10. ENVIRONMENTAL RESEARCH AT THE IDAHO NATIONAL LABORATORY SITE

This chapter summarizes ecological monitoring and research performed at the Idaho National Laboratory (INL) (Sections 10.1 through 10.4) and research conducted on the eastern Snake River Plain and eastern Snake River Plain aquifer by the United States Geological Survey (Section 10.5) during 2020.

10.1 Ecological Monitoring and Research at the Idaho National Laboratory

Ecological monitoring and research on the INL Site generally falls into three categories; 1) Monitoring the condition and conservation status of vegetation communities and sensitive plant species, 2) Annual assessment of sagebrush habitat and restoration-based conservation efforts to support the Candidate Conservation Agreement for Greater Sage-grouse; and 3) research supported through the National Environmental Research Park (NERP).

Chapter 10 Highlights (2020)

Ecological monitoring and research at the Idaho National Laboratory Site in 2020 was focused on: 1) monitoring the condition and conservation status of vegetation communities and sensitive plant species; 2) annual assessment of sagebrush habitat and restoration-based conservation efforts to support the Candidate Conservation Agreement for Greater Sage-grouse; and 3) research supported through the National Environmental Research Park (NERP).

Sagebrush habitat monitoring and conservation measures to support the Candidate Conservation Agreement were addressed by three tasks in 2020. The first entails resampling 75 plots, which have been sampled annually since 2013, and 50 rotational plots, set 3 were sampled in 2020, to assess habitat condition. Absolute cover, height, and density of sagebrush and perennial grass/forbs were measured for this task. The second task, sagebrush habitat distribution, was updated using aerial imagery acquired following five wildland fires, over a hectare in size, that burned on the INL Site in 2020. The final task, which entails sagebrush habitat restoration, continued in 2020 and seedling survivorship assessments of shrubs planted in 2019 were completed.

The INL Site was designated as a NERP in 1975. The NERPs provide rich environments for training researchers and introducing the public to ecological sciences. NERPs have been used to educate grade school and high school students and the general public about ecosystem interactions at U.S. Department of Energy sites; train graduate and undergraduate students in research related to site-specific, regional, national, and global issues; and promote collaboration and coordination among local, regional, and national public organizations, schools, universities, and federal and state agencies. During 2020, three ecological research projects were conducted on the Idaho NERP; continued studies of ants and ant guests at the INL Site, behavioral ecology of pregnant Great Basin Rattlesnakes, and ecosystem responses of sagebrush steppe to altered precipitation, vegetation and soil properties.

The United States Geological Survey has been studying the hydrology and geology of the eastern Snake River Plain and eastern Snake River Plain aquifer since 1949. The United States Geological Survey INL Project Office collects data from research and monitoring wells to create and refine hydrologic and geologic models of the aquifer, to track contaminant plumes in the aquifer and improve understanding of the complex relationships between the rocks, sediments and water that compose the aquifer. Four reports were published in 2020 by the INL Project Office.
able for land use planning, and to support environmental regulatory compliance (i.e., National Environmental Policy Act). Component tasks include the long-term vegetation survey, major vegetation classification and map updates, sensitive species reports, and any other monitoring necessary to address current concerns.

The second set of ecologically based tasks and activities include sagebrush habitat assessments, evaluation of risks to habitat, and conservation measures to improve habitat. These activities support the voluntary agreement U.S. Department of Energy, Idaho Operations Office (DOE-ID) entered into with the U.S. Fish and Wildlife Service to conserve sage-grouse and the habitat they depend on across the INL Site (DOE-ID and FWS 2014). There are currently two habitat monitoring tasks, one to assess annual habitat condition and one to document habitat distribution across the INL Site. The habitat condition task is completed annually, and the distribution task is completed periodically, based on available imagery. In 2020, imagery was acquired for the areas affected by several fires and the habitat distribution task was updated accordingly. There is also a task associated with habitat restoration. This task supports the CCA and is a conservation measure that includes planting sagebrush seedlings to hasten the return of viable habitat in burned areas and monitoring previously planted areas for surviviorship. Sagebrush seedlings have been planted since 2015 and survivorship has been monitored every year since 2016.

The INL Site was designated as a NERP in 1975. According to the Charter for the National Environmental Research Parks, NERPs are intended to be outdoor laboratories where research can be carried out to achieve agency and national environmental goals. Those environmental goals are stated in the National Environmental Policy Act, the Energy Reorganization Act, and the Non-nuclear Energy Research and Development Act. These goals dictate that the task is to understand our environment sufficiently that we may enjoy its bounty without detracting from its value and eventually to evolve an equilibrium use of our natural resources. The desirability of conducting research on the NERP is enhanced by having access to relatively undisturbed sagebrush steppe habitat and restricted public access. Universities typically provide their own funding, and the Environmental Surveillance, Education, and Research (ESER) Program facilitates researcher access to the INL Site. There are three ecological research projects ongoing through the Idaho NERP, one includes documenting ants and associated arthropods on the INL Site, one involves tracking rattlesnake movements through gestation and dispersal of young, and one addresses ecohydrology in sagebrush steppe.

10.2 Vegetation Communities and Sensitive Plant Species

The tasks described in this section are completed on a rotational schedule, once every several years. Vegetation surveys to support the long-term vegetation were last conducted in 2016 and a technical report was completed in 2018. An INL Site Vegetation Map update was initiated in 2017 and a final map and technical report with supporting documentation were completed in 2019. There were no active, ongoing tasks in this category in 2020.

10.3 Sagebrush Habitat Monitoring and Restoration

10.3.1 Sagebrush Habitat Condition

Sage-grouse cannot survive without healthy sagebrush stands that meet certain criteria related to the condition and distribution of their habitat (Connelly et al. 2000). Sage-grouse use sagebrush dominated lands year-round and rely on sagebrush for food, nesting, and concealment from predators. In addition to healthy stands of sagebrush, sage-grouse also require a diverse understory of native forbs and grasses which provide protection from predators and supply high-protein insects necessary for rapidly growing chicks (Connelly et al. 2011).

The CCA between the DOE-ID and the USFWS (2014) outlines a monitoring task to support ongoing assessment of sage-grouse habitat condition. Habitat condition monitoring data have been used to track trends in the quality of habitat available to sage-grouse on the INL Site through time, as well as to identify the effects of threats that may impact habitat condition (e.g., increases in non-native plants). Although the surveys were not designed to address specific interactions between birds and their environment (i.e., nest site selection or foraging behaviors related to brood-rearing), they do provide an index of the overall condition and composition of the plant communities considered to be appropriate habitat for sage-grouse on the INL Site.

Seventy-five habitat condition monitoring plots have been sampled annually since 2013. Sampling ef-
Evening Tufted Primrose
(Oenothera caespitosa)

Environmental Research at the Idaho National Laboratory

Efforts begin in late May and conclude in August. The annual plots are split into two groups, one group consists of plots located in areas currently mapped as sagebrush habitat and the second group contains plots located in recovering habitat where sagebrush has been lost due to wildland fires. Although the 2020 Telegraph Fire affected two annual plots, data are included in the comparative analyses of the annual plots because field crews collected vegetation data prior to the disturbance. For future monitoring efforts the burned sagebrush plots will be included in the recovering habitat group.

To increase sample size and to address potential habitat threats, specifically wildland fire and livestock use, an additional 150 plots are sampled on a rotational basis. Rotational plots are divided into three sets of 50 plots that are each sampled once over a five-year cycle. Rotational plots are analyzed, and results are reported once every five years, after all rotational plots have been sampled; the next scheduled analyses of the rotational plots will be conducted in 2021 and reported in the 2022 CCA Monitoring Report.

Both annual and rotational plots are sampled for vegetation cover by species, height by functional group, sagebrush density, and sagebrush juvenile frequency. All 75 annual habitat condition monitoring plots and 50 rotational plots (set 3) were sampled during the summer of 2020 (Figure 10-1). In 2020, results from annual plots were summarized and compared to site-specific baseline values and to regional habitat guidelines (Connelly et al. 2000).

Figure 10-1. Annual and Rotational Set 3 Sage-grouse Habitat Condition Monitoring Plots Sampled on the Idaho National Laboratory Site in 2020.
10.4 INL Site Environmental Report

Most of the shrub cover in sagebrush habitat plots was from sagebrush species (Shurtliff et al. 2021), and mean sagebrush cover in 2020 was higher than the local baseline (Table 10-1a, Table 10-1b). Perennial grass/forb cover and height were substantially higher in 2020, when compared to the local baseline. Sagebrush density was lower in 2020 than the local baseline (Table 10-1a, Table 10-1b), but it is within the recorded range of variability.

Plots from recovering burned areas (non-sagebrush plots) were also compared to the baseline values (Table 10-1a, Table 10-1b). As a functional group, perennial grasses contribute the greatest amount of vegetative cover on recovering burned plots. Perennial grass/forb cover was slightly above the baseline in 2020. Although sagebrush cover is low on recovering burned plots, the shrub functional group is well represented and green rabbitbrush (*Chrysothamnus viscidiflorus*) was the most abundant shrub in the non-sagebrush plots with nearly 10% absolute cover in 2020 (Shurtliff et al. 2021). As with cover, sagebrush density remained very low in plots recovering from wildland fire, but it was slightly higher in 2020 when compared to the baseline.

Vegetation cover data collected from both sagebrush habitat monitoring plots and non-sagebrush plots are used for trend analyses and trend analyses include data from the first sample period in 2013 through the current.

### Table 10-1a. Summary of Selected Vegetation Measurements for Evaluating the Condition of Sagebrush Habitat Monitoring Plots and Non-sagebrush Monitoring Plots on the Idaho National Laboratory Site in 2020.

<table>
<thead>
<tr>
<th></th>
<th>2020</th>
<th>Mean Cover (%)</th>
<th>Mean Height (cm)</th>
<th>Mean Density (individuals/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em><em>Sagebrush Habitat Plots (n = 45</em>)</em>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sagebrush</td>
<td>23.05</td>
<td>46.24</td>
<td>3.45</td>
<td></td>
</tr>
<tr>
<td>Perennial Grass/Forb</td>
<td>16.17</td>
<td>19.93</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td><em><em>Non-sagebrush Plots (n = 30</em>)</em>*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sagebrush</td>
<td>0.40</td>
<td>39.38</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>Perennial Grass/Forb</td>
<td>20.98</td>
<td>22.61</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

*Indicates sample size difference from past sampling efforts.
N/A = not applicable

### Table 10-1b. Local Baseline Values of Selected Vegetation Measurements for Evaluating the Condition of Sagebrush Habitat Monitoring Plots and Non-sagebrush Monitoring Plots on the Idaho National Laboratory Site.

*Local baseline values were generated from 2013-2017 data.*

<table>
<thead>
<tr>
<th>Baselines</th>
<th>Mean Cover (%)</th>
<th>Mean Height (cm)</th>
<th>Mean Density (individuals/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sagebrush Habitat Plots (n=48)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sagebrush</td>
<td>21.27</td>
<td>47.81</td>
<td>5.19</td>
</tr>
<tr>
<td>Perennial Grass/Forbs</td>
<td>9.99</td>
<td>20.70</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Non-sagebrush Plots (n=27)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sagebrush</td>
<td>0.22</td>
<td>33.54</td>
<td>0.07</td>
</tr>
<tr>
<td>Perennial Grass/Forb</td>
<td>19.73</td>
<td>29.58</td>
<td>N/A</td>
</tr>
</tbody>
</table>

N/A = not applicable
Evening Tufted Primrose (Oenothera caespitosa)

Environmental Research at the Idaho National Laboratory 10.5

These results support the idea that intact sagebrush plant communities are more resistant to cheatgrass dominance than communities affected by wildland fire. However, the threat of annual grasslands should not be underestimated because cheatgrass is found within all habitat types on the INL Site and can increase precipitously in just one growing season (Forman and Hafla 2018, Shurtliff et al. 2021).

Figure 10-2. Mean Cover from Functional Groups in Sagebrush Habitat Monitoring Plots for Native and Introduced Species on the Idaho National Laboratory Site from 2013 through 2020.

*Error bars represent ± SE. Tick marks along the top denote sample size.*
Herbaceous functional groups are highly influenced by precipitation and habitat condition monitoring data results can often be interpreted within the context of local precipitation data. Daily precipitation data have been collected from Central Facilities Area (CFA) since 1950 (National Oceanic and Atmospheric Administration unpublished data), which provides a flexible data set from which to make comparisons. Precipitation was near or higher than average during four out of the past five years, but in 2020 precipitation was about half the yearly average due to dry summer, fall, and winter seasons. These short-term precipitation patterns likely resulted in increases in cover of native and non-native grasses from 2014 through 2018 followed by declines toward more moderate cover values in 2019 and 2020.
A monitoring report containing the full results of the habitat condition monitoring project through 2020 is available on the ESER website: (http://www.idahoeser.com/Wildlife/PDF/2020%20CCA%20Full%20Report_FINAL.pdf).

### 10.3.2 Sagebrush Habitat Distribution

Loss of sagebrush-dominated habitat has been identified as one of the primary causes of decline in sage-grouse populations (Idaho Sage-grouse Advisory Committee 2006, USFWS 2013). Direct loss of sagebrush habitat on the INL Site has occurred through several mechanisms, but the greatest contributing factor is wildland fire. Changes in land cover can be determined using airborne or satellite imagery that is readily available at little or no cost. ESER geographic information system analysts routinely compare new imagery as it becomes available with results from the most current vegetation classification and mapping project. Ground-based point surveys and changes in plant species cover and composition documented through an associated habitat condition monitoring task are also used to provide spatial information to assist with periodic map updates needed to monitor sagebrush habitat distribution.

The Sage-grouse Conservation Area (SGCA) is defined as a portion of the INL Site where conservation of sage-grouse and their habitat is considered a priority, and in which a 20% loss of sagebrush habitat from the 2013 baseline has been identified as a conservation trigger in the CCA (DOE-ID and USFWS 2014). The purpose of the habitat distribution monitoring task is to maintain and update regions of the INL Site vegetation map to accurately document changes in sagebrush habitat amount and distribution within and outside of the SGCA. This task documents changes in sagebrush habitat following losses due to wildland fire or other disturbances that remove or significantly alter vegetation across the landscape. In addition to documenting losses of sagebrush habitat, this monitoring task also maps the addition of sagebrush habitat when sagebrush cover increases within a mapped polygon and warrants a new vegetation map class designation. Lastly, this task supports post-fire mapping when the fire extent is unknown, and it allows for modifying existing wildland fire boundaries and unburned patches of vegetation when mapping errors are observed on the ground.

There were five wildland fires over a hectare in size that burned on the INL Site in 2020 altering existing vegetation map class distribution including sagebrush habitat. The Howe Peak Fire was human-caused and started off-Site on July 2, 2020. Because of wind-driven growth, the fire crossed Highway 33 and spread onto the INL Site. Retardant application and developed agricultural lands limited fire spread to the north and dozer containment lines stopped the fires from spreading further east until the fire was deemed controlled on July 9. The Telegraph Fire ignited near the eastern boundary of the INL Site on July 8, 2020, along with a second separate fire about a mile to the east off-Site. The fire was declared human-caused and began north of the roadside where it spread to the north fueled by high winds. The Telegraph Fire was considered controlled on July 11. The Lost River Fire began on August 6, 2020, south of Highway 20/26 west of the public rest area. The Lost River fire was caused by a lightning strike and due to shifting winds, the fire burned in a patchy manner until it was controlled the following day on August 7. The CFA Fire Complex started on August 15, 2020, as a series of three small fires on the north side of Highway 20/26 east of Gate 3. These fires were deemed human-caused and direct suppression efforts contained the fire the same day without the need for containment lines and it was considered controlled on August 16. The Cinder Butte Fire started on August 18, 2020, southeast of Gate 4 and less than a mile from the 2011 T-17 Fire boundary. The fire ignited under a Red Flag warning and lightning was observed in the area. Fortunately, a rainstorm helped limit initial growth and the fire was declared contained later that same day and controlled on August 19.

There were two additional fires that burned on the INL Site in 2020, however due to the small footprint these fires were not mapped. On June 20, 2020, the Rye Grass Flats Fire started on the roadside of Highway 26 and burned approximately less than 1,011.7 m² (0.25 ac). On August 16, 2020, an Unnamed Fire started near Highway 20/26 and also burned less than 1,011.7 m² (0.25 ac). Both fires were declared to be of human-origin and were controlled with direct suppression efforts not requiring the construction of containment lines.

The initial fire boundaries for the 2020 fires were produced from global positioning system field data to delineate containment lines collected by Battelle Energy Alliance Cultural Resources Management Office. How-
ever, experience with other recent large fires suggests the actual burned area boundary typically differs from the containment line boundary created immediately post-fire. In response to the fires that burned in 2020, and to support post-fire ecological evaluation and recommendations, the INL Wildland Fire Management Committee funded the acquisition of high-resolution satellite imagery across the entire INL Site. On October 4, 2020, Digital Globe’s Worldview-2 and Worldview-3 satellite sensors collected 8-band multispectral imagery across the extent of the INL Site. The Worldview imagery was delivered georeferenced, orthorectified, and pan-sharpened to a spatial resolution of 31 cm (1ft).

The Worldview imagery was mosaicked into a seamless base map image dataset that was used to delineate the burned area extent in each fire. Wildland fire boundaries were manually digitized at a 1:2,000 mapping scale to ensure smaller, unburned patches of sagebrush could be accurately delineated. Once each fire boundary was mapped and updated, the burned area footprint was intersected with the existing sagebrush habitat layer to calculate the area of sagebrush removed from each fire.

The Howe Peak Fire burned an area of 664 ha (1,640.8 ac; Figure 10-4). There was 382 ha (944 ac) of sagebrush habitat within the SGCA removed in the Howe Peak Fire. The most recent vegetation map showed Crested Wheatgrass Ruderal Grassland as the most common non-sagebrush map class within the fire boundary with a small patch of Green Rabbitbrush/Thickspike Wheatgrass Shrub Grassland and Needle and Thread Grassland class also present prior to the fire.

The telegraph Fire showed a burned area of 677.9 ha (1,675.1 ac) which is a reduction from the original burned area estimate from the outer containment line (Figure 10-4). The Telegraph Fire burned area was located entirely within sagebrush habitat inside the SGCA, so the burned area and sagebrush habitat loss were spatially coincident. There were numerous patches of unburned sagebrush habitat mapped inside the fire boundary and in regions where the fire was extinguished prior to reaching the containment line (Figure 10-4).

The Lost River Fire burned an area of 208.4 ha (5,151.1 ac). The Lost River Fire is located within the SGCA in a region that was previously burned in the 2000 Tin Cup Fire. The most recent vegetation map shows the Green Rabbitbrush / Desert Alyssum (Cheatgrass) Ruderal Shrubland vegetation as being the most common vegetation class within the burned area. This task is primarily concerned with sagebrush habitat loss; therefore, a more detailed map of the fire is not presented because there was no sagebrush habitat impacted from the fire.

The CFA Fire Complex burned across three separate areas totaling 17.5 ha (43.2 ac). Nearly the entire area that burned, except for very thin roadside strips, was entirely within sagebrush habitat located outside of the SGCA.

As of 2019, the sagebrush habitat area in the SGCA on the INL Site was 78,553.4 ha (194,109.7 ac). Following the fires in 2020, a total of 1,067.4 ha (2,637.6 ac) of sagebrush habitat was removed from the SGCA. The current estimated acreage of sagebrush habitat in the SGCA is 77,486 ha (191,472.1 ac) representing a 1.4% decrease from original baseline established in the CCA (DOE and USFWS 2014). This is the first year since the signing of the CCA that there has been any appreciable loss in sagebrush habitat inside the SGCA, although the loss is minimal, and we do not anticipate tripping the habitat trigger in the near future.

A monitoring report containing the full results of the habitat distribution monitoring project through 2020 is available on the ESER website: (http://www.idahoeser.com/Wildlife/PDF/2020%20CCA%20Full%20Report_FINAL.pdf).

10.3.3 Sagebrush Habitat Restoration

In the CCA for the INL Site (DOE-ID and USFWS 2014), DOE-ID committed to minimize the impact of habitat loss due to wildland fire and firefighting activities by taking steps to accelerate sagebrush reestablishment whenever a fire burns >40 hectares (>99 acres). Although no wildland fires >40 hectares (>90 acres) occurred between signing the CCA and the Sheep Fire of 2019, beginning in 2015 DOE-ID voluntarily initiated an annually recurring task to plant at least 5,000 sagebrush seedlings each fall in priority habitat restoration areas.
Figure 10-4. Four of the Wildland Fires that Burned on the Idaho National Laboratory Site in 2020 Shown with all Major Wildland Fires since 1994 and the Boundary for the Sage-grouse Conservation Area.
(DOE and USFWS 2014, Section 10.4.4). This ongoing habitat restoration effort has taken place annually over the past six years.

In 2014, 2018, and 2020 sagebrush seeds were collected from a representative sample of stands across the INL Site. Every year, seeds are germinated and grown in greenhouses in 6 in³ or 10 in³ conetainers, and each fall the seedlings are planted into a selected priority restoration area, or an area that meets most of the criteria and is readily accessible. Seedlings are planted at a rate of about 198 sagebrush/hectare (80 sagebrush/acre). The goal of planting at this rate is not necessarily to replace sagebrush at natural densities across a few acres, but rather to establish a seed source to hasten sagebrush re-establishment across larger restoration areas. In 2020, sagebrush seedlings were planted at a location on the eastern edge of the INL Site (Figure 10-5) in the 2010 Jefferson Fire.

Although DOE-ID committed to growing and planting at least 5,000 seedlings every year, more than the minimum number of seedlings have been planted every year since 2015. In 2020, a total of 20,000 seedlings were planted on 46.5 ha (114.8 acres) and the locations of 540 (2.7%) seedlings were marked for future monitoring. Over the past six years, a total of 72,000 seedlings have been planted and sagebrush restoration has now been initiated on a total 219.4 ha (539.7 acres).

In addition to planting seedlings, survivorship of previous planting efforts is monitored every year. Survivorship monitoring occurs at each planting location one- and five-years post-planting. To quantify 2019 seedling

![Image of map showing area planted with big sagebrush seedlings in 2020. The stars on the inset map show the general location of all plantings.](image-url)
survivorship and condition, five hundred sagebrush seedlings were revisited in September 2020. The seedlings were assessed as: 16 (3.2%) were healthy, 7 (1.4%) were stressed, 122 (24.4%) were dead, and 355 (71%) were missing (Figure 10-6). Assuming the missing seedlings were dead, a total of 4.6% of the seedlings survived the first year. For comparison, years 2015-2020 are also shown in Figure 10-6.

Survivorship of seedlings planted in fall 2015 was also assessed in September of 2020. To quantify 2015 seedling survivorship and condition, we revisited the same 501 seedlings that were previously revisited in August of 2016. We relocated 283 seedlings, of which 219 (44%) were healthy, 32 (6%) were stressed, and 32 (6%) were dead. This means over the last 5 years 251 (50%) of the marked seedlings survived. In addition to revisiting seedlings for condition and survivorship, we assessed the number of individuals that have begun developing reproductive structures. Out of the 251 surviving seedlings, 101 have developed reproductive structure. Some seedlings were noted to have several smaller sagebrush individuals surrounding them, which suggests new, naturally occurring seedlings are beginning to establish around the planted individuals. This evidence supports the approach of planting at a lower density to establish sagebrush seed sources in priority areas to shorten the time interval between a fire and the reestablishment of sage-grouse habitat (Shurtliff et al. 2016).

As shown in Figure 10-6, precipitation during the water year associated with the 2019 seedling planting was lower than any other planting year. Water year is calculated by summing annual precipitation from October, the month the seedlings are planted to the following September: it is an appropriate metric for interpreting survivorship because it more closely reflects the water available to seedlings for establishment and development. In 2020, precipitation was atypical in both timing and amount, and it was the driest water year since the first planting in 2015. Winter, spring, and summer precipitation were not ideal for helping the seedlings to

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**Figure 10-6. Sagebrush Seedling Survivorship each Year since 2015.** The black line and dots indicate the fluctuations in water year precipitation levels (October of planting year to September following year.)
establish. While the cause of low survivorship is ultimately unknown due to many potential abiotic variables, the low precipitation would appear to be a large contributing factor to the low survivorship of the seedlings planted in 2019.

Young sagebrush plants experience the highest mortality during the first year (Dettweiler-Robinson et al. 2013). In a review of 24 projects where containerized sagebrush seedlings were planted and survivorship was measured after one year, researchers reported first year survival of stock ranged from 14% to 94% (median = 59%, weighted average = 57%; Dettweiler-Robinson et al. 2013). Thus, in the previous four years of planting (2015-2018), sagebrush establishment one-year post planting on the INL Site is at or above average even when the missing plants are considered dead. It is unfortunate that the 2019 planting has deviated from this trend, but it can provide an opportunity to better inform the planting process and allow us to explore new techniques in order to increase the success of future planting efforts.

A monitoring report containing the full results of the sagebrush habitat restoration project through 2020 is available on the ESER website. (http://www.idahoeser.com/Wildlife/PDF/2020%20CCA%20Full%20Report_FINAL.pdf).

10.4 Ecological Research at the Idaho National Environmental Research Park

10.4.1 Studies of Ants and Ant Guests at the INL Site

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Funding is by the principal investigator with some assistance and collaboration with the Orma J. Smith Museum of Natural History.

Clark and Blom (2007) gave a list of ants found at the INL Site. This has given us a base to study some ecological relationships between some of the ant taxa at the INL Site and a variety of ant guests.

One such ant guest taxa, a desert beetle (Coleoptera: Tenebrionidae, Philolithus elatus; Figure 10-7, Figure 10-8) is not previously known from the INL Site (Staford et al. 1986). We have collected in Pogonomyrmex salinus nests and is the subject of study and description (Clark et al. in prep). We have now taken photographs with light microscopes and scanning electron microscope, and we have observed a Philolithus elatus female ovipositing on a Pogonomyrmex salinus nest. The results will be published in Clark et al. (in prep) and have been presented in Clark et al. (2015).
We are also working on a publication relating to past research at the site involving cicadas and *Pogonomyrmex salinus* nests (Blom and Clark, in prep).

An undescribed species of Jerusalem cricket (Orthoptera: Stenopelmatidae, *Stenopelmatus* sp.) has been found at the INL Site. The *Stenopelmatus* sp. was found in the ant nests during previous fieldwork. A series of live individuals, including both males and females, were needed for a proper species description. Live specimens were collected in July 2013, and additional specimens were collected during September 2014. In addition, one specimen was found in one of the excavated ant nests. They have been shipped to the specialist in the group for rearing and description. This relationship will require more study during future visits to the INL Site. The species will be described in the next couple of years as part of a North American study, by Dr. David Weissman of the California Academy of Sciences.

In addition, during 2015, we made field observations of predation on *Pogonomyrmex salinus*, and this turns out to be a different spider species as predator of the ant from what we have previously reported for the site (Clark and Blom 1992). The spider has since been identified as *Xysticus*, a member of the family Thomisidae (crab spiders). This family and genus are likely new records for the INL and as predators on *Pogonomyrmex salinus*.

During the 2016 field season, we continued research relating to the projects listed above. We observed many (most) nests of *Pogonomyrmex salinus* with small holes dug into them, presumably by heteromyid rodents. This interaction has been reported in the literature by Clark and Comanor (1973) for *Pogonomyrmex occidentalis*, but not yet reported for *Pogonomyrmex salinus*. These seed stores in ant nests may represent a significant food source for the rodents at INL Site.

During July 2018, we observed numerous examples of the beetle *Disonycha latifrons* Schaeffer (Coleoptera, Chrysomelidae) feeding on the shrub, low narrowleaf rabbitbrush (*Chrysothamnus viscidifloris* [Hook.] Nutt. ssp. *viscidifloris* var. *stenophyllus* [Gray] Hall). The beetles were dense on the shrubs, often numbering 50-100 or more per plant.

July 22, 2019, we spent part of the night at the Circular Butte site to search for a rare cactus feeding beetle (*Moneilema* sp.). We did not find the beetle, but our field work was cut short by the Sheep Fire. We plan to continue searching areas at INL that contain cacti (*Opuntia*) this summer and see if we can find the beetles here. They were not reported from the INL Site by Stafford et al. (1986). We were able to find the beetles near Oakley in Cassia County, so it may be possible to find them at the INL Site.

Voucher specimens collected at the INL Site have been deposited in the insect collection at the Orma J. Smith Museum of Natural History, The College of Idaho and are available for research.

Field research will continue into the foreseeable future.

10.4.2 Studies of Great Basin Rattlesnakes on the INL Site: Behavioral Ecology of Pregnant Snakes

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More ecological studies have been conducted on the Great Basin Rattlesnake, *Crotalus oreganus lutosus* than any other reptile species on the INL Site. This species occurs in large numbers in several areas on the INL Site and is best known for their large aggregations, of sometimes several hundred individuals, at underground overwintering sites (hibernacula). During their activity season, *C. o. lutosus* make a lengthy migration away from and back to a hibernaculum. While adult male and non-pregnant female rattlesnakes travel several km during their active season to forage and find mates, pregnant individuals move less and generally remain within 1 km of their hibernaculum. These pregnant snakes spend most of their active season gestating under rocks until they give birth. The selection of an appropriate gestation site is important for pregnant snakes to avoid predators such as badgers and hawks but also to provide proper thermoregulatory opportunities because embryonic development is influenced by temperature. Although any given female rattlesnake may only give birth once every 3-4 years, there is strong observational evidence that these gestation rocks are used frequently by multiple females. Therefore, one can hypothesize that the distribution and abundance of appropriate rocks is important for this species.
In 2018 and 2019, a project was conducted on the INL Site to locate gestation rocks used by pregnant *C. o. lutosus* and to measure their attributes to determine if pregnant rattlesnakes were selecting specific rocks. A total of 22 gestation rocks were identified by the continued presence of pregnant rattlesnakes at these rocks throughout their active season. Transects were set up at each of these gestation sites to measure the physical attributes of the gestation rocks and other nearby rocks that were available ($n = 327$) and could potentially be used. Results indicate that gestation rocks fall within a specific size range and have attributes that are a subset of the available rocks; this suggests pregnant snakes are likely making choices to use specific rocks. While the available rocks ranged in size from 20 - 200 cm$^2$ the majority were less than 80 cm$^2$ (mean = 49 cm$^2$). Pregnant snakes selected larger rocks (mean = 114 cm$^2$) and never chose rocks less than 71 cm$^2$. Additional rock features preferred by pregnant snakes were slightly thicker rocks, rocks with soil underneath (instead of rock on rock), and rocks with little or no vegetation cover. One potential benefit of larger rocks is that they provide greater thermal inertia, retaining heat throughout the night whereas smaller rocks would cool more quickly at night. Another benefit is that larger rocks may provide better protection from predators than smaller rocks. Nevertheless, badgers are a formidable predator of rattlesnakes and three observations were noted on the INL Site of badgers attempting to dig out rattlesnakes from under rocks; all three attempts appeared to be successful. From a management and conservation perspective, once identified, the persistence and non-destruction of gestation rocks could be important for maintaining Great Basin Rattlesnake populations because these rocks have specific characteristics that allow yearly success in reproduction.

Field visits were not conducted in 2020, but work is ongoing for manuscripts describing study results.

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### 10.4.3 Ecosystem Responses of Sagebrush Steppe to Altered Precipitation, Vegetation and Soil Properties

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The INL Site and other landscapes with sagebrush steppe vegetation are experiencing a simultaneous change in climate and plant community composition that are impacting habitat for wildlife, wildfire risks, and ecosystem services such as forage. Determining the separate and combined/interactive effects of climate and vegetation change is important for assessing future changes on the landscape and for hydrologic processes. Since the early 2000s, we have transformed an experiment known as the “Protective Cap Biobarrier Experiment” (initiated by Dr. Jay Anderson and colleagues), that was originally designed to test options for protecting buried waste, into what has become the longest running and most robust ecohidrology experiment in semiarid environments.

The experiment site was burned in entirety by the 2019 Sheep Fire, which on one hand resulted in loss of sampling opportunities and infrastructure, but on the other hand created an exceptional opportunity to test the underlying basis for the theory on resistance to exotic annual-grass invasion (cheatgrass) and resilience of sagebrush steppe. This theory has become the guidance principle for prioritizing land treatments which are designed to reduce or prevent exotic annual grass invasions by land.
agencies across the western US. The theory predicts that a site will be more resistant to invasion and resilient to disturbance, i.e., less likely to have annual grasses invade and more likely to recover after disturbances such as fire, if it has more precipitation, cooler temperatures, or more resprouting perennial bunchgrasses. Perennial bunchgrasses are expected to more readily utilize soil water and nitrogen, preempting these resources that invaders such as cheatgrass would otherwise need to be successful. The long-term treatments conveniently create a gradient of pre-fire climate differences, and the cessation of treatment application has induced large differences in simulated drought conditions on the experiment.

In 2021, we procured a National Science Foundation grant to fund Dr. Maxwell to sample the differences in cheatgrass among the treatments along with the corresponding soil nutrients and water. His sampling was well underway by Spring of 2020, and he will continue to work on the project for the next few years.

10.5 U.S. Geological Survey 2020 Publication Abstracts

In 1949, the USGS was asked to characterize water resources prior to the building of nuclear-reactor testing facilities at the INL Site. Since that time, USGS hydrologists and geologists have been studying the hydrology and geology of the eastern Snake River Plain (ESRP) and the ESRP aquifer.

At the INL Site and in the surrounding area, the USGS INL Project Office:

- Monitors and maintains a network of existing wells
- Drills new research and monitoring wells, providing information about subsurface water, rock, and sediment
- Performs geophysical and video logging of new and existing wells
- Maintains the Lithologic Core Storage Library.

Data gathered from these activities are used to create and refine hydrologic and geologic models of the aquifer, to track contaminant plumes in the aquifer, and to improve understanding of the complex relationships between the rocks, sediments, and water that compose the aquifer. The USGS INL Project Office publishes reports about their studies, available through the USGS Publications Warehouse: https://www.usgs.gov/centers/id-water/science/publications-idaho-national-laboratory?qt-science_center_objects=0#qt-science_center_objects. Three reports and one geologic map were published by the USGS INL Project Office in 2020. The abstracts of these studies and the publication information associated with each study are presented below.

10.5.1 An Update of Hydrologic Conditions and Distribution of Selected Constituents in Water, Eastern Snake River Plain Aquifer and Perched Groundwater Zones, Idaho National Laboratory, Idaho, Emphasis 2016–18 (Bartholomay and others, 2020)

Since 1952, wastewater discharged to infiltration ponds (also called percolation ponds) and disposal wells at the Idaho National Laboratory (INL) has affected water quality in the eastern Snake River Plain (ESRP) aquifer and perched groundwater zones underlying the INL. The U.S. Geological Survey (USGS), in cooperation with the U.S. Department of Energy, maintains groundwater-monitoring networks at the INL to determine hydrologic trends and to delineate the movement of radiochemical and chemical wastes in the aquifer and in perched groundwater zones. This report presents an analysis of water-level and water-quality data collected from the ESRP aquifer and perched groundwater wells in the USGS groundwater monitoring networks during 2016–18.

From March–May 2015 to March–May 2018, water levels in wells completed in the ESRP aquifer declined in the northern part of the INL and increased in the southwestern part. Water-level decreases ranged from 0.5 to 3.0 feet (ft) in the northern part of the INL and increases ranged from 0.5 to 3.0 ft in the southwestern part.

Detectable concentrations of radiochemical constituents in water samples from wells in the ESRP aquifer at the INL generally decreased or remained constant during 2016–18. Decreases in concentrations were attributed to radioactive decay, changes in waste-disposal methods, and dilution from recharge and underflow.

In 2018, concentrations of tritium in water samples collected from 46 of 111 aquifer wells were greater than the reporting level of three times the sample standard deviation and ranged from 260 ± 50 to 5,100 ± 190 pico-curies per liter (pCi/L). Tritium concentrations in water from 10 wells completed in deep perched groundwater
above the ESRP aquifer near the Advanced Test Reactor (ATR) Complex generally were greater than or equal to the reporting level during at least one sampling event during 2016–18, and concentrations ranged from 150 ± 50 to 12,900 ± 200 pCi/L.

Concentrations of strontium-90 in water from 17 of 60 ESRP aquifer wells sampled during April or October 2018 exceeded the reporting level, ranging from 2.2±0.7 to 363 ± 19 pCi/L. Strontium-90 was not detected in the ESRP aquifer beneath the ATR Complex. During at least one sampling event during 2016–18, concentrations of strontium-90 in water from eight wells completed in deep perched groundwater above the ESRP aquifer at the ATR Complex equaled or exceeded the reporting levels, and concentrations ranged from 0.57 ± 0.17 to 34.3 ± 1.2 pCi/L.

During 2016–18, concentrations of cesium-137 were less than the reporting level in all but one ESRP aquifer well, and concentrations of plutonium-238, -239, and -240 (undivided), and americium-241 were less than the reporting level in water samples from all ESRP aquifer wells.

In April 2009, the dissolved chromium concentration in water from one ESRP aquifer well, USGS 65, south of the ATR Complex equaled the maximum contaminant level (MCL) of 100 micrograms per liter (μg/L). In April 2018, the concentration of chromium in water from that well had decreased to 76.0 μg/L, less than the MCL. Concentrations in water samples from 62 other ESRP aquifer wells sampled ranged from less than 0.6 to 21.6 μg/L. During 2016–18, dissolved chromium was detected in water from all wells completed in deep perched groundwater above the ESRP aquifer at the ATR Complex, and concentrations ranged from 4.2 to 98.8 μg/L.

In 2018, concentrations of sodium in water from most ESRP aquifer wells in the southern part of the INL were greater than the western tributary background concentration of 8.3 milligrams per liter (mg/L). After the new percolation ponds were put into service in 2002 southwest of the Idaho Nuclear Technology and Engineering Center (INTEC), concentrations of sodium in water samples from the Rifle Range well increased steadily until 2008, when concentrations generally began decreasing. The increases and decreases were attributed to disposal variability in the new percolation ponds.

During 2016–18, dissolved sodium concentrations in water from 18 wells completed in deep perched groundwater above the ESRP aquifer at the ATR Complex ranged from 6.37 to 143 mg/L.

In 2018, concentrations of chloride in most water samples from ESRP aquifer wells south of the INTEC and at the Central Facilities Area exceeded the background concentrations. Chloride concentrations in water from wells south of the INTEC generally have decreased since 2002 when chloride disposal to the old percolation ponds was discontinued. After the new percolation ponds southwest of the INTEC were put into service in 2002, concentrations of chloride in water samples from one well rose steadily until 2008 then began decreasing. During 2016–18, dissolved chloride concentrations in deep perched groundwater above the ESRP aquifer from 18 wells at the ATR Complex ranged from 3.89 to 176 mg/L.

In 2018, sulfate concentrations in water samples from ESRP aquifer wells in the south-central part of the INL exceeded the background concentration of sulfate and ranged from 22 to 151 mg/L. The greater-than-background concentrations in water from these wells probably resulted from sulfate disposal at the ATR Complex infiltration ponds or the old INTEC percolation ponds. In 2018, sulfate concentrations in water samples from wells near the Radioactive Waste Management Complex (RWMC) mostly were greater than background concentrations and could have resulted from well construction techniques and (or) waste disposal at the RWMC or the ATR complex. The maximum dissolved sulfate concentration in shallow perched groundwater above the ESRP aquifer near the ATR Complex was 215 mg/L in well CWP 3 in April 2016. During 2018, dissolved sulfate concentrations in water from wells completed in deep perched groundwater above the ESRP aquifer near the cold-waste ponds at the ATR Complex ranged from 65.8 to 171 mg/L.

In 2018, concentrations of nitrate in water from most ESRP aquifer wells at and near the INTEC exceeded the western tributary background concentration of 0.655 mg/L. Concentrations of nitrate in wells southwest of the INTEC and farther away from the influence of disposal areas and the Big Lost River show a general decrease in nitrate concentration through time. Two wells south of the INTEC show increasing trends that could be
the result of wastewater beneath the INTEC tank farm being mobilized to the aquifer.

During 2016–18, water samples from several ESRP aquifer wells were collected and analyzed for volatile organic compounds (VOCs). Sixteen VOCs were detected. At least 1 and as many as 7 VOCs were detected in water samples from 15 wells. The primary VOCs detected include carbon tetrachloride, trichloromethane, tetrachloroethene, 1,1,1-trichloroethane, and trichloroethene. In 2016–18, concentrations for all VOCs were less than their respective MCLs for drinking water, except carbon tetrachloride in water from two wells and trichloroethene in one well.

During 2016–18, variability and bias were evaluated from 37 replicate and 15 blank quality-assurance samples. Results from replicate analyses were investigated to evaluate sample variability. Constituents with acceptable reproducibility were major ions, trace elements, nutrients, and VOCs. All radiochemical constituents had acceptable reproducibility except for gross alpha- and beta-particle radioactivity. The gross alpha- and beta-particle radioactivity samples that did not meet reproducibility criteria had low concentrations. Bias from sample contamination was evaluated from equipment, field, and source-solution blanks. Cadmium had a concentration slightly greater than its reporting level in a source-solution blank, and chloride and ammonia had concentrations that were slightly greater than their respective reporting levels in field and equipment blanks. Subtracting concentrations of chloride and ammonia in field blanks from the concurrently collected equipment blank indicates that adjusted concentrations for chloride and ammonia in the equipment blanks were less than their respective reporting levels. Therefore, no sample bias was observed for any of the sample periods.

**10.5.3 Regionally Continuous Miocene Rhyolites Beneath the Eastern Snake River Plain Reveal Localized Flexure at its Western Margin (Schusler and others, 2020)**

The eastern Snake River Plain (ESRP) is a northeast-trending topographic basin interpreted to be the result of the time-transgressive track of the North American plate above the Yellowstone hotspot. The track is defined by the age progression of silicic volcanic rocks exposed along the margins of the ESRP. However, the bulk of these silicic rocks are buried under 1 to 3 kilometers of younger basalts. Here, silicic volcanic rocks recovered from boreholes that penetrate below the basalts, including INEL-1, WO-2 and new deep borehole USGS-142, are correlated with one another and to surface exposures to assess various models for ESRP subsidence. These correlations are established on U/Pb zircon and \(^{40}\)Ar/\(^{39}\)Ar sanidine age determinations, phenocryst assemblages, major and trace element geochemistry, \(^{δ^{18}}\)O isotopic data from selected phenocrysts, and initial \(ε\)Hf values of zircon. These data suggest a correlation of: (1) the newly documented 8.1 ± 0.2 Ma rhyolite of Butte Quarry (sample 17KS03), exposed near Arco, Idaho to the uppermost Picabo volcanic field rhyolites found in borehole INEL-1; (2) the 6.73 ± 0.02 Ma East Arco Hills rhyolite (sample 16KS02) to the Blacktail Creek Tuff, which was also encountered at the bottom of borehole WO-2; and (3) the 6.42 ± 0.07 Ma rhyolite of borehole USGS-142 to the Walcott Tuff B encountered in deep borehole WO-2. These results show that rhyolites found along the western margin of the ESRP dip ~20° south-southeast toward the basin axis, and then gradually tilt less steeply in the subsurface as the axis is approached. This subsurface pattern of tilting is consistent with a previously proposed
crustal flexural model of subsidence based only on surface exposures, but is inconsistent with subsidence models that require accommodation of ESRP subsidence on either a major normal fault or strike-slip fault.

10.5.4 Surficial Geologic Mapping and Cosmogenic Chronology of Pioneer Mountains Glaciation and the Big Lost River floods, Pioneer Mountains and Eastern Snake River Plain, Idaho (Warner, 2020).

The source, size, and chronology of Big Lost River floods in central Idaho have remained enigmatic despite previous mapping, modelling, and dating efforts. Twenty new 10Be cosmogenic exposure ages from the Pioneer Mountains confirm the timing of recent glaciation and the source of the most recent ca. 22 ka flood, Glacial Lake East Fork (GLEF). Six new 3He ages from distal flood boulders at the Arco scablands augment previously dated deposits at Bone and Lost Moon Cataracts near Box Canyon, producing a more complete chronology of flooding. Coupled with HEC-RAS flood extent modelling, results suggest at least one prior flood event ca. 35 ka of larger size and impact; previously recognized ca. 22 ka flood evidence at the Arco scablands is proximal to the Big Lost River and may have been produced by a flood as small as ~10,000 m$^3$/s, while new ca. 35 ka ages from distal flood boulders require ~30,000 m$^3$/s. This higher discharge estimate is also required to produce undated flood evidence at the northern Arco scabland highlands, thus is an estimate of maximum historical peak discharge and confirms the recurrence potential of GLEF. This approach reconciles many of the interpretive issues introduced from poor preservation potential within the geomorphically active Lost River corridor and informs best practices for studying similar paleofloods of modest scale. In addition, age data informs the first cosmogenic glacial chronology from the Pioneer Mountains, thoroughly described with a new surficial geologic map of tributary junctions and potential flood source ages.
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