfaces and limited sand supply (Fig. 5). Parabolic or U-shaped dunes form when there is a moderate supply of sand, wind and vegetation (Fig. 6). These dunes are "U" shaped with arms that trail the dune. Vegetation encroaches on the arms and is essential for their development. The deflation plane is more slowly colonized by plants. The slip face remains free to advance. Climbing dunes climb the windward side of hills as sand sheets (Fig. 7). Dune systems are described as "complex" if they have more than one type of simple dune present in the system.

Inland sand dune systems contain three different functional stages: 1) open/migrating, 2) anchored, and 3) stabilized. These stages differ primarily in the amount of sand movement on the dune surface and movement of the dune itself. The open/migrating stage has large areas of open active surface sand and the dune migrates with the effective wind direction (Fig.8). Unstable slip faces (lee slopes) often form. Vegetation cover is minimal. Anchored dunes have active sands present on the dune surface, but movement / migration of the dune as a whole is inhibited by vegetation (Fig. 9). This stage often

occurs on the trailing arms of migrating parabolic dunes and on vegetated sand sheets. Stabilized dunes lack active sands. The dune surface is sealed with vegetation, cryptobiotic crusts, or volcanic ash (Fig. 10). The anchored and stabilized stages are considered either “native” or “exotic” based on the dominant (>50% of relative cover) vegetation.

Figure 3. Sand dune terminology



Published research on the origins of Washington’s inland sand dunes addresses the geomorphic development of the Hanford Site sand dunes (Gaylord et al. 1991, Gaylord and Stetler 1994), Smith Canyon dune field (Gaylord et al. 2001), Juniper Dunes (Gaylord et al. 1997, 1998) and the Moses Lake dune field (Petrone 1970, Bandfield et al. 2002). These extensive sand dune systems formed from alluvial sediments derived from the Missoula floods. Extensive reworking of these deposits by wind produced widespread Holocene (and possibly late Pleistocene) eolian deposits (Gaylord and Stetler 1994, Gaylord et al. 2001, Banfield et al. 2002, Dalman et al. 2005). Alluvial sources may have provided a minor contribution to the Hanford dunes (Gaylord et al. 1991). Other extensive sand deposits, such as those found west of Walla Walla, are most likely also glacial outburst flood-derived sands (Gaylord et al. 2001). Dune field activity and migration was slowed in the Columbia Basin approximately 3,900 years ago when cooler, moister conditions resulted in expansion of basin vegetation (Gaylord et al. 2001). Prior to the damming of the Columbia and Snake rivers, sand was transported and deposited annually by the rivers to form sand bars. Dune fields occurring along both rivers were later fed by deflation of these fluvial sand deposits.

In recent times, changes in the volume of non-vegetated dune sands are related to natural and anthropogenic influences. Gaylord and Stetler (1994) found a well-defined eolian-

climatic relationship for non-vegetated sand volume vs. precipitation, wind speed, and temperature at the Hanford Site. Non-vegetated dune volumes decreased in the years 1948-1964 and 1978-1987 and increased during 1965-1977 (Gaylord and Stetler 1994). Change in non-vegetated dune volume also occurs due to other variables that influence the surface, such as livestock grazing or anthropogenic impacts such as off-road vehicle use.

B. International Ecological Systems Classification (IESC)

A terrestrial ecological system is a group of plant communities (associations) that tend to co-occur within landscapes with similar ecological processes, substrates, and/or environmental gradients (Comer 2003). Washington inland sand dunes are classified as the *Inter-Mountain Basins Active and Stabilized Dune* ecological system in the IESC (NatureServe 2006). This dune ecological system, however, is described primarily from studies in Idaho, Montana, Wyoming and Colorado and does not fully represent the vegetation variation found in Washington inland sand dunes. The contents of this report will be submitted to NatureServe and used to update the classification and description of the *Inter-Mountain Basins Active and Stabilized Dune* ecological system and the component plant associations (Appendix VI). In this document, the ecological system is the basis for mapping and conservation assessment.

C. Plant Communities

Based on a classification of variable-sized reconnaissance plots (n = 294) from twenty-eight inland Washington dune fields, we have described seven distinct plant community types (Appendix III). These types represent potential changes to the International Vegetation Classification (IVC) of Washington inland sand dune plant communities (NatureServe 2006, Grossman et al. 1998). Because this is not a full, floristic classification strictly following IVC guidelines, however, our community types are not necessarily association-level groupings. Vascular plant names used in naming and describing ecological communities generally follow Kartez (1999). Appendix (VII) lists plants used in the text and encountered during dune assessment.

III. Ecology

A. Range and Distribution of Washington State Inland Sand Dunes

Dune systems are currently found in 13 counties across eastern Washington with a total extent of 106,953 acres (Fig. 1)**.** A majority of systems are either wholly or partially on federally owned lands. Hanford Central Dunes (35,504 acres) in Benton County, Juniper Dunes (15,029 acres) in Franklin County, Saddle Mountain Lake Dunes (5,993 acres) in Grant Count and Moses Potholes North Dunes (5,932 acres) in Grant County are currently the largest extant systems in Washington.

B. Plant Community Type Summaries

Sand dunes are by nature highly dynamic systems and patterns of plant species composition are closely related to the processes of sand erosion, deposition and dune migration and stabilization (Chadwick and Dalke 1965). These processes may occur rapidly, leaving legacies from previous vegetation types. While repeating patterns of vegetation are observed and allow the identification of community types, they are often present in a spatially complex, fine-scale mosaic (Fig. 11**)**. The boundaries between community types range from distinct to highly blurred (Easterly and Salstrom 1997). Our community types are, however, closely related to the successional processes of dune vegetation and stabilization and often have strong affinities to particular positions within a dune system.

Earlier descriptions of vegetation on Washington inland sand dunes contain several discrepancies with our community types. Both Daubenmire (1970) and the description for the IVC Antelope bitterbrush / Indian ricegrass association (NatureServe 2006) note the presence and importance of sand lyme-grass (*Leymus flavescens)* in Washington, similar to the St. Anthony dunes in Idaho (Chadwick and Dalke 1965). However, during our field surveys sand lyme-grass was found only on the dunes of the central Hanford Site and reported at Juniper Dunes. This is tentatively recognized as the sand lyme-grass association, CEGL001563.

Harris (1954) surveyed dune environments stabilized by water in the Moses Lake pothole region noting willow (*Salix* sp.) along the crests and wetland species in the inter-dunes. These dunes were considered converted and, therefore, not included in our surveys.

Several dune systems across inland Washington had unique species compositions that were not captured by our community types. The Beverly Dunes along Crab Creek have overridden salt flats, introducing typically non-dune vegetation, such as black greasewood (*Sarcobatus vermiculatus*), into the dune field. As described by Daubenmire (1970), open savannas of western juniper (*Juniperus occidentalis*) with abundant curly bluegrass (*Poa secunda*) characterize stabilized sections of Juniper Dunes in Franklin County. Delight Dunes in Adams County, contained multiple woody tree and shrub species not found on dunes elsewhere in Washington, including black cottonwood (*Populus balsamifera* ssp. *trichocarpa),* common chokecherry (*Prunus virginiana),* kinnikinnick (*Arctostaphylos uva-ursi),* and western serviceberry (*Amelanchier alnifolia*).

Other vegetation anomalies at Delight Dunes included the presence of common scouring rush (*Equisetum hymenale*) on open, active stoss slopes and of Idaho fescue (*Festuca idahoensis*) on stabilized dunes.

Bugseed community type
***Corispermum* sp. community type**

This community type (*n* = 7) was represented on the sparsely vegetated stoss slopes of active dunes. The native, annual Bugseed was the only species present in these locations and with minimal cover (avg. ~ 6%). Our field sampling found Bugseed only on dunes in the Wahluke Unit of the Hanford Reach National Monument and above the Wanapum Dam along the Columbia River. However, because of the delayed phenology of Bugseed, its presence in other locations may not have been recorded (Fig. 12). Delayed phenology also limited consistent identification in the field, *C. villosum* is the most likely species.

Russian thistle – Jim Hill mustard community type
***Salsola kali – Sisymbrium altissimum* community type**

Most common on the dunes of western Grant County, this community type (*n* = 25) was found on smaller dunes (< 1.5m height) in the process of being stabilized by exotic species. Exotic species dominated with an average exotic species cover of ~ 47%. Along with Russian thistle (*Salsola kali* misapplied *Salsola tragus*) and Jim Hill mustard, other common species included tarweed fiddleneck (*Amsinkia lycopsoides*) and the exotics cheatgrass (*Bromus tectorum*), and common ragweed (*Ambrosia artemisiifolia).* Native Indian ricegrass (*Achnatherum hymenoides*) was occasionally present. The dominant exotic species are commonly found across the Columbia Plateau and are not limited to dune sand substrates. Often, this community type appeared related to the introduction of water into dune systems from adjacent irrigation systems. While native species appear to be excluded by Russian thistle and Jim Hill mustard, both are annual species and the amount of inter-annual variation in their abundance on active dunes is not known (Fig. 13).

Veiny dock community type
***Rumex venosus* community type**

Located primarily on the lee slopes and crests of larger active dunes, this community type (*n* = 22) is typified by the dominance of the native perennial veiny dock. Total vegetation cover averaged ~ 35%, typically with very few exotic species. On dune crests lemon scurfpea (*Psoralidium lanceolatum*) was common and Indian ricegrass was occasionally present along with veiny dock. While this type is found across the range of Washington inland dunes, it is limited to systems with active sand erosion and deposition. Harris (1954) and Daubenmire (1970) both noted the abundance of veiny dock on the slip faces of active dunes. Although veiny dock forms extensive clones, its lack of permanent above ground structure suggests only a minor impact on dune stabilization (Fig. 14).

Indian ricegrass - Lemon scurfpea association
Achnatherum hymenoides - Psoralidium lanceolatum

This community type (*n* = 44) was commonly found on both the crests and the actively eroding upper and lower stoss slopes of dunes across inland Washington. Lemon scurfpea - Indian ricegrass commonly represents the initial colonization and anchoring of open, migrating dunes by perennial native species (Fig. 15). Similar to the veiny dock type, total vegetation cover averages ~ 35% with very few exotic species. Lemon scurfpea - Indian ricegrass is distinguished by the absence of both veiny dock and of woody shrub species. Although with low cover, thick-spiked wheatgrass (*Elymus lanceolatus*) and cheatgrass were also commonly present. Whiteleaf phacelia (*Phacelia hastata)* was occasionally found and may represent a transition to the Grey rabbitbrush – Green rabbitbrush – Snow buckwheat (*Ericameria nauseosa – Chrysothamnus viscidiflorus – Eriogonum niveum*) type. A Lemon scurfpea - Indian ricegrass type was recognized in Washington State by Johnsgard (1956). This type is likely the same as the Indian ricegrass-Lemon scurfpea association (CEGL001650) as listed in NatureServe (2006) in Idaho, Utah, Wyoming and Colorado.

Grey rabbitbrush – Green rabbitbrush – Snow buckwheat community type
***Ericameria nauseosa – Chrysothamnus viscidiflorus – Eriogonum niveum* community type**

Grey rabbitbrush, green rabbitbrush, and snow buckwheat, the first woody shrub species to establish following dune anchoring by herbaceous species define this community type (*n* = 109). Widely distributed across Washington inland dune fields, this type was commonly found on both anchored and stabilized sand plains, inner-dune areas and around blowouts. Grey rabbitbrush was the most common shrub species, while green rabbitbrush and snow buckwheat were occasionally found independent of grey rabbitbrush. With increased sand stabilization total vegetation cover averaged ~ 61% in contrast to herbaceous-dominated community types. The average cover of exotic species (~ 28%) also increased, primarily cheatgrass. Indian ricegrass, lemon scurfpea and thick-spiked wheatgrass were common but had reduced cover beneath the shrubs. Overall species diversity was increased with species such as pale evening-primrose (*Oenothera pallida),* sand-dune penstemon *(Penstemon acuminatus*), whiteleaf phacelia, Carey's balsamroot (*Balsamorhiza careyana*), turpentine wavewing (*Pteryxia terebinthina*), Columbia cut-leaf (*Hymenopappus filifolius*), thread-leaf fleabane (*Erigeron filifolius*) and prairie junegrass (*Koeleria macrantha*). This type was described but not identified by Easterly and Salstrom (1997) and is similar to the Cheatgrass – Green rabbitbrush zone of Johnsgard (1956) (Fig. 16).

Wyoming big sagebrush – Antelope bitterbrush community type
***Artemisia tridentata* ssp. *wyomingensis - Purshia tridentata* community type**

Establishment of the Wyoming big sagebrush – antelope bitterbrush community type (*n* = 59) represents a late stage in the process of dune stabilization across Washington State inland sand dunes (Fig. 17). Wyoming big sagebrush – antelope bitterbrush was typically

found on sand plains trailing behind active dunes, on stabilized sand sheets and in stable inner-dune areas. However, in fully stabilized dune fields, this community type was often widely distributed, irrespective of location within the dune field. As a broad, alliance level grouping, diversity of both shrub and herbaceous species varied considerably. Throughout the range of this community type, green rabbitbrush was common while other shrubs such as grey rabbitbrush,snow buckwheat, grey ball sage (*Salvia dorrii*)**,** and spiny hopsage (*Grayia spinosa*) were occasionally present. Total vegetation cover was the highest of all dune community types (avg. ~ 67%). Along with Indian ricegrass, curly bluegrass was common in the understory. While many of the other native herbaceous species frequent in the grey rabbitbrush – green rabbitbrush – snow buckwheat type were occasionally present, overall species diversity was often limited and cover of exotic cheatgrass was very high. Moving away from active dune systems, the Wyoming big sagebrush – antelope bitterbrush type often grades to very low diversity communities dominated by Wyoming big sagebrush / cheatgrass.

Needle-and-threadgrass community type
***Hesperostipa comata* community type**

The needle-and-threadgrass community type (n = 8) was infrequently found on sand plains trailing behind active dunes and in stable inner-dune areas. This community type may represent a transition away from dune sand substrates towards the surrounding underlying soils. Although intermixed with the Wyoming big sagebrush – antelope bitterbrush type, shrub cover was minimal and total vegetation cover (avg. ~ 50%) was dominated by needle-and-threadgrass. Cheatgrass was occasionally present, but overall exotic cover was very low. Together, the Wyoming big sagebrush – antelope bitterbrush and needle-and-threadgrass community types are superficially similar to Daubenmire's (1970) and NatureServe (2006) Wyoming big sagebrush / needle-and-threadgrass and antelope bitterbrush / needle-and-threadgrass associations. Within Washington inland dune systems, however, needle-and-threadgrass is rarely the dominant understory species beneath Wyoming big sagebrush or antelope bitterbrush, differentiating the Wyoming big sagebrush – antelope bitterbrush community type and needle-and-threadgrass community types (Fig. 18).

Ponderosa pine/Antelope bitterbrush/Indian rice grass association (CEGL000196)
***Pinus ponderosa / Purshia tridentata / Achnatherum hymenoides* association**

This IVC association was not included in our reconnaissance plots but has been identified on a single dune system in Okanogan County on the Colville Indian Reservation (Wakefield Dunes). First described by Clausnitzer and Zamora (1987), this type is characterized by a tree cover of ponderosa pine and a low diversity understory dominated by antelope bitterbrush with sparse Indian ricegrass. The site's current condition was verified by observation from the highway. Known only from two other sites, one in Oregon and one in California, this association has a global rarity rank of G1 – critically imperiled (Fig. 19).

Sand lyme-grass association (CEGL001536)
***Leymus flavescens* association**

This IVC association was not included in our reconnaissance plots but has been tentatively identified at Hanford Central Dunes based on the presence of sand lyme-grass. It may occur at Juniper Dunes as well. According to NatureServe (2007), this is a pioneer plant association occurring on all but the most actively eroding or depositing areas of slowly moving sand dunes. Sand lyme-grass and Indian ricegrass are the principle pioneer species on these dunes. It is documented only from Idaho on the St. Anthony Sand Dunes RNA and reported in the Columbia Basin of Oregon and Washington. More intensive evalulation is needed to verify this occurrence.

C. Rare and declining plant and animal species

Species associated with these systems are adapted to deal with shifting sand, extreme temperature changes and low moisture content. The rare plant and animal species addressed here are primarily associated with the anchored and semi-stabilized habitats of the sand dune system. Many of the rare plant species require some active surface sand. They do not, however, have the special modifications necessary to withstand winds and shifting sands that blow away seeds, bury seedlings and abrade plants; traits necessary to colonize the bare eroded portions of dunes. Pale bugseed (*Corispermum pallidum*) may be an exception. For most animals, the bare or eroded portions of sand dunes provide little forage or shelter. These areas, however, do appear to provide habitat to some insect species. Unidentified insects and beetle tracks, as well as the dune-obligate tenebrionid beetle, *Eusattus muricatus*, were commonly observed in this habitat type (Hallock, pers. ob.).

Plants - Twelve rare plant species are associated with the active sands or sandy soils of Washington's inland sand dunes. Status information is listed in the Management Status section. The information that follows is from the Field Guide to Washington's Rare Plants (http://www.dnr.wa.gov/nhp/refdesk/fguide/htm/fgmain.htm) and WNHP database information.

Northern wormwood (*Artemisia borealis* var. *wormskioldii*) – This species is known from the sand dune field near Beverly and the Miller Island Dunes where plants occur at the river-sand dune interface. Both occurrences are on federal lands. Whether or not the species is actually dependant on sandy soils or persists in the presence of sand is unknown. Conservation of the species, however, depends on protection of the sandy habitats. Soil compaction and direct damage from recreational vehicle use and weed invasions have been identified as threats to this species. Additional inventory is recommended for the area between the John Day and Priest Rapids dams and between Rock Island and Wanapum dams.

Geyer's milk-vetch (*Astragalus geyeri*) – This species is disjunct in Washington, occurring only in Grant County. It occurs in the depressions of mobile or stabilized dunes, sandy flats, and valley floors. It can persist with a high cover of annual weedy

plants like cheatgrass, Russian thistle and Jim Hill mustard. It occurs on BLM's Sentinal Butte Dunes in the Beverly area and the Wahluke Dunes on the USFWS Hanford Monument. Threats include agricultural conversion, damage from recreational vehicles and grazing. Recommended inventory includes systematic surveys of all suitable habitats throughout the Columbia Basin.

Thistle milk-vetch (*Astragalus kentrophyta* var. *douglasii*) – This species has not been documented in Washington since 1883 and may be extirpated. Barneby (1964) lists the historical locations as being within or near the Great Bend of the Columbia River, southeastern Washington or perhaps adjoining Oregon. He suggested that this species occurred on sandy ground, on dunes or on eroded riverbanks at low elevations. The WNHP recommends an intensive search for this species to verify its status.

Rosy pussypaws (*Calyptridium roseum*) – Recent Washington occurrences are known only from sand dunes (Hanford Black Sand Dunes) in the central portion of the Hanford Site, Benton County. These two occurrences are disjunct from the rest of the species' range in Oregon and California. The occurrences were found in low swales in sandy soils that support sagebrush at elevations from 520 to 530 ft. (158 to 161 m). Additional inventory of sandy sites in Benton County is recommended by the WNHP.

Naked-stemmed evening primrose (*Camissonia scapoidea*) – Only two occurrences have been documented in Washington. Both occurrences are on sandy, gravelly sites near the Wanapum Dam on the Yakima Training Center, Kittitas County. The known occurrences are not associated with active sand dunes but do occur on unstable sandy substrates. This suggests that sand dunes may provide appropriate habitat. Additional inventory is needed to determine the full extent of this species in Washington and the significance of sand dune habitat for the species.

Pale bugseed (*Corispermum pallidum*) – This species is endemic to Washington's Grant and Douglas counties. It is known from four historical occurrences documented from 1893 to 1963. No extant populations are known. Historical occurrences were described as coming from sandy sagebrush plains in drifting sand and dry sand at elevations of 948-1312 ft. (300-400 m). The WNHP initiated surveys for this species in 2005 without success. Additional surveys are necessary to confirm the status.

Gray cryptantha (*Cryptantha leucophaea*) – This species is a regional endemic, known from the Columbia and lower Yakima rivers in the western Columbia Basin, and from Wenatchee, Washington to The Dalles, Oregon. Gray cryptantha occurs on sandy substrate along the Columbia River within the Columbia Basin physiographic province. It occurs on the stabilized portions of sand dunes but requires bare ground and surface active sands. Twenty occurrences are documented on dunes in Grant, Benton, Franklin, Kittitas and Klickitat counties. The majority of occurrences are on federal lands. Additional surveys are required to determine the complete distribution of this species.

Spotted buckwheat (*Eriogonum maculatum*) – This species occurs in sandy to heavy soils. In Washington, it is known only from an 1884 occurrence in Yakima County. The species was not detected during a survey in the historical vicinity in 1981.

Great Basin gilia (*Gilia leptomeria*) – The Washington occurrences in Grant, Benton and Franklin counties are disjunct by hundreds of miles from the rest of the species' range. It occurs on gravelly bluffs, sandy swales and on caliche at elevations 143 – 347 m (470- 1140 ft.). The species depends on the extreme dryness of these sites and the lack of competition from other species. Only six recent occurrences are known in Washington. Three of these are associated with sand dunes on the Hanford Site: one in the Vernita Bridge area and the others on the dunes at the Wahluke Unit above the Columbia River (Vernita Bridge Dunes and exotic stabilized portions of the historical Wahluke Dunes). Threats to this species include ground disturbing activities and competition from weedy species. More surveys are needed for this species in Grant, Benton and Franklin counties, as well as the surrounding counties where appropriate habitat occurs.

Loeflingia *(Loeflingia squarrosa* var. *squarrosa)* -The Washington population is disjunct from the nearest known sites in California by 800 miles. In Washington, known occurrences are limited to a small geographic area in northern Benton County. These occurrences are in low swales within sandy areas. The elevation of the populations in Washington is between 122 and 152 m (400 and 500 ft.). One of the four Washington element occurrences is associated with the sand dunes located north of Gable Mountain (Hanford Black Sand Dunes).

Suksdorf's monkey-flower (*Mimulus suksdorfii*) – Washington is on the periphery of the species' range where few extant occurrences are known. The species has been collected and/or observed in Benton, Chelan, Grant, Kittitas, Klickitat, and Yakima counties. Some level of substrate disturbance appears to be necessary for this species. It occurs on the Hanford Black Sand Dune north of Gable Mountain. The primary threat is ground disturbances that result in exotic species invasions.

Coyote tobacco (*Nicotiana attenuata*) – In Washington, Coyote tobacco has a scattered distribution, with recent occurrences known from Douglas, Grant, Kittitas, Klickitat, and Yakima counties. Historical sites are known from Chelan and Franklin counties. It occurs in dry, sandy bottom lands, dry rocky washes, and in other dry open places that are prone to periodic natural disturbances. Elevation ranges from 122 to 3048 m (400 to 10,000 ft). None of the known recent occurrences are on sand dunes. Historical occurrences appear to have been associated with the sand dunes in the Dallesport area, Klickitat County; sand dunes northeast of the confluence of the Snake and Columbia rivers; on the historical sand dunes of the Satus-Mabton area, Yakima County; and on sand dunes in the Vantage area, Kittitas and Grant counties. The WNHP recommends a systematic inventory for this species throughout eastern Washington. Threats to this species include all ground disturbing activities, herbicide spraying (for occurrences near roads), and invasion of exotic species into the habitat.

Vertebrate species – The following nine vertebrate species are rare or declining in Washington primarily due to habitat loss and alteration. Three species are sandy soil

obligates: Sagebrush Lizards occur almost exclusively on or in the vicinity of sand dunes. The remaining species utilize sand dune habitat (facultative users) in parts of their ranges. Status information is listed in the Management Status section.

Woodhouse's Toad (*Bufo woodhousii*) – The Washington distribution is limited to the Snake and Columbia rivers (Hallock and McAllister 2005). Distribution on the Columbia River is from the Hanford Site near Vernita Bridge to the John Day Dam (Hallock and McAllister 2005). The significance of sand dune habitat for Woodhouse's Toads in Washington has not been examined. They are documented to occur in the Juniper, Walla Walla Flats, Patterson Slough and Saddle Mountain Lake sand dunes (Hallock, unpubl. data, WDFW herp database). The toads are present in areas where annual grasses have stabilized the sand (ex. Patterson Slough) (Hallock pers. ob.). Breeding site conditions also play a significant role in determining distribution.

Sagebrush Lizard (*Sceloporus graciosus*) – In Washington, this species occurs in the Columbia Plateau Ecoregion. Occurrences are patchy. A study in Oregon found Sagebrush Lizards limited to habitats that had sandy soils (Green 2001). Recent surveys (1995-2004) in Washington found Sagebrush Lizards associated with sand dune habitats (Hallock, unpubl. data). They are documented on 26 of the historical sand dune systems mapped from 1970s orthophotos including the largest systems (Hallock, unpubl. data, WDFW herp database). Anecdotal observations suggest that the lizards may decline or be extirpated in sand dune habitats where invasive annual grasses dominate the ground cover (Hallock, pers. ob.).

Ord's Kangaroo Rat (*Dipodomys ordii*) – The species is limited to the central Columbia Basin where it occurs in Walla Walla, Frankin, Benton (Johnson and Cassidy 1997) and lower Grant County (Gitzen et al. 2001). The species is expanding its range northward in Washington (Johnson and Cassidy 1997, Gitzen et al. 2001). They are restricted to loose, sandy soils in habitats with sparsely vegetated ground (Dalquest 1948). This species has been trapped in habitats where cheatgrass (*Bromus tectorum*) dominates the ground vegetation. The burrows at these sites, however, are restricted to sandy eroded road cuts (Verts and Carraway 1998). Research is underway at University of Calgary (by D. Bender and D. Gummer) to determine if living in roadsides makes the kangaroo rats more vulnerable to predators and parasites than those living in undisturbed habitats. Ord's Kangaroo Rats occur in five of the historical sand dune systems: Juniper, Page, Walla Walla Flats, Beverly and Wanapum (WDFW Heritage database).

Sagebrush Vole (*Lemmiscus curtatus*) – This species occurs in scattered, short sagebrush (*Artemisia* spp.) with sparsely grassed understory on dry, loose soils (Dalquest 1948, Johnson and Cassidy 1997). It has been trapped in the Juniper and Hanford Central sand dunes (WDFW Heritage database).

Grasshopper Mouse (*Onychomys leucogaster*) – This species prefers open areas of sand and avoids heavy cover (Dalquest 1948, Verts and Carraway 1998). It has been documented in five of the historical sand dune systems: Juniper, Walla Walla Flats, Wahluke, Hanford Central and Moses Lake. Older museum records have low precision

making it more difficult to associate some of the records with specific dunes. These records are from the Wanapum, Paterson Slough and Yakima dune (= Satus-Mabton area) areas (WDFW Heritage database).

Townsend's Ground Squirrel (*Spermophilus townsendi townsendi*) – This species occurs on the Hanford Central dune. The rest of the occurrences are not associated with sand dunes (WDFW Heritage database).

Washington Ground Squirrel (*Spermophilus washingtoni*) – This species occupies a variety of shrub-steppe habitats including sandy places (Dalquest 1948). It occurs on the Juniper and Page sand dunes (WDFW Heritage database).

Black-tailed Jackrabbit (*Lepus californicus*) – This species occupies a variety of shrub-steppe habitats (Johnson and Cassidy 1997). It has been observed on the Juniper, Wanapum, Hanford Central, Crow Butte, Sand Spring, Moses Lake, West Richland 36 and Mattawa West dunes (WDFW Heritage Database).

White-tailed Jackrabbit (*Lepus townsendii*) – This species occupies a variety of shrub-steppe habitats (Johnson and Cassidy 1997). It has been observed in the Juniper Dunes system (WDFW Heritage database).

Insects – Arthropod surveys conducted on the Hanford Central and Wahluke dunes in the last decade have found invertebrate fauna distinct from other areas of the Hanford Site and likely many of the dune taxa are limited outside the Hanford Site (Zack et al. 2003). At least four species new to science have been discovered. Further inventory of the dune habitats on the Hanford Site is recommended, as are surveys of other sand dune systems (R. Zack, pers. comm.). Entomological surveys of sand dunes in other states have found unique, often endemic groups of beetles (Coleoptera), true bugs (Hemiptera), and grasshoppers and crickets (Orthoptera) (Rust 1986).

Moths and Butterflies - Order Lepidoptera

Four new species of moths were discovered on Hanford Central and Wahluke dunes including species of *Arenoscythris* (Scythrididae) and *Copablepharon* (Noctuidae) (Zack et al 2003). Wahluke and Hanford Central dunes each had a unique species of *Arenoscythris*. These species fly only a few inches over the substrate. The fact that distinct species were found on each dune suggests that ecological separation of these dunes may have been for an extended period of time (Zack et al. 2003). The noctuid moth, *Protogygia comstocki* (Noctuidae), was collected for the first time in Washington since the 1950s at the Wahluke dune. This may represent one of the few remaining populations in Washington (Zack et al. 2003). Other species of interest may be found with additional survey work (Zack et al. 2003).

Beetles - Order Coleoptera

Columbia River Tiger Beetle (*Cicindela columbica*) – The historical range of this species includes Idaho, Washington and Oregon. Extant occurrences are known only from Idaho. In Washington, the species occurred on sandbars and dunes along the banks of the

Columbia River (Freitag 1999). Surveys in 1995 along the Columbia and Snake rivers failed to detect this species (Bartels 1995). Habitat loss in many areas resulted from dam construction. Systematic surveys in all suitable habitats on the Columbia and Snake rivers is needed to determine if any populations persist in Washington.

Bees, Wasps and Ants - Order Hymenoptera

Perdita similis pascoensis is a rare Columbia Basin endemic bee collected once in 1904 at Pasco, Washington, Franklin County (Tepedino and Griswold 1995). The habitat type was Pinyon-Juniper Woodland. The only remaining Juniper woodland on sand in Washington is on Juniper Dunes. Other juniper stands are located in Klicktat County. Tepedino and Griswold (1995) recommend that this species should be a very high research priority.

Columbia Basin sand dunes have a rich and distinctive bee fauna (Tepedino and Griswold 1995). Tepedino and Griswold (1995) recommend that this habitat be given priority for surveys because they are areas of species richness with high degrees of endemism and because significant threats from recreational vehicle use reduce floral resources and destroy nest sites. The sand dunes serve as pollinator reservoirs important for floral maintenance on adjacent lands (Tepedino and Griswold 1995).

Bees collected at the Hanford Site in 2002-2003 are still being processed (Zack et al. 2003). New records and rare species are expected (Pabst 1994). The fact that wild bees are the most common Hymenopterans at the site was significant in comparison to most areas where the introduced honeybee is most common (Zack et al. 2003).

D. Trends

The total extent of inland sand dune systems has declined from approximately 448,177 acres in the early 1970s to 106,953 ac by 2006, a loss of 76% (Appendix II). Dune systems wholly or partially on federal lands experienced a similar degree of loss, decreasing 78% from an historical extent of 422,217 total acres to a current extent of 93,589 acres (Fig. 20)**.**

Historically, the largest individual systems included the Hanford Central Dunes (94,011 ac) in Benton County, the Juniper Dunes (95,681 ac) in Franklin County and the Moses Lake Dunes (128,116 ac) in Grant county. Significant dune systems or concentrations of smaller systems were also located in Walla Walla County (39,261 ac), northwestern Franklin County (46,796 ac), southeastern Grant County (18,914 ac) and southern Benton County (5,811 ac).

Approximately 35% of the loss detected in 2006 was due to stabilization by exotic species (Fig. 21); the rest was primarily due to agricultural conversion, development, and flooding behind reservoirs (Fig. 22). Prior to this project's "historical" baseline of the early 1970s dune stabilization was an objective of land managers, however, the extent of these efforts is not known.

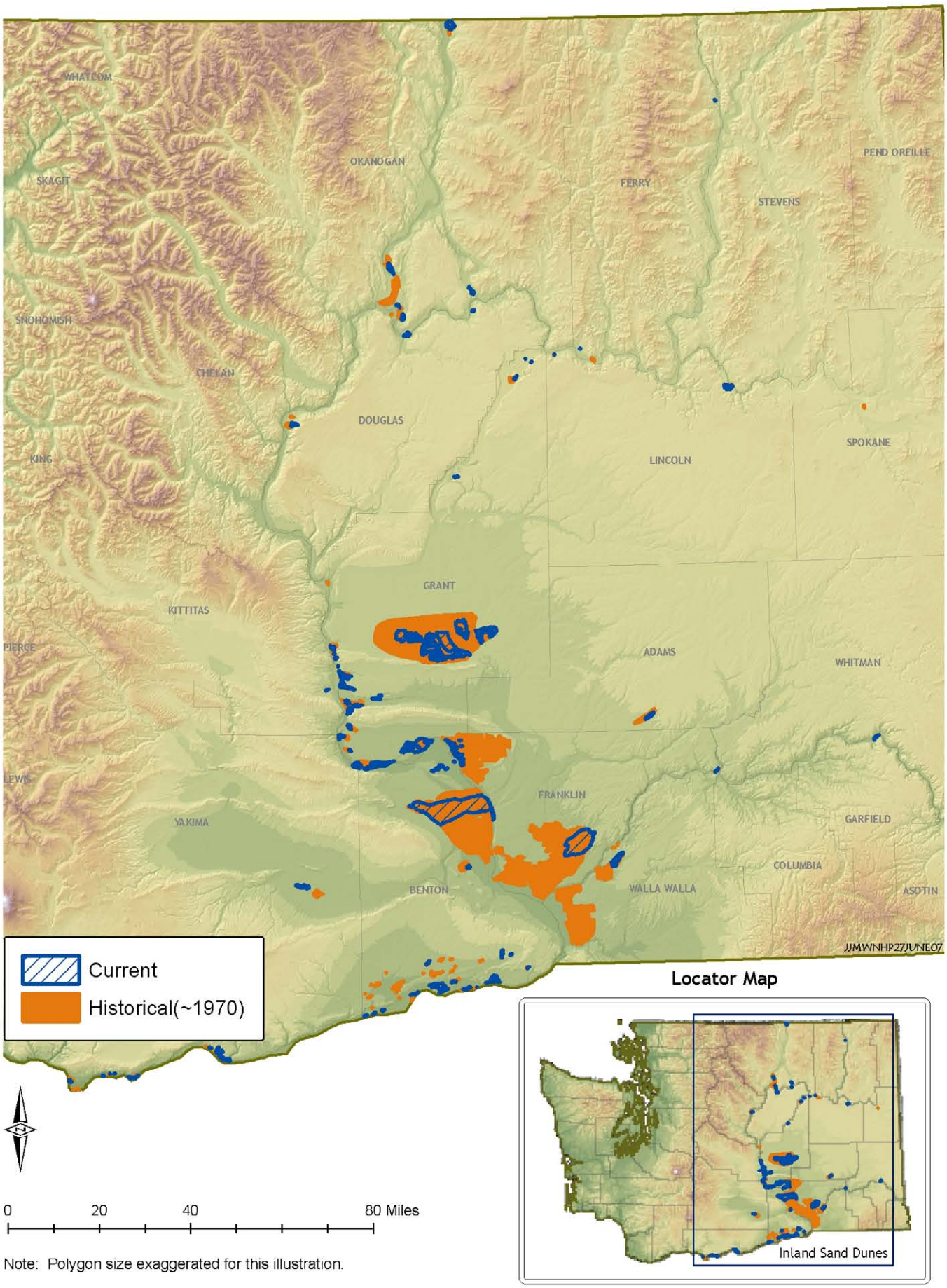


Figure 20. Current & Historical (~1970) Extent of Inland Sand Dunes

While the Central Hanford Dunes (38% loss), Juniper Dunes (84% loss) and Moses Lake Dunes (79% loss) all experienced significant declines, they still represent the largest inland dune systems in eastern Washington. Large portions of the historical Moses Lake dune field have been flooded behind O'Sullivan Dam in Grant County. Hanford Central is the only remaining system that has not been fragmented by agricultural conversion, urban development or water inundation although it is increasingly becoming isolated by those same factors.

Within individual dune systems, there is a trend toward an overall decrease in the amount of active dune area and number of active dunes. The result is an abundance of the Grey rabbitbrush – Green rabbitbrush – Snow buckwheat and the Wyoming big sagebrush – Antelope bitterbrush community types with understories increasingly dominated by cheatgrass (*Bromus tectorum*). Few, diverse, "late successional" dune communities were observed with native bunchgrasses. In addition to inundation, water from adjacent irrigation is also increasing damage to dune systems. Raised water tables allows invasion of wetland and moist site plant species between open dunes that effectively isolates them as a functioning ecological dune system.

E. Demography

No relevant information for Washington sand dune ecological systems "demography" exists. Few studies addressing demographic issues for Washington's sand dune-obligate species have been conducted. A common western North American dune-obligate tenebrionid beetle, *Eusattus muricatus* occurs in Washington. Britten and Rust (1996) studied *E. muricatus* in the Great Basin and Mojave Deserts to develop a conservation strategy for sand dune-obligate organisms (Britten and Rust 1996). Fragmentation and isolation of sand dune systems will likely continue in Washington State, affecting species population sizes, dispersal, and genetic characteristics.

F. Other Ecological Considerations

To our knowledge, the work presented here is the first attempt to summarize information about the flora, fauna and ecology of Washington's inland sand dunes. The ephemeral nature and natural isolation of sand dune habitats may allow for rapid natural selection of sand dune-obligate species and populations (Rust 1986). Additional surveys for rare plants and animals, particularly insects, will most likely produce more species whose life history is restricted to sand dune environments.

Knowledge of fire effects on sand dune systems in Washington is limited to observation and extrapolation from other areas. In general, fires initiate eolian activity by reducing vegetation cover and its anchoring or stabilizing influence on sand stability (http://www.fs.fed.us/database/feis/). Burzlaff (1962) suggests that lack of fire leads to stabilization of dunes at the Nebraska sandhills. The degree and amount of blowing sand and dune movement following a fire depends on season, intensity and size of fire and reaction of vegetation. Vegetation response generally depends on climate, topography, soil moisture, site condition, timing of fire, propagule availabiity and severity of wind and blowing sand. Typically, fire in shrubsteppe ecosystems increases annual exotic plant abundance (Brown et al. 2000) which could have negative impacts on dune function.

IV. Conservation

A. Threats

1. Stabilization by invasive species
At this time, invasive species, primarily cheatgrass, are the greatest threat to sand dune systems in Washington. Sand dunes are dynamic systems that respond to climatic change (Gaylord and Stetler 1994, Helm 2003). The vegetated portions of dune systems increase during years with high precipitation and decrease during drought years. Increased native vegetation may not lead to complete stabilization, rather it creates anchored dunes with bare soil remaining between plants and some sand movement continues on the surface (Fig. 23). Cheatgrass invasion can completely alter these dynamic fluctuations by achieving densities that stop sand movement (Fig. 24). The cheatgrass can then increase to the point where it dominates the understory or forms dense mats of litter. Additional moisture from irrigation and other human sources facilitates these invasions.

2. Agriculture
Agricultural conversion continues to represent a significant threat to Washington inland sand dune systems (Fig. 22, 25). Until the 1970s, dune fields were not considered suitable for agriculture (Washington county soil survey information, US Department of Agriculture). The 1957 Walla Walla County Soil Survey (p. 61) lists Active dune land; Hezel-Quincy complex, eroded; Quincy fine sand, 30 to 60 percent slopes, eroded; and Qunicy-Duneland complex as "soils and land types that are too sandy for use other than recreational, watershed, wildlife habitat, or other nonagricultural uses." Changes in technology and the availability of water for irrigation have made dune lands suitable for agriculture. Today, irrigated crops on sandy soils and duneland include small grain, potatoes, corn, alfalfa and grasses (1987 Grant County Soil Survey). Sand dune habitat in the Mattawa area (Mattawa West dunes) is being converted to orchards (Fig. 26). "Virgin sandy land", isolated from established fruit orchards, is in demand for growing fruit rootstock (Lawyer Nursery Inc. Winter 2003-Spring 2004 newsletter).

Effects from adjacent irrigation are also significant. Higher moisture causes an increase in vegetation cover and alters the flora and dynamic patterns of sand movement. The result can be an increase in weedy species such as cheatgrass, Russian thistle, and Jim Hill mustard. In some areas, irrigation water flows through dunes causing erosion and transporting sand away from the dune (for example, Sand Hollow and Beverly dunes) (Fig. 27). Irrigation water can raise water tables to form ponds and wetlands within the dune system (for example, Moses Lake Dunes). Wetland species quickly invade these sites and may including trees and shrubs such as Russian-olive (*Elaeagnus angustifolia*) and willows (*Salix* spp.).

3. Off-road vehicles (ORVs)
ORV use is a threat to many of the sand dune systems. On the semi-stabilized and anchored portions of sand dune systems, ORV use damages and destroys vegetation and seedlings (Fig. 28). This can lead to increased erosion and compaction that may alter

vegetation, eliminating habitat for wildlife and plant species. The biological impact of off-road vehicle use on Washington's sand dune-associated species has not been studied. Intensive ORV use has been repeatedly cited in petitions to the US Fish and Wildlife Service (USFWS) and Bureau of Land Management (BLM) as a threat to rare endemic sand dune plant and animal species in other western states (for example, Andrew's Dunes Scarab, Peirson's milkvetch, Sand Mountain Pallid Blue Butterfly). The oft cited study by Luckenbach and Bury (1983) concluded that ORV activities in the Algodones Dunes (Imperial County, California) were highly detrimental to dune biota. Ecological impacts on insect, lizard and rodent species included removal of food and shelter, destruction of burrow systems and direct mortality. In Washington, unsanctioned ORV use was widespread wherever it was not prevented. Efforts are needed to determine the effects of ORV use on sand dune biota, resolve how these effects can be minimize and engage ORV enthusiasts in conservation efforts. Areas of Beverly, Moses Lake, and Juniper dunes allow designatec ORV use.

4. Intentional sand dune stabilization
For this conservation assessment, no attempt was made to determine the extent of where intentional stabilization was applied. Accounts concerning areas that were stabilized from the 1940s – 1960s such as "Grand Dalles" in the Dallesport area, were found during the project but were not verified. Schwendiman (1977) notes that Volga," a strain of Mammoth wildrye, (*Elymus giganteus* Vahl), selected for its vigor and rapid vegetative growth, was used to stabilize inland migrating sands in Washington since 1964. It was used by the Army Engineers, the Bureau of Reclamation, Soil Conservation Districts, and State Game Departments (now Washington Department of Fish and Wildlife). Recent attempts to deter sand movement were currently observed at two dune systems (Vernita Bridge and Wanapum North dunes). Hay bales were present adjacent to agricultural fields to block sand migration from the Sand Hollow South sand dune (Fig. 29). Tree rows were planted on private property adjacent to the Priest Rapids wildlife area (Mattawa West dune) (Fig. 30), and else where on this dune system, presumably to slow sand movement.

5. Conversion to residential lots
Residential properties are present on the Moses Lake, Mattawa West and Desert Aire sand dunes. During these surveys, unconverted lots were also for sale. Landscaping around these homes typically includes sand stabilizing trees, and other non-native plants and often lawns.

6. Mining activities
The mining operation at the Avery Dune covers most of the historical (1970s) extent of the dune. A Department of Transportation borrow pit was present at the northeast end of the Sand Hollow South Dune. The amount of sand removed, if any, is unknown.

7. Livestock grazing – Historically, the main issue regarding livestock grazing on sand dunes has been concern that poor grazing practices or overgrazing would lead to erosion (Washington State County Soil Surveys). The ecological impact of livestock grazing on Washington's sand dunes has not been directly addressed. Livestock may be vectors for

exotic plants species and overgrazing on adjacent shrub-steppe ecosystems may increase exotic species propagule pressure into dune systems. Other areas of investigation may include impact on rare plants, crushing of vertebrate and insect burrows and changes in shrub structure as it relates to shelter for native animals avoiding mid-day heat.

B. Conservation Objective – The Washington Natural Heritage Program recommends the following conservation objectives: 1) minimize or halt conversion or permanent damage to sand dune habitats on federal and state owned lands, 2) protect sand dune sites of significant conservation value and manage them for their unique features; 3) protect the associated rare plant and animal species from threats; 4) initiate research addressing sand dune stabilization by exotic species; and 5) address landscape level relationships and connectivity between these systems.

C. Selection of Management Areas – The following eight sand dune systems have been identified as having significant conservation value. The significance value is a combination of ecological condition, system size and landscape setting, as well as the presence and condition of rare species. This methodology is detailed in Appendix IV - Element Occurrence specifications for the PNW Inland Sand Dune Ecological System. Appendix V provides detailed information on Ecological Occurrence Ranks and Descriptions.

<u>Hanford Central Dunes</u>
County: Benton
Location: T12N R25E sec 23-25; T12N R26E sec 19-30, 32-36; T12N R27E sec 13-36; T12N R28E sec 7-9, 15-23, 26-35 ; T11N R26E sec; 1-3, 11-12, T11N R27E sec 3-7
Ownership: US Fish and Wildlife Service (Federal)

Conservation significance: The Hanford Central Dunes is the largest remaining sand dune system in Washington and the only one that has not been fragmented other than a powerline corridor. Natural processes are intact and the overall species diversity is high. To our knowledge, human disturbance over the last 70 years has been limited primarily to researchers.

Rare species: Coyote tobacco (*Nicotiana attenuata*), dwarf evening-primrose (*Camissonia pygmaea*), Thompson's sandwort (*Aremaria franklinii* var. *thompsonii*), gray cryptantha (*Cryptantha leucophaea*), Sagebrush Lizard (*Sceloporus graciosus)*, Black-tailed Jackrabbit (*Lepus californicus*), Townsend's Ground Squirrel (*Spermophilus townsendi townsendi*), Grasshopper Mouse (*Onychomys leucogaster*). Recently three new species of moths were discovered on Central Hanford including species of *Arenoscythris* (Scythrididae) and *Copablepharon* (Noctuidae) (Zack et al. 2003).

Issues: Stabilization by cheatgrass is occurring in some areas of the dune. If the most recent (February 2007) US Fish and Wildlife Preferred Alternative for the Hanford Monument is implemented, portions of the Hanford Central Dunes will be open to the public for the first time since the Hanford Site was established.

Recommendations:
We recommend a baseline inventory be conducted previous to allowing public access. Regular monitoring of the plant communities and rare species should take place at least every five years to determine the impact that public access has on the site and to review management options. Due to the size, ecological condition, and landscape context of this dune system, the site meets the criteria for Research Natural Area designation and should therefore be evaluated for its potential as an RNA. The Washington Natural Heritage Program will pursue this with the U.S. Fish and Wildlife Service.

Juniper Dunes Wilderness
County: Franklin
Location: T10-11N, R31-32
Ownership: Bureau of Land Management (Federal)

Conservation Significance: Juniper Dunes is a very large dune system where natural processes are intact and the overall species diversity is high. This is the only dune system in Washington with Juniper Woodlands.

Rare species: Gray cryptantha (*Cryptantha leucophaea*), Sagebrush Lizard (*Sceloporus graciosus*), Black-tailed Jackrabbit (*Lepus californicus*), White-tailed Jackrabbit (*Lepus townsendi*), Washington Ground Squirrel (*Spermophilus washingtoni*), Grasshopper Mouse (*Onychomys leucogaster*), Ord's Kangaroo Rat (*Dipodomys ordii).*

Issues: Within the area burned by the 1990s fire, lowlands exhibited very high exotic species cover (cheatgrass, Russian thistle and Jim Hill mustard) while uplands tended to remain stabilized by native grasses (curly bluegrass and Indian ricegrass). ORV use is permitted outside the wilderness area. The sands are apparently migrating to the northeast and will eventually move onto private property.

Recommendations:
Retain wilderness and Juniper Forest ACEC designation and update management plan to ensure future viability incorporating future dune migration. Conduct an inventory for a possible occurrence of the G2 (globally imperiled) sand lyme-grass association.

Delight Dunes
County: Adams
Location: T15N, R34E, sec 11, 14, 15, 21, 22, 23
Ownership: Private

Conservation significance: The vegetation at Delight Dunes is extremely diverse for an active-stable inland dune ecosystem and is unique in that regard within Washington State.

Documented rare species: Sagebrush Lizard (*Sceloporus graciosus*)

Issues: To our knowledge, rare plant and animal species (with the exception of a brief Sagebrush Lizard survey) have not been conducted on this dune system. ORV trails are

present. The presence of a Great Plains sand dune grass, prairie sandreed (*Calamovilfa longifolia*), presumably a vestige of an old dune stabilization effort, will present unique management challenges.

Recommendation: The WNHP plans to evaluate this site as a potential Natural Area Preserve for inclusion within the statewide system of natural areas.

Wanapum and Wanapum North Dunes
County: Grant
Location: T16N R23E Sections 10, 11, 12, 13.
Ownership: Bureau of Reclamation (Federal)

Conservation significance: This is a long, linear system of active dunes and stable sand sheets including a wide range of vegetation community types and qualities. These sand dune occurrences are in good ecological condition. The landscape context is good. Under current conditions, dune migration can continue to the southeast without causing problems on roads or agricultural lands. Wanapum North dune is of lower quality but has a gray cryptantha occurrence not identified to be present on the Wanapum Dune. These sand dunes may be important in providing connectivity for native species to the Sand Hollow and Beverly dune systems to the north and south.

Documented rare or obligate species: Gray cryptantha (*Cryptantha leucophaea*), Sagebrush Lizard (*Sceloporus graciosus*) and Black-tailed Jackrabbit (*Lepus californicus*).

Issues: Irrigation water moves through the northern Wanapum Dune in two places. Unsanctioned ORV use occurs on both dune systems.

Recommendations: WNHP is currently in the process of evaluating this site for possible Natural Area Preserve designation and inclusion within the statewide system of natural areas.

Wahluke Dunes
County: Franklin and Grant
Location: T14N R27E, sec 8-9, 11, 14-17, 21-22, 26-28, 34-36; T13N R27E sec 1-2
Ownership: US Fish and Wildlife Service (Federal), managed by Washington Department of Fish and Wildlife (State)

Conservation significance: This is a large dune system in good ecological condition with an active sand source. Overall species diversity across this system is high with most components of native diversity present. The only functional stage not present within this system was a significant amount of “native stabilized.” The landscape context is good. Sand migration is possible without causing significant issues with roads or agricultural land.

Rare or obligate species: Gray cryptantha (*Cryptantha leucophaea*), Sagebrush Lizard (*Sceloporus graciosus*), unique species of moth (*Arenoscythris* sp.) new to science and likely endemic to Wahluke dune.

Issues: Stabilization by cheatgrass and other weedy species in some areas of the dune.

Recommendations: Continued management for the natural processes and diversity of this system and a management designation for future protection. RNA designation should be considered.

Hanford Black Sand Dunes
County: Benton
Location: T13N R26E Sections 1, 11-12, 14; T13N R27E Sections 6-7
Ownership: United States Department of Energy, Hanford Site (Federal)

Conservation significance: The Hanford Black Sand Dunes have unique vegetation patterns not found elsewhere on Washington sand dunes. The active sands throughout the system support diverse spring annual communities. The dominance of black basalt sand suggests an origin different from Hanford Central Dunes.

Rare or obligate species: Rosy pussypaws (*Calyptridium roseum*), loeflingia *(Loeflingia squarrosa* var. *squarrosa),* Suksdorf's monkey-flower (*Mimulus suksdorfii*), Sagebrush Lizard (*Sceloporus graciosus*).

Issues: Stabilization by cheatgrass in some areas of the dune. The dune is bisected by a road.

Recommendations: Research Natural Area designation should be considered for this dune system. The Washington Natural Heritage Program will pursue this with the U.S. Fish and Wildlife Service.

Sentinel Butte Dunes
County: Grant
Location: T15N R23E Sections 10-12.
Ownership: Bureau of Land Management (Federal).

Conservation significance: This is an excellent example of the climbing dune type and contains a complex pattern of vegetation related to the varying terrain. Sand migration is possible without causing significant issues with roads or agricultural land.

Rare or obligate species: Gray cryptantha (*Cryptantha leucophaea*), Geyer's milk-Vetch (*Astragalus geyeri*), Sagebrush Lizard (*Sceloporus graciosus*)

Issues: The rather extensive ORV use in the vegetated areas is a threat to the rare species. Stabilization due to cheatgrass invasion is occurring in some areas of the lower dune.

Recommendations: Consider Sentinel Slope ACEC designation and increase management for natural features associated with dune system.

Wakefield Dunes
County: Okanogan County.
Location: T 31N R25E Sections 4, 5, 9.
Ownership: Colville Indian Reservation

Conservation significance: The Ponderosa pine/Antelope bitterbrush/Indian Rice Grass association (*Pinus ponderosa / Purshia tridentata / Achnatherum hymenoides* association) on this dune is globally rare (G1). Only three occurrences have been identified. The other occurrences are in Oregon.

Documented rare or obligate species: Sagebrush Lizard (*Sceloporus graciosus*)

Issues: Some conversion to agriculture and scattered residences have taken place at the northern end of the sand dune. A state highway bisects the dune system. Introduction of yucca (*Yucca flaccida*) has occurred in road cuts.

Recommendations: Consult with the Colville Nation regarding ecological significance of this dune system.

D. Management

Washington's inland sand dunes are composed of a mosaic of open sands and vegetated communities (i.e., functional stages; Appendix III) and are dynamic in nature. Management must account for the highly dynamic nature of dune systems. Sands migrate and vegetation communities shift naturally based on climatic variation. Activities that change the amount, structure and/or composition of vegetation can alter the dynamic process of sand movement and dune migration. A sand dune can become completely devoid of vegetation or completely stabilized by vegetation. In either extreme case, the complex mosaic of community types is changed along with the rare plant and animal species associated with those habitats. Management should promote a range of dune functional stages to maintain species diversity.

Both long-term and short-term issues need to be addressed in management planning. Long-term issues include projected trajectory and rate of movement of dune systems and effects of surrounding landscape conditions and use. Short-term issues must address exotic plant invasion and on-site activities, such as ORV use, that influence whole system functioning and destroy or alter particular species' habitat.

To conserve the natural dynamic function of the sand dune systems listed in the Management Areas section, activities that alter, damage, or destroy the vegetation should be prohibited or carefully managed.

V. Research, Inventory, and Monitoring Opportunities

Research Priorities: 1. Invasive species impact and control; 2. Restoration of dune systems; 3. Rare species demographics, especially distribution; 4. Complete floristic sampling of plant communities and their seral and environmental relationships to complete International Vegetation Classification; and 5) Research on the range of fire effects in sand dune systems, particularly addressing the response of annual exotic plant abundance and sand movement and stabilization.

Inventory – Insects and rare plants have been identified as high priority for inventory. Information on small mammals would also be beneficial. The sand dune systems listed in the Management Areas section are the highest priority for inventory. An inventory on the Hanford Central Dunes and at Juniper Dunes is needed to verify classification of the sand lyme-grass association, CEGL001563, (*Leymus flavescens*) and determine its extent in Washington.

Monitoring Opportunities – Sand dunes are considered sensitive indicators of climate change because they reflect overall moisture balance, degree of vegetation cover, and wind patterns. Establishing a monitoring system of sand dune field rate of movement and stabilization/destabilization with climate change will inform management of dune species and whole dune system. Dune systems are a confined, limited resource and are targeted for recreational use. Monitoring of recreational impacts, use levels, and public demand for recreational dune "resources" is needed.

VI. Adaptive Management

This conservation strategy should be revised in five years. Specifically, dune extent should be re-mapped and the general condition (weediness and rare species presence) of dune systems should be re-evaluated. More specific measures of the extent and location of dune functional stages in high conservation priority areas are needed to increase precision of detection of change in the internal dynamics of the systems. Coordinated research and monitoring by biologist and geologist or soil scientist on projected long-term fate of dunes needs to be included.

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Personal Communication

Dr. Richard Zack, Department of Entomology, Washington State University, Pullman, Washington

Appendices

Appendix I: Photographs (Figures 4-19, 21-30)

Sand Dune Geomorphology

Figure 4. Longitudinal dune (Frenchman Coulee Dunes, Grant County).

Figure 5. Barchan dunes, a type of transverse dune (Sand Hollow North Dunes, Grant County).

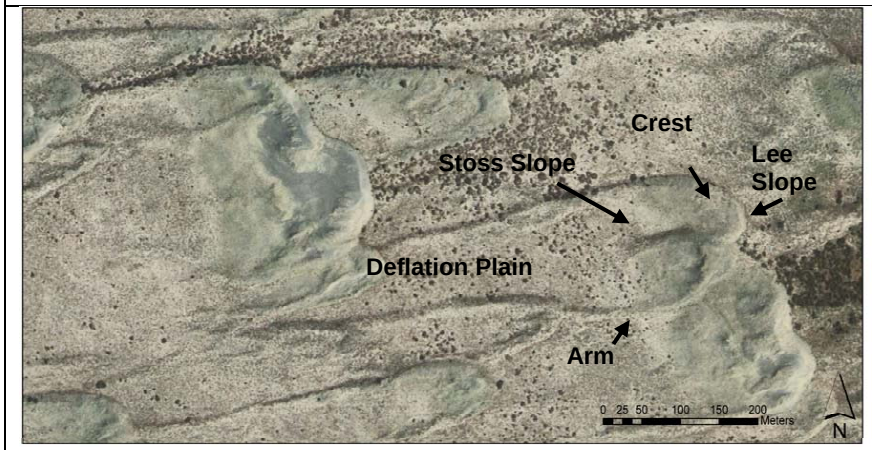

Figure 6. Parabolic dunes, aerial view (Moses Potholes North Dunes, Grant County).

Figure 7. Climbing dune (Frenchman Coulee Dunes, Grant County).

Sand Dune Geomorphology (cont.)

Figure 8. Open / Migrating dunes (Wahluke Dunes, Grant County).

Figure 9. Anchored dune (Sand Hollow South Dunes, Grant County).

Figure 10. Stabilized dunes (Juniper Dunes Wilderness, Franklin County).

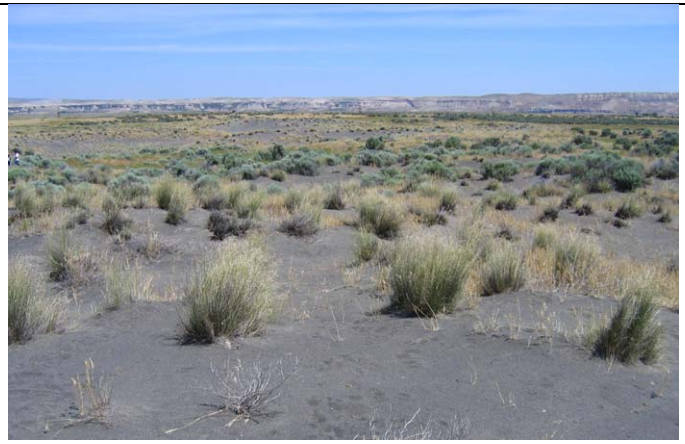

Figure 11. Fine scale vegetation mosaic (Hanford Black Sand Dunes, Grant County).

Community Types

Figure 12. Bugseed community type (*Corispermum* sp.*)* (Wanapum Dunes, Grant County).

Figure 13. Russian thistle – Jim Hill mustard community type (*Salsola kali – Sisymbrium altissimum*) (Sand Hollow South Dunes, Grant County).

Figure 14. Veiny dock community type (***Rumex venosus*)** (Beverly South Dunes, Grant County).

Figure 15. Indian ricegrass - Lemon scurfpea association (*Psoralidium lanceolatum – Achnatherum hymenoides*) (Vantage Bridge Dunes, Grant County).

Community Types (cont.)

Figure 16. Grey rabbitbrush – Green rabbitbrush – Snow buckwheat community type (*Ericameria nauseosa – Chrysothamnus viscidiflorus – Eriogonum niveum*) (Sentinel Butte Dunes, Grant County).

Figure 17. Wyoming big sagebrush – Antelope bitterbrush community type (*Artemisia tridentata* ssp. *wyomingensis - Purshia tridentate*) (Sand Hollow North Dunes, Grant County).

Figure 18. Needle-and-threadgrass community type **(***Hesperostipa comata*) (Frenchman Coulee Dunes, Grant County).

Figure 19. Ponderosa pine/Antelope bitterbrush/Indian ricegrass association (*Pinus ponderosa / Purshia tridentata /Achnatherum hymenoides*) (Wakefield Dunes, Colville Fed. Tribes Land, Okanogan County)

Trends

Figure 21. Dune stabilized by cheatgrass (foreground; Wahluke Dunes, Grant County)

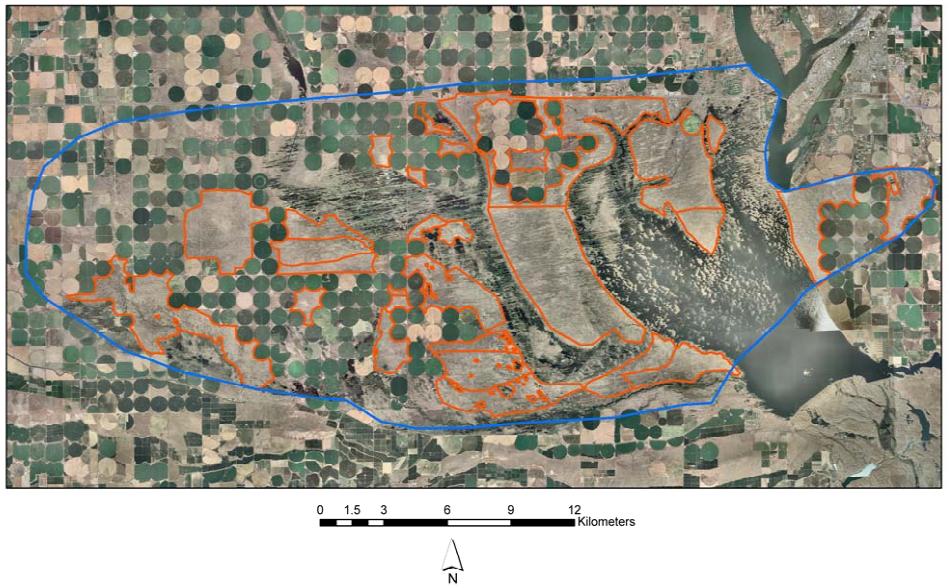

Figure 22. Dune fragmentation due to agricultural conversion and water inundation (Moses Lake Dunes near Potholes Reservoir, Grant County). Blue line represents dune system extent ~ early 1970s, orange line represents current dune system extent.

Threats

Figure 23. Bare ground between plants on native anchored dune (Mattawa West Dune, Grant County). Compare to Figure 24.

Figure 24. Invasive stabilized dunes (West Richland Dune, Benton County).

Figure 25. Agricultural conversion (Sand Hollow South Dunes, Grant County)

Figure 26. Dune conversion to orchard. Drifting sand sign still remains (Mattawa West Dune, Grant County).

Threats (cont.)

Figure 27. Irrigation run-off altering migrating dune front (aerial view) (Wanapum Dunes, Grant County).

Figure 28. ORV use (Moses East ORV Dunes, Grant County).

Figure 29. Line of hay bales used to slow sand movement (Sand Hollow South Dunes, Grant County).

Figure 30. Tree row to slow sand movement (Mattawa West Dunes, Grant County).

Appendix II: Current and Historical Dune System Extent

Across the Columbia Basin in Washington State, we located deposits of quaternary dune sands using Washington State Geology 1:100,000 maps (Stoffel 1991, Schuster 1997) and county soil surveys (1:24,000). Within areas containing quaternary sand dune deposits, we digitally mapped both the historical (ca 1970) and current (ca 2006) extents of active / stable dune fields using a geographic information system (GIS; ESRI ArcMap 9.1). The early 1970s were in a period when non-vegetated dune volumes at Hanford Dunes increased relative to 1948-1964 and 1978-1987 decreases (Gaylord and Stetler 1994). Precise historical dune field extent and location was determined from aerial photography (Washington Department of Natural Resources), which was not available for much of inland Washington until the early 1970s (Appendix Table A). Dune fields were defined to include all land with deposits of quaternary dune sands and evidence of sand movement. Evidence of sand movement included linear streaks and variation in color and / or topographic variation (crescents, linear rills, etc.) consistent with eolian sand movement. Land under agricultural, commercial or residential development or with evident water damage at the time of the photo was excluded.

Appendix Table A. Aerial photography flights used to determine historical dune extent.

Flight	Year	Color / BW	Scale
EC – 67	1967	Black and White	1:60,000
NE – 68	1968	Black and White	1:60,000
ST – 70	1970	Black and White	1:12,000
CB – H – 70	1970	Black and White	1:63,360
CH – 72	1972	Black and White	1:12,000
FO – 73	1973	Black and White	1:12,000
SC – C – 77	1977	Color	1:24,000

Based on Natural Heritage staff field surveys and/or recent digital orthophotos viewed between 1:20,000 and 1:50,000 scale, the current (ca 2006) condition of areas within historical dune fields was assessed. Lands were classified and mapped as developed (agricultural, commercial, flooded), active / stable dune field or exotic stabilized. When field surveys indicated complete sand stabilization by predominately exotic vegetation (i.e. *Bromus tectorum*) and the absence active dune processes we classified lands as exotic stabilized. The 2003 / 2004 color digital orthophotos from the WADNR were available for most of inland Washington. In select areas, however, including the Central Hanford Reservation and Hanford National Monument, we were limited to the use of 1993 black and white digital orthophotos.

Using GIS (ESRI ArcMap 9.1), we calculated historical (ca 1970) dune field extent and the current (ca 2006) extent of both active / stable dune fields and exotic stabilized dune fields (Appendix Table A, B).

Appendix Table B. Area of dune fields lost since ca 1970.

	Acres	**Percent of Historical Total**
Historical Extent	448,177	
Loss to Development	221,838	49.5
Loss to Exotic Stabilization	119,385	26.6
Total Loss	341,223	76.1

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Appendix III: Classification Methodology of Plant Community Types

Between June and July 2006 field surveys characterized 28 dune systems across the range of inland sand dunes in Washington State (Fig. 1). Variable sized reconnaissance plots were placed to capture the entire range of vegetation and un-vegetated variation within each system. The dominant species were recorded in order of abundance along with total cover of all vascular plant species, shrub species, herbaceous species and exotic species, the degree of sand activity, position on the dune, and degree of anthropogenic disturbance at time of survey. Each reconnaissance plot was also assigned an ecological rank based on Element Occurrence Specifications (EO SPECS) for inland sand dune communities (Appendix IV).

To identify distinct assemblages of species, that is, community types, from the reconnaissance plot (n = 294) dominant species data we used a combination of multivariate clustering and indirect ordination techniques. Agglomerative, hierarchical clustering (Wishart 1969) using Euclidean distance and Ward's linkage method (Ward 1963) produced a classification dendrogram with 0.6 percent chaining. "Pruning" the dendrogram at the level of 50% remaining (McCune and Grace 2002) resulted in 11 groupings. These groupings were assessed using an indirect ordination technique, Detrended Correspondence Analysis (DCA; Hill and Gauch 1980). All species were included in the DCA analysis and rare species were not down-weighted. Ten outlier plots were identified from the DCA ordination and subsequently removed. Comparison of the DCA ordination and the clustering dendrogram resulted re-classification of 45 reconnaissance plots and combination of the 11 groupings into 7 community types. A centroid ($\pm$ SD) was computed for each community type based on plot scores along DCA axes 1 and 2 (Appendix Fig. A). All analyses were run using PC-ORD 4.0 (McCune and Medford 1999). Appendix Table C provides basic species, cover and ecological rank summaries. Cover and constancy tables were not calculated for the community types because our variable sized reconnaissance plots do not provide the necessary species level data.

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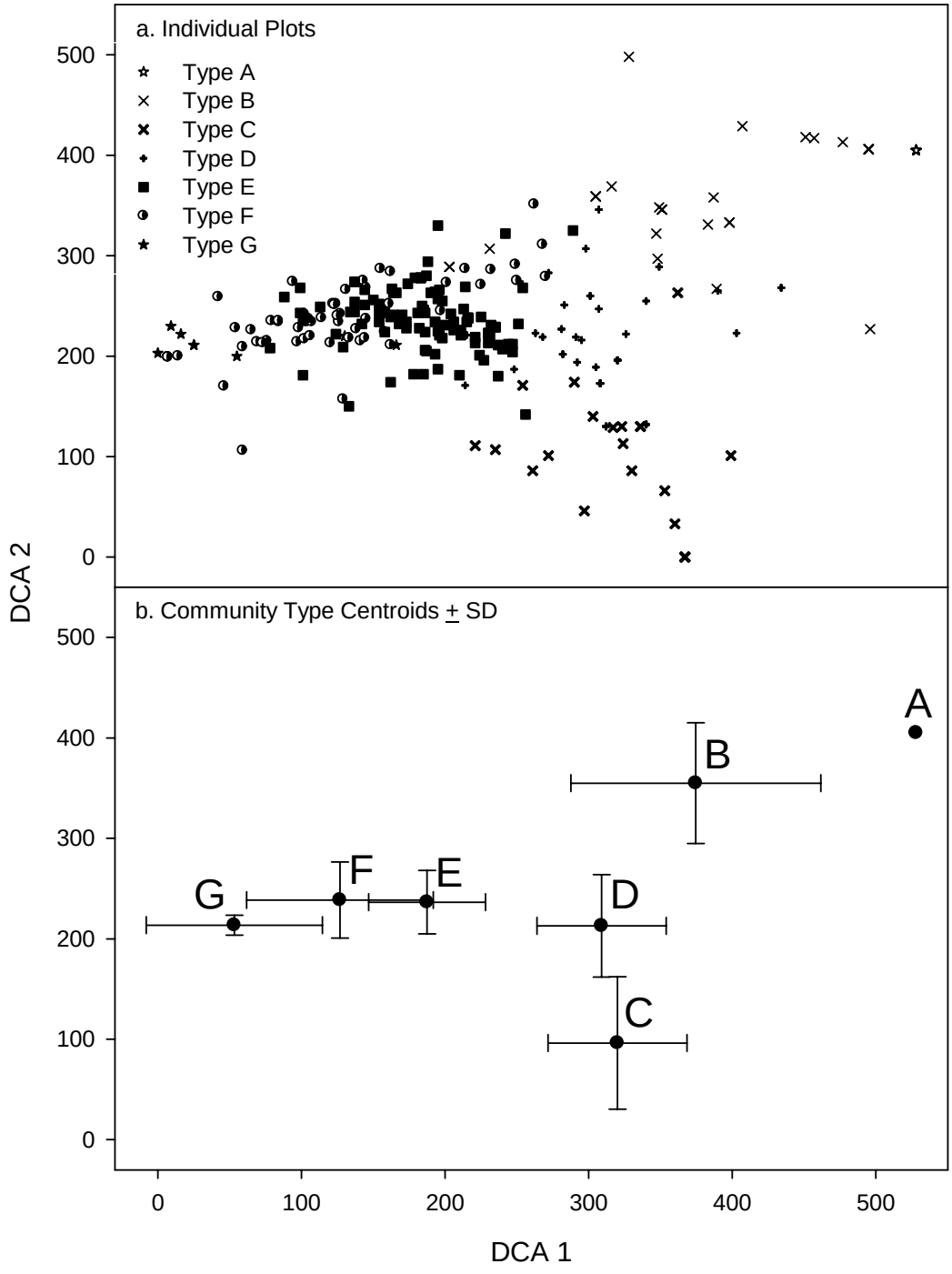

Appendix Figure A. DCA ordination of (a.) individual plots coded by community type and (b.) community type centroids (±1 SD).

Appendix Table C. Washington State inland sand dune community types. Summaries include the characteristic species, average cover of all vegetation (Total Cover), herbaceous species (Herb cover) and exotic species (Exotic cover) with 90% confidence intervals and the average ecological rank for each type. Average ecological rank not determined for type A due to discrepancies with EO SPECS.

	Community Type						
	A	**B**	**C**	**D**	**E**	**F**	**G**
Characteristic Species	*Corispermum* sp.	*Sisymbrium altissimum* *Salsola kali*	*Rumex venosus*	*Psoralidium lanceolatum* *Achnatherum hymenoides*	*Ericameria nauseosa* *Chrysothamnus viscidiflorus* *Eriogonum niveum*	*Artemisia tridentata* *Purshia tridentata*	*Hesperostipa comata*
Sample Size (*n*)	7	25	22	44	109	59	8
Total Cover (%)	5.9 ± 2.4	54.0 ± 6.5	34.5 ± 7.9	34.9 ± 6.7	60.8 ± 3.2	67.2 ± 4.1	49.4 ± 6.9
Herb Cover (%)	5.9 ± 2.4	53.8 ± 9.5	33.8 ± 7.5	34.5 ± 6.6	47.1 ± 3.1	48.8 ± 5.0	46.9 ± 17.4
Exotic Cover (%)	0.0	47.3 ± 10.4	9.6 ± 6.7	9.7 ± 3.3	27.6 ± 3.3	27.6 ± 4.5	11.0 ± 8.8
Average Ecological Rank	-	CD	BA	BA	CB	C	B

Appendix IV: EO specs for PNW Inland Sand Dune Ecological System

Subset of CES304.775 Inter-Mountain Basins Active and Stabilized Dune ecological system modified 03/12/2007 by Rex Crawford and Ryan Haugo.

SPECS.GROUP

These SPECS are intended to apply to sand dune systems in eastern Washington and adjacent Idaho and Oregon. Dune systems are identified by both a geological/historical record of active dune sands and dune topography which presently may be either vegetated or un-vegetated. This is a patch type system that occurs over a wide range of areas (1 to over 100,000 acres) and may be bounded by matrix ecological systems (i.e. soils and/or vegetation), water or cultivated lands.

This system includes multiple plant associations that represent a range of conditions from sparse (<20%) to moderate (> 60%) vegetation cover and are often found together in fine scale spatial mosaics. Plant species composition often relates to the degree of sand stabilization / vegetation cover and position on a particular dune. *Psoralidium lanceolatum,* an herb and *Achnatherum hymenoides,* a bunchgrass typically dominate the initial stages of stabilization but are also commonly found on dunes with a wide range of stabilization / vegetation. Prior to stabilization shrubs tended to be sparse while *Elymus lanceolatus*, a rhizomatous grass and herbs *Corispermum* sp., *Rumex venosus* and *Phacelia hastata* were common. With increased sand stabilization shrubs *Ericameria nauseosa, Chrysothamnus viscidiflorus, Purshia tridentata,* and *Artemisia tridentata* ssp. *wyomingensis* were often present to dominant. *Eriogonum niveum* was also common, especially when gravel was present. With shrubs, herbs *Oenothera pallida, Penstemon acuminatus, Phacelia hastata, Balsamorhiza careyana, Pteryxia terebinthina, Hymenopappus filifolius, Erigeron filifolius* and grass *Koeleria macrantha* were common but contributed little to total vegetation cover. *Pinus ponderosa* or *Juniperus occidentalis* trees can be members of dune vegetation. Exotic annuals, *Bromus tectorum, Salsola kali* and *Sisymbrium altissimum* are common and at times abundant. Where dunes have overridden or partially covered "normal" soil, *Pseudoroegneria spicata, Poa secunda* or other species are often present.

MINIMUM SIZE:

Washington Geology maps the size of dunes between 1 – 105,000 acres. Female home range of Sagebrush Lizard (*Sceloporus graciosus*) averaged 0.04 ha, and male 0.06 ha in Utah (Johnson and O'Neil 2001). Minimum of 100 lizards for a "viable" population, therefore, minimum size is 5 ha (12 ac).

EO SEPARATION:

EO Separation Distance: 1) substantial barriers to natural processes or species movement, including cultural vegetation (agriculture) or urban development greater than ½ mile wide 2) natural community from a different ecological system wider than one mile wide, 3) permanent water of any distance, or 4) major break in topography, soils, geology, etc.

SEPARATION JUSTIFICATION: Primary criteria to be considered are the reactions of endemic beetles and other sand dune insects to fragmentation, seed dispersal by dominant grasses and forbs,

and dispersal behavior and requirements of the Sagebrush Lizard. The separation distance for intervening natural or semi-natural communities assumes a distinct landscape difference that is not conducive to species migration.

EO TYPES

SSPECS AUTHORSHIP
Crawford, R.C. and Haugo, R.D.

SSPECS DATE
2007-02-12

RANK PROCEDURE: 1) condition, 2) size, 3) landscape context.
Note: Occurrence size criteria may not be as critical for patch communities as it is for matrix-forming communities. Factors such as the landscape context, current condition, and historical continuity may contribute more to the diversity of an occurrence than does occurrence size, although the species-area relationship still holds up for patch type communities.

EO RANK FACTOR (1st)

CONDITION.SPECS

Inland sand dune systems may contain individual dunes in 3 different functional stages: 1) open / migrating, 2) anchored, and 3) stabilized. The anchored and stabilized stages are considered either "native" or "exotic" based on the dominant (>50% of relative cover) vegetation.

Open / Migrating: Active sands on the dune surface and movement / migration of the dune as a whole. Dune movement / migration is often indicated by the presence of unstable slip faces (lee slopes). Minimal vegetation (< 20% total cover)

Anchored: Active sands present on dune surface, but movement / migration of the dune as a whole is inhibited by vegetation. Often found on the trailing arms of migrating parabolic dunes and on vegetated sand sheets.

Stabilized: Active sand no longer present as the dune surface is sealed with vegetation, cryptobiotic crusts, or volcanic ash.

A SPECS:

- Functional proportions of open/migrating, native anchored and native stabilized stages.
    - Dune functioning will be retained within a 50 year time frame
- Native dominated vegetation
- Complete representation of native plant diversity
- Insignificant human disturbance (ORV/grazing)

- "A" condition systems not currently found within Washington State

"B" Ranked Condition

- Two "non-exotic" functional stages are present:
    - Open/migrating and native anchored stages present
    - Exotic stabilized replacing native stabilized on <50% of total area.
- Disturbance minimally alters natural processes.
- Most native diversity present.

"C" Ranked Condition

- Single, natural functional stages (vestiges of other states may be present)
    - Exotic stabilized represents <50% of total area

OR

- Both migrating/barren and native anchored are present
    - Exotic stabilized replace native stabilized (>50% of total area)

- Disturbance significant enough to visibly alter natural processes

C/D Threshold

- C rank have potential for restoration over several decades, incomplete representation of native diversity
- D rank little or not potential for restoration because of extensive degradation, poor or no representation of native diversity

"D" Ranked Condition

- Highly disturbed due human disturbance (ORV) or exotic invasion such that restoration of functional proportions is unlikely over several decades. Absence of native species prevents native re-vegetation.
    - Intensive ORV Parks
    - Water inundation
    - Complete exotic stabilized/dominated

Justification for A-rated criteria: Sand dune systems are dependent on the ability to have a mosaic of non- vegetated shifting sands and sparsely vegetated sand dunes or swales. A-ranked occurrences have all functional stages, with native species composition, and the physical environment intact.

Justification for C/D threshold: C-ranked occurrences have potential for restoration over several decades. D-ranked occurrences have little or no potential for restoration because of extensive degradation.

EO RANK FACTOR (2nd)

Size:
A – rated size: Very large (>2,000 acres)
B – rated size: Large (1,000-2,000 acres)
C – rated size: Moderate (400 – 1,000 aces)
D – rated size: Small (<400 acres)

Justification for A-rated criteria: Sand dune systems are composed of a mosaic of open/migrating, anchored and stabilized functional stages. It would likely contain sufficient internal variability to capture characteristic biophysical gradients and retain natural geomorphic disturbance as well as recover from major sand movement. They are also adequately buffered from edge effects.

Justification for C/D threshold: C-ranked occurrences maintain a size that will allow for a complex structure allowing for several plant associations to occur, natural ecological processes to occur, and a minimum viable population of the insects. D-ranked occurrences are too small to remain viable with natural or unnatural changes to the surrounding landscape and are easily subject to loss of plant associations and their associated plants and animals.

Landscape Ranks

A-rated landscape context: Adjacent systems are unaltered by urban or agricultural uses (> 90% natural). Connectivity of adjacent systems allows natural ecological processes, e.g., sand deposition and wind dispersion to occur.

B-rated landscape context: Adjacent systems surrounding occurrence have moderate urban or agricultural alteration (60-90% natural) but retaining much connectivity. Few non-natural barriers present.

C-rated landscape context: Adjacent systems surrounding occurrence are fragmented by alteration (20 – 60% natural), with limited connectivity. Some non- natural barriers are present. There is a significant alternation of processes and/or composition, but easily restorable.

D-rated landscape context: Adjacent systems surrounding occurrence are mostly converted to agricultural or urban uses. Connectivity is severely hampered.

Justification for A-rated criteria: The sand dune complex is fully connected with natural intact vegetation and allowing for species migration and is fully buffered by a natural landscape.

Justification for C/D threshold: C-ranked occurrences have some limited buffering from invasive species. D-ranked occurrences have no buffering, and are subject to altered composition and invasive species.

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Appendix V: Ecological System Occurrence Ranks and Descriptions

Beverly South Dunes
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T15N, R23E, sec 1, 2; T16N, R23E, sec 36; T16N, R24E, sec 31

CONDITION / REPRESENTATIVENESS RANK: BC
LANDSCAPE RANK: B
SIZE RANK: D
EO RANK: CB
EO RANK DATE: 2/16/2007

This site had patches of active dunes with *Achnatherum hymenoides, Psoralidium lanceolatum, Rumex venosus* and little *Bromus tectorum*. Stabilized inner-dunes were characterized by *Chrysothamnus viscidiflorus* and *Ericameria nauseosa*, and moderate to heavy *B. tectorum*. *Artemisia tridentata ssp. wyomingensis* is adjacent along upper slope and mixes especially with colluvial material. Included were patches of dense *P. lanceolatum*. On the west end older, stabilized dunes have *A. hymenoides*. Numerous animal signs are present – deer, coyote, bird, beetle, and rodent tracks. Lee sides of active dunes moving into alkali basin with *Sarcobatus vermiculatus*. Little / no human disturbance was evident except a small, single ORV trail crossing the site and some tires that rolled down from upper slopes.

Delight Dunes
COUNTY NAME: Adams
TOWN RANGE / SECTION (+ ¼, ¼): T15N, R34E, sec 11, 14, 15, 21, 22, 23

CONDITION / REPRESENTATIVENESS RANK: AB
SIZE RANK: C
LANDSCAPE RANK: D
EO RANK: B
EO RANK DATE: 02/09/07

The vegetation at Delight Dunes was extremely diverse for an active-stable inland dune ecosystem and is unique within Washington State. *Artemisia tridentata* ssp. *tridentata* was common on stabilized dunes within the southwest portion of the site, however, the amount of cover varied tremendously. *Hesperostipa comata* was the most abundant grass on the southwest stabilized dunes with *Poa secunda* and *Festuca idahoensis* also common. Unusual for Washington state stabilized dunes, *Arctostaphylos uva-ursi*, *Purshia tridentata*, *Amelanchier alnifolia* and *Salvia dorrii* were also common and locally abundant. *P. tridentata* was found on lower slopes / inner-dunes while *A. alnifolia* abundant along the upper slopes and crests of active-stable dunes. *S.dorrii* was at times found with *F. idahoensis*. *Ericameria nauseosa*, *Arenaria franklinii* and *Koeleria*

macrantha were common on more sparsely vegetated active dunes. An introduced Great Plains grass, *Calamovilfa longifolia,* was locally abundant on the upper slopes crests of several dunes. *Bromus tectorum* and *Sisymbrium altissimum* were present throughout and more common on lower slopes and inner-dune areas. *B. tectorum* did not form mats of litter and overall exotic species cover was high only in select locations.

Large portions of the northeast section consisted of *A. tridentata* ssp. *tridentata* shrub-steppe with scattered *Chrysothamnus viscidiflorus* and common *H. comata, P. secunda* and *F. idahoensis*. Exotic cover (*B. tectorum*) was consistently low throughout. In the very northeast corner large (10-20 m height) active dunes were migrating to the northeast. *Hymenopappus filifolius* and *Elymus lanceolatus* were common on the sparsely vegetated stoss slopes and *Rumex venosus* and *Elymus lanceolatus* on steep stoss slopes. Large sections of open sand had no vegetation. Within the active dune were inclusions of *A. tridentata* ssp. *tridentata* on stable inner-dune areas. One open stoss and crest was completely dominated with *Equisetum hymenale*. The shrub-steppe of the northeast section constituted a large portion of the overall shrub-steppe on the landscape

ORV trails were found throughout the site. However, they appear to be little used and originated / ended at a single house.

Hanford Black Sand Dunes
COUNTY NAME: Benton
TOWN RANGE / SECTION (+ ¼, ¼): T13N, R26E sec1, 11-12, 14; T13R R27E sec 7-8

CONDITION / REPRESENTATIVENESS RANK: B
SIZE RANK: D
LANDSCAPE RANK: A
EO RANK: B
EO RANK DATE: 2/16/07

The Hanford Black Sands contained unique vegetation patterns not found elsewhere on Washington state dunes. The active sands throughout the system supported diverse spring annual communities. Most species could not be identified at the time of sampling due to summer desiccation. In addition to the native annuals, *Ambrosia* sp. was also common on the active sands.

Surrounding the open sands were *Purshia tridentata* dominated shrub lands in which the sand appeared to be active as well. *Ericameria nauseosa* and *Chrysothamnus viscidiflorus* were common associates of *P. tridentata* while *Artemisia tridentata* ssp. *wyomingensis* was less common. Beneath the shrubs *Bromus tectorum* was locally abundant in addition to the native annuals. Notable was the near complete absence of native bunchgrasses. Only *Achnatherum hymenoides* was present; to a small degree on the southern end of the site.

A paved road passes through the northern edge of the system, but otherwise the degree of human disturbance appears to be very low.

Hanford Central Dunes

COUNTY NAME: Benton
TOWN RANGE / SECTION (+ ¼, ¼): T12N R25E sec 23-25; T12N R26E sec 19-30, 32-36; T12N R27E sec 13- 36; T12N R28E sec 7-9, 15-23, 26-35 ; T11N R26E sec; 1-3, 11-12, T11N R27E sec 3-7

CONDITION / REPRESENTATIVENESS RANK: B
SIZE RANK: A
LANDSCAPE RANK: A
EO RANK: A
EO RANK DATE: 2/16/07

Across this large system of sand plains and active and stable dunes, vegetation composition ranges widely due to naturally occurring dune processes. Encompassing such a large area and range of conditions, overall species diversity was high.

Sparse *Purshia tridentata* shrub lands characterize the large, undulating sand plains that comprise much of the central and western half of the system. *Eriogonum niveum* was a common associate of *P. tridentata*. *Artemisia tridentata* ssp. *wyomingensis* was present but much less common. *Hesperostipa comata* and *Poa secunda* were common within the understory while exotics (*Bromus tectorum, Sisymbrium altissimum*) were locally dominant. *S. altissimum* was also dominant locally, commonly with very low shrub cover.

Small blowouts within the sand plain and active dunes to the east are characterized by the absence of *P. tridentata* and *A. tridentata* ssp. *wyomingensis*. *Ericameria nauseosa* and *E. niveum* were the only common shrub species. The *Leymus flavescens* association was common within the regions of active sand appearing with *Oenothera pallida, Achnatherum hymenoides*, *Psoralidium lanceolatum, Corispermum* sp., and *Rumex venosus*. *P. tridentata* was found however, within the small inner-dune areas between the large, active dunes.

Little human disturbance was evident; roads were present but appear to be infrequently used. The natural dune processes operate uninhibited.

Hanford Isolated Dunes
COUNTY NAME: Benton
TOWN RANGE / SECTION (+ ¼, ¼): T13N, R27E, sec 3-4

CONDITION / REPRESENTATIVENESS RANK: B
SIZE RANK: D
LANDSCAPE RANK: A

EO RANK: B
EO RANK DATE: 2/16/07

Plant composition was homogeneous across this small dune system. Much of the area was characterized by open, sandy flats dominated by small clumps of *Eriogonum niveum* interspersed with patches of *Achnatherum hymenoides*. Occasional pockets of *Ericameria nauseosa* were found and *Bromus tectorum* had only low cover values throughout.

Artemisia tridentata ssp. *wyomingensis* was not present and *Purshia tridentata* was found in only a small patch on the east end of the dune system.

Juniper Wilderness Dunes
COUNTY NAME: Franklin
TOWN RANGE / SECTION (+ ¼, ¼): T10-11N, R31-32,

CONDITION / REPRESENTATIVENESS RANK: B
SIZE RANK: A
LANDSCAPE RANK: B
EO RANK: BA
EO RANK DATE: 03/01/07

Composition varied widely across the surveyed area. Lowlands to the north in front of the active dunes were predominately *Artemisia tridentata* ssp. *wyomingensis* shrublands with characteristic sand species. Moving up the dunes, the shrub composition shifted with *Ericameria nauseosa - Chrysothamnus viscidiflorus* replacing the *A. tridentata* ssp. *wyomingensis*. Further up the dunes, shrubs were replaced with *Psoralidium lanceolatum* / *Elymus lanceolatus - Achnatherum hymenoides*. Stoss slopes were large active and free of vegetation. The active sands of dune crests were commonly vegetated with *Rumex venosus – P. lanceolatum* / *E. lanceolatus - A. hymenoides*. Several very large dunes were almost entirely free of vegetation.

Inner-dune areas and smaller, stabilized dunes to the south were rarely if ever flat and characterized by native grass dominance. *Poa secunda* was found throughout and was often very abundant. *A. hymenoides* was also found throughout but formed dense stands less frequently then did *P.secunda*. Across these areas woody species (*Purshia tridentata, A. tridentata* ssp. *wyomingensis*, *Juniperus occidentalis*) maintained a constantly low (~10%) cover. Exotics *Bromus tectorum* and *Lactuca serriola* were found throughout but did not commonly achieve high levels of cover. Occasionally *Ericameria nauseosa* formed denser shrublands, but with a similar composition of herbaceous species. Certain inner-dunes areas had a high cover of *P. tridentata*.

Individual *J. occidentalis* did not have appreciable impacts on overall vegetation composition; however, there was increased cover of *B. tectorum* and *L. serriola* directly below their canopy. *J. occidentalis* woodlands, found within the southern half of the EO had decreased cover of *P. secuna*

and *H. comata* and increased cover of *Balsamorhiza careyana* and *Calochortus macrocarpus*. *B. tectorm* cover also tended to be higher in the Juniper woodlands.

Across the 1990's fire, lowlands exhibited very high exotic species cover (*B. tectorum, Salsola kali, Sisymbrium altissimum*) while uplands tended to remain stabilized by native grasses (*P. secuna* and *H. comata*). *Pseudoroegneria spicata* was also locally abundant. Many *J. occidentalis* survived within burned areas.

Narrow trails were common throughout the dunes, but are more likely attributable to game than to humans. No other evidence of human disturbance was found within the wilderness boundaries.

Mattawa North Dunes
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T15N, R23E, sec 23, 26-27

CONDITION / REPRESENTATIVENESS RANK: B
SIZE RANK: D
LANDSCAPE RANK: D
EO RANK: C
EO RANK DATE: 2/09/07

Composition varied consistently with the degree of dune stabilization. Active sands above, below and climbing up the basalt face had little vegetation, mostly *Corispermum* sp. *Eriogonum niveum* and *Achnatherum hymenoides* dominate the semi-stabilized and stabilized dunes. Shrubs were largely absent below and on the basalt face. On the flat plain above the ridgeline shrubs (*Chrysothamnus viscidiflorus* and *Ericameria nauseosa*) were dominant along with *Eriogonum niveum* and *A. hymenoides*. *Bromus tectorum* was present throughout, but never >50% of herbaceous cover and was reduced with more active sands.

Where active sands were overriding rock outcroppings, additional species not present elsewhere in the system were found (*Salvia dorrii, Balsamorhiza careyana, Eriogonum sphaerocephalum*).

Mattawa West Dunes
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T14N, R23E, sec 4, 5

CONDITION / REPRESENTATIVENESS RANK: DC
SIZE RANK: D
LANDSCAPE RANK: CD
EO RANK: D
EO RANK DATE: 7/15/06

This system consisted almost entirely of sands anchored and stabilized with shrub steppe vegetation. Composition transitioned from *Eriogonum niveum* / *Achnatherum hymenoides* dominated with some shrubs (*Ericameria nauseosa, Purshia tridentata, Grayia spinosa*) to shrub dominated (*P. tridentata -Artemisia tridentata* ssp. *wyomingensis-Chrysothamnus viscidiflorus*) with open sand between shrubs. Within the *P. tridentata - Artemisia tridentata* ssp. *wyomingensis* shrub steppe, exotic cover (*Bromus tectorum*) was relatively low and patchy.

Within the eastern third of the system *B. tectorum* contributed ~90% of total vegetation cover, apparently the result of fire (many charred shrub stumps).

Small blowouts were present on the southern sections, but with little native vegetation

Moses Dodson East Dunes
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T18N, R26E, sec 14, 15, 22, 23, 25-28, 33-36; T17N, R26E, sec 1-4, 10-12; T17N, R27E, sec 6-8

CONDITION / REPRESENTATIVENESS RANK: CB
LANDSCAPE RANK: D
SIZE RANK: A
EO RANK: C
EO RANK DATE: 02/09/07

The Dodson dune system was a complex patchwork of active and stabilized dunes between agricultural fields and anthropogenic wetlands. Throughout species composition followed a consistent pattern. Upper stoss slopes tended to be active sands with little (some *Psoralidium lanceolatum*) to no vegetation. Dune crests were vegetated primarily with *Achnatherum hymenoides, P. lanceolatum* and *Rumex venosus*. *Elymus lanceolatus* was also common on dune crests and *Bromus tectorum* was present on anchored dunes. Active lee slopes were dominated by *R. venosus* while on less active dunes dense *B. tectorum* was found with *R. venosus*. *P. lanceolatum* and *Eriogonum niveum* were common on the anchored sand plains immediately following the dunes. *Ericameria nauseosa* and *Chrysothamnus viscidiflorus* increased with distance from the dune. Smaller, stabilized dunes were dominated by *P. lanceolatum* and *E. niveum* with *A. hymenoides*.

Purshia tridentata - Artemisia tridentata ssp. wyomingensis shrub-steppe dominated stabilized inner dune areas, all with sandy soils. *C. viscidiflorus* and *E. nauseosa* were also found throughout in the shrub-steppe inner dunes. Mat forming *B. tectorum* was common throughout. *Hesperostipa comata* and *Poa secunda* were both locally abundant. Species diversity was moderate on the stabilized inner dunes, often limited by *B. tectorum.*

Moses I-Road Dunes
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T18N, R25, sec 9-11, 14-16, 21-23

CONDITION / REPRESENTATIVENESS RANK: C
SIZE RANK: A
LANDSCAPE RANK: D
EO RANK: C
EO RANK DATE: 6/06/2006

This site consisted primarily of small dunes stabilized by native vegetation. Shrub cover was high throughout much of the site. Lower elevations were commonly dominated by *Artemisia tridentata* var. *wyomingensis* while *Chrysothamnus viscidiflorus* and *Ericameria nauseosa* were more common in elevated locations. Cover of *Bromus tectorum* ranged from low to high amongst the shrubs, but is rarely mat forming. A range of herbaceous species were found throughout the shrub-dominated areas. Stoss slopes and small blowouts (<10% of total area) provided a break in the shrub matrix. Along the southern half of the site, large areas with greatly reduced shrub cover were found, dominated by *Hesperostipa comata* and *Psoralidium lanceolatum*. The cause of this variation is unclear. However, vehicle tracks were abundant and the southern half displayed indications of recent grazing. Observed vegetation patterns may be a response to past human activities.

Moses Potholes North Dunes
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T18N, R26E, sec 12-13, 24; T18N, R27E, sec 7-8, 17-21, 27-34; T17N, R27E, sec 3-5

CONDITION / REPRESENTATIVENESS RANK: C
LANDSCAPE RANK: D
SIZE RANK: A
EO RANK: C
EO RANK DATE: 02/27/07

The northern half of the system contained individual dunes located within a homogeneous matrix with low cover of *Ericameria nauseosa* and *Chrysothamnus viscidiflorus* and high cover of mat forming *Bromus tectorum*. *Purshia tridentata* was very infrequent. Smaller dunes were also dominated by *B. tectorum*, along with the lee slopes of large dunes. Patches of native vegetation were limited to the stoss slopes and tops of large dunes. Common herbs included *Psoralidium lanceolatum*, *Phacelia hastata*, and *Eriogonum niveum*. Grasses *Hesperostipa comata*, *Achnatherum hymenoides* and *Elymus lanceolatus* were all present along tops of large dunes, often associated with active sands (a small proportion of the overall system). No direct evidence of human disturbance was evident on the dunes. However, signs of recent grazing were observed on surrounding landscape with no physical barriers to prevent grazing within the dunes. The southern

half of the system consisted of an active dune field. Large, active dunes tended to be free of exotic species and had little vegetation on the upper stoss slopes. Both lower stoss slopes and dune crests were dominated by *P. lanceolatum, A. hymenoides* and *E. lanceolatus*. *P. lanceolatum* was less dense on dune crests. On smaller, stabilized dunes *E. nauseosa* and *B. tectorum* were also common. The majority of inner-dune vegetation had a moderate to high (30-70%) cover of *E. nauseosa* with varying levels of *B. tectorum* and *P. lanceolatum* in the understory. Inner-dune vegetation within the SE corner of the site tended to have lower exotic cover. Other sections were dominated by *P. tridentata* with dense *B. tectorum* in the understory. Throughout the southern half of the system were small wetlands dominated by exotic species.

Moses Potholes South Dunes
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T17N, R27E, sec 1-4, 9-12; T17N, R28E, sec 6; T18N, R27E, sec 35

CONDITION / REPRESENTATIVENESS RANK: CB
LANDSCAPE RANK: D
SIZE RANK: A
EO RANK: C
EO RANK DATE: 02/09/07

A consistent pattern of vegetation was found on the multiple active and stabilized dunes. Upper stoss slopes tended to have active sands with little or no vegetation. Dune crests were vegetated primarily with *Achnatherum hymenoides, Psoralidium lanceolatum* and *Rumex venosus*. *Elymus lanceolatus* was also common on dune crests and *Bromus tectorum* was present on more stabilized dunes. More active lee slopes were dominated by *Rumex* while on less active dunes dense *B. tectorum* was found with *R. venosus*. Sand plains immediately following the dunes were commonly vegetated with *P. lanceolatum* and *Eriogonum niveum*. *Ericameria nauseosa* and *Chrysothamnus viscidiflorus* increased with distance from the dune. Smaller, stabilized dunes were dominated by *P. lanceolatum* and *E. niveum* with *A. hymenoides* throughout.

Purshia tridentata dominated inner-dune sand plains with some *Artemisia tridentata* ssp. *wyomingensis, C. viscidiflorus E. nauseosa* and little to no *A. hymenoides*. Areas with decreased *Purshia* cover were characterized by increased *A. hymenoides* and mats of *B. tectorum* litter.

Priest Rapids Dunes
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T13N, R23E, sec 1-2, 11-12; T13N, R24E, sec 6-7

CONDITION / REPRESENTATIVENESS RANK: C
SIZE RANK: C
LANDSCAPE RANK: DC

EO RANK: C
EO RANK DATE: 02/09/07

Moderate changes in compositional changes occur across the system. The majority of active sands were found in northeast portion of the system. These were dominated by *Psoralidium lanceolatum* and *Corispermum* sp. along with *Achnatherum hymenoides*. *A. hymenoides* was also common in areas of active sand with greater shrub cover, commonly *Ericameria nauseosa, Chrysothamnus viscidiflorus* and /or *Purshia tridentata*.

The majority of the system was composed of flat shrub dominated sand plains. *E. nauseosa* was common throughout along with *P. tridentata, Artemisia tridentata* ssp. *wyomingensis,* and *C. viscidiflorus*. *Eriogonum niveum* was common in the understory along with *P. lanceolatum*. *Bromus tectorum* was constant on all but the active sands, often forming mats of litter. However, sections of bare sand/gravel were usually present along with a moderate diversity of herbaceous species.

East of the bisecting canal, *P. tridentata - E. nauseosa - C. viscidiflorus– A. tridentata* ssp. *wyomingensis,* shrublands dominated the flat sand plain. These shrubs were completely absent, however, from some sections dominated instead by *Eriogonum sphaerocephalum, Eriogonum microthecum, Salvia dorrii*. *B. tectorum* cover was moderate to high, yet bunches of *Pseudoroegneria spicata* were also found.

The southeast portion was dominated by anchored *P. tridentata - Eriogonum niveum* sandplains with varying amounts of *B. tectorum*. Again, gravel was present on bare sands, minimizing sand movement in small open patches.

Several moderate use ORV roads crossed through the site, but did not appear to influence dune processes. A large canal/wasteway dominated by exotics bisected the system originating at the Priest Rapids dam.

<u>Saddle Mountain Lake Dunes</u>
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T14N, R25E, sec 11-14, 22-24; T14N, R26E, sec 7-11, 15-21, 30

CONDITION / REPRESENTATIVENESS RANK: C
SIZE RANK: B
LANDSCAPE RANK: A
EO RANK: B
EO RANK DATE: 02/09/07

Across the system species composition was relatively consistent. *Achnatherum hymenoides* along with *Psoralidium lanceolatum* and *Eriogonum niveum* dominated the active and anchored dunes.

Ambrosia sp. and *Elymus lanceolatus* were common on more active sands while *Oenothera pallida* was found throughout. Exotics *Bromus tectorum, Sisymbrium altissimum* and *Salsola kali* were very common on stabilized dunes but decreased with increasing sand activity.

Sand plains, which comprise the majority of system, were by and large dominated by exotics (*B. tectorum* and *S. altissimum*). *A. hymenoides* was also common on the sand plains. Large areas contained a moderate shrub cover (*Chrysothamnus viscidiflorus, Ericameria nauseosa*) with dense exotic cover in the inner-shrub/understory. *Artemisia tridentata ssp. wyomingensis* were scattered throughout the sand plains.

A little used road cut through the NE corner of the system, otherwise little human disturbance was evident.

Sand Hollow North Dunes
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T17N, R23E, sec 26-28

CONDITION / REPRESENTATIVENESS RANK: C
LANDSCAPE RANK: C
SIZE RANK: D
EO RANK: C
EO RANK DATE: 02/09/2007

There was a consistent elevational pattern of vegetation pattern along this climbing dune system. The upper vegetated zone was at the very top of the climbing dune and just below the gorge wall and dominated by species such as the exotic *Bromus tectorum, Sisymbrium altissimum* and native *Amsinkia lycopsoides.* Some sections of the upper stoss slopes were, however, characterized by more native vegetation including *Achnatherum hymenoides*, *Psoralidium lanceolatum* and *Oenthera pallida*.

Below this upper vegetation zone, sands tended to be very active and contain little vegetation. With decreasing elevation along the lower stoss slopes there was a gradient from active sands with sparse *A. hymenoides* to stabilized sands with *P. lanceolatum*, light to heavy *B. tectorum* and occasional shrubs (*Ericameria nauseosa*).

On the undulating sand plain beneath the climbing dunes vegetation cover was consistently high with variable composition. *E. nauseosa* and *Chrysothamnus viscidiflorus* dominated shrub fields were common, while areas of very high (>70%) cover of dense *Artemisia tridentata* ssp. *wyomingensis* and *Grayia spinosa* were also present. Other sections of the sand plain had very little shrub cover and were instead dominated by *P. lanceolatum*. Throughout the sand plain, *B. tectorum* cover varied but was always present.

Sand Hollow South Dunes
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T27N, R23E, sec 33, 34, 35

CONDITION / REPRESENTATIVENESS RANK: C
SIZE RANK: C
LANDSCAPE RANK: DC
EO RANK: C
EO RANK DATE: 02/09/07

Vegetation was highly variable due to extremely active dune processes. Distinct and spreading monoculture patches of *Salsoa kali* and *Sisymbrium altissimum* with very little native vegetation (some *Achnatherum hymenoides*) were located within the open/mobile dunes on the eastern end of the system. Along with these open/mobile dunes were inclusions of the surrounding shrub communities (*Artemisia tridentata* ssp. *wyomingensis – Chrysothamnus viscidiflorus*) and over-run shrub communities (*A. tridentata* ssp. *wyomingensis – C. viscidiflorus* / *A. hymenoides - Hesperostipa comata*). In the *C. viscidiflorus* anchored shrub lands following the dunes there was a high cover of exotic *Bromus tectorum* in the understory.

Anchored and stabilized sand plains to further to the west had diverse shrub and herbaceous components with decreased exotic species cover. *A. tridentata* ssp. *wyomingensis, C. viscidiflorus, Ericameria nauseosa, Purshia tridentata* and *Grayia spinosa* were shrubs all commonly found with *Oenothera pallida, Achnatherum, Hesperostipa* and *Elymus elymoides* in the open understory. On the smaller, active dunes climbing the basalt formations *Rumex venosus* and *Corispermum* sp. were common. *Bromus tectorum* was found throughout the sand plain, but was not dominant and often had minimal (<15%) cover.

The very eastern end of the system was not surveyed but likely contained a mosaic of active sand and dwarf shrub scabland communities.

Sentinel Butte Dunes
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T15N, R23E, sec 2, 10-11

CONDITION / REPRESENTATIVENESS RANK: C
SIZE RANK: DC
LANDSCAPE RANK: C
EO RANK: C
EO RANK DATE: 02/09/2007

Complex patterns of vegetation produced by dunes climbing into varying terrain characterized this system. The sides and upper end of climbing dunes supported stabilized sand or overridden shrub communities of native species. Recently anchored sands were commonly vegetated with *Rumex venosus - Psoralidium lanceolatum / Elymus elymoides.* Overridden shrub communities appeared

along the gorge wall above the active dunes included *Chrysothamnus viscidiflorus – Ericameria nauseosa* at lower elevations and *Artemisia tridentata ssp. wyomingensis – Grayia spinosa* or *A. tridentata* ssp. *wyomingensis – Purshia tridentata* at slightly higher elevations. The *A. tridentata* ssp. *wyomingensis - G. spinosa* community was located at the mouth of a ravine and appeared to be sub-irrigated. Inclusions of rocky outcroppings were also characterized by either *A tridentata* ssp. *wyomingensis – P. tridentata* or *C. viscidiflorus – E. nauseosa* shrub communities. *Eriogonum sphaerocephalum* was also common with both shrub types. Cover of *Bromus tectorum* was light to moderate within the stabilized and overridden communities.

Vegetation was patchy within the matrix of active dunes. *P. lanceolatum, Achnatherum hymenoides, Eriogonum niveum, Phacelia hastata* and *C. viscidiflorus* were all common within the active dunes but with few discernable patterns. *B.tectorum* was locally heavy but limited in distribution. The sand plain below the dunes was stabilized with *P. lanceolatum* and moderate to heavy *B. tectorum.*

ORV tracks were found throughout the system and appeared to playing a major role in keeping the dunes open. The role of ORV impacts on the natural processes of erosion and deposition downwind of the ORV impacts were not obvious.

Vernita Bridge Dunes
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T14N, R24E, sec 34-35; T13N, R24E, sec 1-4, 8-11; T13N, R25E, sec 5-6; T14N, R25E, sec 32

CONDITION / REPRESENTATIVENESS RANK: C
SIZE RANK: A
LANDSCAPE RANK: DC
EO RANK: C
EO RANK DATE: 02/09/07

The dune system was largely characterized by a broad, flat, sandy plain with abundant *Eriogonum niveum* and *Achnatherum hymenoides*. *Ericameria nauseosa, Oenothera pallida* and occasionally *Chrysothamnus viscidiflorus* were also common on the sand plain. *Artemisia tridentata* ssp. *wyomingensis* and *Purshia tridentata* were scattered throughout. Small blowouts tended to be dominated by *A. hymenoides*. To the south and west, *P. tridentata* becomes more abundant. Exotic cover, primarily *Bromus tectorum* varied from moderate to heavy across the sand plain. Sandy substrates continued into the surrounding *A tridentata* ssp. *wyomingensis,* shrub-steppe communities, blurring the boundaries of the dune system.

Two small sections of active sands were included in the dune system. Small dunes (1 m height) were found within the sand plain and were characterized by large clumps of *Leymus racemosus*, a past, failed stabilization effort. Along the northern portion of the system, a small area of active, climbing sands largely contained exotic vegetation, *Salsola kali* and *Sisymbrium altissimum* along with native *Corispermum* sp. and *A. hymenoides.*

Wahluke Dunes
COUNTY NAME: Grant/Franklin
TOWN RANGE / SECTION (+ ¼, ¼): T14N R27E, sec 8-9, 11, 14-17, 21-22, 26-28, 34-36; T13N R27E sec 1-2

CONDITION / REPRESENTATIVENESS RANK: B
LANDSCAPE RANK: B
SIZE RANK: B
EO RANK: B
EO RANK DATE: 02/09/07
The eastern half the sand plain is largely dominated by shrubs *Artemisia tridentata* ssp. *wyomingensis* and *Ericameria nauseosa* with a consistently heavy cover of exotic *Bromus tectorum*. Small blowouts within the sand plain tended to be characterized by a *Chrysothamnus viscidiflorus* / *Psoralidium lanceolatum / Achnatherum hymenoides, Elymus lanceolatus* or very distinct *Hesperostipa comata* community. Moving west towards the large, stabilized dunes *A. tridentata* ssp. *wyomingensis* was largely replaced with *C. viscidiflorus - E. nauseosa.*

The active sections along the western edge of the system and atop the stabilized dunes were largely un-vegetated with small patches of *P. lanceolatum* and *Corispermum* sp. Composition within the active dunes tended to be more diverse and complex. *C. viscidiflorus, E. nauseosa*, and *A. hymenoides* were found throughout. Shrubs were limited in areas of active sands were *Rumex venosus* and *P. lanceolatum* were found along with *A. hymenoides*. *P. lanceolatum* dominated large sections of stabilized dune (stoss and crest). *Eriogonum niveum* was locally abundant within the stabilized dunes along with *Purshia tridentata* and *Salvia dorrii*.

Overall species diversity across this system was high with most/all native diversity present. The only functional stage not present within this system in significant amounts was native stabilized.

Wanapum Dunes
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T16N, R23E, sec 9, 10, 11, 13, 14, 15

CONDITION / REPRESENTATIVENESS RANK: B
LANDSCAPE RANK: BC
SIZE RANK: C
EO RANK: B
EO RANK DATE: 02/09/2007

This long, linear system of active dunes and stable sand sheets included a wide range of vegetation community types and qualities.

The extreme southeast end of the system contained active dunes extensively altered by agricultural water run-off. Exotic species dominated with dense *Salsola kali, Bromus tectorum, Lactuca serriola*. Moving to west, away from the influence of agricultural water were open/migrating dunes characterized by native *Achnatherum hymenoides* and *Corispermum* sp.

To the west of the active dunes was an anchored sand sheet characterized by a sparse, native dominated shrubland (10-30% shrub cover). The primary shrubs were *Artemisia tridentata* ssp. *wyomingensis* and *Ericameria nauseosa* with occasional *Chrysothamnus viscidiflorus* and *Purshia tridentata*. Vegetation between the shrubs was diverse but discontinuous. Natives *A. hymenoides, Elymus elymoides* and *Oenthera pallida* were common in the understory. Locally *A. tridentata* drops out with *A. hymenoides* and *E. nauseosa* dominating. *B.tectorum* was found throughout but was never abundant. ORV tracks were found across the shrubland and resulted in locally significant soil/sand disturbance.

Larger (to 3m height) active dunes were found in the middle of the system polygon. Exotics *S. kali* and *Ambrosia artemisiifolia* are common but never abundant. There was little vegetation on the stoss, crest or lee slopes of the dunes while *Rumex venosus* was abundant on dune arms.

The western end of the system was likely comprised of sand blowing up the steep slopes and basalt outcroppings of the Columbia Gorge. This end of the system was not directly surveyed. Comparison with nearby dune systems suggested a mosaic of *Artemisia tridentata-P. tridenata* / *A. hymenoides* communities on deeper, stabilized sand, *Artemisia rigida* on rocky outcroppings and *Rumex venosus –Corispermum* sp. - *A. hymenoides* on active sands was likely.

Wanapum North Dunes
COUNTY NAME: Grant
TOWN RANGE / SECTION (+ ¼, ¼): T16N, R23E, sec 3, 4

CONDITION / REPRESENTATIVENESS RANK: BC
LANDSCAPE RANK: BC
SIZE RANK: D
EO RANK: CB
EO RANK DATE: 7/20/06

This system contained complex compositional patterns produced by sand overriding *Artemisia tridentata* ssp. *wyomingensis – Purshia tridentata* and *Artemisia rigida* shrub steppe communities. Open/migrating and native anchored stages were present, but native stabilized was absent. Within anchored areas *Ericameria nauseosa, Chrysothamnus viscidiflorus,* and *A. tridentata* were common along with occasional *P. tridentata, Grayia spinosa*. Grasses *Elymus lanceolatus* and *Bromus tectorum* were common with occasional *Achnatherum hymenoides*. On basalt outcroppings *A. rigida* was the dominant shrub along with *Eriogonum sphaerocephalum* and *Salvia dorrii*. Areas of more open, migrating dunes were sparsely vegetated with *Psoralidium lanceolatum* and *A. hymenoides*.

Larger, active dunes characterized the upper-most plateau. *Rumex venosus, A. hymenoides* and *Ambrosia artemisiifolia* were most common species on the upper plateau. Shrub islands (*P. tridenata, C. viscidiflorus, A. tridentata*) were also present and appeared to being actively eroded away

A large ORV trail / sand road run through the middle of the system and appeared to be responsible for at least some of the open sands. Smaller ORV trails ran throughout along with a substantial amount of trash near Hwy 243.

Appendix VI: NatureServe Ecological System Definition

CES304.775 Inter-Mountain Basins Active and Stabilized Dunes

Spatial Scale & Pattern: Large Patch **Classification Confidence:** medium
Required Classifiers: Natural/Semi-natural, Non-vegetated (<10% vasc.), Upland
Diagnostic Classifiers: Dune (Landform), Dune field, Dune (Substrate), Temperate [Temperate Continental], Sand Soil Texture, Aridic, W-Landscape/High Intensity

Non-Diagnostic Classifiers: Lowland [Lowland], Shrubland (Shrub-dominated), Woody-Herbaceous, Dune (undifferentiated)

Concept Summary: This ecological system occurs in Intermountain West basins and is composed of unvegetated to moderately vegetated (<10-30% plant cover), active and stabilized dunes and sandsheets. Species occupying these environments are often adapted to shifting, coarse-textured substrates (usually quartz sand) and form patchy or open grasslands, shrublands or steppe, and occasionally woodlands. Vegetation varies and may be composed of *Achnatherum hymenoides, Artemisia filifolia, Artemisia tridentata ssp. tridentata, Atriplex canescens, Ephedra* spp., *Coleogyne ramosissima, Ericameria nauseosa, Leymus flavescens, Psoralidium lanceolatum, Purshia tridentata, Redfieldia flexuosa, Sporobolus airoides, Sarcobatus vermiculatus, Tetradymia tetrameres,* or *Tiquilia* spp. In the Centennial Valley of southwestern Montana, where the dunes are more stable, *Artemisia tridentata ssp. tridentata* and *Artemisia tripartita ssp. tripartita* can have moderate cover and are associated with *Hesperostipa comata* or *Festuca idahoensis* (in more mesic settings). Early-seral communities in these dunes are dominated by *Ericameria nauseosa* and *Hesperostipa comata.* Several rare plant species occur in the Centennial Valley dunes, and are associated with early-successional stages. These dunes are very similar to the St. Anthony dunes in Idaho.

DISTRIBUTION

Divisions: 304
TNC Ecoregions: 10:C, 11:C, 19:C, 6:C, 8:C
Subnations/Nations: AZ:c, CO:c, ID:c, MT:c, NM:p, NV:c, OR:c, UT:c, WA:c, WY:c

CONCEPT

Associations:

- Achnatherum hymenoides - Psoralidium lanceolatum Herbaceous Vegetation (G3Q, Indian Ricegrass - Lemon Scurf-pea Mixedgrass Prairie, CEGL001650)
- Achnatherum hymenoides - Sporobolus contractus Herbaceous Vegetation (G2G4, CEGL001652)
- Artemisia filifolia - Ephedra (torreyana, viridis) Shrubland (GNR, CEGL002786)
- Elymus lanceolatus - Phacelia hastata Herbaceous Vegetation (G2, CEGL001745)
- Ephedra torreyana - Achnatherum hymenoides Hummock Shrubland (GNR, CEGL005802)
- Ericameria nauseosa / Leymus flavescens / Psoralidium lanceolatum Shrubland (G1?, Grey Rabbitbrush / Sand Wildrye - Lanceleaf Scurfpea Shrubland, CEGL001329)
- Ericameria nauseosa Sand Deposit Sparse Vegetation [Provisional] (GNR, CEGL002980)
- Eriogonum leptocladon Sparse Herbaceous (GNR**,** CEGL002822)
- Leymus flavescens Herbaceous Vegetation (G2, CEGL001563)

- Pinus ponderosa / Achnatherum hymenoides Sparse Vegetation (G1, Ponderosa Pine / Indian Ricegrass, CEGL001490)
- Populus angustifolia Sand Dune Forest (G1, CEGL002643)
- Psorothamnus polydenius var. polydenius / Achnatherum hymenoides Shrubland (G3G4, CEGL001353)
- Purshia tridentata - Artemisia tridentata ssp. tridentata Shrubland (G1, Antelope Bitterbrush - Big Sagebrush, CEGL001054)
- Purshia tridentata - Ericameria nauseosa Shrubland (G1, Antelope Bitterbrush - Grey Rabbitbrush Shrubland, CEGL001056)
- Purshia tridentata / Achnatherum hymenoides Shrubland (G1, CEGL001058)
- Purshia tridentata / Prunus virginiana Shrubland (G1?, CEGL001060)
- Quercus harvardii var. tuckerii Shrubland (GNR, CEGL002486)
- Redbeds (Siltstone, Sandstone, Gypsum) Sparse Vegetation (GNR, Redbeds (Siltstone) Rock Outcrop, CEGL005261)
- Redfieldia flexuosa - (Psoralidium lanceolatum) Herbaceous Vegetation (G1?, CEGL002917)
- Sarcobatus vermiculatus Dune Shrubland (G5?, CEGL001364)
- Tetradymia tetrameres Dune Sparse Vegetation (G3Q, Cotton-thorn Dune Shrubland, CEGL002759)

SOURCES

References: Bowers 1982, Caicco and Wellner 1983, Fryberger 1990, Knight 1994, Pineada 1999

Last updated: 20 Apr 2006 **Stakeholders:** WCS

Concept Author: NatureServe Western Ecology Team **LeadResp:** WCS

Appendix VII: Vascular Plant List

Vascular plants listed with synonym and common name that were encountered in survey or used in community names.

Kartesz 1999	***Hitchcock and Cronquist 1973***	**Common Name**
Abronia mellifera	*Abronia mellifera*	white sandverbena, white abronia
Achillea millefolium	*Achillea millefolium*	yarrow
Achnatherum hymenoides	*Oryzopsis hymenoides*	Indian ricegrass
Agoseris heterophylla	*Agoseris heterophylla*	annual agoseris
Agropyron cristatum	*Agropyron cristatum*	crested wheatgrass
Ambrosia artemisiifolia	*Ambrosia artemisiifolia*	annual ragweed, Roman wormwood
Amelanchier alnifolia	*Amelanchier alnifolia*	western service berry
Amsinkia lycopsoides	*Amsinkia lycopsoides*	tarweed fiddleneck, bugloss fireweed
Antennaria dimorpha	*Antennaria dimorpha*	low pussy-toes
Arctostaphylos uva-ursi	*Arctostaphylos uva-ursi*	kinnikinnick, bearberry, sandberry
Arenaria franklinii	*Arenaria franklinii*	Franklin's sandwort
Aristida purpurea var. longiseta	*Aristida longiseta*	red threeawn
Artemisia rigida	*Artemisia rigida*	stiff sagebrush
Artemisia tridentata ssp. *wyomingensis*	*Artemisia tridentata* spp. *wyomingensis*	Wyoming big sagebrush
Artemisia tridentata var. tridentata	*Artemisia tridentata var. tridentata*	basin big sagebrush
Asclepias speciosa	*Asclepias speciosus*	showy milkweed, Greek milkweed
Balsamorhiza careyana	*Balsamorhiza careyana*	Carey's balsamroot
Betula occidentalis	*Betula occidentalis*	water birch
Bromus tectorum	*Bromus tectorum*	cheatgrass
Calamovilfa longifolia	*Calamovilfa longifolia*	prairie sandgrass
Calochortus macrocarpus	*Calochortus macrocarpus*	sagebrush mariposa, green-banded star-tulip
Castilleja thompsonii	*Castilleja thompsonii*	Thompson's paintbrush
Chaenactis douglasii	*Chaenactis douglasii*	hoary chaenactis, false-yarrow
Chrysothamnus viscidiflorus	*Chrysothamnus viscidiflorus*	green rabbitbrush
Cichorium intybus	*Cichorium intybus*	wild succory, blue-sailors
Comandra umbellata	*Comandra umbellata*	comandra
Conyza canadensis	*Conyza canadensis*	horseweed, Canada fleabane
Corispermum sp.	*Corispermum sp.*	bug weed
Crepis sp.	*Crepis sp.*	hawksbeard
Cryptantha leucophaea	*Cryptantha leucophaea*	gray cryptantha
Cryptantha sp.	*Cryptantha sp.*	cryptantha
Descurainia pinnata	*Descurainia pinnata*	western tansymustard
Elymus elymoides	*Sitanion hystrix*	bottlebrush squirreltail

Kartesz 1999	***Hitchcock and Cronquist 1973***	**Common Name**
Elymus lanceolatus	*Agropyron dasytachyum*	Thick-spiked wheatgrass
Equisetum hymenale	*Equisetum hymenale*	Dutch rush,common scouring-rush
Ericameria nauseosa	*Chrysothamnus nauseosus*	grey rabbitbrush, rubber rabbitbrush
Erigeron filifolius	*Erigeron filifolius*	thread-leaf fleabane
Erigeron sp.	*Erigeron sp.*	fleabane
Eriogonum heracleoides	*Eriogonoum herculoides*	Wyeth buckwheat, parsnip eriogonum
Eriogonum microthecum	*Eriogonum microthecium*	slenderbush buckwheat
Eriogonum niveum	*Eriogonum niveum*	snow buckwheat
Eriogonum sphaerocephalum	*Eriogonum sphaerocephalum*	round-headed eriogonum, rock buckwheat
Eriogonum strictum	*Eriogonum strictum*	strict buckwheat
Eriogonum vimineum	*Eriogonum viminenum*	broom buckwheat
Erodium cicutarium	*Erodium cicutarium*	alfilaria, filaree, clocks, crane's-bill, stork's-bill
Erysimum asperum	*Erysimum asperum*	sand-dwelling wallflower
Festuca idahoensis	*Festuca idahoensis*	Idaho fescue
Grayia spinosa	*Artiplex spinosa*	spiny hopsage
Hesperostipa comata	*Stipa comata*	needle-and-threadgrass
Heterotheca villosa	*Chrysopsis villosa*	hairy goldenaster
Holostemon umbellatum	*Holostemon umbellatum*	jagged chickweed
Hordeum sp.	*Hordeum sp.*	barley
Hymenopappus filifolius	*Hymenopappus filifolius*	Columbia cut-leaf
Ipomopsis minutiflora	*Gilia minutiflora*	small-flower skyrocket, small-flowered gilia
Juncus balticus	*Juncus balticus*	Baltic rush
Juniperus occidentalis	*Juniperus occidentalis*	western juniper
Koeleria macrantha	*Koeleria cristata*	Prairie Koeler's Grass, junegrass
Lactuca serriola	*Lactuca serriola*	prickly lettuce
Layia glandulosa	*Layia glandulosa*	white layia, white daisy tidytips
Leymus flavescens	*Elymus flavescens*	sand lyme Grass
Leymus racemosus	*Elymus giganteus*	Mammoth lyme Grass
Lupinus leucophyllus	*Lupine leucophyllus*	velvet lupine
Lupinus sp.	*Lupine sp.*	lupine
Machaeranthera canescens	*Machaeranthera canescens*	hoary aster
Maianthemum stellatum	*Smilicina stellata*	star-flowered Solomon's-Seal
Mentzelia laevicaulis	*Mentzelia laeviculmis*	blazing-star mentzelia
Oenothera pallida	*Oenothera pallida*	pale evening-primrose, white-stemed evening primrose
Opuntia sp.	*Opuntia sp.*	prickly-pear
Orthocarpus sp.	*Orthocarpus sp.*	owl-clover
Penstemon acuminatus	*Penstemon acuminatus*	sand-dune penstemon

Kartesz 1999	***Hitchcock and Cronquist 1973***	**Common Name**
Penstemon sp.	*Penstemon sp.*	penstemon
Phacelia hastata	*Phacelia hastata*	whiteleaf phacelia, silverleaf phacelia
Phacelia linearis	*Phacelia linearis*	threadleaf phacelia
Philadelphus lewisii	*Philadelphus lewisii*	mockorange, syringa
Phlox hoodii	*Phlox hoodii*	Hood's phlox
Phlox longifolia	*Phlox longifolia*	long-leaf phlox
Plantago patagonica	*Plantago patagonica*	Indian-wheat
Poa bulbosa	*Poa bulbosa*	bulbous bluegrass
Poa pratensis	*Poa pratensis*	Kentucky bluegrass
Poa secunda	*Poa juncifolia*	alkali bluegrass
Poa secunda	*Poa secunda*	curly bluegrass
Polygonum douglasii	*Polygonum douglasii*	knotweed
Populus balsamifera ssp. trichocarpa	*Populus tricarpa*	black cottonwood
Prunus virginiana	*Prunus virginiana*	common chokecherry
Pseudoroegneria spicata	*Agropyron spicatum*	bluebunch wheatgrass
Psoralidium lanceolatum	*Psoralea lanceolata*	lemon scurf pea; wild lemonweed
Pteryxia terebinthina	*Cymopterus terebinthinus*	turpentine wavewing
Purshia tridentata	*Purshia tridentata*	antelope bitterbrush
Ribes aureum	*Ribes aureum*	golden currant
Rosa sp	*Rosa sp*	rose
Rosa woodsii	*Rosa woodsii*	Woods rose
Rumex venosus	*Rumex venosus*	veiny dock
Salsola kali (= tragus)	*Salsola kali (= tragus)*	Russian thistle
Salvia dorrii	*Salvia dorrii*	gray ball sage
Sisymbrium altissimum	*Sisymbrium altissimum*	Jim Hill mustard, tumblemustard
Sporobolus cryptandrus	*Sporobolus cryptandrus*	sand dropseed
Stephanomeria sp.	*Stephanomeria sp.*	wirelettuce
Tetradymia spinosa	*Tetradymia spinosa*	gray horse-brush
Tragopogon dubius	*Tragopogon dubius*	yellow salsify
Vulpia sp.	*Vulpia sp.*	small fescue

References:

Hitchcock, C.L. and A. Cronquist. 1973. Flora of the Pacific Northwest. University of Washington Press. Seattle, Wa. 730p.

Kartesz, J.T. 1999. A synonymized checklist and atlas with biological attributes for the vascular flora of the United States, Canada, and Greenland. First edition *In*: Kartesz, J.T. and C.A. Meacham. *Synthesis of the North American flora* [computer program]. Version 1.0. North Carolina Botanical Garden: Chapel Hill, NC.

Appendix VIII: ArcPublisher GIS Information

ArcPublisher GIS information was created to accompany the Conservation Strategy for Washington State Inland Sand Dunes. This information was designed specifically for federal and state agencies to provide specific information pertaining to land management planning. Information included in the digital data includes locations of all Washington State inland sand dunes, assigned dune names, currently extent polygons, historical (ca. 1970s) extent polygons, ownership information, rare plant and animal species occurrences, community occurrences, and known threats. Details of attribute tables are described in the accompanying metadata file.