2020 Idaho
Douglas-fir Tussock Moth
Monitoring Report

Defoliation at Moon Pass, Idaho in 2020

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Report No. IDL 20-1

December 2020

2020 IDAHO DOUGLAS-FIR TUSSOCK MOTH MONITORING REPORT

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Background and History

Douglas-fir tussock moth (DFTM) is a native defoliator of true firs, Douglas-fir, and occasionally other conifers in western North America. Adult males are common-looking gray-brown moths with feathery antennae (figure 1). Females are heavy-bodied and flightless, and release sex pheromones that attract males to mate. After mating, females lay egg masses (figure 2) on host tree branches in late summer or fall. Egg hatch coincides with bud burst the following spring, and developing larvae (figure 3) feed on host foliage (figure 4). Development timing can vary with temperature and elevation, but pupation typically occurs in late July or August, and new adult moths emerge in late summer or fall.

In most years, DFTM populations are low and do not cause visible defoliation, but populations can periodically irrupt in cyclical outbreaks. During the outbreak phase of the cycle, DFTM populations build rapidly over a few years, then quickly collapse within one to two years as starvation, predation, parasitism, and infection by a DFTM-specific nuclear polyhedrosis virus (NPV) cause high levels of DFTM mortality. In northern Idaho, there is a long history of periodic outbreaks causing widespread defoliation (figure 5). In southern Idaho, large outbreaks have also occurred, but on a less regular basis. Tree defoliation during a DFTM outbreak can appear very dramatic, but trees with light or moderate defoliation usually recover following the outbreak.

Since 1977, Idaho has participated in the DFTM Early Warning System (EWS), which uses a series of permanent pheromone trap sites in recorded historic outbreak areas to identify increasing populations prior to undesirable tree defoliation (system adapted from Daterman *et al.*, 1979) (figure 6). Pheromone lures that mimic sex pheromones produced by female moths are placed in sticky traps before the DFTM flight period and the number of captured adult males caught throughout the flight period is recorded each year (figure 7). Sharp increases in trap catches provide land managers advance warning of building populations.

North Idaho Outbreaks and EWS trapping

In northern Idaho, four periods of DFTM outbreaks have been detected since implementing the EWS just after major outbreaks in the mid-1970s.The first outbreak detected by EWS traps occurred in the 1980s in Latah County and McCroskey State Park (figure 5). According to records, outbreaks of DFTM have occurred in this general area approximately every 8-10 years since at least the late 1940s when aerial detection surveys became common. The 1980s outbreak was preceded by high numbers of moth captures, but defoliation was only recorded by aerial observers in 1986 (figure 8).

The next documented northern Idaho outbreak occurred in the early 2000s and resulted in three years of defoliation on state and private lands between Plummer and Moscow, and on adjacent Clearwater National Forest lands. Similar to the 1980s outbreak, trap captures averaged over 40 moths per trap prior to visible defoliation (figure 8).

A third outbreak occurred between 2010 and 2012 and did not follow the same trends in location or moth captures. Defoliation was centered farther north than previous outbreaks, with limited defoliation near Moscow Mountain. Most of the defoliation was in Kootenai County near Signal Point, in Benewah County near Plummer, and in McCroskey State Park. The average number of moths/trap captured prior to observed defoliation was much lower relative to the two earlier periods of outbreaks. In 2010, the average number of moths/trap was 11.8, a slight decrease from 11.9 the previous year, but over 8,500 acres of defoliation were mapped in aerial surveys. Defoliation peaked in 2011 at over 106,000 acres (~68,000 acres on state and private ownership in Latah and Benewah counties, with the remaining defoliation occurring on the Nez Perce-Clearwater National Forest), and an average of 43.8 moths/trap were captured that same year. Averages >40 moths/trap would normally be expected the year prior to observed defoliation. In 2012, only 6.3 moths/trap were captured and approximately 31,000 acres of defoliation were detected (figure 8).

Finally, a fourth northern Idaho outbreak is currently building. Aerial surveyors detected 13,700 acres of Douglas-fir tussock moth-caused defoliation in northern Idaho in 2020, with additional defoliation in western Montana (figure 9). Trap catch has been rising since 2017, but defoliation occurred further east of the historic recorded outbreak areas, where EWS traps have mostly not been established. Additional information on the current northern Idaho outbreak is outlined in the Results section.

South Idaho Outbreaks and EWS trapping

Records of EWS trapping date back to 1980 in southern Idaho, but trapping has been carried out inconsistently over the decades, and early aerial survey data is not consolidated in this region. Trap catch records indicate there may have been DFTM outbreaks in the early 1980s in USFS Region 4 portion of Idaho, but there were no acres of defoliation recorded through aerial survey at that time. From 1990-1992, a major DFTM outbreak in southern Idaho caused defoliation on over 400,000 acres, primarily affecting areas east of Highway 21 on the Boise and Sawtooth National Forests. The Sagehen Reservoir area near Smiths Ferry and the Cuddy Mountain area were also defoliated in the early 1990s outbreak (figure 5). Smaller outbreaks in the early 2000s affected the most southern reaches of the state that included large areas in the Owyhee Mountains. Trap catch numbers began increasing significantly again in 2014, and in 2017, heavy defoliation was noted in stands of Douglas-fir in Craters of the Moon National Monument and several other areas. Beginning in 2018 and continuing in 2019, a large outbreak affected the forests surrounding the Long Valley and Round Valley areas (figures 5 & 10). In 2020, defoliation subsided in most locations in southern Idaho, with the exception of the Cuddy Mountain and Hitt Mountain areas west of Cambridge (Payette National Forest) and the Big Hole mountains west of Driggs.

Outbreak Forecasting

Early Warning System trapping is often effective for predicting when DFTM outbreaks will occur, but it is not intended to predict the location or extent of tree defoliation. Therefore, additional population sampling methods for other life stages are needed to improve outbreak forecasting. Egg mass and larval sampling are two additional methods to supplement EWS monitoring for predicting DFTM outbreak intensity and pinpointing precise locations of expected defoliation (Mason and Torgersen, 1983, Kegley *et al.*, 2004). Observations of damage to ornamental trees in landscaped settings are another indicator that outbreaks of DFTM will soon develop in forested settings (Tunnock *et al.*, 1985; Sturdevant, 2000). These 'sentinel trees' are often spruce. Although spruce are lesser-preferred DFTM host species during outbreaks in natural forests, these ornamental trees are often stressed from being planted off-site and are regularly evaluated for various issues. Prior to the 2010-2012 outbreaks in northern Idaho, defoliation of ornamental spruce was first observed at the USFS Coeur d'Alene nursery in 2007 and 2008, and grand fir yard trees were defoliated at Twin Lakes and Mica Flats in 2009 and 2010. Sentinel trees were also observed in Kootenai county and in Spokane County, Washington prior to 2020 defoliation.

Monitoring Methods

Pheromone Traps

The Idaho Department of Lands (IDL) and U.S. Forest Service Region 1 (USFS R1; northern Idaho) and Region 4 (USFS R4; southern Idaho) cooperatively manage EWS DFTM monitoring sites throughout the state (figure 6). In general, IDL maintains trap sites from Coeur d'Alene south to Moscow and east to Harvard. Six additional trap sites were installed by IDL on the Floodwood State Forest east of Clarkia in 2020 after defoliation was observed nearby. Additionally, 10 new IDL-monitored sites were installed in 2020 near Smith's Ferry in southern Idaho on the Packer John State Forest. The Packer John State Forest was heavily defoliated in

2018 and 2019, so state personnel will continue to monitor the area. Forest Health Protection, Coeur d'Alene Field Office (USFS-R1), generally maintains trap sites from Potlatch to Lucille. Due to prior defoliation by the western hemlock looper and high numbers of caterpillars observed in larval surveys, USFS R1 added five new DFTM trapping sites near Elk Summit in 2020. Forest Health Protection, Boise Field Office (USFS-R4), maintains most trap sites in southern Idaho.

Each year, five pheromone-baited sticky traps (figure 7) are installed along a transect at each trap site, with approximately 75 feet between traps. Traps are placed in young, open-grown host trees (grand fir or Douglas-fir) in late July to early August, to coincide with DFTM flight timing. Traps are collected in late September or October and the number of male moths captured in each trap is recorded. The common threshold used to predict defoliation the following years is an average of 25 moths/trap at a site, but we have learned over time that even 15 males on average indicate a potential outbreak and more surveys are recommended. EWS pheromone trapping is not designed to predict the exact location of future defoliation.

Egg Mass Sampling

When trap captures are high (near the 25 average moths/trap threshold), fall egg mass sampling may be used to estimate the potential for defoliation in a specific area the following year. Two egg mass sampling methods are used in Idaho: (1) the "timed plot technique" and (2) methods described in Shepherd *et al.*, 1985 ("sequential sampling"). The timed plot technique works well for smaller crews and is conducted by examining grand fir and Douglas-fir trees for a total of ten working minutes (i.e., 10 minutes for a single person, 5 minutes for two people working simultaneously), and counting the number of egg masses observed. The sequential sampling method works well with larger crews and involves sampling three branches each on between 20 and 82 trees, depending on the cumulative number of egg masses found (figure 11). The mean number of egg masses per tree is then calculated. Areas where high numbers or densities of egg masses are observed during sampling are considered to be likely locations of defoliation the following year. However, it is important to note that egg masses are exposed to winter injury, predation, and parasitism prior to hatching the following spring, and first instar larvae may be susceptible to starvation if many egg masses are observed in areas that have already been heavily defoliated.

Larval Sampling

At sites where the EWS average moths/trap threshold (25 moths/trap) is reached, larval sampling may be conducted the following spring to pinpoint injurious population densities (Daterman *et al.*, 1979) and locate areas for treatment, if necessary. Larval sampling may also be useful at sites with a history of DFTM-caused defoliation occurring before trap counts reach the threshold. Sequential sampling for DFTM larvae in the lower crown is performed according to procedures outlined in Mason, 1979. A stretched canvas 'beat sheet' is placed below a host tree branch and the branch is hit several times with a stick. Larvae that fall from the branch onto the sheet are inspected and counted. Sequential larval surveys are most useful before widespread defoliation occurs and are of limited use during an outbreak (Mason, 1979). Larval sampling may also be conducted toward the end of an outbreak cycle to confirm DFTM population crash.

Results of 2020 Survey Season

Trapping

A total of 185 sites were monitored in northern Idaho (147 by IDL and 38 by USFS-R1), and 34 sites were monitored in southern Idaho (24 by USFS-R4, and 10 single trap sites by IDL on the Packer John State Forest) during 2020 (figures 12, 13, & 14). The single trap sites were installed by IDL in 2020 for a quick assessment of crashing DFTM populations, but the standard five traps per site will be used at these sites in the future. In 2018, four sites that were traditionally monitored by IDL were transferred to USFS R1 (209, 211, 212, and 821) and four sites that were traditionally monitored by USFS R1 were transferred to IDL (5021, 5033, 5034, and 5035) to reduce travel times and improve efficiency in trap monitoring efforts. The transfer of these sites was maintained in 2019 and 2020 and is expected to be maintained into the future.

The overall mean trap capture for the IDL traps in 2020 was 9.95 moths/trap, compared with 7.28, 1.51, and 0.17 moths/trap in 2019, 2018, and 2017, respectively. An average of 10.58 moths/trap were caught in USFS-R1 traps in 2020, compared with 4.44, 1.15, and 0.1 moths/trap in 2019, 2018 and 2017, respectively. The five new trap sites added by USFS R1 near Elk Summit yielded high numbers of DFTM male adults and trapping will continue at these sites in 2021. The increasing trap catch numbers for IDL and USFS R1 traps preceded defoliation events in northern Idaho in 2020.

The 2020 USFS-R4 average for southern Idaho was 10.89 moths/trap compared to 18.31, 19.73, and 12.92 moths/trap in 2019, 2018 and 2017, respectively. In southern Idaho, there was some continued observed defoliation in 2020, but this was limited to the Cuddy Mountain and Hitt Mountain areas (figure 10) and the Big Hole area near Driggs. 2020 was the fourth year of defoliation in the current outbreak, and outbreaks usually last three years. It is possible that the populations in these outlying areas are on a different outbreak schedule than the population in the Smiths Ferry area that caused extensive defoliation in 2018 and 2019. While southern Idaho trap captures have decreased, continued high trap captures is not unusual during outbreak collapse, since male DFTMs (the sex targeted in traps) develop faster than females and therefore are exposed to fewer natural enemies. Despite the survival of some males, however, high mortality in female moths nonetheless results in a population crash.

Larval Surveys

In northern Idaho, larval sampling was conducted by IDL at 53 sites in 2020 (figure 15). Sites were selected for larval sampling because they had high numbers of moths/trap relative to other IDL-monitored sites in 2019, they were located in areas where outbreaks had historically occurred, or they were located near current defoliation. Most sites were surveyed in June using sequential survey methods outlined in Mason, 1979, but sites near the Floodwood State Forest and Elk River were informally sampled during trap deployment in August. Five sites in historical outbreak areas had low larval populations (1/9 trees infested) with no defoliation observed, two sites near current defoliation on the Floodwood State Forest had high larval populations and defoliation was observed, one site on the Floodwood State Forest had low larval populations, and one site near Elk River had low larval populations. Trappers searched the other adult trap sites on the Floodwood for larvae in August as well, but no larvae were observed.

On July 14, 2020, USFS R1 conducted informal larval sampling at Elk Summit (Idaho county). The sampled sites were previously defoliated by western hemlock looper. Live insect collections included 5 early instar, sick western hemlock looper larvae and >30 early instar Douglas-fir tussock moth larvae from the crown of defoliated and recovering Douglas-fir and grand fir (Malesky *et al*., 2020)

In southern Idaho, larval sampling was conducted at 31 sites around areas defoliated in 2019 and around areas experiencing 2020 defoliation (figure 15). In areas where defoliation occurred in 2018-2019, no larvae were found. In areas near 2020 defoliation (Cuddy and Hitt Mountains) larvae were found at eight sites, six of which had high larval populations. Where larvae were observed, several caterpillars looked unhealthy with signs of NPV infection, suggesting that natural controls are acting on the population. Sites near Cuddy and Hitt Mountains were surveyed during trap deployment in late July using sequential sampling; the remaining sites were sampled in June.

Egg Mass Sampling

In northern Idaho, egg mass sampling was conducted at 96 sites (72 sites by IDL, 24 sites by USFS R1). (figure 16) Additional egg mass sampling was conducted by PotlatchDeltic east of Clarkia. Egg mass sampling conducted by IDL and PotlatchDeltic used the timed plot technique; egg mass sampling conducted by USFS R1 used the Shepherd *et al*., 1985 sequential sampling method. No egg masses were observed at sites where defoliation has historically occurred, but egg masses were found near the 2020 defoliation in the Silver Valley and near the Floodwood State Forest (figures 16 and 17). Two egg masses were also found at one site near Elk Summit north of Elk City, ID. Notably, egg masses in the Silver Valley appeared small and unhealthy (figure 18), with evidence of parasitism and NPV (figure 19), whereas egg masses near the Floodwood state forest appeared large and healthy. This suggests that the Silver Valley population may be on the Montana outbreak cycle. Defoliation began in western Montana in 2019, meaning that 2020 is the second year of the outbreak and natural controls are likely to be emerging. The Floodwood population may be on a new Idaho outbreak cycle, where natural controls are not yet present in high numbers.

In southern Idaho, egg mass sampling was conducted using sequential sampling at 27 sites (figure 16). Although many old egg masses were observed (figure 18), current egg masses were only observed at three sites. Two egg masses were observed near Mann Creek in the Hitt Mountains, eight egg masses were observed at Cracker Jack trail on Cuddy Mountain, and 22 egg masses were observed in the Big Hole Mountains near Driggs. Evidence of natural controls was observed in all three areas. Therefore, while additional defoliation may occur in 2021, especially near Driggs, populations are expected to crash over the course of the 2021 season.

Defoliation

In north Idaho, approximately 13,700 acres of defoliation by Douglas-fir tussock moth were recorded through aerial survey in 2020. Additional defoliation occurred across the state border into western Montana (figure 9). In Idaho, defoliation occurred in two main areas: the Silver Valley and around the Floodwood State Forest. Records dating back to the 1940s show that in northern Idaho, defoliation due to Douglas-fir tussock moth outbreaks is typically centered in

Latah and Benewah counties, so 2020 defoliation is further east than in recent history (figure 5). Defoliation is not, however, unprecedented in the Floodwood area, since early records from the 1940s and 1950s show that defoliation occurred during outbreaks in those decades as well (figure 20). Defoliation in both the Silver Valley and the Floodwood area was light to moderate in most areas, with aerial footage over the Floodwood State Forest obtained via UAS plots: http://gis1.idl.idaho.gov/portal/apps/webappviewer/index.html?id=6bc68140a73e469cbc291a20fd1315f7 (figures 21, 22 & 23). The Floodwood and Elk Summit areas also recently experienced defoliation from the western hemlock looper which defoliated over 400,000 acres from Elk City to Avery in 2019 (figure 24). As of July, 2020, many trees had recovered, however examples of top kill, understory and overstory tree mortality from severe defoliation were noted (Malesky, *et al.*, 2020). Heavy defoliation in successive years may impact tree recovery in some cases.

In southern Idaho, nearly 3,000 acres of defoliation were recorded in aerial surveys. Aerial surveys only recorded current defoliation in the Cuddy and Hitt Mountain areas (figure 10), but additional defoliation was observed in ground surveys in the Big Hole mountains near Driggs. Defoliation was mostly moderate, but severe in some areas. The defoliation in the Big Hole Mountains was highly visible from Driggs and surrounding areas, and therefore has generated public interest. The Driggs area was also heavily defoliated in 2019 and possibly in 2018 as well. Heavy western spruce budworm activity in the same area (which can appear similar to DFTM-caused damage) and the challenge of appropriately timing aerial survey flights to capture current visible defoliation has made tracking the DFTM-caused defoliation in this area difficult. USFS R4 entomologists plan to establish new EWS trap sites near Driggs in the future for improved monitoring. Much of the Cuddy Mountain area was also burned in the Woodhead fire in the late summer of 2020, however ground reports indicate that tree crowns were mostly spared. In 2019, over 200,000 acres of defoliation occurred in the Smiths Ferry area, but most of these areas did not see any additional defoliation in 2020.

In both northern and southern Idaho, aerial detection and ground survey coverage was more limited in 2020 due to Covid-19. Therefore, it is possible that additional areas of defoliation occurred on the landscape but were missed in surveys.

Additional Monitoring

Defoliation recovery monitoring was conducted by USFS R4 at 23 plots in the Sagehen area, which experienced heavy defoliation in 2018 and 2019 (figures 25 and 26). Data is still being processed and will be presented in a USFS R4 Forest Health Protection report. Preliminary assessments are that bark beetle populations were high even in areas that appeared recovered from defoliation. Additional tree mortality is expected in grand fir and Douglas-fir due to fir engraver beetle and Douglas-fir beetle. Salvage operations have been implemented throughout this area in response to the damage.

Conclusions

The DFTM-EWS has been generally effective at predicting outbreaks in Idaho, and an increase in trap catch in northern Idaho preceded 2020 defoliation. This occurred even though 2020 defoliation was located further east than historical outbreaks, and there were not many monitoring traps located in the 2020 outbreak areas.

Due to natural controls that are already present in the Silver Valley DFTM population, we expect only limited defoliation in the Silver Valley in 2021. This population may be on the Montana outbreak cycle, which began seeing defoliation in 2019 and is expected to collapse in 2021. In the Floodwood area, however, populations appear to be healthy and building, and we expect an increase in defoliation extent in this area in 2021. Adult trap catch data suggests we may also see additional defoliation in the historic outbreak areas in Benewah and Latah counties in 2021. No egg masses were observed in these areas in surveys. Likely, egg masses were too high up in the tree canopies to be observed by surveyors because Douglas-fir tussock moths have a natural inclination to move upwards, and egg masses will be concentrated in treetops until populations are high.

In southern Idaho, despite some continued trap captures of male DFTMs, only limited defoliation was observed. Ground surveys indicate that high levels of parasitism and NPV infection have resulted in a DFTM population collapse in most areas. The Cuddy and Hitt Mountain area may experience defoliation in 2021 based on some DFTM egg mass surveys this fall. However, those surveys also observed evidence of NPV in this population, suggesting it may be collapsing. Monitoring in the Driggs area should be continued due to the high number of egg masses observed there in 2020, as notable defoliation is likely in 2021 even though the population may crash over the course of the 2021 season.

In all parts of Idaho, trees with light or moderate defoliation typically recover. However, trees that are heavily defoliated or defoliated for multiple years in a row may die from defoliation alone. Especially in areas where there have been consecutive years of defoliation, increased bark beetle activity may result, leading to additional tree mortality in the area. In anticipation of this likely future mortality in heavily impacted areas in southern Idaho, both the USFS and IDL initiated and implemented timber sales to salvage useable timber and reduce potential fuel loads from dying trees.

For additional information (including data, maps, reports, photos, or videos) please contact the Idaho Department of Lands Forest Health Program

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This survey and report was partially funded by the USDA Forest Service.

Figure 1. Adult Douglas-fir tussock moth male (left) and female (right). Female moth is pictured on an egg mass**.**

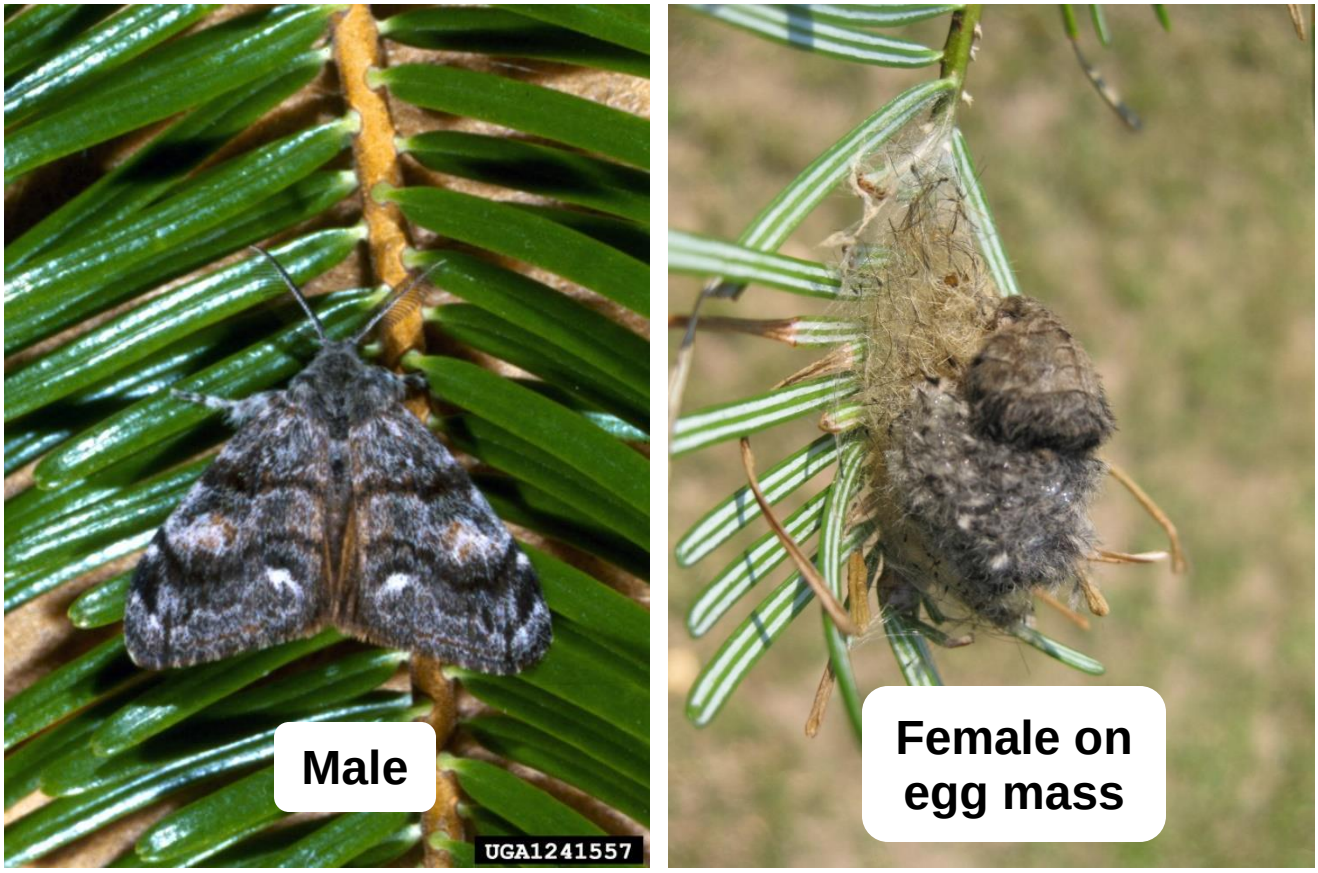

Figure 2. Douglas-fir tussock moth egg mass.

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Figure 3. Newly hatched (left) and fully grown (right) Douglas-fir tussock moth larvae.

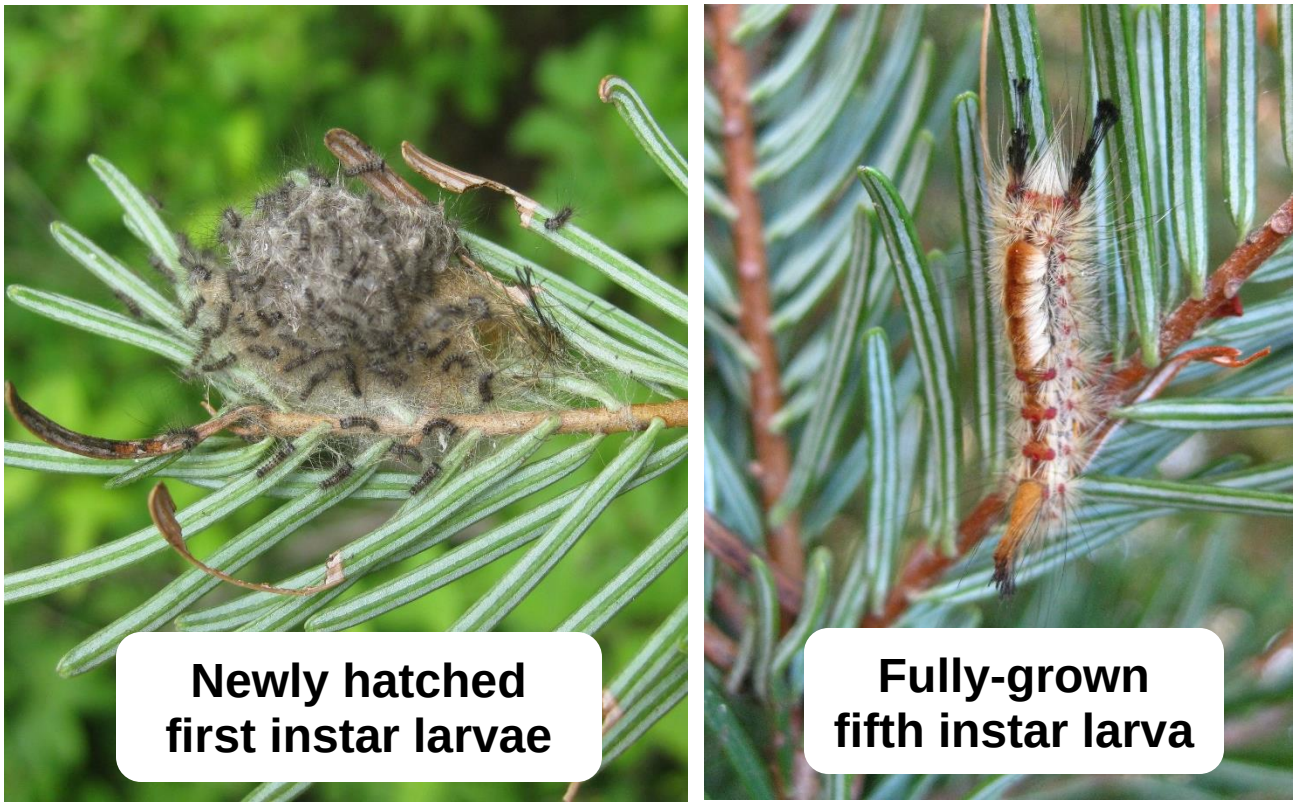

Figure 4. Douglas-fir tussock moth (DFTM)-caused tree defoliation.

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Figure 5. Aerially mapped defoliation by Douglas-fir tussock moth for the 1940s to 2020. Outbreaks often occur in the same general areas in north Idaho.

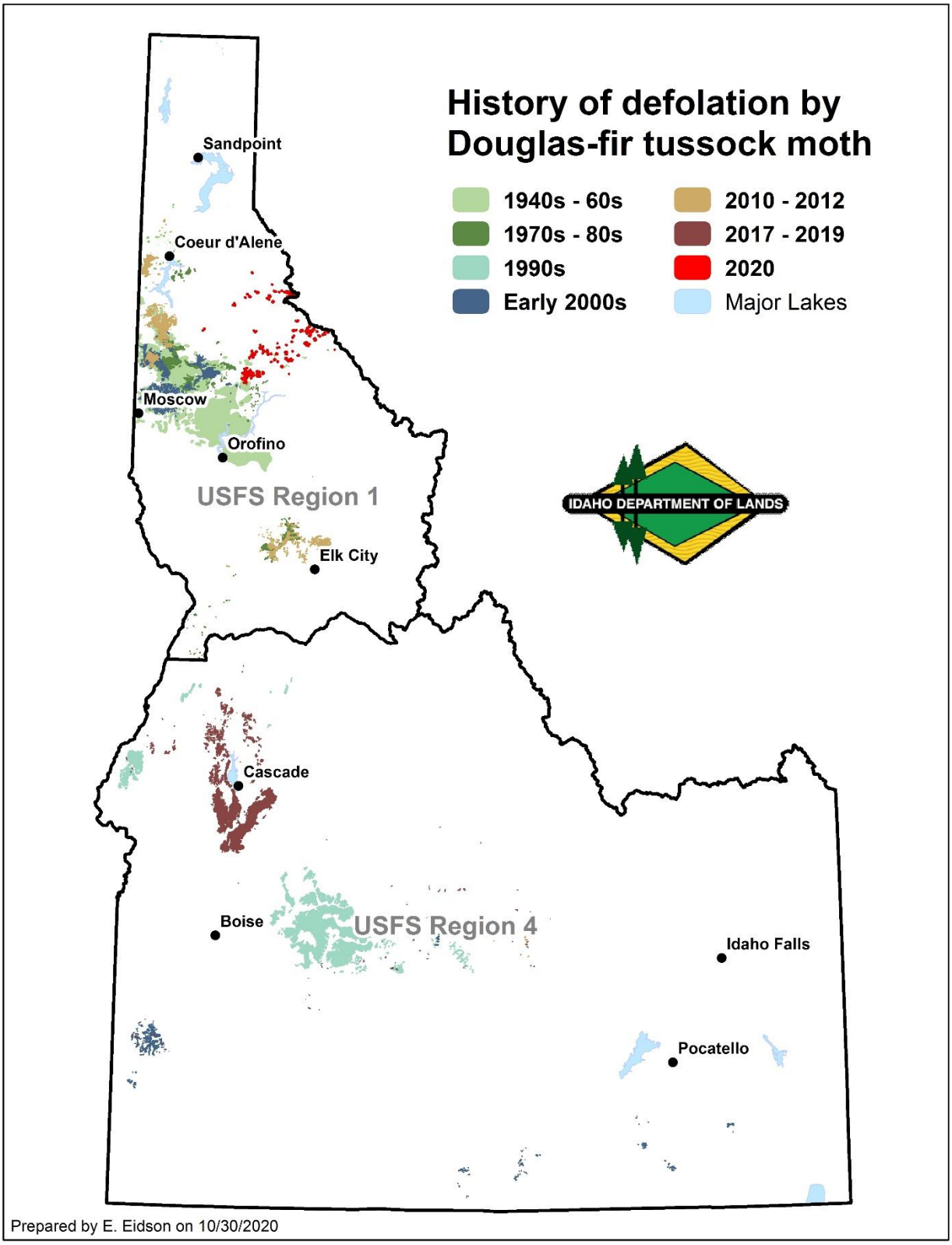

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Figure 6. Early Warning System trap distribution in Idaho in 2020.

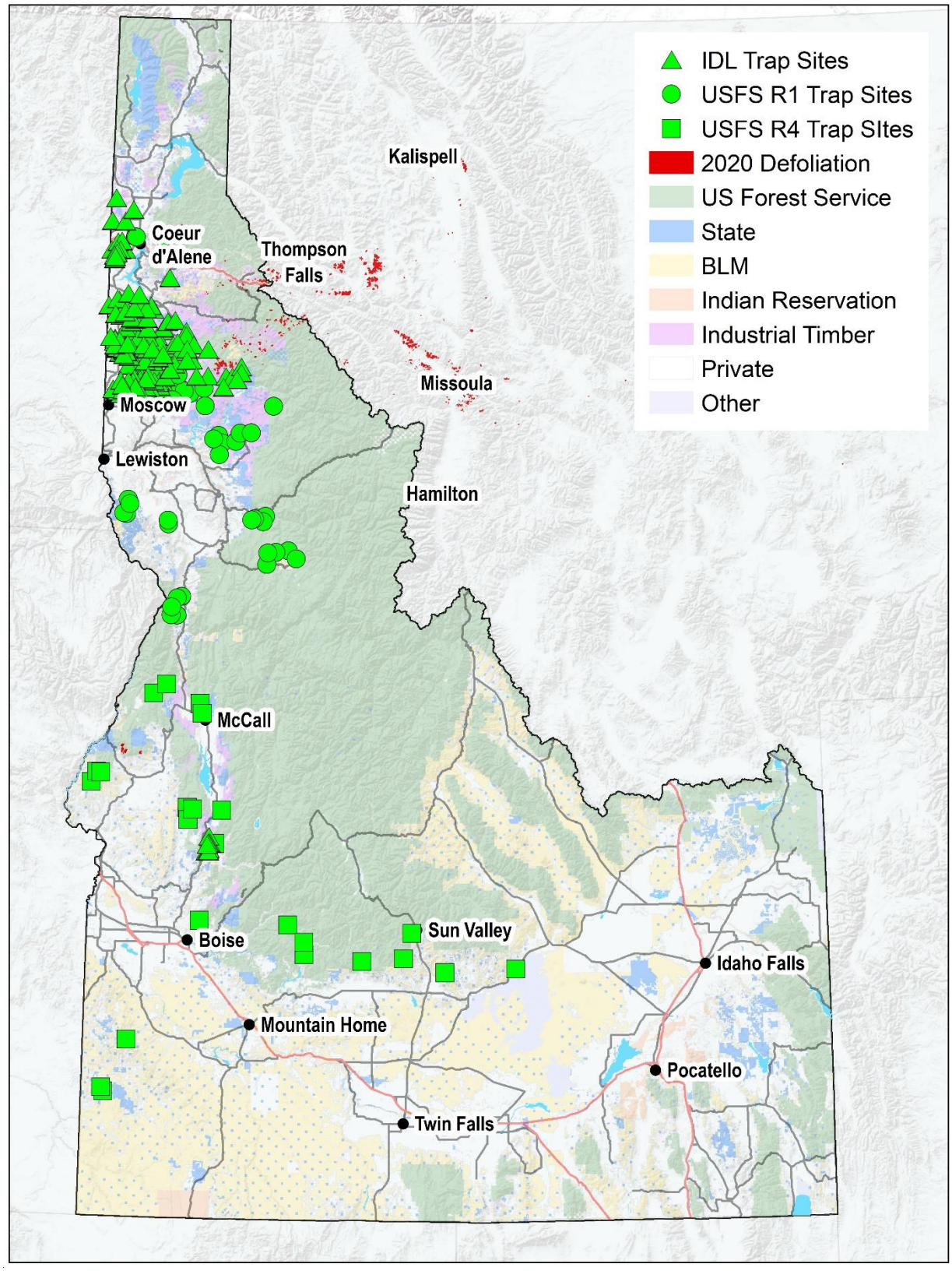

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Figure 7. Early Warning System (EWS) pheromone-baited sticky trap and captured adult male moths.

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Figure 8. Mean trap catches of Douglas-fir tussock moth on plots monitored by IDL (top) and visible defoliation in northern Idaho (bottom) from 1977 – 2020.

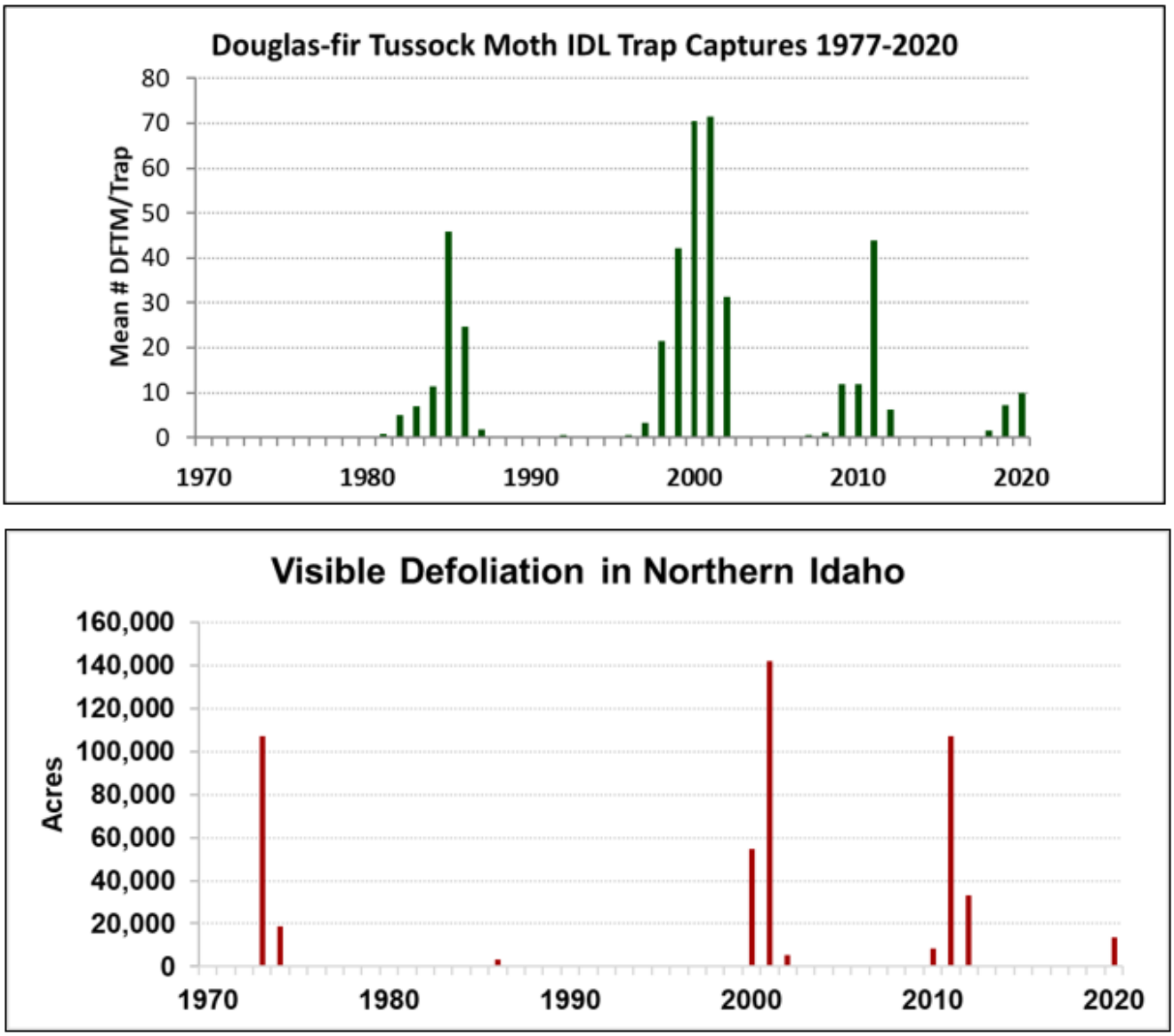

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Figure 9. Douglas-fir tussock moth-caused defoliation in northern Idaho and western Montana in 2020.

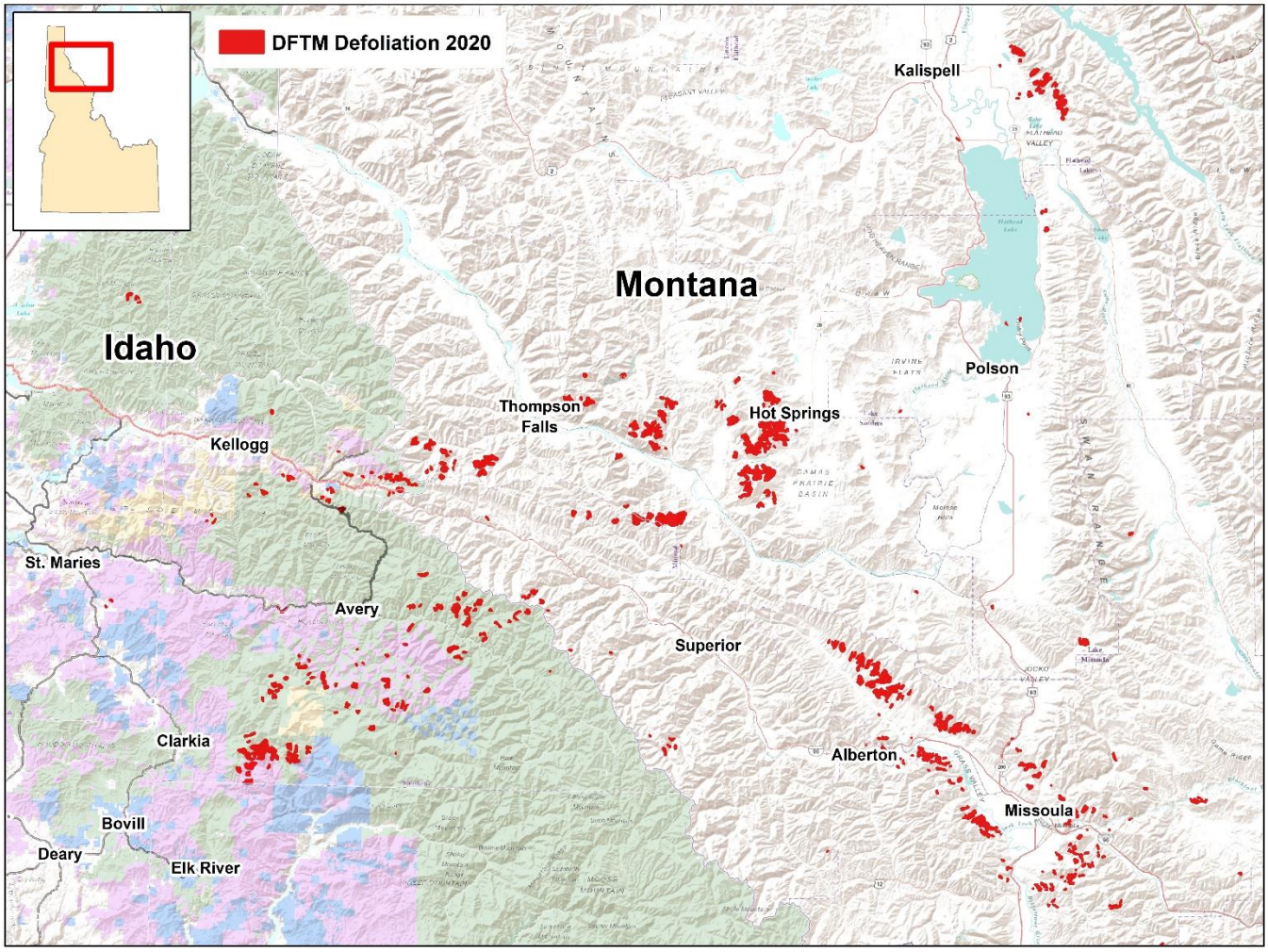

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Figure 10. Douglas-fir tussock moth-caused defoliation recorded by Aerial Detection Survey in southwestern Idaho, 2018 - 2020.

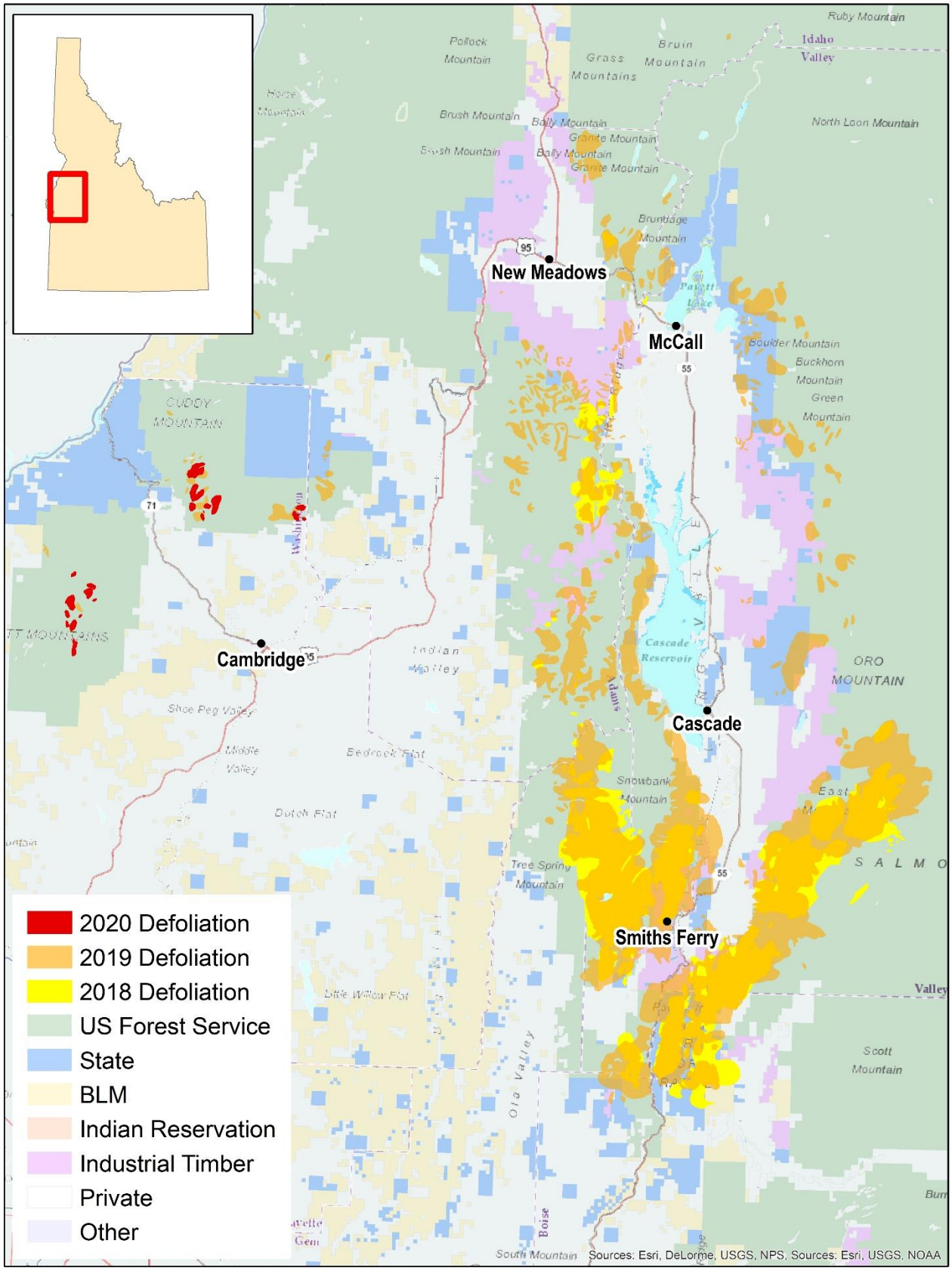

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Figure 11. Data sheet for Shepherd *et al*., 1985 Douglas-fir tussock moth egg mass sampling method. Data sheet shows number of host trees to be sampled (by inspecting three branches per tree) based on cumulative egg masses observed at a site. If the Lower Stop number of cumulative egg masses has been observed when a given Tree # is reached, sampling at the site is complete and the average number of egg masses per tree is calculated.

Douglas-fir tussock moth egg-mass survey

Plot # _____ Location _____

Observer _____ Date _____

Tree #	# Egg Masses	Cumulative # Egg Masses	Lower Stop #	Tree #	# Egg Masses	Cumulative # Egg Masses	Lower Stop #
2			–	44			18
4			–	46			19
6			–	48			20
8			–	50			21
10			–	52			22
12			–	54			23
14			–	56			24
16			–	58			26
18			–	60			27
20			5	62			28
22			5	64			29
24			6	66			30
26			8	68			31
28			9	70			33
30			10	72			34
32			11	74			35
34			12	76			36
36			13	78			37
38			14	80			38
40			15	82			39
42			17				

Predicted Defoliation

L M S

Map overleaf

Stop sampling when cumulative egg masses reaches 40 or is equal to or below lower stop number.

Total # egg masses / # trees = _____ = _____

Figure 12. Map of sites trapped by IDL for Douglas-fir tussock moth in 2020.
Ten additional single-trap sites, not shown on this map, are located on the Packer John State Forest in southern Idaho (Figure 14)

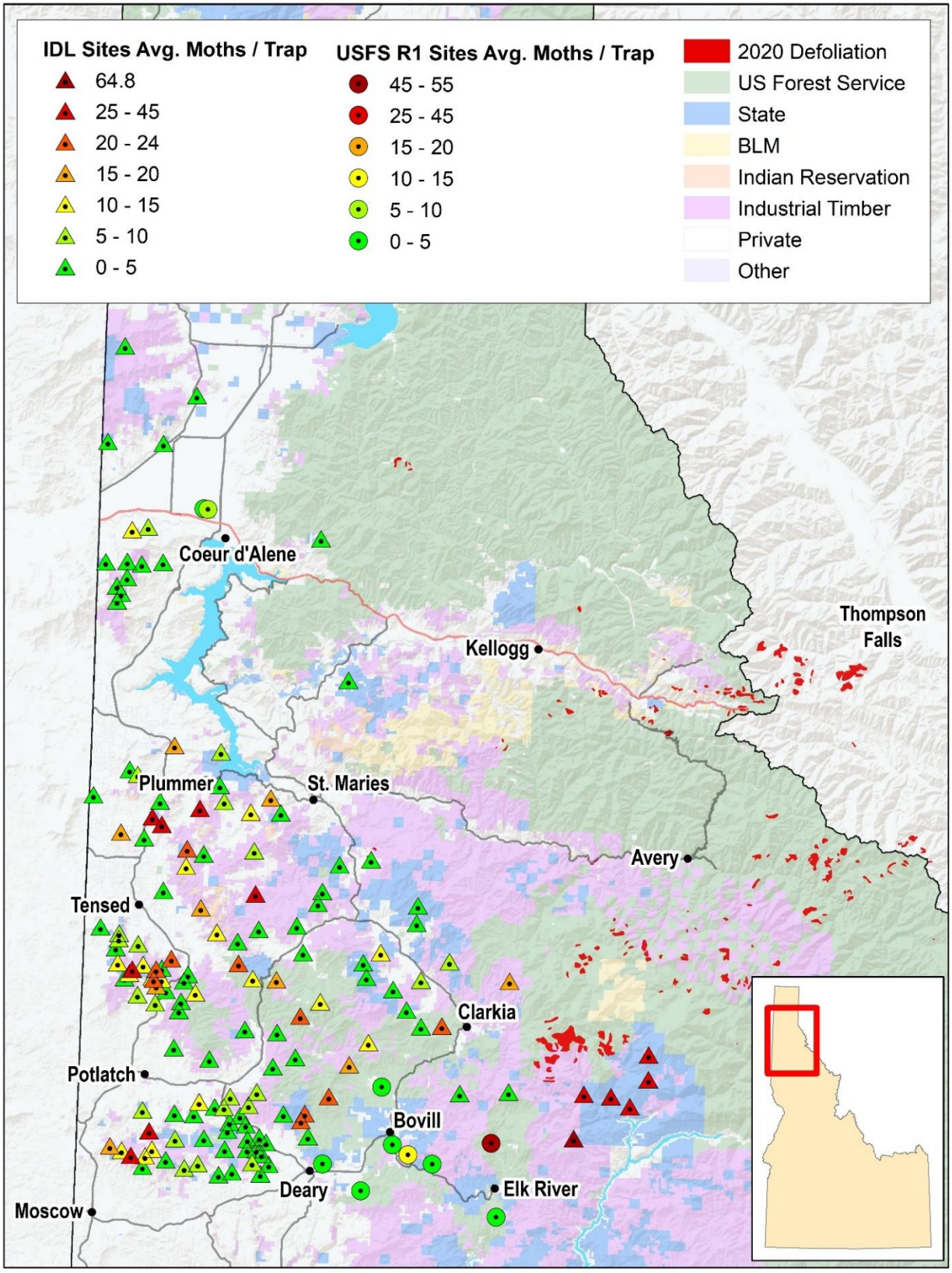

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Figure 13. Map of sites trapped by USFS Region 1 for Douglas-fir tussock moth in 2020. Additional trapping, not shown on this map, was conducted by USFS Region 1 in Coeur d'Alene at the USFS Forest Service Nursery (figure 12).

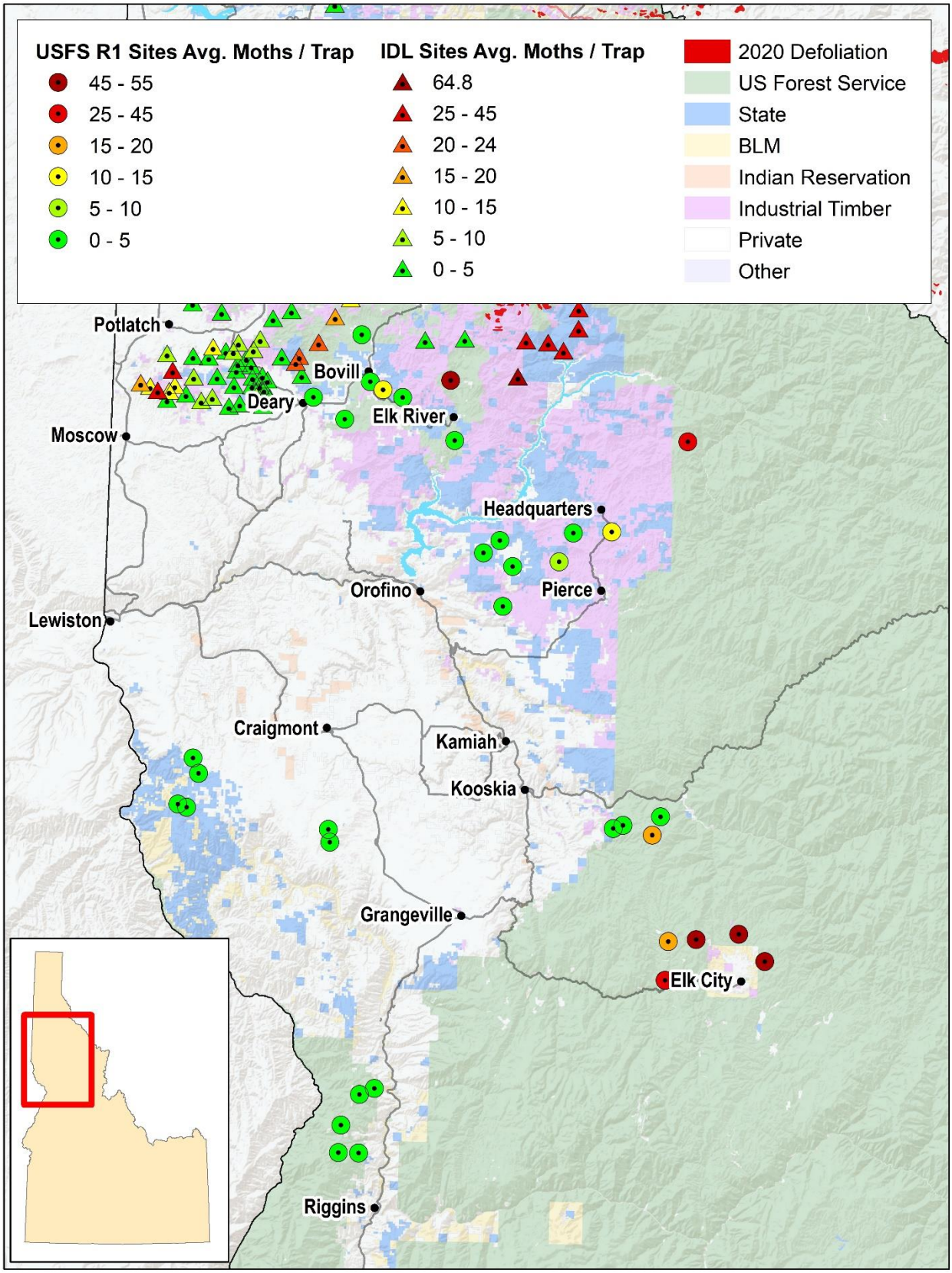

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Figure 14. Map of sites trapped by USFS Region 4 for Douglas-fir tussock moth in 2020.

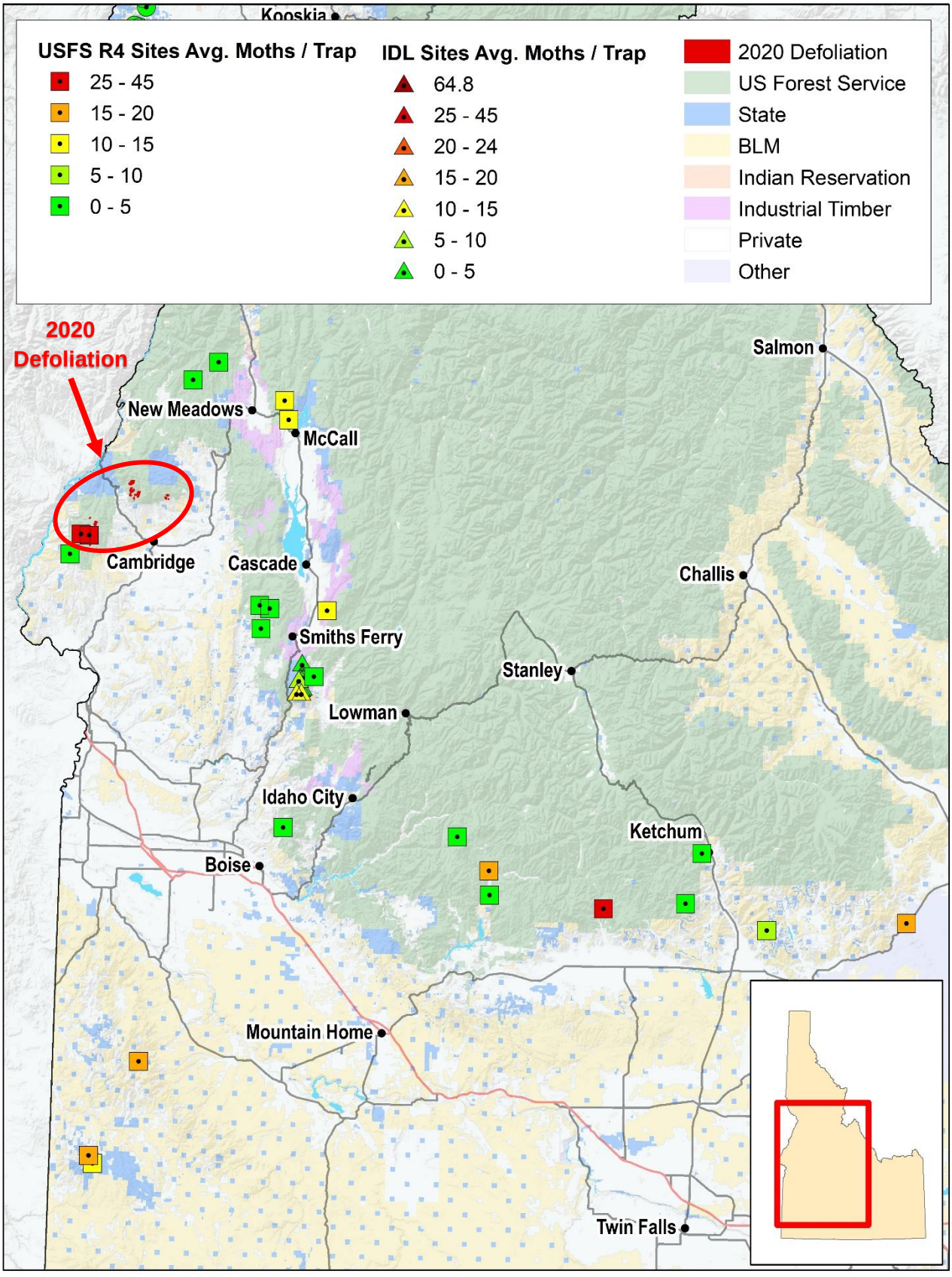

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Figure 15. Map of sites surveyed for Douglas-fir tussock moth larvae in 2020.
No larvae were observed in the two sample areas near Smiths Ferry, ID.

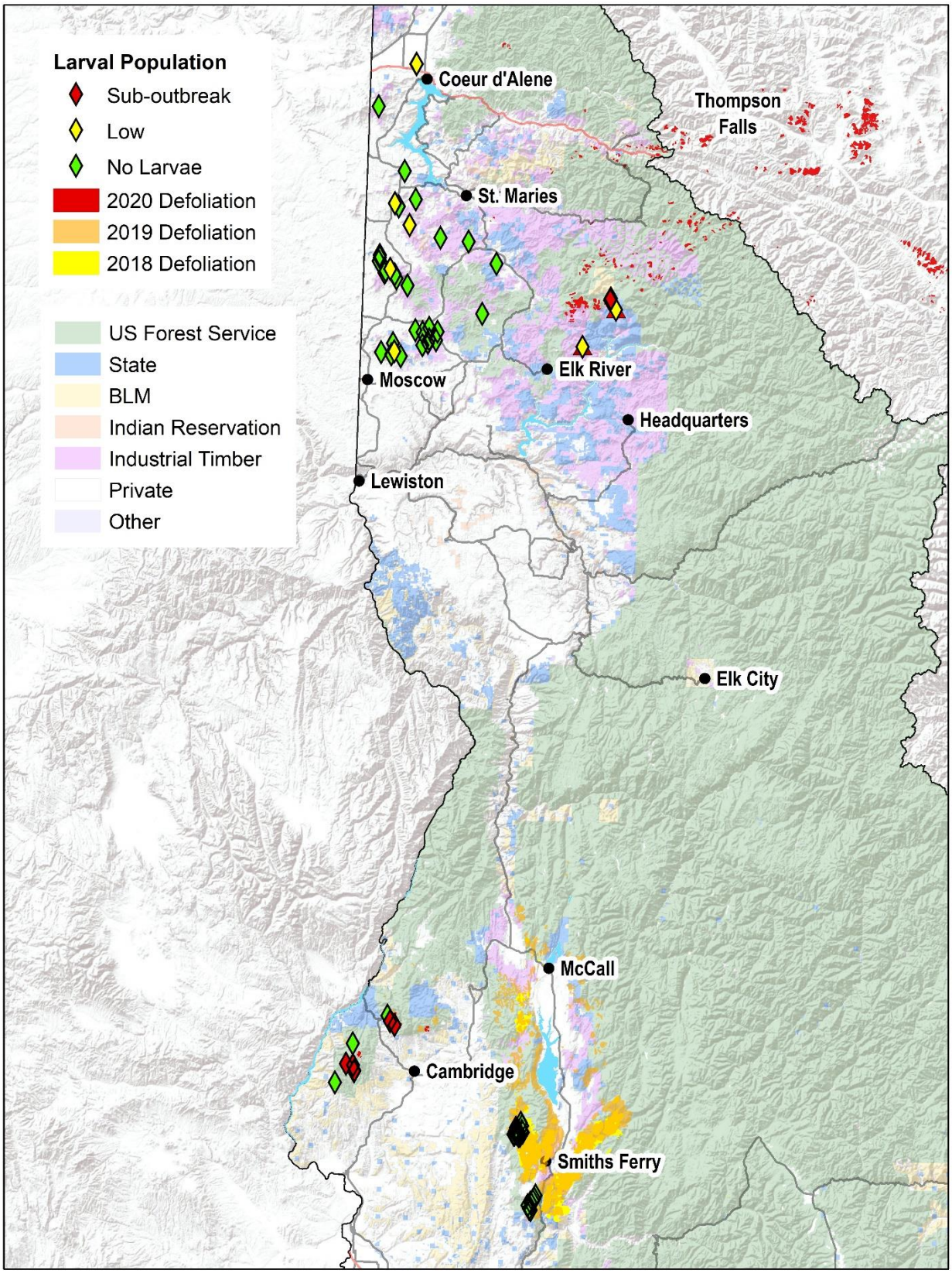

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Figure 16. Map of sites surveyed for Douglas-fir tussock moth egg masses in 2020.

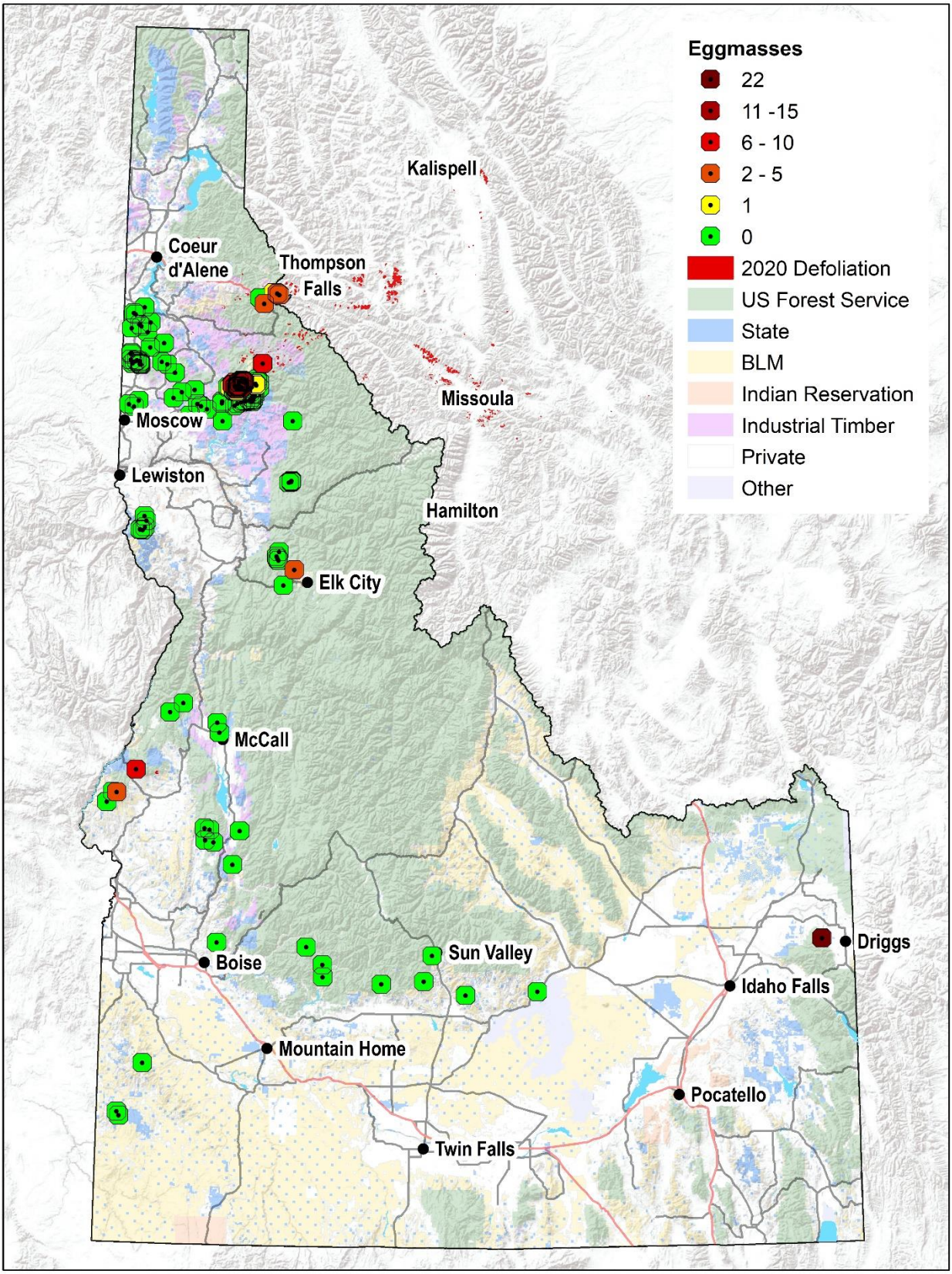

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Figure 17. Map of sites surveyed near the Floodwood State Forest for Douglas-fir tussock moth egg masses in 2020.

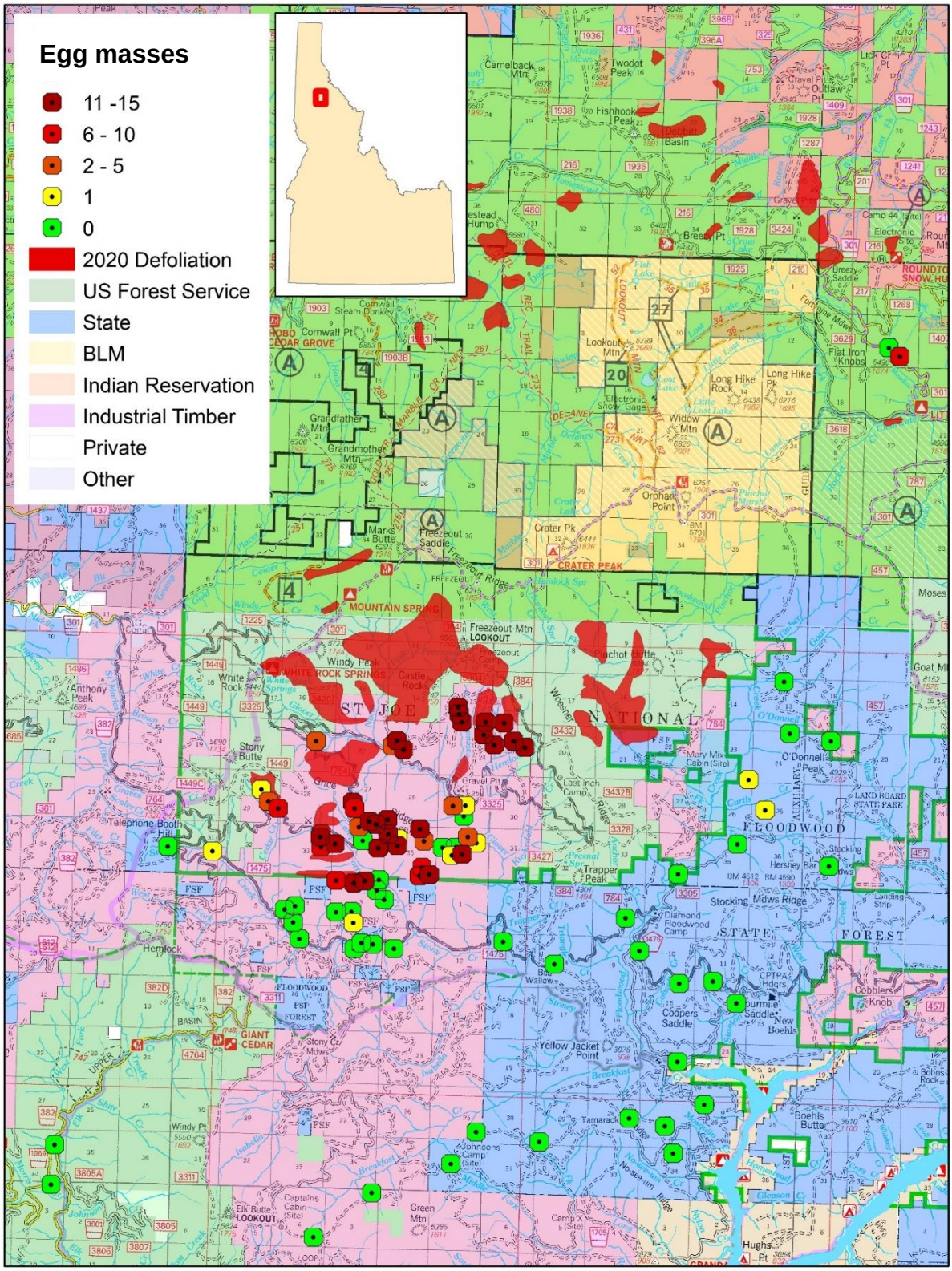

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Figure 18. Comparison of Douglas-fir tussock moth egg masses.
Only current egg masses that are potentially viable are counted during surveys. Old egg masses are not used for next year's estimation and are not counted in surveys. Current, unhealthy egg masses are counted in surveys, but are not likely to produce many offspring. Unhealthy egg masses suggest natural controls are acting on the population. The bottom photo shows an unhealthy, current year, egg mass that was collected near Moon Pass, Idaho in fall 2020.

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Figure 19. Douglas-fir tussock moth larva and cocoons that have been fatally infected by NPV. A. Dead DFTM caterpillar hanging in pose that indicates it was killed by NPV, a fatal virus that crashes populations. **B**. Parasitized larva that will not develop into an adult. Both photos taken in the Silver Valley in September 2020. No evidence of NPV was observed in the Floodwood area in 2020.

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Figure 20. Historic map of defoliation by Douglas-fir tussock moth near the Floodwood State Forest.

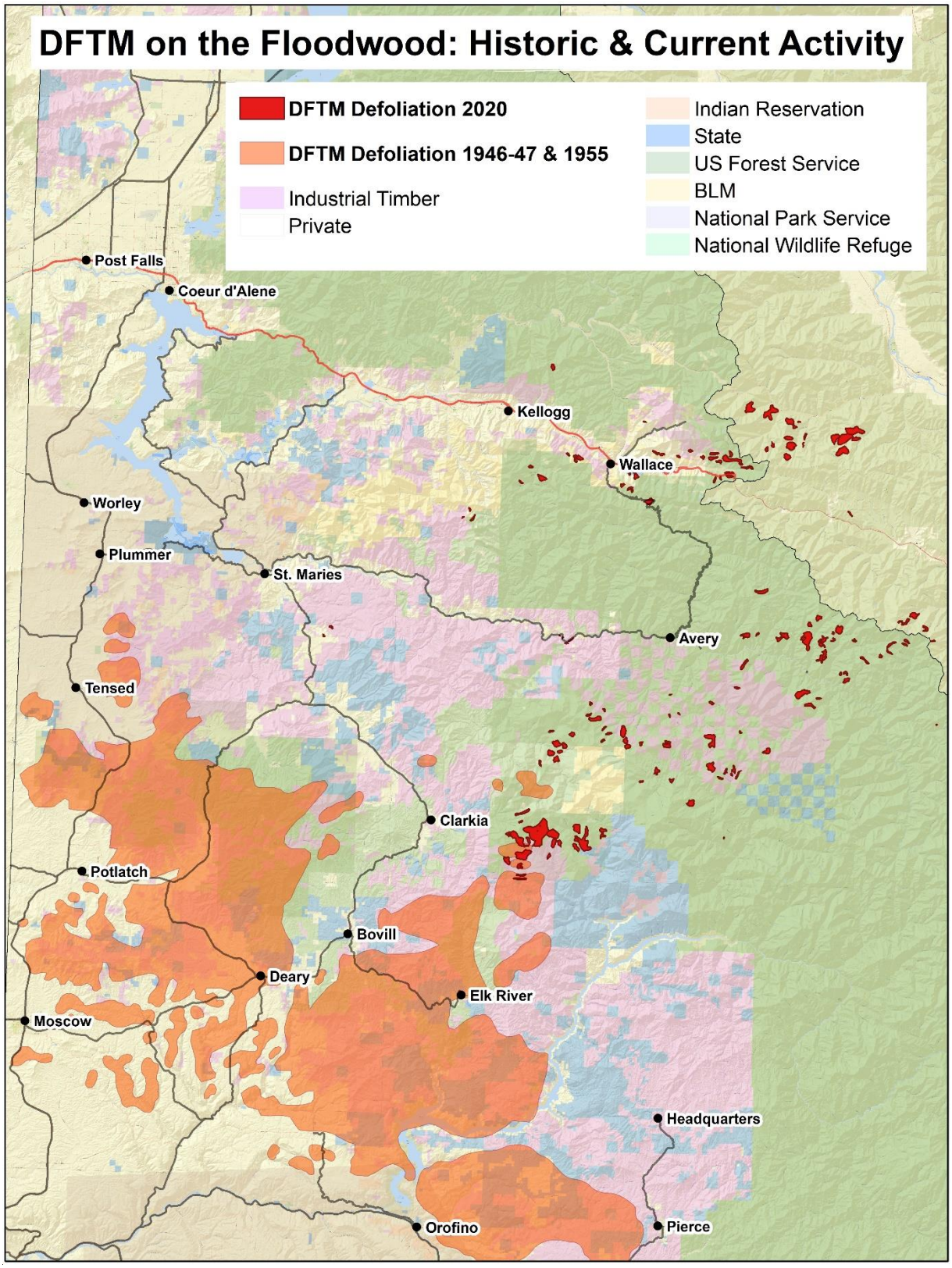

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Figure 21. Moderate Douglas-fir tussock moth defoliation seen at Moon Pass, Idaho in fall, 2020.
These trees will likely recover.

Figure 22. Map of UAS hanger plots on the Floodwood State Forest collected by the IDL remote sensing team. Plots show very little defoliation on IDL ownership, and defoliation that is captured is very light in severity. It is likely that defoliation will intensify in 2021. Click the link below to be taken to the interactive map.
http://gis1.idl.idaho.gov/portal/apps/webappviewer/index.html?id=6bc68140a73e469cbc291a20fd1315f7

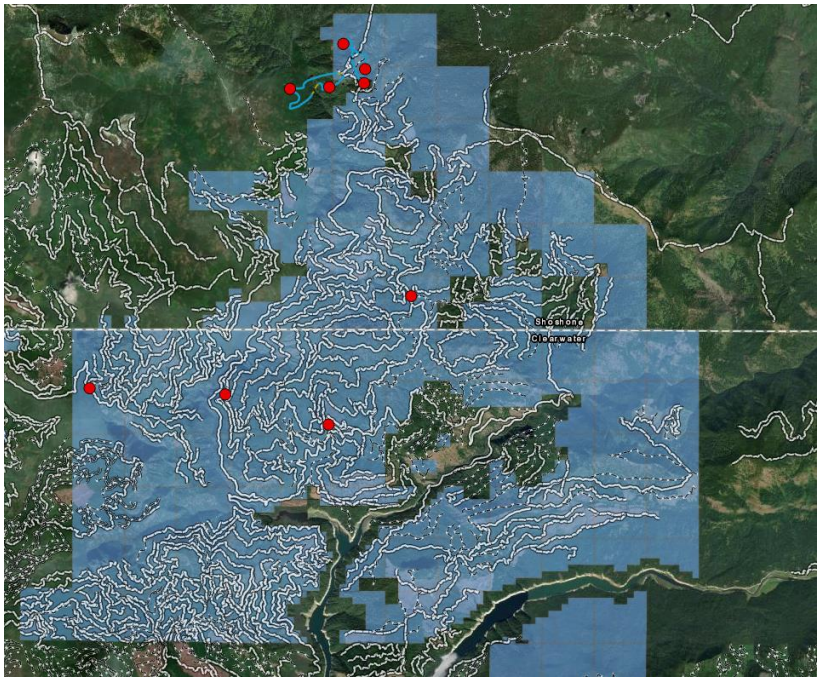

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Figure 23. **UAS footage of Douglas-fir tussock moth-caused defoliation on the Floodwood State Forest. A**. Light Douglas-fir tussock moth-caused defoliation as seen from far west point of the northern group of hanger plot points (figure 22). Only treetops have been defoliated. **B**. Very light defoliation as seen in the northernmost UAS hanger plot point. This defoliation was missed in aerial survey, but activity is evident in this drone footage.

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Figure 24. Defoliation caused by western hemlock looper in 2019 and Douglas-fir tussock moth in 2020. The outbreak zones overlap south of Avery and east of Clarkia. Trees defoliated multiple years in a row may have fewer resources to recover.

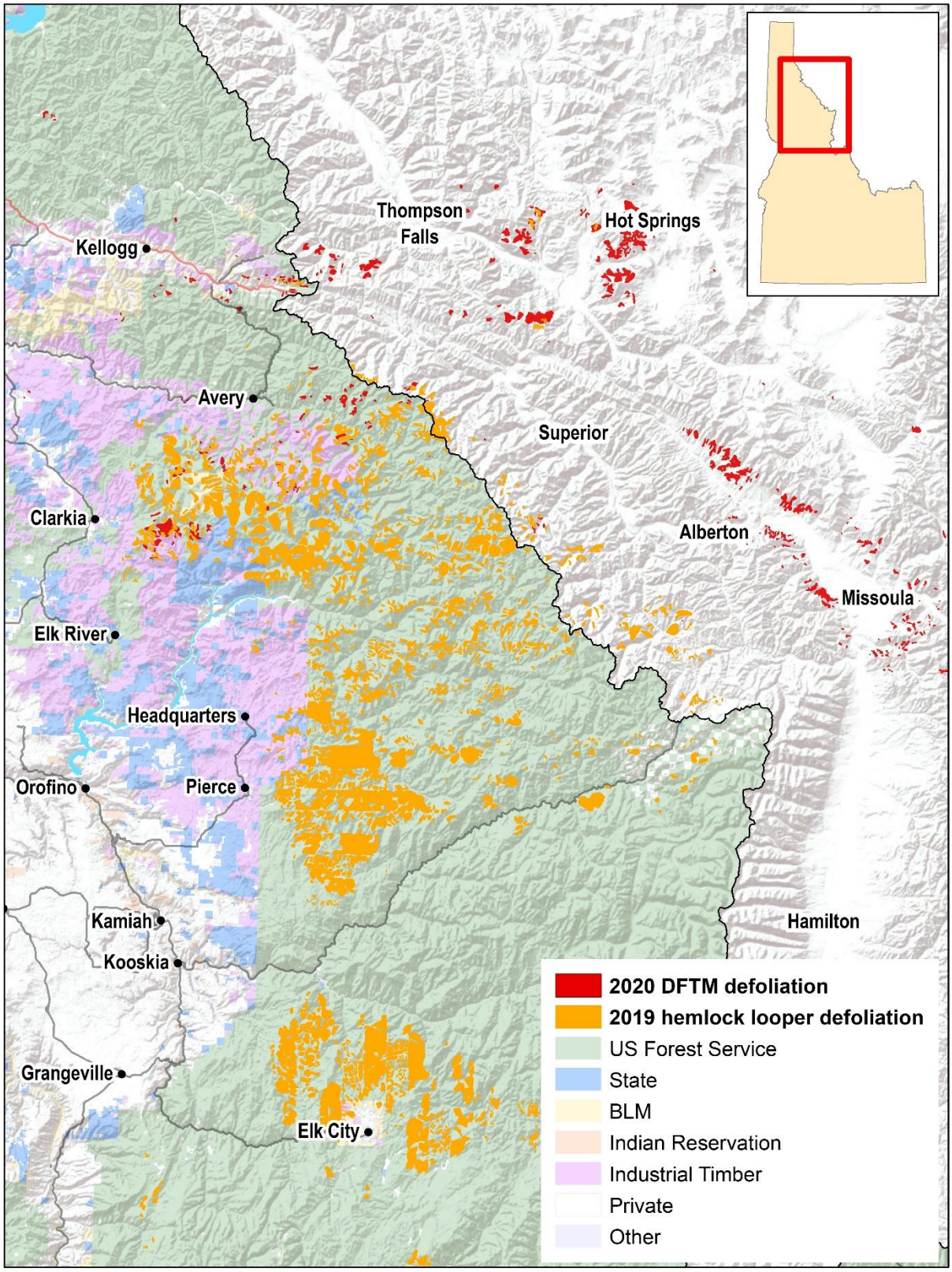

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Figure 25. Defoliation recovery monitoring plots in the Sagehen area on the Boise National Forest near Smiths Ferry.

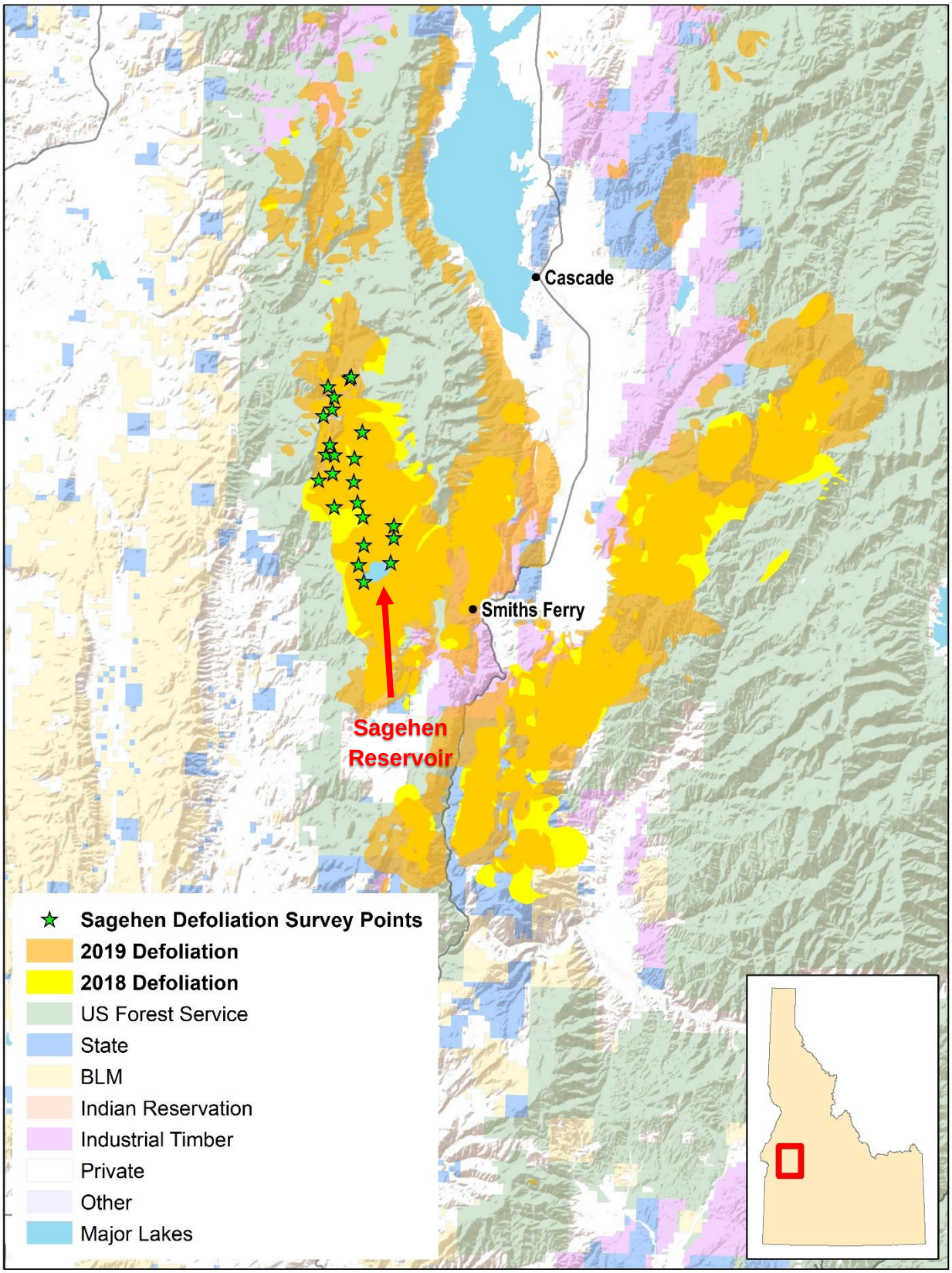

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Figure 26. Photos of 2020 tree recovery from defoliation monitoring plots in the Sagehen area. Trees were defoliated in this area by Douglas-fir tussock moth in 2018 and 2019. Photos by Nicole Green, USFS R4.

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