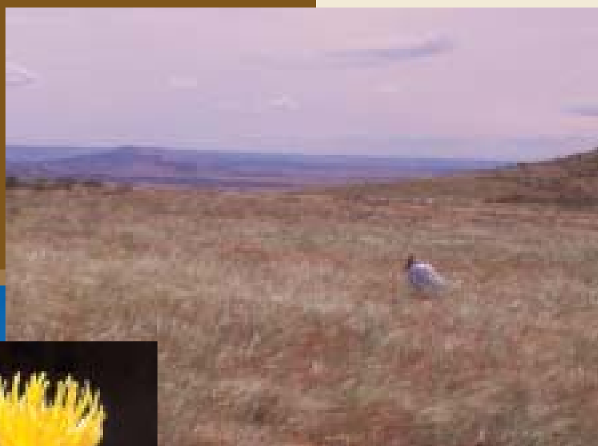
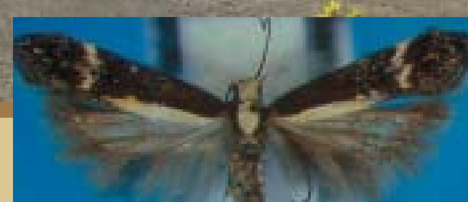
Biodiversity Studies of the Hanford Site 2002-2003





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Biodiversity Studies of the Hanford Site

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Executive Summary

Background

The Hanford Site is recognized as a critical reservoir of biodiversity for the semi-arid interior of the Pacific Northwest. Less than 40% of the great shrub-steppe ecosystem that once dominated the Columbia Plateau of Washington, Oregon, and Idaho has escaped development to date, and much of what remains unconverted exists in a highly degraded condition. The biological importance of the Hanford Site's relatively undisturbed shrub-steppe, riverine, and riparian habitats only increases as more and more of the surrounding landscape is converted to urban or agricultural uses.

A decade ago, the U.S. Department of Energy and The Nature Conservancy of Washington cooperated in conducting an inventory of the natural biological diversity of the Hanford Site. Between 1994 and 1998, researchers surveyed the length and breadth of the site, identifying, cataloging, and mapping the plants, animals, and biological communities of this special landscape. This work culminated with the publication of the volume *Biodiversity Inventory and Analysis of the Hanford Site: Final Report, 1994–1999* (Soll et al. 1999). The inventory documented occurrences of dozens of rare taxa, mapped critical biological resources such as plant communities, and documented concerns regarding invasive species. Although the study accomplished much of its mission and provided a great deal of valuable information, some questions remained unanswered, and new information provided by the report generated many new questions. The current work is intended to address some of these questions.

The Hanford Site and the Hanford Reach National Monument

The Hanford Site was established in 1943 for the Manhattan Project of the United States Department of Defense. The 586-square-mile site has been managed by the Department of Energy (DOE) and its predecessors since that time. In May 2000, 175,000 acres of the Hanford Site surrounding Central Hanford was designated as the Hanford Reach National Monument by proclamation of President William J. Clinton. DOE continues to hold title to Monument lands, is the primary manager for some portions of the Monument, and cooperates with USFWS in comanagement of other Monument Lands. Five management units of the Hanford Reach National Monument—the Fitzner-Eberhardt Arid Lands Ecology Reserve, the McGee Ranch–Riverlands Unit, the Saddle Mountain Unit, the Wahluke Unit, and the River Corridor Unit—encircle Central Hanford, which remains under DOE management.

The Hanford Site lies within the Columbia Basin, the hottest, driest part of Washington state (Franklin and Dyrness 1973). Annual precipitation varies with elevation, from as little as 16 cm at the lowest elevations (ca. 400 ft./122 m) up to 35 cm along the crest of Rattlesnake Mountain (3500 ft./1067 m). Major soil types include sandy soils, which are typical of lower elevations, as well as silt loams and stony loams. Upland vegetation, where undisturbed, is dominated by Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) and associated shrubs, perennial bunchgrasses, and forbs, especially on zonal, silt loam soils. Plant communities on sandy soils and stony loams may be characterized by bitterbrush (*Purshia tridentata*) and desert buckwheat (*Eriogonum*) species, respectively, along with associated grasses and forbs. Where disturbed, communities may be converted to annual grasslands dominated by cheatgrass (*Bromus tectorum*). Riparian areas are characterized by shrubs such as woods rose (*Rosa woodsii*), mock orange (*Philadelphus lewisii*), and traveler's joy (*Clematis ligusticifolia*), by occasional trees such as black cottonwood (*Populus trichocarpa*), quaking aspen (*P. tremuloides*) and willows (*Salix* spp.), and by moisture-loving graminids and forbs.

The Hanford Site and the Hanford Reach National Monument constitute a conservation site of national and regional importance (Soll et al. 1999). The landscape scale of the shrub-steppe ecosystem, the diversity of habitats varying with substrate, elevation, and other factors, the relatively undisturbed nature of much of the site, and the large relatively intact tracts of native shrub-steppe vegetation make the site a unique haven for native biodiversity of all kinds. Riverine and riparian habitats are equally important. The Monument encompasses most of the Hanford Reach. The 51-mile Reach is the last free-flowing non-tidal stretch of the Columbia River in the United States and is home to the last major salmon spawning grounds on the great river, as well as other aquatic resources.

Areas of Research

VEGETATION OF THE MCGEE RANCH–RIVERLANDS UNIT

The McGee Ranch–Riverlands Unit of the Hanford Reach National Monument occupies approximately 9,100 acres bounded by State Route 24 to the south and east, the Columbia River to the north, and private lands to the west. The unit is characterized by diverse soils and topography. The vascular plant communities are diverse as well. Topography, geology, fire history, and land-use history have combined to create a complex mosaic of vegetation types within the McGee Ranch–Riverlands Unit. This survey delineated 245 polygons of existing vegetation representing 17 major vegetation types. The greatest diversity in vegetation types occurred along the crest of Umtanum Ridge and adjacent areas. The gentle slopes down to the Cold Creek Valley south of Umtanum Ridge, along with the Riverlands area to the north, tended to have relatively more uniform vegetation, as reflected by the fewer, larger polygons identified there.

The McGee Ranch–Riverlands Unit contains large-scale examples of characteristic native shrub-steppe plant communities of regional importance. These high-quality plant communities include big sagebrush/needle-and-thread (*Artemisia tridentata/Stipa comata*), big sagebrush/bluebunch wheatgrass (*Artemisia tridentata/Pseudoroegneria spicata*), stiff sagebrush/Sandberg's bluegrass (*Artemisia rigida/Poa secunda*), big sagebrush-spiny hopsage/Sandberg's bluegrass (*Artemisia tridentata-Grayia spinosa/Poa secunda*), and winterfat/needle-and-thread – Sandberg's bluegrass (*Eurotia lanata/Stipa comata-Poa secunda*). These areas have been proposed for inclusion in Washington state's Natural Heritage database as Element Occurrences, representing native landscapes of significant conservation value. The Unit also contains some areas that are highly degraded, especially where agricultural activities and other developments have taken place in the past.

BIOLOGICAL SOIL CRUSTS OF THE HANFORD REACH NATIONAL MONUMENT

Biological soil crusts are complex groupings of organisms that occupy soil surfaces in many arid and semi-arid landscapes. The dominant organisms that comprise biological soil crusts are lichens, bryophytes (mostly mosses as well as a few liverworts), and cyanobacteria. These crusts perform a number of ecologically important roles that contribute to the production, hydrology, nutrient cycling, and other functions of arid land ecosystems, and are an important component of the biodiversity of these lands. In general these crusts are highly sensitive to disturbance. Biological soil crusts of the Hanford Reach National Monument are typically fragmented and in early to middle successional states resulting from the site's history of wildfire, domestic grazing, and anthropogenic activities.

The objectives of this study were to extend the biodiversity inventories of lichens and bryophytes begun during the 1990s on the Hanford Site and to begin investigations into the community associations these organisms form with each other and with vascular plant communities. The Hanford Reach National Monument has a rich diversity of lichens and mosses that are found in shrub steppe plant communities as well as in a variety of other habitats. Over 120 taxa of lichens and mosses were found within the Monument. The study found 54 lichen and 24 moss taxa growing as part of the terrestrial soil crust community. Twenty-six additional lichen taxa and five moss taxa were collected growing on rock outcrops, stones, or talus. Eleven lichen taxa are epiphytic on bark of shrubs and trees, and five species of mosses are associated with wetland habitats.

The study of soil crust communities and their relationships to environmental factors is at a very early stage. This study tentatively describes three late-successional soil crust communities found on the Monument. The *Trapeliopsis steppica – Bryoerythrophyllum columbianum* Community occurs on silt loam soils on the west side of the Monument; the *Syntrichia* spp. – *Caloplaca tominii* Community occurs on sandier soils on the North Slope; and the *Phaeorrhiza sareptana – Lecanora* spp. – *Encalypta rhaptocarpa* Community occurs on stony loams and lithosolic soils at higher elevations along Rattlesnake Mountain, the Rattlesnake Hills, and the Saddle Mountains.

We are still only beginning to learn about the extent of the biodiversity of biological soil crusts on the Hanford Site and to document their role in plant communities and ecosystem processes. Further research in this area is likely to uncover additional species and to build our understanding of the composition, structure, and function of biological soil crusts in arid ecosystems. At present, no proven techniques exist for the restoration of microbiotic crusts at a landscape scale. Therefore, all management activities related to restoration, invasive species, and fire management, along with general road and facilities maintenance, should be conducted in such a way as to minimize or eliminate any adverse effect on existing microbiotic crust.

RARE PLANTS

The results of rare plant surveys during the 1990s confirmed the Hanford Site as a critical area for the conservation of rare shrub-steppe, riparian, and aquatic plant taxa in Washington state. Demographic information is necessary to interpret population fluctuations and guide management activities in the conservation of rare species. However, little is known about the reproduction and other life history traits of Hanford's important rare plants. The objectives of rare plant studies during the 2002 field season were to collect and analyze data regarding the status and population dynamics of three of Hanford's rare plant taxa. Taxa that were targeted for study included the local endemics Umtanum desert buckwheat (*Eriogonum codium*), and White Bluffs bladderpod (*Lesquerella tuplashensis*), and the more widespread Columbia yellowcress (*Rorippa columbiae*). An additional objective was to survey potential habitats for the reintroduction of northern wormwood (*Artemisia campestris* ssp. *borealis* var. *wormskioldii*) along the Columbia River.

Since 1997 there has been a precipitous decline in the number of patches and in the number of stems of Columbia yellowcress on the Hanford Reach. In 2002 less than 200 stems were seen in an area which had supported at least 36,000 stems in 1992. Little or no sexual reproduction was observed during the last two monitoring years, 1998 and 2002. The cause of this population decline is not known with certainty but may be related to changes in river hydrology resulting from upstream flow control. Careful monitoring of this population over the next three years, along with an analysis of river flow regimes over the period of perceived decline, is strongly recommended.

Since population monitoring efforts for Umtanum desert buckwheat were initiated in 1997, only a single seedling has established successfully, while approximately 10% of monitored plants have suffered mortality. Because of the relatively short time that monitoring has been conducted, it is not clear if these observations indicate a true decline of the population or a situation of extremely episodic recruitment; however, the observed trends are cause for concern over this narrow endemic. Continued monitoring and protection of this sensitive species' habitat is strongly recommended.

The population size of White Bluffs bladderpod appears to fluctuate widely from year to year. Population size estimates based on monitoring efforts in 2002 represent the lowest levels since monitoring of this taxon began in 1997. However, this estimate falls within the possible surveyor error of 1997 estimates. Too little is known as yet regarding natural population fluctuations of this rare species to support predictions regarding population trends. A full monitoring once every three to five years is recommended to determine whether population numbers remain within acceptable limits. No immediate threat to the overall population is perceived; however, portions of the population are threatened by slumping of their White Bluffs habitat and by invasive species. These issues must be addressed in order to ensure the continuing viability of the sole population of this Hanford endemic.

No existing populations of northern wormwood were found in surveys along the Hanford Reach. However, a number of islands in the Reach exhibited habitats that were highly similar to offsite areas this rare taxon currently occupies. Areas that appeared most suitable were mapped as potential reintroduction sites for northern wormwood.

AQUATIC MACROINVERTEBRATES

The primary objective of this study was to survey and compile existing records of aquatic macroinvertebrates of the Hanford Reach, its local tributaries, and spring streams on the Hanford Reach National Monument in order to document changes to the taxa of aquatic macroinvertebrates in these environments over time. Additional sampling sought to assess the status of crayfish and western pearl mussels on the Hanford Reach and to assess the status of aquatic macroinvertebrate diversity in spring streams of the Arid Lands Ecology (ALE) Reserve in the aftermath of a landscape-scale wildfire in summer 2000.

Macroinvertebrate taxa new to the Hanford Site continue to be collected in the Hanford Reach and in the spring streams of the ALE Reserve. The macroinvertebrate fauna of the Hanford Reach has changed over the last 50 years, with certain taxa and taxonomic groups increasing while others decrease. Ephemeroptera (mayfly) diversity has increased; Plecoptera (stoneflies) have disappeared; Trichoptera (caddisfly) diversity and abundance remain high; Odonata (dragonflies and damselflies), Hemiptera (true bugs), Lepidoptera (butterflies and moths) and Coleoptera (beetles) are rare; and Diptera (fly) diversity remains relatively constant. More intensive sampling of the Hanford Reach and its shoreline is recommended to create a comprehensive inventory of macroinvertebrates for the Reach. Long-term, seasonal studies are needed to develop baseline data that can be used to monitor the effects of both natural and anthropogenic disturbances, such as unstable hydrological regimes, on benthic fauna over time.

Aquatic invertebrate diversity has changed over time in the spring streams of the ALE Reserve as well. Some historically collected taxa have not been collected in over a decade; however, previously uncollected taxa have been recorded as recently as 2000. Rattlesnake Spring was affected by the 2000 wildfire, with invertebrate diversity declining as a result of the deposit of large amounts of sediment and plant debris in the aftermath of the fire. Sampling in Benson, Snively, and Rattlesnake springs should occur periodically to document the status of invertebrate populations and to monitor recovery from the 2000 wildfire. Monitoring of stream morphology and chemistry can provide valuable baseline information to help assess the impacts of erosion and sedimentation and to interpret changes in invertebrate diversity and abundance in these spring channel ecosystems.The Pacific crayfish (*Pacifasticus leniusculus*) population on the Hanford Reach appears to be robust. However, the western pearl mussel (*Margaritinopsis falcata*) seems to have nearly disappeared from the Reach, where it was once abundant. An intensive survey for possible remnants of this once-large population is recommended. One introduced mollusk, the Asiatic clam (*Corbicula fluminea*) appears to be extremely abundant in the Hanford Reach. Impacts of the huge population of this mollusk on other benthic fauna are unknown.

TERRESTRIAL INVERTEBRATES

The primary objective of this study was to extend the entomological inventories of the 1990s regarding selected taxonomic groups, to extend the inventory to groups not previously examined, and to examine habitats on the Wahluke and Saddle Mountain Units that had not been sampled during previous studies.

The Hanford Site represents the closest approximation to a pre-European colonization insect fauna that can be found in Eastern Washington. Patterns of entomological diversity suggest a strong connection between the expanses of native vegetation and other natural habitat features on the Hanford Site and the predominantly native invertebrate fauna, compared to the introduced invertebrate fauna of the surrounding urban and agricultural landscape.

The 2002–2003 study collected and processed approximately 12,000 specimens of terrestrial invertebrates. To date, 376 species, representing approximately 50–60% of the insects collected, have been identified thus far, with the majority of identifications coming from the Lepidoptera (moths) and Coleoptera (beetles). Numerous species not previously collected at Hanford, especially in the orders Trichoptera (caddisflies) and Lepidoptera, have been added to the invertebrate fauna of the Hanford Site. Approximately 200–300 species are still awaiting identification. It is likely that it is from these specimens that the most significant finds will be made. Most of these specimens are in the hands of taxonomic experts. Groups with the highest percentages of unidentified specimens include Lepidoptera and Coleoptera while identifications for groups such as Siphonaptera (fleas) and Dermaptera (earwigs) are complete.

Several groups of insects appear to be associated with areas of extensive microbiotic soil crusts. The Hydracarina (mite) and Collembola (springtail) fauna represented significant portions of pit fall samples where the crust was intact and were virtually nonexistent in samples where the crust had been destroyed. The distribution of snow scorpionflies (*Boreus*: Mecoptera: Boreidae) exhibits the same contrast: The larvae of these small insects feed on mosses within the soil crust and are not found in areas where the crust has been degraded or destroyed. Intact shrub-steppe areas of the Hanford Site appear to be especially rich in this genus. During the 1990s four species of *Boreus* were collected on the ALE Reserve, making Hanford the only site known to the world authority on this taxonomic group from which four species have been recorded.

The sand dune habitats of Central Hanford and the Wahluke Slope exhibit an invertebrate fauna distinct from other areas of the site. Based on collections from dune habitats around the state, it appears that a number of these dune taxa are also limited outside the Hanford Site due to isolation of habitats and, perhaps, habitat degradation and conversion.

At the time of the publication of Soll et al. (1999), 1,536 species of terrestrial arthropods had been identified. Since that time another 143 species have been positively identified, making a total of 1,679 species. These additions include species identified after 1999 and those thus far identified from the 2002–2003 study. Although no species new to science have been added from the 2002–2003 study as yet, three new species have been identified from previous collections since Soll et al. (1999) for a total of 46 from Hanford studies over the last decade. The three new species include a scarab beetle (*Aphodius* sp.), a snow scorpionfly (*Boreus* sp.) and a parasitic wasp (*Macrocentrus shawi Ahlstrom*). The number of species new to Washington state, difficult to ascertain precisely because of the lack of catalogs and checklists, is estimated at 150–200 species.

Insects not only are important as organisms of biological study, but they also have economic importance as pests and beneficials. Entomological studies of the site continue to indicate that Hanford is unusual in its lack of pest species and in its abundance of native taxa. The native arthropod fauna of the Hanford Site provides one of the few remaining areas where potentially beneficial native insects may be sought and, perhaps, found. Insect diversity may also serve as an indicator of habitat condition, and Hanford can provide an excellent laboratory for studies of this nature. Areas of the Hanford Reach National Monument and Central Hanford should be considered for long-term entomological diversity studies.

INVASIVE PLANT SPECIES INVENTORY AND MANAGEMENT

Invasive plant species represent one of the most serious threats to the native biodiversity of the Hanford Site. Invasive plant species compete against and reduce habitat available for native plant species, alter ecosystem structure and function, disrupt food chains and other ecosystem characteristics vital to wildlife, and can dramatically alter key ecosystem processes such as hydrology, productivity, nutrient cycling, and fire regime. Noxious weed surveys in 2002 and 2003 confirmed the presence of 23 invasive plant species on the Hanford Reach National Monument, including three species that had not previously been documented on Monument lands. Overall, the inventory recorded more than 400 occurrences of invasive species, infesting more than 9000 acres (> 3600 ha) over all management units of the Monument. Diffuse knapweed (*Centaurea diffusa*) was the most widespread and abundant invasive plant species surveyed, infesting more than 3600 acres (> 1480 ha), just over 40% of the land area occupied by all invasive species. A number of other species of concern, such as Yellow starthistle (*Centaurea solstitialis*), rush skeletonweed (*Chondrilla juncea*), saltcedar (*Tamarix* spp.), Russian knapweed (*Acroptilon repens*), whitetop (Cardaria draba), and other species are widespread on the Monument. Several invasive species, such as dalmatian toadflax (*Linaria dalmatica*) and Scotch thistle (*Onopordum acanthium*), are presently known from only one or a few small colonies on the Monument. Several invasive species that have not yet been recorded on the Monument are present nearby on Central Hanford or elsewhere in the Columbia Basin. Invasive species that are already nearly ubiquitous, such as cheatgrass (*Bromus tectorum*), were not included in the inventory. The number of invasive species of concern, along with the size and complexity of the Monument landscape, present extreme challenges to managers of the Hanford Reach National Monument. To assist in maximizing the effectiveness of limited resources for invasive species management, a weed management plan for the Monument has been developed. The plan includes protocols prioritizing invasive plant species and infestated sites for treatment based on characteristics of the invasive species, the size of the infestation, and the proximity of the infestation to key conservation targets. A listing of highest priority treatment sites is included, along with a discussion of treatment options for each species based on weed management literature and the experience of local professionals . An integrated approach is recommended, utilizing manual, mechanical, and chemical means of control individually or in combination as appropriate depending on characteristics of the invasive species to be treated, the size of the infestation, and other factors. Ongoing, thorough monitoring is a critical element of the plan. An aggressive, coordinated weed management program will be necessary to adequately conserve the natural features that the Hanford Reach National Monument was designated to protect.

Conclusions

Biological studies continue to confirm Hanford's national and regional importance as a refuge for both rare and common species and communities that were once far more widespread in the inland Northwest. Biodiversity studies over the last decade have allowed us to learn much about the natural systems of the Hanford Site, and of the diverse array of native organisms that populate these systems and contibute to their natural processes. However, in many ways, our investigations have just begun to scratch the surface of the complex biology of this arid land. Studies of aquatic and terrestrial invertebrates and of biological soil crusts continue to uncover new species; our understanding of the function of these organisms in ecosystems is in its infancy. Our knowledge of rare plant population trends is severely limited by the short time period during which we have been able to study them; a much more long-term perspective is required to provide the information necessary to adequately manage these limited resources. Plant communities may change gradually in response to long-term fluctuations in climate and rapidly in response to episodic events such as wildfires and other disturbances. Invasive species populations are dynamic and will continue to pose a challenge for natural resource managers into the forseeable future, a challenge that will only increase with the increasing globalization of commerce. A strong commitment to ongoing monitoring programs to maintain up-to-date capabilities for assessment of the status of biological resources and the threats to those resources throughout the Hanford Site is highly recommended.

The biological inventories and associated studies conducted over the past decade have shown that every management unit of what is now the Hanford Reach National Monument, as well as Central Hanford, possesses important resources that contribute to the biodiversity of the site and the region. It is important that these biological values be given strong consideration by the U.S. Fish and Wildlife Service, the U.S. Department of Energy, and the engaged public in planning for the use and development of the Hanford Reach National Monument and the other lands of the Hanford Site.

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Introduction

1. Introduction

The Hanford Site was established in 1943 for the Manhattan Project of the United States Department of Defense. Decades of restricted development and limited public use over most of the site have resulted in the site's recognition as a critical reservoir of biodiversity for the semi-arid interior of the Pacific Northwest (Soll et al. 1999, Clinton 2000, Rickard et al. 1988). Less than 40% of the great shrub-steppe ecosystem that once dominated the Columbia Plateau of Washington, Oregon, and Idaho has escaped development to date, and much of what remains unconverted exists in a highly degraded condition (DOE-RL 2001). The biological importance of the Hanford Site's relatively undisturbed shrub-steppe habitats only increases as more and more of the surrounding landscape is converted to other uses.

The aquatic and riverine habitats of the Hanford Site also represent areas of highly significant conservation value for the interior Northwest. The 51-mile extent of the Hanford Reach represents the last free-flowing, non-tidal stretch of the Columbia River within the United States, critical habitat for the rivers last great runs of anadramous fish, and important stopover and nesting sites for migratory birds. Freshwater springs are all the more valuable for their scarcity, standing out like green jewels in the surrounding semi-arid landscape, providing habitats for specialized plant and insect life, offering nest sites for migratory songbirds, and focusing the activities of upland wildlife.

The Hanford Site lies within the Columbia Basin, the hottest, driest part of Washington state (Franklin and Dyrness 1973). Environmental characteristics are summarized in Soll et al. (1999), in Rickard et al. (1988), and elsewhere. Elevations range from below 400 ft. (122 m) a.s.l. along the Columbia River to more than 3500 ft. (1067 m) at the summit of Rattlesnake Mountain near the western boundary of the site. Annual precipitation varies with elevation, ranging from as little as 16 cm at the lowest elevations up to 35 cm along the crest of Rattlesnake Mountain.

Background: The Biodiversity Inventory and Analysis of the Hanford Site, 1992–1999. In 1992 the U.S. Department of Energy and The Nature Conservancy of Washington entered into a Memorandum of Understanding, which laid the groundwork for cooperation between the two entities in conducting an inventory of the natural biological diversity of the Hanford Site. Over four field seasons between 1994 and 1998, researchers surveyed the length and breadth of the site, identifying, cataloging, and mapping the plants, animals, and biological communities of this special landscape. This important phase of work culminated in 1999 with the publication of the volume *Biodiversity Inventory and Analysis of the Hanford Site: Final Report, 1994–1999* (Soll et al. 1999). The inventory documented occurrences of dozens of rare taxa, mapped critical biological resources such as plant communities, and documented concerns regarding invasive plant species. Although the study accomplished much of its mission and provided a great deal of valuable information, some questions remained unanswered. Moreover, new information provided by the report generated many additional questions.

Since the publication of Soll et al. (1999) the Hanford Site has experienced significant changes, both on the landscape as well as in the management arena:

- In June 2000, approximately 195,000 acres of the Hanford Site surrounding Central Hanford was designated as the Hanford Reach National Monument by proclamation of President William J. Clinton (Presidential Proclamation 7319). The proclamation calls for the protection of the Monument's riparian, aquatic, and upland shrub-steppe habitats, including rare vascular plants, microbiotic soil crusts, shrub-steppe-dependent wildlife, insects, migratory birds, and fisheries resources, as well as cultural and geological features.

- In late June 2000, a wildfire burned more than 160,000 acres of the Hanford Site, including nearly all of the 77,000-acre Fitzner-Eberhardt Arid Lands Ecology Reserve Unit of the newly proclaimed national monument, along with significant portions of Central Hanford. Wildfires burned smaller acreages in the Vernita Flats area of the Saddle Mountain Unit, north of the Columbia River, in 2000, and near the White Bluffs of the Wahluke Unit during July 2002.
- In fall 2003, construction of a large high-voltage powerline is scheduled to traverse Umtanum Ridge and other portions of the McGee Ranch–Riverlands Unit of the Monument.

Current Management Units of the Hanford Site and the Hanford Reach National Monument

The Hanford Site consists of Central Hanford and the Hanford Reach National Monument (Fig. 1.1). The Monument itself is divided into six administrative units. Land ownership for the entire site resides with the U.S. Department of Energy (DOE). However, the U.S. Fish and Wildlife Service (USFWS) exercises direct management over 165,000 acres of Monument lands, while the Washington Department of Fish and Wildlife (WDFW) manages a small recreational access area. The administrative management units of the Hanford Site are as follows:

- **Central Hanford.** Central Hanford is a wide expanse of the Columbia River Plain in the center of the Pasco Basin. Managed by DOE, Central Hanford contains portions of the Hanford Reach National Monument, most notably the Hanford Dunes and a one-quarter-mile strip along the Columbia River shoreline (see River Corridor Unit). Other significant natural features of Central Hanford include Gable Mountain and Gable Butte. Portions of the site have been subjected to considerable human impacts, from old agricultural sites and townsites to construction camps, reactor sites, and processing areas associated with the nuclear weapons program of the mid- to late-twentieth century.
- **The Fitzner-Eberhardt Arid Lands Ecology (ALE) Reserve.** The 77,000-acre ALE Reserve lies along the southwest boundary of the Hanford Site, in Benton County. The Reserve was officially recognized as a valuable site for scientific study in 1967 due to the rich and relatively undisturbed character of its native shrub-steppe ecosystem. The Reserve was subsequently designated a federal Research Natural Area in 1971. The area, managed by USFWS since 1999, is closed to public uses and is maintained for scientific and educational purposes.
- **The McGee Ranch–Riverlands Unit.** This 9100-acre unit of the Monument lies north of ALE and is managed directly by DOE. The unit lies entirely within Benton County and contains the biologically diverse Umtanum Ridge area and some intact shrublands as well as powerline corridors and former agricultural lands, homesteads, and townsites. Public access is limited to the Riverlands area north of the Midway Substation Road.
- **The Vernita Bridge Recreation Area.** This small (approximately 800 acres) area on the Columbia River just north of the Vernita Bridge has been managed by WDFW since 1971, primarily to provide river access for fishing and boating.
- **River Corridor Unit.** This 25,000-acre unit of the Monument includes the Hanford Reach of the Columbia River along with the Columbia River islands and a one-quarter-mile corridor along the south and west shore of the river. The unit also contains the Hanford Dunes, reportedly the only active dunefield within Washington state. Management of this unit is multijurisdictional, involving DOE, USFWS, the U.S. Bureau of Land Management, and state and county agencies. In general, the south and west shores of the Columbia, its islands, and the Hanford Dunes are managed by DOE, while the north and east shores of the Columbia are managed by USFWS.

Fig. 1.1. The Hanford Site, including Central Hanford and the Hanford Reach National Monument.

- **Saddle Mountain Unit/Saddle Mountain National Wildlife Refuge.** This 32,000-acre unit borders the north shore of the Columbia River and is located entirely within Grant County. This unit of the Monument, managed by USFWS since 1971, contains sagebrush stands and important rare plant habitats, along with heavily disturbed former agricultural lands and the Saddle Mountain Lakes, a large area of irrigation wasteway impoundments. The unit is bisected by State Route 24 but is otherwise closed to public access.
- **Wahluke Unit.** The 57,000-acre Wahluke Unit, located primarily in Grant and Franklin counties (with a small portion in Adams County), is open to the public. This unit, managed by USFWS since 1999, includes most of the Monument's signature geologic feature, the White Bluffs, as well as significant shrub-steppe habitats and irrigation district wasteway impoundments.

Current Scope of Work

The *Biodiversity Inventory and Analysis of the Hanford Site* (Soll et al. 1999) identified a number of areas where planned inventories could not be completed, or where the findings of preliminary inventories indicated that additional work was needed. The studies summarized within this current volume were designed to address some of these gaps in current knowledge of the site's organisms and understanding of the relationships between organisms. Field work was begun in 2002, with some field investigations continuing into 2003 (Table 1.1) Specific objectives of these studies included the following:

- **Vegetation mapping.** The *Biodiversity Inventory and Analysis of the Hanford Site* mapped vegetation over most of the Hanford Site. One remaining major unit, the McGee Ranch–Riverlands Unit, has now been mapped as a part of these studies (Easterly and Salstrom 2003).
- **Microbiotic crusts.** Studies of microbiotic crusts accomplished through the *Biodiversity Inventory and Analysis of the Hanford Site* were the first attempts to systematically collect and identify soil mosses and lichens at Hanford. Work during 2002–2003 involved more extensive surveys for these organisms around the site, surveyed previously unsurveyed habitats such as talus, rock outcrops, and other habitats, and examined community relationships among soil crust organisms, environmental variables, and vascular plant communities (McIntosh 2003).
- **Rare plant studies.** The *Biodiversity Inventory and Analysis of the Hanford Site* identified numerous populations of rare vascular plant taxa, including several taxa new to science. Little is known about the reproduction and other life history traits of many of Hanford's rarest plants. The recent round of studies assessed the population status and viability of the Hanford endemics Umtanum desert buckwheat (*Eriogonum codium*) and White Bluffs bladderpod (*Lesquerella tuplashensis*), along with Columbia yellowcress (*Rorippa columbiae*), and surveyed for occurrences and potential habitat for northern wormwood (*Artemisia campestris* ssp. *borealis* var. *wormskioldii*; Caplow 2003).
- **Aquatic invertebrates.** This portion of the current studies focused on a synthesis of existing literature on Hanford's aquatic invertebrates, while conducting new surveys for selected aquatic invertebrate taxa on the Hanford Reach, and made comparisons of historical collections from spring stream habitats on the Fitzner-Eberhardt Arid Lands Ecology Reserve with new collections following a landscape-scale wildfire (Newell 2003).
- **Terrestrial invertebrates.** Collections of terrestrial invertebrates on the Hanford Site during the 1990s contributed large numbers of taxa new to science and indicated that this area of study would likely yield many additional contributions to local, regional, and worldwide biodiversity. Ongoing work at Hanford continues to add to the entomological record of the site (Zack et al. 2003).

- **Invasive plant species.** Invasive plant species have been identified as one of the greatest threats to biodiversity on the Hanford Site. This scope of work included two elements to assist site managers in addressing this issue: 1) an inventory of noxious weeds on the Hanford Reach National Monument, and 2) development of a noxious weed management plan for the Monument (Evans et al. 2003).

The results of these studies have been provided to the U.S. Department of Energy and to the U.S. Fish and Wildlife Service, co-managers of the Hanford Reach National Monument, to inform ongoing resource management and land use decisions.

Table 1.1. Research conducted in this study, including management units where work was performed, and time frames. Management Units are abbreviated as follows: ALE (Arid Lands Ecology Reserve); HR (Hanford Reach, River Corridor Unit); HRNM (Hanford Reach National Monument—entire monument); MR (McGee Ranch–Riverlands Unit); W (Wahluke Unit).

	Year	
Subject Area	**2002**	**2003**
Plant Community Mapping	MR	
Microbiotic Crusts	HRNM	HRNM
Rare Plants	W, MR, HR	
Aquatic Invertebrates	HR, ALE	
Terrestrial Invertebrates	W	W
Weed Inventory and Management	HRNM	HRNM

Plant Communities

2. Vegetation of the McGee Ranch–Riverlands Unit

Richard Easterly and Debra Salstrom

Introduction

Between 1994 and 1998, vascular plant communities were inventoried and mapped over most of the Hanford Site (Soll et al. 1999). These mapping studies, characterized by intensive walking surveys and field checking, were conducted on the Fitzner-Eberhardt Arid Lands Ecology Reserve and the North Slope (Wilderman 1994), Central Hanford (Easterly and Salstrom 1997), and the south shorelines and islands of the Columbia River (Salstrom and Easterly 1995). Mapping of the McGee Ranch–Riverlands Unit completes the detailed vegetation mapping of the Hanford Site. Complete details of this study are reported in Easterly and Salstrom (2003).

Site Description and Geology

The McGee Ranch–Riverlands Unit of the Hanford Reach National Monument occupies approximately 9,100 acres and is bounded by State Route 24 to the south and east, the Columbia River to the north, and privately-owned lands to the west. The unit is characterized by diverse soils and topography and by a varied land use history. The McGee Ranch–Riverlands Unit is under the direct management of the U. S. Department of Energy.

The study area is located on and adjacent to eastern Umtanum Ridge, which is composed of numerous basalt flows of the Columbia River Basalt Group. Umtanum Ridge is one of a series of east-west trending anticlines that comprise the Yakima Fold Belt. It is asymmetrical, with a relatively gentle south slope and a steep, intensely folded and faulted north slope.

Between some of the upper basalt flows are sedimentary interbeds. The largest of these, the Vantage Interbed, is the major water-bearing stratum in the area, and the source of numerous cold springs along the north flank of Umtanum Ridge (Goff 1981). Water in this buried interbed is also likely the source of several artesian wells on the south flank of the ridge (Goff 1981), such as at the McGee Well.

Eastern Umtanum Ridge is located along the route of catastrophic floods that occurred during the 1.5-2.5 million years of the Pleistocene Epoch (Bjornstad et al. 2001). Umtanum Ridge deflected a major trajectory of these floodwaters to the east, scouring the north slope of the ridge. The surging and temporarily ponded water deposited large quantities of fine-textured materials on the south slope of Umtanum Ridge (Lindberg 1994). On the south side of the ridge, some road cuts expose a carbonate horizon that has developed in the wind- and water-borne sediments. This carbonate-cemented sandy-silt occurs throughout the fine deposits at a depth of 30-60 cm (Lindberg 1994).

Substrates north of Umtanum Ridge along the Columbia River are composed chiefly of boulders, cobble, gravels and sand from the Pleistocene outburst floods (Reidel and Fecht 1994), and is generally mantled with Quaternary alluvium (Goff 1981).

LAND USE HISTORY

Overgrazing by livestock occurred in the area as early as 1880-81 (Parker 1979). This long-term grazing pressure undoubtedly suppressed the preferred grasses and promoted increased density of shrubs, a condition that is probably still evident in some of the oldest unburned portions on the site. The study area has two areas that were under early cultivation and development. As early as 1892, settlers along the Columbia River developed natural springs, dug wells, or pumped irrigation water from the river using gasoline engines. Artesian wells near the McGee Ranch on the south side of Umtanum Ridge provided irrigation water for agriculture and a number of home sites prior to 1943, when the site was acquisitioned by the Federal Government for the Hanford Site.

In the early 1950s, several anti-aircraft artillery batteries were established around the Hanford Site's nuclear production facilities. One of these batteries was located on Umtanum Ridge in the eastern portion of the study area. Although the approximately 20-acre facility was decommissioned and razed during the early 1960s, its footprint can still be seen near the east end of the study area. Activities surrounding this site are presumably responsible for some ground disturbances along the ridge. In the lowland north of Umtanum Ridge, a railway depot was located in the Riverlands Area, along the Milwaukee Road right of way. The depot was dismantled in 1990 and the railway tracks removed. The Bonneville Power Administration's Midway Substation is located nearby. A townsite where substation workers and their families were housed was located near the substation, just downslope from Juniper Springs. Several power transmission lines cross the area. Roads, many of which are associated with powerline construction and maintenance, provide access to much of the site. The southern portion of the unit is closed to the public, and vehicle access is regulated with locked gates. The Riverlands portion of the site near the Columbia River is open to public access. Some of the primitive roads in this section are closed to vehicles.

Livestock grazing has presumably been prohibited on the unit since about 1950, although active enforcement was apparently sporadic until the 1970s. Incidences of trespass grazing by sheep continue to be reported occasionally along the western edge of the site.

Methods

Mapping methodology was similar to that described in Easterly and Salstrom (1997, 1999,2002a, 2002b). Prior to beginning work in the field, a preliminary assessment of vegetation polygons was made using aerial photos. These photos were extremely useful in discerning large-scale vegetation patterns and developing a preliminary map of polygon distributions, but they were generally not useful in delineating changes in shrub or grass species. In addition, portions of the study area burned in 1996, after the most recent aerial photos were taken. Extensive ground surveys were done between May and September 2002 to adjust and refine preliminary polygon boundaries and to detect plant community types that were beneath the resolution of the aerial photos. Polygon boundaries were drawn to reflect the sinuosity of plant community boundaries as much as possible.

Distributions of priority species (Table 2.1) were used to delineate polygon boundaries. Boundaries were drawn to reflect changes in cover of priority species when trends were observed at a level that could be mapped. Mapping units were identified by the dominant shrub and grass species, or by the dominant grasses where no shrubs were present. Plant community identifications were based on technical literature (Crawford 1999, Daubenmire 1970) and personal experience. Significant natural biological resources are classified as 'elements' of biodiversity and reported to the Washinton Natural Heritage Program. Each polygon that represented an element identified in the state's Natural Heritage Plan (WNHP 2003, 1999) was evaluated for its conservation potential based on a ranking of the plant community's condition, size, and factors in the surrounding landscape. Community condition was evaluated in terms of the cover and condition of microbiotic crusts, cover of non-native and disturbance-oriented plant species, and the similarity of the community's composition to published accounts of the vegetation type. Criteria for community size relate to the community's potential long-term viablility; these criteria vary with the type of system being evaluated and with other factors. Landscape factors include the proximity of areas or corridors of disturbance, the presence of disturbance vectors such as grazing or development, and other factors (NatureServe 2002).

TAXONOMIC NOMENCLATURE

Taxonomic nomenclature follows Hitchcock and Cronquist (1973), with three exceptions. Updated taxonomy is used in referring to *Atriplex spinosa* (= *Grayia spinosa*), *Agropyron spicatum* (= *Pseudoroegneria spicata*), and for the *Poa secunda* complex, which formerly included *Poa nevadensis*, *Poa sandbergii*, and *Poa scabrella*, among others.

Table 2.1. Partial list of priority species used to define polygon boundaries and generate mapping-unit names.

Common Name	Scientific Name
Shrubs	
stiff sagebrush	*Artemisia rigida*
Wyoming big sagebrush	*Artemisia tridentata* ssp. *wyomingensis*
Douglas' desert buckwheat	*Eriogonum douglasii*
snow buckwheat	*Eriogonum niveum*
rock buckwheat	*Eriogonum sphaerocephalum*
thyme-leaved desert buckwheat	*Eriogonum thymoides*
winterfat	*Eurotia lanata*
spiny hopsage	*Grayia spinosa*
bitterbrush	*Purshia tridentata*
purple sage	*Salvia dorrii*
Grasses	
crested wheatgrass	*Agropyron cristatum*
thickspike wheatgrass	*Agropyron dasytachyum*
cheatgrass	*Bromus tectorum*
alkali saltgrass	*Distichlis spicata*
Great Basin wildrye	*Elymus cinereus*
bulbous bluegrass	*Poa bulbosa*
Sandgerg's bluegrass	*Poa secunda*
bluebunch wheatgrass	*Pseudoroegnaria spicata*
sand dropseed	*Sporobolus cryptandrus*
needle-and-thread	*Stipa comata*

Results and Discussion

Topography, geology, fire history, and land-use history have combined to create a complex mosaic of vegetation types within the McGee Ranch–Riverlands Unit of the Hanford Reach National Monument. This survey delineated 245 polygons of existing vegetation, representing 17 major vegetation types on the unit (Fig. 2.1; Table 2.2). The greatest diversity in vegetation types occurred along the crest of Umtanum Ridge and adjacent areas. The gentle slopes down to the Cold Creek Valley south of Umtanum Ridge, along with the Riverlands area to the north, tended to have relatively more uniform vegetation, as reflected by the fewer, larger polygons identified there.

Table 2.2. Coverage of existing plant community types on the McGee Ranch–Riverlands Unit, Hanford Reach National Monument. Areas covered do not include riparian and rivershore communities of the Columbia River previously mapped by Salstrom and Easterly (1995) and Easterly and Salstrom (2001).

Plant Community	**Number of Polygons**	**Total Acreage Mapped**	**WNHP Protection Priority Status, Columbia Plateau**
bluebunch wheatgrass	13	329	1
cheatgrass	2	12	
crested wheatgrass	1	14	
big sagebrush/bluebunch wheatgrass	19	253	3
big sagebrush/needle-and-thread	2	12	1
big sagebrush/Great Basin wildrye	2	4	
big sagebrush/alkali saltgrass	2	13	
big sagebrush/Sandberg's bluegrass	97	3409	
big sagebrush – stiff sagebrush/bluebunch wheatgrass	3	119	
needle-and-thread	4	307	1
purple sage/bluebunch wheatgrass	1	34	
Sandberg's bluegrass	76	3975	
stiff sagebrush/bluebunch wheatgrass	2	27	
stiff sagebrush/sandberg's bluegrass	14	120	3
winterfat/needle-and-thread – Sandberg's bluegrass	3	338	2
winterfat/bluebunch wheatgrass	2	45	
Facilities	2	51	
Total	245	9060	

Fig. 2.1. Existing vegetation of the McGee Ranch–Riverlands Unit, Hanford Reach National Monument, 2002.

GENERAL VEGETATION DESCRIPTION

The historic floodplain of the Columbia River north of Umtanum Ridge is gravel and cobble with occasional sandy areas and some secondary flood channels. The dominant cover type in this area is Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*)/Sandberg's bluegrass (*Poa secunda*), commonly with spiny hopsage (*Grayia spinosa*) on substrate that appears to be coarser in texture and/or shallower. Snow buckwheat (*Eriogonum niveum*) is common and sometimes dominant on sandy sites. The grass layer is frequently dominated by Sandberg's bluegrass (which is sometimes vigorous), sometimes with high densities of cheatgrass (*Bromus tectorum*). Bulbous bluegrass (*Poa bulbosa*) replaces Sandberg's bluegrass in some of the most heavily disturbed areas.

Closer to the river, the vegetation grades into riparian communities mapped in previous studies (Salstrom and Easterly 1995, Easterly and Salstrom 2001), which include thickspike wheatgrass (*Agropyron dasytachyum*), creeping wildrye (*Elymus triticoides*), and sand dropseed (*Sporobolus cryptandrus*). The latter species also occurs intermittently in some historic flood channels and along some roads. Some of the old flood channels that were intensely disturbed (possibly historically used as livestock bedding areas) are infested with Russian knapweed (*Centaurea* [= *Acroptilon*] *repens*). Diffuse knapweed (*Centaurea diffusa*) has colonized most roadways in this area to some degree, as well as the surface of the old railroad bed.

Along the top of Umtanum Ridge, lithosols occur repeatedly and support stiff sagebrush (*Artemisia rigida*)/Sandberg's bluegrass with and without thyme-leaved buckwheat (*Eriogonum thymoides*) and Douglas' buckwheat (*Eriogonum douglasii*). While some of them burned, these lithosols generally served as firebreaks for the 1996 fire.

On the north slope of Umtanum Ridge, substrates include basalt outcrops, lithosols, sedimentary interbeds, and loess. On much of this area, the substrates (and accompanying vegetation) recur on a relatively small scale and intergradations are common. Lithosols along spur ridges support stiff sagebrush/Sandberg's bluegrass, frequently with purple sage (*Salvia dorrii*) and rock buckwheat (*Eriogonum sphaerocephalum*). Elsewhere, bluebunch wheatgrass (*Pseudoroegneria spicata*) is common, especially on soils with a loess component. Cheatgrass is a frequent component of the vegetation on the south aspects of secondary ridges. Needle-and-thread (*Stipa comata*) occurs sporadically along the slope, usually in areas with a relatively higher percentage of sand sorted from the slack-water Pleistocene sediments. Portions of the slope, especially in the western part of the study area, burned in 1996. There, as in most other burned sites within the study area, big sagebrush reproduction was often abundant. Both grey and green rabbitbrush (*Chrysothamnus nauseosus* and *C. viscidiflorus*) occur sporadically, especially on upper slopes in the burned areas where they have resprouted. Small areas with Winterfat (*Eurotia lanata*) occur along the slope, apparently associated with soils derived from the sedimentary interbed materials.

On the upper slope south of Umtanum Ridge in the western portion of the study area, winterfat/needle-and-thread occurs on slack-water flood sediments and associated loess. Parts of this area burned in 1996, after which the winterfat resprouted. Within this zone, needle-and-thread generally occurs intermittently, creating a mosaic of winterfat/needle-and-thread and winterfat/Sandberg's bluegrass. Fire eliminated most of the mature individuals of Wyoming big sagebrush in this area. Bluebunch wheatgrass occurs with winterfat along the western margin of the study area, a cover type that continues upslope to the west off the site. To the east and south, the elevation drops, the substrate becomes coarser, and winterfat drops out. Needle-and-thread and bluebunch wheatgrass continue along the ridge to the east, with the latter species becoming confined to north aspects as the elevation continues to drop. Big sagebrush seedlings are abundant in much of the burned area.

The south flank of Umtanum Ridge burned patchily in 1996. On the lower to middle portion of the slope, unburned sites support big sagebrush/Sandberg's bluegrass. Spiny hopsage is frequently present at relatively high concentrations, especially at lower elevations. Large patches of needle-and-thread occur regularly at mid-elevations, especially on sandier sites where the shrub cover has been reduced by fire. Adjacent burned and unburned sites often seem to indicate an inverse relationship between needle-and-thread and shrub cover that is evidently not due to substrate variation. Needle-and-thread drops out at lower elevations within the study area. As elsewhere on the site, reproduction of big sagebrush is generally abundant, although uneven, in the burned area.

Hemishrubs such as longleaf phlox (*Phlox longifolia*) and a wide variety of forbs are conspicuous in many areas. On the south flank of Umtanum Ridge, the forbs buckwheat milkvetch (*Astragalus caricinus*) and hoary aster (*Machaeranthera canescens*) are common and sometimes abundant. Large patches of Cusick's sunflower (*Helianthus cusickii*) are also conspicuous throughout the lower south slope, usually where shrub cover is low. Carey's balsamroot (*Balsamorhiza careyana*) occurs throughout much of the entire area, sometimes in high concentration. The unit provides habitat for rare plants such as Columbia milkvetch (*Astragalus columbianus*), Piper's daisy (*Erigeron piperianus*), Hoover's desert parsley (*Lomatium tuberosum*), Umtanum desert buckwheat (*Eriogonum codium*), and others (Soll et al. 1999).

Non-native invasive species occur sporadically throughout the area, sometimes in high concentrations. Russian thistle (*Salsola kali*) occurs in areas of recent disturbance. Diffuse knapweed (*Centaurea diffusa*) occurs along most roadways in the area, and in some disturbed grasslands and shublands. Old agricultural fields have been colonized by numerous invasive species, including extensive infestations of Russian knapweed (*Centaurea* [= *Acroptilon*] *repens*), whitetop (Cardaria draba), and perennial pepperweed (Lepidium latifolium), among others.

In and around McGee Ranch on the lower south slope, the vegetation is dominated by cheatgrass (*Bromus tectorum*). This is presumably a result of historic cultivation and livestock grazing, along with recurring wildfires in recent years. Big sagebrush seedlings are present in much of the area.

VEGETATION CONDITION

Although parts of the site exhibit evidence of heavy disturbance by cultivation, fire, grazing, and invasion by non-native species, much of the study area is in relatively good ecological condition. Disturbed areas at the higher elevations have potential for natural recovery. At lower elevations, the potential for recovery from past disturbances is likely slowed or reduced because of the lower productivity and resilience in these harsher physical settings. These areas are apparently below the ecotone for needle-and –thread and bluebunch wheatgrass, and the initial diversity was probably low relative to sites at higher elevations. Although cheatgrass is a component of the vegetation in much of the site, it is seldom dominant above the low elevation areas.

In some portions of the site, dense shrub cover likely reflects a response to historical overgrazing. These high shrub densities have been reduced or removed in some areas as a result of the 1996 wildfire. It is not yet clear to what extent those areas will recover the perennial bunchgrass component of the vegetation, but initial observations frequently indicate higher bunchgrass cover where the shrub cover has been reduced or removed, especially at middle to upper elevations. The structure of the communities will continue to be modified as the shrub seedlings present at many of these sites come to maturity.

NATURAL HERITAGE ELEMENT OCCURRENCES

Vegetation polygons that meet minimum standards for size, condition, and landscape factors represent areas of significant conservation value, termed elements of biodiversity, and will be reported to the Washington Natural Heritage Program. The extensive, unconverted, natural landscape of much of the McGee Ranch–Riverlands Unit, some of which is managed for conservation, gives a high landscape rank for all elements that can be identified on the site. Elements are based on potential native plant communities: the existing "climax" vegetation or the climax vegetation projected to occur if the site is left undisturbed. In some cases ecosystem components, such as a complete shrub layer, may be missing at present, but may be expected to develop in the absence of outside disturbance.

Fig. 2.2. Proposed Natural Heritage Element Occurrences on the McGee Ranch–Riverlands Unit, Hanford Reach National Monument.

Elements that meet minimum size standards for regional importance are big sagebrush/needle-and-thread (*Artemisia tridentata/Stipa comata*), big sagebrush/bluebunch wheatgrass (*Artemisia tridentata/Pseudoroegneria spicata*), stiff sagebrush/Sandberg's bluegrass (*Artemisia rigida/Poa secunda*), big sagebrush-spiny hopsage/Sandberg's bluegrass (*Artemisia tridentata-Grayia spinosa/Poa secunda*), and winterfat/needle-and-thread – Sandberg's bluegrass (*Eurotia lanata/Stipa comata-Poa secunda*; Fig. 2.2, Table 2.3). Many of these elements occur within a landscape mosaic rather than as discrete polygons.

Proposed element occurrences on the McGee Ranch–Riverlands Unit are presented in Table 2. Letter ranks are assigned on a scale from A to F where A = highest or most favorable quality and F = the lowest or least favorable quality (NatureServe 2002). All elements large enough to meet size criteria for element occurrences will be considered eligible for entry into the WNHP Information System. Two of the elements mentioned above are more specific than those currently in the Natural Heritage system. Big sagebrush-spiny hopsage/Sandberg's bluegrass is a subset of big sagebrush/Sandberg's bluegrass, and winterfat/needle-and-thread – Sandberg's bluegrass is a subset of winterfat/Sandberg's bluegrass. In addition, some of the polygons on the north slope of Umtanum Ridge represent vegetation that is transitional between big sagebrush/bluebunch wheatgrass and stiff sagebrush/Sandberg's bluegrass, often including rock buckwheat (*Eriogonum sphaerocephalum*) and purple sage (*Salvia dorrii*). These polygons are included in the records for big sagebrush/bluebunch wheatgrass and stiff sagebrush/Sandberg's bluegrass, depending on the community type to which it was most similar.

Table 2.3. Ecosystem Element Occurrences on the McGee Ranch–Riverlands Unit, Hanford Reach National Monument, with tentatively assigned ranks. See text for more complete explanation.

Element	Landscape Rank	Size Rank	Condition Rank	Overall Rank	Acreage Total
big sagebrush – spiny hopsage/Sandberg's bluegrass	A	B	BC	B	1483
big sagebrush/bluebunch wheatgrass	A	CB	C	B	830
big sagebrush/needle-and-thread	A	CB	CB	B	394
winterfat/needle-and-thread – Sandberg's bluegrass	A	CB	CB	B	401
stiff sagebrush/Sandberg's bluegrass	A	C	CD	BC	151

Management Recommendations

Plant community element occurrences should be managed to conserve the values of the natural resource. Soil disturbance, in particular, should be avoided in these areas.

The entire site is susceptible to recurring wildfire. Several of the recent fires in the area were human-caused, and most originated from vehicles. Regardless of the source of ignition, the frequency, severity, and extent of wildfires in the Columbia Basin have increased in recent years, as they have elsewhere throughout the arid West, in reponse to increasing abundance of cheatgrass and other invasive species (USFS 2001, Brooks and Pyke 2001, Whisenent 1990, Young and Evans 1985, 1978). To reduce the risk of unintended ignition, highway rights-of-way in the area should be maintained free of weeds and fuels with controlled fires or other means compatible with management objectives. Firebreaks could be maintained along some secondary roads within the site as well. All vehicles with back-road access should be equipped with a fire extinguisher and shovel, and drivers should be informed of fire-prevention behavior.

Several areas within the study site are infested with noxious weeds, including large infestations of diffuse knapweed and Russian knapweed, along with some yellow starthistle. Successful treatment of these infestations is likely to require many years of effort and should begin as quickly as possible. Roads through untreated areas should be closed to vehicles during periods of seed dispersal.

3. Biological Soil Crusts of the Hanford Reach National Monument

Terry T. McIntosh

Introduction

In most shrub-steppe and grassland plant communities of the Intermountain West, thin crusts of living organisms occupy the soil surface in the interspaces between widely spaced vascular plants. Easily overlooked by the casual observer, these biological soil crusts, also known as cryptogamic crusts or microbiotic crusts, perform important ecological functions and are an important component of the biodiversity of arid lands. The following section presents the results of a study of the lichens and bryophytes of the biological soil crusts in the Hanford Reach National Monument conducted during 2002–2003. Full details are presented in McIntosh (2003).

The primary objectives of this study were as follows:

- To expand upon previous surveys of the biodiversity of the lichens and bryophytes of the Hanford Site. While the microbiotic crusts of shrub-steppe and grassland habitats were the primary focus of this study, lichens and bryophytes in other habitats, including rock outcrops and talus, shrub and tree surfaces, and wetlands, were also investigated.
- To examine relationships between the distribution of lichens and bryophytes of the biological soil crusts and major vascular plant communities.
- To examine relationships between the distribution of lichens and bryophytes of the biological soil crusts and readily measurable environmental variables.

Biological Soil Crusts: Composition and Function

Biological soil crusts are complex groupings of organisms that occupy soil surfaces in many arid and semi-arid landscapes (Belnap et al. 2001, Ponzetti 2000). The dominant organisms that comprise biological soil crusts are lichens, bryophytes (including mosses as well as a few liverworts), single-celled algae, and cyanobacteria. These organisms are intermixed with fungal hyphae, algae, plant roots, litter, and soil. Biological crusts can be extremely diverse: More than 10 species of organisms can be present on as little as 2 cm of soil. As a unit, these assemblages are often compact and fragile.

Biological crusts perform a number of ecologically important roles that contribute to ecosystem health and integrity (Belnap et al. 2001, Ponzetti 2000, Evans and Johansen 1999). An example is their function in respect to soil stability. Open soils are often in constant movement, as particles are displaced by wind and water. As a biological crust develops, the soil stabilizes and soil displacement is reduced or eliminated, mainly due to the binding of soil particles by the various crust organisms (Belnap and Gardner 1993, Schulten 1985). The complex microtopography of mature biological crusts creates a boundary of still air at its surface which further protects it and the underlying soil from wind erosion (Eldridge and Kinnell 1997, Neuman and Maxwell 1999, Lehrsch et al. 1988).

The presence of a biological soil crust can influence the surface hydrology of a site. In many sites, it appears that infiltration rates are increased with the presence of a crust, although this depends on a number of factors, including soil type, crust composition, and climate (Ponzetti 2000, Eldridge 1993). The presence of intact biological crusts may also inhibit the establishment of cheatgrass (Bromus tectorum) and other invasive species (Belnap et al. 2001, Kaltenecker et al. 1999).

Lichens, bryophytes, cyanobacteria, and green algae in the crust fix atmospheric carbon, contributing to the overall productivity of a plant community. Free-living cyanobacteria and many lichens in the crust are capable of fixing atmospheric nitrogen, which is subsequently released into the soil and used by vascular plants and fungi, contributing to enhanced productivity (Belnap et al. 2001, Evans and Belnap 1999). In some cases, vascular plants that grow in areas of well developed crust have higher accumulations of essential plant nutrients than in sites that lack a crust (Belnap et al. 2001, Ridenour and Callaway 1997).

Most biological soil crusts are fragile and readily disturbed, with susceptibility to disruption related in part to site factors such as soil type, local climate, the vascular plant community, and other factors (Belnap et al. 2001, Ponzetti 2000). Over the past century, most biological crusts in the Pacific Northwest have been heavily altered and sometimes destroyed by livestock, agricultural practices, wildfire, invasive species, and off-road vehicle use. There is evidence that the biological soil crusts in the Pacific Northwest, including those in the Hanford area, evolved in low disturbance environments, where impacts by large herbivores and fire were much less severe than at present.

PREVIOUS SOIL CRUST RESEARCH IN THE HANFORD AREA

Biological soil crusts have frequently been overlooked in studies of shrub-steppe vegetation, and until recently, little research has been completed on the biological crusts of the Hanford area. McIntosh (1986) collected bryophytes and lichens on the Fitzner-Eberhardt Arid Lands Ecology (ALE) Reserve in 1981, before several landscape-scale wildfires had swept the site. The lichens in these collections are still awaiting identification. Johansen et al. (1993) studied the effects of fire on the algal and cyanobacterial components of biological soil crusts in the area.

The first study of lichens and bryophytes in the biological soil crusts at Hanford was completed in 1998. Link et al. (2000, summarized in Soll et al. 1999) collected lichens and bryophytes from 13 locations across the Hanford Site, including six locations in the Central Hanford area. They reported 29 lichen and six moss species. Six of the lichen species that they collected were unidentified at the time of their survey, but since then, two have been described as new species of *Trapeliopsis* (McCune et al. 2002). Five of their lichen collections were reported as new to Washington state.

Ponzetti et al. (2000) completed an extensive grazing management-related ecological study of the biological crust communities in the Horse Heaven Hills, in Benton County south of the Yakima River. Their research identified more than 50 lichen species and 11 bryophytes in the biological crusts in this area. Another 50 or more species of lichens were identified from rock surfaces or on wood or bark.

The rare lichen species *Texosporium sancto-jacobi* (McCune and Rosentreter 1992) is the subject of a long-term study in the region by Von Reis and her students at Columbia Basin College. Although this species has not yet been found on the Monument, there is potential for it to be present (J. von Reis pers. comm.).

CONSTRAINTS ON THE IDENTIFICATION OF LICHENS AND BRYOPHYTES

Lichens and bryophytes are inherently difficult to identify with confidence in field studies. Most species of arid land lichens and bryophytes are very small in stature. Lichen thalli and apothecia and the gametophyte stage of many mosses often range from only 1 mm to 2 mm in size at maturity. These organisms are often difficult to distinguish in the field and usually must be collected in order to confirm identifications. In the laboratory their small stature leads to difficulties in identification, even with the use of microscopes. Chemical testing, leaf cross-sections, spore analysis, and other methods must frequently be employed before conclusive identifications can be made.

Few taxonomic keys and little illustrative material is available for most groups of these taxa. These groups of organisms have comparatively few specialists who fully understand specific genera, let alone the full suite of taxa that are present in a geographic region. Consequently, collections must often be sent to experts far away, sometimes overseas, before identifications can be confirmed. Bryophyte and, especially, lichen taxonomies are far from resolved. There can be conflicts in species concepts, and identical specimens may be identified differently by different experts.

Methods

Field work was conducted between August 2002 and April 2003. One hundred and eighteen microbiotic biodiversity sites were established across the Monument. Sites were chosen based primarily on richness of the microflora and/or on the presence of an unusual habitat. At each site, all identifiable lichen and bryophyte species were listed in the field, and collections were made for later identification. General ecological observations, including vegetation type, were recorded at each site.

The primary focus of biodiversity surveys was on soil crust taxa; however, additional collections were made on rock outcrops, talus, rocks, and stones, and on the branches and bark of shrubs and trees. Two collections were made in wetland habitats: one site along the Hanford Reach of the Columbia River, and another in a seepage area in the southern portion of the Wahluke Unit.

Fifteen sites were selected for community sampling of biological soil crusts (Table 3.1, Fig. 3.1). Sites were chosen based on the distinct and well-developed character of the crust communities, following an extensive reconnaissance of Monument lands. All of the community sampling sites exhibit a more or less irregular mosaic of biological crusts, with patches of open soil alternating with patches of crust, mainly as a result of past or ongoing disturbance.

Table 3.1. Biological soil crust community sampling sites, 2002–2003.

Site	Management Unit	UTM Coordinates (NAD27)	Elevation (Ft.)	Soil Type	Slope	Aspect
1	ALE	300789 / 5140760	3520	stony loam	20^o–30^o	W–SW
2	ALE	306215 / 5139957	1140	sandy loam	0^o	0
3	Saddle Mountain	293688 / 5172363	787	loamy sand	5^o	SE
4	Saddle Mountain	293688 / 5172363	787	loamy sand	5^o	SE
5	Saddle Mountain	302951 / 5176023	432	sandy loam	0^o	0
6	ALE	296714 / 5146925	1618	sandy loam	5^o–10^o	SW
7	ALE	291354 / 5150809	946	sandy loam	0^o–5^o	0–NW
8	McGee-Riverlands	286889 / 5165518	1362	sandy loam	5^o	N
9	ALE	288469 / 5152773	810	sandy loam	0^o	0
10	ALE	290797 / 5158731	782	sandy loam	0^o	0
11	McGee-Riverlands	288564 / 5164812	1053	loamy sand	0^o	0
12	McGee-Riverlands	288614 / 5165458	1040	sandy loam	0^o–5^o	0–N
13	Saddle Mountain	289687 / 5169108	454	loamy sand	0^o	0
14	Saddle Mountain	297146 / 5177298	640	sandy loam	0^o –5^o	0–N
15	Wahluke	321208 / 5160233	400	loamy sand	0^o	0

The initial intent of the study was to select sites representative of the major vascular plant communities and to sample associated crust assemblages. Owing to the disturbed condition of much of the Monument, however, it was difficult to find clearly defined vascular plant communities with sufficiently developed crusts. Therefore, the site selection protocol was modified to emphasize the better-quality crust assemblages, and the associated vascular plant communities were described following site selection.

A single 20 m transect was laid out in the most homogeneous part of the site and through the most representative part of the crust community, avoiding shrubs when possible. The transect was placed parallel to a slope, if present. At Site 4 this protocol was altered; this plot was installed to sample undisturbed areas under shrubs along a 80 m transect in order to compare the microbiotic species there with the open crust areas.

Twenty 20 x 20 cm microplots were sampled at 1m intervals along each transect (Belnap et al. 2001). Microplots that fell on heavily disturbed locations were moved to the opposite side of the transect, or 40 cm along the transect if the opposite side was also disturbed.

Cover of mineral soil, litter, total crust, vascular plant bases, stones, and individual microbiotic species or species groups were estimated using a cover class scale (Ponzetti 2000). In most sites, there were juvenile or colonizing microbiotic taxa that were lumped into unidentified lichen (UL, including lichens and cyanobacteria) or unidentified bryophyte (UB) categories. In all cases, greater than 90% of all species present along or near the transect were captured in the sampling plots.

Small collections of representative species were collected from many of the plots in order to confirm identifications later and to ensure that smaller taxa had not been overlooked.

Each site was photographed, and general habitat conditions, including surface soil characteristics, slope, aspect, and other observations, were recorded. Coordinates were recorded at the origin of each transect using a portable GPS device.

Surface soil samples were collected from each site near the center of the transect. Samples were taken from areas of open soil so that the crust was not disturbed. Conductivity and pH were assessed for all samples, following the protocols outlined by Ponzetti (2000). Unfortunately, soil pH and electro-conductivity values varied considerably within sites and could not be used in the site-based community analysis. Soil texture was estimated by hand for the purpose of site characterization.

Community data were analyzed using non-metric multidimensional scaling (NMS). NMS is an ordination method designed to produce a graphical representation of a set of data points, in this case representing species and sites, based on their similarity or dissimilarity (McCune and Grace 2002, Kenkel and Orloci 1986). Distance in the ordination diagram is roughly proportional to the dissimilarity between sampling units calculated from the correlation values of their species composition data. The goodness of fit of the ordination dimensions to the actual calculated distance matrix is represented by a stress value, with smaller stress values representing a better fit than larger values. Only confirmed lichen and bryophyte species and genera (45 taxa in total) were used in the analysis.

Unlike other commonly used ordination methods in ecology, NMS does not require assumptions of linearity or unimodality of species along environmental gradients. Thus, NMS is often considered the method of choice where species distributions are patchy and discontinuous (De Grandpré et al., 2000, Kenkel and Orloci 1986, Pyke et al. 2001, Qian et al. 2003), as in this data set. The ordination axes generated by NMS represent the optimum number of dimensions for summarizing the data and do not necessarily account for sequentially declining proportions of variation in the data as is the case with other ordination methods. For this reason, once the final multidimensional solution has been determined for a given dataset, the selection of axis combinations to use for graphic representation is that which leads to the clearest overall interpretation. The NMS was run in autopilot mode using PC-ORD version 4.17 (McCune and Mefford 1999).

Fig. 3.1. Locations of microbiotic crust community sampling sites, Hanford Reach National Monument, 2002–2003.

TAXONOMY AND NOMENCLATURE

Collections of lichens and bryophytes were made at both biodiversity and community sites for later identification in the laboratory. In total, over 2000 individual specimens were examined during this project. While many taxa were identified, a number of specimens were too undeveloped or too small to identify. Other taxa could be identified only to the genus level and are still awaiting identification to the species level.

There is no single comprehensive reference available for arid land lichens. Goward et al. (1994), McCune and Rosentreter (1995), and Brodo et al. (2001) proved to be useful general guides. There are more references available for the bryophytes, including Flowers (1973), Lawton (1971), McIntosh (1986, 1989), Rossman (1977), and some of the recently published works for the Bryophyte Flora of North America Project (BFNA 2003). J. Ponzetti, B. McCune, and T. Goward assisted with the identification of lichens. Bryophytes were identified by the author, and some specimens have been sent away for confirmation or identification by other experts. Herbaria at Oregon State University, at the University of British Columbia, and the private herbaria of T. Goward and J. Ponzetti were also helpful in the identification of lichens.

Vascular plant taxonomy follows Hitchcock and Cronquist (1973).

At this time, an increasing number of arid land lichen and bryophyte taxa are under revision and many generic names are in flux. In most cases, the taxonomic names that are used here are the more familiar traditional names, with a few exceptions. Following the work of Zander (1993), the moss genus *Syntrichia* is used here instead of the more familiar *Tortula* for the larger and coarser species of this group. Also, some researchers consider *Syntrichia ruralis* var. *papillosissima* to be a separate species, but this taxon is kept as a variety here, pending results of the ongoing research of Chan (2003).

Representative specimens of all species, once identified, will be packaged, labeled, and sent to the U.S. Fish and Wildlife offices in Hanford. Extra specimens will be housed at Oregon State University, the University of British Columbia, and, for the bryophytes, at the University of Washington, a request of Judith Harpel, a rare plant specialist for Washington state.

Vascular plant nomenclature follows Hitchcock and Cronquist (1973).

Results

LICHENS

This study found 54 lichen taxa growing as part of the terrestrial soil crust community (Table 3.2). Thirty-six of these taxa have been identified to species, while the identifications of the remainder are conditional at present. Of these, four taxa have tentative species identifications and14 have been identified to the genus only. Twenty-six lichens are common and widespread to locally common across the Monument, and the remaining taxa are uncommon to rare.

In addition to the terrestrial lichens, at least 26 taxa of saxicolous lichens were collected growing on rock outcrops, rocks, or stones (Table 3.3). Most collections of saxicolous lichens have been identified to genus only; five taxa are still of unknown identity. Not enough information is available to assess the distributions of saxicolous lichens.

Eleven lichen taxa are epiphytic on bark of shrubs and trees (Table 3.4). Most have been identified to genus, with species identification pending. Most of the epiphytic lichens listed in Table 3.4 appear to be relatively widespread, at least where sagebrush is present.

Four lichen species were found on two substrata. *Lecanora muralis* and an unknown, *Xanthoria*-like lichen are both primarily saxicolous, but are also found on soil. *Physconia enteroxantha* is found commonly on both bark and soil, and *Candelaria concolor*, primarily epiphytic, was occasionally found on soil.

Table 3.2. Terrestrial Lichens on the Hanford Reach National Monument, 2002–2003. X = taxa identified in 2002 (this study) and 1998 (Link et al. 2000). Numbers in parentheses indicate estimated number of species collected from that genus in 2002. General distribution of the taxa as observed in 2002 is indicated as follows: C = common and widespread; L = locally common, but not widespread; U = uncommon; R = rare.

Taxon	**2002**	**1998**	**Distribution**
Acarospora schleicheri	X	X	L
Amandinea punctata	X	X	L
Arthonia glebosa	X	X	C
Aspicilia filiformis	X	X	U
Aspicilia reptans	X	X	L
Aspicilia spp. (2)	X	X	R
Aspicilia cf. *terrestrialis*	X		R
Caloplaca jungermanniae	X	X	L
Caloplaca stillicidiorum	X		L
Caloplaca tominii	X	X	C
Caloplaca sp.	X		R
Candelaria concolor	X		R
Candelariella terrigena	X	X	L
Catapyrenium sp.	X		R
Cladonia cariosa	X		C–U
Cladonia fimbriata		X	
Cladonia cf. *pyxidata*	X	X	C–U
Cladonia sp. (unknown number)	X		L
Collema cf. *coccophorum*	X		U
Collema tenax	X	X	C
Collema spp. (2)	X		U–R
Diploschistes muscorum	X	X	C
Endocarpon pusillum	X	X	L
Lecanora sp.	X		R
Lecanora hagenii	X	X	L
Lecanora muralis	X	X	L
Lecanora zosteri	X		U
Lecidiella stigmatea	X		U
Lepraria sp.	X		R
Leptochidium albociliatum	X	X	L
Leptogium lichenoides	X	X	C
Leptogium spp. (2)	X		R

(Table continues)

Table 3.2 (continued).

Taxon	**2002**	**1998**	**Distribution**
Massalongia carnosa	X	X	U
Megaspora verrucosa	X		L
Mycobilimbia lobulata	X		R
Peltigera rufescens	X	X	R
Phaeorrhiza sareptana	X		L
Physconia enteroxantha	X	X	C
Physconia isidiigera	X	X	U
Physconia muscigena	X		R
Placidium sp.	X		R
Placynthiella cf. *uliginosa*	X	X	C
Psora cerebriformis	X		U
Psora decipiens	X		R
Psora globifera	X	X	L
Psora luridella	X	X	U–R
Psora montana	X	X	L
Toninia sedifolia	X		R
Trapeliopsis bisorediata	X	X	L
Trapeliopsis sp. (possibly *T. californica*)	X		R
Trapeliopsis steppica	X	X	L
possibly *Xanthoria* sp.	X		R

Table 3.3. Saxicolous lichens on the Hanford Reach National Monument, 2002–2003. Question marks (?) indicate taxonomic uncertainty. Figures in parentheses indicate estimated number of species collected in that genus.

Taxon	**Taxon**
Acarospora cf. *fuscata*	?*Lobothallia* sp.
Acarospora sp.	*Melania* cf. *disjuncta*
Aspicilia cf. *calcarea*	*Melania* sp.
Aspicilia cf. *contorta*	*Neofuscelia* sp.
Aspicilia sp.	*Rhizocarpon* sp.
Caloplaca sp.	*Rhizoplaca peltata*
Candelariella cf. *vitellina*	*Rhizoplaca* sp.
Endocarpon cf. *pulvinatum*	*?Sarcogyne* sp.
Lecanora cf. *garovaglii*	*Umbillicaria* cf. *arctica*
Lecanora muralis	*Umbillicaria* spp. (2)
Lecanora cf. *rupicola*	*?Verrucaria* sp.
Lecanora sp.	*Xanthoria* sp.*
Lecidia atrobrunnea	Unknown spp. (2–5)
Lecidia cf. *tessellata*	

Table 3.4. Epiphytic lichens on the Hanford Reach National Monument, 2002–2003. Question marks (?) indicate taxonomic uncertainty. Figures in parentheses indicate estimated number of species collected in that genus.

Taxon	**Taxon**
Candelaria concolor	*Physcia* sp.
?*Cyphelium tigillare*	*Physconia enteroxantha*
Lecanora cf. *piniperda*	*Xanthoria* spp. (2)
Leptogium sp.	Unknown spp. (2)
Melanelia sp.	

BRYOPHYTES

At least 35 bryophyte taxa, all mosses, were found during this survey (Table 3.5). Twenty-eight species identifications have been confirmed, and seven have been identified to genus only. Twenty-four of the moss species are associated principally with soil crusts. Five species are principally saxicolous, although two of these species, *Grimmia alpestris* and *G. trichophylla,* are also found on some crusts with finer soils, and one species, *Grimmia anodon*, on the edges of silt-rich cliffs. Five species are associated with wetland habitats.

Table 3.5. Bryophytes on the Hanford Reach National Monument, 2002–2003. Question marks (?) indicate taxonomic uncertainty. Figures in parentheses indicate estimated number of species collected in that genus. Habitat codes are as follows: C = soil crust, R = rock or stones, W = wetland. General distribution of the taxa is indicated as follows: C = common and widespread; L = locally common, but not widespread; U = uncommon; R = rare.

Taxon	Habitat Code	Distribution
Aloina bifrons	C	L
Aloina cf. *rigida*	C	R
Amblystegium sp.	W	R
Anacolia mensiesii	R	R
Barbula sp.	C	R
Bryoerythrophyllum columbianum	C	C
Bryum argenteum	C	L
Bryum cf. *caespiticium*	C	C
Bryum sp.	C	C
?Calliergon sp.	W	R
Ceratodon purpureus	C	C
Crossidium seriatum	C	R
Didymodon brachyphyllus	C	U
Didymodon cf. *nevadensis*	C	R
Didymodon tophaceus	W	R
Didymodon vinealis	C	L
Didymodon spp. (2)	C	U
Drepanocladus aduncus	W	R
Encalypta rhaptocarpa	C	U
Funaria hygrometrica	W	R
Grimmia alpestris	R/C	U–R
Grimmia anodon	R/C	R
Grimmia ovalis	R	U
Grimmia trichophylla	R/C	U
Phascum cuspidatum	C	R
Pseudocrossidium obtusulum	C	L
Pterygoneurum ovatum	C	U
Pterygoneurum subsessile	C	R
Syntrichia caninervis	C	C
Syntrichia princeps	C	L
Syntrichia ruralis	C	C
Syntrichia ruralis var. *papillosissima*	C	C
Tortula brevipes	C	C
Trichostomopsis australasiae	C	C

COMMUNITY ANALYSES

NMS ordination resulted in a three-dimensional solution that explained 93% of the variance in the microbiotic soil crust community data (Table 3.6) and minimized stress in the ordination (Table 3.7). Of the three axes of the solution, Axis 1 (59%) and Axis 3 (30%) explained the greatest proportion of the variation (Table 3.6). Axes 1 and 3 are presented in the ordination diagram (Fig. 3.2).

In the diagram, distances between the sample units approximate similarity or dissimilarity in species composition (McCune and Grace 2002), thus S5, S12, S13, and S14 have similar species assemblages but are dissimilar to S11, and still more dissimilar to S2. Based on the results of the ordination, several sites or groups of sites can be distinguished:

- **Group 1 (Sites 2, 6, 7, and 9).** Group 1 includes four sites on silt loam soils of the Arid Lands Ecology (ALE) Reserve. The sites have similar vascular plant assemblages: herb layers are dominated by bluebunch wheatgrass (*Agropyron spicatum* [= *Pseudoroegneria spicata*]) and Sandberg's bluegrass (*Poa sandbergii* [=*Poa secunda*]) along with associated forbs. The shub layer of Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) is still present in sites 7 and 9. Sites 2 and 6 have burned recently but the species composition of their biological crusts still exhibit strong similarities to the other sites in the group.

  Lichen diversity is high in this group of sites. Defining species include *Acarospora schleicheri*, *Arthonia glebosa*, *Aspicilia* sp., *Cladonia* sp., *Diploschistes muscorum*, *Leptochidium albociliatum*, *Leptogium* cf. *lichenoides,* and *Trapeliopsis bisorediata* and *T. steppica*. The sites exhibit relatively high cover of mosses, with *Bryoerythrophyllum columbianum*, *Aloina bifrons*, *Syntrichia caninervis*, and *S. ruralis* usually present.

Table 3.6. Proportion of species variance explained. Non-metric multidimensional scaling (NMS) ordination of biological soil crust communities of the Hanford Reach National Monument, 2002–2003.

Axis	Proportion Explained: Incremental	Cumulative
1	.594	.594
2	.042	.635
3	.296	.932

Table 3.7. Stress in relation to dimensionality (number of axes). Non-metric multidimensional scaling (NMS) ordination of biological soil crust communities of the Hanford Reach National Monument, 2002–2003.

Axes	Stress: Minimum	Mean	Maximum
1	26.969	36.169	53.513
2	11.446	14.647	18.028
3	6.178	6.300	6.772
4	3.860	5.215	18.360

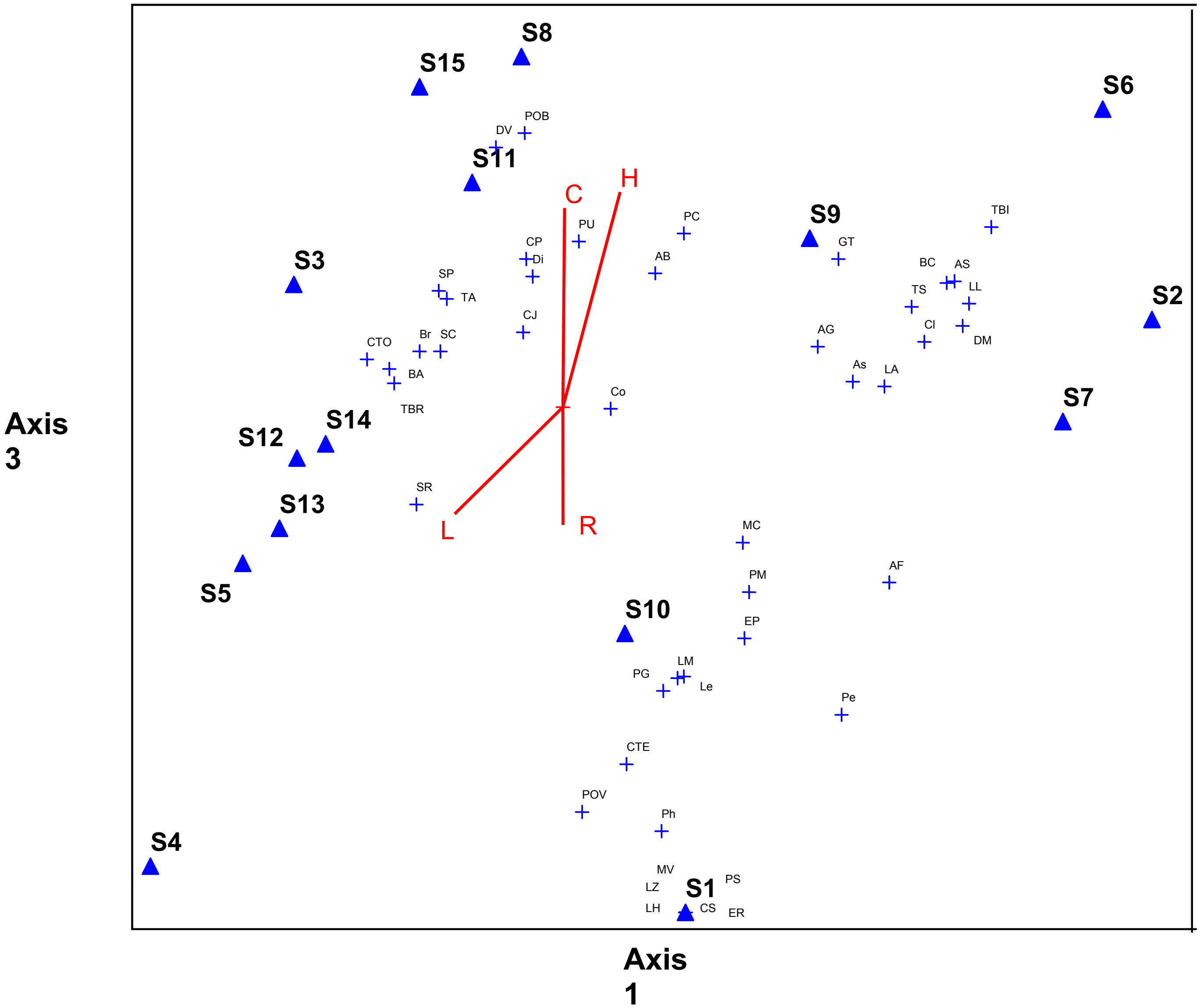

Fig. 3.2. Non-metric multidimensional scaling (NMS) ordination of biological soil crust communities: triplot of sites (▲), lichen and bryophyte taxa (+), and environmental vectors. Species codes for lichen and bryophyte taxa are presented in Table 3.8. Environmental vectors are as follows: C = total percent cover of all microbiotic crust; H = percent cover of herbaceous layer; L = percent cover of litter; R = percent cover of rock and stone.

Table 3.8. Species codes for lichen and bryophyte taxa used in non-metric multidimensional scaling (NMS) analysis (Fig. 3.2).

Lichens	**Code**	**Bryophytes**	**Code**
Acarospora schleicheri	AS	*Aloina bifrons*	AB
Arthonia glebosa	AG	*Bryoerythrophyllum columbianum*	BC
Aspicilia filiformis	AF	*Bryum argenteum*	BA
Aspicilia spp.	As	*Bryum* sp.	Br
Caloplaca jungermaniae	CJ	*Ceratodon purpureus*	CP
Caloplaca stillicidiorum	CS	*Didymodon* sp.	Di
Caloplaca tominii	CTO	*Didymodon vinealis*	DV
Candelariella terrigena	CTE	*Encalypta rhaptocarpa*	ER
Cladonia sp.	Cl	*Grimmia trichophylla*	GT
Collema sp.	Co	*Pseudocrossidium obtusulum*	POB
Diploschistes muscorum	DM	*Pterygoneurum ovatum*	POV
Endocarpon pusillum	EP	*Syntrichia caninervis*	SC
Lecanora hagenii	LH	*Syntrichia princeps*	SP
Lecanora muralis	LM	*Syntrichia ruralis*	SR
Lecanora zosteri	LZ	*Tortula brevipes*	TBR
Leptochidium albociliatum	LA	*Trichostomopsis australasiae*	TA
Leptogium lichenoides	LL		
Leptogium spp.	Le		
Massalongia carnosa	MC		
Megaspora verrucosa	MV		
Peltigera sp.	Pe		
Phaeorrhiza sareptana	PS		
Physconia sp.	Ph		
Placynthiella cf. *uliginosa*	PU		
Psora cerebriformis	PC		
Psora globifera	PG		
Psora montana	PM		
Trapeliopsis bisorediata	TBI		
Trapeliopsis steppica	TS		

- **Group 2 (Sites 3, 4, 5, 8, 11, 12, 13, 14, and 15).** This is a somewhat diverse group of sites characterized by sandy to sandy loam soils. The vascular plant communities are characterized by moderately well-developed to well-developed shrub layers, with Wyoming big sagebrush, bitterbrush (*Purshia tridentata*), and rabbitbrush (*Chrysothamnus* spp.) dominant on particular sites. Characteristic grasses include needle-and-thread (*Stipa comata*), Indian ricegrass (*Oryzopsis hymenoides*), Sandberg's bluegrass, and, occasionally, bluebunch wheatgrass. Site 4 appears as an outlier to this group, but represents sampling exclusively under sagebrush, in the same plant community as, and adjacent to, Site 3

  Mosses are the major defining species for this group. They include *Bryum argenteum*, *Bryum* sp., *Ceratodon purpureus*, *Didymodon vinealis*, *Didymodon* spp., *Pseudocrossidium obtusulum*, *Syntrichia caninervis, S. princeps, S. ruralis*, *Tortula brevipes*, and *Trichostomopsis australasiae*. *Caloplaca tominii* and *Placynthiella* cf. *uliginosa* are representative lichens.

- **Site 1.** This site on the west-facing slope near the summit of Rattlesnake Mountain is unique among the sample sites. It is the highest elevation site in the survey, and its stony loam, regosolic soils are distinct from the soils of the other community sampling sites.

  The vascular plant community is characterized by scattered low shrubs (*Eriogonum* spp., *Artemisia tripartita*), along with bluebunch wheatgrass (*Agropyron spicatum*), Sandberg's bluegrass (*Poa sandbergii*), and forbs. There is some sign that fire has burned through the site, but the effects of fire have probably been minimized by the discontinuous distribution of vascular plants on the stony soil. The crust here appears to be mid- to, possibly, late seral.

  Characteristic crust lichen species include *Caloplaca* cf. *stillicidiorum*, *Lecanora* spp., *Megaspora verrucosa*, *Phaeorrhiza sareptana*, and *Physconia* sp. *Lecanora muralis* is common on stones in the site, and also grows on soil, especially adjacent to the stones it inhabits. Characteristic mosses include, *Encalypta rhaptocarpa* and *Pterygoneurum ovatum*, along with *Ceratodon purpureus* and a small form of *Syntrichia ruralis*.

- **Site 10.** The species composition of microbiotic crusts at site 10 is roughly intermediate between the associations on silt loam, sand, and stony loam soils described above, as its placement near the center of the diagram indicates. The vascular plant community of this unburned remnant of shrubland on the ALE Reserve is characterized by big sagebrush, spiny hopsage (*Grayia spinosa*), and Sandberg's bluegrass. The soil is a sandy loam, with occasional stones. Characteristic species include *Candelaria terrigena*, *Endocarpon pusillum*, *Lecanora muralis*, *Leptogium* sp., *Massalongia carnosa*, and *Psora* spp. There are no bryophytes that define this group.

Sites to the right of the ordination diagram all occur on silt loam, sandy loam, or stony loam soils, all on the ALE Reserve (Fig. 3.2). Sites to the left are located on the McGee Ranch-Riverlands, Saddle Mountain, and Wahluke units, and exhibit sandy loam to sandy soils, suggesting a soil gradient along Axis 1.

The variable litter (L) exhibited a moderately negative correlation with both Axis 1 (r = - 0.465) and Axis 3 (r = - 0.463; Table 3.9). All other correlations of environmental and community variables with Axis 1 tended to be weak. Correlations of variables with Axis 3 tended to be moderate, with total herb cover (H; r = 0.655) and total crust cover (C; r = 0.630) exhibiting the strongest correlations. Correlations of all variables with Axis 2 tended to be weak. Cover of mineral soil was the variable least correlated with any of the NMS axes and is not displayed on the ordination diagram.

Table 3.9. Correlations of community and environmental variables with ordination axes. Non-metric multidimensional scaling (NMS) ordination of biological soil crust communities of the Hanford Reach National Monument, 2002–2003.

	Axes		
Variables	**1**	**2**	**3**
Crust cover	0.049	0.178	0.630
Herb cover	0.339	- 0.131	0.655
Litter	- 0.465	- 0.255	- 0.463
Mineral soil	0.167	0.297	0.422
Rock & stone	- 0.033	- 0.019	- 0.485

Discussion

LICHENS

This survey has shown that the Hanford Reach National Monument has a rich assemblage of lichens and mosses that are found in shrub steppe plant communities as well as in a variety of other habitats. Over 120 taxa of lichens and mosses were found within the Monument. Due to the inherent difficulties associated with the identification of lichens and bryophytes, a number of taxa still await identification. The number of species is expected to increase as identification work continues. The saxicolous and epiphytic lichens, and the wetland bryophytes reported in this study represent the first formal collections of cryptogamic taxa from these habitats on the Monument.

At least 24 taxa have been added to the list of soil crust lichens reported on the Hanford Site (Table 3.2). The two new species of *Trapeliopsis* reported by Link et al. have been recently identified as *T. bisorediata* and *T. steppica* (McCune et al. 2002), and both were confirmed during the present survey. Twenty-two of the 23 known taxa identified by Link et al. (2000) have been confirmed, with only *Cladonia fimbriata* unconfirmed. Species of *Cladonia* are almost always only present as squamules and are difficult to identify to species without mature podetia (reproductive structures). There are probably more species of *Cladonia* present than have been reported. *Acarospora geogena*, listed by Link et al. (2000), is probably best considered within the *A. schleicheri* complex (B. McCune pers. comm. 2002). One lichen taxon (possibly *Xanthoria*) has an uncertain generic affinity, and may represent a new lichen record for North America (T. Goward pers. comm.).

Ponzetti et al. (2000) found a comparable number of terrestrial lichen taxa (52) from the nearby Horse Heaven Hills area. The Horse Heaven Hills area was characterized by generally more extensive and less disturbed crusts than those found on the Hanford Reach National Monument, as well as a wider diversity of crust habitats. Ponzetti et al. (2000) also reported approximately 40 saxicolous lichens and some 16 epiphytic lichens from the Horse Heaven Hills area.

BRYOPHYTES

This study has recorded more than 5 times the number of bryophyte taxa as had previously been reported for the Hanford Site. Four of six mosses collected earlier (Link et al. 2000) have been confirmed, and two of their collections were found to be misidentifications. In their collections, *Grimmia* cf. *montana* is *G. alpestris*, and *Ceratodon purpureus* is *Grimmia trichophylla*. *Ceratodon purpureus* has been confirmed for the Monument by the present study, but *G. montana* has not. Ponzetti et al. (2000), focusing primarily on lichens, reported 11 bryophyte species on the Horse Heaven Hills.

Four species of bryophytes found earlier by McIntosh (1986) on the ALE Reserve in 1981 were not found during the present survey, although they are suspected to still be present on the Monument. They include the mosses *Bryoerythrophyllum recurvirostrum*, *Didymodon vinealis* var. *luridus*, and *Grimmia pulvinata*, and the thallose liverwort *Athalamia hyalina*.

During the present survey, a number of collections were made of unusual forms of *Syntrichia caninervis* and *S. ruralis* that do not clearly fit into familiar North American taxonomic concepts, but strongly resemble European species. These taxa are presently under investigation at the University of British Columbia (Chan 2003), and will be sent to European authorities for confirmation.

Some of the as yet unidentified mosses may prove to be species of biogeographic significance. At least one moss, *Crossidium seriatum*, a rare endemic western North American species, is new to Washington state.

COMMUNITY ANALYSES

Species that have similar ecological requirements overlap in space to form assemblages that traditionally have been called communities. Although there has been a great deal of ecological discussion regarding vascular plant communities, very little information is available in the literature concerning arid land bryophyte and lichen communities.

There are some constraints to defining crust communities in the Hanford Reach National Monument, first and foremost being the various types and degrees of disturbance and the resulting irregularity and patchiness of the soil crusts. Most of the sites that were sampled have had fire disturbance at some level of intensity, and some have ongoing disturbance by animals and wind. Although the crusts at most sites appear to be at an early to middle successional stage of development, some sites have patches of crust that probably represent late successional stages.

A minor constraint in the process of defining communities is the incomplete stage of the taxonomy and understanding of morphological variation of many of the taxa in the Monument. While the major contributing taxa are known, better understanding of the taxonomy of associated microbiotic species will enable researchers to define soil crust communities more accurately.

Because of these constraints, combined with the generally early stage of exploration of the soil crusts on the Monument, the following community identifications and descriptions remain speculative, and further research is required before they can be more fully clarified. The following late seral soil crust communities are postulated, based on extensive reconnaissance of the site and supported by the results of community sampling and multivariate analysis:

1. *Trapeliopsis steppica – Bryoerythrophyllum columbianum* Community. This community is typical of Group 1 sites (see Results). Additional microbiotic indicator species include the lichens: *Acarospora schleicheri*, *Arthonia glebosa*, *Aspicilia* sp., *Cladonia* sp., *Diploschistes muscorum*, *Leptochidium albociliatum*, *Leptogium* cf. *lichenoides,* and *Trapeliopsis bisorediata*. Early to mid-successional species present in this association include the lichens: *Arthonia glebosa*, *Cladonia* sp., *Diploschistes muscorum*, and *Trapeliopsis bisorediata*. This community was also observed during a visit to ALE in 1981 (McIntosh 1986), when it was relatively widespread around the ALE Research Laboratories. In addition to *Bryoerythrophyllum columbianum*, the mosses *Aloina bifrons*, *Syntrichia ruralis*, and *Trichostomopsis australasiae*, and the lichen *Diploschistes muscorum* were collected there from all eight grazing control plots sampled during this visit (McIntosh 1986).

This community develops on generally finer sandy loam and silt loam soils that predominate on the west side of the Monument. It is associated mainly with the Wyoming big sagebrush/bluebunch wheatgrass vascular plant community types. Although sample sites for this community type were all on relatively gentle slopes, this community may be present on steeper slopes at higher elevations in the Rattlesnake Hills and along the slopes of Rattlesnake Mountain.

Five of the indicator lichens for this community (*Acarospora schleicheri*, *Arthonia glebosa*, *Diploschistes muscorum*, *Leptochidium albociliatum*, and *Leptogium* cf. *lichenoides*) are classified as non-calciphiles by McCune and Rosentreter (1995). This suggests that the substrates on which these crusts grow are relatively low in calcium and, following Ponzetti (2000), may also have comparatively low pH. Ponzetti (2000) found that crust cover in the Horse Heaven Hills was generally highest on these types of soils.

2. *Syntrichia* spp. (in particular *Syntrichia ruralis*, but also *S. caninervis* and *S. princeps*) – *Caloplaca tominii* Community. This moss-dominated community is characteristic of Group 2 sites (see Results). It is common on sandier soils and thus is probably less stable and more prone to disturbance (Ponzetti 2000) than the ***Trapeliopsis steppica – Bryoerythrophyllum*** community, with early seral species such as *Bryum* spp., *Ceratodon purpureus*, and *Didymodon* spp. common across the community and persisting even into later seral stages. Additional indicator species include the mosses: *Bryum argenteum*, *Caloplaca jungermanniae*, *Ceratodon purpureus*, *Didymodon vinealis*, *Pseudocrossidium obtusulum*, *Tortula brevipes*, and *Trichostomopsis australasiae*, and the lichen *Placynthiella* cf. *uliginosa*.

This community develops on sandy soils with a relatively low proportion of clays and/or silts. The sands themselves range from fine to coarsely textured. The community is associated with a variety of vascular plant community types, including big sagebrush, bitterbrush, and rabbitbrush shrublands. Although sample sites were primarily on gentle slopes, this community may develop on steeper slopes as well, although many of these slopes are lacking significant crust cover.

Two of the indicator lichens for this community (*Caloplaca tominii* and *Caloplaca jungermanniae*) are classified as calciphiles by McCune and Rosentreter (1995). This suggests, although weakly, that the substrates on which these crusts grow are high in calcium and, following Ponzetti (2000), also have comparatively high pH.

3. *Phaeorrhiza sareptana – Lecanora* spp. – *Encalypta rhaptocarpa* Community. This community has a diverse assemblage of relatively small lichens, including *Caloplaca* and *Lecanora* spp., many of which inhabit the bases of dead grasses and other litter that are common across the site. Although represented by a single community sampling site, microbiotic species associations similar to this community were observed at a number of other sites in the Rattlesnake Hills area and near the top of Saddle Mountain. Additional indicator species include the lichens *Candellaria terrigena*, *Caloplaca stillicidiorum*, *Megaspora verrucosa*, *Peltigera* sp., and *Physconia* sp. and the moss *Pterygoneurum ovatum.*

This community is characteristic of stony loam soils, and is found in low shrub (*Eriogonum* spp., *Artemisia tripartita*)/bluebunch wheatgrass communities at higher elevations on the Monument. The generally cooler and moister conditions at these elevations may contribute to the distinctive microbiotic flora of this community.

One of the indicator lichens for this community (*Phaeorrhiza sareptana*) is classified as a calciphile by McCune and Rosentreter (1995). This suggests, also weakly, that the substrates on which these crusts grow may be somewhat high in calcium and, according to Ponzetti (2000), have comparatively high pH.

ENVIRONMENTAL FACTORS

Soil factors, including structure, pH, electro-conductivity, and $CaCo_3$ availability, appear most critical in the development and composition of biological crusts (Belnap et al. 2001, Ponzetti 2000). Understanding of the relationship between soil chemistry and the composition of biological soil crusts is at a very early stage.

There appears to be a strong relationship between soil texture and crust composition and stability on the Monument. Soils with finer materials, including silts, clays, and finer sands, occur most commonly on the west side of the Monument and east of the Columbia River in the central part of the White Bluffs area. These soils appear to favour the development of crusts with a relatively high richness and cover of lichen species. Soils comprised of coarser materials, such as the sandier soils that predominate in the Wahluke, McGee Ranch–Riverlands, and Saddle Mountain units, appear to have a higher richness and cover of bryophytes and comparatively few lichens. Climatic factors, in particular heat load, and elevation also influence crust composition (Belnap et al. 2001).

Large areas of the Monument have been heavily disturbed, particularly by fire. Disturbance, though varied in severity and extent, was common across the entire Monument, rendering crust development patchy. The influences of wildfire and disturbance by grazing or burrowing animals are reflected in the seral stages of the various crusts; i.e., increasing disturbance leads to an increase in early seral taxa at any particular site, and a generally lower seral stage of succession across the local landscape. Soil crusts across the Monument have been affected to a greater or less degree by fire. Large areas are devoid of readily discernible crusts, although, following rainfall, early crust development can be seen in many of these sites. The types of devastating fires that caused this severe damage were probably nonexistent or rare in the pre-European past.

Although grazing by domestic animals has halted in the Monument, lasting effects of this activity can still be seen in some sites. Elk also impact the soil crust to some degree over large areas of the Monument, especially in some of the remaining small patches of Wyoming big sagebrush on the ALE Reserve where, apparently, elk use has concentrated since the 2000 wildfire. The impacts of elk are likely not beneficial to the recovery of soil crusts. Exclosure studies may be necessary to document these impacts.

Some areas are strongly impacted by invasive plant species, in particular cheatgrass (*Bromus tectorum*). In a few areas on sandy soils, the presence of small amounts of cheatgrass may provide some mosses with a foothold in an otherwise unstable habitat. In general, however, cheatgrass abundance is inversely related to microbiotic soil crust cover (Ponzetti et al. 2000). Cheatgrass dominates the interspaces between perennial vascular plants, competing with microbiotic crusts for moisture and light (Ponzetti et al. 2000) and smothering crusts with its copious annual production of dense litter (Belnap and Philips 2001, Belnap et al. 2001). Cheatgrass infestations promote changes in other ecosystem factors such as soil chemistry, soil nutrient regimes, and soil fauna (Evans et al. 2001, Belnap and Phillips 2001), which may impact microbiotic crusts. Impacts of these changes on crust communities are unknown but are worth investigating.

The study of soil crust communities and their relationships to environmental factors is at a very early stage, and the results presented here are tentative. Communities of cryptogamic organisms are difficult to define, especially in disturbed environments (McCune and Grace 2002), and very little is known about the community dynamics and rates of succession in soil crusts, especially for the bryophytes (Ponzetti 2000, Ponzetti et al. 2000). The Monument provides an excellent opportunity to observe this process on a broad scale. Knowledge of the environmental relationships of taxa and communities is often completely lacking. Detailed studies of soil factors, in particular, are likely to yield important information in terms of species distribution on the landscape. Such knowledge will help in the conservation and restoration of microbiotic crust communities in the future.

Recommendations

BIODIVERSITY STUDIES

No biological inventory is ever truly complete in an area of the size and complexity of the Hanford Reach National Monument. While most of the representative microbiotic taxa have likely been reported from large areas of the Monument, some areas of significant cryptogam biodiversity have probably not been sampled. At minimum, the following areas merit further investigation:

- Central Hanford, including Gable Mountain, Gable Butte, and the Hanford Dunes.
- Western portions of Rattlesnake Mountain on ALE.
- The Yakima Ridge area on ALE.
- Springs, streams, and shaded gullies of the Rattlesnake Hills north of Rattlesnake Mountain.
- Outcrops, ridges, and bluffs in the White Bluffs area. From a distance, much of this area appears to be barren, but areas of microbiotic species richness are likely to be found, especially alongside shaded gullies.
- Lithosol, talus, and rock outcrop communities throughout the area, at all elevations.

RESEARCH AND MONITORING

Studies of soil crust communities and their relationships to environmental factors on the Monument are at a very early stage and much could be learned by their continuation. Monitoring changes in the soil crust through time will contribute to a more thorough understanding of the ecological dynamics of all the ecosystems in the Monument. Monitoring is often used to provide an objective platform for changing or maintaining a current management practice (Rosentreter et al. 2001). However, data collected by monitoring programs can also be applied to basic questions of conservation biology and can assist in the development and refinement of best management practices. Rosentreter et al. (2001) and Belnap et al. (2001) provide detailed guidance in the development of soil crust monitoring plans.

At present, no proven techniques exist for the restoration of microbiotic crusts at a landscape scale (J. Belnap pers. comm.). Therefore, all management activities related to restoration, invasive species, and fire management, along with general road and facilities maintenance, should be conducted in such a way as to minimize or eliminate any adverse effect on existing quality microbiotic crust (Belnap 1994). Research into management actions that can enhance or restore biological soil crust communities should be strongly considered. Some promising techniques are outlined in Belnap et al. (2001).

Rare Plants

Overview

Large-scale rare plant surveys conducted during 1994, 1995, and 1997 discovered more than 100 occurrences of 28 rare plant taxa across the Hanford Site (Soll et al. 1999). Three of these rare taxa were entirely new to science: Umtanum desert buckwheat (*Eriogonum codium*), White Bluffs bladderpod (*Lesquerella tuplashensis*), and basalt milkvetch (*Astragalus conjunctus* var. *rickardii*). The results of these surveys confirmed Hanford as a critical area for the conservation of rare shrub-steppe, riparian, and aquatic plant taxa in Washington state.

The *Biodiversity Inventory and Analysis of the Hanford Site* (Soll et al. 1999) identified key areas for additional rare plant inventory work. Little is known about the reproduction and other life history traits of newly discovered taxa, nor of many of Hanford's rarest plants. Demographic information is necessary to interpret population fluctuations and guide management activities in the conservation of rare species. The goals of rare plant studies during the 2002 field season were to increase understanding of the population dynamics of selected rare taxa, and to extend inventories into selected special habitats. The following section summarizes these investigations. Full details can be found in Caplow (2003).

Purpose and Scope

The design of rare plant investigations for 2002 focused on demographic studies of several rare plant species, a targeted search for individuals and habitat for another taxon, and targeted searches in special habitat types for rare annuals. Since low precipitation dramatically reduces the expression of the annual flora, unusually dry conditions during winter and spring 2002 (Hanford Meteorological Station 2002) necessitated a reassessment of this last priority. In order to utilize time and funding most efficiently, resources that had been budgeted for this task were reallocated to other tasks within the rare plant scope of work. The revised list of objectives was as follows:

- Objective 1. Document current status and summarize previous years' demographic data for *Rorippa columbiae.*
- Objective 2. Document current status and summarize previous years' demographic data for *Eriogonum codium*.
- Objective 3. Document current status and summarize previous years' demographic data for *Lesquerella tuplashensis*.
- Objective 4. Survey islands of the Hanford Reach of the Columbia River for occurrences or potential habitat of *Artemisia campestris* subsp. *borealis* var. *wormskioldii*.

4. Current Status of Columbia Yellowcress (*Rorippa columbiae*) on the Hanford Reach

Florence E. Caplow

Introduction

Columbia yellowcress, *Rorippa columbiae*, is a low-growing perennial herb in the mustard family (Brassicaceae). Columbia yellowcress is listed as a Species of Concern with the USFWS and is considered Threatened in Washington (WNHP 1997).

The local population of Columbia yellowcress is one of 11 populations of the species, which is known from the Hanford Reach of the Columbia River (Fig. 4.1), the lower Columbia, south-central Oregon, and the Modoc Plateau in northeastern California. Based on fieldwork in 1982 and 1994, the Hanford Reach population of Columbia yellowcress had been considered the species' most vigorous known population (Salstrom and Gehring 1994). The other ten populations supported a total of between 12,000 and 22,000 plants in 1996 (Kaye 1996).

Although the habitat of Columbia yellowcress varies across its range, there are several habitat characteristics that all populations share: inundation for part of the year, seasonal fluctuation of water level, wet soil well into the growing season, and open habitats with a low cover of competing vegetation. Population numbers can fluctuate from year to year, and these fluctuations seem to be hydrologically driven (Kaye 1996). The plants grow and reproduce in late summer and early fall, when water levels are lowest. The species is rhizomatous and may also spread vegetatively by rooting at the nodes of aboveground stems. Stems are found in clusters, indicating the possibility of large clones (Gehring 1994).

Methods

Two methods were used in 2002 to document the current status of *Rorippa columbiae* on the Hanford Reach:

1. Re-surveying of long-term monitoring plots installed by the U.S. Bureau of Land Management (BLM) at the downstream end of the Hanford Reach.
2. Direct visual surveys of areas along the reach that once supported large numbers of *R. columbiae* plants.

BLM Monitoring Transects

In 1991 the BLM installed seven transects within the Hanford reach population of *R. columbiae* (Fig. 4.2). The transects are located on three islands: Homestead Island (three transects), Plow Island (three transects), and North Forked Island (one transect). The monitoring was designed based on the protocol developed by Janet Gehring (1992). Two-meter-wide transects were subjectively placed in areas that support *R. columbiae*. Transects varied in length, depending on the spatial organization of the *R. columbiae* subpopulation. Within each transect, subjectively chosen 2 m x 5 m macroplots were placed in 1991 within areas that supported *R. columbiae*. These macroplots have been used since 1991. The number of macroplots per transect also varies. Sixteen 0.5 m x 0.5 m microplots were placed within each macroplot in 1991. The number, height, and reproductive status of all stems in each microplot were recorded. The transects were surveyed by BLM in 1994, 1995, 1997 (partial), 1998, and 2002. The 1997 data has not been used in this analysis, since only two transects were surveyed. Transect #3 on Plow Island has not been relocated since 1994, so the monitoring has focused on six transects rather than seven. Although the monitoring was designed for data analysis within macroplots rather than by transect, the number of plants per transect has dropped to such low levels that data were analyzed by transect for this study.

Monitoring plots were surveyed on October 8, 2002. Another visit was made on November 1 to see if any of the plants had produced flowers or fruit between October 8 and November 1.

VISUAL SURVEYS

Some visual survey work took place on October 8, 2002, in the vicinity of the BLM monitoring plots. An attempt at a visual survey was made on October 9, but water levels were too high. A visual survey by boat of populations at the lower end of the Hanford Reach was made on November 1, 2002.

Fig. 4.1. Range of *Rorippa columbiae* on the Hanford Reach.

Fig. 4.2. Location of BLM monitoring transects established in 1991 for *Rorippa columbiae*.

Results

There was a precipitous decline in the number of stems per transect between 1995 and 1998, and there has been little recovery between 1998 and 2002 (Fig. 4.3; Table 4.1).

The presence of flowers and fruits (Table 4.2) also decreased precipitously between 1995 and 1998. These data combined with the visual observations of the Hanford Reach population in 2002 suggest that virtually no sexual reproduction took place in the Hanford Reach population in 1998 or 2002.

The visual survey included islands and shoreline from Homestead Island upstream to just below the White Bluffs boat launch. Plants were found in four areas: within two BLM monitoring transects, on Homestead Island outside of a monitoring transect, and on an island just below the White Bluffs boat launch. A total of seven patches totaling 110 stems were found on the island south of the White Bluffs boat launch. None of the stems had either flowers or fruit. No other areas supported plants; at least some of these areas supported plants as recently as 1995.

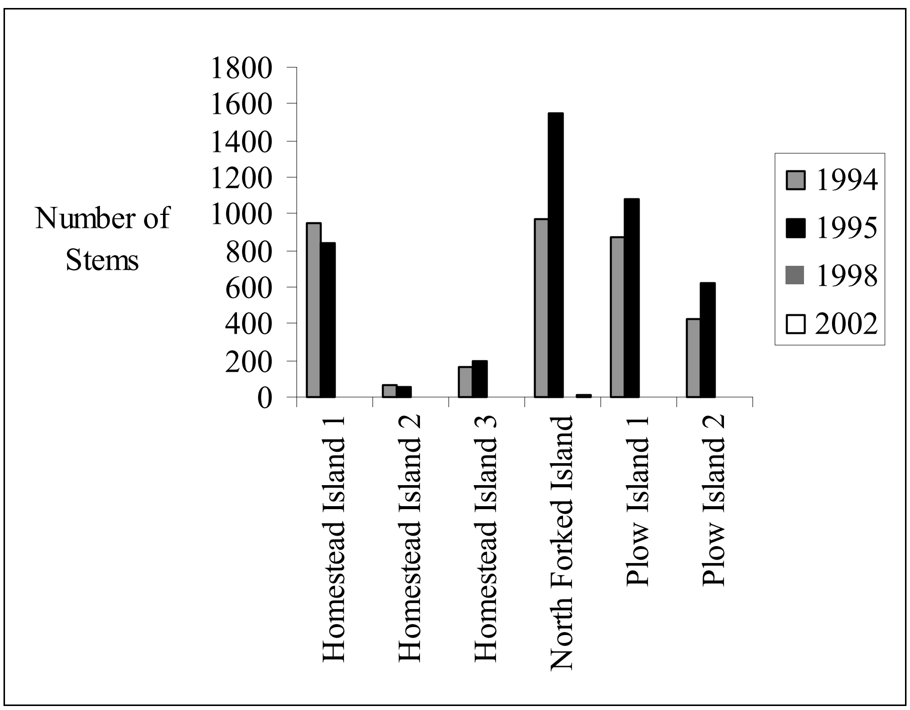

Fig. 4.3. Stem counts of Columbia yellowcress (*Rorippa columbiae*) in study plots on the Hanford Reach, 1994–2002. Stem counts in 1998 and 2002 ranged only between 0–3 and 0–10 respectively.

Table 4.1. Number of stems observed per transect, Hanford Reach population of Columbia yellowcress (*Rorippa columbiae*), 1994–2002.

Transect	1994	1995	1998	2002
Homestead Island 1	953	845	3	0
Homestead Island 2	64	59	0	0
Homestead Island 3	159	201	0	0
North Forked Island	967	1546	3	10
Plow Island 1	878	1082	3	4
Plow Island 2	425	621	1	0

Table 4.2. Average numbers of flowers and fruit per plant, Hanford Reach population of Columbia yellowcress (*Rorippa columbiae*), 1994–2002.

	1994		1995		1998		2002	
Transect	Flowers	Fruit	Flowers	Fruit	Flowers	Fruit	Flowers	Fruit
Homestead Island 1	0.6	2.1	0.4	0.1	0	0	0	0
Homestead Island 2	0	Fruits present	0	0	0	0	0	0
Homestead Island 3	Flowers present	Fruits present	Flowers present	Fruits present	0	0	0	0
North Forked Island	0.8	1.1	0.1	0.1	0	0	0	0
Plow Island 1	0.4	0	0	0	0	0	0	0
Plow Island 2	1.9	1.8	0	0	0	0	0	0

Discussion

In 1982 and in 1994, the Hanford Reach supported millions of stems of Columbia yellowcress in numerous clumps along a 50-mile stretch of river (Sauer and Leder 1985, P. Camp pers.obs.). Since 1997, there has been a precipitous decline in the number of observed stems and patches of stems on the Hanford Reach. In 2002, less than 200 stems were seen in the area from the White Bluffs boat launch to the Ringold Boat Launch, an area which once supported at least 36,000 stems (Camp 1992). In 2002, there were no observed flowers or fruits on any stems.

It seems likely that some hydrologic change may be implicated in the current decline. Simmons (2000) conducted an experimental manipulation of an artificial population of *Rorippa columbiae* and found that continuously submerged plants exhibited leaf chlorosis, weak stems, and negative growth. Monitoring of several populations has shown that hydrologic changes influence population levels of Columbia yellow cress (Kaye 1996). Gehring (1994) hypothesized that sexual reproduction may depend on “long days,” and so plants exposed too late in the season to experience long photoperiods may not flower.

Gehring’s work from 1991 through 1993 on the Hanford Reach took place through the month of September (Gehring 1994). Sauer and Leder (1985) also commented that in 1982 the areas where the plants grew were more or less continuously exposed after late August. Observation on the Hanford Reach since 1997 suggests that plants are not regularly exposed until October, and during the period of maximum growth for plants (late summer and early fall), the elevation at which the plants grow on the Hanford Reach is submerged for most of the daylight hours. Plants are submerged during daylight hours on the lower Hanford Reach even after Reverse Load Factoring begins in mid-October, due to the 6–8 hour lag time from Priest Rapids Dam to the lower Hanford Reach. Reverse Load Factoring is a river management strategy designed to keep river levels low over Vernita Bar to allow for redd counting, and it begins in mid-October and continues until mid-November. However, at least one subpopulation of *R. columbiae* close to Vernita Bar also appears to be extirpated. Hydrologic changes include Reverse Load Factoring (which began in 1988), summer spill for non-listed fish species (July 1–August 15), and/or higher river levels for power production prior to Reverse Load Factoring. There have also been lower spring peaks since 1995 (T. Dresser pers. comm.). Further work should be done to characterize the hydrologic changes on the Hanford Reach since 1982 and their possible impacts on *R. columbiae*. The USFWS has requested this work from Grant County PUD.

The lack of spring scouring floods and the subsequent development of woody vegetation in the riparian zone has been implicated in the decline of Columbia yellowcress at Pierce Island on the lower Columbia (Habegger et al. 2000) but seems unlikely as a major causative factor in the current decline of the Hanford Reach population. The combination of very high population levels during portions of the last 20 years and the presence of large areas of suitable non-vegetated habitat upslope from the existing clusters of plants suggests that the current decline is probably attributable to more recent hydrologic changes. Siltation, also implicated at Pierce Island (Habegger et al. 2000), may be another factor in the decline of *R. columbiae* on the Hanford Reach.

It is difficult to evaluate the significance of the current decline. Monitoring records for the Hanford Reach population reach back to 1982 (Table 4.3). There was a strong decline in the late 1980s and then high population levels from 1990 to 1994. The current, very low population levels were first seen in 1997 and have been low in every year since 1997. No hourly analysis of the flow rate at Priest Rapids dam has been done to see if there are correlations between river regulation and the decline of the Hanford population.

Table 4.3. General trends in Columbia yellowcress (*Rorippa columbiae*) population on the Hanford Reach, 1982–2002. BLM = Bureau of Land Management; PNNL = Pacific Northwest National Laboratory; TNC = The Nature Conservancy; WNHP = Washington Natural Heritage Program.

Year	Population	Information	Agency
1982	high	survey	PNNL
1988	low	monitoring	BLM
1989	low	monitoring	BLM
1991	high	monitoring	BLM
1992	high	monitoring	BLM
1993	high	monitoring	BLM
1994	high	survey, monitoring	BLM, PNNL, TNC
1996	high	monitoring	PNNL
1997	none	monitoring	PNNL
1998	low	monitoring	PNNL
1999	low	monitoring, survey	PNNL
2000	low	monitoring	PNNL
2002	low	monitoring, survey	BLM, WNHP

Recommendations

- Gather information on the status of the species throughout its range. (WNHP)
- Using established monitoring protocols, continue annual monitoring of BLM sites for at least the next three years and conduct further surveys along the Hanford Reach to evaluate the population as a whole (BLM, Hanford Reach National Monument).
- Perform an analysis of river flows on an hourly basis and patterns of decline of the species (Grant County PUD).
- Re-evaluate the known information in 2-3 years and consider further action if decline continues. Further action could include hydrologic manipulation, establishment of new subpopulations, or control of riparian vegetation (all parties).

5. Current Status of Umtanum Desert Buckwheat (*Eriogonum codium*) on the Hanford Site

Florence E. Caplow

Introduction

Umtanum desert buckwheat, *Eriogonum codium*, is a small, mat-forming shrub in the buckwheat family (Polygonaceae). The species, which forms low mats up to 1 m in diameter, is an extremely narrow endemic and has no close relatives in Washington. The only known population is comprised of approximately 5000 plants spread over a 2 km long, 0.79 ha section of Umtanum Ridge in Benton County (Dunwiddie et al. 2000a). The site lies entirely within the McGee Ranch–Riverlands Unit of the Hanford Reach National Monument. *Eriogonum codium* Reveal, Caplow & Beck was first described in 1996 (Reveal et al 1996). It is a Candidate species for listing with the U.S. Fish and Wildlife Service and is listed as Endangered in Washington.

Eriogonum codium has been the subject of an intensive demographic monitoring project since 1997. Initial findings indicate that *E. codium* is a long-lived species (greater than 100 years) with high flower production, low germination rates, high seedling mortality, and high variability of growth between individuals and between years. Between 1997 and 1999 annual adult mortality exceeded recruitment, ranging from 0% to 4%. One hundred and sixty-nine new seedlings were observed during the same period, and none survived more than one year. Most seedlings died between May and July (Dunwiddie et al. 2000a).

This report summarizes the results of monitoring during the period 2000-2002, with further discussion of the trends over the six years since monitoring began.

Methods

In 1997, a series of 24 permanent 1 m x 2 m plots were randomly placed along three 50 m belt transects within the largest subpopulation of *Eriogonum codium*. Individual adult plants were mapped and tagged. More than 100 adult plants have been followed annually since 1997. For each tagged adult, data was collected on length and width of plants, number of inflorescences, and percent of canopy dead within each adult. Seedlings also were mapped within the 1 m x 2 m plots in May and in July of each year. Number of leaves and distance to nearest adult were recorded for each seedling (Dunwiddie et al. 2000a). The May seedling search was omitted in 1998 and 2002.

Results

Annual Mortality and Recruitment

One adult plant died between 1999 and 2000, four adult plants died between 2000 and 2001, and one adult plant died between 2001 and 2002 (Table 5.1). This pattern is consistent with what we have seen since 1998. The average annual mortality rate between 1998 and 2002 is 2.0 %. 1999 and 2001 were high mortality years, while 1998, 2000, and 2002 were low mortality years.

Table 5.1. Annual mortality and recruitment of Umtanum desert buckwheat (*Eriogonum codium*) on the Hanford Site.

Year	Mortality (# of Plants)	Mortality Rate	Recruitment (# of Plants)
1998	0	0	1
1999	4	0.04	0
2000	1	0.01	0
2001	4	0.04	0
2002	1	0.01	0
TOTAL	10		1
Annual Avg.	2	0.02	0.2

Recruitment has continued to be very low. Only one recruitment event has been observed since monitoring began in 1997. A single plant that was first observed in 1999 and believed to be a 1998 seedling was still alive in 2002. It is now 24 cm^2 in area but has not yet flowered. Another plant suspected to be from the 1995 cohort has also not yet flowered.

INFLORESCENCE PRODUCTION

Inflorescence production varies widely between years and between plants (Fig. 5.1).

Average production has varied from a high of 27.1 inflorescences per plant (range 0–209) in 1997 to a low of 5.4 inflorescences per plant (range 0–61) in 1999. 1999 and 2001 were years of low production. These were the same years that had the highest mortality (Table 5.1).

A small number of plants (7) produced more than 100 inflorescences in 2002, while more than half of the plants produced less than 10 inflorescences in 2002. This pattern has also been seen in other years. In other words, a small number of plants are producing a disproportionate percentage of the inflorescences.

SEEDLING PRODUCTION

Seedling production varies between years (Fig. 5.2). The highest year for seedling production was 2000 (72 seedlings). The lowest year for seedling production was 2002, when no seedlings were produced. Seedling production also varies widely between quadrats: Three of the 24 permanent quadrats have produced 45% of the total number of seedlings counted since the study began (Fig. 5.3). Three quadrats have produced no seedlings at all. Only one quadrat has produced seedlings in every year, and only eight quadrats have produced seedlings in at least half the years. Seedling mortality has been 100% from one year to the next, with the exception of 1998. The 1998 seedling that survived was not found during the July survey and is believed to have germinated later in the season. Seed viability studies conducted by Ransom Seed Laboratory in 2002 found that 5% of the seed was not dormant and germinated in 21 days with moisture and light. This suggests that a fraction of the seed would not require stratification to germinate and could potentially germinate during summer or fall. This is further suggested by the 1999 data, in which more seedlings were found in July than in May. The weather from May through July in 1999 was unusually cool and dry (Hanford Meteorological Station web site, February 6, 2003).

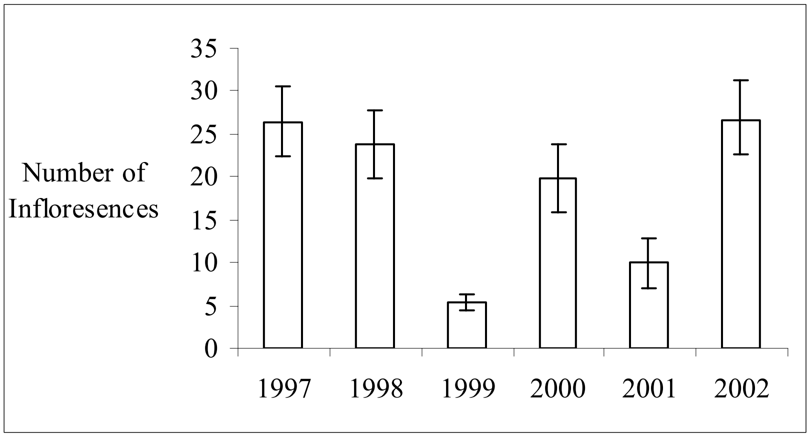

Fig. 5.1. Average number of infloresences of Umtanum desert buckwheat (*Eriogonum codium*) per plant, 1997–2002. Vertical bars indicate ± one standard error.

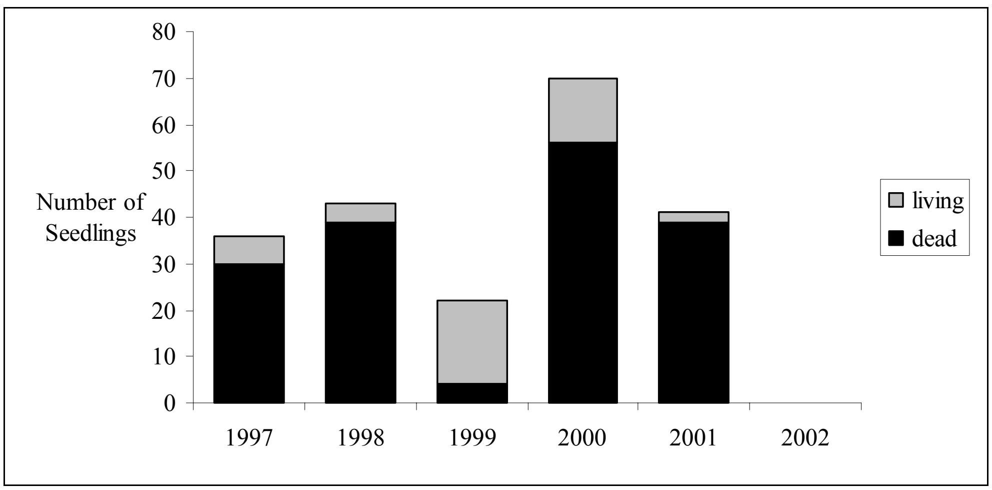

Fig. 5.2 Annual seedling production of Umtanum desert buckwheat (*Eriogonum codium*), 1997–2002. Results are from July surveys.

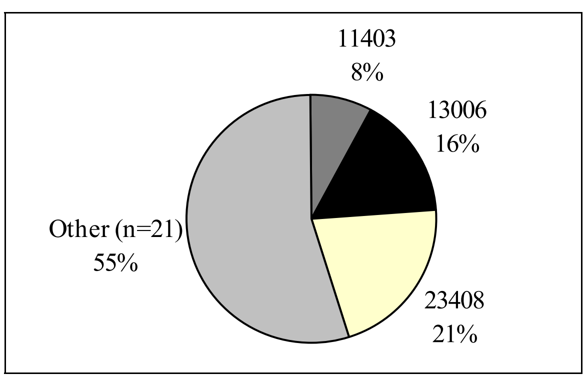

Fig. 5.3. Proportion of total seedlings of Umtanum desert buckwheat (*Eriogonum codium*) produced by the three most productive quadrats, 1997–2002.

Mortality between May and July has varied from 70% to 92% (Table 5.2). In general, we have been successful at relocating May seedlings during the July survey, whether alive or dead at the time of the survey. This suggests that most of the year's seedlings were found in the 1998 and 2002 July surveys.

Discussion

The years of 1999 and 2001 were both years of relatively low flower production and high mortality of adult plants. 1999 was also a year of low seedling production. Due to the correlation between annual mortality and annual inflorescence production, meteorological patterns between 1997 and 2002 were investigated, with particular attention to 1998–1999 and 2000–2001 (HMS 2003). In general, there were no extreme patterns, with the exception of March and April of 1999 (unusually dry) and November and December of 2000 (unusually cold). The dry conditions of 1999 might explain the low seedling production, but March and April of 2001 (another year of high mortality and low flower production) were quite wet. There were also no unusual cold periods in the winter of 1998–1999 or 2000–2001. In fact, most winters since 1997 have been slightly above average in temperature. However, low seedling production in 2002 could be correlated with dry conditions: All months from March through July exhibited below-average precipitation, with the exception of June. At this point, there is only a weak potential relationship between meteorological conditions and plant performance or mortality.

Because monitoring efforts have spanned such a short period of time, it is not clear if observations indicate a true decline of the population *E. codium* or a situation of extremely episodic recruitment. Most years since the monitoring began have been years of average precipitation. 1999 was an unusually dry year (50% of normal precipitation), and 2000 was a somewhat wet year (116% of normal precipitation). 1995 and 1996 were the wettest years since records began in 1946 (200% average precipitation), so one would expect those years, if any, to be years of recruitment. We have one suspected 1995 cohort plant in the study, but when monitoring began in 1997 we saw very few small plants (Dunwiddie et al. 2000a).

We continue to be concerned about the low recruitment in the population. Further studies on the seed bank and competition with cheatgrass are planned for in 2003.

Recommendations

It is recommended that annual monitoring be continued for at least the next four years. Within a ten-year period there may be at least one episode of significant recruitment; by skipping one or more years, we may miss the year in which that recruitment occurs.

Effects of monitoring on the population could be minimized by eliminating the May seedling count. It is also desirable to check portions of the populations that are not within the monitoring area to determine whether recruitment patterns are low outside the monitoring area as within, and are not the result of the monitoring itself.

Methods for evaluating cheatgrass cover and its impact within the study plots should also be developed.

Currently the Umtanum Ridge portion of the McGee Ranch–Riverlands Unit of the Hanford Reach National Monument is closed to public access. Because of the extremely limited distribution of *Eriogonum codium*, the species' lack of fire tolerance, and the potentially disruptive effects of off-road vehicle use and other recreational impacts, it is recommended that current management policies regarding public access to this area be continued in order to protect this extremely rare species.

Umtanum desert buckwheat is completely intolerant of wildfire (Dunwiddie et al. 2000a). A wildfire burning through Umtanum desert buckwheat's habitat would have a devastating effect upon the only known population of this extremely rare species. In order to help perpetuate this sensitive species, methods aimed at protecting the population from wildfires as well as from impacts associated with fire suppression activities must be incorporated into a comprehensive fire management plan for the Umtanum Ridge portion of the Hanford Reach National Monument.

Table 5.2. Total seedling production of Umtanum desert buckwheat (*Eriogonum codium*) on the Hanford Site, 1997–2002.

Year	Month	Living	Dead	Total
1997	June	41	0	41
1997	July	6	29	35
1998	July	5	8	43
1999	May	0	1	1
1999	July	18	6	24
2000	May	54	18	72
2000	July	16	56	72
2001	May	36	1	37
2001	July	3	45	48
2002	July	0	0	0

6. Current Status of White Bluffs Bladderpod (*Lesquerella tuplashensis*) on the Hanford Site

Florence E. Caplow

Introduction

White Bluffs bladderpod, *Lesquerella tuplashensis*, is a low-growing, taprooted perennial herb in the mustard family (Brassicaceae). Discovered only in 1994, *L. tuplashensis* is a narrow endemic, restricted to a 17 km stretch of the White Bluffs of the Columbia River in Franklin County (Rollins et al. 1995, WNHP 2000). The population lies entirely within the Wahluke Unit of the Hanford Reach National Monument. The species inhabits dry, steep exposures of the White Bluffs where a layer of alkaline calcium carbonate (caliche) soil has been exposed. Overall vegetation cover is low in this stressful environment. Common associates include Wyoming big Sagebrush, Sandberg's bluegrass, and cheatgrass. *L. tuplashensis* is a Candidate species for listing by the U.S. Fish and Wildlife Service under the Endangered Species Act and is listed as Threatened in Washington (Washington Natural Heritage Program 1997).

Lesquerella tuplashensis is a short-lived perennial most closely related to *Lesquerella douglasii*, which grows on cobble bars on the Columbia River. Demographic studies of *L. tuplashensis* were begun in 1997. The studies had two components: life history plots placed non-randomly throughout the population, and counts of reproductive individuals in 100 m transects placed randomly throughout the northern half of the population. In 2002, only the transects were surveyed, and only this portion of the study is summarized below. Results from life history plots, 1997 to 1999, are presented in Dunwiddie et al. (2000b).

Methods

Sampling was conducted in the northern one-third of the *L. tuplashensis* population. This area contains the most contiguous and least disturbed portion of the population: There are no evident impacts from nearby agricultural activities, and this portion of the population is generally <1 km from a vehicle track. In 1997, ten permanent 100 m transects were installed at random locations within a 3.7 km length of this area. An additional ten transects were added in 1998. All flowering plants were counted along each transect, and recorded according to their location: Plants growing on the top of the bluff are recorded as "Top" plants, plants growing in the cross-section of the caliche layer exposed at the top of the bluffs are recorded as "caliche" plants, and plants growing below the caliche on the upper slope are recorded as "slope" plants. Plants were censused in mid-May to early June in 1997, 1998, 1999, and 2002.

Results

The numbers of adult *L. tuplashensis* varied greatly between years. Our counts increased 21% on the transects between 1997–98, decreased by 65% between 1998–99, and decreased by 58% between 1999–2002 (Fig. 6.1). The total of 3,212 plants over ten transects in 2002 is the lowest since the study began, but that figure is within the possible surveyor error of the 1997 count of 3,793.

Results from the life-history plots showed that nearly all adult plants flower every year (Caplow and Dunwiddie 2000). Therefore, counts of flowering plants likely represent most of the adults in the sample population. Projecting the transect data to the 3.7 km portion of the population from which these samples are derived, one may conclude that the number of adult plants within the 3.7 km area varied between a low of approximately 12,000 plants in 2002 to a high of approximately 32,000 plants in 1998 (Fig. 6.2). Therefore, it is reasonable to conclude that the White Bluffs population is probably well in excess of 50,000 plants in "good" years. More monitoring is needed to determine the magnitude and frequency of high- and low-number years, as well as to obtain an understanding of the causes of these annual fluctuations.

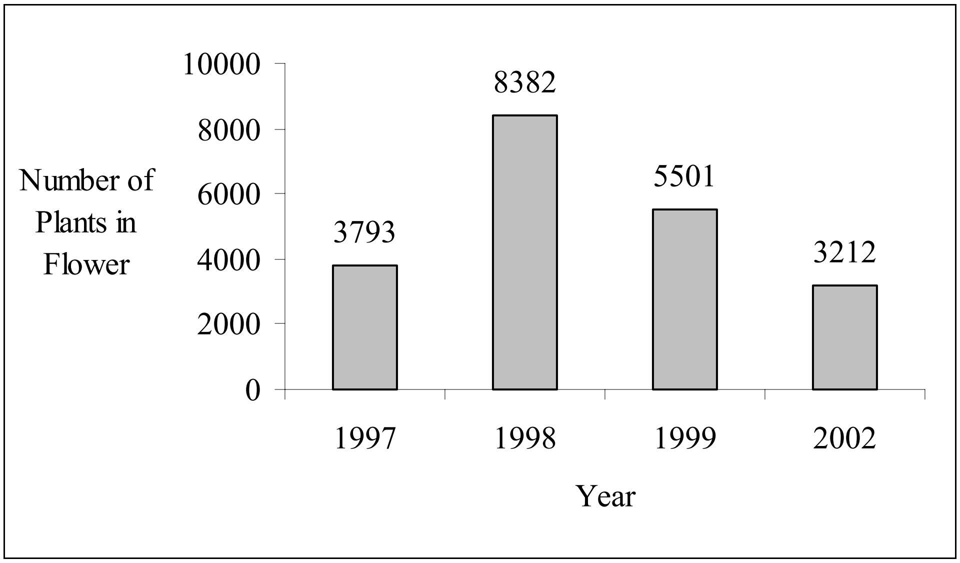

Fig. 6.1. Total number of flowering plants of White Bluffs bladderpod (*Lesquerella tuplashensis;* 10 transects), 1997–2002.

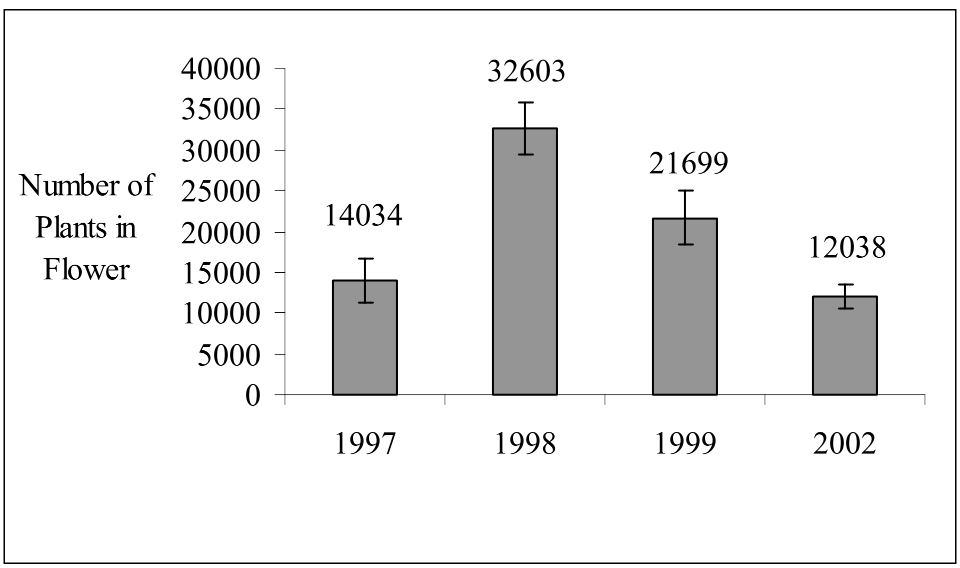

Fig. 6.2. Estimated number of flowering plants of White Bluffs bladderpod (*Lesquerella tuplashensis*) in the sample area. Sample area is a 3.7 km length of the northern one-third of the entire population. Vertical bars indicate 95% confidence intervals. Estimated values are based on 20 transect samples except for 1997, which is based on 10 transect samples.

Lesquerella tuplashensis is not uniformly distributed in the study area. Counts of plants along the 100 m transects varied considerably. However, plants along most of the transects appear to respond similarly to annual conditions (Fig. 6.3).

There are also changes in the spatial distribution of plants along the slope (Fig. 6.4). For instance, between 1997 and 1999 the proportion of plants found on the slope itself vs. in the caliche or on top of the caliche decreased from nearly 20% to less than 5%. Conversely, the proportion of plants on the flat top of the caliche layer increased from slightly more than 30% to nearly 60% between 1997 and 1999.

Discussion

Data from the permanent transects provide some indication of the magnitude and direction of trends in the overall population of *Lesquerella tuplashensis* from 1997–2002 (Figs. 6.1, 6.2). Since these transects were randomly selected only within the northern portion of the site, they may not necessarily represent changes in the overall population. However, they should be representative of changes that occur in the northern portion of the population.

The long-term trend and significance of changing proportions over slope position is not known. Given the relatively short life span of individual plants (4–5 years, based on life history plots; Dunwiddie et al.2000b), there may be cyclical colonization of and extirpation from various portions of the slope.

The population of *L. tuplashensis* is threatened by a number of factors within the Hanford Reach National Monument and beyond its borders. Slope failure along the White Bluffs, attributable to irrigation agriculture in neighboring lands, has the potential to create local disturbances within a portion of the population. Recreational impacts such as trampling and illegal off-road vehicle use increase erosion locally. Invasive plant species, especially yellow starthistle (*Centaurea solstitialis*), may compete with *L. tuplashensis* for limited moisture and contribute to increases in wildfire frequency (WNHP 2000, Soll et al. 1999).

A critical methodological question is the number of transects and the frequency of monitoring needed to detect a significant change in the population of *L. tuplashensis*, particularly when natural fluctuations in the population can be 100% or more from year to year. One approach is to assume that the years from 1997 to 2002 represent a normal range of variation: i.e., the northern portion of the population can range from 12,000 +/- 1450 plants to 33,000 +/- 3100 plants without affecting the viability of the population. The lower end of the confidence interval of the lowest population estimate is 10,550, so a conservative threshold for concern could be 10,500 plants. Data indicate that the population can fluctuate widely from year to year, so just one year of a population below 10,500 may not be cause for concern. Multiple years of low population levels are likely to be of greater significance.

Recommendations

SAMPLING PROTOCOLS

A reasonable management objective for *Lesquerella tuplashensis* would be to maintain at least 10,500 reproductive plants of *L. tuplashensis* in the northern 3.7 km of the White Bluffs population from 2003–2013. If the population remains below this threshold for two years or more, management should conduct further research into the causes of decline and/or initiate management action(s). Under this scenario, a sampling objective could then be 90% confidence that the population estimates are within 25% of the estimated true value.

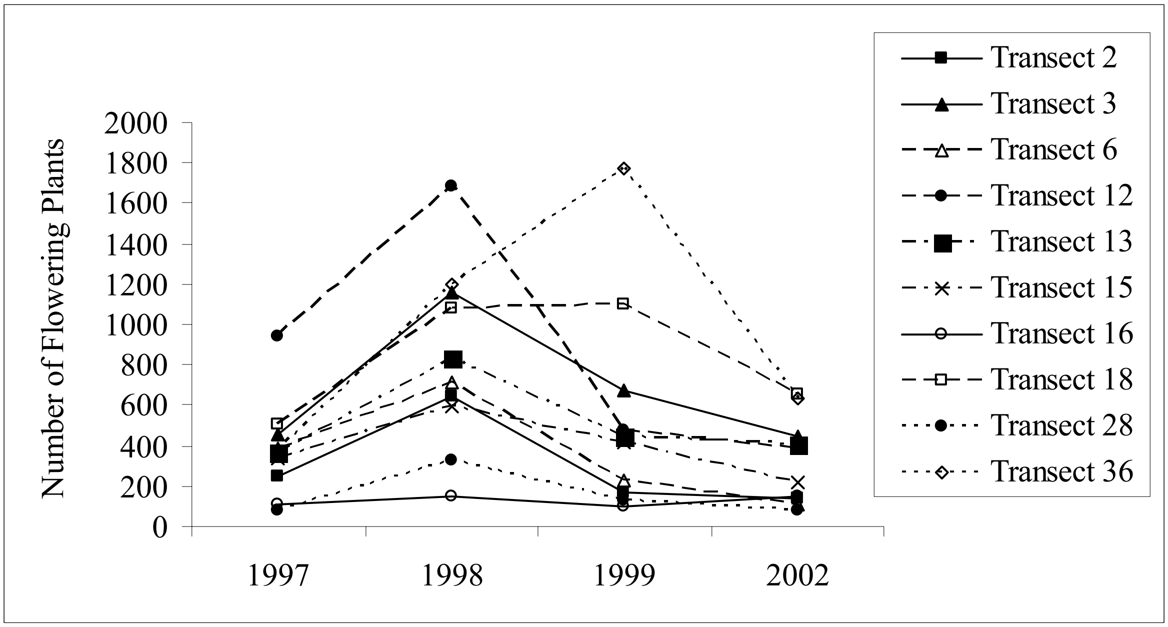

Fig. 6.3 Total number of flowering plants of White Bluffs bladderpod (*Lesquerella tuplashensis*) per transect (10 transects), 1997–2002.

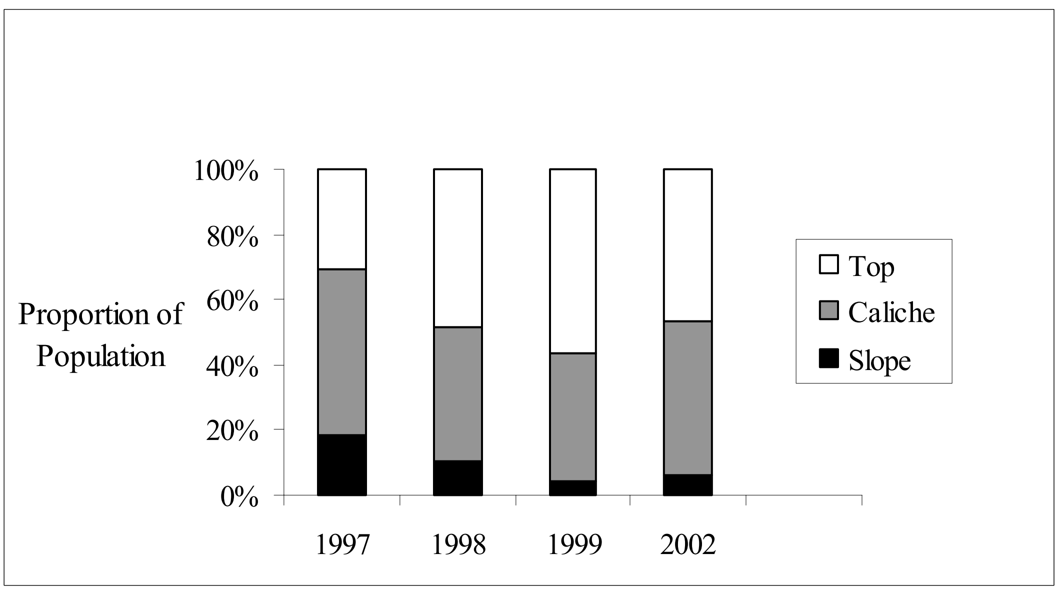

Fig. 6.4 Relative spatial distribution of flowering plants of White Bluffs bladderpod (*Lesquerella tuplashensis;* 10 transects), 1997–2002.

A full monitoring of once every three to five years is recommended for the current degree of threat for this population. However, if the population estimate (including its confidence interval) is at or below the threshold of 10,500 plants, the population should be sampled again in the following year. In years where full monitoring is not taking place, a visual survey of the northern end of the population should take place. Monitoring and visual surveys should also assess the extent of invasive plant species within the population area.

There is a clear decrease in the range of confidence intervals when 20 transects are sampled, suggesting that all 20 transects must be sampled in order to be within 25% of the estimated true population value. When confidence intervals were calculated on the basis of 20 transect samples between 1998 and 2002, confidence intervals were nearly always within the target range; when calculations were based on only 10 transects, estimates were rarely within this range (Table 6.1).

INVASIVE SPECIES

Invasive plant species pose a threat to at least portions of the White Bluffs bladderpod population. Invasive species may compete with White Bluffs bladderpod for moisture, nutrients, or other limiting resources, and may alter fire regimes or other ecosystem properties upon which *Lesquerella tuplashensis* depends. Invasive species within the range of *L. tuplashensis* should be mapped and appropriate treatments applied to minimize these species' effects on the bladderpod population. An infestation of yellow starthistle (*Centaurea solstitialis*) was discovered during 2003 within a portion of White Bluffs bladderpod's range (Evans et al. 2003). The infestation was mapped and plants were removed manually. Timely followup treatment and monitoring of this infestation is necessary to protect the narrow habitat of *L. tuplashensis*.

Table 6.1. Comparison of confidence intervals for White Bluffs bladderpod (*Lesquerella tuplashensis*), sampling 10 or 20 transects.

a. 95% confidence

	Twenty Transects			Ten Transects		
Year	**Estimated Total Individuals**	**Confidence Interval**	**Proportion of Mean**	**Estimated Total Individuals**	**Confidence Interval**	**Proportion of Mean**
1997				14034	5491	0.39
1998	32603	6287	0.19	31013	10394	0.34
1999	21699	6589	0.30	20354	12025	0.59
2002	12038	2893	0.24	11884	4904	0.41

b. 90% confidence

	Twenty Transects			Ten Transects		
Year	**Estimated Total Individuals**	**Confidence Interval**	**Proportion of Mean**	**Estimated Total Individuals**	**Confidence Interval**	**Proportion of Mean**
1997				14034	4608	0.33
1998	32603	5276	0.16	48211	8723	0.28
1999	21699	5530	0.25	34854	10091	0.50
2002	12038	2428	0.20	20609	4116	0.35

7. Survey for Northern Wormwood (*Artemisia campestris* subsp. *borealis* var. *wormskioldii*) and Potential Habitat on the Islands of the Hanford Reach

Florence E. Caplow

Northern wormwood, *Artemisia campestris* ssp. *borealis* var. *wormskioldii*, is a low, taprooted biennial or perennial forb in the composite family (Asteraceae). Northern wormwood is a regional endemic within the Columbia Basin, known only from riparian areas of the Columbia River at two locations: Miller Island at the eastern end of the Columbia Gorge in Klickitat County, and the Beverly site in Grant County. Northern wormwood is a Candidate species for listing under the Endangered Species Act with the USFWS and is considered Endangered in Washington (WNHP 1997).

The islands of the Hanford Reach were surveyed for existing or potential habitat of northern wormwood on April 22–23, 2003. While no existing populations of this rare taxon were found, a number of islands exhibited habitats that were highly similar to that of the Beverly site. The Beverly site, upstream of the Hanford Reach, currently supports the largest known population of *Artemisia campestris* subsp. *borealis* var. *wormskioldii*. This site has the following characteristics (Framatome AMP DE&S 2003):

- Stabilized cobble or sand substrate.
- Elevation of most of the population between 1 ft. and 6 ft. of the elevation of the high-water line.
- Most of the population on gravel islands or peninsulas surrounded on two or more sides by water.
- Low total vegetation cover.
- High cover of bare ground.
- Low noxious weed cover.
- Most common associated native species: *Eriogonum compositum*, *Artemisia campestris* var. *scouleriana*, *Lesquerella douglasii, Descurainia pinnata, Lomatium grayii, Draba verna.*

The areas on the islands which most resembled the Beverly site in terms of substrate, vegetation, and elevation above high water were mapped as potential reintroduction sites (Table 7.1). Each polygon was identified as being either “moderate” or “excellent” habitat, based on the presence or absence of weedy species and the similarity of the site to the Beverly population area. Areas on the islands of the reach that are not within these polygons are less likely to be appropriate habitat for the species. Further detailed work is necessary before choosing a particular site as a reintroduction area.

Potential habitat for northern wormwood on the Columbia River shoreline was not assessed. Potentially suitable habitat could be identified using existing vegetation maps (Easterly and Salstrom 2001). Shoreline habitat is considered a lower priority as a reintroduction area, however, due to its greater vulnerability to disturbance. Both extant populations occur on islands, so there may be aspects of island hydrology that are particularly important for the species.

Table 7.1. Potential habitat for northern wormwood (*Artemisia campestris* subsp. *borealis* var. *wormskioldii*) on islands in the Hanford Reach. Island names are from USGS 71/2′ maps. Island numbers are from Hansen and Eberhardt (1971).

Island	Area	Habitat Quality
Locke Island	West side	Moderate
Rosseau Island	Most of island	Moderate
East of 100F	East side	Excellent
Plow Island (Island 12)	North end	Moderate
Plow Island (Island 12)	Center	Moderate
Homestead Island	Southeast side	Moderate
Island 15	West side	Moderate
Wooded Island	North end	Moderate
Johnson Island	North end	Excellent
Island 18	North end	Excellent
Island 19	Most of island	Excellent

Invertebrates

8. Aquatic Macroinvertebrates

Robert L. Newell

Introduction

This chapter reviews the literature of aquatic macroinvertebrates of the Hanford Site and compares taxonomic findings of studies conducted between 1948 and 2002. The results of recent benthic (bottom dwelling) and light-trap sampling are presented in relation to the distribution of Trichoptera (caddisflies) in Hanford aquatic environments and to the effects of wildfire on macroinvertebrates in two spring streams. Surveys of the Hanford Reach of the Columbia River for Pacific crayfish (*Pacifasticus leniusculus towbridgii*) and the western pearl mussel (*Margaritinopsis falcate*) are described. Newell (2003) provides details not included here.

Purpose and Scope

The primary objective of this study was to survey and compile all known records of aquatic macroinvertebrates of the Hanford Reach National Monument, including records from the Hanford Reach of the Columbia River, its local tributaries, and three spring streams on the Fitzner-Eberhardt Arid Lands Ecology (ALE) Reserve, in order to prepare a comprehensive literature review and to document changes in the taxa of aquatic macroinvertebrates in these environments over time. In 2002, this study also conducted benthic (bottom dwelling) sampling of Rattlesnake Spring and Snively Spring on the ALE Reserve. These collections were compared to those from light-trap sampling that recently had been conducted near the two springs, in the sand dunes area between the springs and the Columbia River, and on the Hanford Reach in order to evaluate the origin of several species of adult Trichoptera that had been captured in the light traps near the springs. The benthic sampling was also compared to similar sampling that had been conducted during spring 2000 in order to evaluate the effects on aquatic macroinvertebrates of the major wildfire that occurred in July 2000. Additionally, this study examined the current status of the crayfish, *Pacifasticus leniusculus towbridgii*, and the western pearl mussel, *Margaritinopsis falcata*, in the Hanford Reach.

Methods

THE HANFORD REACH OF THE COLUMBIA RIVER

The Hanford Reach is the only free-flowing, non-tidal segment of the Columbia River within the United States. The Hanford Reach study area has previously been described in Newell (1998) and elsewhere. The Reach is home to a diverse assemblage of fish and other aquatic organisms, is a major spawning site for Chinook salmon, and provides valuable nesting and feeding habitat for migratory waterfowl such as ducks, geese, and pelicans. The width of the river varies from approximately 1000 ft. to 3300 ft. (305–1005 m) within the Hanford Reach (PNNL 1998). Flows through the Reach fluctuate significantly on a daily basis as well as seasonally and annually and are controlled by releases from Priest Rapids Dam. During the last ten years, flows have averaged 120,000 cfs (340 m^3/sec). But in 1996–97 peak flows reached 415,000 cfs (1175 m^3/sec), far from the most recent flood of 1948 when peak discharge reached 742,000 cfs (2101 m^3/sec)

(PNNL 1998). Large annual and diurnal flow variations can cause water level fluctuations of about 25 ft. (7.6 m) that can be devastating to aquatic invertebrates. Even during the summer and fall, daily water levels may fluctuate by nearly 5 vertical feet (1.5 m) as hydroelectric generating needs dictate (pers. obs.).

Crayfish (*Pacifasticus leniusculus towbridgii*) and western pearl mussel (*Margaritinopsis falcata*) sampling occurred on the Hanford Reach during late winter (February–March 2002) and late spring (May 2002). Shorelines were walked, looking for mussel shells, and live mussels and rocks were randomly turned to search for crayfish. Crayfish traps were baited with fish and left overnight. Sampling areas were in the vicinity of the old Hanford townsite and one mile upstream from the Hanford 300 area. Several miles of shoreline were examined in both locations. The Washington Department of Fish and Wildlife was contacted for data on their recent snorkeling surveys. Current and historical records for *M. falcata* were reviewed and tabulated.

SPRING STREAMS OF THE ARID LANDS ECOLOGY RESERVE

Sampling was conducted in Snively Spring and Rattlesnake Spring to assess effects of the recent fire that burned areas around the spring streams. The study area, including a third spring, Benson Spring, has been described in Newell (1998), Pickel (2000), Newell et al. (2001), and elsewhere. Benson Spring is located in Bobcat Canyon and comprises three small springs that seep out of the base of the foothills near the north end of Rattlesnake Mountain. The discharge for this spring is approximately 0.0023 cubic meters/second, and it flows approximately 800–900 m before disappearing into the ground. Snively Spring originates from ground seeps about 5 km south of Rattlesnake Spring. Its perennial flow is approximately 3.6 km. Rattlesnake Spring originates from ground seeps, and its perennial flow is approximately 2.5 km before it disappears into the ground. This stream is the largest of the three and average discharge is approximately 0.01 cubic meters/second. Prior to the recent wildfire, Rattlesnake Spring had a luxuriant riparian zone that was heavily used by many animals, including the large elk herd present on the Monument, especially during the hot summers.

Each of the spring sampling stations was visited during the winter of 2002. Four stations in Rattlesnake Spring and four stations in Snively Spring were sampled. Stations were approximately equidistant from one another along the entire flowing water stretch of each spring stream. Samples were taken with a D-ring aquatic net with a 500-micron mesh. The sampler waded into the stream and placed the net downstream. The substrate was disturbed by kicking, wiping, and brushing the rocks and substratum. The current then carried the thus dislodged organisms into the net. Typically, up to 6 linear feet (2 m) of bottom was disturbed at each sample point. The net contents were placed into an enamel pan. All large pieces of detritus were carefully cleaned of organisms and discarded. The contents of the pan were poured through a very fine mesh net to remove the excess water. All organisms were preserved with 70% ethyl alcohol, labeled, and returned to the laboratory. Pickel (2000) used a quantitative sampler (0.093 m sq. area) of the same mesh size and similar separation and identification techniques.

In the laboratory, the benthic samples were processed and preserved for later identification. Organisms were identified to the lowest possible taxon, using the most current, regional, and complete references such as: Plecoptera (stoneflies), Baumann et al. (1977) and Stewart and Stark (1993); Odonata (dragonflies and damselflies), Paulson (1998); Trichoptera (caddisflies), Wiggins (1996); all other aquatic insects, Merritt and Cummins (1996); and other invertebrates, Smith (2001). A reference collection of all organisms is stored at the museum of the Washington State University/Tri-Cities campus in Richland, Washington, or at the Entomological Museum, Washington State University in Pullman, Washington. Appendix B of this volume acknowledges taxonomists who assisted in the identification of organisms for this study.

Night collecting trips for adult insects were conducted at both Rattlesnake Spring and Snively Spring. Mercury vapor and ultraviolet lights were illuminated at dusk at ground level, and sampling continued until approximately two hours after dark. Light trap sampling continued approximately twice monthly in 1998 and

1999, from March until adults failed to appear, usually in October (Newell et al. 2001). Some adult caddisflies were also collected from pheromone traps set to collect Lepidoptera. D. Strenge conducted additional unpublished sampling during 2001 near the springs and in a sand dunes area located between the springs and the Hanford Reach. This sampling provided some additional taxa and provided species names for some genera. Casual light-trap sampling was also conducted by Newell and others along the Hanford Reach between 1998 and 2002.

Results and Discussion

LITERATURE REVIEW

The first and possibly the most complete study of the benthic aquatic macroinvertebrates of the Hanford Reach was by Davis and Cooper (1951). This research was conducted during 1948. No one since this study has used a similar, intensive and comprehensive sampling approach. Davis and Cooper used a huge bottom dredge to collect samples during 1948–1950. This study began the same year as the most recent flood on the Columbia River (PNNL 1998). The principal objective was to survey radioactivity from the river aquatic organisms. Any resulting radioactivity would have originated from the nuclear reactors situated on the Columbia River along the northern boundary of the Hanford Site. The taxonomic treatment by Davis and Cooper (1951) was extensive, given the date and state of the taxonomy of many western species of aquatic organisms at that time. The report by Davis and Cooper (1951), like many early reports prepared at Hanford, was classified as “Secret” for many years and was only declassified in the 1990s.

Coopey (1948, 1953) completed one of the first limnological studies of the Columbia River. He studied the abundance of benthic organisms and provided a list of phytoplankton and zooplankton. Coopey (1953) also studied other crustacea of the river and found an extraordinary number of crayfish, *Pacifasticus leniusculus* (39 /ft^2, 420 /m^2).

The Pacific Northwest Laboratory, now the Pacific Northwest National Laboratory (PNNL), took charge of research at Hanford beginning in 1965. Battelle’s researchers have published numerous papers on the fauna, flora, and ecology of Hanford. Annual reports in the 1960s contain numerous studies on Columbia River aquatic organisms. Coutant (1966), for example, studied phototaxis on the caddisfly, *Hydropsyche cockerelli* and determined the retention time of radionuclides in mollusks and algae. Coutant et al. (1967b) also examined upstream dispersal of some caddisflies, *Hydropsyche cockerelli, Cheumatopsyche campyla*, and *C. enonis.* The limpet, *Fisherola nutalli*, was a favorite study organism (Coutant et al. 1967a, and Coutant 1968a, b).

Becker (1972a, b) examined effects of thermal discharges on aquatic biota such as the blackfly, *Simulium vittatum*, and thermal resistance of the crayfish. Wolf and Cushing (1972) published one of the earliest studies on Rattlesnake Spring. Their work provided some productivity estimates and records of the occurrence of periodic severe floods that had a devastating effect on the biota.

In the early 1970s, research on benthic organisms was stimulated by plans of the Washington Public Power Supply System (WPPSS) to build nuclear power plants on the Hanford Site near the Columbia River and to extract cooling water from the Hanford Reach (PNL 1977, 1978, 1979a, b, c; Beak Consultants Inc. 1980; WPPSS 1977, 1984, 1985, 1986). One of these reactors operates today. These studies provide the bulk of river aquatic invertebrate data available in the published record. Schwab et al. (1979) conducted a survey of all springs on Hanford and provided maps, water chemistry data, elevations, and drawings. Wolf and Cushing (1972) published one of the first studies on the ecology and environment around Rattlesnake Spring. Cushing and Rader (1982) investigated the food of *Callibaetis* sp. (Ephemeroptera) nymphs from Rattlesnake Spring. Cushing and Wolf (1982) provided an energy budget and water chemistry data. Gaines et al. (1992) and

Gaines (1987a, b) calculated secondary production of benthic insects in Rattlesnake and Snively Springs. Gaines et al. (1989) studied trophic relations and functional group composition of some benthic insects in both springs. Pickel (2000) was the first to survey Benson Spring for macroinvertebrates.

COMPARISONS OF INVERTEBRATE COMMUNITIES OVER TIME

The Hanford Reach of the Columbia River

Table 8.1 lists results of 11 previous studies covering a 50-year period. These studies utilized at least three very different sampling schemes, and this would affect sampling results. Davis and Cooper (1951) utilized a large, barge-mounted suction dredge, and their study occurred prior to the construction of Priest Rapids Dam. Some studies emphasized certain taxa, e.g., the WPPSS studies found many taxa of Annelida and Mollusca and resulted in the greatest number of taxa collected (92). Some studies identified most taxa to order or genus only, rather than to species. Differences in benthic assemblages are expected between the river suction dredge results gathered before Priest Rapids Dam was constructed and the wading sampling conducted by Newell (1998). Major taxa collected in all studies included Porifera, Annelida, Mollusca, Hemiptera, Ephemeroptera, Trichoptera, Lepidoptera, Diptera, and Arachnida. Some of the species identification was made from adult collections (Newell 1998). It is uncertain if the other studies collected adults. Major taxonomic revisions make comparisons very difficult in the Mollusca and for other taxa. No reference collections remain for comparison.

Tributaries of the Hanford Reach

Newell (1998) provided the first examination of Hanford Reach tributaries. The assumption that tributary streams might contain a microcosm of the river's fauna or that the streams might function as refugia proved **not** to be true. However, some organisms were collected here and not in the nearby river in 1998, including damselflies (Odonata—two species of *Argia, Enallagma* sp., and one unknown species), flatworms (Turbellaria), and two species of riffle beetles (Elmidae).

A total of 21 taxa were collected in the tributaries in 1998 (Table 8.2) compared to 52 from the Hanford Reach. The irrigation-return stream at Ringold had the most diverse fauna of the tributaries with 14 taxa collected. Several major taxa found in the Hanford Reach were missing from the tributaries, including Porifera, Bryozoa, Decapoda, Lepidoptera, and Arachnida.

Spring Streams of the Arid Lands Ecology Reserve

All aquatic macroinvertebrates collected in Rattlesnake Spring from all published studies are listed in Table 8.3. Gaines (1987a, b) collected 20 taxa, and Newell (1998) found 30 taxa, while the present study found 21 taxa. Gaines apparently did not collect or did not identify Oligochaeta, Mollusca, Amphipoda, and Hemiptera but did identify Chironomidae to genus, while Newell (1998 and this study) identified all of these groups but identified Chironomidae only to family. When only those groups collected and identified by both researchers are compared, the results are: Gaines (1987a,b) 15 taxa; Newell (1998) 15 taxa; and Newell (this study) 12 taxa.

All aquatic macroinvertebrates collected in Snively Spring from all published studies are listed in Table 8.4. Gaines (1987a, b) collected 18 taxa, while Newell (1998) found 14 taxa, and Newell (this study) collected 13 taxa. Gaines apparently did not collect or did not identify Decapoda, Amphipoda, Hemiptera, or Coleoptera but did identify Chironomidae to genus, while Newell (1998 and this study) identified all of these groups but identified only Chironomidae to family. Since Gaines identified Coleoptera in Rattlesnake Spring but not in Snively Spring, there may not have been any beetles collected from Snively Spring. When only those groups collected and identified by both researchers are compared, the total taxon count is: Gaines (1987a,b) 13 taxa;

(Text continues on page 87)

Table 8.1. Summary of all benthic invertebrate taxa reported by the major benthic studies on the Hanford Reach, 1948–1998, including all organisms, immatures and adults. Current taxonomic names are provided when applicable. **PHYLUM/SUBPHYLUM** is in uppercase bold. CLASS/SUBCLASS is in uppercase. **Order/suborder** is in lowercase bold.

Benthic Invertebrates	Davis & Cooper (1951)	PNL (1976-1979)	Beak Consul-tants (1980)	WPPSS (1977, 1984-1986)	Newell, (1998)
PORIFERA—Sponges					
Spongilla lacustris	X	X	X	X	X
COELENTERATA—Jellyfish, hydroids, corals, sea anemones					
Craspedacusta sowerbii				X	
Hydra sp.	X	X		X	
PLATYHELMINTHES—Flatworms, tapeworms, planarians, flukes					
Cura sp.			X		
Dugesia sp.		X			
Dugesia dorocephala				X	
Planaria sp.	X				
BRYOZOA—Moss animals					X
Plumatella sp.	X			X	
Pertinatella sp.	X			X	
NEMATODA—Nematodes, roundworms, eelworms	X	X	X		
ANNELIDA—Earthworms, marine worms, leeches		X		X	
HIRUDINEA—Leeches	X		X	X	
Erpobdella punctata				X	
Helobdella stagnalis				X	
Illinobdella moorei				X	
Piscicola sp.				X	
Placobdella montifera				X	
Theromyzon rude				X	
OLIGOCHAETA—Earthworms, freshwater ringed worms, pot worms			X	X	X
Chaetogaster sp.				X	
Triannulata montana				X	
Xironogiton instabilis				X	
MOLLUSCA—Mollusks: clams, snails, octopi					
BIVALVIA—Bivalves: clams/mussels				X	X
Anodonta californiensis				X	
Anodonta compressum				X	
Anodonta nuttalliana	X				
Corbicula fluminea				X	X
Cyclas fluminea (=Corbicula?)	X				
Margaritifera margaritifera (=falcata)				X	
Pisidium sp.					X

(Table continues)

Benthic Invertebrates	**Davis & Cooper (1951)**	**PNL (1976-1979)**	**Beak Consul-tants (1980)**	**WPPSS (1977, 1984-1986)**	**Newell, (1998)**
Pisidium columbiana	X			X	
Pisidium compressum	X				
GASTROPODA—Snails					
Fluminicola sp.				X	X
Fluminicola nuttalliana	X	X		X	
Gyraulus parvus					X
Gyraulus vermicularis	X			X	
Goniobasis plicifera	X				
Limnaea sp.		X	X	X	
Lymnaea stagnalis				X	
Lithoglyphus sp.			X		
Parapholyx sp.			X	X	
Parapholyx effusa costata	X			X	
Parapholyx effusa neritoides	X			X	
Parapholyx sp.			X	X	
Planorbis sp.				X	
Physa sp.		X	X	X	
Physa nuttalla (=nuttallii?)	X	X		X	
Radix auricularia					X
Radix japonica	X			X	
Stagnicola apicina	X			X	
Stagnicola nuttalliana	X			X	
Vorticifex (Parapholyx) sp.					X
Basommatophora—Freshwater limpets, pond snails					
Fisherola sp.				X	
Fisherola nuttallii	X	X	X	X	
ARTHROPODA—Arthropods: crayfish, insects, spiders, etc.					
CRUSTACEA—Crustaceans					
Cerophium spinicorne	X				
Decapoda—Crayfish, shrimp					
Astasus trowbridgii	X				
Pacifasticus leniusculus trowbridgii		X		X	X
Amphipoda—Scuds, sandhoppers, beach fleas				X	
Gammarus sp.		X		X	X
Isopoda—Isopods: sow bugs, pill bugs					
FAMILY Asellidae					
Caecidotea sp.					X
UNIRAMIA—Insects, millipedes, centipedes, symphylans					

Benthic Invertebrates	**Davis & Cooper (1951)**	**PNL (1976-1979)**	**Beak Consul-tants (1980)**	**WPPSS (1977, 1984-1986)**	**Newell, (1998)**
HEXAPODA (INSECTA)—Insects					
Hemiptera—Bugs		X			
FAMILY Corixidae—Water boatmen			X		X
Corixa sp.	X				
Sigara washingtonensis					X
FAMILY Gerridae—Water striders					
Gerris sp.				X	
FAMILY Notonectidae—Backswimmers					
Notonecta sp.				X	
Ephemeroptera—Mayflies		X	X	X	
FAMILY Baetidae			X	X	X
Acentrella insignificans					X
Baetis sp.	X			X	X
Baetis bicaudatus					X
Baetis tricaudatus					X
FAMILY Baetiscidae					
Baetisca columbiana [collected by Edmunds (1960) only]					
FAMILY Ephemerellidae				X	
Ephemerella yosemite (=Drunella grandis)	X			X	
Ephemerella inermis					X
Ephemerella sp.	X			X	X
FAMILY Ephemeridae					
Ephemera simulans					X
Ephoron album	X			X	
Hexagenia sp.	X			X	
FAMILY Heptageniidae				X	
Heptagenia sp.					X
Heptagenia solitaria					X
Nixe sp.					X
Nixe simplicioides					X
Stenonema sp.	X		X	X	X
Stenonema terminatum terminatum					X
FAMILY Leptophlebiidae					
Paraleptophlebia bicornuta	X			X	
FAMILY Tricorythidae				X	X
Tricorythodes minutus					X

(Table continues)

Benthic Invertebrates	**Davis & Cooper (1951)**	**PNL (1976-1979)**	**Beak Consul-tants (1980)**	**WPPSS (1977, 1984-1986)**	**Newell, (1998)**
Plecoptera—Stoneflies	X	X			
Arcynopteryx parallela (= Skwala americana)				X	
Isogenus sp.	X				
Perlodes americana (=Skwala americana)	X				
Pteronarcys californica	X				
Trichoptera—Caddisflies	X	X	X	X	X
FAMILY Brachycentridae					
Brachycentrus sp.		X			
Brachycentrus occidentalis	X			X	
FAMILY Glossosomatidae			X	X	
Glossosoma sp.					X
Glossosoma parvulum	X				X
Glossosoma velona (= velonum?)	X			X	X
FAMILY Hydropsychidae—Net-spinning caddisflies			X	X	
Cheumatopsyche sp.	X	X		X	X
Cheumatopsyche campyla	X	X		X	X
Cheumatopsyche enomis (= enonis)	X	X		X	X
Cheumatopsyche logani		X			
Hydropsyche sp.				X	X
Hydropsyche (=Ceratopsyche) cockerelli	X	X		X	X
Hydropsyche californica	X			X	X
FAMILY Hydroptilidae—Micro-caddisflies			X	X	
Hydroptila sp.	X			X	X
Hydroptila argosa	X			X	X
Leucotrichia pictipes	X			X	
FAMILY Leptoceridae—Long-horned caddisflies			X	X	
Athripsodes annulicornis	X			X	X
Lepidostoma strophis	X			X	
Leptocella sp.	X			X	
Mystacides alafimbriata	X			X	
Oecetis sp.		X			
FAMILY Limnephilidae—Northern caddisflies					
Limnophilus sp. *(=Limnephilus ?)*				X	
FAMILY Psychomyiidae—Tube making and trumpet-net cad.			X	X	
Psychomyia flavida	X			X	X
FAMILY Rhyacophilidae—Primitive caddisflies			X		
Rhyacophila coloradensis	X			X	
Odonata—Damselflies and dragonflies		X			

Benthic Invertebrates	**Davis & Cooper (1951)**	**PNL (1976-1979)**	**Beak Consul-tants (1980)**	**WPPSS (1977, 1984-1986)**	**Newell, (1998)**
FAMILY Gomphidae—Clubtails					
Ophiogomphus sp.					X
Lepidoptera—Moths and butterflies		X			
FAMILY Pyralidae—Snout and grass moths			X	X	
Argyractis angulatalis	X			X	
Petrophila confusalis					X
Diptera—Flies		X			
FAMILY Chironomidae—Midges		X	X	X	X
SUBFAMILY Hydrobaeninae (=Chironomidae)	X				
FAMILY Simuliidae—Black flies or buffalo gnats		X	X		
Simulium sp.	X	X			X
Simulium vittatum				X	
FAMILY Tipulidae—Crane Flies				X	
Coleoptera—Beetles					
FAMILY Dytiscidae—Predacious diving beetles					X
Dytiscus sp.					X
FAMILY Elmidae—Riffle beetles			X	X	
FAMILY Gyrinidae—Whirligig beetles					
Gyrinus sp.				X	
CHELICERATA					
ARACHNIDA—Arachnids: spiders, mites, ticks, scorpions					
Araneida—Spiders	X			X	
Acari -- Mites					
Hydracarina— Water mites	X	X	X	X	X
FAMILY Hygrobatidae			X		
TOTAL TAXA	**58**	**30**	**28**	**92**	**52**

NOTE: Taxa are listed and names are spelled as they appeared in the original documents. In some cases the current correct name has been added.

Table 8.2. Aquatic benthic invertebrate taxa collected from tributaries to the Hanford Reach of the Columbia River, February 1998 (Newell 1998). **PHYLUM/SUBPHYLUM** is in uppercase bold. CLASS/SUBCLASS is in uppercase. **Order/suborder** is in lowercase bold.

Benthic Invertebrates	Hatchery Outlet (1)	Ringold Spring (2)	Irrigation Return (3)	P.R. Hatchery (4)
PLATYHELMINTHES—Flatworms, tapeworms, planarians				
TURBELLARIA—Flatworms	X			
ANNELIDA—Earthworms, marine worms, leeches				
OLIGOCHAETA—Earthworms, freshwater ringed worms				X
MOLLUSCA—Mollusks: clams, snails, octopi				
Gyraulus sp.			X	
Vorticifex (Parapholyx) sp.			X	
ARTHROPODA—Arthropods: crayfish, insects, spiders, etc.				
Amphipoda—Scuds, sandhoppers, beach fleas				
Gammarus sp.	X			X
Isopoda—Isopods: sow bugs, pill bugs				
FAMILY Asellidae				
Caecidotea sp.				X
HEXAPODA (INSECTA)—Insects				
Ephemeroptera—Mayflies				
Baetis tricaudatus	X	X	X	X
Tricorythodes minutus	X			
Trichoptera—Caddisflies				
Hydropsyche sp.	X	X	X	X
Hydroptila sp.			X	
FAMILY Limnephilidae—Northern caddisflies		X		
Odonata—Damselflies and dragonflies				
Argia vivida		X		
Argia sp.			X	
Enallagma sp.			X	
Unknown			X	
Diptera—Flies				
FAMILY Chironomidae—Midges	X	X	X	X
FAMILY Empididae—Dance flies				
Hemerodromia sp.			X	
FAMILY Simuliidae—Black flies or buffalo gnats	X	X	X	X
FAMILY Stratiomyiidae—Soldier flies	X		X	
Coleoptera—Beetles				
FAMILY Elmidae—Riffle beetles				
Optioservus sp.	X	X	X	
Zaitzevia sp.			X	
TOTAL TAXA =	**9**	**7**	**14**	**7**

1-Hatchery Outlet Stream = Outlet from the Ringold Fish Hatchery, river mile 355.

2-Ringold Spring = Spring stream originating from the hill east and across the road from the Ringold Fish Hatchery.

3-Irrigation Return = Irrigation return stream that enters the Columbia River adjacent to Ringold Hatchery land at river mile 354.5.

4-P.R. Hatchery = Outlet stream from the Priest Rapids Dam fish hatchery. This stream enters the Columbia River approximately 1 mile (1.6 km) downstream from Priest Rapids Dam, east bank.

Note: The sampling points for all but the spring stream at the Ringold fish hatchery were below the river's high-water mark and within 100 m of the river.

Table 8.3. Aquatic invertebrate taxa collected from Rattlesnake Spring. Cushing and Rader (1982) worked with a single taxon, Callibaetis (Ephemeroptera), that is not listed in this table. **PHYLUM/SUBPHYLUM** is in uppercase bold. CLASS/SUBCLASS is in uppercase. **Order/suborder** is in lowercase bold.

Benthic Invertebrates	Gaines 1987 a,b	Newell 1998	Pickel 2000	Newell 2003
ANNELIDA—Earthworms, marine worms, leeches				
OLIGOCHAETA—Earthworms, freshwater ringed worms		X		X
MOLLUSCA—Mollusks: clams, snails, octopi				
Physella sp.		X		X
Pisidium sp.		X	X	X
Radix auricularia		X		X
Fisherola sp.			X	
ARTHROPODA—Arthropods: crayfish, insects, spiders, etc.				
Amphipoda—Scuds, sandhoppers, beach fleas				
Hyalella azteca		X	X	X
HEXAPODA (INSECTA)—Insects				
Hemiptera—Bugs				
FAMILY Belostomatidae—Giant water bugs				
Belostoma bakeri		X		
FAMILY Corixidae—Water boatmen				
Cenocorixa bifida hungerfordi		X		
Corisella inscripta		X		
Graptocorixa californica		X		X
Hesperocorixa laevigata		X		
Sigara alternata		X		X
FAMILY Gerridae—Water striders		X		
FAMILY Notonectidae—Backswimmers		X		X
Notonecta kirbyi		X		
Notonecta undulata		X		
Notonecta sp.				X
Ephemeroptera—Mayflies				
Baetis sp.	X	X		X
Callibaetis sp.		X	X	
Paraleptophlebia sp.	X			
Tricorythodes sp.	X			
Trichoptera—Caddisflies				
Cheumatopsyche sp.	X	X		
Hesperophylax sp.		X	X	X
Lepidostoma sp.			X	
Limnephilus sp.	X			
Parapsyche sp.			X	

(Table continues)

Benthic Invertebrates	Gaines 1987 a,b	Newell 1998	Pickel 2000	Newell 2003
Odonata—Damselflies and dragonflies				
FAMILY Aeshnidae—Darners			X	
Aeshna multicolor (adult)		X		
Aeshna umbrosa(adult)		X		
Aeshna sp.				X
Archilestes californica		X		
FAMILY Coenagrionidae—Narrow-winged damselflies				
Argia tibialis	X			
Argia sp.		X	X	X
Enallagma sp.				X
Diptera—Flies				
FAMILY Chironomidae—Midges	X	X	X	X
Chaetocladius sp.	X			
Chironomus sp.	X			
Heleniella sp.	X			
Polypedilum sp.	X			
Thienemannimyia sp.	X			
FAMILY Dixidae—Dixid midges	X		X	X
FAMILY Empididae—Dance flies	X			X
FAMILY Psychodidae—Moth flies and sand flies			X	X
FAMILY Simuliidae—Black flies or buffalo gnats	X	X	X	X
Simulium sp.	X	X		X
FAMILY Tabanidae—Horse flies and deer flies	X			
FAMILY Tipulidae—Crane Flies				
Dicranota sp.	X			
Coleoptera—Beetles				
FAMILY Dryopidae—Long-toed water beetles			X	
FAMILY Dytiscidae—Predacious Diving Beetles		X		
Hydaticus sp.	X	X		
Unknown		X		
FAMILY Elmidae—Riffle beetles				
Optioservus sp.			X	
Rhizelmis sp.			X	
FAMILY Gyrinidae—Whirligig Beetles		X		X
FAMILY Hydrophilidae—Water scavenger beetles	X			
ARACHNIDA—Arachnids: spiders, mites, ticks, scorpions				
Acariformes—Mite-like mites			X	
TOTAL TAXA	**20**	**30**	**17**	**21**

Table 8.4. Aquatic invertebrate taxa collected from Snively Spring. **PHYLUM/SUBPHYLUM** is in uppercase bold. CLASS/SUBCLASS is in uppercase. **Order/suborder** is in lowercase bold.

Benthic Invertebrates	Gaines 1987a, b	Newell 1998	Pickel 2000	Newell 2003
MOLLUSCA—Mollusks: clams, snails, octopi				
PELECYPODA (=BIVALVIA)				
FAMILY Sphaeriidae—Fingernail clams			X	
ARTHROPODA—Arthropods: crayfish, insects, spiders, etc.				
Decapoda—Crayfish, shrimp				
Pacifasticus leniusculus		X		X
Amphipoda—Scuds, sandhoppers, beach fleas				
Gammarus sp.		X	X	X
HEXAPODA (INSECTA)—Insects				
Ephemeroptera—Mayflies				
Baetis sp.	X	X	X	X
Paraleptophlebia sp.	X			
Tricorythodes sp.	X			
FAMILY Heptageniidae			X	
Trichoptera—Caddisflies				
Cheumatopsyche sp.	X	X	X	X
Parapsyche sp.	X	X		X
Odonata—Damselflies and dragonflies				
Argia sp.		X		X
Argia tibialis	X			
Diptera—Flies				
FAMILY Chironomidae—Midges	X	X	X	X
Chaetocladius sp.	X			
Chironomus sp.	X			
Heleniella sp.	X			
Polypedilum sp.	X			
Thienemannimyia sp.	X			
FAMILY Dixidae—Dixid midges	X	X	X	X
FAMILY Empididae—Dance flies	X			X
FAMILY Psychodidae—Moth flies and sand flies				X
FAMILY Simuliidae—Black flies or buffalo gnats	X	X	X	X
Simulium sp.	X	X		X
FAMILY Tabanidae—Horse flies and deer flies	X			
FAMILY Tipulidae—Crane Flies	X	X	X	X
Dicranota sp.		X		
Coleoptera—Beetles				
FAMILY Curculionidae—Weevils or snout beetles			X	
FAMILY Elmidae—Riffle beetles		X		
FAMILY Hydrophilidae—Water scavenger beetles		X	X	
TOTAL TAXA	18	14	11	13

Table 8.5. Aquatic Macroinvertebrates from Benson, Snively, and Rattlesnake Springs collected and identified by Pickel (2000). **PHYLUM/SUBPHYLUM** is in uppercase bold. CLASS/SUBCLASS is in uppercase. **Order/suborder** is in lowercase bold.

Benthic Invertebrates	Benson	Snively	Rattlesnake
MOLLUSCA—Mollusks: clams, snails, octopi			
FAMILY Lymnaeidae—*Fisherola* sp.			X
FAMILY Sphaeriidae—Fingernail clams	X	X	X
ARTHROPODA—Arthropods: crayfish, insects, spiders, etc.			
Decapoda—Crayfish, shrimp			
Pacifasticus leniusculus	X		
Amphipoda—Scuds, sandhoppers, beach fleas			
Gammarus sp.		X	
Hyalella azteca			X
HEXAPODA (INSECTA)—Insects			
Hemiptera—Bugs			
FAMILY Corixidae—Water boatmen, *Graptocorixa* sp.	X		
Ephemeroptera—Mayflies			
Baetis tricaudatus	X	X	
Callibaetis sp.			X
Paraleptophlebia sp.	X		
FAMILY Heptageniidae		X	
Trichoptera—Caddisflies			
Cheumatopsyche sp.		X	
Parapsyche sp.			X
Lepidostoma sp.			X
FAMILY Limnephilidae—Northern caddisflies	X		
Hesperophylax sp.			X
Odonata—Damselflies and dragonflies			
FAMILY Aeshnidae—Darners			X
FAMILY Coenagrionidae—Narrow-winged damselflies, *Argia* sp.	X		X
Diptera—Flies			
FAMILY Chironomidae—Midges	X	X	X
FAMILY Dixidae—Dixid midges, *Meringodixa* sp.	X	X	X
FAMILY Psychodidae—Moth flies and sand flies, *Pericoma* sp.	X		
FAMILY Simuliidae—Black flies or buffalo gnats	X	X	X
FAMILY Tipulidae—Crane Flies	X	X	X

Benthic Invertebrates	Benson	Snively	Rattlesnake
Coleoptera—Beetles			
FAMILY Curculionidae—Weevils or snout beetles	X	X	
FAMILY Dryopidae—Long-toed water beetles			X
FAMILY Dytiscidae—Predacious Diving Beetles	X		
FAMILY Elmidae—Riffle beetles, *Optioservus* sp.	X		
FAMILY Elmidae—Riffle beetles, *Rhizelmis* sp.			X
FAMILY Hydrophilidae—Water scavenger beetles	X	X	
ARACHNIDA – Arachnids: spiders, mites, ticks, scorpions			
Acariformes—Mite-like mites			**X**
TOTAL TAXA	**16**	**11**	**17**

Newell (1998) 10 taxa; and Newell (this study) 11 taxa. The following taxa previously collected by Gaines (1987a, b) and/or by Newell (1998) were not found by Newell in the 2002 study: *Paraleptophlebia*, *Tricorythodes*, Elmidae, Hydrophilidae, *Argia tibialis*, *Dicranota* sp., Tabanidae, and perhaps some Chironomidae. The 2002 study found the previously undetected Diptera family Psychodidae.

Pickel (2000) sampled all three springs prior to the 24 Command Fire of June–July 2000 (Table 8.5 has more specific taxonomic entries than Tables 8.3 and 8.4 for Pickel's collections). He noted 16 taxa in Benson Spring, 11 in Snively Spring and 17 in Rattlesnake Spring. When compared to Newell's (1998) pre-fire sampling, the results for Pickel's and Newell's results are: Snively Spring—11 and 14 taxa respectively; Rattlesnake Spring—17 and 30 taxa respectively. Important differences between the two studies at Snively Spring are that Pickel (2000) found new taxa of Sphaeriidae, Heptageniidae, and Curculionidae, but did not collect *Pacifasticus leniusculus, Parapsyche* sp., *Argia* spp., *Simulium* sp., *Dicranota* sp., nor Elmidae (Table 8.4).

For Rattlesnake Spring, the differences between Pickel (2000) and Newell (1998) are as follows. Pickel found the following new taxa: *Fisherola* sp., *Lepidostoma* sp., *Parapsyche* sp., Dixidae, Psychodidae, Dryopidae, Elmidae (2 genera), and Acariformes. Newell found the following taxa not noted by Pickel: Oligochaeta, *Physella* sp., *Radix auricularia*, *Belostoma bakeri*, Corixidae (5 species), Gerridae, Notonectidae (2 species), *Baetis* sp., *Cheumatopsyche* sp., adults of three species in the family Aeshnidae (Pickel did note collecting the family Aeshnidae), perhaps *Simulium* sp., Dytiscidae (2 species), and Gyrinidae (Table 8.3). Some of the Hemiptera are not technically benthic organisms, but are aquatic insects.

OVERVIEW OF SELECTED AQUATIC INSECT ORDERS

Ephemeroptera (Mayflies)

Several of the taxa of adult mayflies that were captured in 1998 in the vicinity of the Columbia River (within 1 mile/1.6 km) but not noted recently from the Hanford Reach are listed in Table 8.6. These catches were far enough from the river to raise questions as to their habitat and origin. These species may potentially occur in the Reach; other possible origins include the Yakima River and nearby irrigation ditches, ponds, etc.

Ephoron album is very abundant in the nearby Yakima River and was collected in the Columbia River by Davis and Cooper (1951). In late July and early August, huge numbers of adults of this mayfly are attracted to light sources in Richland, Washington, during the evening hours. Over many years of collecting, the author has not caught nymphs of this species in the Hanford Reach, nor has he collected adults immediately adjacent to the Reach. Davis and Cooper also collected nymphs of the largest U.S. mayfly, *Hexagenia*; more recently, this species has been collected in Lake Wallula but not in the Hanford Reach (pers. obs.). Since nymphs of both of these species are burrowers, their specialized habitat could have been missed in Newell's sampling of the Reach but collected by Davis and Cooper with their bottom-dredge sampling procedure.

Fourteen mayfly species in 8 genera were collected by Newell (1998), and Davis and Cooper (1951) listed 7 species in 6 genera from the river (Table 8.1). Three of the genera reported by Davis and Cooper (1951) were collected by Newell (1998): *Ephemerella, Stenonema*, and *Baetis*. *Paraleptophlebia bicornuta,* collected in small streams in southeastern Washington, was not found in the Hanford Reach. The species *Ephemerella yosemite* is now known as *Drunella grandis* and is common in cold mountain streams in Washington and elsewhere in the west, but it has not been collected recently in the Hanford Reach. Newell (1998) found a number of species of mayflies previously unreported from the Hanford Reach: *Acentrella insignificans*, *Baetis bicaudatus* and *B. tricaudatus, Ephemerella inermis, Ephemera simulans, Heptagenia solitaria* and *H.* sp., *Nixe simplicioides* and *N.* sp., *Stenonema terminatum*, and *Tricorythodes minutus.* During July–September in the Richland area, large numbers of adults of *Heptagenia, Nixe, Ephemerella, Stenonema*, and *Tricorythodes* are commonly encountered adjacent to the Reach shoreline. Adults of the burrowing mayfly, *Ephemera simulans,* were encountered only once by this author in 1998, swarming near the river shoreline at Leslie Groves Park on a warm summer evening at dusk.

Edmunds (1960) reported a record of a rare mayfly, *Baetisca columbiana,* from the Columbia River, collected near Pasco, Franklin County, Washington, in 1948. No one else has collected or confirmed the presence of this species in the subsequent 50 years.

Table 8.6. Taxa of adult Ephemeroptera (mayflies) captured by Newell in 1998 in the vicinity of the Columbia River, Richland, WA.

Callibaetis fluctuans (Eaton)
Callibaetis montanus (Eaton)
Callibaetis pictus (Eaton)
Camelobaetidius sp.
Ephoron album (Say)
Heterocloeon sp.
Labiobaetis propinquus (Walsh)

Hemiptera (True Bugs)

Table 8.7 includes Hemiptera collection records from R. Zack, Washington State University, from the Hanford Site (Benton County) during and prior to 1998 (R. Zack pers. comm.). Adult Corixidae and Notonectidae are excellent flyers, and their powers are excellent, thus they may appear in any suitable habitat. The immatures and/or adults of these species may or may not live in the Columbia River or other Hanford water bodies.

Odonata (Dragonflies and Damselflies)

Table 8.8 lists Odonata nymphs and adults captured by Newell (1998) or R. Zack (pers. comm.) in or near the Columbia River, Rattlesnake Spring, Snively Spring, and other locations on the Hanford Site. Gaines (1987a, b) listed only *Argia tibialis* from both spring streams, but Paulson (1998) does not list this species from Benton County. The list of taxa collected by Newell and Zack is more diverse than previously reported, probably because other researchers did not sample for adult Odonata. Odonata adults are excellent fliers and can migrate great distances from larval habitats.

Table 8.7. Hemiptera collected on or near the Hanford Site (Zack pers. comm.). Species are listed by the closest water sources as follows: Hanford Reach of the Columbia River (CR), Rattlesnake Spring (RS), Snively Spring (SS), and Gable Mountain Pond (GP), a temporary artificial pond on Central Hanford.

TAXA	CR	RS	SS	GP
FAMILY Belostomatidae—Giant water bugs				
Belostoma bakeri Montandon		X		
FAMILY Corixidae—Water boatmen				
Cenocorixa bifeda hungerfordi Landsbury	X	X	X	X
Cenocorixa wileyae (Hungerford)	X			
Corisella decolor (Uhler)	X			
Corisella inscripta (Uhler)	X	X		X
Hesperocorixa laevigata (Uhler)	X	X	X	X
Sigara alternata (Say)	X	X		X
Sigara washingtonensis Hungerford	X	X		
FAMILY Gerridae—Water striders				
Gerris buenoi Kirkaldy		X	X	
Gerris incurvatus Drakes & Hottes		X	X	
Gerris remigis Say		X	X	
Limnoporus notabilis (Drake & Hottes)			X	
FAMILY Notonectidae—Backswimmers				
Notonecta kirbyi		X	X	
Notonecta undulata Say		X	X	
Notonecta unifasciata		X	X	
TOTAL TAXA	**7**	**12**	**9**	**4**

Plecoptera (Stoneflies)

This study collected no stoneflies in the river, tributaries, or the spring streams, and no adults were captured anywhere on the Hanford Site. Davis and Cooper (1951) found three species in the river. Only two other studies (PNL 1979a,b,c, WPPSS 1977) noted Plecoptera in their samples. No stoneflies have been captured in the Hanford Reach since 1979.

Diptera (Flies)

The Diptera are a difficult group to identify beyond the family level in most cases. Becker (1972a,b) did identify one black fly to species, *Simulium vittatum*. Gaines (1987a, b) identified Chironomidae larvae to genus. Zack (1998) has compiled a list of shoreflies (family Ephydridae) of the Hanford Site from past years of sampling. The diversity of Diptera is great, but only the Chironomidae and Simuliidae are abundant in the Hanford Reach and the springs of the ALE Reserve.

Table 8.8. Odonata (adults and nymphs) captured in or near the following locations on the Hanford Site by Newell (1998) and Zack (1998, pers. comm.). Species are listed by the closest water sources as follows: Columbia River (CR), Rattlesnake Spring (RS), Snively Spring (SS), or other locations on the Hanford Site (H).

TAXA	CR	RS	SS	H
Aeshna californica Calvert	X			X
Aeshna multicolor Hagen		X		
Aeshna umbrosa Walker		X		
Aeshna sp.		X		
Ophiogomphus sp.	X			
Amphiagrion abbreviatum (Selys)		X		
Argia sp.		X	X	
Argia vivida		X	X	X
Argia tibialis		X	X	
Enallagma cyathigerium (Charpentier)		X		
Enallagma carunculatum Morse	X			
Ishnura cervula Selys		X		
Ishnura perparva Selys		X		
Libellula pulchella Drury		X		
Archilestes californica McLachlan		X		
Total Taxa	**3**	**12**	**3**	**2**

ORIGIN OF ADULT TRICHOPTERA (CADDISFLIES)

The caddisfly fauna of the Columbia River and Rattlesnake and Snively Springs is rich and varied. Gaines (1987a, b) has published the most complete benthic faunal list from these two springs. He reported two and three genera of caddisflies, respectively, from the spring streams' benthic sampling. Newell et al. (2001) and Strenge (pers. comm.) found 21 genera and 35 species of adults near Rattlesnake Spring and 2 genera near Snively Spring by light trapping. The increase in the faunal list from Rattlesnake Spring was due largely to the light trap sampling of adults after dark (Table 8.9). Davis and Cooper (1951) reported 17 taxa of caddisflies from benthic samples from the river, 11 of which were among the 13 taxa collected by Newell et al. (2001).

Larvae of many of the taxa of adult Trichoptera that were collected in light traps between 1998 and 2001 have never been collected from any of the spring streams. Immatures of many of the adult taxa collected near the springs are, however, common in the Columbia River. This leads to speculation that some of the adult specimens collected near the spring streams originated from the river. This was partially confirmed by sampling for adults in the dunes area between the river and the spring streams. Sixteen taxa of adult caddisflies were caught in the dunes, where no water is available, indicating that the adults were dispersing from their aquatic source of origin.

Table 8.9. Caddisfly adults collected using ultraviolet and mercury vapor light trapping and Lepidoptera pheromone traps. Sources include Newell et al. (2001), Pickel (2000) for the Benson Spring area, unpublished data from D. Strenge (pers. comm.) for 2001 and 2002 from the springs and the dunes area, and casual sampling by Newell and others from the Hanford Reach. The dune area is located on Central Hanford about 5 miles west of the Columbia River near the Energy Northwest power plant.

TAXAFamily/Genus/Species	Rattlesnake & Snively Springs 1999	Rattlesnake & Snively Springs 2001	Benson Spring 1999–2000	Dunes 1999 & 2001	Hanford Reach 1998–2002
FAMILY Brachycentridae					
Amiocentrus aspilus (Ross)	X				
Brachycentrus americanus (Banks)		X?			
FAMILY Glossosomatidae					
Culoptila cantha (Ross)	X	X		X	
Glossosoma parvulum Banks					X
Glossosoma velonum Ross	X	X	X	X	
Protoptila coloma Ross		X		X	
Protoptila erotica Ross	X	X		X	
FAMILY Hydropsychidae—Net-spinning caddisflies					
Cheumatopsyche campyla Ross	X	X	X	X	X
Cheumatopsyche gelita Denning				X	
Ceratopsyche oslari Banks				X	
Hydropsyche californica Banks	X	X		X	X
Hydropsyche cockerelli Banks	X	X	X	X	X
Parapsyche almota Ross	X	X			

(Table continues)

TAXAFamily/Genus/Species	Rattlesnake & Snively Springs 1999	Rattlesnake & Snively Springs 2001	Benson Spring 1999–2000	Dunes 1999 & 2001	Hanford Reach 1998–2002
FAMILY Hydroptilidae—Micro-caddisflies					
Hydroptila arctica Ross		X			
Hydroptila argosa Ross	X	X		X	X
Hydroptila modica Mosely	X				
Hydroptila xera Mosely		X			
Leucotrichia pictipes (Banks)	X				
FAMILY Leptoceridae—Long-horned caddisflies					
Ceraclea latahensis (Smith, S.D.)	X				
Ceraclea annulicornis (Stephems)					X
Oecetis avara (Banks)	X	X		X	
Oecetis immobilis (Hagen)	X				
Oecetis inconspicua (Walker)	X	X		X	
Trianedes baris Ross				X	
Trienodes tardus Milne	X	X			
Ylodes frontalis (Banks)	X	X			
Ylodes reuteri (MacLaughlin)		X			
Nectopsyche sp.	X	X			
Nectopsyche lahontanensisHaddock		X		X	
Polycentropus cinereus (Hagen)		X		X	
FAMILY Limnephilidae—Northern caddisflies					
Hesperophylax designatus (Walker)	X	X			
Limnephilus abbreviatus Banks	X				
Limnephilus aretto Ross		X			
Limnephilus assimilis (Banks)	X	X			
Limnephilus diversus (Banks)		X			
Limnephilus frijole Ross	X	X			
Limnephilus sitchensis (Kalenati)	X				
Limnephilus spinatus Banks	X	X			
FAMILY Psychomyiidae—Tube making and trumpet-net caddisflies					
Psychomyia flavida Hagen	X	X		X	X
FAMILY Lepidostomatidae					
Lepidostoma cinereum (Banks)	X	X			
TOTAL TAXA	**26**	**28**	**3**	**16**	**7**

WILDFIRE EFFECTS ON SPRING-STREAM INVERTEBRATES

Visits to Rattlesnake Spring subsequent to the 2000 wildfire and two years later revealed a severely impacted stream and devastated riparian zone. The wildfire burned much of the riparian vegetation and deposited ash and charred material into the stream. Vegetation not burned was killed by the heat and much of this material fell into the stream channel. With the surrounding soil unprotected and no riparian buffer zone, winds have blown sand, silt, ash, and dead vegetation into the stream. The result is a great increase in sediment, reduced flow velocities, and dramatic change in substrate composition. This detritus material cannot be flushed from the stream due to the large amount of dead vegetation now restricting stream flow. Bottom sampling revealed a tremendous amount of silt and large amounts of particulate organic matter. Bottom samples also revealed a decrease in diversity and a reduction in numbers of organisms compared to sampling conducted in 1998 and 2000 (Table 8.3), while some taxa such as the Chironomidae (midges), Simuliidae (black flies or buffalo gnats), Amphipoda (scuds, sandhoppers, beach fleas), and the fingernail clam *Pisidium* (Sphaeriidae) remained high. Chironomidae and Amphipoda are very tolerant of extreme environmental conditions and adaptable, but the high populations of filter feeders such as Simuliidae and *Pisidium* are unexpected because of the huge amounts of sediments that could disrupt their filter feeding habits. The huge sediment additions to the substrate, and reduced flows could smother the small *Pisidium* clams.

The benthic fauna of Snively Spring has changed little from the pre-fire studies, although no aquatic beetles were caught in 2002 sampling (Table 8.4). Snively Spring was apparently less impacted than Rattlesnake Spring by the fire. This may be attributable to the location of the spring streams and their stream channel configuration. Snively Spring is located primarily in a steep canyon. This may have reduced wind effects and lessened input of detritus from outside of the stream channel. The Snively stream channel is narrow and V-shaped; this has prevented much of the dead vegetation from reaching and restricting stream flow. Thus, flows in Snively have been maintained much as before the fire. Silt, ash, and debris that might have reached the stream would have been washed downstream. This seems to be born out by the large amounts of silt and debris found in the lower 200 m of the Snively Spring channel.

STATUS OF THE PACIFIC CRAYFISH, *PACIFASTICUS LENIUSCULUS,* IN THE HANFORD REACH

One objective of this small study in 2002 was to increase the sampling effort in an attempt to determine the status and condition of the Pacific crayfish, *Pacifasticus leniusculus*, in the Hanford Reach. This concern arose from Newell's (1998) report that noted not a single intact crayfish specimen was captured or seen, although body parts were found, while previous studies noted an incredible abundance of crayfish in the Columbia River (Coopey 1953). This portion of the 2002 study was merely a few days in length but involved some sampling efforts that differed from previous studies. Sampling was conducted in the late winter prior to river fluctuations, again in late spring, and with traps. The traps failed to attract crayfish, but sampling at low and steady river levels in late winter revealed large numbers of crayfish in many size classes. Nearly every rock harbored a crayfish beginning at the water's edge and out as far as the surveyor could wade. Sampling in May revealed no crayfish. Perhaps this crayfish has adapted to the daily river fluctuations by staying in deeper water except when flows are constant over long periods as during the winter.

Crayfish populations are present in both Benson and Snively Springs. Specimens caught in these springs do not achieve the large size of Hanford Reach specimens.

STATUS OF THE WESTERN PEARL MUSSEL, *MARGARITINOPSIS FALCATA*, IN THE HANFORD REACH

Freshwater mussels are mollusks in the class Bivalvia (Stock 1996). There are seven species of native large freshwater bivalves in Washington state, but literature on their ecology and distribution is limited. The seven species belong to the genera *Anodonta* and *Gonidea* (Unionidae) and *Margaritinopsis* (Margaritiferidae). Mussels will not occur in streams where the substrate is substantially disturbed by torrents (Toy 1998). Pearly freshwater mussels of the order Unionoida reproduce by releasing immature mollusks called glochidia into the stream. These glochidia must attach to the gills of a fish within a few days in order to survive. They eventually fall off of the host as a small mussel. Both of these events exhibit high mortalities, which are compensated for by production and release of huge numbers (millions) of glochidia and by long-lived adults.

Margaritinopsis is usually found in cold, well oxygenated, oligotrophic (low in nutrients) waters with a sand and gravel substrate. Distribution is affected by current velocity, temperature, particle size of substrate, water chemistry, timing and nature of organic inputs (Toy 1998), floods and river stability (Vannote and Minshall 1982), and availability of suitable hosts for their glochidia (usually young fish of the family Salmonidae-trout, char, and salmon). Under optimal conditions, *Margaritinopsis* can form extensive beds. Murphy (1942) estimated over 20,000 individuals in a three-quarters-mile channel of the Truckee River in California. Unfavorable fluvial processes and lithology can work to confine *Margaritinopsis* to localized places in a river, such as in protected areas behind large boulders (Vannote and Minshall 1982) or behind large woody debris (Stock 1996). This mussel prefers areas of stable substratum and current velocities sufficient to prevent deposition of silt and sand. Stock (1996) found mussels predominately in cobble substratum with large logs and boulders present, which provide substrate stabilization during flood events. DiMaio and Corkum (1995) also noted that Unionidae bivalves are adversely affected by unstable hydrologic regimes. Stock (1996) believed that mussel habitat corresponded to that of juvenile forms of their host fishes, primarily salmonids.

The western pearl mussel, *Margaritinopsis falcata* (Gould), is endemic to the North American states or provinces west of the Rocky Mountains, including California, Idaho, Montana, Nevada, Oregon, Washington, and British Columbia. Glochidia of *M. falcata* are highly host specific (Bauer et al. 1991) and are generally restricted to the salmonid family, especially Chinook salmon, cutthroat trout, steelhead, and coho salmon. Stream velocities affect this mussel with stream gradients of 1.4% containing mussels and those averaging 2.4% absent of mussels. Koenig (2000) determined that *M. falcata* can adjust to natural variable stream conditions, but these adaptations may be inadequate to compensate for larger scale stream habitat degradation. *M. falcata* is one of the most common species of freshwater mussels in the Pacific Northwest. It is closely related to, and until recently was considered a subspecies of, *Margaritifera margaritifera* (L.) (Burch 1972), which is a circumpolar species found in northern Europe, Russia, Great Britain, and the eastern United States and formerly known as *Margaritana margaritifera* (Elrod 1902). *M. falcata* is found in west coast drainages from California to Alaska, with a suspect disjunct population occurring in the upper Missouri drainage in Montana (Clarke 1981, Stober 1972). Smith (2000) elevated this species to a new genus, *Margaritinopsis*, for all specimens in Pacific Northwest coastal drainages.

M. falcata may be one of the longest living freshwater invertebrates. The oldest known specimens have been aged at greater than 90 years (Toy 1998), 100 years (Vannote and Minshall 1982), and >100 years old (Stock 1996).

Native Americans have been harvesting *M. falcata* from the Columbia River drainage for as long as 5000–7000 years (Toy 1998, and T. Marceau pers. comm.). Lyman (1980) noted 13 archaeological sites along the Columbia and Snake Rivers, and Round Butte in Central Oregon. Many of these sites contained remains of *M. falcata* and dated from nearly 9000 years before present.

While once very abundant in this stretch of the Columbia River, recent collecting efforts suggest that the population of *M. falcata* has drastically declined in the Hanford Reach and probably in much of the Columbia and Snake Rivers inundated by dams. The only recent collection of this taxon on the Hanford Reach is by Newell (2003), who discovered a dead specimen of *M. falcata* on the shore of the Columbia River at Leslie Groves Park in Richland, Benton County, during August 2000. This shell was recently dead since it had fresh muscle flesh attached to one of the unbroken shell halves. A search of the immediate area found three live specimens in about 6–10 inches of water. All were about the same size, approximately 100 mm in length. The river flow this time of year is typically very reduced with little diurnal or diel fluctuations and relatively low discharge. This location is not far from the upper reaches of the influence of Lake Wallula. The substratum in this side channel is sand and gravel with relatively modest current flows. Based on other studies, these individuals could be 60+ years of age and would have hatched before any of the Columbia River dams were constructed. The author has sampled, fished, and recreated on the Hanford Reach for 15 years and has extensively observed aquatic life in and along the river; if even a modest population of these bivalves exists in the Hanford Reach, it is likely more shells and live specimens would have been found. Even in the presence of many young host specimens of Chinook salmon, some factor(s) has caused an apparent drastic decline in this species. Based on the substrate and flow requirements of this species, and given the large daily and seasonal water level fluctuations on the Hanford Reach, substrate conditions resulting from this flow regime would be detrimental for the adults and probably more so for the young bivalves. It is possible that the huge population of the non-native Asiatic clam, *Corbicula fluminea,* in the Reach may also have a detrimental influence.

Williams et al. (1993) listed this species as one of undetermined conservation status due to a lack of knowledge of this species. Anderson (2002) attributes the decline of *Margaritifera* and other mollusks to the presence of dams. Dams impound flowing habitat, reducing water velocities as well as inundating diverse substrates with fine sediments (Bogan 1993). Mussels downstream from dams are subject to scouring effects from the outflow, which can create unstable substrates as well as inundation. Frest and Johannes (1995) list the following actions as threats to this species: extensive diversion of streams, hydroelectric and water supply projects, heavy nutrient enhancement, sedimentation, and unstable substrate. These and other factors likely have greatly reduced populations in the main stem Snake and Columbia Rivers (Frest and Johannes 1995). Frest and Johannes (1995) did not recommend federal or state listing of the species, although they believe the species should be considered sensitive. They recommend further work to document range changes. They note that populations showing repeated reproduction (at least several age classes) are now the exception rather than the rule.

Newell (2003) lists historic and contemporary collection records for *Margaritanopsis falcata* and provides a partial bibliography of literature regarding this taxon.

Summary and Conclusions

The macroinvertebrate fauna of the Hanford Reach has changed over the last 50 years. Records of aquatic invertebrate catches (Table 8.1) indicate that mayfly diversity has increased; stoneflies have disappeared; caddisfly diversity and abundance remain high; Odonata, Hemiptera, Lepidoptera, and Coleoptera are rare; and Diptera diversity remains relatively constant. Recent surveys found that the population of the crayfish, *Pacifasticus leniusculus*, remains high, but the western pearl mussel, *Margaritinopsis falcata*, seems to have nearly disappeared from its past high densities. Taxonomic revisions of the mollusks make it difficult to compare catches from numerous studies conducted over several decades, and no voucher specimens are available for study. The one healthy mollusk population is that of the introduced exotic Asiatic clam, *Corbicula fluminea,* which is extremely abundant in the Hanford Reach. Impacts of the huge population of this mollusk on other benthic fauna is unknown.

One problem in comparing current data with data collected over 50 years ago is revision of taxonomy. Taxa have been split (e.g., the mayfly families Ephemerellidae and Baetidae) making some comparisons impossible without voucher specimens to examine. In some instances the early studies were only able to identify most benthic organisms to genus. Apparently adult specimens were not a priority, and thus identification to species was not possible. Additionally, sampling techniques and sampling intensity have varied with different studies.

Benthic macroinvertebrate diversity in the spring streams of the ALE Reserve has changed over the last 15 years. In Rattlesnake Spring, the mayfly genera *Paraleptophlebia* and *Tricorythodes* and the caddisfly genus, *Limnephilus,* have not been captured since 1987, nor has any hydrophilid beetle or tabanid fly (Table 8.3). Similarly, *Paraleptophlebia* and *Tricorythodes* have not been caught since 1987 from Snively Spring, nor has any tabanid fly (Table 8.4). It is impossible to compare the status of some groups prior to Newell (1998) since previous studies did not collect some taxa (Hemiptera, Amphipoda, and Mollusca). Pickle (2000) found some taxa previously unreported from Rattlesnake or Snively Springs and found diversity in Benson (Bobcat) Spring to be similar to the other two spring streams (Table 8.5).

The streams of both Rattlesnake and Snively Springs were impacted by the fire of June–July 2000 that engulfed much of the Hanford Site. Rattlesnake Spring was the most severely impacted by a combination of ash, silt, charred wood, and dead and wind-blown vegetation detritus.

Recent studies by Newell have found new taxa of Ephemeroptera, Trichoptera, and Odonata from the Hanford Reach, and new taxa of Odonata, Hemiptera and Coleoptera from one or more of the spring streams of the ALE Reserve. Many of the Trichoptera in Table 8.9 represent first-time records for the Hanford Site. The tributaries of the Hanford Reach had never been sampled before Newell's (1998) study.

Recommendations

Recommendations for future research:

- Benthic sampling in Benson, Snively, and Rattlesnake Springs should occur periodically to document the status of invertebrate populations and monitor recovery from the 2000 wildfire.
- Periodic monitoring of the morphology, chemistry, and temperature of the ALE spring streams should be initiated to establish baseline conditions and to evaluate changes over time. Stream profile monitoring can help assess the impacts of erosion and sedimentation on these spring channel ecosystems.
- Studies of select groups of aquatic macroinvertebrates should be designed with consideration of the methods and season of earlier studies in order to facilitate comparability between studies and thus better evaluate changes in the benthic fauna over time.
- More intensive sampling of the Hanford Reach and its shoreline should be considered to create a valid current species list. Long-term, seasonal studies of the Reach are needed to develop baseline data that can be used to monitor the effects of both natural and anthropogenic disturbances, such as unstable hydrological regimes, on benthic fauna over time.
- Comprehensive surveys for the western pearl mussel, *Margaritinopsis falcata*, should be conducted to determine whether isolated populations of this formerly abundant mussel exist within the Hanford Reach.

Recommendations for management:

- Rattlesnake and Snively Springs are fragile ecosystems that have been greatly disturbed by the wildfire of 2000. The springs are ecologically important in that they provide water and some remaining riparian habitat to animals, and they provide rare habitat for a diverse assemblage of benthic fauna in an otherwise arid environment. Additional disturbances to these fragile ecosystems should be avoided.
- Management plans designed to protect salmon should include measures to protect aquatic insects, which are the main food for young chinook salmon (Dauble et al. 1980).

9. Terrestrial Invertebrates

Richard S. Zack, Dennis L. Strenge, and Peter J. Landolt

Introduction

The Hanford Site serves as a refuge for many insects that were probably once common throughout the Columbia Plateau but today are confined to the few remaining undisturbed tracts of land. Terrestrial invertebrates at Hanford have been the subject of several general surveys (ERDA 1975, Rogers 1979). Specific groups of insects studied at Hanford include darkling beetles (Tenebrionidae) (Rickard et al. 1974, Rickard and Haverfield 1965, and Rogers et al. 1978), ground dwelling beetles (Rickard 1970), and grasshoppers (Sheldon and Rogers 1978). More recently, the Hanford Site was the subject of relatively intensive arthropod surveys (principally insects) from 1994 to 2000. Results of these studies have been reported in Soll et al. (1999) and in a number of scientific publications (Grissell and Zack 1996, Newell et al. 2001, O'Brien and Zack 1997, Strenge and Zack 2003, Zack 1998, Zack and Looney 2001, Zack et al. 1998, and Zack et al. 2001).

The following section summarizes work on the biodiversity of terrestrial invertebrates during 2002–2003 at this critical site. Some of the information included in this report refers to specimens collected during previous Hanford studies (Soll et al. 1999) but which had not been identified until recently. Full details are presented in Zack et al. (2003).

Purpose and Scope

The current study was essentially a continuation of previous entomological diversity surveys conducted on the Hanford Site from 1994 to 2000. The primary goal was to add to developing knowledge regarding selected taxonomic groups, to extend the inventory to groups not previously examined, and to examine habitats on the Wahluke and Saddle Mountain Units that had not been sampled during previous studies.

The investigation focused on ground dwelling beetles and on moths, as these were groups on which previous biodiversity studies had concentrated and groups for which the investigators could perform identifications without relying on outside consultants. These taxa are studied elsewhere by those conducting biological diversity studies, and the current study will enable comparisons with work from other regions and habitats. Caddisflies were collected in order to supplement studies in the Rattlesnake and Snively Springs areas of ALE (Newell 2003, Newell et al. 2001).

Methods

Three series of 10 pitfall traps were established on the North Slope of the Hanford Site on the Hanford Reach National Monument during April 2002. Pitfall trapping locations were placed in habitats favorable to the collection of diverse arthropod assemblages and in areas that were comparable to sites established on the ALE Reserve and Central Hanford during the 1994–2000 studies. Site 1 (Coordinates [UTM NAD27]: E - 298338 / N - 5175107) is located in the Saddle Mountain Unit in a big sagebrush/cheatgrass area with sandy soil. Site 2 (Coordinates E 301905 / N - 5173935) is also located on the Saddle Mountain Unit near the end of an irrigation runoff. The site is on sand with little cheatgrass and diverse native vegetation including some specific to sand dunes. Site 3 (Coordinates: E - 312676 / N - 5171820) is located on the Wahluke Unit near the White Bluffs Ferry landing. The vegetation in this area is primarily Russian knapweed and other introduced species.

Each series of pitfall traps was laid out along a linear transect. Specimens were collected on a weekly basis for one year. Samples were removed to the laboratory in Pullman, sorted, prepared, and when identified, recorded in the appropriate taxonomic database. These databases are included in Zack et al. (2003).

Databases contain identifications, site location, and dates of collection for the period April 2002–April 2003. All specimens thus far identified are recorded.

Light trapping for moths and other light-attracted insects was also initiated in April 2002. Both a mercury vapor system, which involves active collecting, and a series of black light traps, where the light is placed over a bucket and allowed to capture insects throughout the night, were used. Contents of black light traps were collected the following morning.

Light trapping was conducted at 15 sites that were monitored every 2–3 weeks from April 2002 to April 2003. Sites were concentrated in three habitat types: the Wahluke sand dunes, intact shrub-steppe areas, and riparian zones (especially wooded riparian zones) along the Wahluke irrigation system and associated impoundments.

Species level identification of arthropods can be a long, slow process that often depends ultimately on sending specimens off to recognized experts in particular taxonomic groups. Thousands of specimens are still awaiting identification from the 1994–2000 studies. However, because of the amount of baseline data for the Hanford Site that has been accumulated over the last decade, and because of the presence of authoritatively identified voucher material that is now in entomological collections at Washington State University in Pullman, it is now possible to identify many specimens without sending them off to outside experts. This is evident in the number of species identified in the beetle and moth databases for 2002–2003.

Results and Discussion

This study collected and processed approximately 12,000 specimens of terrestrial invertebrates. Approximately 50–60% of the insects collected have been identified to date. To date, 376 species have been identified (Table 9.1), the majority coming from the Lepidoptera (moths) and Coleoptera (beetles). Numerous species not previously collected at Hanford, especially in the orders Trichoptera (caddisflies) and Lepidoptera (moths), have been added to the invertebrate fauna of the Hanford Site. Approximately 200–300 species are still awaiting identification. Most of these specimens are in the hands of taxonomic experts. Groups with the highest percentages of unidentified specimens include moths and beetles while identifications for groups such as fleas and earwigs are complete.

The results presented in this report should be considered preliminary due to the numerous species still awaiting identification; it is likely that it is from these specimens that the most significant finds will be made.

At the time of the publication of Soll et al. (1999), 1,536 species of terrestrial arthropods had been identified. Since that time, another 143 species have been positively identified, making a total of 1,679 species. These additions include species identified after 1999 and those thus far identified from the 2002–2003 study. Approximately 200–300 taxa from these collections still await identification. These latter taxa are ones for which we have not been able to find competent taxonomists or groups for which taxonomists do not exist. Although no species new to science have been added from our 2002–2003 study as yet, three new species have been identified from previous collections since Soll et al. (1999) for a total of 46 from Hanford studies over the last decade (Table 9.2). The three new species include a scarab beetle (*Aphodius* sp.), a snow scorpionfly (*Boreus* sp.), and a parasitic wasp, *Macrocentrus shawi* Ahlstrom. New state records are sometimes difficult to ascertain because of the lack of catalogs and checklists; however, the number of species new to Washington state is estimated between 150–200.

Table 9.1. Number of species level identifications of terrestrial invertebrates, 2002–2003 study.

Class	Order	Number of Species Identified	Approximate Number of Species Remaining to Be Identified
Malacostraca	Isopoda (sowbugs)	1	0
Arachnida	Araneae (spiders)	0	50-100
	Scorpiones (scorpions)	1	0
	Solifugae (sun spiders)	2	2
Diplopoda (millipedes)		2	2
Chilopoda (centipedes)		2	1
Insecta (insects)	Coleoptera (beetles)	78	50-75
	Dermaptera (earwigs)	1	0
	Hemiptera (true bugs)	3	10-20
	Hymenoptera (bees, wasps, and ants)	12	30-40
	Lepidoptera (moths and butterflies)	236	50-75
	Orthoptera (crickets and grasshoppers)	2	2-3
	Siphonaptera (fleas)	2	0
	Trichoptera (caddisflies)	34	0
TOTAL TAXA		**376**	**197-318**

TREATMENTS OF INDIVIDUAL ORDERS

Order Isopoda – Sowbugs

A single species of sowbug occurs at one pitfall site near the White Bluffs Ferry landing. Sowbugs are omnivores in their feeding habitats and like relatively moist soils higher in organic content. This is the only site on the Monument where sowbugs have been collected, although they are probably common in similar environments.

Order Araneae – Spiders

Over 150 pit trap samples of spiders have been collected in the course of the 2002–2003 study alone, representing between 1,500 and 2,000 specimens. A portion of these (approximately 1,000 specimens) is currently in the hands of a taxonomic specialist, but results are still forthcoming. The identification of spiders should add significant information to our findings relative to both the biodiversity and the ecology of terrestrial arthropods on the Hanford Site.

Order Scorpiones – Scorpions

A single species of scorpion, *Paruroctonus boreus* (Girard), is found on the Hanford Site and throughout Eastern Washington. The species is common in shrub-steppe environments, especially those in which cheatgrass is not a significant portion of the ground cover (Zack and Looney, in prep.). As a large predator, the scorpion may have difficulty navigating through dense cheatgrass; alternatively, factors such as soil structure and moisture may limit scorpions to drier, sandier sites.

Table 9.2. Arthropod taxa new to science collected at Hanford, 1994–2003.

Order	Family	Genus and Species	Taxa New to Science
Coleoptera (Beetles)	Scarabaeidae	*Aphodius* sp. 1 *Aphodius* sp. 2 *Glaresis* sp.	3
Diptera (True flies)	Anthomyiidae	*Paradelia* sp.	1
	Asilidae	*Efferia* sp. 1 *Efferia* sp. 2	2
	Dolichopodidae	*Asyndetus* sp. *Sympycnus* sp. *Thrypticus* sp.	3
	Sarcophagidae	*Blaesoxipha* sp. *Eumacronychia* sp. *Senotainia* sp.	3
Homoptera (Leafhoppers)	Cicadellidae	*Auridius ordinatus crocatus* Hamilton *Aceratagallia compressa* Hamilton *Aceratagallia zacki* Hamilton *Ceratagallia vipera* Hamilton	4
Hymenoptera (Bees, Wasps, and Ants)	Andrenidae	*Andrena* sp. *Perdita* sp.	2
	Braconidae	*Macrocentrus shawi* Ahlstrom	1
	Colletidae	*Colletes* sp.	1
	Megachilidae	*Osmia* sp. 1 *Osmia* sp. 2	2
	Perilampidae	*Perilampus* sp.	1
Lepidoptera (Moths)	Coleophoridae	*Coleophora* spp. 1-12	12
	Noctuidae	*Copablepharon* sp. 1 *Copablepharon* sp. 2 *Oncocnemis parvacana* Troubridge and Crabo *Protogygia* sp. *Spaelotis bivaca* Lafontaine	5
	Scythrididae	*Arenoscythris* sp. 1 *Arenoscythris* sp. 2 *Asymmetrura* sp. *Neoscythris* sp.	4
Mecoptera (Scorpionflies)	Boreidae	*Boreus* sp.	1
Solifugae (Sun Spiders)	?	?	1
TOTAL			**46**

Order Solifugae – Sun Spiders

Sun spiders are an unusual group of predatory arthropods that have very painful bites but no toxic effects. They are not commonly collected, and their distributions, especially in Washington state, are in need of study. Their taxonomy is not well understood. Only adult males (rarely females through association) can be identified to species. This can complicate efforts at identification, as most collections consist largely of immatures and females. Until recently, two species of sun spider had been identified from Hanford. Both of these species are listed as species of concern in British Columbia (LTABC 2002), but their distribution and abundance in Washington state is virtually unknown. A third species of sun spider from previous Hanford collections has recently been identified as new to science and is currently being described (J. Brookhart pers. comm.).

Order Dermaptera – Earwigs

There is a single species of earwig, *Forficula auricularia* L., at Hanford and throughout the central basin of Washington. This introduced species is widespread throughout the United States and Canada. The species can be common in pitfall traps, and records were maintained in order to obtain habitat and season information. Our findings indicate that earwigs are more common in moist and disturbed areas. Moisture probably limits its distribution on the Hanford Site.

Order Orthoptera – Grasshoppers and Relatives

Little attempt was made to document grasshoppers, crickets, and relatives. One of the ground crickets—*Stenopelmatus fuscus* Haldeman—was commonly taken in the pit traps and phenological information was kept for this species.

Order Hemiptera – True Bugs

Permanent irrigation waters, especially canals with naturalistic channels and shorelines, have significant numbers of aquatic bugs. Only limited resources were applied to this order during the current study, although many as yet unidentified adult specimens were collected during light trapping. A sampling objective was to locate specimens, via aquatic sampling, of a naucorid bug (creeping water bug) that was recorded from a pond on central Hanford (Emery and McShane 1978). The closest area from which this bug is known is extreme southern Idaho. Knowledge of this group indicates that if the insect does occur at Hanford, the irrigation canals would be the best place to look. However, we conducted an intensive search for the bug and did not find it. Previous Hanford records may be in error, as those authors are known to have misidentified a number of insect taxa. No voucher material is available to confirm the earlier reports.

Order Trichoptera – Caddiflies

Caddisflies are a group of insects with aquatic larvae and moth-like adults. Adults are collected at light traps, and it is impossible to know from what aquatic source they derive. At least 34 species have been collected from light traps along the Columbia River and the Wahluke irrigation channels. Thirteen of the taxa were species not collected by Newell et al. (2001) at Rattlesnake and Snively Springs on the ALE Reserve. Six or seven of these species may represent new records for the state of Washington, but this conjecture needs to be verified by a search of the literature. Interestingly, 9 of the 26 species collected by Newell et al. (2001) were not represented in the collections from the current study. It is possible that these species occur solely in association with spring systems.

Order Lepidoptera – Moths and Butterflies

Over 200 species of moths have already been identified by this study, with another 50–75 species awaiting identification. Based on identifications so far, the moth fauna of the Wahluke and Saddle Mountain regions appears to be roughly comparable to that found from 1994–2000. The number of species collected and identified is somewhat smaller than that during previous studies but that is probably an artifact of less collection time and fewer habitats surveyed. A greater number of moths that are associated with trees and riparian areas have been found by the current study, as these habitats are more common on the North Slope. Several of the new species of *Coleophora* (Coleophoridae) discovered in previous Hanford studies were again found during this project. Several groups of moths such as pyralids, geometrids, and micromoths will be sent to taxonomic experts in the very near future.

The collection and identification of moths can provide significant information regarding land use and disturbance as these insects often are closely associated to specific host plants as larvae. As host plant availability changes throughout the season, so will the appearance and abundance of certain species. In order to take full advantage of the potential of moths as indicator species, it is important to conduct monitoring throughout the complete season. Additionally, it can be important to study a fauna for several seasons due to the physical and climactic events that affect plant occurrence and abundance.

Considerable time and effort was spent surveying the moth fauna of the dunes on central Hanford (1994–2000) and in the Wahluke Wildlife area (2002–2003). At least four species new to science have been discovered on the dunes, including species of *Arenoscythris* (Scythrididae) and *Copablepharon* (Noctuidae). Because of the extensive moth collecting conducted on ALE and central Hanford from 1994–2000, the discovery of many species new to science or new state records was not expected during the 2002–2003 study. Still, two significant finds were discovered. One is a new species of *Arenoscythris* (Scythrididae) from the Wahluke sand dunes. This discovery is very noteworthy in light of the new species of *Arenoscythris* moth previously found on the central Hanford dunes. Although capable of flight, these moths fly only a few inches over the substrate. The finding of distinct species in these two areas may be an indication of the ecological separation of these dunes systems for an extended period of time and suggests that further surveys of the dunes may yield more species of interest.

Another noctuid moth, *Protogygia comstocki* (Noctuidae) was also collected in the Wahluke dunes. This species had not been collected in Washington since the 1950s. These specimens may represent one of the few remaining populations in Washington. These findings are significant when one considers that other sand dune habitats in central Washington have been extensively surveyed for noctuid moths without finding these taxa. More extensive sampling for other taxonomic groups in sand dune habitats off of the Hanford Site is likely to further underscore the unique importance of these habitats at Hanford.

Numerous moth species not previously collected on ALE or Central Hanford were collected, especially in wooded riparian areas adjacent to irrigation runoff streams or ponds. For the most part these are common species that would be found in this type of riparian zone habitat throughout Eastern Washington. This type of habitat, however, is rare on the ALE Reserve and on Central Hanford.

The two new species of *Copablepharon* (Lepidoptera: Noctuidae) are being described by Crabo (in prep.) in the Moths of America North of Mexico series in a fascicle to be published in late 2004.

In previous management recommendations (Soll et al. 1999) it was stated that we should try to retain populations of milkweed on the North Slope. Milkweed is the primary food source for monarch butterfly larvae, the Northwest populations of which have been declining recently. Milkweed is very common along the irrigation canals and ponds on the Saddle Mountain Unit . Even though we searched milkweed throughout the season, we never encountered the larvae of monarch butterfly. Although these areas appear to be perfect for larval development, it may be that they have not yet been “discovered” by adults—the number of monarchs may be a low point in long-term population cycles.

Order Coleoptera – Beetles

During the current study, beetles were taken primarily through pit trapping. The primary foci were ground beetles (Carabidae) and darkling beetles (Tenebrionidae). The species richness of these groups was lower than that encountered during previous Hanford studies, but that was to be expected due to the significantly smaller number of habitats sampled and the single year of sampling during the current study. One darkling beetle not found in previous studies was discovered in pit traps located at the White Bluffs Ferry site; this taxon is still awaiting identification. Additionally, a single specimen of the ground beetle, *Pseudaptinus tenuicollis*, was also discovered at the Ferry site location. The finding of this beetle represents a significant range extension from its nearest locality in southern Idaho. Nothing is known of this species' distribution or habitat preferences in Washington. The rare beetle *Cononotus lanchesteri* (Zack and Looney 2001) was consistently collected at one of the pit trap sites. This beetle is known only from Hanford in Washington state but appears to be somewhat widely distributed across the Site.

Order Hymenoptera – Bees, Wasps, and Ants

The primary concentration in this order was the collection of diversity and phenological data on ants and bees. Ant collections have been submitted to a taxonomic authority. No significant findings are expected from a rarity standpoint. The bee specimens are still being processed and will be submitted to taxonomic collaborators in the near future.

When one collects in Eastern Washington off of the Hanford Site, one of the most commonly encountered species of bee is the honeybee, a domesticated introduced species. Honeybees were collected very rarely on the Site during both the 1994–2000 and 2002–2003 studies while numerous species of wild bees were common. This may be due to the predominance of native vegetation on the Hanford Site, as well as its distance from urban or agricultural areas where honeybees are most common.

Conclusions

The diverse insect fauna of the Hanford Site was one of the resources called out in the Presidential Proclamation establishing the Hanford Reach National Monument in June 2000 (Presidential Proclamation 7319). Insects not only are important as organisms of biological study, but they also have economic importance as pests and beneficials. Entomological studies of the site continue to indicate that Hanford is unusual in its lack of pest species and in its abundance of native taxa. Agricultural pest species such as corn earworm, alfalfa looper, celery looper, and numerous cutworms make up the bulk of trap samples outside of the Hanford Site. These taxa are collected only in small numbers at Hanford. At the same time, the native arthropod fauna of the Hanford Site provides one of the few remaining areas where potentially beneficial native insects may be sought and, perhaps, found.

Shrub-steppe habitat has a relatively distinctive arthropod fauna, which appears to vary with the amount of disturbance and degradation within the habitat. Based on invertebrate collections thus far, it appears that shrub-steppe habitats in the Wahluke and Saddle Mountain Units are more degraded than that of the ALE Reserve. Several arthropod species that were encountered in habitats south and west of the Columbia River (e.g., snow scorpionflies [Mecoptera: Boreidae] and a winter scarab [*Aphodius* new species – Coleoptera: Scarabaeidae]) were not found on the North Slope. The species richness of ground dwelling beetles is also less in the Wahluke and Saddle Mountain areas. It is not possible to say at this time whether these areas exhibit greater or lesser overall diversity than Central Hanford and the ALE Reserve because of differences in the extent of sampling between the surveys of the 1990s and the present study, as well as the number of species remaining to be identified (especially in the non-noctuid moths). It must be noted that invertebrate collections on the ALE Reserve were made prior to the 2000 wildfire that swept the Reserve and severely altered some shrub-steppe habitats (Evans et al. 2002). Fire has been associated with reductions in total invertebrate family richness as well as in total taxa richness of predatory, detritus-feeding, and ground dwelling invertebrates in shrub-steppe environments at Hanford (Karr 2000). The reliability of certain invertebrate taxa as indicators of habitat condition merits further study.

The Hanford Site likely represents the closest approximation to a pre-European colonization insect fauna as can be found in Eastern Washington. The unique character of the Hanford fauna is likely associated with the predominance of native vegetation and other natural habitat characteristics. For example, wild bees are the most commonly encountered Hymenopterans on the Hanford Site, an indication of the predominance of native vegetation on the site. In the surrounding urban and agricultural landscape, the introduced domesticated honeybee is most common. Several groups of insects appear to be associated with areas of extensive microbiotic soil crusts. The mite and Collembola (springtail) fauna represented significant portions of pit fall samples where the crust was intact and were virtually nonexistent in samples where the crust had been destroyed. The distribution of snow scorpionflies (*Boreus*: Mecoptera: Boreidae) exhibits the same contrast: The larvae of these small insects feed on moss and are not found in areas where the crust has been degraded or destroyed. During our 1994–2000 sampling, we collected four species of *Boreus* on ALE—one of which is a species new to science. This is the only site known to the world authority on this taxonomic group from which four species have been recorded (N. Penny pers. comm.)!

The sand dune habitats of Central Hanford and the Wahluke Slope exhibit an invertebrate fauna distinct from other areas of the Site. Based on collections of dune habitats throughout the state, it appears that a number of these dune taxa are also limited outside the Hanford Site due to isolation of habitats and, perhaps, habitat degradation and conversion.

Despite extensive and fruitful entomological diversity studies, we still know very little concerning the arthropod fauna of the Hanford Site. Species new to Washington state and new to science continue to be found. Such discoveries are likely to continue and accelerate if longer-term studies can be conducted, especially if surveys are focused on lesser-studied taxa. Large numbers of specimens in some of the lesser known groups (e.g., spiders) have been collected and processed, and it is hoped that the identification and evaluation of these organisms will add significantly to our understanding of the biological diversity of the Hanford Site.

Recommendations

- Areas of the Hanford Reach National Monument and Central Hanford should be considered for long-term entomological diversity studies. The collection and preparation of insects is a very time-intensive activity; the tremendous number of species within any large system, their varied habits, and methods of collection make it impossible to obtain a true indication of the breadth of species diversity unless a multiyear study is conducted. Survey work for moths in particular should be continued. Survey work in riparian zones is needed, as is further work on the sand dunes. The sand dunes have an extensive and distinct fauna, especially of moths, and should be the subject of weekly to biweekly collecting for at least one to several full years. A number of species new to science as well as several rarely collected species have already been collected from these habitats, and more taxa of biogeographic significance are likely to be found.
- A series of pitfall traps was established near the White Bluffs Ferry landing. This is a disturbed area with some introduced vegetation but also is more naturally riparian being along the Columbia River. Perhaps because of this it has a distinct fauna not found in general shrub-steppe. Access to less modified sites (especially those along the River) is limited and boat access is difficult, but some of these areas should be sampled.
- This study did not survey in riparian areas associated with the extensive irrigation wasteway system in the Wahluke and Saddle Mountain Units. There may be a distinct fauna associated with these areas that should be examined.The sand dune habitats of the Hanford Reach National Monument support a distinctive fauna of moth species found nowhere else on the Hanford Site , including a number of species that are regionally rare. These dunes represent a high-quality habitat that is increasingly rare in Washington state. Shrub-steppe habitats with intact biological soil crusts also support a distinctive invertebrate fauna. Management should aim to minimize disturbance to both these critical habitat types and to maintain them in as natural a state as possible.
- The Monument maintains an active invasive plant species control program that includes the use of chemical herbicides to control selected noxious weeds. The collecting site near the White Bluffs Ferry was relatively disturbed and may be a candidate area for the use of herbicides. While the site does appear to have a different ground beetle fauna than other sample sites, most of this fauna is common to disturbed areas throughout the Hanford Site and should not be considered at risk from chemical spray.

Invasive Plant Species

10. Invasive Plant Species Inventory of the Hanford Reach National Monument: 2002–2003

James R. Evans, John J. Nugent, and Jennifer K. Meisel

Introduction

Invasive plant species are one of the greatest threats to the biodiversity of the Hanford Site (Soll et al. 1999). In order to assess the current status of invasive plant species on the Hanford Reach National Monument, an inventory of noxious weeds in Monument management areas was conducted by personnel from The Nature Conservancy's Washington Field Office and staff of the Hanford Reach National Monument in 2002 and 2003 (Evans et al. 2003).

Methods

A preliminary target list of actual and potential invasive plant species for the Monument (Table 10.1) was developed during winter 2002 after consulting ecological literature (TNC 2002, Sackschewsky and Downs 2001, CNAP 2000, Mitchell 2000, Mullins et al. 2000, PNEPPC 1997) and Washington state weed law (NWCB 2003a), and following discussions with staff of the Hanford Reach National Monument, personnel from the Hanford Biological Control Program, and local professionals. Species selected for inventory (hereafter referred to as "target species") were those which met the following criteria: 1) a demonstrated ability to outcompete native plant species and to change the structure and/or function of natural ecosystems in the Columbia Basin and/or elsewhere in the arid and semiarid West, and 2), ranges that currently include the Lower Columbia Basin or nearby areas or which can reasonably be expected to migrate into the Columbia Basin within the relatively near future. This working list of target weeds is intended to be a flexible tool that can be expanded or reduced as new information about plant migrations and ecological effects becomes available.

The noxious weed list is divided into upland and riparian habitat types. Species that may occur in either habitat type were placed into the type where they were most likely to be encountered, but surveys for that species were not necessarily limited to that habitat type. The list of species for each habitat type is further divided into species that have been confirmed to occur on Monument lands (Active List) and species which have not yet been documented on Monument lands (Watch List). An additional category identifies invasive plant species that display considerable ecological impacts on infested lands, but which are already so widespread on the Monument that control is feasible only in selected areas for particular management purposes (Table 10.1c). Since they are already ubiquitous throughout all or most of their suitable habitats, these widespread species of concern were not inventoried during the surveys.

Noxious weed surveys were performed between April 1 and October 10, 2002, and between April 15 and July 1, 2003. Geographic locations of invasive species occurrences were recorded as either points, lines, or polygons using portable GPS units. For each occurrence, the following additional information was also documented:

- Species name
- Infestation size (length x width)

(Continued)

Table 10.1. Target list of invasive plant species for the Hanford Reach National Monument. a) Species that occur primarily in uplands; b) species that occur primarily in wetlands and riparian areas; c) species of concern that are already widespread. Scientific names are from Kartesz and Meacham (1999). Boldface indicates nomenclatural changes since Hitchcock and Cronquist (1973). Column 4 indicates weed regulatory status in Washington state, including Monitor (M) and species not listed (NL) by the Washington State Noxious Weed Control Board (NWCB 2003a).

a. Upland Species: Active List

Scientific Name	Hitchcock & Cronquist (1973)	Common Name	Weed Class
Acroptilon repens	*Centaurea repens*	Russian knapweed	B
Alhagi maurorum	No record	camelthorn	B
Bassia scoparia	*Kochia scoparia*	kochia	B
Cardaria draba	*Cardaria draba*	white top	C
Centaurea diffusa	*Centaurea diffusa*	diffuse knapweed	B
Centaurea solstitialis	*Centaurea solstitialis*	yellow starthistle	B
Chondrilla juncea	No record	rush skeletonweed	B
Cirsium arvense	*Cirsium arvense*	Canada thistle	C
Cirsium vulgare	*Cirsium vulgare*	bull thistle	C
Convolvulus arvensis	*Convolvulus arvensis*	field bindweed	C
Gypsophila paniculata	*Gypsophila paniculata*	baby's breath	C
Lepidium latifolium	*Lepidium latifolium*	perennial pepperweed	B
Linaria dalmatica	*Linaria dalmatica*	dalmatian toadflax	B
Onopordum acanthium	*Onopordum acanthium*	Scotch thistle	B
Secale cereale	*Secale cereale*	winter rye	C
Sphaerophysa salsula	No record	swainsonpea	B
Tribulus terrestris	*Tribulus terrestris*	puncturevine	B

Upland Species: Watch List

Scientific Name	Hitchcock & Cronquist (1973)	Common Name	Weed Class
Abutilon theophrasti	No record	velvetleaf	A
Anthriscus sylvestris	No record	wild chervil	B
Carduus nutans	*Carduus nutans*	musk thistle	B
Cenchrus longispinus	*Cenchrus longispinus*	sandbur	B
Centaurea biebersteinii	*Centaurea maculosa*	spotted knapweed	B
Euphorbia esula	*Euphorbia esula*	leafy spurge	B
Sorghum halepense	*Sorghum halepense*	johnsongrass	A
Taeniatherum caput-medusae	*Elymus caput-medusae*	medusahead wildrye	NL

b. Wetland and Riparian Species: Active List

Scientific Name	Hitchcock & Cronquist (1973)	Common Name	Weed Class
Eleagnus angustifolia	*Eleagnus angustifolia*	Russian olive	NL
Lythrum salicaria	*Lythrum salicaria*	purple loosestrife	B
Myriophyllum spicatum	*Myriophyllum spicatum*	Eurasian watermilfoil	B
Phragmites australis	*Phragmites communis*	common reed	C
Sonchus arvensis ssp. *arvensis*	*Sonchus arvensis* ssp. *arvensis*	perrennial sowthistle	B
Tamarix parviflora	*Tamarix parviflora*	saltcedar, tamarisk	NL
Tamarix ramosissima	No record	saltcedar, tamarisk	B

Wetland and Riparian Species: Watch List

Scientific Name	Hitchcock & Cronquist (1973)	Common Name	Weed Class
Amorpha fruticosa	No record	indigobush	B
Cyperus esculentus	*Cyperus esculentus*	yellow nutsedge	B
Epilobium hirsutum	No record	hairy willow-herb	M
Myriophyllum aquaticum	*Myriophyllum brasiliense*	parrotfeather	B

c. Species of concern that are already widely established.

Scientific Name	Hitchcock & Cronquist (1973)	Common Name	Weed Class
UPLAND			
Bromus tectorum	*Bromus tectorum*	cheatgrass, downy brome	NL
Salsola tragus	*Salsola kali*	Russian thistle, tumbleweed	NL
WETLAND AND RIPARIAN			
Phalaris arundinacea	*Phalaris arundinacea*	reed canarygrass	C

- Cover class (< 1%, 1-10%, 11-25%, 26-50%, 51-100%)
- Management Unit
- County
- USGS 7.5′ quadrangle
- Location information
- Disturbance type, if known
- Associated vegetation

All GPS coordinates were imported into GIS layers (UTM NAD27). Weed occurrences were also drawn on USGS 7.5′ topographic maps. Some large polygons in degraded, low-quality areas were recorded only on topographic maps, which were digitized later. A few large polygons were approximated from existing vegetation maps (*Secale cereale*), from aerial imagery (*Eleagnus angustifolia*), or from direct expert accounts (*Myriophyllum spicatum*).

INVENTORY SEARCH STRATEGIES

Inventory staff searched over 20,000 acres (8097 ha) of the Monument for targeted invasive plant species (Fig. 10.1). Inventories focused on areas where noxious weeds have been previously reported, on special habitats (e.g., springs or riparian areas) where certain target species were expected to occur, and in disturbed lands and corridors. Most non-native plant species establish most readily in areas such as roadsides, gravel pits, abandoned agricultural fields, and other disturbed lands. Roads and watercourses, in particular, can function as corridors for weed transport and migration into new areas. Detection of weeds along corridors prompted systematic searches of surrounding areas. Searches of the target areas such as these have a high likelihood of turning up many noxious weed occurrences (Zamora and Thill, 1999). Some noxious weed species are highly mobile and capable of establishing in undisturbed habitats, necessitating systematic overland searches. Such overland searches were limited by time constraints for this inventory but were conducted in areas of particular biological importance such as Umtanum Ridge on the McGee Ranch–Riverlands Unit, the White Bluffs, and portions of the Arid Lands Ecology (ALE) Reserve. Inventory staff also searched for noxious weeds while traversing expansive areas of the ALE Reserve in the course of a concurrent vegetation-monitoring project.

The inventory was conducted primarily on shrub-steppe uplands and natural springs. Aquatic environments associated with irrigation wasteways and artificial impoundments on the North Slope were not included in the survey. Riparian habitats surrounding these features were only partially surveyed, and invasive species associated with these habitats are undoubtedly substantially underreported here. Aquatic and shoreline habitats of the Columbia River were surveyed on five different days during July and October 2002 and July 2003 and were undoubtedly undersampled. Hydrophytic weeds and other invasive species that occur between the high- and low-water marks of the river appeared to be widespread to ubiquitous along the length of the river shore and were not mapped.

Results and Discussion

Noxious weed surveys in 2002 and 2003 confirmed the presence of 23 invasive plant species on the Hanford Reach National Monument (Table 10.1), including three species that had not previously been documented on Monument lands. Overall, the inventory recorded 401 occurrences of invasive species, infesting more than 9000 acres (> 3600 ha) over all management units of the Monument (Table 10.2, Fig. 10.2).

Diffuse knapweed (*Centaurea diffusa*) infested more than 3600 acres (>1400 ha), more than 40% of the total area occupied by target invasive plant species on the Monument. Diffuse knapweed infestations were common along roads but also occurred in riparian areas, in old fields, and, most noteworthy, in some shrublands. Diffuse knapweed appears to be ubiquitous along the shoreline of the Hanford Reach between the high- and low-water marks. This acreage has not been mapped or included in area figures, so that the total acreage of diffuse knapweed infestations reported here are clearly underestimates.

Clonal colonies of Russian knapweed (*Acroptilon repens*; 943 acres/381 ha) and whitetop (*Cardaria draba*) dominated considerable acreage in riparian areas, former agricultural lands, and other disturbed areas. Whitetop (63 occurrences, 497 acres) in particular was present at nearly every spring, seep, well, or other area where soil moisture may have been closer to the surface than in the surrounding landscape.

Rush skeletonweed (*Chondrilla juncea*; 692 acres/280 ha) and yellow starthistle (*Centaurea solstitialis*; 312 acres/126 ha) both formed large patches in highly disturbed areas. However, these highly mobile species appeared in lightly to moderately disturbed grasslands and shrublands as well. New occurrences documented by USFWS personnel during spring 2003 indicate that infestations of both of these composite species have been underestimated by this inventory.

Fig. 10.1. Search areas for invasive plant species, Hanford Reach National Monument, 2002–2003.

Fig. 10.2. Areas infested by invasive plant species, Hanford Reach National Monument, 2002–2003.

Saltcedar (*Tamarix* spp.; 1284 acres/520 ha) was the second most common species in the inventory, comprising more than 14% of the total area occupied by target invasive plant species. Saltcedar was common on seeps along the face of the White Bluffs as well as along irrigation wasteways and impoundments, where it was often codominant with Russian olive (*Eleagnus angustifolia*; 579 acres/234 ha). With the exception of these woody species, the invasive species of the artificial wetlands and riparian areas associated with wasteway impoundments were considered low priorities for inventory purposes. Species such as purple loosestrife (*Lythrum salicaria*) and common reed (*Phragmites australis*) were consequently undersampled during this inventory, and the results presented here are poor indicators of these species' abundance on the Monument. Three invasive plant species were documented for the first time on the Hanford Reach National Monument. A single individual of dalmatian toadflax (*Linaria dalmatica*) was observed along the west side of the White Bluffs Road in the Wahluke Unit. Several individuals of Scotch thistle (*Onopordum acanthium*) were recorded at the mouth of an abandoned quarry on the ALE Reserve. Perennial sowthistle was observed in some abundance in a riparian area that is associated with the WB 10 Ponds on the Wahluke Unit. This species may have been present in this area for some time without notice.

Table 10.2. Occurrences and areas infested by target invasive plant species, Hanford Reach National Monument 2002–2003.

Common Name	Scientific Name	Total Occurrences	Area (hectares)	Area (acres)
Russian knapweed	*Acroptilon repens*	48	381.6	943.1
camelthorn	*Alhagi maurorum*	1	< 0.1	< 0.1
whitetop	*Cardaria draba*	63	201.2	497.0
diffuse knapweed	*Centaurea diffusa*	88	1488.9	3679.1
yellow starthistle	*Centaurea solstitialis*	29	126.5	312.7
rush skeletonweed	*Chondrilla juncea*	31	280.0	692.0
Canada thistle	*Cirsium arvense*	24	6.1	15.1
bull thistle	*Cirsium vulgare*	3	< 0.1	< 0.1
field bindweed	*Convolvulus arvensis*	29	33.7	83.3
Russian olive	*Eleagnus angustifolia*	8	234.3	579.0
baby's breath	*Gypsophila paniculata*	1	< 0.1	< 0.1
kochia	*Kochia scoparia*	8	17.3	42.7
perennial pepperweed	*Lepidium latifolium*	13	122.7	303.1
dalmatian toadflax	*Linaria dalmatica*	2	< 0.1	< 0.1
purple loosestrife	*Lythrum salicaria*	3	0.8	2.0
Eurasian watermilfoil	*Myriophyllum spicatum*	2	9.4	23.1
Scotch thistle	*Onopordum acanthium*	3	0.1	0.2
common reed	*Phragmites australis*	11	36.1	89.3
winter rye	*Secale cereale*	3	192.6	475.8
perennial sowthistle	*Sonchus arvensis*	1	Area Unknown	
swainsonpea	*Sphaerophysa salsula*	10	15.0	37.10
saltcedar	*Tamarix ramosissima, T. Parviflora*	19	519.5	1283.8740.3
puncturevine, tackweed	*Tribulus terrestris*	1	0.1	0.2
	TOTALS	**401**	**3665.8**	**9058.67755.**

CHARACTERIZATION OF INFESTATIONS OF TARGET SPECIES BY MANAGEMENT AREA

The Fitzner-Eberhardt Arid Lands Ecology (ALE) Reserve. While ALE contains many of the highest quality native plant communities on the Monument, invasive species are a mounting concern. Riparian vegetation at important spring systems (Rattlesnake, Snively, and Benson/Bobcat) is highly degraded and increasingly dominated by invasive species such as Russian knapweed, whitetop, and Canada thistle. Whitetop is common also at many seeps along the middle slopes of the Rattlesnake Hills. Russian knapweed and whitetop are common and probably spreading in highly disturbed lands along the length of Cold Creek. Diffuse knapweed is widespread along many of the Reserve's roadways, including those at higher elevations and in remote locations, and in the dry creekbed of upper Cold Creek, but has not yet been documented in surrounding natural areas. Rush skeletonweed is established in the lower Cold Creek Valley and has recently appeared in lightly to moderately disturbed lands in Iowa Flats and other areas on the low slopes of Rattlesnake Mountain. The unit's recent fire history has favored the increase and spread of many of these invasive species, along with cheatgrass (*Bromus tectorum*) and Russian thistle (*Salsola tragus*).

The McGee Ranch–Riverlands Unit. Compared to ALE, this is an extremely weedy area. Diffuse knapweed, Russian knapweed, whitetop, perennial pepperweed (*Lepidium latifolium*), and other invasive species infest large areas of the McGee Ranch area north of SR 24. It is notable that diffuse knapweed has escaped from gravel roads in this area and infested sagebrush shrublands, as well as abandoned agricultural fields, at the west end of the site. The Riverlands area hosts a number of large infestations of Russian knapweed, most notably in the vicinity of the Midway townsite and at China Bar. China Bar also hosts the unit's only documented occurrence of saltcedar. Fortunately, biologically rich Umtanum Ridge appears to be largely free of target invasive plant species at this time, except for small infestations of diffuse knapweed and Russian knapweed on unpaved roads through the area. These isolated occurrences should be high priorities for treatment.

The Vernita Bridge Recreation Area. Diffuse knapweed, which is common along the Columbia River shorelines up and down the length of the Hanford Reach, is scattered throughout this unit, particularly on roadways and in parking and boat launch areas. Two small borrow pits in the eastern section of the site support riparian vegetation, including Canada thistle and common reed.

Saddle Mountain Unit/Saddle Mountain National Wildlife Refuge. Large areas of this unit between SR 24 and the Columbia River are lightly to heavily infested with noxious weeds. Diffuse knapweed occupies extensive former agricultural lands in the flats along the shore of the Columbia. Abandoned quarries host saltcedar, rush skeletonweed, and Russian knapweed. The Saddle Mountain Wasteway and its impoundments, including Saddle Mountain Lake, host large populations of many riparian weed species, including saltcedar, Russian olive, common reed, and purple loosestrife.

Wahluke Unit. The riparian areas surrounding the WB 10 Ponds are dominated by Russian olive and host many other riparian weed species. Saltcedar is abundant in places, particularly along the White Bluffs. Yellow starthistle is well established in the lowlands and bluffs of the southern portion of this unit, while extensive patches of Russian knapweed, along with other invasive species, occur in Ringold Flats.

River Corridor Unit. The River Corridor Unit consists of the Hanford Reach and its islands, a one-quarter-mile buffer along the south and west shores of the river (bordering Central Hanford), and the Hanford Dunes. The dynamism of the great river, the wide daily fluctuations in riverflow owing to upstream hydroelectric generation, and a steady supply of riverborne alien propagules make the Columbia River shoreline an extremely favorable site for colonization by invasive plant species. Hydrophytic weeds such as purple loosestrife and reed canarygrass (*Phalaris arundinacea*) are common between the high- and low-water marks along the length of the Hanford Reach. Diffuse knapweed colonizes this same disturbed elevational zone and is the most abundant and widespread weed along the river. Large clonal patches of common reed can be observed upstream from the Wahluke ferry landing. Eurasian watermilfoil (*Millefolium spicatum*) occurs in several persistent patches south of the White Bluffs boat launch.

Island uplands are subject to infestations similar to mainland uplands with Russian knapweed, diffuse knapweed, yellow starthistle, rush skeletonweed, and Canada thistle the most widespread and abundant of invasive species in these areas.

Conclusions

There are more species of noxious weeds infesting larger land areas of the Hanford Reach National Monument than had previously been documented. While this inventory represents a concerted effort to provide a detailed picture of the extent of invasive plant species on the Monument, it is far from a complete picture. Due to inevitable time limitations, large areas of the Monument remain unexplored by inventory personnel, so that the numbers of species and areas infested that are reported here must be taken as minimum estimates for invasive plant species on the Monument.

A biological inventory represents only a snapshot in time. Invasive plant populations are dynamic and will require monitoring annually or more often to accurately apprise management of patterns of abundance and threats to biological resources. Invasive species that have not yet been recorded on the Monument occur in as close proximity to its boundaries as in Central Hanford or in the nearby Tri-Cities area (Rice 2002, R. Roos pers. comm.). In the years ahead, new species of non-native plants will continue to arrive from near and far (McNeely 2001, Mack et al. 2000).

Managers of the Hanford Reach National Monument will require timely information regarding the distribution and abundance of invasive plant species in order to adequately protect the biodiversity of the site. This inventory has documented important information about major noxious weed infestations on the Monument and helped to lay the groundwork for continuing surveys, which should follow.

Recommendations

Because of the dynamic nature of established invasive plant species populations and the likelihood of further introductions of non-native species, establishing and maintaining a well-staffed and trained, year-round invasive species monitoring program in accordance with recommendations in Evans et al. (2003) and Section 11 (this volume) should be a high priority for the Hanford Reach National Monument.

This inventory dealt only with invasive vascular plant species. However, some species of non-native insects, mollusks, fish, birds, reptiles, amphibians, and mammals are likely to have important impacts on the native biodiversity of the Hanford Site, now or in the future. Inventories of taxa likely to have deleterious effects upon conservation targets are strongly recommended.

Herbaceous weeds of artificial riparian areas associated with irrigation wasteway impoundments on the Wahluke and Saddle Mountain Units were considered low priorities for inventory activities and were, as a result, considerably undersampled. A more accurate estimate of the abundance and distribution of these invasive species can only be obtained by a thorough inventory of these areas, should resources permit.

Weed inventory personnel were unable to gain access to the southern portion of the McGee Ranch area through Gates 121 (from SR 240) and 121B (from Cold Creek County Rd.). Keys to padlocks on these gates did not work. Hanford Biological Control Program personnel mentioned that their keys to these gates had stopped working some time ago. Although the area can be accessed via a rough track through sagebrush from the Umtanum Ridge Rd., this route may not be appropriate for all kinds of transport and may represent a potential fire hazard during the dry months. Repair or replacement of the Gate 121 and 121B locks would greatly facilitate inventory and control efforts in this portion of the McGee Ranch–Riverlands Unit.

A gate in sagelands along a powerline access road at the southwest boundary of the McGee Ranch–Riverlands Unit consists only of loops of barbed wire. This gate, in a remote part of the Monument and near habitats of high biological value, was found open during a survey in 2002. Installation of a standard security gate with padlock may help to reduce incidences of trespass, which are occasionally reported. Trespassing individuals or livestock represent an avenue of invasive species introductions that can be controlled by this simple security measure.

Wide-ranging surveys during 2002–2003 suggest that bull thistle (*Cirsium vulgare*) is present only as scattered individuals and does not pose a significant threat to Monument resources. This non-native thistle may be considered for removal from the priority list of target species. At the same time, dense, persistent patches of black locust (*Robinia pseudo-acacia*) at Ringold and elsewhere suggest that monitoring may be prudent to determine if sexual reproduction is occurring in this potentially invasive species (M. Tu pers. comm.).

11. Invasive Plant Species Management Plan for the Hanford Reach National Monument

James R. Evans, John J. Nugent, and Jennifer K. Meisel

Introduction

Invasive alien plant species pose one of the most serious threats to the native biodiversity, wildlife habitat, and scenic values that the Hanford Reach National Monument was created to protect, and for which the entire Hanford Site is well known (Soll et al. 1999). Managing invasive plant species in a large landscape requires adequate information about the nature and extent of weed populations, along with careful planning and judicious use of limited resources in control efforts. The following section describes the main points of a weed management plan for the Hanford Reach National Monument that is currently being developed by The Nature Conservancy in cooperation with the U.S. Department of Energy and the U.S. Fish and Wildlife Service. Full details of the plan are available in Evans et al. (2003).

Impacts of Invasive Plant Species

At Hanford, as elsewhere in western North America, invasive and noxious alien plant species compete against and reduce habitat available for rare plant taxa and native plant species in general. Invasive species alter ecosystem strucure and function, disrupt food chains and other characteristics vital to wildlife (including rare and endangered species) and can dramatically alter key ecosystem processes such as hydrology, productivity, nutrient cycling, and fire regime.

The deleterious effects of invasive plant species are not limited to natural areas but may also severely impact local economies. Invasive weeds compete with agricultural crops for light, moisture, and nutrients, clog irrigation systems, and reduce livestock forage values in pastures and rangelands (Mack et al. 2000, Bridges 1994). Degradation of agricultural lands resulting from invasive species infestations may drastically reduce land values (TCWPP 2003, Weiser 1997). One local invasive species is even known to puncture bicycle tires.

Management Setting

Shrub-steppe ecosystems such as that represented on the Hanford Reach National Monument are highly susceptible to infestation by invasive plant species, especially when disturbed (DiTomaso 2000). The Monument's large size (195,000 acres) and the large number of documented or potential invasive plant species in the area present significant challenges to the stewards of biological resources. Past and present land use practices such as farming and ranching, military activities, road building and quarrying, and riverflow management have helped to create conditions favorable for the establishment of many invasive plant species on Monument lands and throughout the Columbia Basin.

The introduction and spread of invasive plant species is enhanced by the existence of disturbed lands and corridors (Mack et al. 2000). Potential corridors for the migration of invasive species into and within the Hanford Reach National Monument include (HRNM 2003):

- Forty-four miles of the Columbia River, including 15 islands.
- Eleven miles of active irrigation canals and wasteways, and more than 1000 acres of associated impoundments.

- More than 50 miles of state highway, and more than 180 miles of paved and unpaved secondary roads in widely varying condition.
- More than 20 miles of powerline corridors and associated access roads.

Certain trends may make invasive species even more of a problem in the future than they are at present. New weeds may be expected to arrive within the coming years as technology and commerce continue to reduce barriers to plant migrations (Mack et al. 2000, Mullins et al. 2000). At the same time, recurrent wildfires, powerline development and maintenance, continued slumping of the White Bluffs, and other disturbances continually create new habitats for invasive species to colonize.

Management Program Overview

An invasive species control program must be based upon the overall conservation and management goals of the area for which it is designed. Long-term conservation planning for the Hanford Reach National Monument is underway; however, the process has not been completed as of this writing. In light of guidance included in the Presidential Proclamation of June 2000 (Presidential Proclamation 7319), current management practices, and preliminary results of the Comprehensive Conservation Planning process (USFWS and CBSG 2003, 2002), the following generalizations have been made regarding Monument conservation goals as a basis for this weed management plan:

- Fully functioning shrub-steppe habitats and the processes that characterize and maintain them, including their full array of native species.
- Healthy spring and stream habitats with their full complement of associated native vegetation and wildlife.
- Healthy aquatic and riparian habitats of the Hanford Reach of the Columbia River.

When the final version of a long-term Comprehensive Conservation Plan (CCP) for the Monument is adopted, weed planning documents should be reviewed to ensure full compatibility with the goals and objectives outlined in the CCP.

While weed management practices vary, the most successful programs adopt an adaptive, integrated management approach. The key elements of such an approach are presented in the following sections (adapted from Tu and Meyers-Rice 2002, DiTomaso 2000, Zamora and Thill 1999, Randall 1996, S. Johnson pers. comm.).

RESOURCE-BASED MANAGEMENT

Managers should address invasive species issues within the context of Monument conservation goals. A particular focus on the desired vegetation in place of the invasive weeds at a site rather than on simply eliminating the weeds themselves is recommended. Restoration of native vegetation is a desirable end goal for most, but not necessarily all, infested sites. In some cases, non-native species may be used as competitive plantings or place holders in treatment areas.

PREVENTION

The most effective method of control for invasive plant species is to prevent their establishment. Measures to minimize the introduction of potentially invasive species onto Monument lands may include administrative control of access to sites, limitation of access to designated entry points (as along a single, carefully monitored road), inspection and decontamination of vehicles, cooperative agreements with contractors and other parties that need regular access to the site, educational programs, and other measures. Different measures may be applied to different management units or subunits within the Monument, reflecting different levels of biological value and condition, and different management goals for particular units. Strong preventive measures are recommended for the ALE Reserve and for the Umtanum Ridge portions of the McGee Ranch–Riverlands Unit.

EARLY DETECTION AND SUSTAINED MONITORING

Next to prevention, the most effective method for control of invasive plant species is to detect their presence early. Existing weed populations are dynamic, and occasional new introductions may be expected even when rigorous preventive measures are in place. An essential component in successful weed management plans is provision for extensive and ongoing surveys to detect new occurrences and to monitor existing ones (Snyder-Conn 2001). An aggressive monitoring program is one of the most cost-effective strategies that can be applied in weed management. This is critically important in an era where funding for natural resources management is in decline. Early detection of invasive species occurrences makes it possible for treatment to be applied before a spot infestation can spread more extensively across the landscape. Timely intervention in turn increases treatment effectiveness while reducing treatment duration (Belnap and Phillips 2001, Moody and Mack 1988), thus reducing expenditures for staff time and materials and minimizing chemical inputs to the environment; this in turn reduces the potential for treatment impacts to non-target resources such as native plants, wildlife, and aquatic resources.

Ongoing monitoring of the status of weed occurrences and the effectiveness of control treatments is also essential for adaptive management. Documented occurrences of high priority target species (Priorities 1 and 2, described below) must be visited and assessed at least annually. In addition to the precise location of the infestation, the size and percent aerial cover of the infestation must be recorded. Density measurements (stem counts) may be the best measure of very small infestations such as the camelthorn infestation in the Wahluke Unit. All sites (Priorities 1, 2, and 3) that are undergoing active treatment should be assessed at least two times per year: in the spring, and in the fall following the end of the drought period but before the onset of dormancy. Some successful programs monitor even more often. A monitoring schedule should be flexible enough to allow the timing of monitoring visits to fit the phenology of the target species.

To maintain an effective monitoring program, well-trained personnel must be maintained at adequate staffing levels to carry on this work without serious interruption. While some degree of staff turnover is inevitable in any position, maintaining continuity of personnel experienced in invasive species monitoring and management should be a very high priority for the Monument.

PRIORITIZATION OF SPECIES AND SITES

Thirty-six species of invasive weeds have been identified as target species for the Hanford Reach National Monument weed management program (Section 10, this volume). Twenty-three of these species have been documented as presently occurring on the Monument. In a large landscape with numerous target weed species and where infestations vary from a single plant to hundreds of acres or larger in size, a prioritization strategy for control and elimination of invasive plant species is essential to effectively allocate limited management resources.

This plan combines species-based criteria with site-based criteria to prioritize specific weed occurrence sites for treatment. The following factors are among the key criteria considered in the prioritization of sites for treatment:

- Invasive potential of the weed species.
- Ecological impacts of the weed species on native species and communities (especially in relation to specific conservation targets),
- The size of the infestation.

- Proximity of the infestation to valuable biological resources.
- Susceptibility of the invasive species to treatment.
- Potential impacts of treatment upon non-target species.

Invasive species that are fast growing, exhibit high reproductive rates, are highly dispruptive to conservation targets, occur along pathways of spread, or are otherwise highly mobile on the landscape must be given priority consideration. High priority is also assigned to small, incipient, isolated or satellite infestations, since these are the primary loci of population spread and at the same time are the sites where control and eradication efforts are most likely to be successful (Moody and Mack 1988). Difficulty of control must also be considered. Infestations where control efforts using available technology and resources are likely to yield positive results receive higher priority than those where available methods are likely to have little effect.

Target invasive plant species for the Hanford Reach National Monument are divided into an active list of species documented as occurring on the Monument and a watch list of species not yet documented on the Monument (Section 10, this volume). Active list species are further divided into groups for prioritization of treatment activities.

Priority 1 species (Table 11.1a) are perceived as the greatest and most immediate threats to the biological resources of the Hanford Reach National Monument. Priority 1 species are annual, biennial, and perennial species that are, in general, prolific seed producers, highly mobile on the landscape, aggressive competitors, and tenaciously persistent when established.

Table 11.1. Invasive plant species treatment priorities, Hanford Reach National Monument, 2002–2003: a) Priority 1 species; b) Priority 2 species.

a. Priority 1 Species

Common Name	Scientific Name
camelthorn	*Alhagi maurorum*
diffuse knapweed	*Centaurea diffusa*
yellow starthistle	*Centaurea solstitialis*
rush skeletonweed	*Chondrilla juncea*
baby's breath	*Gypsophila paniculata*
dalmatian toadflax	*Linaria dalmatica*
Scotch thistle	*Onopordum acanthium*
saltcedar	*Tamarix ramosissimus, T. parviflora*
puncturevine	*Tribulus terrestris*

b. Priority 2 Species

Common Name	Scientific Name
Russian knapweed	*Acroptilon repens*
whitetop	*Cardaria draba*
Canada thistle	*Cirsium arvense*
Russian olive	*Eleagnus angustifolia*

The Priority 1 rank includes species such as diffuse knapweed and saltcedar, which are among the most abundant on the Monument (Section 10, this volume). It also includes several species that are among the least abundant on the Monument and may, because of the small size of the colonies, be amenable to early eradication. Ideally, all populations of Priority 1 species should be attacked aggressively with the goals of eradicating small infestations within a few years and gradually reducing larger infestations. In practical terms, some infestations of diffuse knapweed and saltcedar in low-quality areas probably cannot be dealt with effectively without taking critical resources away from areas where high-quality resources must be protected. In the short term, treatment must concentrate on infestations of Priority 1 species in areas of high biological value, while larger infestations in low-quality areas must be monitored and contained until resources permit more aggressive control of all infestations of the species.

Priority 2 species (Table 11.1b) pose somewhat less of an immediate threat to Monument resources than do Priority 1 species but are still invaders of great concern. The principal characteristic distinguishing the two ranks is one of reproductive biology: Priority 2 species do not spread as rapidly by seed as Priority 1 species. Priority 2 species are perennial species that spread primarily by vegetative means, although new colonies are initiated from time to time from seed. The weed management plan offers recommendations for treating infestations of Priority 2 species in specific sites wherever small, isolated populations occur and where Priority 2 species threaten high-quality natural areas, rare species, or other biological resources.

Priority 3 species include all other active list invasive species (Section 10, this volume). Priority 3 species are perceived as less likely to increase, spread, or otherwise threaten Monument resources than Priority 1 and Priority 2 species, but are still invasive species of concern. The weed management plan offers recommendations for treatment of many Priority 3 species in specific sites, especially where these species occur in isolated or satellite populations, or where they threaten high-quality natural areas, rare species, or other biological resources.

INTEGRATED TREATMENT PROGRAM FOR PRIORITY SPECIES AND SITES

The invasive plant species management plan for the Hanford Reach National Monument provides a profile of the ecology, reproductive characteristics, and impacts of each target invasive species, including a discussion of integrated pest management (IPM) treatment options based upon invasive species literature (TNC 2003, NWCB 2003b, William et al. 2002, Bossard et al. 2000, CNAP 2000, Sheley and Petroff 1999, and other sources) and discussions with local professionals. Manual, mechanical, cultural, chemical, and biological methods are available for the control and eradication of invasive species. The most appropriate treatment for an infestation typically depends on the scale of the infestation and on the morphology and ecology of the target species (Youtie 1997, S. Johnson pers. comm.). Biological control by itself may be effective for only a few species. Viable biological controls are lacking for many species and, where available, are typically not effective for small-scale infestations. Manual pulling or digging may effectively control small infestations of annuals or biennial weeds but may be ineffective against larger infestations or against deep-rooted perennials. Chemical control may be the most practical and effective option for small- to moderate-scale infestations of perennial plant species but must be applied so as to minimize impacts on non-target plant species as well as other organisms and systems. In actual practice, effective treatment for many weed infestations will require a long-term, integrated approach utilizing all methods that are available. For example, pulling, mowing, or burning at the most favorable time of year or plant developmental stage may enhance the effectiveness of later chemical treatments, thus reducing the chemical inputs required for eradication or for a target level of control (Renz 2000). Competitive plantings are also part of integrated weed management programs for many species, and restoration with native plant species will inhibit recolonization of treated sites by undesirable species (Brooks and Pyke 2001).

Treatment success is greatly enhanced by aggressive, early intervention at newly discovered, isolated satellite weed occurrences. As mentioned above, timely intervention may reduce or, in some cases, even eliminate the need for chemical inputs, reducing potential non-target impacts to desirable native species and to the surrounding environment.

With many invasive plant species, successful control of even small infestations requires several years of treatment, often utilizing multiple treatments per year. A long-term perspective is particularly important for a noxious perennial weed where total eradication is not a realistic short-term goal. Treatment success depends as much upon long-term diligence as it does upon the methods used (Mack et al. 2000, Snyder-Conn 2001). The duration of treatment required for a successful outcome is generally reduced by early detection and timely treatment.

ADAPTIVE MANAGEMENT

The ongoing monitoring of weed populations and of the results of control programs will allow management to evaluate the effectiveness of treatment methods in light of the site goals. Managers can then use this information to modify and improve control priorities, methods, and plans. The modification of weed control goals begins a new round of treatment, monitoring, and assessment.

BUILDING PARTNERSHIPS

Invasive plant species have impacts that ignore ownership and cross management boundaries. Effective weed control efforts in one area can be nullified if similar measures are not taken simultaneously on neighboring properties. Monument co-managers USFWS and DOE should coordinate weed control efforts closely. Partnerships with other local and regional management entities can greatly increase efficiency in education, detection, and treatment.

Monument co-managers already participate in valuable partnerships through the Noxious Weed Task Force, an organization that originally formed around efforts to control saltcedar. Task Force members include federal and state agencies (USFWS, DOE, WDFW, U.S. Bureau of Reclamation) along with local jurisdictions such as county and district weed boards and public utility and irrigation districts. The Task Force has already achieved important gains in outreach, detection, and treatment of saltcedar in the mid-Columbia region and fostered a spirit of cooperative partnership among members (Hill 2003). These partnerships should be maintained or expanded, and cooperative partnerships should be explored wherever opportunities are perceived.

EDUCATION AND OUTREACH

Education and outreach regarding noxious weed identification and the ecological and economic impacts of invasive species enhances the long-term success of weed management programs (Svejcar 1999). Adequate training for field staff is critical. Educational programs should also reach out to non-field staff, partners, landowners, public and private schools, user groups, and the public at large. Increasing public awareness can lead to assistance in the prevention and early detection of weed occurrences. Avenues for educational outreach can include workshops, brochures, interpretive displays at visitor centers, along roadsides, and at community fairs and similar events.

FIRE MANAGEMENT

The unique role of wildfire in invasive species behavior in arid lands deserves mention. At Hanford as throughout the arid West, the increase in both the frequency and extent of wildfires over the last half-century is attributable in large part to invasive species and has created conditions that favor invasive plant species and communities over native ones (Grace et al. 2001, Bushey 1995). Implementation of a fire management plan aimed at maintaining fire frequencies at appropriate intervals for the perpetuation of intact native vegetation will be a critical tool in limiting the spread and abundance of invasive plant species on the Hanford Reach National Monument.

Conclusions

The full weed management plan for the Hanford Reach National Monument is a detailed plan for the management of invasive plant species that pose critical threats to the biological resources of the Monument. The provisions in this plan can and should grow and change in response to changes in invasive species populations, new information concerning either invasive species autecology or biological resources, advances in weed technologies, and clarification of Monument conservation goals. Weed laws, personnel, conservation goals, and even the invasive species of greatest concern may change over time, but invasive plant species will remain a relatively constant threat to native biodiversity in the Columbia Basin. Effective management and control of invasive plant species on the Hanford Reach National Monument will require a dedicated, persistent, and long-term effort. Careful planning must be coupled with sufficient resources to sustain determined and long-term inventory and control efforts in the field.

Conclusions

Conclusions

The predecessor to this report, the *Biodiversity Inventory and Analysis of the Hanford Site* (Soll et al. 1999), convincingly documented the biological importance of the Hanford Site as a refuge for rare species of native plants and animals and, as importantly, for common species and communities that were once far more widespread in the inland Northwest. The biological studies outlined in this report continue to confirm Hanford's national and regional importance as a refuge both for biodiversity and for the natural processes that characterize shrub-steppe and associated habitats. The large size of the Hanford Site as a whole, the continuity of habitats between the Hanford Reach National Monument and Central Hanford, and the site's proximity to other important natural areas such as those on the Department of Defense's Yakima Training Center contribute to the importance of the Hanford Site as a reservoir of native biodiversity.

The biodiversity studies of the past decade have allowed us to learn a great deal about the natural systems of the Hanford Site and to catalogue a diverse array of native organisms that populate these systems and contribute to their natural processes. Current discoveries underline, in many ways, how our investigations have still only begun to scratch the surface of the complex biology of this arid land.

Studies of aquatic and terrestrial invertebrates and of biological soil crusts continue to uncover new taxa and provide new information regarding the distribution of these organisms across the landscape. Additional new organisms may continue to be identified as researchers work through existing collections. It is likely, too, that in these poorly known groups, taxa of biogeographic significance still remain uncollected. Although researchers have begun to piece together the relationships between taxa and the environment, our understanding of the function of these organisms in the ecosystems of the Lower Columbia Basin is still in its infancy. Further inventories and ecological studies of these groups are likely to continue to yield important discoveries.

Our knowledge of rare plant population trends is severely limited by a lack of information regarding life history and reproductive strategies for most of these species. For the taxa that *have* been studied, our knowledge is still often limited by the short time period during which we have been able to study these populations. This is especially true for the Hanford endemics Umtanum desert buckwheat and White Bluffs bladderpod, which were discovered less than 10 years ago. A much more long-term perspective is required to adequately interpret the significance of perceived fluctuations in rare plant populations and thus provide meaningful information to the agencies that manage these limited resources.

Plant communities as a whole change over time. Changes may be gradual, as in response to long-term fluctuations in climate, or may occur rapidly in response to episodic events such as wildfires and other disturbances. The vegetation maps produced by this and previous studies represent conditions at a single point in time. However, plant communities are always dynamic elements in a landscape, and this is especially true in shrub-steppe landscapes of the twentieth and twenty-first centuries. Plant community surveys must be updated at least periodically, and in a timely manner when large-scale disturbance events dictate, in order to remain fully valuable as management tools.

The warning sounded in Soll et al. (1999) regarding the threat posed by invasive species to the biodiversity of the Hanford Site is even more pertinent today than it was four years ago. Invasive plant species are more numerous and widespread than previous records indicate, and the areas they occupy are likely increasing. The extent, distribution, and impacts of other invasive organisms, such as invertebrates, amphibians, birds, and others, on the Hanford Site are poorly known and merit study as well. Invasive species populations are dynamic and will continue to pose a challenge for natural resource managers into the foreseeable future, a challenge that will likely become greater in an era of changing climate and increasing globalization of commerce. Only a well-planned and coordinated invasive species management program, bolstered by adequate staffing and resources, can be successful in protecting the natural resources and processes for which the Hanford Reach National Monument was proclaimed and for which the entire Hanford Site is well known.

Given the dynamic environment of the Columbia River corridor, shrub-steppe uplands, and natural spring streams of the Hanford Site, biological monitoring is a critical tool for the managers of the Hanford Reach National Monument and Central Hanford. It will be essential to maintain up-to-date assessments of biological resources, and the threats to those resources, in order to successfully manage the unique natural heritage of the Hanford Site throughout the years ahead. Commitment to strong, ongoing biological monitoring programs is highly recommended.

The biological inventories and ecological studies conducted at Hanford over the past decade have shown that every management unit of the Hanford Reach National Monument and Central Hanford possesses important resources that contribute to the overall biodiversity of the site and the region. These resources may be the plants and animals themselves, or the biological and physical environments and habitat features on which the organisms depend. It is important that these biological values be given strong consideration by the U.S. Fish and Wildlife Service, the U.S. Department of Energy, and the engaged public in the course of planning for the conservation, land use, and development of the Hanford Reach National Monument and the other lands of the Hanford Site.

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Appendices

Appendix A – Biodiversity Studies Contributors and Personnel

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