Industrial Land-use and the Conservation of Native Biota in the Shrub-steppe Region of Western North America

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INTRODUCTION

The shrub-steppe region occupies about 16% of the area of semi-arid vegetational types in western North America (Lauenroth, 1979) (Fig. 1), but there is probably no part of it that has not been disturbed by the activities of immigrant Europeans over the past 150 years. Livestock grazing, vegetal management for livestock forage (such as planting of exotic grasses and shrub removal by fire, chemical herbicides, and mechanical means), dryland farming and irrigated farming—all have contributed to the demise of native biota. However, industrial use of the region has been light: a few aluminium factories are scattered along the Snake and Columbia Rivers in Washington and Idaho, usually located near hydro-electric dams, but there are no steel mills in the region, while except in the extreme eastern parts of the shrub-steppe (Wyoming) there are relatively few coal deposits and few coal-fired power-plants. There are also relatively few urban centres, the largest cities being Tri-Cities, in the State of Washington, and Boise in Idaho.

One of the reasons for selecting the two sites in the shrub-steppe region for the production of nuclear materials for military purposes, was the sparsity of the human population. Hanford, Washington, and the Idaho National Engineering Laboratory site, were established in the 1940s and have been used as locations for Nuclear Energy research and production since then; their locations are indicated in Fig. 1. This article describes past, present, and future, land-uses of a part of the Hanford site that is located in the shrub-steppe region of south-central Washington, and the role of industrial land-use in the conservation of native shrub-steppe biota in a formerly thinly-populated region that is steadily being converted to agricultural land-use and urbanization.

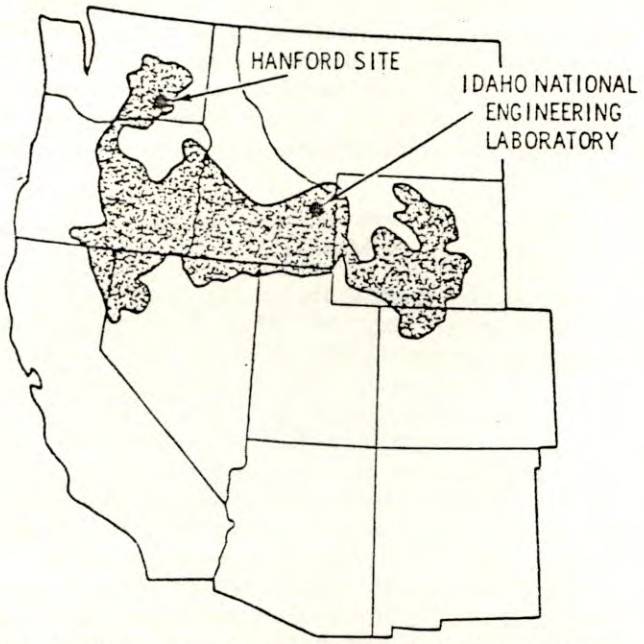

FIG. 1. *Sketch-map showing the extent of the shrub-steppe region in the northwestern United States (dark-shaded) and the locations of the two US Department of Energy land holdings. The State of Washington is ca 540 km from west to east.*

THE BITTERBRUSH–SAGEBRUSH/CHEATGRASS HABITAT-TYPE

The Bitterbrush–Sagebrush habitat-type occupies about 300 km² in the southeastern sector of the Hanford Site (Fig. 2). Desert shrubs, especially Sagebrush (*Artemisia tridentata*) and Bitterbrush (*Purshia tridentata*), comprise most of the overstorey (cf. Fig. 3). The herb understorey beneath and between the widely-spaced shrubs consists mostly of Sandberg Bluegrass (*Poa sandbergii*) and Cheatgrass Brome (*Bromus tectorum*) (Rickard & Sauer, 1982), with Needle-and-thread Grass (*Stipa comata*) only sparsely represented. Whether or not Needle-and-thread Grass was an important constituent of the vegetation before the introduction of domestic livestock-grazing to the region in the early 1800s is unknown. *Stipa comata* is palatable to livestock, and it is conceivable that its local demise could have been implemented by many years of overgrazing in the years prior to 1940 (Daubenmire, 1970).

Prior to 1943, cattle and sheep probably roamed freely over the Hanford site at all seasons of the year, and overgrazing may at least partly account for the now ubiquitous presence of an introduced European grass, Cheatgrass Brome. This assumes that livestock-grazing depleted the native grasses and forbs, disturbing the ground surface and so helping to create microhabitats suitable for the establishment of Cheatgrass Brome.

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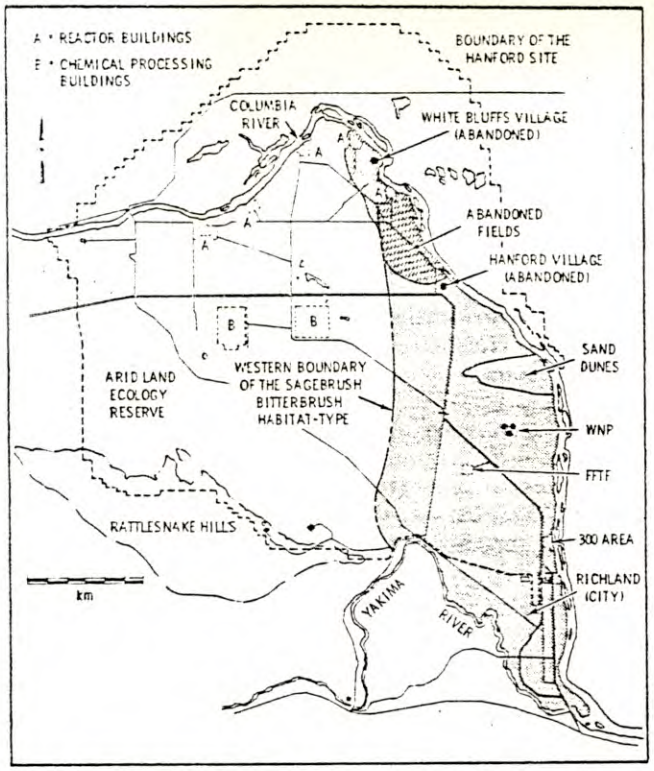


FIG. 2. *Map showing the extent of the Bitterbrush–Sagebrush/Cheatgrass Habitat-type (shaded area) on the Hanford Site in southeastern Washington. WNP indicates the location of three commercial nuclear power-plants.*

Although livestock-grazing has been excluded since 1943, Cheatgrass Brome not only persists but dominates the herbaceous vegetation in the Bitterbrush–Sagebrush vegetal type on the Hanford Site and throughout the shrub-steppe region in general (Young *et al.*, 1979).

Irrigated agriculture was once practised on land in the northern part of the Bitterbrush–Sagebrush habitat-type in the vicinity of the abandoned sites of Hanford and White Bluffs Villages (Fig. 2). The fields that were abandoned in 1943 are vegetally dominated by Cheatgrass Brome and are devoid of shrubs (Fig. 3). Other obvious forms of severe land-disturbance are roads, railroads, and transmission lines. The Bitterbrush–Sagebrush habitat-type is traversed in a north-to-south direction by a paved highway and many kilometres of dirt roads, several transmission lines, and a railroad track. The habitat-type also includes three large industrial complexes: the laboratory facilities at the 300 Area, the Fast Flux Test Facility (FFTF), and three commercial nuclear-power reactors (WNP 1, 2, and 4) that are in various stages of construction. An open gravel-pit and four 'retired' low-level radioactive-waste burial grounds have also contributed to land and vegetal disturbances (Fitzner *et al.*, 1979).

Primary production in the Bitterbrush–Sagebrush vegetal type is low when compared with other kinds of wild plant communities in the semi-arid parts of North America. Over a four-years' period the herb stratum production, mostly Cheatgrass Brome, averaged 126 g/m² at peak yield and ranged between 10 and 195 g/m²/yr (Rickard & Sauer, 1982). The lowest yield was measured in 1977, when the entire shrub-steppe region experienced severe drought. Nevertheless, the Cheatgrass managed to set seed, and a large crop of it was produced in 1978, thus continuing its strong dominance.

Response of the Bitterbrush–Sagebrush/Cheatgrass Habitat-type to Disturbance

Wildfire is a recurring event in the Bitterbrush–Sagebrush habitat-type. Large burns (10,000 ha or more) occurred in 1963 and again in 1970. Smaller burns are of yearly occurrence (Fig. 3). Sagebrush and Bitterbrush shrubs are easily killed by burning; they do not sprout after being burned. However, rabbitbrushes (*Chrysothamnus nauseosus* and *C. viscidiflorus*) have some ability to sprout after burning, and these are often the first shrubs to colonize burned ground (Fig. 3). The herbaceous perennial plants are usually not killed by burning, and recover in the spring season following the burn.

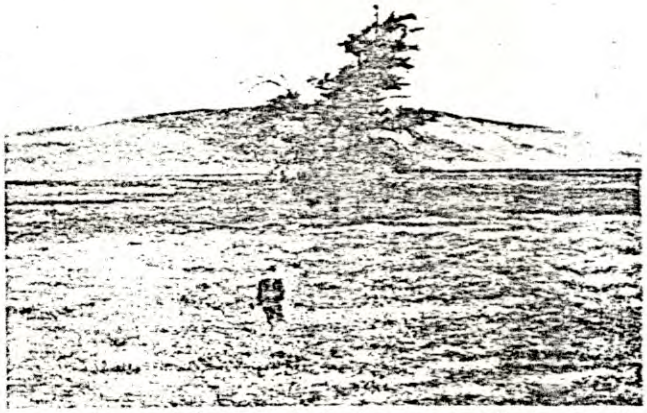
Seeds of annual plants are commonly destroyed by burning, but enough seeds that are buried in the soil usually survive to provide for new generations of plants. Following the 1970 fire, the herbaceous vegetation had attained pre-burn species composition and abundance (except for shrubs) by the year 1974 (Rickard & Sauer, 1982). Although fire is destructive to desert shrubs, it has relatively little effect on herbs; but ploughing destroys both shrubs and herbs. Ploughed fields that have been abandoned since 1943 were colonized by Cheatgrass Brome in the early years following abandonment, and Cheatgrass Brome has persisted on them for 38 years with little evidence of colonization by native herbs or shrubs (Fig. 3).

Trenches dug into the ground and used to dispose of solid waste have been covered with earth. These have been colonized by Cheatgrass Brome or sometimes *Salsola kali* (Common Saltwort), an alien, annual forb. As on the ploughed ground, native species have been slow to recolonize retired nuclear-waste burial trenches (Fitzner *et al.*, 1979).

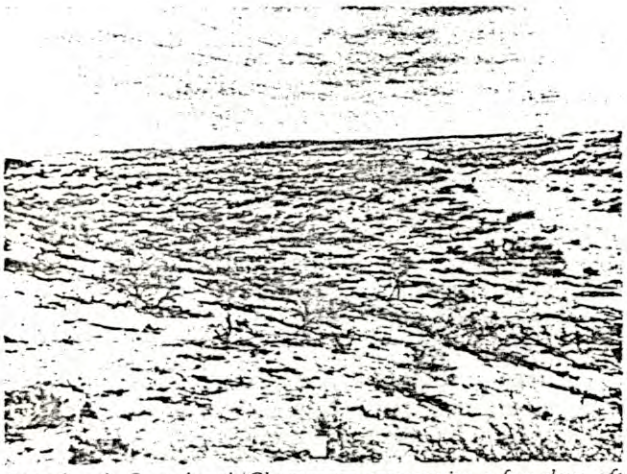
Mammals

It is likely that, prior to the acquisition of the land by the Government, very few Mule Deer (*Odocoileus hemionus*) resided in the Bitterbrush–Sagebrush habitat-type on the Hanford Site. The Mule Deer populations were probably kept to very low levels by the resident humans in the settlements of Richland, White Bluffs, and Hanford. Because the economy of these villages at this time was largely based on agriculture, Mule Deer depredations upon crop plants were not tolerated, and their populations were probably at extremely low levels if not locally extirpated. When the human population of White Bluffs and Hanford was evacuated to provide for plutonium production facilities, the farms were abandoned. Under the protection provided by the strict security regulations, and the absence of hunting within

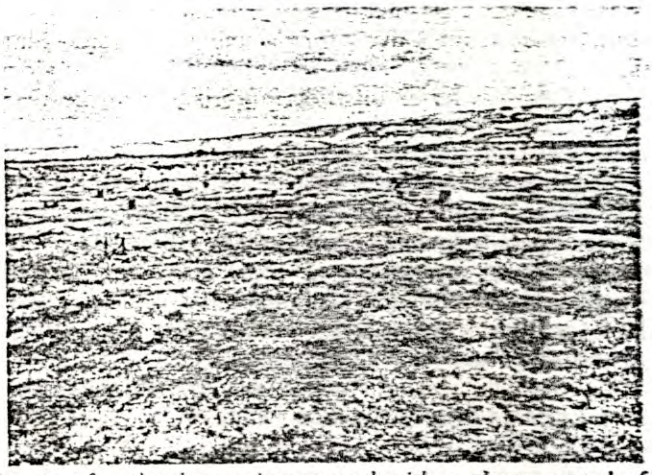
Undisturbed Bitterbrush–Sagebrush/Cheatgrass community.



Siberian Elm tree (Ulmus pumila) *adjacent to a 38-years-earlier (1943) abandoned irrigated field. The field is occupied by Cheatgrass and Tumble Mustard* (Sisymbrium altissimum).



Bitterbrush–Sagerbrush/Cheatgrass community a few days after a wildfire.



Stumps of orchard trees interspersed with a dense sward of Cheatgrass 38 years after abandonment.

Appearance of the Bitterbrush–Sagebrush/Cheatgrass community 11 years after an extensive fire. Note the burn line at left-centre and the three nuclear power-plants in the distance. The small shrubs in the burned area are Rabbitbrush (Chrysothamnus nauseosus).

Alfalfa field north of Richland, Washington.

FIG. 3. *Photographs taken in June 1981 at various locations in the Bitterbrush–Sagebrush vegetation-type on the Hanford Site in South-central Washington.*

the boundaries of the Hanford Site, the Mule Deer population increased.

By 1960, Mule Deer were abundant enough to warrant studies being made of them. Tagging studies of Mule Deer fawns were initiated to obtain information on the movement of tagged individuals beyond the boundaries of the Hanford Site (Hedlund, 1975). During the fawning season in May and June, female Mule Deer tended to seek the protection and isolation provided by islands in the Columbia River and by sand-dunes. Returns of tags from Mule Deer killed by hunters showed that they had travelled off the Hanford Site and been killed during the autumn hunting-season. Most of these kills of tagged Mule Deer were made along the eastern shore of the Columbia River.

The protection provided by the Hanford Site also enhanced the population of the common Coyote (*Canis latrans*). A study of Coyote predation on Mule Deer fawns indicated that, in the 1970s, it was an important contributor to fawn mortality (Steigers, 1980). To help protect nesting populations of Canadia Geese (*Branta canadensis*) from Coyote predation, Washington State Game Department personnel killed 268 Coyotes along the Columbia River on the Hanford Site in the years 1978–81 (D. Flohr, pers. comm.).

Bobcats (*Lynx rufus*) and Badgers (*Taxidea taxus*) also inhabit the Bitterbrush–Sagebrush habitat-type; but there have been no studies to estimate their population densities, though clearly their populations are much smaller than those of Coyotes.

Black-tailed Hares (*Lepus californicus*) are spread throughout the Bitterbrush–Sagebrush habitat-type, and dead animals often appear as road-kills along the well-travelled highways; but it is not known if their population has been suppressed by a postulated increased Coyote population since 1943.

The Great Basin Pocket-mouse (*Perognathus parvus*) is ubiquitous and by far the most abundant small mammal in the Bitterbrush–Sagebrush habitat (Gano & Rickard, 1982). Eighty per cent of the trap-catch of small mammals in the habitat-type consists of these Pocket-mice. Deer-mice, Harvest-mice, Townsend Ground-squirrels, and Grasshopper Mice (respectively *Peromyscus maniculatus*, *Reithrodontomys megalotis*, *Spermophilus townsendii*, and *Onychomys leucogaster*), also occur in the habitat-type, but in much smaller numbers than the Pocket-mice. Pocket-mouse populations vary from year to year and from place to place, and at times the population density is at least 56 mice per hectare (0.84 kg/ha). Small-mammal populations are probably too limited to play important roles in determining the vegetal composition of the plant community through herbivory and granivory, although Cheatgrass caryopses are an important food-item in the diet of Pocket-mice (Schreiber, 1973).

Small mammals provide an important food-source for snakes, predatory mammals, and birds (Stoel, 1976; US Department of the Interior, 1979; Fitzner *et al.*, 1981).

Birds

The shrub-steppe region of western North America is well endowed with large predatory birds. Probably the highest nesting-density of large predatory birds in the world is located in the shrub-steppe region along the Snake River Canyon in southwestern Idaho, a region endowed with many steep cliffs (US Department of the Interior, 1979).

A few pairs of Swainson's Hawks (*Buteo swainsonii*) and Red-tailed Hawks (*B. jamaicensis*) nest in and adjacent to the Bitterbrush–Sagebrush habitat-type on the Hanford Site. Nest locations on the Hanford Site are provided by living shade-trees which were planted at now-abandoned farm-house locations.

Golden Eagles (*Aquila chrysoaetes*) fly over the Bitterbrush–Sagebrush habitat-type, especially in winter, searching for Black-tailed Hares. The endangered Bald Eagle (*Haliaeetus leucocephalus*) also occurs on the Hanford Site in winter, seeking food in the form of dead salmon and wintering waterfowl along the Columbia River (Fitzner & Hanson, 1980). Kestrels and Marsh Hawks (*Falco sparverius* and *Circus cyaneus*, respectively), are present on a year-around basis. The Burrowing Owl (*Speotyto cunicularia*) nests in holes in the ground, and nesting pairs are scattered throughout the Bitterbrush–Sagebrush habitat-type but their nesting density is unknown.

Of the shrub-steppe gallinaceous birds, only the Sage-grouse (*Centrocercus urophasianus*) historically occupied the Bitterbrush–Sagebrush habitat-type. It was occasionally observed in small numbers by one of us (W.H.R.) in the Bitterbrush–Sagebrush habitat-type in the early 1960s, but has not been seen in more recent years (Rickard *et al.*, 1982). Nevertheless, small populations of Sage-grouse still persist in the Rattlesnake Hills sector of the Hanford Site (Fig. 2). The Chukar Partridge (*Alectoris chukar*) has been a successful Eurasian game-bird introduction to the shrub-steppe region of Washington, and large populations of it occur in the Rattlesnake Hills. However, they are seldom seen in the Bitterbrush–Sagebrush habitat-type and apparently do not nest there.

Shrub-steppe communities support relatively few species of nesting passerine birds in comparison with tree-dominated plant communities (Rotenberry *et al.*, 1979). Rotenberry (1980) estimated nesting-bird densities at 130–260 per km², with Horned Larks (*Eremophila alpestris*), Western Meadowlarks (*Sturnella neglecta*), and Sage Sparrows (*Amphispiza belli*), as the important species in Sagebrush–Bunchgrass communities in the Rattlesnake Hills. Small passerine birds provide a source of food for raptorial birds, but are not nearly as important in their diet as snakes and small mammals (Fitzner *et al.*, 1981).

The Long-billed Curlew (*Numenius americanus*) nests on the ground at scattered locations in the Bitterbrush–Sagebrush habitat-type (Allen, 1980). The preferred nesting-sites are the sparsely-vegetated Cheatgrass areas that are nearly devoid of shrubs and also remote from human activities.

Snakes and Lizards

The most abundant snakes of the Bitterbrush–Sagebrush habitat-type are the Yellow-bellied Racer

(*Coluber constrictor*) and the Gopher Snake (*Pituophis catenifer*). Snakes, especially the Yellow-bellied Racer, are important items in the diet of nesting Swainson's Hawks (Fitzner *et al.*, 1981).

Three species of lizards, the Side-blotched, Sagebrush, and Short-horned (*Uta stansburiana*, *Sceloperus graciosus*, and *Phrynosoma douglassi*, respectively), are found in the Bitterbrush–Sagebrush habitat-type as localized populations. The Sagebrush Lizard appears to be mostly restricted to the vicinity of sand-dunes (R.E. Fitzner, pers. comm.), but there is a general paucity of data concerning the population density of cold-blooded vertebrates on the Hanford Site.

Insects

One of the most conspicuous and abundant groups of insects in the Bunchgrass–Sagebrush habitat-type are the ground-dwelling, darkling beetles (Tenebrionidae). These large black beetles are very conspicuous as adults; however, the larval forms are inconspicuous because they spend most of their time burrowing in the soil especially beneath plant detritus. The most commonly-trapped darkling beetles in the Bitterbrush–Sagebrush habitat-type are *Eleodes hispilabris*, *E. novoverrucla*, *E. humeralis*, *Eusattus muricatus*, *Coniontus setosa*, and *Philolithus densicollis* (Rogers & Fitzner, 1980). *Stenomorpha puncticollis* is an abundant beetle at high elevations on the Hanford Site, but it is absent from the Bitterbrush–Sagebrush habitat-type (Rickard, 1970*a*, 1970*b*). Darkling beetles are probably more abundant in terms of biomass than are birds and mammals, as the biomass of adult darkling beetles at times can amount to as much as 20 kg/hectare (Rickard *et al.*, 1974).

Grasshoppers are conspicuous insects in the Bitterbrush–Sagebrush habitat-type in spring and summer. Sheldon & Rogers (1976) identified the following fourteen species from a Sagebrush–Cheatgrass Brome community.

GRASSHOPPER SPECIES

Apote notabilis Scudder
Trimerotropis caeruleipennis Brunner
Conozoa wallula (Scudder)
Melanoplus cinereus Scudder
Melanoplus yarrowii (Thomas)
Oedaleonotus enigma (Scudder)
Ageneotettix deorum (Scudder)
Hesperotettix viridis (Thomas)
Aulocara elliotti Thomas
Melanoplus sanquinipes (Fabricius)
Trimerotropis bilobota Rehn & Bebard
Xanthippus lateritus Saussure
Trimerotropis pallidipennis (Burm.)
Steiroxys sp.

Ants occur throughout the Bitterbrush–Sagebrush habitat-type (Fitzner *et al.*, 1979). The most abundant species is the Red Harvester-ant (*Pogonomyrmex owyheei*). Other ant species are *Solenopsis molesta*, *Formica manni*, and *F. subpolita*. The role of ants as seed harvesters in the Bitterbrush–Sagebrush community has not been investigated, at least so far as we are aware.

Insects probably provide at least some food for most of the vertebrate species in the shrub-steppe community except the Hares and Deer. Larval insects are especially important in the diets of young birds (Rotenberry, 1980), Deer-mice (Kritzman, 1974), and lizards (Vaughan, 1981).

Present Status

The Bitterbrush–Sagebrush habitat-type today consists of a mosaic pattern of plant communities of contrasting vegetal structure (Fig. 3). Some communities support Sagebrush and Bitterbrush shrubs with an understorey of Cheatgrass Brome and a relatively rich mixture of herbaceous species. Other communities are devoid of shrubs owing to recent burning, and still others because they represent the early stages of plant colonization of abandoned cultivated fields. Native plants have been slow to colonize these fields. After 38 years, Sagebrush and Bitterbrush shrubs are missing. One-hundred years or more may be required for the return of Sagebrush and Bitterbrush shrubs on burns and abandoned fields. A few trees planted around abandoned farmsteads still survive after 38 years without care, and these currently serve as nesting sites for hawks. As these trees age and eventually die, there will be no suitable places for hawks to nest.

The removal of the resident human population from the Hanford Site, the exclusion of livestock grazing, and the imposing of a strict 'no-hunting' policy for 38 years, have been favourable actions in protecting native plant and animal populations. This has happened at a time when much of the adjacent surrounding shrub-steppe land was converted to intensive agricultural use (Fig. 3). Outside the Hanford Site, undeveloped land is mostly confined to very steep slopes and extremely stony soils that are too difficult to irrigate and cultivate. Even so, these lands are subjected to heavy grazing by livestock. The largest expanse of ungrazed (by livestock) land in the shrub-steppe of Washington today is on the Hanford Site.

Future

Some of the land within the Bitterbrush–Sagebrush habitat-type will quite likely be industrially developed in the near future. Some habitat acreage will be usurped by construction of buildings, new roadways, new transmission lines, and railroads. However, if commercial nuclear power-plants are elected to be built, large areas of land will remain undeveloped. This kind of industrial use will probably be less deleterious to the existing, remnant populations of native flora and fauna than would be the case if the land were to be developed totally for irrigated agriculture (Table I).

TABLE I

Comparison of Land-uses: Intensive Irrigated Agriculture versus *Nuclear Power-plants in the Sagebrush–Bitterbrush habitat-type.*

Irrigated Agriculture	*Nuclear Power-plant Siting*
All land is ploughed and irrigated; native vegetation is destroyed	A portion of the land is occupied by buildings and other structures; native vegetation persists
Indigenous animal populations are mostly extirpated	Indigenous animals persist but with some reduction in overall population
Wildlife mitigation centres upon certain game species: Ring-necked Pheasant (*Phasianus colchicus*), California Quail (*Lophortyx gambelii*)	Wildlife mitigation centres upon Mule Deer, Swainson's Hawk, Burrowing Owl, Long-billed Curlew, Jackrabbit (*Lepus californicus*), Pocket-mouse
Air pollutants: dust from ploughing and harvesting, burning of crop residues, aerial drift of chemical herbicides and pesticides	Air pollutants: cooling tower drift droplets, biocides (chlorine), and soluble salts
Solid wastes: crop residues; manure from farm animals	Solid waste: spent fuel
Product: biomass for food and fibre	Product: electrical energy

One of the worth-while uses of the interstitial land between the widely-spaced nuclear reactors would be the conservation of remnant populations of native, shrub-steppe biota for research and educational purposes and as a refugium for breeding populations of Swainson's Hawks, Long-billed Curlews, Mule Deer, Badgers, and other native fauna. Such maintenance seems desirable from at least two points of view: nuclear power-plants are purposefully sited in low-population areas to reduce radiation doses to people in the event of a destructive accident, and also because the land in the immediate vicinity is not committed to agricultural use.

There are only a few places in the entire shrub-steppe region of western North America that have been identified specifically for the conservation and/or study of shrub-steppe biota. Of some 48 federal research 'natural areas' established in the states of Washington and Oregon, most are in forested areas. Only one is located in the shrub-steppe region, located in the Rattlesnake Hills on the Hanford Site (Franklin *et al.*, 1972).

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SUMMARY

The Bitterbrush–Sagebrush/Cheatgrass vegetation-type occupies about 300 km² on the US Department of Energy's Hanford Site in the shrub-steppe region of southeastern Washington State. Prior to 1943, part of the land was used for irrigated agriculture and the remainder as grazing land for domestic livestock. In 1943, farming and livestock grazing were terminated and the resident human population was relocated. Use of the land since 1943 has been industrial, mostly for nuclear energy development. The land is not available for public use and shooting of wildlife is prohibited.

Nuclear energy development on the Hanford Site consists of a few large buildings that are widely separated, with undeveloped land in between which supports native plants and animals. This undeveloped land provides habitats for native species that are not adapted to intensive irrigated agriculture—a potential use of almost all of the land in the Bitterbrush–Sagebrush vegetation type. The primary disturbance to vegetation is wildfire. Fire destroys Bitterbrush and Sagebrush and these plants are slow to recolonize the burns. Other species are less affected by burning and are capable of quick recovery. The industrial use of the land provides a potential for the ecological study of self-revegetation of abandoned ploughed ground and the response of biota to wildfire.

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