FINAL REPORT

The Relationships of Site and Stand Attributes and Management Practices to Douglas-fir Tussock Moth Epidemics

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INTRODUCTION

For forest and pest management systems to be effective, they must have the capability of predicting spatial and temporal changes in pest populations and resultant damage. The manager must be able to forecast, with a reasonable probability of success, *where*, *when* and to *what* extent a particular pest will damage the resource. The primary objective of the work reported herein has been the development of such forecasting ability, in particular, development of models capable of risk-rating sites and stands to defoliation by the Douglas-fir tussock moth, *Orgyia pseudotsugata* McDunnough. This research was based on the hypothesis that tussock moth outbreaks are triggered by interactions of climatic conditions with conditions intrinsic to certain forest environments which favor reproduction and survival of the moth and/or restrict these processes in its natural enemies. Literature and our own exploratory research supports this hypothesis. There is ample evidence that site, tree and stand condition directly affect population dynamics of forest insects, particularly larval defoliators (reviews by Mattson and Addy 1975, Kulman 1971, Stark 1965). Aspects of the bionomics and population dynamics of the tussock moth lend additional support to the hypothesis.

The tussock moth, associated with Douglas-fir, *Pseudotsuga menzsiesii* (Mirb.) Franco, and true firs, *Abies* sp., in western North America, is capable of changing from an enzootic level to an epizootic peak of outbreak proportions within three years. The outbreak is considered to go through three phases: release, outbreak, and decline (Wickman et al. 1973). The release phase is typified by rapid multiplication of the

population. During the outbreak phase, defoliation of host trees becomes evident. Rapid population growth continues until density-dependent factors take effect, leading to the decline phase and collapse of the population. The population remains at an enzootic level until conditions conducive to release again occur.

The female is flightless, larval dispersal is facilitated by wind and air currents and outbreaks develop in place (Mason 1974). This suggests that the tussock moth is an inhabitant of relatively permanent habitats which allow moth survival under adverse conditions, and which, when influenced by extrinsic factors, favor increase in the moth population. Tussock moth outbreaks are highly variable in terms of defoliation intensity and land area subjected to infestation. Severe defoliation is at times confined to small groups of trees or to widely scattered, small stands in the midst of host types. Frequently however, outbreaks cover hundreds of thousands of acres of forests with a mosaic of varying defoliation intensities (Evenden 1948, Tunnock 1973). The outbreaks are cyclic (Clendenen 1974, Wickman et al. 1973) with periodic recurrance in the same general area. In northern Idaho, for example, the outbreak cycle has a periodicity of nine to ten years (Tunnock 1973).

The simultaneous occurrence of outbreaks in separate regions suggests a synchronization through climatic factors. Clendenen (1974) showed positive correlations between pest outbreak cycles and above average spring temperatures and below average August precipitation. Observation by Wickman (1963) and Lessard (1974) suggest that outbreaks are preceeded by one or more years of below-normal precipitation. The number of years with below-normal precipitation was found by Lessard to be positively correlated with the number of acres infested during an outbreak. Lessard

also showed a relationship between increasing radiation index and the likelihood of defoliation in a given area.

In 1974 we conducted an exploratory study in northern Idaho and attempted to relate the intensity of tussock moth defoliation during the outbreak phase of a population cycle (*sensu* Wickman et al. 1973) to site and stand characteristics. The results showed that stands in which Douglas-fir was the dominant host-species component sustained lower levels of defoliation than stands on similar sites in which grand fir, *Abies grandis* Dougl. Lindl., was the dominant component. This suggests that grand fir is the preferred host in northern Idaho. The highest defoliation levels were associated with grand fir stands on sites with a high exposure to solar radiation. Young, one-storied stands were less defoliated than mature and overmature, multi-storied stands. Selective logging appeared to increase stand vulnerability to tussock moth defoliations (Stoszek et al. 1975).

Based on these preliminary results, we decided to initiate in 1975 a more detailed study. Our objectives here were three-fold:

1) to further elucidate the relationships between defoliation intensity and site and stand characteristics;

2) to develop models capable of identifying (risk-rating) sites and stands susceptible to tussock moth outbreak;

3) to provide information for a conceptual understanding of interactions between stand conditions and insect population dynamics as a basis for preventive silvicultural and other forest and pest management strategies.

METHODS AND PROCEDURES

The study was conducted in Latah and Benewah counties of northern Idaho (Figure 1a). The study area, approximately 265 square miles (685km^2), is one of rolling hills, mountains and mountainous ridges. The area lies on the boundary between the Northern Rocky Mountain Province and the Palouse Hills section of the Columbia Intermontane Province (Ross and Savage 1967). The Palouse Range lies to the south, the Hoodoo Mountains to the east, and the Palouse Prairie to the west (Figure 1b). Major mountain ridge systems, oriented east-west, extend toward the Palouse Prairie. These join other mountain ridges to the east, with elevations ranging from 2500 to 5000 feet (750 to 1500m) and a vertical relief from 200 to 1500 feet (60 to 460m).

The major underlying rock type is the Belt series metasediments, a very old and variable formation. Within the study area, this formation is composed of weathered siltites and quartzites (Shively 1977). Basalts of the Columbia River lava flows abutt the area on the west and southwest, and infiltrate the low lying valleys. The basalts and gently sloping hills from the metasediments are covered with or influenced by loess deposits (Richmond et al. 1965). The more mountainous portions of the study area are influenced by a deposit of volcanic ash of varying thickness from the Mount Mazama (Crater Lake) eruption of 6600 years ago (Fryxell 1965). This ash overlies older soils developed from loess and/or metasediments.

Precipitation ranges from 22 inches (56cm) on the prairie fringes to approximately 35 inches (89cm) in the mountainous eastern portion of the study area (National Oceanic and Atmospheric Administration 1976).

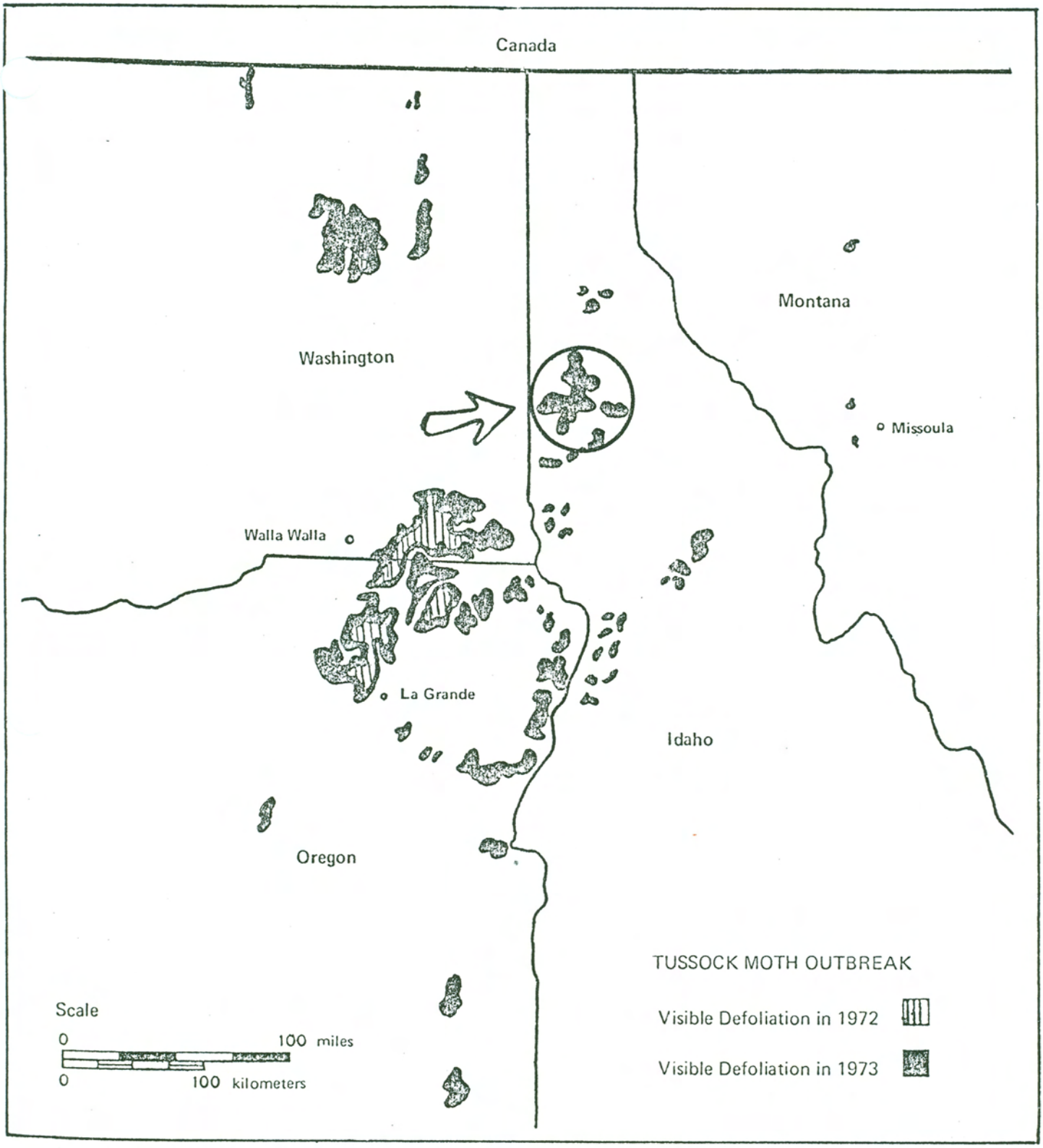

Figure 1a. Douglas-fir tussock moth site/stand study area in northern Idaho and its relationship to outbreak areas of the Pacific Northwest (from "The Tussock Moth Epidemic", Dec. 1973. National Forest Products Association, Washington D.C.)

The climate is characterized by dry summers from mid June to mid September, with the major precipitation falling as rain or snow from November through March (Klages 1965).

The diversity of plant communities occurring in the Palouse Range reflects the edaphic and climatic complexity of the area. Ponderosa pine, *Pinus ponderosa* Laws, and Douglas-fir habitat types (*sensu* Daubenmire and Daubenmire 1968) are found on drier and warmer sites at lower elevations. Sites with increasing availability of soil moisture and cooler temperatures support, in the indicated order, grand fir, western red cedar, *Thuja plicata* Donn, and western hemlock, *Tsuga heterophylla* (Raf.) Sarg., habitat types. Subalpine fir, *A. lasiocarpa* (Hook) Nutt., habitat types occur on moist and cool sites at high elevations and in moist to wet frost-pocket situations.

Succession, structure and species composition of forests in the area were greatly influenced by wildfires of various magnitudes, intensities and frequencies. Burned areas regenerated to a mixture of shade intolerant species, primarily Douglas-fir, western larch, *Larix occidentalis* Nutt., ponderosa pine on drier sites, western white pine, *P. monticola* Dougl., on more productive sites, and lodgepole pine, *P. contorta* var. *latifolia* Dougl., usually in frost-prone areas. Under these seral even-aged stands, the environment was favorable for the establishment of shade tolerant trees, such as grand fir, western redcedar, western hemlock and subalpine fir. However, these latter species, especially when young, were readily injured or killed by ground fires. Thus, in addition to slowing or even preventing succession, ground fires decreased stand density and vertical diversity.

The advent of farming and logging activities at the turn of this century altered the natural pattern. Successful fire control and selective logging of high value mature white pine, ponderosa pine, Douglas-fir or larch created conditions conducive to establishment and growth of shade tolerant species. As a result, the density and vertical diversity of forests in the area increased, as did the rate of succession toward climax stands. Patch clearcutting, applied sporadically since the late 1940's produced even-aged stands composed of shade tolerant and intolerant species. With increasing demands for wood fiber, drastic diameter limit cuts created a considerable acreage of stands composed primarily of climax species of poor vigor.

From 1944 to 1947 an extensive acreage of forests in the study area was defoliated by the Douglas-fir tussock moth. The outbreak was controlled by aerial application of DDT. From 1963 to 1965 a new outbreak was recorded, and again controlled with DDT (Tunnock 1973).

The most recent outbreak in the area was detected in 1973. The outbreak, resulting in a mosaic of varying defoliation levels, occurred over the same general area as the preceding epizootics. A decision was made to control the tussock moth population on about 75,300 acres (30,500ha) using DDT applied in late June and early July of 1974 (Graham et al. 1975).

The diversity of site/stand conditions, the forest and pest management history of the area, and especially the defoliation pattern resulting from larval feeding in the outbreak phase of the moth population cycle appeared to provide ideal conditions for attaining the study objectives.

SUMMARY

The study was conducted in northern Idaho, an area subject to a history of Douglas-fir tussock moth outbreaks, with a diversity in climatic, geomorphologic and phytocenotic conditions. Forest succession, stand composition and structure has been influenced by selective logging, exclusion of fire and application of direct controls of defoliator populations.

Seventy study stands were selected to cover a range of site and stand conditions. Three sample plots were established in each stand and data collected on tussock moth defoliation intensity and various site and stand characteristics.

Several regression techniques were used to identify and quantify the relationships between defoliation levels and site and stand variables. Defoliation intensity was a function of slope position, depth of volcanic ash, host age, proportion of grand fir in the stand, and the ratio of stand density to site index. Several alternative formulations of the hazard rating model are presented. The "best" model accounted for approximately 50 percent of the variation in defoliation intensity.

The results suggest that moth populations increase in response to biomass accumulation overtaxing factors important to site-host relationships. Inferences are made about the role of the insect as a regulator of primary production. This concept and the stand hazard models provide a basis for discussion of forest managerial and silvicultural practices designed to reduce the magnitude of tussock moth outbreaks.

Location of Complete Research:

Author & Title: Karel J. Stoszek, Harold L. Osborne, Peter G. Mika, and James A. Moore:
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