III. Entomology (Connie Mehmel)

A. Objectives

Project Entomology had five objectives (USDA 2000):
1. Verify that Douglas-fir tussock moth (DFTM) populations were at sub-outbreak (3 larvae/1000 sq. inches foliage, mid-crown) or higher in Analysis Units proposed to be treated.
2. Ensure the proper timing of insecticide application.
3. Estimate pre-treatment DFTM population densities in blocks to be sprayed.
4. Compare pre-treatment and post-treatment DFTM population densities.
5. Measure defoliation rates and monitor the short-term protection of areas of concern.

B. Verification Of Treatable Populations by Analysis Unit

Extensive cocoon and egg mass sampling was conducted in the fall to determine tussock moth population densities. Sample plots were concentrated in areas of concern. Additional plots were established outside areas of concern to identify sites that could be used to compare the effects of treatment with no treatment. A total of 242 plots were taken in the Methow Valley, at a density of one per square mile. Sampling protocol can be found in the Project Entomology Plan. Based on fall cocoon and egg mass samples, sub-outbreak populations were predicted in five Analysis Units (AUs): Mazama, Wolf Creek, Eightmile, Cub Creek, and portions of Twisp River. Mazama, Wolf Creek, Eightmile and Twisp River were identified as areas of concern in the EIS.

The analysis units were then divided into spray blocks, which had similar topographic characteristics and were operationally feasible to treat with helicopters. These spray blocks were the units which were sampled to determine larval density and stage of development.

Table 1: Analysis Units for Douglas-fir Tussock Moth Project 2001, Treatment and Control

ANALYSIS UNIT	TOTAL ACRES	# OF SPRAY BLOCKS	PREDICTED LARVAL DENSITY
Mazama (treatment)	22,147	128	18.60
Wolf Creek (control)	1,408	19	4.51
Wolf Creek (treatment)	664	9	4.51
Eightmile (treatment)	7,816	40	2.45
Cub Creek (control)	9,641	46	2.40
Twisp River (control)	43,921	159	1.50

Predicted larval densities in the analysis units were relatively low overall. This indicated that heavy defoliation would not occur for at least one year with or without treatment, although the valley floor of the Mazama AU had reached outbreak level. The decision was made to treat sub-outbreak and outbreak populations in the Mazama, Wolf Creek and Eightmile Analysis Units. Cub Creek was retained as a control (non-treatment) Analysis Unit, since it did not include any "areas of concern" identified in the November 2000 Tussock Moth Record of Decision (ROD). Although Twisp River was an "area of concern" identified in the ROD, predicted larval densities overall were below suboutbreak. Two blocks with suboutbreak larval density were identified through sampling in the spring and summer of 2001, and control plots were established in these blocks.

The Tussock Moth EIS identified a portion of Wolf Creek within the Lake Chelan-Sawtooth Wilderness as an "area of concern" to be treated. After further analysis, the Wilderness portion of the AU was withdrawn from

treatment, and only that portion of the watershed between the Wilderness boundary and the private land was treated.[1] This reduced the total potential treatment acreage from 2,072 to 664.

C. Insure Proper Timing of Insecticide Application

In order to ensure proper timing of insecticide application, the entomology crew needed to be able to identify current year egg masses and to be familiar with the differences between larval instars. Therefore, several current year egg masses were collected in early April before entomology field personnel began work. These egg masses were kept in the office, where some were refrigerated and others were kept at room temperature. The non-refrigerated egg masses hatched with 10 days. The unhatched egg masses and young larvae were valuable training aids for new crew members, as well as displays for interested visitors. Entomology field crews began work on May 7.

Every spray block in the Mazama, Eightmile, and Cub Creek Analysis Units, as well as every lower elevation block in Wolf Creek and Twisp River, was surveyed for tussock moth egg masses. Wherever three to ten egg masses could be found within 100 feet of each other, an egg development plot was established as described in the Entomology Plan. Plots that met protocols in the Plan could only be established in Mazama, because egg masses were difficult to find in the other Analysis Units. Thirty-three plots were established between 2000' and 4500' elevation, with at least one plot in each 500-foot elevation band. Between 2000' and 4000' there was at least one plot on each major aspect. These plots were visited every 2 to 3 days to check for egg hatch and larval dispersal.

After every spray block had been surveyed, some egg development plots were established in Eightmile, Cub Creek and Twisp River that had only one or two egg masses. These plots were also monitored for egg hatch and larval dispersal as described in the Entomology Plan.

The first reported egg hatch on national forest land was May 21 at 2150' on a south slope. The first reported egg hatch on private land at the valley floor occurred at about the same time. (Washington State Department of Natural Resources shared project office space, and posted private land egg development plots on a shared map.) The last reported egg hatch was June 18 at 3000' on a north slope.

Once egg hatch had occurred in a given elevation band, spray blocks at that elevation were sampled every 2 to 3 days to determine the stage of larval development. Once 60% of the larvae in a given block reached the second instar or larger, that block was released for spray. If any block was not sprayed within 72 hours of its release, the block was re-sampled. This only occurred once, when spraying had to be delayed because of weather.

D. Estimate Population Densities in Spray Blocks

After egg hatch and dispersal was complete, population densities were estimated for each individual spray block prior to treatment. Population density plots were taken in a grid pattern at an intensity of one plot per 50 acres, or a minimum of two plots per block. Each plot consisted of three trees, using the protocol described in the Entomology Plan. Information from these plots was used for estimating both larval density and larval development.

The overall objective of this Project was to prevent widespread defoliation in identified Analysis Areas. In order to achieve the objective it was necessary to treat tussock moth populations that had mostly reached Phase II (USDA 2000), so that damage characteristic of Phase III could be avoided. This required scheduling

[1] Letter from Regional Forester Harv Forsgren to Forest Supervisor, Wenatchee-Okanogan National Forest, dated June 6, 2001.

Analysis Units for treatment before populations were at high levels. As a result, portions of some Analysis Units were actually below suboutbreak numbers by the time larval development was reaching the second instar, and a number of blocks were dropped from the treatment schedule.

Table 2: Changes in Proposed Treatment Blocks and Acres Based on Population Density Sampling

ANALYSIS UNIT	BLOCKS SPRAYED	BLOCKS DROPPED	ACRES SPRAYED	ACRES DROPPED
Mazama	74	54	15,713	6,437
Wolf Creek	3	6	177	487
Eightmile	6	34	800	7,017

Establishing the presence of treatable populations during this early stage of the outbreak was the most time-consuming task performed by the entomology crew. In order to meet the Purpose and Need stated in the Tussock Moth EIS (page I-4), a site-specific decision was made for each spray block. This meant that every block was visited at least once, and most were visited several times in order to determine both population density and stage of development.

In order to identify adequate control areas for monitoring, every block in Cub Creek, Twisp River, and the wilderness portion of Wolf Creek was visited at least once, and most were visited at least twice, in order to identify blocks in which evaluation plots could be established (see Section 4 below).

In the Mazama AU, two of the blocks dropped from treatment actually had suboutbreak or outbreak tussock moth populations (blocks 221 and 226). These blocks were located in spotted owl habitat, and were used as control sites to compare the effects of treatment with no treatment in this habitat type. This decision was made because suboutbreak populations could not be located in spotted owl habitat type outside areas of concern. One other control block was identified in the Mazama area outside the EIS areas of concern (block 314 in Fawn Creek).

In the Wolf Creek AU, one of the blocks treated had a tussock moth population below suboutbreak level. This block had a spotted owl nest with young, and was sprayed in order to monitor the effects of helicopter overflight on owls as required in the EIS.

E. Compare Pre-Treatment and Post-Treatment DFTM Population Densities

In order to compare the effects of treatment with no treatment, evaluation plots were established in both treatment and control blocks. Each evaluation plot consisted of 20 trees. The first five trees were sampled for larval population. All 20 trees were observed for defoliation and placed in one of eight defoliation categories (see Section 5 below). These plots were sampled immediately before treatment, and again 20 to 23 days after treatment. They will be sampled one more time, in June of 2002, to determine if the spray had the desired long-term effect. In the case of control blocks, the first sample was taken at the time when spraying would have occurred, and again 20 to 23 days later.

Fifty-one evaluation plots were established in treatment blocks: 39 in Mazama, 11 in Eightmile, and one in Wolf Creek. Twenty-two evaluation plots were established in control blocks: three in Mazama, eight in Wolf Creek, nine in Cub Creek and two in Twisp River. This means that there were fewer than 50 evaluation plots in control areas, as called for in the Entomology Plan. However, no other blocks with suboutbreak population densities could be located. All of these blocks had larval densities at suboutbreak or greater according to larval density plot averages, but many individual evaluation plots had calculated densities below suboutbreak.

Walking routes to the evaluation plots were clearly marked on the ground as described in the Entomology Plan. Individual plot trees were marked with a band of orange paint at dbh and an aluminum tag at the base. The GPS location of each plot was also recorded and mapped. Exceptions to clear marking on the ground were made in

the case of evaluation plots established in Wolf Creek Control. These plots were within the Chelan-Sawtooth Wilderness, and were marked using the wilderness protocols for Continuous Vegetation Survey plots.

Walking routes to the evaluation plots were used by ground observers to access treatment blocks for weather observation during spray days. In the future, entomology crews should flag walking routes into every treatment block, whether or not an evaluation plot is established, to facilitate access for ground observers.

The pre-treatment and 20 to 23-day post treatment larval densities are listed in Table 3. The densities are portrayed in numbers per 1000 square inches of foliage, mid crown (Mason, 1979).

Table 3. Corrected Mortality Derived from Pre-Treatment and Post-Treatment Larval Density Samples on Treated Spray Blocks and Untreated Control Blocks

	TREATMENT BLOCKS	CONTROL BLOCKS
Mean Pre-Treatment Density	10.8 ± 2.2	3.6 ± 0.9
Mean Post-Treatment Density	1.0 ± 0.4	1.1 ± 0.7
Mortality	90.6%	69.4%
Corrected Mortality	69.3%	

The means are reported plus or minus the standard error.

Corrected mortality represents the amount of mortality attributable to the spray, after accounting for natural mortality. It is calculated using Abbot's formula (Abbott 1925):

$$\frac{\text{Survival in Control Blocks-Survival in Treatment Blocks}}{\text{Survival in Control Blocks}}$$

F. Defoliation and Short-Term Protection

Tree defoliation on established Evaluation Plots was estimated at the time of the pre-spray larval density sample and again at the post-spray larval density sample. All 20 trees on each plot were observed for defoliation and placed in one of eight defoliation categories, with Category 1 indicating no defoliation and Category 8 indicating total defoliation. Wickman's (1979) 'Annotated Table of Tree Defoliation Classes by Percent of Crown Defoliated' was used to estimate and classify the amount of defoliation on a sample host tree. The same plots will be sampled again in late July, 2002.

Overall defoliation did not exceed 10% in either treated blocks and controls. Aphid damage to new foliage was heavy in some blocks, and made it difficult for field crews to determine the true extent of tussock moth damage. In some cases, defoliation estimates on a given tree were higher at pre-treatment than post-treatment, particularly when it was necessary to determine the difference between zero defoliation and one percent.

Table 4. Percentage of Trees in each Defoliation Class in each Analysis Area

DEFOLIATION CLASS	TREATMENT BLOCKS	CONTROL BLOCKS
1 (no defoliation)	68%	84%
2 (1-10% defoliation)	31%	16%
3 (11-25% defoliation)	1%	0%
4-8 (>25% defoliation)	0%	0%

In all treated areas the corrected larval mortality figures and the defoliation intensities suggest that initial treatment objectives were met. Defoliation of 25% or less will probably result in no mortality attributable to tussock moth feeding (Wickman 1978). The overall treatment objective of interrupting the population cycle and its damage can only be assessed during follow up surveys in 2002.

G. Calculation of Larval Density

Errors in the calculation of midcrown larval density affected the release of spray blocks, and resulted in blocks being dropped that should have been sprayed.

Larval density per 1,000 square inches of midcrown foliage was calculated using the formula from the "Integrated Sample Form for Monitoring WSB and DFTM by Direct Counts," contained in the Entomology Plan for Tussock Moth Control 2000 (Umatilla and Walla-Whitman National Forests):

$$\frac{Total\ Number\ of\ Larvae\ per\ 3\ branch\ sample}{Number\ of\ Trees\ Sampled} \times 2^{*} \times 2^{**}$$

* Lower Crown density per 1,000 square inches
**Crown Distribution Correction

This formula underestimates midcrown density for first instar larvae and overestimates larval density for larger instars. This is because for each tree sampled, larvae were counted from the outer 18 inches of 3 branches. Branch area of these samples was 500 square inches, not 1,000 square inches. Therefore, the number of trees sampled should have been multiplied by 0.5 (Scott and Mason, 1992). For example, if 47 first instar larvae were counted on a 25-tree sample, the midcrown density calculation from the Integrated Sample Form would be:

$$\frac{47}{25} \times 2 \times 2 = 7.5$$

Using the formula given by Scott and Mason, the midcrown density would be calculated with a correction for branch area, and a ratio of midcrown to lower crown density (R) from Mason, 1987:

$$\frac{47}{(0.5)(25)} \times R = Midcrown\ larval\ density$$

Where $R = (5.727)(\text{average larval age in days})^{-0.598}$

Assuming the average age of first instar larvae is 2 days, R = 3.78. Therefore:

$$\frac{47}{(0.5)(25)} \times 3.78 = 14.21$$

Here it can be seen that the Integrated Sample Form formula underestimates the midcrown population of first instar larvae by 47%.

Because the Integrated Sample Form formula fails to account for stage of larval development, it overestimates populations of older larvae. This is because older larvae tend to move downward in the crown, while younger larvae tend to concentrate in the tops. When older larvae are counted in a lower crown sample, the count must be weighted according to the stage of development:

Instar	Weighting Factor
2	15
3	25
4	35

The weighting factor represents the average age (in days) of the larvae. Weighted average age of the sample must then be calculated, as in the following example:

Instar	No. Larvae Sampled	Weighting Factor	Weighted Total
2	13	15	195
3	23	25	575
4	11	35	385
TOTALS	47		1155

Next, the average age of the population represented by the above sample is calculated:

$$\frac{Weighted\ Total}{Total\ Larvae\ Sampled} = \frac{1155}{47} = 24.6\ (average\ age\ in\ days)$$

The ratio of midcrown to lower crown density is calculated using the regression equation:

$$R=(5.727)\ X^{-0.598}$$

In this example, X=24.6. Therefore:

$$R = (5.727)(24.6)^{-0.598} = 0.8436$$

For this example of a sample of older larvae, the estimated density would be:

$$\frac{47\ Larvae}{(0.5)(25\ trees)} \times 0.8436 = 3.17\ Lavae/1{,}000\ square\ inches\ midcrown$$

Here it can be seen that the Integrated Sample Form formula overestimates the midcrown population of older larvae by 137%.

Care should be taken during future projects to estimate populations using the correct formula.

C. Safety

Half of the personnel on the 20-person entomology field crew were experienced forest workers, and half were college students hired under the STEP program. This combination worked extremely well, providing a valuable opportunity for training new, mostly young employees. Briefings were held every morning to provide opportunities for questions, discussion of assignments, and updates on safety concerns. The project safety

officer was usually involved in morning briefings. Particular hazards encountered by field personnel were steep, rocky terrain, heat, rattlesnakes, and driving with unsecured loads. Rental vehicles used on the project also presented a potential hazard, as some of them arrived with mechanical problems that could not be detected on initial inspection.

The entomology field crew sampled a total of 85,597 acres; most of this ground was sampled at least twice. Despite many hours of driving and many more hours of walking on very rugged terrain only two minor injuries were reported.

H. Management Practices and Tussock Moth Hazard

The importance of management practices in reducing tussock moth hazard cannot be overemphasized. The application of direct control measures indicates a willingness on the part of land managers to manipulate stand conditions to meet certain objectives, as specified in the 1999 Tussock Moth EIS. However, unless direct control is followed by appropriate silvicultural practices, it has the potential to further magnify the problem (Stoszek 1978). For example, in certain spray blocks entomology field crews had difficulty locating plots for population surveys because dwarf mistletoe infection rates were so high. Having taken direct control action in these Analysis Units, the Forest should now develop a silvicultural prescription for every treated block with the objective of managing for desired stand conditions.

I. References

Abbott, W.S., 1925. A Method of Computing the Effectiveness of an Insecticide. J. Econ. Entomol. 18:265-267

Mason, R.R., 1979. How to Sample Douglas-fir Tussock Moth Larvae. USDA Handbook 547

Mason, R.R., 1987. Frequency Sampling to Predict Densities in Sparse Populations of the Douglas-fir Tussock Moth. Forest Science Vol. 33, No. 1, pp. 145-156

Scott, Donald W. and Mason, Richard R., 1992. Procedures for Converting Lower Crown Douglas-fir Tussock Moth Densities to Midcrown Densities. BMZ-92-01

Stoszek, Karel J., 1978. Management Practices and Tussock Moth Hazard, in The Douglas-Fir Tussock Moth: A Synthesis, USDA Forest Service Tech. Bul. 1585, p.188-189

Wickman, Boyd E., 1978. Tree Injury, in The Douglas-Fir Tussock Moth: A Synthesis, USDA Forest Service Tech. Bul. 1585, p.66-77

USDA Forest Service, 2000. Douglas-fir Tussock Moth Environmental Impact Statement.