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DOUGLAS-FIR TUSSOCK MOTH BIOLOGICAL EVALUATION PALOUSE RANGER DISTRICT, CLEARWATER NATIONAL FOREST - 2000

Carol Randall, Forest Entomologist

ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

The Douglas-fir tussock moth (DFTM) periodically reaches outbreak levels in the forested lands of the Palouse Ranger District, Clearwater National Forest. In 2000, Idaho Department of Lands reports approximately 54,700 acres defoliated by Douglas-fir tussock moth near the town of Potlatch, Idaho (Ladd Livingston, Personal Communication). Most of the defoliation occurred on state and private ground, but 2,997 acres of light defoliation occurred on lands administered by the National Forest System.

There have been four other DFTM outbreaks near Potlatch since the 1940's. Outbreaks have generally been 10 or more years apart, and have resulted in 1 to 2 years of visible defoliation. Severe defoliation can result in growth loss, top kill, or tree mortality. Tree mortality tends to be patchy and occurs on a small percentage of the defoliated lands.

Surveys indicate that in 2001, defoliation will likely recur in the areas defoliated in 2000. Two areas on National Forest System lands, near Gold Hill and Mica Mountain, were not defoliated in 2000 but may experience defoliation in 2001; defoliation in 2001 is not expected on other USDA Forest Service (Forest Service) lands surveyed.

The need to respond to DFTM outbreaks should be dictated by an assessment of the potential for tussock moth defoliation to result in unacceptable consequences. There are a number of stand hazard rating systems available to help determine which stands are most likely to experience heavy defoliation, growth loss, top kill, and/or tree mortality. Once these high-hazard stands are identified, managers can work with other resource specialists to determine where tussock moth defoliation could result in an inability to meet stand management objectives. Those stands can then be evaluated for treatment.

Treatment strategies include prevention in which stand susceptibility is altered to prevent tussock moth populations from causing significant damage; and suppression, or direct control in which tools like insecticides are employed to directly reduce DFTM population levels. In areas where DFTM damage is not regarded as likely to result in unacceptable stand changes, managers may decide not to respond to outbreaks.

The visible defoliation experienced in 2000 indicates that the DFTM population either reached its peak in 2000 or will do so in 2001. DFTM outbreak populations decline rapidly after reaching their peak. The best time to initiate treatment strategies for DFTM is prior to the occurrence of defoliation. Treatments after the first year of defoliation are useful for foliage protection. For the Forest Service to respond to the current outbreak with direct control measures (aerial spray), an Environmental Impact Statement (EIS) would need to be completed. We anticipate populations will be declining from natural causes by 2002.

It is not too early to begin to consider how to respond to the next DFTM outbreak. Forest Health Protection is available and interested in working with Forest personnel on this issue.

INTRODUCTION

The Douglas-fir tussock moth (*Orgyia pseudotsugata*) periodically defoliates Douglas-fir, true firs, and other conifers in forests of the western United States and Canada. In the Northern Region, Douglas-fir tussock moth defoliation occurs about once every decade (Tunnock 1973). In 2000, Idaho Department of Lands reports approximately 54,700 acres of defoliation were mapped around Moscow Mountain and along Skyline Drive near Potlatch, Idaho (Figure 1). The last recorded defoliation from the Douglas-fir tussock moth in this area occurred in 1986 when 3,385 acres of defoliation were detected in aerial detection surveys (Stipe and James 1987).

The tussock moth is known as a fast cycling insect; populations rise quickly to visible defoliation levels which can cause significant growth loss, top kill, and mortality, and disappear just as quickly (Shepherd 1994). Defoliation tends to recur in the same general areas; the area defoliated in 2000 had four other defoliation episodes chronicled in regional reports. In this biological evaluation, I will review the basic biology of the tussock moth, the most common impacts of tussock moth defoliation, and site and stand characteristics associated with significant tussock moth damage. I will present information collected to date on the current tussock moth population in northern Idaho, review management options available, and discuss strategies for dealing with this insect on the Clearwater National Forest through future outbreaks.

GENERAL INFORMATION

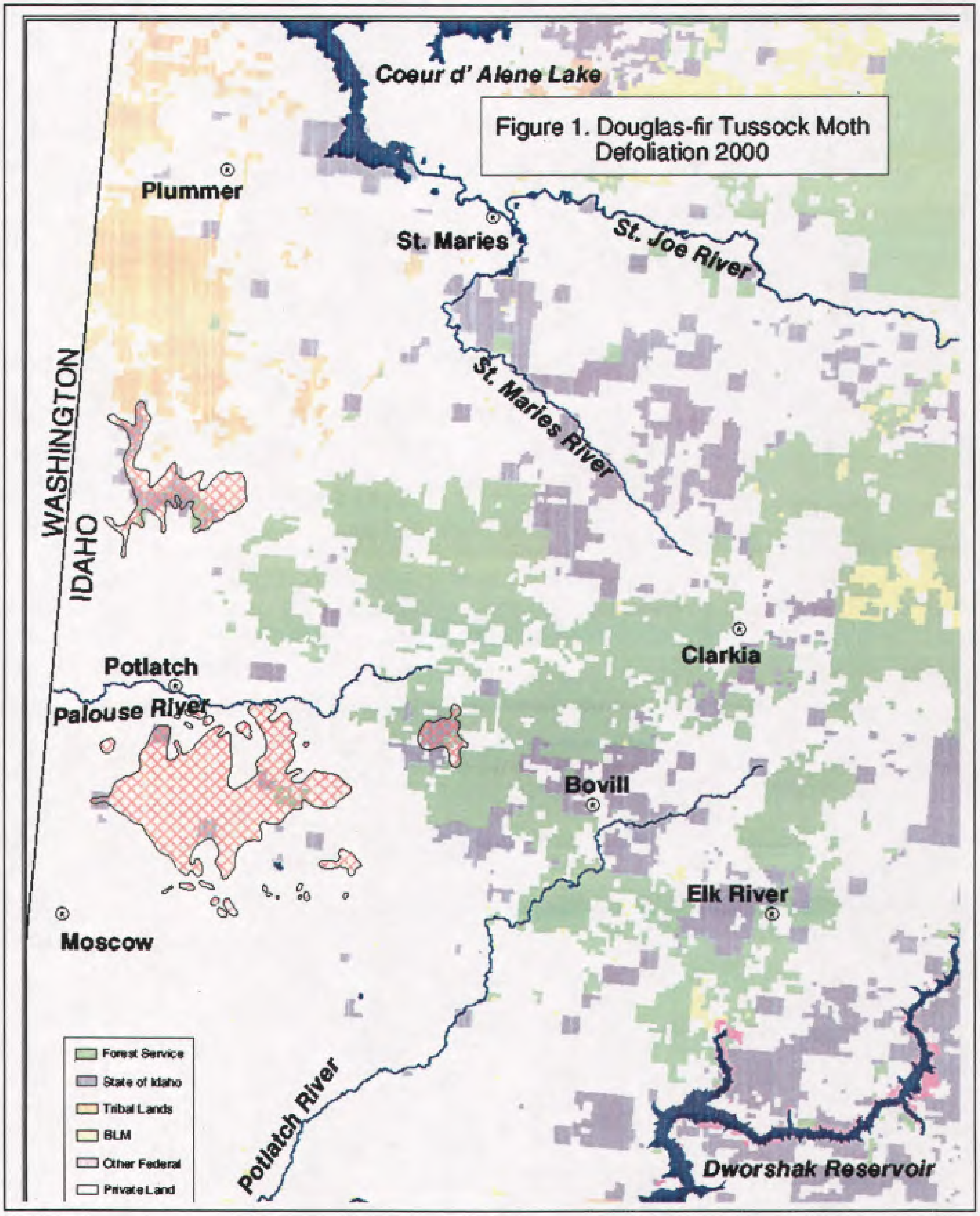
Host Species

The major tree species affected by the Douglas-fir tussock moth are Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*), and white fir (*Abies concolor*). Subalpine fir (*Abies lasiocarpa*) is a minor host (Wellner 1978). Defoliation in northern Idaho is largely restricted to grand fir stands; at lower elevations in eastern Washington, Oregon, and Idaho defoliation is most severe in Douglas-fir stands (Berryman 1986).

During tussock moth outbreaks, the foliage of less susceptible hosts may be eaten as preferred host foliage is depleted. Larvae that drop from host trees in the overstory often feed upon understory trees of all species. Plantings of ornamental spruces and firs may also be defoliated in towns miles from the nearest tussock moth infested forest (Mason and Wickman 1988).

Life Cycle

The Douglas-fir tussock moth has one generation per year. The insect overwinters in egg masses that contain between 150-250 eggs. Egg masses


Coeur d' Alene Lake
Figure 1. Douglas-fir Tussock Moth Defoliation 2000
Plummer
St. Maries
St. Joe River
St. Maries River
WASHINGTON
IDAHO
Clarkia
Potlatch
Palouse River
Bovill
Elk River
Moscow
Potlatch River
Dworshak Reservoir
Forest Service
State of Idaho
Tribal Lands
BLM
Other Federal
Private Land

gift

are most commonly found on the undersides of small branches. Egg masses are distributed throughout the foliar portions of the crown, but are concentrated in the upper crown (Sower et al. 1983), and may be found on the tree, including the trunk.

Eggs hatch in late spring, and leave the egg mass when shoot elongation is about 50% completed. Larval feeding occurs when it is too late in the season for a tree to respond with latent bud development, so when significant defoliation occurs, the tree cannot initiate new buds to replace lost foliage the next spring (Shepherd 1994). Small larvae produce silk strands for wind dispersal through the forest. First and second instar larvae feed exclusively on the undersides of soft, new foliage. This feeding kills foliage, which turns red, but may persist on the tree throughout the summer giving the tree a characteristic reddish cast. Faded foliage is often the first sign of tussock moth defoliation.

Because first and second instar larvae must feed on new foliage, and egg masses are concentrated in the upper portion of the crown, defoliation is most visible in the tops of host trees where the proportion of new foliage is highest. At higher densities of larvae, new foliage may be consumed in 2 or 3 weeks and larvae forced to feed on older foliage (Shepherd and Otvos 1986). Later instar larvae can completely strip all needles from trees if larval densities are extremely high (Mason and Wickman 1988).

Larval feeding lasts approximately 60 days (June and July), then pupation occurs (late July through August). Larvae spin cocoons in foliated portions of the crown, in bark crevices, on dead branches, and on twigs in the lower crown. Moths emerge in late summer, approximately 2 weeks after pupating. The female tussock moth is flightless and stays on her cocoon where she emits a pheromone attracting male moths. Mating occurs and the female lays egg masses on her cocoon. Female moths produce significantly more eggs when fed foliage from the upper crown. Tussock moth populations forced to feed on older, less nutritious foliage are generally smaller as larvae and pupae, have a lower female sex ratio, lower fecundity, and longer developmental times (Sower et al. 1983).

Population Dynamics

Douglas-fir tussock moth abundance may be extremely variable over time with densities fluctuating by orders of magnitude (10-100,000 fold) in susceptible stands. Populations of tussock moth periodically increase sharply, persist for a few years, and then suddenly decline (Mason and Luck 1978; Harris et al. 1985).

Population fluctuations that lead to visible defoliation are easily identified, but lesser peaks in population may go unnoticed. Sudden defoliation of trees gives outbreaks the appearance of having developed spontaneously when populations have been building continuously for years (Mason and Wickman 1988).

At low population levels, insect parasites and vertebrate and invertebrate predators are primary causes of tussock moth mortality. These predators and parasites may cause the collapse of populations before defoliation occurs. In overcrowded populations, dispersal loss, starvation, infertility, and disease become increasingly important (Mason and Wickman 1988).

OUTBREAKS

Definitions

During outbreaks, trees become conspicuously defoliated (Mason and Wickman 1988). Tussock moth outbreaks are generally preceded by several years of consecutive population increases that may be detected by conventional methods of sampling adults and larvae (Mason et al. 1993). In some areas, perhaps due to inaccurate sampling, tussock moth populations appeared to reach outbreak levels from endemic levels in a single year making prediction of impending damage impossible (Harris et al. 1985).

Suboutbreak populations do not cause visible defoliation. Not all populations that reach suboutbreak densities cause outbreaks (Mason et al. 1993).

Conceptual Model of an Outbreak

Outbreaks have a pattern that can be separated into four phases: a release phase in which tussock moth populations rapidly increase to outbreak numbers; a peak phase when insect densities reach their maximum; a decline phase when populations begin a rapid decrease; and a post decline phase when populations reach their lowest levels Figure 2). Each phase generally lasts a year and is defined by population level, defoliation intensity, and within generation insect survival rates. Once a population has entered the outbreak sequence, the course of the outbreak is relatively predictable. Insect survivorship is relatively high during the peak phase so more larvae are available to feed for longer periods of time resulting in highest defoliation. By the declining phase, an increase in natural mortality usually reduces survival and the population declines. However, defoliation may still be significant. By the post decline phase, populations are continuing to decrease and defoliation is not as severe as in the peak phase (Mason and Luck 1978).

Spatial and Temporal Development of an Outbreak

Outbreaks appear to be synchronized over large geographic areas (such as northern Idaho and the Blue Mountains of eastern Oregon). Tussock moth outbreaks do not seem to spread, but build up more or less synchronously in particular areas (Berryman 1986). In some parts of the tussock moth range, the same stands are involved in each outbreak episode. In other parts, the same stands seldom have successive outbreaks; outbreaks merely occur in the same general area (Berryman 1986, Stage 1978). During outbreaks, not all stands that appear identical in present conditions and past history are defoliated (Stage 1978), but stands adjacent to outbreak areas generally experience suboutbreak populations that may reach outbreak levels in subsequent years leading to the appearance of spreading populations.

The appearance of defoliation is less synchronized than the collapse of populations (Shepherd et al. 1988).

The interval between outbreaks is usually 8 years or longer, with some indication of periodicity (Stage 1978). Outbreaks may only occur every second or third population fluctuation of the tussock moth, meaning that for every incidence of defoliation witnessed, tussock moth populations may have reached suboutbreak population levels 2–3 times, but declined before causing defoliation (Harris et al 1985).

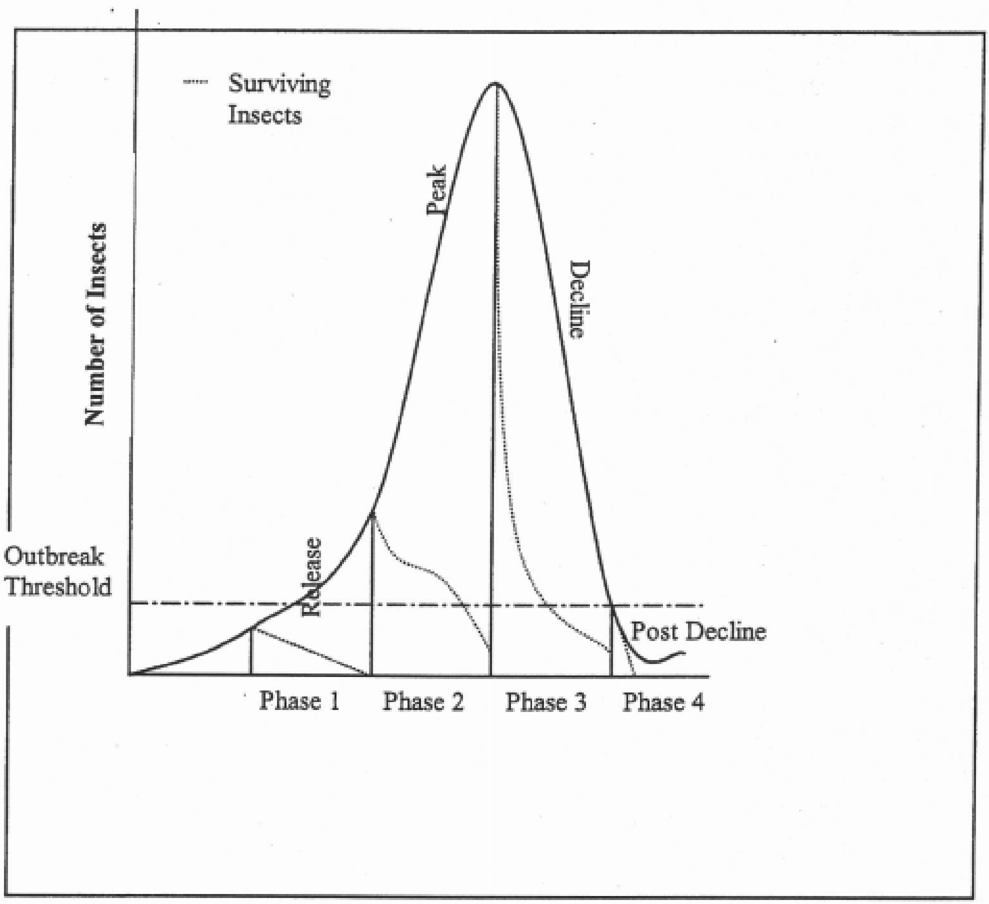
Outbreaks of tussock moth in the forest may be preceded a year or two by infestations of individual ornamental or shade trees (including spruce as well as preferred host species) around private homes or farms, in some cases miles away (Harris et al. 1985; Berryman 1986; Mason and Wickman 1988; Shepherd et al. 1988). In the forest, defoliation generally occurs in distinct patches in the first year, with patches coalescing in the second and third years of the outbreak as populations in adjacent stands rise to outbreak levels (Shepherd and Otvos 1986; Shepherd et al. 1988).

After 1-5 years, populations of tussock moth in all stands collapse together regardless of population density, and rapidly decrease to low population levels (Shepherd et al 1988). Slight lags effects may occur in fringe areas of outbreaks. Populations in fringe areas may not collapse until a year after populations in the main outbreak area have subsided (Mason 1978).

Causes of Collapse

The collapse of outbreaks is thought to be due to natural factors in the system such as predators, lack of food, and/or disease. Douglas-fir tussock moth survival rates during outbreaks are inversely related to the degree of defoliation; outbreaks collapse faster in heavily defoliated areas than in lightly defoliated areas (Mason and Wickman 1988)

Figure 2. Conceptual representation of an outbreak sequence of the Douglas-fir tussock moth with generalized patterns of within generation survivorship.



Reviews of outbreaks suggest repeated widespread nucleopolyhedrosis viral (NPV) epizootics are responsible for the collapse of tussock moth populations (Shepherd et al. 1988). In most observed tussock moth outbreaks, NPV has initially either been absent or present at a rate below detection (Thompson and Scott 1979). Virus epizootics are triggered suddenly in stressed populations rather than building up gradually with increasing population density (Mason and Wickman 1988; Thompson and Scott 1979). The ingestion of a single virus particle is probably sufficient to cause infection of a larva (Shepherd et al. 1988). The spread of virus by dispersing larvae, parasites, wind, etc. result in virus epizootics that reduce tussock moth populations to very low levels over large areas and may synchronize the next tussock moth outbreak cycle (Berryman 1986). In suburban infestations of tussock moth on spruce trees where virus was not present, defoliation persisted for an extended period of time (9-12 years) (Shepherd et al. 1988), further supporting the role of NPV in regulating the short timeline of tussock moth outbreaks on the Forest.

Site and Stand Conditions Favoring Douglas-fir Tussock Moth Outbreaks

Outbreaks of the Douglas-fir tussock moth are most common on the warm, dry edges of the distribution of its major hosts. The most severe outbreaks tend to develop in forest/grassland ecotones that are only marginal for the growth of fir (Mason and Wickman 1988).

Stoszek and Mika (1978) studied outbreaks in northern Idaho and found that tussock moth population dynamics were apparently influenced by conditions peculiar to particular sites and stands. After conducting surveys in outbreak and non-outbreak areas, they found the following site conditions to be associated with outbreak populations.

- Stands on or near ridge tops sustained heavier defoliation than stands lower on slopes.
- Stands on sites with a deep mantle of volcanic ash (increasing water holding capacity) were less defoliated than those on sites with little or no ash.
- Defoliation was higher on sites with poorer productivity.
- Defoliation increased as average age of host trees increased. Young stands (less than 50 years old) showed little defoliation, regardless of the nature of the location of the stand.
- Defoliation was greater in stands with a large range in tree heights. One-storied stands were less defoliated than multi-storied stands.
- Defoliation increased as the ratio of density or amount of tree biomass per unit area to site productivity increased.
- Defoliation increased as the proportion of grand fir increased. Grand fir was more heavily defoliated than Douglas-fir, indicating that it was the preferred host in northern Idaho.

In northern Idaho, land management practices may be partially responsible for development of Douglas-fir tussock moth outbreaks. Historically, ponderosa pine likely dominated many of the fir forests currently affected by tussock moth outbreaks. Ponderosa pine was slowly replaced by fir species through logging activities and fire suppression (Mason and Wickman 1988). Likewise, in northern Idaho many low-elevation Douglas-fir sites were harvested and grand fir was left on the site. Exclusion of fire on these sites increased tussock moth hazard by allowing multi-storied, dense, grand fir dominated stands to develop. Historically, Douglas-fir tussock moth populations likely existed in ponderosa pine and Douglas-fir forests, but since preferred hosts were not overly abundant, it is likely that outbreaks did not frequently develop (Berryman

1986). As long as susceptible host types prevail on high-risk sites, periodic outbreaks are likely to continue (Mason and Wickman 1991).

Impacts of Outbreaks on Trees

Tussock moth outbreaks may reduce tree growth, cause top kill, or kill trees outright. Data on tree mortality, top kill, and stand development after outbreaks show a consistent relationship between the degree of defoliation and the amount of damage to Douglas-fir and grand fir.

Impact of tussock moth on host species differs from defoliation by western spruce budworm (*Choristoneura occidentalis*). Tussock moth defoliation causes significantly more rapid growth reductions and greater growth loss than budworm defoliation. Budworm defoliation tends to impact grand fir growth more than Douglas-fir; tussock moth defoliation effects on growth loss are not significantly different between Douglas-fir and grand fir (Brubaker and Green 1979). Tussock moth defoliation is more damaging than budworm defoliation because it completes its feeding later in the season. Budworm defoliation occurs early in the year allowing latent buds to form in the axils of needles. Tussock moth defoliation occurs too late in the season for trees to respond with latent bud development. Consequences of tussock moth defoliation are, therefore, more serious and tree mortality is more likely to occur (Shepherd 1994).

Both radial and height growth of trees is sharply reduced during and immediately after a tussock moth outbreak. Growth reduction is proportional to the amount of defoliation and most pronounced in trees defoliated 50% or more. Recovery from defoliation is often dramatic and growth usually returns to pre-outbreak rates within 5 years. After 10 years, growth rates may surpass pre-outbreak levels (Mason and Wickman 1988).

Top kill is common in trees defoliated more than 50%; pole or larger trees with dieback of one-half or more of the crown become more susceptible to bark beetle attacks and heart rot. As a general rule, 90% of trees that die have been defoliated at least 90%. Trees that lose 50%-75% of their foliage rarely die from effects of defoliation alone, but in some outbreaks many trees were subsequently attacked and killed by bark beetles. Indirect mortality from bark beetles usually occurs within 3 years of defoliation.

Patterns of Tree Mortality

More than 50% of total tree mortality is concentrated in patches that make up a relatively small portion of the outbreak area (usually 10%-14%) (Mason and Wickman 1988). Forest stands are often thinned during tussock moth outbreaks, and total mortality rarely exceeds 25%-30% even in severe outbreaks. Within 2 years of tussock moth outbreaks, impacted stands look green again (Berryman1986).

Ecological Implications of Outbreaks

Traditionally, tussock moth outbreaks have been blamed for declines in forest health, however many researchers now view tussock moths and other native defoliators as agents which contribute to the maintenance or recovery of forest health (Schowalter 1991 and 1993, Mattson and Addy 1975). Studies suggest that tussock moth outbreaks reflect an over taxed biomass carrying capacity (Klock and Wickman 1978).

Mortality caused directly by defoliation, or by subsequent attack by bark beetles helps to reduce the biomass on a site. Mortality also causes a thinning effect, resulting in increased availability of nutrients and light to residual trees. Defoliation is also thought to lead to enhanced tree growth through increased nutrient cycling. Fallen needles and insect frass (insect excrement and partly digested needles) have been estimated to increase available nitrogen and other nutrients by nearly 10 times that returned with normal litterfall (Mason and Wickman 1988).

While there are serious short- and long-term impacts of tussock moth defoliation on timber production, the role of the tussock moth as a regulator of forest health should not be overlooked. Increases in the quality of host food and decreases in host resistance tend to be brought about by the interaction of host age, stressful climatic conditions, low fertility of the site, and bottlenecks in the flow of certain vital nutrients (Mattson and Addy 1975). Tussock moth outbreaks in northern Idaho are occurring on sites that were historically dominated by pine and Douglas-fir. Stress of the environment reduces vigor of grand fir, and abundance of grand fir supports higher endemic populations of tussock moth. Tussock moth outbreaks may help to alter future stand composition on these sites to better-adapted species such as pine.

In one study on an historic pine-dominated, mixed-conifer site, which converted to grand fir dominance, tussock moth defoliation resulted in heavy grand fir mortality and increased abundance of pine regeneration. While tussock moth defoliation increased the abundance of pine, grand fir was still the most prevalent species, and barring further disturbance (such as fire), grand fir will slowly dominate and canopy closure will occur preventing pine from becoming a significant stand component setting the stage for subsequent tussock moth outbreaks (Wickman, Seidel, and Starr 1986).

In conclusion, tussock moth outbreaks may play a beneficial role, over the long term, as regulators of forest health. Tussock moth outbreaks respond to site and stand conditions that are not optimal for tree growth, and resulting mortality in these overtaxed stands may benefit residual trees by thinning the stand and increasing availability of necessary nutrients and light. Tussock moth outbreaks alone, however, are not capable of restoring historic stand conditions if other disturbance factors (such as fire) are excluded.

Impacts of tussock moth outbreaks on other ecosystem components are variable. The abundance of caterpillars in the peak phase of an outbreak cycle may provide local animals with an additional food source. Significant defoliation can result in changes in amount of light penetration to the forest floor, stand ambient air temperatures, and wind speed through the canopy. Defoliation may impact water yield, wildlife habitat quality, and wildfire fuel loadings; these impacts tend to be short lived, from 1 to 3 years after defoliation ceases. Where tussock moth outbreaks result in tree mortality, the patchy nature of mortality groups may create small meadows or thin stands. Impacts on stand microclimate and wildlife habitat resulting from tree mortality will be longer lived than defoliation impacts.

Effects of Douglas-fir Tussock Moth on Human Health

In addition to tree and stand impacts, tussock moth outbreaks may impact human health. The hairs of the tussock moth are urticating, and are known to cause nonspecific irritations as well as allergic reactions (commonly called tussockosis). The most common reaction to the presence of urticatious hairs in the environment is a rash, though respiratory track symptoms (difficulty breathing) are possible. Individuals who have a history of continuous contact with the insect most commonly experience respiratory symptoms. Persons with a history of general allergic symptoms show a higher incidence of reactions to tussock moths hairs (Perlman et al. 1976).

Tussockosis may occur in humans during suboutbreak populations of tussock moth. Rogers (2000) was alerted to high tussock moth populations at the Dale Resler Boy Scout Camp by a Center for Disease Control Epidemic Intelligence Officer assigned to the New Mexico Department of Health. The officer was following up on an inquiry from an allergist who was treating a 12-year-old boy for fatigue, hives, and headache following the boy's return home from a camp. No defoliation of the site was visible, though tussock moths were abundant.

The History of Douglas-fir Tussock Moth around Potlatch, ID

Periodic outbreaks of Douglas-fir tussock moth have been recorded in northern Idaho for over 50 years. At least four of these outbreaks resulted in visible defoliation in the vicinity of the 2000 defoliation

1946-47: The 1946 aerial survey showed defoliation visible over 350,000 acres in Clearwater, Latah and Benewah Counties. In 1947, the defoliated acres increased to 395,535 (Figure 3) and all 395,535 acres were sprayed with DDT. No living larvae were found anywhere in the treated area. In 1947 another outbreak was located on 20,000 acres east of Orofino Idaho. This second outbreak was not treated and a combination of virus and parasites terminated the infestation before moths could emerge in the late summer (Tunnock et al. 1985).

1964-1965: The 1964 aerial survey showed defoliation visible over 70,000 acres in Benewah and Latah Counties. In 1965, visible defoliation increased to 225,000 acres in Benewah and Latah Counties (Figure 4). About 120,000 acres of this infestation were sprayed with DDT. Six days after the spray, no living larvae were found on sample trees along mortality lines in spray blocks. Few 1965 egg masses could be found in the untreated defoliated areas in the fall of 1965. Infestations in untreated areas are thought to have died out from virus and parasites (Tunnock et al. 1985).

1973-1974: In 1973, aerial surveys showed defoliation was visible on 70,000 acres of grand fir type in Benewah and Latah Counties. In 1974, visible defoliation was recorded on 115,000 acres in Idaho, Clearwater, Benewah, and Latah counties. On the Palouse Ranger District, defoliation occurred on approximately 54,000 acres (Figure 5). Also in 1974, DDT was applied to 75,254 acres in Benewah and Latah Counties. The reason for the collapse of this outbreak is not certain, though insecticide applications did result in significant larval mortality. Egg masses could be found in infested areas in the fall of 1974; however; no defoliation was noted in 1975 (Tunnock et al. 1985).

1985-1986: In 1985, there was no visible defoliation, but pheromone traps, larval, and egg mass surveys indicated an increasing population of tussock moth larvae from Moscow to Plummer, Idaho. A spray project was planned for 1986, but high populations never materialized and visible defoliation only occurred on 3,385 acres (Figure 6). There was no readily apparent cause of population collapse.

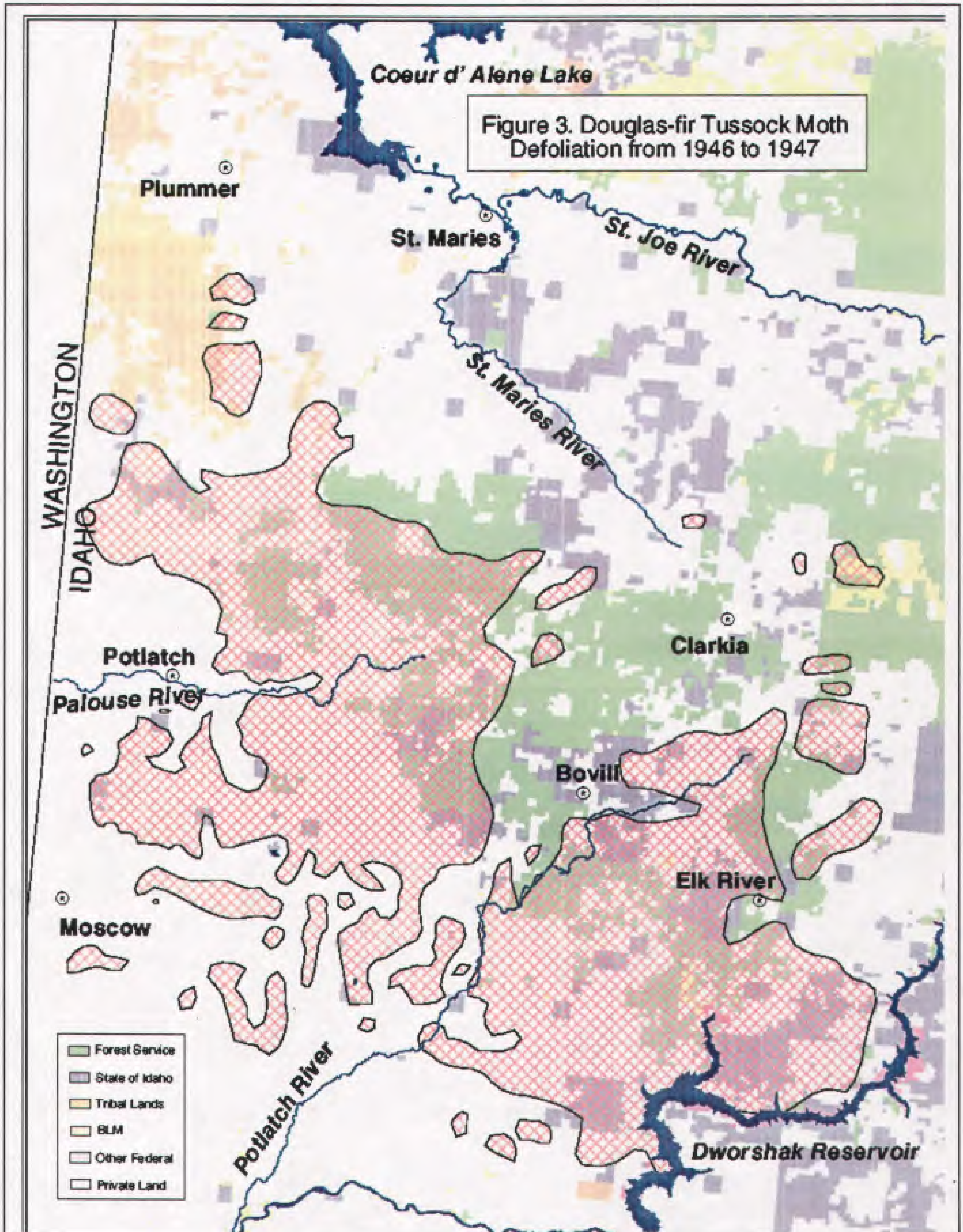
INFORMATION ON THE 2000 OUTBREAK

Idaho Department of Lands has been monitoring Douglas-fir tussock moth populations in forested lands around Potlatch, Idaho since the early 1980's. Each year pheromone detection traps are placed in established monitoring sites. Idaho Department of Lands personnel also conduct annual lower crown larval sampling at pheromone trap sites. Once the numbers of moths in pheromone traps or lower crown larval sampling results reach certain threshold levels, additional cocoon, and/or egg mass surveys are conducted to help define the distribution of the increasing tussock moth population and determine if defoliation is imminent.

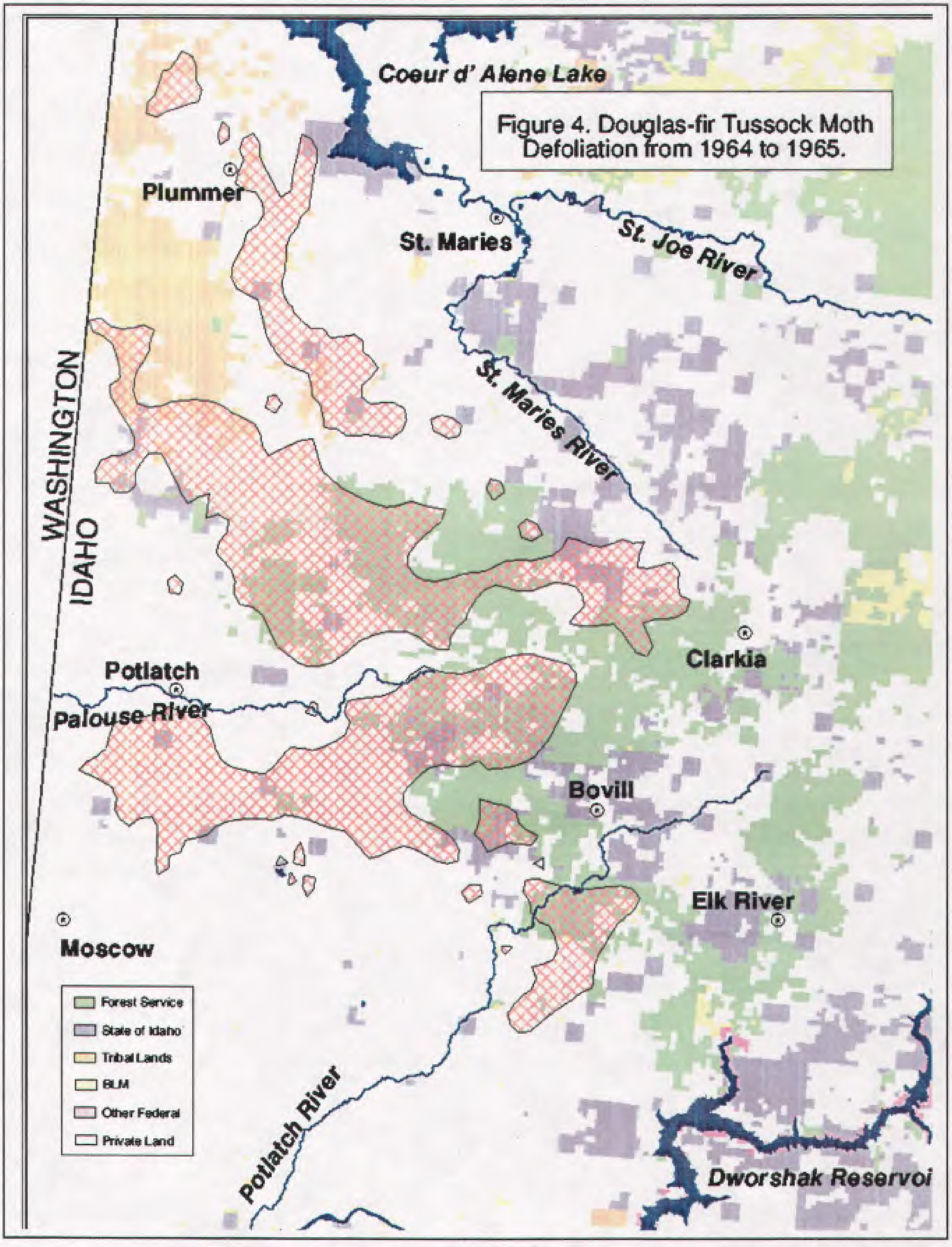
Pheromone Detection Trapping and Larval Sampling

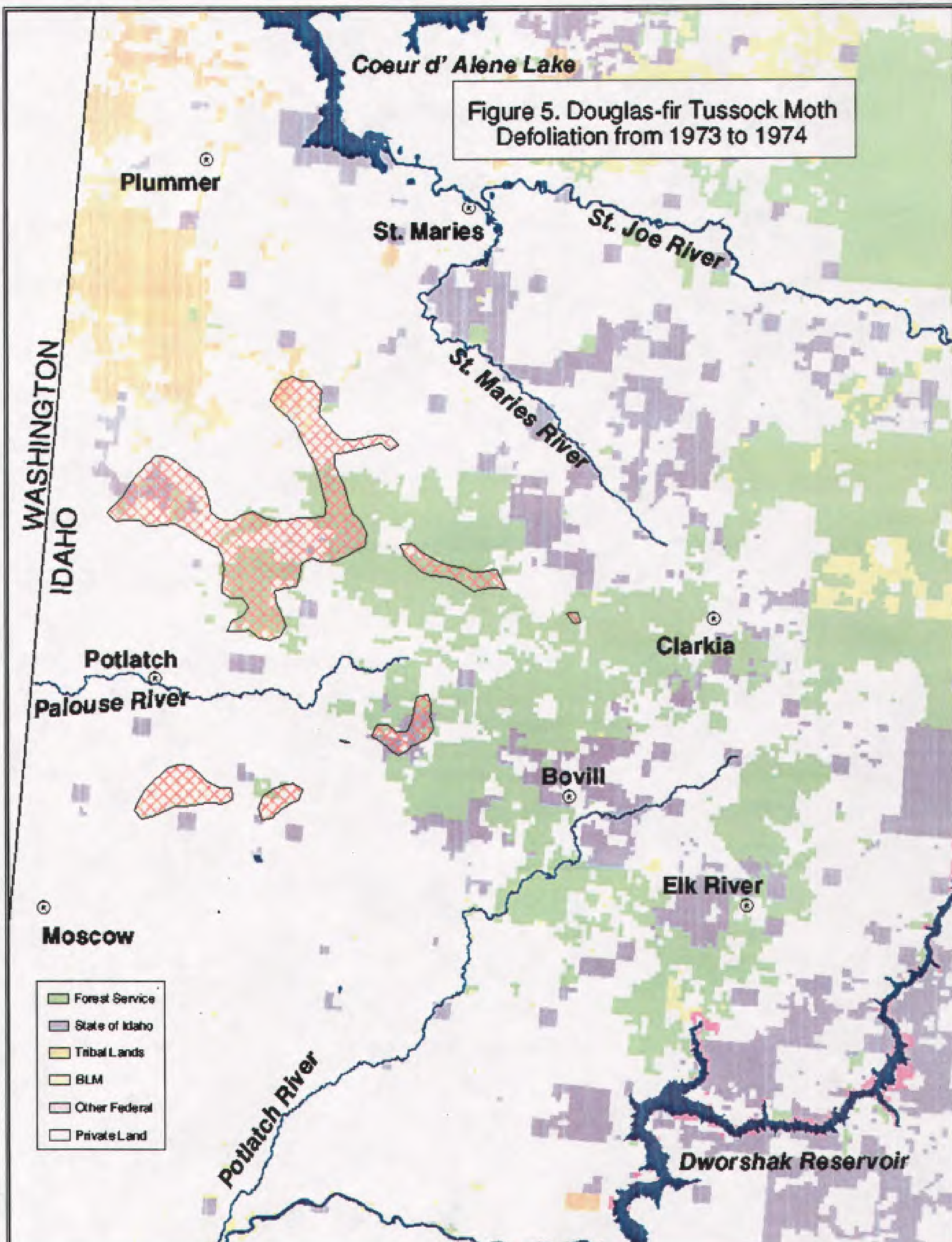
The Douglas-fir Tussock Moth Early Warning System is a cooperative effort between Forest Service and Idaho Department of Lands. This system uses a series of permanent pheromone trapping sites to identify increasing populations of the tussock moth prior to a defoliation event. Idaho Department of Lands maintains Douglas-fir tussock moth traps sites north of Lewiston, ID (Figure 7); the Forest Service maintains trap sites south of Lewiston to the Salmon River. Similar Douglas-fir Tussock Moth Early Warning Systems are in place in other western states.

Once pheromone trap catches reach a certain threshold level (generally 25 or 40 average male moths per trap) additional population sampling is conducted. Additional sampling of cocoons and/ or egg masses may be conducted following trapping efforts, or early larval sampling the following spring (Mason et al. 1993; Mason and Paul 1994; Shepherd et al. 1984).



Coeur d' Alene Lake
Figure 3. Douglas-fir Tussock Moth Defoliation from 1946 to 1947
Plummer
St. Maries
St. Joe River
St. Maries River
WASHINGTON
IDAHO
Potlatch
Palouse River
Clarkia
Bovill
Elk River
Moscow
Potlatch River
Dworshak Reservoir
Forest Service
State of Idaho
Tribal Lands
BLM
Other Federal
Private Land


Coeur d' Alene Lake
Figure 4. Douglas-fir Tussock Moth Defoliation from 1964 to 1965.
Plummer
St. Maries
St. Joe River
St. Maries River
WASHINGTON
IDAHO
Clarkia
Potlatch
Palouse River
Bovill
Elk River
Moscow
Forest Service
State of Idaho
Tribal Lands
BLM
Other Federal
Private Land
Potlatch River
Dworshak Reservoi


Coeur d' Alene Lake
Figure 5. Douglas-fir Tussock Moth Defoliation from 1973 to 1974
Plummer
St. Maries
St. Joe River
St. Maries River
WASHINGTON
IDAHO
Potlatch
Palouse River
Clarkia
Bovill
Elk River
Moscow
Forest Service
State of Idaho
Tribal Lands
BLM
Other Federal
Private Land
Potlatch River
Dworshak Reservoir

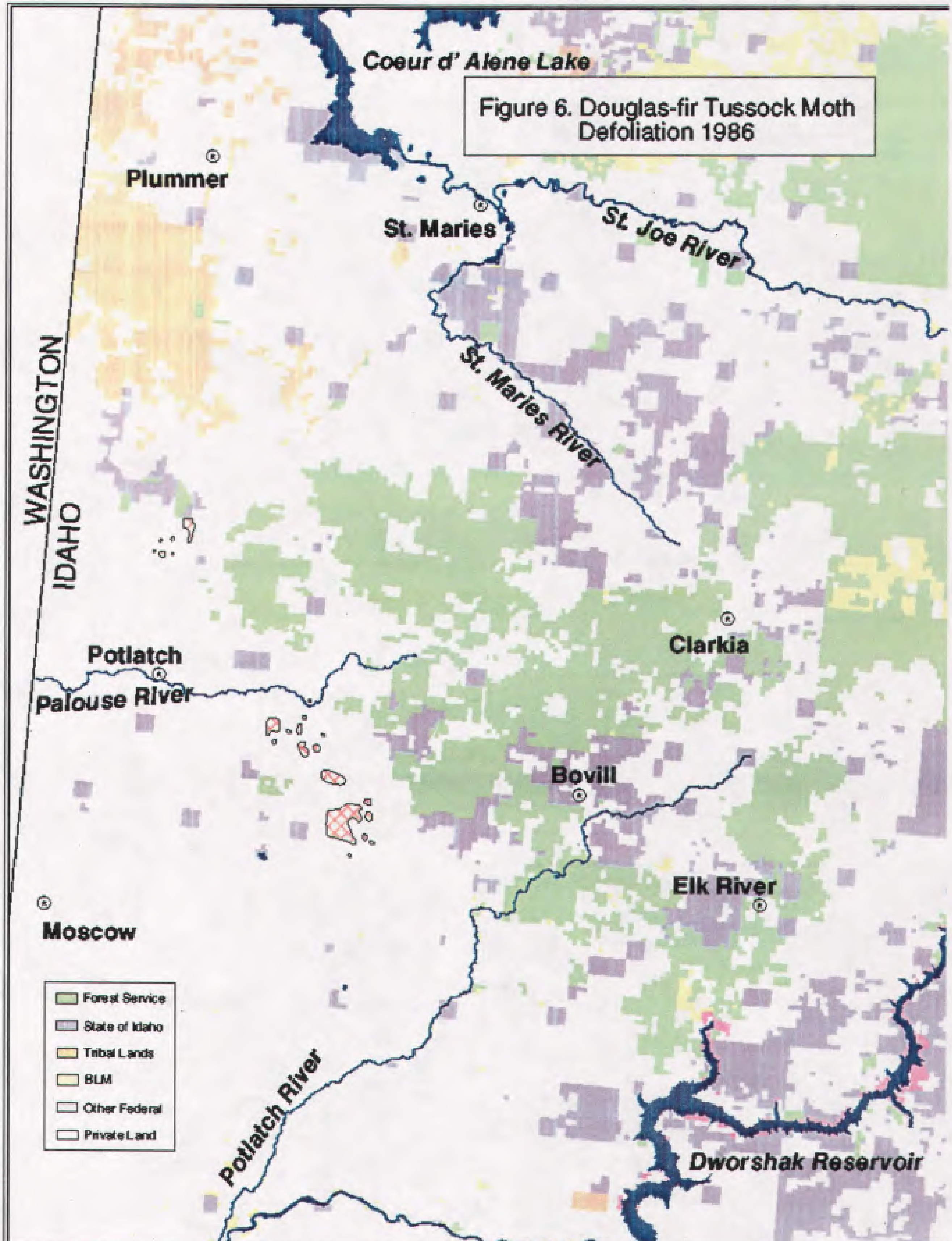


Figure 6. Douglas-fir Tussock Moth Defoliation 1986

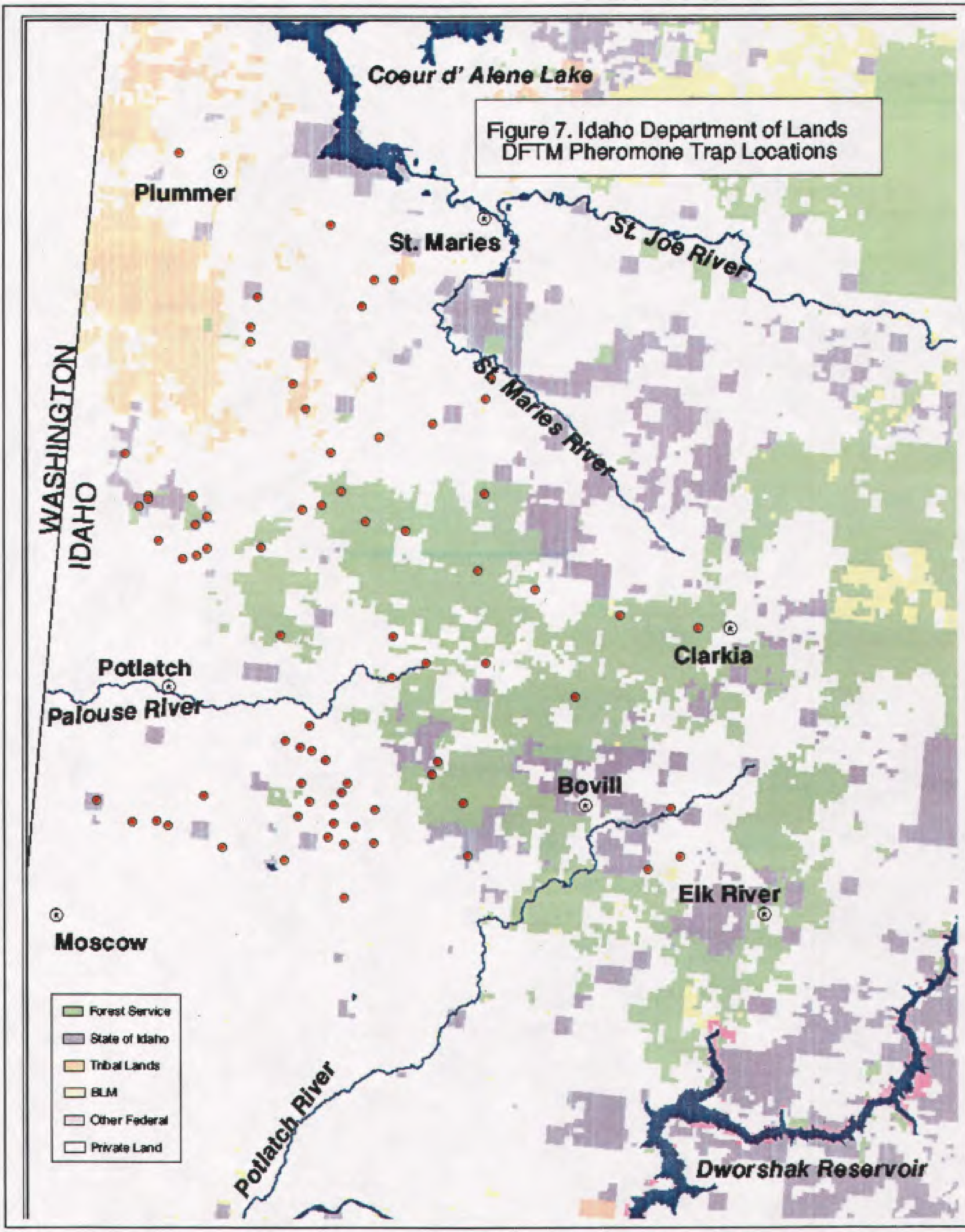
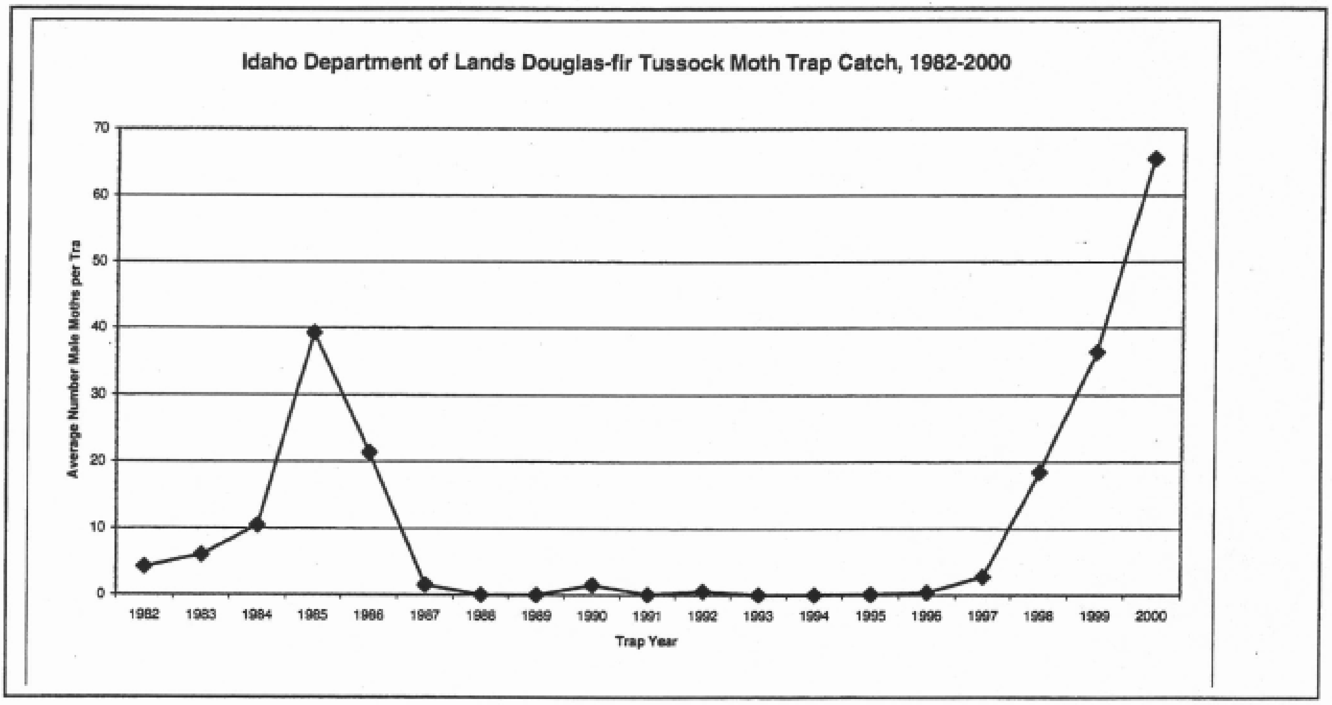


Figure 7. Idaho Department of Lands
DFTM Pheromone Trap Locations
Coeur d' Alene Lake
Plummer
St. Maries
St. Joe River
St. Maries River
WASHINGTON
IDAHO
Potlatch
Palouse River
Clarkia
Bovill
Elk River
Moscow
Potlatch River
Dworshak Reservoir
Forest Service
State of Idaho
Tribal Lands
BLM
Other Federal
Private Land

Figure 8 represents 18 years of trapping information for Douglas-fir tussock moth in northern Idaho collected by Idaho Department of Lands. The early detection trapping system accurately predicted defoliation in 1986 and showed an increasing population level of Douglas-fir tussock moth throughout the trapped portion of northern Idaho (trap locations run from Township 39 (Latah County) to 50 (Kootenai County) since 1997.

Figure 8. 1982-2000 Idaho Department of Lands Douglas-fir Tussock Moth average trap catch in northern Idaho.

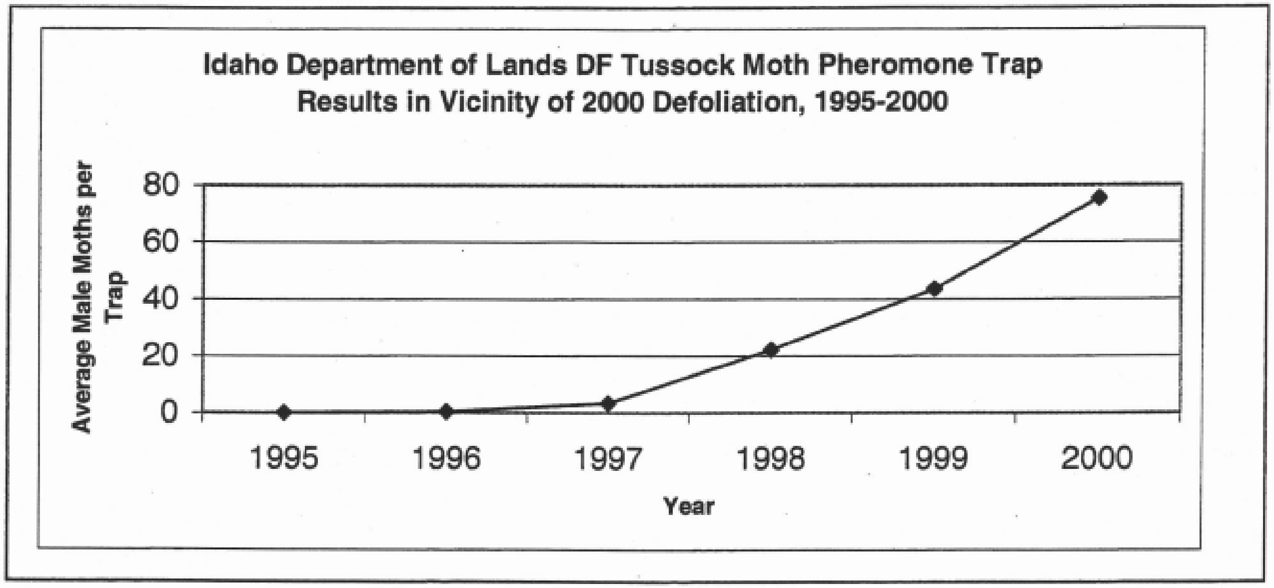


When only traps in and adjacent to defoliated acres during 2000 are considered, the trend becomes more pronounced (Figure 9). Daterman et al. (2000), suggest that an average 25 or 40 male moths per trap should be followed up with ground sampling for larvae, cocoons, or egg masses in the general area (1 or more miles periphery around the trapping location). Idaho Department of Lands personnel conduct lower crown larval sampling annually and beginning in 1998, found suboutbreak larval population levels on some sites. Forest Service Douglas-fir tussock moth detection trap catches south of Lewiston, Idaho were between 0 and 5 from 1995-2000, well below the threshold to trigger subsequent ground sampling (Nancy Sturdevant, personal communication).

Viral Screening of 1999/2000 Tussock Moth Egg Masses

Dr. Ladd Livingston and David Beckman of the Idaho Department of Lands noted the increasing pheromone trap catches and in 1999 collected egg masses to check for levels of nucleopolyhedrosis virus (NPV). The presence of NPV on egg masses generally signals that tussock moth populations are going to decline. There had been no visible defoliation in 1999,

Figure 9. 1995-2000 Idaho Department of Lands Douglas-fir tussock moth average trap catch in and adjacent to areas defoliated in 2000.



so if NPV was present in egg masses, it was likely that tussock moth populations would collapse before causing visible defoliation.

In 1999, David Beckman collected 50 egg masses from sample sites near Mary Minerva McCrosky Memorial State Park and Moscow Mountain near Potlatch, Idaho. The egg masses were shipped to Dr. Imre Otvos in British Columbia, Canada. Dr. Otvos conducted a bioassay to determine the natural occurrence of virus in the egg masses. The results of the virus screening are summarized in Table 1.

Table 1. Natural occurrence of nucleopolyhedrosis virus in Douglas-fir tussock moth egg masses collected in Idaho, 1999/2000.

Collection location	No. new egg masses reared	No. eggs reared	No. larvae emerged (%)	No. larvae reared for virus determination[a]	No. dead larvae[b]	No. dead larvae with NPV	Est. % NPV in pop. in 2000
ID-9	15	600	511 (85.2)	351	20 (5.8)	0 (0.0)	0.0
ID-12	15	603	550 (91.2)	377	15 (4.0)	0 (0.0)	0.0
ID-117	10	404	350 (86.6)	225	7 (3.2)	0 (0.0)	0.0
A.	10	401	376 (93.8)	250	12 (4.8)	0 (0.0)	0.0
ID-216							
Totals(x)	**50**	**2008**	**1787 (89.0)**	**1203**	**54 (4.6)**	**0 (0.0)**	**0.0**

[a] A maximum of 25 larvae from each egg mass were used for determining the natural occurrence of NPV.
[b] All dead larvae were examined.

Results of the bioassay were negative, and populations of tussock moths reached outbreak levels in 2000.

Idaho Department of Lands collected egg masses from Moscow Mountain, and Skyline Drive in the fall of 2000, and the Forest Service collected egg masses from Gold Hill and Moses Mountain. Defoliation was heavy in sites where egg masses were collected by the state, and had not yet occurred on the sites sampled by the Forest Service. All egg masses were shipped to Dr. Otvos for viral and egg parasite screening. Results from this screening should be available by late spring 2001.

2000 Aerial Detection Survey Results

Idaho Department of Lands reports approximately 54,753 acres were mapped as defoliated by Douglas-fir tussock moth in northern Idaho in 2000. Digitized aerial detection survey maps indicate 2,997 acres of defoliation occurred on National Forest System (Clearwater National Forest) Lands.

Defoliation in 2000 was concentrated in two general areas: along Skyline Drive through Mary Minerva McCrosky Memorial State Park, and south of Potlatch around Moscow Mountain, Rocky Point, Turnbow Point, and Browns Meadows (Figure 1). Defoliation was mostly light; however, two pockets of heavy defoliation were mapped south of Moscow Mountain along Randall Flat (T40N, R4W concentrated in sections 20 and 29) and around Rocky Point (T41N, R4W concentrated in sections 31 and 32). None of the heavy defoliation was mapped on National Forest System Lands. A smaller polygon of light defoliation was mapped around Mica Mountain (T41N, R2W, concentrated in sections 10, 15, 16, 22, and 23).

2000 Egg Mass Surveys

In response to the defoliation, Idaho Department of Lands personnel, aided by Forest Service personnel conducted Douglas-fir tussock moth egg mass surveys. Surveys were conducted in areas defoliated in 2000, and in areas that had been defoliated in previous outbreaks with elevated Douglas-fir tussock moth pheromone trap catches in the late 1990's.

The egg mass survey consisted of a 10-minute visual observation. If no egg masses were seen during the 10 minute observation period, 20 host trees were chosen at random, three lower branches were examined and cocoons and egg masses counted. Results of this survey are summarized in Figure 10. Presence of any egg masses indicates there is a potential for defoliation. The greater the number of egg masses, the more severe defoliation is likely to be, though there have been no studies to conclusively characterize defoliation intensity based upon number of egg masses found at a site the previous fall.

Egg masses were most abundant in areas that experienced defoliation in 2000. The majority of survey plots in areas that had not been defoliated in 2000 had no egg masses. There were two areas not defoliated in 2000 that had 20-100 egg masses: (1) Gold Hill on Forest Service Land, north of Potlatch (T42 N, R4W, Sec 24), and (2) south of Lolo Pass on private land (T 45N, R4W, Sec 28, 33, 34). A number of plots with 1-20 egg masses were scattered through the forested lands north of Gold Hill to Prospect Peak on Forest Service Lands indicating there may be some defoliation in this area in 2001. Some egg masses (<20) were found on egg mass survey plots on Forest Service Lands near Schwartz Creek and Vassar Meadows (T41N, R2W) indicating that defoliation may occur in the vicinity in 2001. Forest Service land inside the areas defoliated in 2000 will likely be defoliated again in 2001.

Conclusions

All monitoring activities conducted in conjunction with tussock moth populations indicate that 2000 represented a peak phase in a Douglas-fir tussock moth outbreak. Whether 2001 will be the declining phase is yet to be determined. Egg mass surveys indicate that in 2001, defoliation is likely to recur in areas defoliated in 2000. In addition, egg masses were present in three areas (Lolo Pass, Gold Hill, and Mica Mountain) not visibly defoliated in 2000, indicating defoliation may occur in these areas in 2001. Defoliation in 2001 is likely to be more severe in areas where egg mass surveys found more egg masses; defoliation is not expected in areas where egg masses were not found (Figure 10).

Forest Service land did experience light defoliation in 2000; however, most defoliation occurred on small, scattered Forest Service parcels less than 1,000 acres in size surrounded by state and private lands. There was little defoliation in larger Forest Service parcels on the Palouse Ranger District. Egg mass surveys conducted in the fall of 2000 found few egg masses on larger Forest Service parcels east of areas defoliated in 2000. The only egg mass survey plot within larger Forest Service administered lands with more than 20 egg masses was on Gold Hill.

In 2001, we plan to conduct lower crown larval sampling around Gold Hill and north to Prospect Peak (T42-43N, R3-4W) and in the area south of Sand Mountain to Vassar Meadows (T40-41N, R2W). These areas were not defoliated in 2000, but do have potential for defoliation in 2001 according to egg mass surveys. We also plan to conduct larval samples in Forest Service administered lands within 2000 defoliated areas.

TREATMENT OPTIONS

Managers have a number of options when responding to tussock moth outbreaks. There are two general response strategies: prevention and direct control. In order to best determine an appropriate response, areas likely to become involved in an outbreak should be identified. Tussock moth outbreaks tend to recur in the same general areas enabling managers to anticipate future outbreaks (Figures 1, 3-6). Tussock moth management strategies strive to identify stands at risk of incurring significant damage if defoliated, and reduce the likelihood of defoliation through stand manipulations prior to an outbreak or direct control activities once an outbreak is imminent. A number of hazard rating systems have been developed based on information gained in past outbreaks. Hazard rating systems currently available for the tussock moth use site and stand characteristics and historic defoliation boundaries to rank stands in terms of potential to be involved in an outbreak. Once high-hazard stands are identified, managers can prioritize which stands would require treatment to prevent tussock moths from interfering with long-term stand management objectives, and to develop a timeline for accomplishing necessary hazard reduction or analysis prior to direct control operations.

Hazard Rating Systems for Douglas-fir Tussock Moth

Hazard is the ability of a stand to support an outbreak population of tussock moths. High-hazard stands are capable of supporting outbreak populations, and can experience significant defoliation and associated mortality, tree damage, and growth reductions. Hazard rating systems attempt to identify high-hazard stands by using site and stand characteristics.

There are a number of hazard rating systems available to rank stands by potential for damage from tussock moth outbreaks (Stoszek et al. 1981; Heller and Sader 1980; Steele et al. 1996). Stoszek et al. (1981) considered five factors: topographic location of the stand, depth of the ash mantle at the site, average age of all host trees in the stand, site occupancy (ratio of density of all trees in the stand to an index of site productivity), and grand fir as a proportion of total trees. This system was developed from sample stands on the Palouse Ranger District. It predicts heavier defoliation on upper slope sites and ridges, in mature and over-mature stands, in stands with high site occupancy (ratio of basal area per acre to site index of Douglas-fir), in stands with decreasing depth of ash mantle and increasing proportions of grand fir.

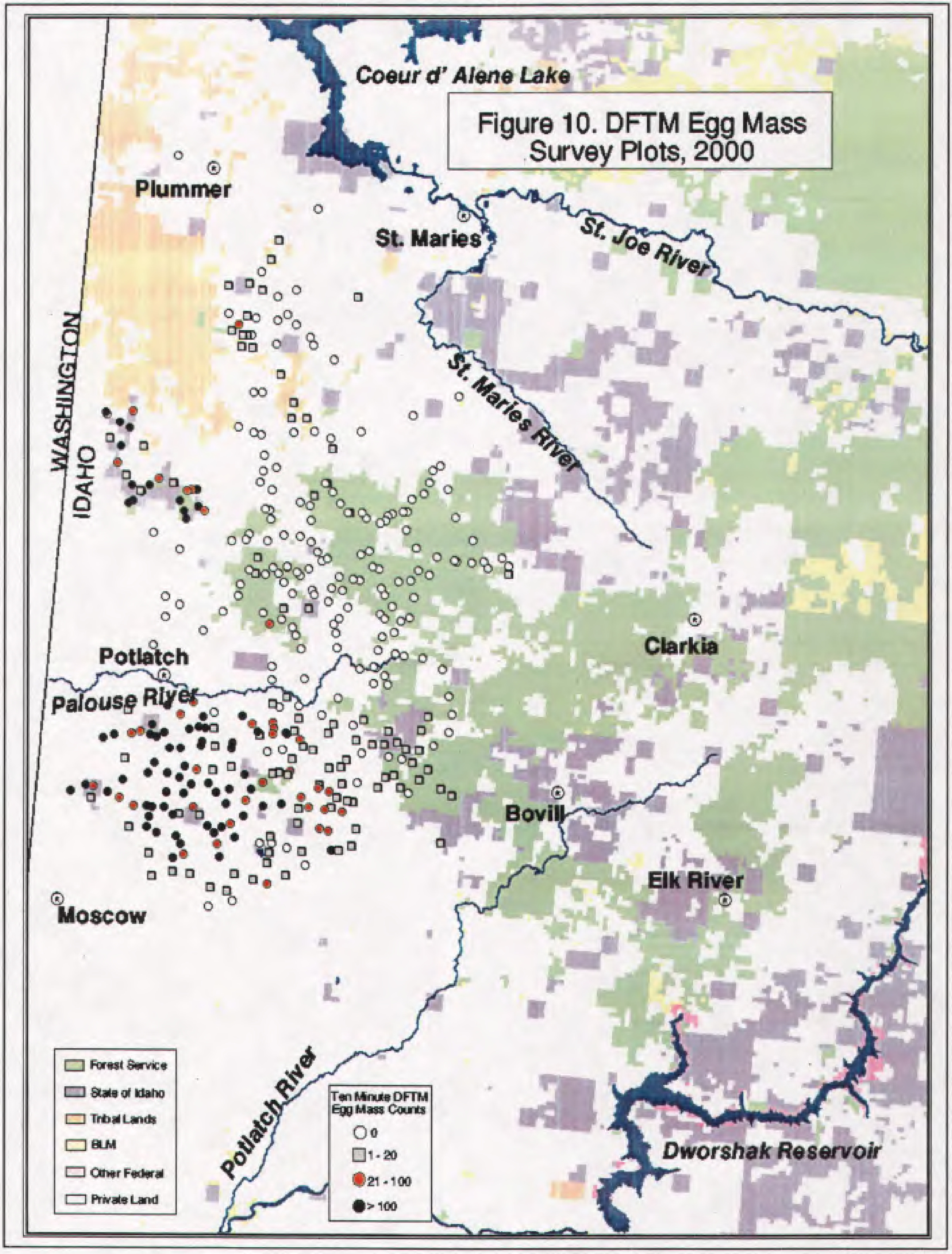


Figure 10. DFTM Egg Mass Survey Plots, 2000
Coeur d' Alene Lake
Plummer
St. Maries
St. Joe River
St. Maries River
WASHINGTON
IDAHO
Potlatch
Palouse River
Clarkia
Bovill
Elk River
Moscow
Potlatch River
Dworshak Reservoir
Forest Service
State of Idaho
Tribal Lands
BLM
Other Federal
Private Land
Ten Minute DFTM Egg Mass Counts
0
1 - 20
21 - 100
> 100

Steele et al. (1996) developed a hazard rating system for stands in central Idaho and based hazard determination on stand aspect, topographic position, stand defoliation history, and percent of host (Douglas-fir, grand fir, subalpine fir) in the stand.

Heller and Sader (1980) used aerial photographs to develop their hazard rating system and considered Douglas-fir and/or grand fir in pure stands or mixed composition stands with other species. Their system bases hazard on crown diameter, canopy closure by species, topographic position, elevation, slope, and aspect.

Priority Setting

The delineation of stands into hazard categories facilitates the priority setting process. High-hazard stands are those more likely to experience tussock moth outbreaks, and incur damage from defoliation. Once high-hazard stands are identified across a landscape, managers can begin the process of determining in which areas would effects of outbreak populations of tussock moth be unacceptable (high priority areas for treatment).

In Region 6, as a part of the development of an EIS, a number of issues were identified for consideration in identifying priority areas for treatment using direct control measures (USDA Forest Service 2000). Many of the same issues pertain to preventive treatments. Region 6's issues are included as an example of topics to be considered in Douglas-fir tussock moth management.

- ***Human Health Effects:*** Human health could be affected through direct contact with tussock moth larvae at suboutbreak and outbreak levels. Consideration of high human traffic, such as campgrounds and recreational areas, may receive higher priority for preventive treatment to prevent tussockosis. The potential for tussockosis may merit development of a public information program to inform forest users.
- ***Protection of Timber Values:*** Tussock moth outbreaks may result in tree mortality, top kill, and growth loss. High-hazard stands not scheduled for harvest may be prioritized to ensure tussock moth defoliation won't reduce the value of fiber to be utilized.
- ***Maintaining Healthy Forests:*** Most high-hazard tussock moth stands occur on high-risk sites at the edge of preferred host range. As long as susceptible host types prevail on high-risk sites, periodic outbreaks will continue. The most effective way to reduce tussock moth susceptibility and ensure forest health is to return high-risk sites to non-host seral species.
- ***Fuel Build-up and Fire Risk:*** In high-hazard stands, tussock moth outbreaks may result in accumulation of fuels from trees killed by defoliation and/or accumulation of fine fuels in the form of partially eaten needles on the forest floor. Managing high-hazard stands in the urban interface may prevent tussock moth outbreak generated fuel loading.
- ***Water Quality:*** Defoliation of riparian areas could affect stream temperature, peak flows, sediment input, etc. By proactively managing susceptible riparian areas, the manager maintains some control over changes that occur in the riparian zone and can mitigate predictable impacts caused by management as opposed to trying to mitigate unpredictable outcomes from defoliation.
- ***Economic Effects from Decreased Tourism:*** A tussock moth outbreak could result in decreased use of recreation areas, which could hurt local communities by reducing tourist and recreation income. Reducing stand susceptibility in recreation areas will decrease the likelihood of outbreaks and reduced tourism.

- ***Operations:*** Stand management operations could limit access to forests during treatment. Treatments could be timed to conflict as little as possible with peak recreation use.
- ***Secondary Mortality:*** Weakened trees that survive tussock moth infestations could die from secondary attacks from bark beetles or other forest pathogens. Priority may be given to highly susceptible stands with a significant old growth component more likely to be attacked by bark beetles.
- ***Wildlife Habitat:*** Tussock moth outbreaks may result in patches of tree mortality or top kill. These stand impacts may have ramifications on wildlife habitat, positive and negative.

In order to accurately assess priority areas for treatment, managers may want to request input from staff specialists and review management objectives for high-hazard stands.

Prevention

In prevention strategies, the focus of control efforts is to prevent pest populations from reaching damaging levels by altering stand susceptibility. Preventive treatments do not remove Douglas-fir tussock moth populations or change their cycles of abundance. Preventive treatments change the magnitude of population increases, which may result in failure of outbreaks to develop (Mason and Wickman 1988).

By managing high-priority areas to reduce susceptibility to tussock moth defoliation in advance of an outbreak, damage from defoliation may be reduced or eliminated.

Silvicultural Strategies

Management systems that reduce susceptibility of a stand to tussock moth outbreaks have the potential to realize long-term effects in inhibiting population increases (Shepherd 1994). Observations by Stoszek and Mika (1978) found a number of stand characteristics associated with outbreaks and significant damage from Douglas-fir tussock moth. Many of these stand characteristics can be altered through stand manipulations.

Many grand fir dominated stands supporting tussock moth outbreaks were historically dominated by either ponderosa pine or Douglas-fir (Berryman 1986, Mason and Wickman 1988). By implementing silvicultural systems that reduce the proportion of grand fir in these stands and restore pine and Douglas-fir, tussock moth populations may no longer be able to reach outbreak proportions, or if outbreaks do occur, total impact on the stand may be reduced by presence of non-preferred hosts.

Silvicultural systems that alter stand structure may also be able to reduce potential for tussock moth outbreaks to occur. Stoszek and Mika (1978) observed that in multi-storied stands (stands with a wide range of tree heights) defoliation was significantly higher than in single-storied stands. By reducing the range of tree heights by either thinning from above or below, significant decreases in intensity of defoliation may be achieved.

May, Stoszek, and Dewey (1984) suggest the following generalized silvicultural prescriptions to reduce stand hazard:

In immature, mixed-species stands, thinning treatments favoring nonhost species are potentially best capable of providing long-term control of the tussock moth. In inoperable mixed-species stands, the no treatment alternative is also a viable management option; however, without some disturbance such as fire to reduce the abundance of preferred host species, as these stands mature they will likely support tussock moth outbreaks.

- In immature host-species stands, thinning regimes that favor the less preferred host species would facilitate both short- and long-term reductions in tussock moth susceptibility.

- In mature, predominantly host species stands, timely harvests favoring the removal of grand fir will reduce stand susceptibility to tussock moth outbreaks.

The reduction of susceptibility of the Forest to tussock moth attack is a long-term objective in which cultural or silvicultural methods may be used to change the host species composition and/or manipulate stand structure. These methods can potentially reduce rates of increase of the tussock moth and decrease potential for them to reach damaging levels.

Direct Control

In a direct control strategy, the focus is the insect population and the objective is to reduce the target pest populations so that no damage to the resource is incurred. There are a number of tools available to managers for direct control projects of Douglas-fir tussock moth populations including chemical insecticides, microbial insecticides, and behavior modifying pheromones. A brief description of each follows.

Chemical Insecticides

The application of insecticides usually has an immediate effect upon the generation of insects treated and is most useful when the population is not expected to rebound during the following generation. Insecticides may be a good choice in high-value stands where timber values are high and harvest for gain is anticipated, and in seed orchards or small parks where the key objective is to protect the foliage of host trees (Shepherd 1994). Direct application of insecticides is becoming more controversial. Many insecticides impact a number of non-target organisms and more consideration is being given to these non-target impacts when looking at cost benefit ratio for treatment.

There are a number of insecticides registered for use against tussock moth. Dewey (1984) discussed carbaryl (Sevin), acephate (Orthene), and diflubenzuron (Dimilin). Stein and Mori (1994) found that acephate (Acecap) implants were the most effective treatments for individual trees; one treatment of acephate provided 2 years of protection. In one study, acephate decreased the average percent of defoliation by over 99%. Mimic (tebufenozide) is a relatively new insecticide that is registered for use against Douglas-fir tussock moth, but which has not been widely used (Wayne Stewart, personal communication).

Aerial application of an insecticide, chemical or microbial, on Forest Service land automatically triggers the need to prepare an environmental impact statement (EIS) under the National Environmental Policy Act (NEPA) (Earl Sutton, personal communication). With the short outbreak cycle of the tussock moth (1-3 years of defoliation before populations collapse), an EIS would need to be prepared before any visible defoliation occurs to allow insecticide application during the peak phase of an outbreak. Biologically, the best time to apply insecticide would be in the release phase (Figure 2) when tussock moth populations are increasing to outbreak levels, but prior to defoliation and damage to the trees. Waiting for defoliation before beginning preparation of an EIS would result in treatments during the declining phase of an outbreak, when populations are declining rapidly due to natural factors and significant resource damage may have already been incurred. Treatments during the decline phase may reduce the intensity of defoliation resulting in less growth loss and top kill in host trees. Decline phase treatments may also reduce the number of late instar larvae present in treated areas decreasing the likelihood for humans to experience tussockosis.

Insecticide treatments of individual trees on a small scale using ground-based equipment in high-value areas may be able to proceed under an environmental assessment (EA), reducing the time necessary to prepare environmental documentation. Acephate implants have been found to be extremely effective at reducing tussock moth populations on scionwood producing white fir (Stein and Mori 1994), and would likely prevent defoliation on individual high-value trees in campgrounds.

Microbial Controls

Microbial controls are a form of biological control using naturally occurring insect pathogens to reduce populations of insect pests to acceptable levels. Because insect pathogens are natural components of the forest ecosystem, microbial control does not add new or synthetic toxic substances to the environment. Some microbials are species specific, and applications of insect pathogens may initiate epizootics (an outbreak of a disease in which many cases occur) early enough in an outbreak to prevent serious damage to trees.

This type of biological control, where it has proved effective, is becoming more attractive as the public becomes increasingly aware of environmental problems associated with some chemical insecticides (Thompson 1978).

The U.S. Environmental Protection Agency (EPA) currently registers two microbial insecticides for use against Douglas-fir Tussock moth: TM-Biocontrol, a nucleopolyhedrosis virus; and B.t.k. (*Bacillus thuringiensis* var. *kurstaki*), a bacterium. Aerial application of either microbial would require preparation of an EIS.

TM-Biocontrol The nucleopolyhedrosis virus (NPV) used in TM-Biocontrol occurs naturally in the soil in areas affected by tussock moth outbreaks. NPV is highly host specific, affecting 3 species of *Orgyia* in addition to Douglas-fir tussock moth: western tussock moth (*O. cana*), rusty tussock moth (*O. antiqua*), and white marked tussock moth (*O. leucostigna*). NPV has been associated with the natural collapse of many Douglas-fir tussock moth outbreaks (Shepherd et al. 1988; Thompson and Scott 1979; Mason and Wickman 1988; Tunnock 1973; Shepherd et al 1988). Epizootics of virus develop best in stressed populations (starved and/or overcrowded).

In the natural system, early instar tussock moth larvae eat NPV-contaminated eggshells as they emerge. These small larvae become infected with NPV and die almost always by the end of the first instar. Before dying, the infected larvae disperse through stand-spreading NPV that is then eaten by larvae that escaped egg contamination. Later instar infected larvae stop eating, firmly attach themselves to branches, and their bodies become sacks of NPV. The highest concentration of larvae occurs in the tops of host trees so when infected larvae die and their bodies rupture, NPV drops onto lower branches and the forest floor. Most NPV that makes it to the forest floor, persisting until the next outbreak cycle, comes from infected older larvae (Thompson 1978).

The incidence of NPV increases greatly in fifth and sixth instars larvae because these larvae consume the most foliage thus increasing chances for ingesting NPV particles. When NPV is ingested so close to pupation, larvae may not die until after constructing a pupal case. NPV in dead pupae may persist for up to 3 years (Thompson 1978).

The purpose of aerially applying NPV in tussock moth populations is to initiate an epizootic of NPV causing the tussock moth population to collapse prior to damaging host trees. Viruses are slow acting and feeding may not be inhibited until the larvae are close to pupation resulting in little foliage protection. For this reason, the best time to apply virus is in the release phase before defoliation becomes visible. Virus application does have carry over effects that reduce and maintain the population below tolerable damage levels for the remainder of the outbreak cycle (Shepherd 1994).

The Forest Service owns TM-Biocontrol and its application requires completion of an EIS, regardless of land ownership to be treated.

B.t.k. *Bacillus thuringiensis* var. *kurstaki* (B.t.k.) is an aerobic spore-forming bacterium that produces a diamond shaped proteinaceous crystalline inclusion that damages the midgut cells of tussock moths after ingestion. Once ingested, B.t.k. causes almost immediate cessation of feeding. B.t.k. affects the larvae of many species of moths and butterflies, but it has to be ingested to be effective. Unlike NPV, epizootics of B.t.k. are only known to occur naturally in populations of stored grain pests. Larvae killed by B.t.k. usually drop intact from the foliage to the forest floor, which may prevent contamination of the foliage (Stelzer et al. 1978).

B.t.k. is commonly used against a variety of forest defoliators. It has been used to control Douglas-fir tussock moth on various occasions in the early 1970's and was used operationally in 1989 on the Plumas National Forest, and in 1991 on the Wallowa-Whitman National Forest (USDA Forest Service 2000).

Aerial application of B.t.k. on Forest Service Lands would require preparation of an EIS. Recently the use of B.t.k. has been questioned by a number of groups concerned about the impact of B.t.k. on non-target Lepidoptera. This issue may warrant further consideration in an EIS.

Pheromones

Use of mating disruption pheromones for the Douglas-fir tussock moth is a promising new control technology in which the treatment area is saturated with the female tussock moth's sex pheromone (z-6-heneicosen 11-one). Application of mating pheromone blocks mating, and the oviposition of viable egg masses is reduced dramatically (Hulme et al. 1994). Mating pheromones are highly specific and have little other environmental impacts, but long-term effects and interactions with parasites and predators are, as yet, unknown (Shepherd 1994).

Mating disruption is aimed at holding back a population that is in the release phase (e.g. prior to visible defoliation). This strategy has the most promise in protecting localized, isolated infestations in sensitive areas. It may also be used in areas where treatments earlier in the year did not achieve desired results (Dewey 1984).

Presently there is no commercial source for tussock moth pheromone, and no commonly accepted formulation. Forest Health personnel in Region 6 are working with some manufacturers and hope to begin trials using a new formulation in the near future.

Considerations for Direct Control

There is some evidence that the use of any direct control measure against tussock moth may result in a lower accumulation of nucleopolyhedrosis virus (NPV) in forest soils by artificially reducing the number of late instar larvae which produce the largest quantities of NPV (Thompson 1978; Thompson and Scott 1979; Thompson et al.1981). NPV is thought to cause the natural collapse of most tussock moth populations (Shepherd et al. 1988; Thompson and Scott 1979; Mason and Wickman 1988; Tunnock 1973; Shepherd et al 1988). The impact of less viral accumulation in the soil is not well understood, but could affect future population dynamics of the insect. Where direct control measures appear to be essential, applications of moderate doses of NPV will have the least undesirable impact on long-term population dynamics of tussock moth (Thompson and Scott 1979, Thompson et al. 1981).

NO ACTION

Douglas-fir tussock moth is a native insect. Tussock moth outbreaks have occurred in forests around Potlatch, Idaho for at least 50 years. In the four previous documented outbreaks, populations collapsed in untreated areas within a year or two of visible defoliation. While tussock moth outbreaks have been short in duration, defoliation during the outbreak can be severe and result in growth loss, top kill, and tree mortality. The amount of damage that can be expected is directly related to the level of defoliation that occurs (see Impacts of Outbreaks on Trees and Patterns of Tree Mortality for more details). The amount of defoliation cannot be accurately predicted in advance of an outbreak, or between years within an outbreak. Population sampling techniques can provide managers with some indication of where larval populations may be higher, resulting in more defoliation.

Defoliation intensity tends to be greater in high-hazard stands (see Hazard Rating Systems for the Douglas-fir Tussock Moth) so high-hazard stands tend to have most growth loss, top kill, and tree mortality. Heavy defoliation and tree mortality may have impacts on other forest management considerations such as wildlife habitat, stream flow, and fire hazard (see Ecological Implications of Outbreaks). High populations of tussock moth may affect human health (see Effects of Douglas-fir Tussock Moth on Human Health).

Many researchers now suggest that tussock moth defoliation may play a beneficial role in maintaining and/or restoring forest health by thinning heavily defoliated stands and favoring species better suited to the site.

Managers may decide after conducting an analysis that in certain areas no action is required in response to tussock moth outbreaks.

An Integrated Strategy for Dealing with Future Douglas-fir Tussock Moth Outbreaks:

The Palouse Ranger District has a history of Douglas-fir tussock moth outbreaks. Since the first recorded outbreak in the 1940's, there have been four outbreak cycles. In the last outbreak in 1986, defoliation was well below expected levels.

Since the 1970's there has been a considerable amount of research aimed at developing pest management systems for tussock moth. The basic activities associated with tussock moth management systems are: (1) identify areas with high tussock moth hazard, (2) establish and maintain tussock moth population monitoring sites within susceptible areas, (3) prioritize potential treatment areas and, (4) develop a contingency plan if tussock moth populations begin to increase.

Hazard rating stands on the Palouse Ranger District can be accomplished. Three systems are currently available. Stand data would need to be checked for accuracy. In the absence of stand data, photo interpretation could be used to assist with hazard classification efforts. Hazard rating within historic outbreak boundaries could be completed first, followed by hazard rating in adjacent areas.

Idaho Department of Lands established and has maintained tussock moth pheromone monitoring sites since the early 1980's. The IDL trapping sites are not intended to delineate potential defoliation pockets. In an integrated strategy, land managers would review high-hazard areas and determine in which areas high tussock moth populations and/or defoliation would result in a management response. Within these areas tussock moth pheromone traps would be evenly distributed and deployed annually, one set of five traps per 10 square miles of relatively uniform stand structure, species composition, and topography (Daterman et al. 1974).

When average trap catches reach 25 or more moths on the plot, follow up sampling for egg masses and larvae should be conducted as described in Mason (1979) to help determine distribution on increasing populations. Annual survey results from the early warning grid will provide forest managers with more lead time to cope with sudden outbreaks of tussock moth, especially when attention is paid to results from individual trap sites as well as area averages. Trapping and follow up surveys conducted in this manner has yielded an early warning of impending outbreak 2 years prior to occurrence of defoliation (Daterman et al. 2000).

After completion of hazard rating efforts and establishment of an inclusive early detection pheromone-trapping grid, managers could turn their attention to preventive treatments. Once tussock moth populations begin to increase, managers may want to review planned silvicultural treatments to determine whether or not certain treatments should be accelerated in advance of an outbreak. In addition, thought should be given to beginning the analysis process that may lead to an EIS for additional stand management activities or direct control operations.

While it is not yet, and may never be, possible to prevent significant tussock moth defoliation, by completing a hazard analysis, maintaining an early detection monitoring grid, and considering potential for tussock moth defoliation to impact stands and schedule treatments accordingly, managers will be better prepared to deal with the next outbreak and reduce impacts in priority areas. By completing the hazard and prioritization process, managers will also be able to identify areas in which defoliation is not incompatible with management objectives and will not feel compelled to act in these areas.

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CAUTION: PESTICIDES

Pesticides used improperly can be injurious to humans, animals, and plants. Follow directions and read all precautions on the labels. Consult your local forest entomologist, county agricultural agent, or State extension agent about restrictions and registered uses of particular pesticides.