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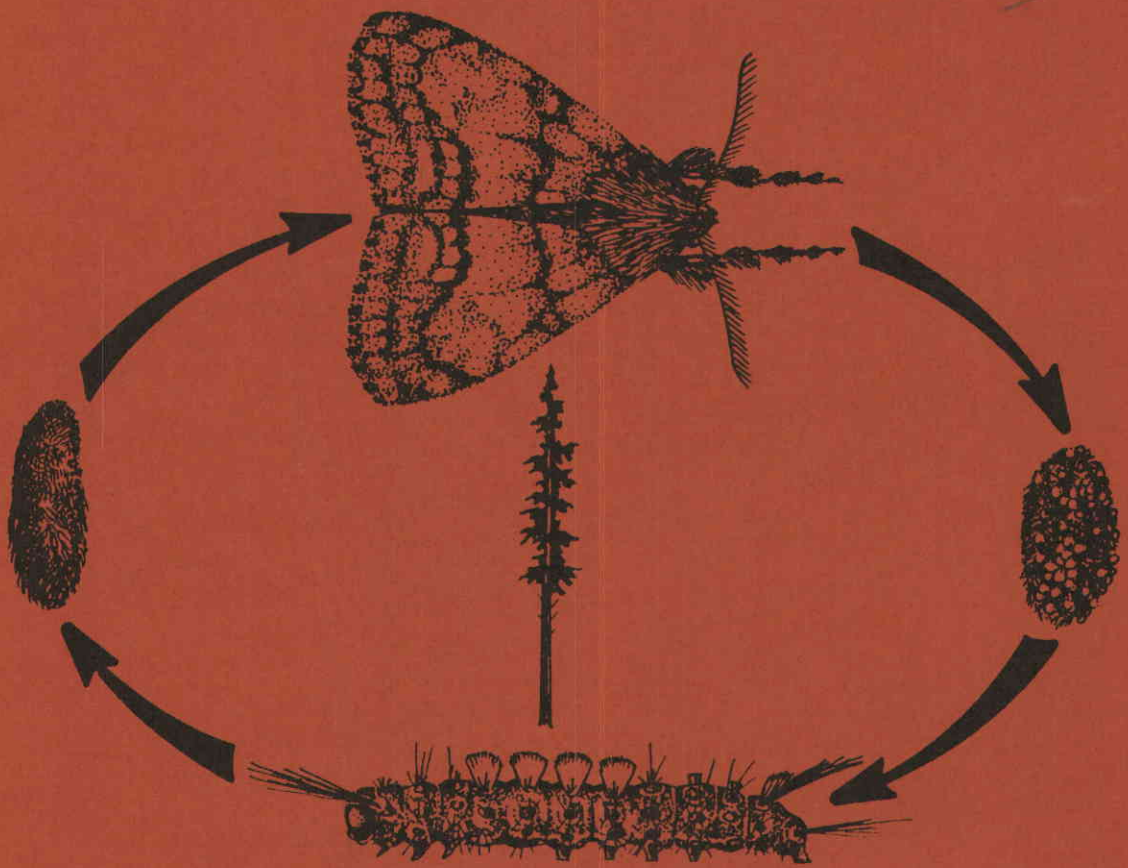
DOUGLAS-FIR TUSSOCK MOTH: AN ANNOTATED BIBLIOGRAPHY



PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
PORTLAND, OREGON

Acknowledgments

Many of the unpublished papers were drawn from an earlier bibliography accumulated by Paul Iwai, Forestry Sciences Laboratory, Corvallis, Oregon. Thomas Seibert, Entomology Department, Oregon State University, Corvallis, compiled most of the references in the current file. Finally, we thank the many investigators who graciously allowed us access to their unpublished reports.

USDA FOREST SERVICE
General Technical Report PNW-68

DOUGLAS-FIR TUSSOCK MOTH—

An Annotated Bibliography

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Corvallis, Oregon

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Foreword

This annotated bibliography includes references to 338 papers. Each deals in some way with either the Douglas-fir tussock moth, Orgyia pseudotsugata (McDunnough), or a related species. Specifically, 210 publications and 82 unpublished documents make some reference, at least, to the Douglas-fir tussock moth; 55 are concerned with other species in the same genus. The subject matter in each paper has been indexed to at least one general topic (General, Taxonomy, Biology, Host Relationships, Outbreaks, Control, Related Material). Most of these general topics have been subdivided into more specific headings. For example, Host Relationships includes separate categories for white fir, grand fir, and Douglas-fir. A complete listing of the references in each general and specific category is presented in the index.

By intent, at least, this bibliography is complete for the Douglas-fir tussock moth through December 31, 1977. A copy of virtually every document in the bibliography is on file at the Forestry Sciences Laboratory, 3200 Jefferson Way, Corvallis, Oregon. Investigators wishing to obtain copies of specific documents are urged to write the author(s) directly. Usually, specific authors' current addresses can be obtained by writing the senior author of this bibliography. Copies of documents in our master file in Corvallis will only be supplied as a last resort.

Bibliography

1. Almas, D., W. Bousfield, L. Livingston, and W. Ludeman. 1975. 1974 North Idaho cooperative Douglas-fir tussock moth control project. Report. State Idaho, Dep. Lands. Div. For. Manage., Coeur d'Alene, Idaho. Rep. 75-1. 60 p.

"This report summarizes the results of a 1974 forest protection project using DDT for control of the Douglas-fir tussock moth." Signs that an outbreak was building up in northern Idaho were discovered at isolated spots in 1971 and 1972. An egg mass survey, conducted February 1973, substantiated the buildup. Another survey that fall showed 103,878 acres of forest with population that could cause damage in 1974.

Treatment boundaries for the project were based on 20 larvae per 1,000 in^2 of foliage. A total of 75,254 acres were sprayed with DDT at a rate of 3/4 lb of DDT per acre. Corrected larval mortality averaged 97.77% 4 days after spraying and 99.8% 21 days after spraying. Comparison of sprayed and unsprayed areas showed that a significant amount of foliage was saved by the spray.

Spray deposit was monitored in sprayed and buffered areas. Pesticide residues were monitored before, during, and after spray application in water, fish, and air.

Meat from livestock in the spray areas was inspected. Actual levels found in livestock were not presented.
Control - 2, 3

2. Anderson, W. B. 1919. Notes on the tussock moth, Hemerocampa vetusta gulosa Hy. Edw., in British Columbia. Agric. Gaz. Can. 6(2):139.

Two local infestations of the tussock moth, Hemerocampa vetusta gulosa Hy. Edw., were observed at Hedley and Chase, British Columbia, in 1917 and 1918. Douglas-firs were severely defoliated and

some top-kill was reported. Ponderosa pines were lightly attacked and many cocoons were found on them. The attacks started at the top of the crown and worked downward.
Related Material - 3

3. Atkins, E. L., Jr. 1958. The western tussock moth, Hemerocampa vetusta (Bdv.), on citrus in southern California. J. Econ. Entomol. 51(6):762-765.

"Larvae of the western tussock moth, Hemerocampa vetusta (Bdv.), caused economic losses in 10,000 acres of oranges during the springs of 1956 and 1957 in parts of southern California. Population levels were as high as 1,000 larvae per tree. The larvae may destroy the new spring flush of growth and the newly set fruit and scar maturing oranges so that the fruit drops or the grade is lowered. This moth has one generation a year. The wingless females lay their eggs on the trees in masses from May to July; the eggs hatch during March and April of the following year. The average life cycle is 75 days. A population level of 100 caterpillars per orange tree, or an average of one egg mass per tree, is considered the economic level. Six parasite species, one hyperparasite, and two predator species were collected during 1956 and 1957 and were observed to reduce the population approximately 50% in some groves. Chemical control studies showed that parathion, TDE (DDD), DDT, Dilan®, Guthion®, Sevin® (N-methyl-1-naphthyl - carbamate), methyl parathion, and Phosdrin® gave excellent control; nine other pesticides did not provide adequate control. Parathion, TDE, and DDT are now registered for use on citrus and are recommended for control of the western tussock moth when applied as complete foliage sprays at the rate of 2, 5, and 5 lbs, respectively, of actual toxicant per acre."
Related Material - 3

4. Austara, O., and T. Jones. 1971. Host list and distribution of lepidopterous defoliators of exotic softwoods in East Africa. East Afr. Agric. For. J. 36(4):401-413.

Lepidoptera that defoliate pines and cypresses in East Africa are listed, including Orgyia basalis, O. hopkinsi, and O. mixta.
Related Material - 3

5. Austara, O., and J. Migunda. 1971. Orgyia mixta Snell. (Lepidoptera: Lymantriidae) a defoliator of exotic softwoods in Kenya. East Afr. Agric. For. J. 36(3):298-307.

"Orgyia mixta Snell. is a native tussock moth which has adapted itself to feeding on exotic softwoods, and has occurred in small outbreaks in Kenya plantations. The biology of the pest was studied in the field and the laboratory. The duration of the life cycle ranged between 48 and 85 days, and it was concluded that the moth was potentially capable of producing up to six generations a year. It was estimated that approximately 20-25 larvae per meter of branch could cause 100% defoliation, and that young plantations are likely to be more vulnerable to attacks than older stands." A nematode parasite is the main agent of natural control. Three insecticides were tested against late-instar larvae.
Related Material - 3

6. Balch, R. E. 1930. The fir tussock moth (observations in 1929). USDA Bur. Entomol., For. Insect Invest., For. Insect Field Stn., Coeur d'Alene, Idaho. 19 p. Unpubl.

The results of preliminary investigations of three Douglas-fir tussock moth infestation sites in Idaho conducted during August 1929 are presented. A complete description of the insect in all stages of development and its life history are given. Larval feeding patterns are deduced from laboratory observations and examinations of tree defoliation. Host preference and species upon which the moth can reach epidemic proportions are listed. The possible effects of Douglas-fir tussock moth defoliation on stand composition and its commercial importance are discussed.

12. Baugh, T. M. 1976. Pest management tests seek new control methods. West. Conserv. J. 33(4):34-36.

The highlights of the research of the Expanded Douglas-fir Tussock Moth Research and Development Program are presented. Effort is being directed toward the development of an integrated pest management program by 1977. Initial results of the program include: identification of the female sex pheromone and its use in sticky traps; promising tests of Dimilin®, carbaryl, and Dylox® as alternatives to DDT; effective control produced by microbial agents; and a greater understanding of the relationship between stand characteristics and outbreaks. Plans for future reasearch are briefly outlined.
Related Material - 2

13. Beckwith, R. C. 1975. Douglas-fir tussock moth Orgyia pseudotsugata (McD.) (Lepidoptera: Lasiocampidae): influence of host foliage. J. N.Y. Entomol. Soc. 83(4):282-283.

"A resume of tussock moth biology is presented with special emphasis on host effects. . . . Populations can increase equally well on grand fir and Douglas-fir, the degree of acceptance of old-growth foliage may govern survival rate and ultimate tree damage." Only current foliage is consumed during the release phase of an outbreak, but larvae will feed on old-growth foliage during the outbreak phase. Subsistence on old-growth foliage by early instar larvae is ultimately detrimental to survival.
Biology - 1; Host Relationships - 2, 3

14. Beckwith, R. C. 1976. Influence of host foliage on the Douglas-fir tussock moth. Environ. Entomol. 5(1):73-77.

"Douglas-fir tussock moth (Orgyia pseudotsugata (McDunnough)) larvae were fed foliage obtained from the top and bottom of the crowns of Douglas-fir, grand fir, and subalpine fir under controlled laboratory

conditions. High-density field populations were simulated by forcing larvae to feed upon old-growth foliage creating a stress factor that was detrimental to the population. The host plant and crown position had a significant effect on frass production, head-capsule size, and pupal weight. The number of eggs produced was significantly greater from foliage obtained from the top of the crown. The most significant factor was whether larvae were forced to feed on old-growth foliage. This "stress" resulted in increased development time, frass production, number of instars and decreased head-capsule size, and egg production."
Biology - 1; Host Relationships - 2, 3

15. Bedard, W. D. 1938. An annotated list of the insect fauna of Douglas-fir (Pseudotsuga mucronata Rafinesque) in the northern Rocky Mountain region. Can. Entomol. 70(9):188-197.

A record is given of insects that have been found in or on Douglas-fir in the northern Rocky Mountain region by personnel of the Forest Insect Field Laboratory at Coeur d'Alene, Idaho. It includes insects that feed on the tree as well as the parasites and associates of those insects. Most of the 153 species listed were collected by the writer during a study of the Douglas-fir beetle. Hemerocampa pseudotsugata is listed, and sporadic outbreaks have been recorded in various parts of the northern Rocky Mountains. Adults are prevalent in the infested areas during September.
Host Relationships - 3

16. Bergstrom, D. 1976. Pheromones for insect control. In Forestry research: What's new in the West, September 1976. USDA For. Serv., p. 9-10.

The possible uses of the synthetic sex pheromone of the Douglas-fir tussock moth as a control agent, as well as a survey and detection tool, are explored. The procedure used to isolate and identify insect pheromones is briefly outlined.
Biology - 2, Outbreaks - 2, 3; Control - 10

17. Berryman, A. A. 1973. Population dynamics of the fir engraver, Scolytus ventralis (Coleoptera: Scolytidae). 1. Analysis of population behavior and survival from 1964 to 1971. Can. Entomol. 105(11):1465-1488.

"Populations of the fir engraver reached epidemic proportions and then declined to a very low level over the study period (1964-71). . . . The population trend over the past 40 years was associated to some degree with rainfall deficits and with Douglas-fir tussock moth outbreaks."
Host Relationships - 2, Outbreaks - 5.

18. Bischoff, A. I., and J. D. Linn. 1967. Completion report on the evaluation of the effects on fish and wildlife of the Douglas-fir tussock moth control project in California - 1965. Calif. Dep. Fish and Game. 4 p. Unpubl.

"In 1965, the California Department of Fish and Game initiated a 2-year surveillance program to determine the effects of a DDT forest spray program on nontarget fish and wildlife." This paper is an addendum to a 1965 progress report on the first year's results. Residue in the environment increased considerably, with a general buildup of DDT residues in wild animals following the DDT application. "The highest levels of the DDT complex were reported in samples of chickadees (51.5 ppm) and deer (84.1 ppm). The residue levels reported for the 1-year postspray samples of these species declined nearly to the prespray levels."
Control - 3

19. Blackmore, E. H. 1919. Report of the Provincial Museum of Natural History, for 1918. Victoria, B.C. 16 p.

A summary is given of work carried out by the museum during the year. Damage done by various species of insects is recorded, as well as

their relative abundance. A list of rare and uncommon insects taken in British Columbia is presented, along with the new specimens described in the province. One of the newly described species of Lymantriidae is Hemerocampa vetusta gulosa Hy. Edw. A brief sketch of its biology is given. Photographs of the new species are included.
Related Material - 3

20. Bogenschütz, V. H. 1975. Parasitenstudien als Entscheidungshilfen bei der integrierten Bekampfung von Forstschadlingen. [Parasite studies as aids in decision-making in the integrated control of forest pests.] Z. Angew. Entomol. 78(1):1-4. [In Ger.]

This paper deals with studies on parasites for integrated control in forests. "The results of the studies on parasitism of the two spruce damaging insects Orgyia antiqua and Laspeyresia pactolana provided not only better knowledge of the ecology of these lepidopterous species but also indicate the importance of host-parasite-relationships as they apply to forest and environmental protection."
Related Material - 3

21. Bousfield, W. E. 1974. Sampling the target insect. In Aerial application of insecticides against forest defoliators (chemicals and microbials). Proceedings of workshop held April 23-25, 1974, Univ. Mont., Missoula, p. 107-111. USDA For. Serv., State and Private Forestry, Northern Region, Missoula, Mont.

Techniques are described for sampling the target insect to measure the efficacy of aerial operations. Formulas for estimating the population variance between branches, trees, and areas or clusters of trees for estimating sample size and unit are included.
Outbreaks - 3

control measures used are cited. Also mentioned was the initiation in 1947 of a study to determine the viability and parasitisms of egg clusters from the Troy, Oregon, area.
Outbreaks - 1, 2

27. Buckman, R. E. 1974. Deadly tussock moth threatens more timber stands in Pacific Northwest. West. Conserv. J. 21(1):25-31.

A popular account is given of the tussock moth outbreak in the Blue Mountains and the methods of control. A brief review of the biology of the moth, detection and prediction of population trends, impact of defoliation, and alternatives for control is presented. The use of DDT is called for if the natural virus incidence is too low to suppress the outbreak population.
Outbreaks - 2

28. Burke, H. E. 1906. Notes on the natural history of Notolophus oslari. In Minutes of the 209th regular meeting of the Entomological Society of Washington. Proc. Entomol. Soc. Wash. 8(1,2):142-143.

During the 209th meeting of the Entomological Society of Washington, the author exhibited a rare tussock moth, Notolophus oslari Barnes. This was the first record of this species from California. A discussion followed on the damage done by the larvae to fir, comparisons between the egg mass construction of N. oslari and other closely related species, and possible biological control agents.
Related Material - 3

29. Burke, H. E. 1930. Which insects are the important enemies of shade, park, and ornamental trees in the Pacific States? J. Econ. Entomol. 23(5):783-785.

Fifty of the most important insect enemies of trees used for ornamental, shade, and recreational purposes in the Pacific States are ranked in importance according to the information provided by questionnaires sent to university, city, county, State, and Federal personnel working with insects. The importance of any species varies with the area. Hemerocampa pseudotsugata McD. was rated number 39. General Background

30. Cameron, E. A. 1970. Larval eclosion in Douglas-fir tussock moth, Hemerocampa pseudotsugata. Ann. Entomol. Soc. Am. 63(4):1110-1113.

Douglas-fir tussock moth "eggs were field collected in northeastern California, early in December 1965, treated with a solution of formaldehyde for virus decontamination, then stored at 2-3°C. After storage for 18-360 days, eggs were observed for percent of eclosion and duration and diel periodicity of eclosion."

"Both percent eclosion and the duration of the eclosion period were reduced by storage up to 186 days. No eggs hatched after 360 days storage. Low hatchability after long periods of storage may have resulted from formaldehyde fumigant action, suffocation, or depletion of stored energy by maintenance metabolism.

"Continuous illumination or constant darkness following storage influenced neither the initiation of eclosion nor the duration of the eclosion period. Eclosion was highest in the 6-hr period which included sunrise, but continued throughout the diel. Implications of such a pattern on larval establishment and dispersal in nature are discussed." Biology - 1

31. Campbell, R. W. 1977. Integration of program outputs: Development of a pest management system. Bull. Entomol. Soc. Am. 23(3):179-180.

The life history of tussock moth and damage caused by it are presented, along with pictures of the different life stages. Control of the insect on ornamental trees is obtained by the use of methoxychlor or Bacillus thuringiensis (Dipel®) spray application.
General Background

37. Carnegie, J. W., and G. S. Beaudreau. 1969. Deoxyribonucleic acid synthesis in insect larvae after inoculation with nucleopolyhedrosis virus. J. Virol. 4(3):311-312.

DNA synthesis by Hemerocampa pseudotsugata after inoculation with nucleopolyhedrosis virus occurs in a large burst, 72 to 96 hr after infection and continues through the 5th day of the disease cycle.
Biology - 5

38. Chauthani, A. R., and D. Claussen. 1968. Rearing Douglas-fir tussock moth larvae on synthetic media for the production of nuclear polyhedrosis virus. J. Econ. Entomol. 61(1):101-103.

"A technique for rearing larvae of the Douglas-fir tussock moth, Hemerocampa pseudotsugata McDunnough, in large numbers on a synthetic medium for the production of nuclear polyhedrosis virus is described. The insect was reared from the egg stage generally to the 4th and 5th instar before infection." Egg masses were collected from the field and stored at 4°C to fulfill diapause requirements. Surface sterilization of the egg with a 10% formaldehyde solution provided virus-free larvae. The synthetic diet used to rear the larvae is included. Virus infection of the larvae was initiated 25 days after eclosion, when larvae had an average weight of 310 mg. Infected larvae were collected 8-12 days after infection, lyophilized, and placed in vacuum sealed jars. Mortality of larvae before infection was very low.
Biology - 6; Control - 9

39. Ciesla, W. M. 1975. Pilot control projects of chemical and microbial insecticides against Douglas-fir tussock moth - 1974. West. For. and Conserv. Assoc., Perm. Assoc. Proc. 1974:16-18. Portland, Oreg.

Tests of chemical and microbial insecticides were carried out in 1974 to find an alternative to DDT for controlling the Douglas-fir tussock moth. Five pilot control projects were conducted: Sevin-4-oil and Bacillus thuringiensis (B.t.), applied near Missoula, Montana, with Sevin-4-oil causing a 90 to 99% reduction in population and B.t. causing a 73% reduction; Sevin, Dylox, and DDT, applied near Halfway, Oregon, with Sevin causing a 53-89.5% reduction, Dylox with a 70-83.1% reduction, and DDT a 100% population reduction; B.t. and nucleopolyhedrosis virus applied in Idaho, with both sprays aborted because of a 93% population reduction from natural virus infection; Sevin-4-oil applied in Idaho, with an 83.15-96.77% population reduction; and Dylox in Oregon, with a 68.4% and 78.6% reduction before a natural population collapse occurred. Problems encountered during the spray programs were discussed.
Control - 1, 2, 5, 6

40. Ciesla, W. M. 1977. Douglas-fir tussock moth: Direct control with chemical and microbial insecticides. Bull. Entomol. Soc. Am. 23(3):174-176.

The effort directed toward the development of chemical and microbial insecticides for Douglas-fir tussock moth control is described. Laboratory screening procedures, field experiments, and pilot control projects have been directed toward bringing carbaryl, trichlorfon, acephate, and TH 6040 to or close to registration. Bacillus thuringiensis and the tussock moth nucleopolyhedrosis virus have been tested. Improvement of application technology has also received considerable research attention.

The research has resulted in the registration of Thuricide 16B (commercial B.t. formulation) and the nucleopolyhedrosis virus for tussock moth control.
Control - 1, 5, 6, 7

41. Ciesla, W. M., S. Kohler, J. E. Dewey, and M. D. McGregor. 1976. Field efficacy of aerial applications of carbaryl against Douglas-fir tussock moth. J. Econ. Entomol. 69(2):219-224.

"Sevin-4-oil, an oil suspension of carbaryl, was applied by helicopter to forested areas infected by Orgyia pseudotsugata (McDunnough), in western Montana and northern Idaho. Dosage was 2 lb AI/0.75 gal of carrier/acre. Spray was applied to 1st-instar larvae in Montana and 3rd and 4th instars in Idaho. Treatments provided a high degree of insect mortality and measurable foliage protection; the residual population did not produce egg masses in suffient quantity to repopulate infested areas."
Control - 1

42. Cleary, B., and J. Brown. 1974. After the tussock moth: salvage, rehabilitation, protection: A guide for forest landowners. Oreg. State Univ. Ext. Serv. Spec. Rep. 422, 35 p.

This publication discusses tussock moth damage, salvage cutting opportunities, rehabilitation and reforestation methods, protection measures, available help, and applicable State laws. Appended are lists of local sawmills, tree nurseries, helpful publications, and important tree species in the northeastern Oregon and eastern Washington forests.
General Background; Outbreaks - 5

43. Cole, W. E. 1957. Douglas-fir tussock moth appraisal survey in Owyhee County, Idaho. USDA For. Serv. Intermt. For. and Range Exp. Stn., Ogden, Utah. 4 p. Unpubl.

An infestation of the Douglas-fir tussock moth was detected in August 1956. An appraisal survey was conducted in September 1957, and about 26,000 acres were found infested. The author predicted that defoliation would occur again in 1958 even though he found a high degree of parasitism.
Outbreaks - 2

44. Cole, W. E. 1958. Douglas-fir tussock moth situation in Owyhee County, Idaho, 1958. USDA For. Serv. Intermt. For. and Range Exp. Stn., Ogden, Utah. 4 p. Unpubl.

In August 1956, an infestation of the Douglas-fir tussock moth was reported in the Owyhee Mountains, Idaho. Defoliation ranged from 60 to 70%, and a high degree of parasitism was evident. The area was checked in 1957 and defoliation estimated at less than 50% with 19.5% pupal parasitism. Large numbers of sawfly larvae were present also. Control operations by aerial spraying were recommended, and plans were formulated. But in late 1957 dead larvae and pupae were found showing symptoms of virus disease. Presence of virus was confirmed, and control plans were cancelled. The area was sampled each month from June through October 1958 for feeding of tussock moths and sawflies, but only for the tussock moth pupal population. Populations of both tussock moths and sawflies had greatly decreased in all but one area. Larval samples were taken and analyzed for the amount of virus present.
Outbreaks - 2

45. Condrashoff, S. F., and J. Grant. 1962. Sampling Douglas-fir tussock moth populations. Can. Dep. For., For. Entomol. and Pathol. Branch Bi-Mon. Prog. Rep. 18(4):3.

In the summer of 1961 several localized infestations of the Douglas-fir tussock moth were observed in the North Okanagan, British

Columbia. "Three sample plots were established in separate areas to detect any future expansion of the infestations, to assess tree mortality and to obtain information on distribution of cocoons and egg masses in the trees. . . . Severely defoliated trees contained over twice the concentration of cocoons of the lightly defoliated trees, whereas the average concentration of egg masses was about equal." Male and female larvae pupate in different sites--females in green foliage and males more or less at random. Successful emergence of adults decreased with crown level.

Outbreaks - 3

46. Congressional Record - House. 1969. A technological alternative to pesticides. June 27, 1969:17646. H5359.

On June 27, 1969, Mr. Hosmer of California, spoke about a virus which is specific for the Douglas-fir tussock moth as an alternative to DDT control. The USDA Forest Service is working with the Atomic Energy Commission's Oak Ridge National Laboratory to purify the virus. Dr. M. E. Martignoni established the toxicity of the virus toward the tussock moth and asked that the project be initiated. The zonal centrifuging system with a K-11-C rotor system was used to purify the virus. The centrifuge system reduces the bacteria present in the virus homogenate to a level safe for use on watersheds.

Control - 6

47. Crisp, W. 1974. The tussock moth scare, will it collapse? Am. For. 80(4):58-63.

This paper is a report on the EPA public hearing of January 1974 on the USDA Forest Service application to use DDT against the current Douglas-fir tussock moth infestation in Washington, Oregon, and Idaho. Proponents of the use of DDT were led by Senator Robert Packwood, and the opposition was represented by William Van Dyke of OSPIRG. Arguments for

DDT were based on the potential damage to timber and watershed values if the outbreaks were not quickly halted, coupled with the lack of registered alternative chemical controls. OSPIRG and the Oregon Environmental Council questioned the Forest Service estimate of potential damage and its test results with other chemical agents. They contended that the benefits of DDT use did not outweigh the hazards.
Control - 4

48. Crouch, G. L., and R. F. Perkins. 1968. Planning a surveillance program for the Douglas-fir tussock moth in Oregon. Pestic. Monit. J. 2(2):97-100.

"This is a brief account of the planning and organizing of a surveillance team to determine the adverse effects, if any, of a forest aerial spray project. Particular effort was made to ensure that all interested persons, organizations, and agencies were advised of the proposed project well in advance and invited to participate on the surveillance team. . . . Final plans called for gathering short-term information on the effects of proposed DDT application on big game, range cattle, forage plants, water, aquatic insects, and fish. Long-term research will investigate levels and persistence of DDT in aquatic environments and movement of DDT and its metabolites from conifer litter through soil particles."
Control - 3

49. Crouch, G. L., and R. F. Perkins. 1968. Surveillance report, 1965 Burns Project, Douglas-fir tussock moth control. Malheur and Ochoco National Forests. USDA For. Serv. Pac. Northwest Reg., Insect and Dis. Control Branch, Div. Timber Manage. 20 p. Unpubl.

This report provides a record of the buildup of an infestation of the Douglas-fir tussock moth near Burns, Oregon, in 1965 and the control and surveillance efforts used to suppress it. In 1963, 15 acres were

defoliated by the moth, and by 1964, 41,000 acres had become infested. Entomologists predicted that 200,000 acres would become infested in 1965 unless control measures were applied. They predicted that virus incidence was too low to cause a population collapse, and DDT was selected for control. An analysis for DDT residues was conducted on aquatic organisms, big game animals, range cattle, and forage plants. Few visible adverse effects of the spray project on nontarget organisms were observed. Control - 2, 3

50. Cunningham, J. C. 1972. Preliminary studies of nuclear polyhedrosis viruses infecting white marked tussock moth, Orgyia leucostigma. Can. For. Serv. Insect Pathol. Res. Inst. Inf. Rep. 11 p. Unpubl.

"Larvae of Orgyia leucostigma were found to be susceptible to nuclear polyhedrosis viruses isolated from Hemerocampa (Orgyia) pseudotsugata and O. antiqua as well as to their homologous virus. A very marked difference in susceptibility to virus was found between first- and fourth-instar larvae, the fourth-instar larvae being extremely resistant. It is recommended that field applications of the virus be made when the larvae are in the first instar, and an approximate dosage rate is suggested." Related Material - 3

51. Dahlsten, D. L., E. A. Cameron, and W. A. Copper. 1970. Distribution and parasitization of cocoons of the Douglas-fir tussock moth, Hemerocampa pseudotsugata (Lepidoptera: Lymantriidae), in an isolated infestation. Can. Entomol. 102(2):175-181.

"Douglas-fir tussock moth cocoons were collected and their distribution recorded by crown level on white fir, Abies concolor, in northeastern California. Nine trees were sampled in two defoliation classes, light (20 to 30% defoliated) and moderate to heavy (50 to 80% defoliated). Cocoons were more abundant in the lower crown levels as defoliation became greater. The proportion of female cocoons increased toward the lower levels of the crown. An overall sex ratio of 1.2 males:1.0 females was recorded. Significantly more male cocoons were

parasitized than female. A list of the natural enemies of the tussock moth in the study area is given." Parasitization played an important part in the collapse of the population. In addition, some females emerged successfully from their cocoons but did not oviposit. This may have been due to the virus disease present in the epidemic population in 1965. Biology - 3; Host Relationships - 1; Outbreaks - 4

52. Dahlsten, D. L., and R. F. Luck. 1972. Evaluation of the natural enemy complex of the Douglas-fir tussock moth at three sites in the El Dorado National Forest. Part VI. In Results of field experiments for controlling Douglas-fir tussock moth with aerial application of polyhedrosis virus and associated studies. Progress report. USDA For. Serv., Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg. 4 p. Unpubl.

This preliminary report is on a study to determine the natural enemy complex of the tussock moth, to associate the various parasites and predators with the stages of the life cycle of the moth, and to evaluate their impact on these stages. Alternate hosts of the natural enemies were sampled as well. The study included an attempt to describe the complex of spiders on white fir and to evaluate their effectiveness as predators of the tussock moth. Eggs, larvae, and cocoons were sampled and laboratory reared to determine parasites. A partial list of known natural enemies of the tussock moth in El Dorado County is presented as is a preliminary listing of the percent of egg and cocoon parasitization. Biology - 3; Host Relationships - 1

53. Dahlsten, D. L., R. F. Luck, E. I. Schlinger, J. M. Wenz, and W. A. Copper. 1977. Parasitoids and predators of the Douglas-fir tussock moth, Orgyia pseudotsugata (Lepidoptera: Lymantriidae), in low to moderate populations in central California. Can. Entomol. 109(5):727-746.

"Douglas-fir tussock moth, Orgyia pseudotsugata (McDunnough), populations were studied on white fir at four areas in central Sierra

Nevada mountains of California during 1971-73. Life tables were constructed for four populations in El Dorado County. The number of eggs per egg mass decreased and the percentage eggs parasitized doubled with declining moth populations. Hymenopterous parasitoids were collected from all immature stages of the moth: 1 egg parasitoid, Telenomus californicus Ashmead, 6 species of larval parasitoids, principally, Hyposoter sp., and 13 species of larval-pupal parasitoids. Tachinids were predominant and accounted for 73% of the parasitoidism of the cocoons in 1971. The apparent mortality of female pupae due to the parasitoid complex was greater than 97% in 1971 and 75% in 1972. One population in Placer County collapsed in 1971, apparently due to a combination of heat exhaustion and low levels of virus infection. Other defoliators, spiders, and several predatory insect species were collected from the foliage samples simultaneously with the tussock moth during larval sampling. Twelve species of 'free living' spiders which could be capable of preying on the defoliator complex of white fir were collected. Parasitoids and predators appear to be potentially important biotic factors at low to moderate host population levels. This is the first recorded case where an agent other than the nucleopolyhedrosis virus has been responsible for the collapse of a Douglas-fir tussock moth population."
Biology - 3, Host Relationships - 1.

54. Dahlsten, D. L., and G. M. Thomas. 1969. A nucleopolyhedrosis virus in populations of the Douglas-fir tussock moth, Hemerocampa pseudotsugata, in California. J. Invertebr. Pathol. 13(2):264-271.

"A nucleopolyhedrosis virus of the Douglas-fir tussock moth, Hemerocampa pseudotsugata, was found in the white fir forests of California for the first time. Tussock moth populations declined in 1965, and this virus may be one of the important mortality factors. Egg masses were collected in selected study areas and the larvae reared in petri dishes on an artificial diet. Larvae were also collected in several instars during the course of the summer and reared individually in petri dishes. An attempt was made to design a survey technique that would indicate the rate of decline, due to virus, of tussock moth populations in the field.

Further refinement will be necessary before egg-mass collections can be used as a survey tool, but these studies indicate a good potential. Evidence from this study shows the rate of dying in sample dishes in the laboratory to be related to the rate of larval mortality in the field. The primary use of such a survey would be an indicator to those making pest control decisions."
Biology - 5

55. Daterman, G. E., R. L. Livingston, and R. G. Robbins. 1977. How to identify tussock moths caught in pheromone traps. U.S. Dep. Agric., Agric. Handb. 517, 14 p. Combined Forest Pest Research and Development Program.

Sticky traps baited with synthetic tussock moth pheromone ((Z)-6-heneicosen-11-one) used to detect and monitor Douglas-fir tussock populations, frequently attract moths of closely related species. This pictorial guide identifies species likely to be trapped between August and mid-November in the Western U.S. and British Columbia. The guide distinguishes O. pseudotsugata, O. cana, O. antiqua, O. leucostigma, Dasychira vagans grisea, D. grisefacta ella, and species of Geometridae.
Biology - 2; Outbreaks - 2, 3.

56. Daterman, G. E., L. J. Peterson, R. G. Robbins, L. L. Sower, G. D. Daves, Jr., and R. G. Smith. 1976. Laboratory and field bioassay of the Douglas-fir tussock moth pheromone, (Z)-6-heneicosen-11-one. Environ. Entomol. 5(6):1187-1190.

"Laboratory bioassay demonstrated that the pheromone (Z)-6-heneicosen-11-one, its (E)-stereoisomer, and an epoxide (Z)-6,7-epoxyheneicosen-11-one are all attractive to the male Douglas-fir tussock moth, Orgyia pseudotsugata (McDunnough). The pheromone was approximately 27 times more attractive than the (E)-isomer and 300 times more attractive than the epoxide. An alcohol, (Z)-6-heneicosen-11-ol, was found to have a weak inhibitory effect on pheromone response.

"In the field, dosages of synthetic pheromone as low as 10 ng captured males and 50-ng baits were still attractive after 7 days' exposure. A controlled-release formulation, emitting pheromone at an estimated rate of 4 ng/min at 25°C, approached but did not equal the attractiveness of a live female. It is likely that an additional compound is present in the natural pheromone that is required to optimize response to the synthetic preparation.

"(Z)-heneicosen-11-one is also an effective attractant for the western tussock moth, O. cana Edwards, the rusty tussock moth, O. antiqua (Linn.), Dasychira vagans grisea (Barnes and McDunnough), and D. grisefacta ella Bryk."
Biology - 2; Related Material - 3

57. Daterman, G. E., and L. L. Sower. 1977. Douglas-fir tussock moth pheromone research using controlled-release systems. 1977 Int. Controlled Release Pestic. Symp. Proc., August 22-24, Corvallis, Oreg., p. 68-77. Oreg. Agric. Exp. Stn., and Coll. Sci., Oreg. State Univ., Corvallis.

The research effort with the sex pheromone of the Douglas-fir tussock moth to devise survey and control techniques and the requirements of a controlled release system for pheromone dissemination are examined. Survey trapping requires a weak but long-lasting pheromone bait system that can capture moths in proportion to population numbers. Strong baits fill traps to capacity in a short time even in low populations. Control of the tussock moth with pheromones requires a high rate of release to achieve mating disruption. The formulations necessary to satisfy these requirements are discussed.
Biology - 2, Outbreaks - 2, 3; Control - 10

58. Dewey, J. E. 1975. Douglas-fir tussock moth research and development highlights. West. For. and Conserv. Assoc., Perm. Assoc. Proc. 1975:66-67. Portland, Oreg.

Highlights of the accomplishments of the 3-year USDA Expanded Douglas-fir Tussock Moth Research and Development Program are presented. Information has been gathered on factors of natural population control, physical and geographic factors contributing to outbreak populations, uses of Douglas-fir tussock moth sex pheromones, possible chemical and microbial insecticides for tussock moth control, and improved methods of aerial application of insecticides.
Related Material - 2

59. Dodge, H. R. 1956. An analysis of Douglas-fir tussock moth cocoons, winter of 1955-56, with reference to the trend of the current outbreak in eastern Washington. USDA For. Serv. Intermt. For. and Range Exp. Stn., Missoula, Mont. 9 p. Unpubl.

In the summer of 1955 the Douglas-fir tussock moth defoliated 9,000 acres in eastern Washington. A ground survey of cocoons was made in the winter of 1955-1956 to determine whether aerial spraying would be necessary. Cocoons were collected from three areas--one in the main forest infestation, another where farmsteads adjacent to the forest were infested, and the last one where firs are found only on farmsteads. A low ratio of new to old egg masses was found, indicating a subsiding population in all areas. Only 14.3% of the total cocoons yielded egg masses. Parasitism in the forested region was 71.3%; in the farmstead regions it was 35.6 - 60.0%. Survival of the eggs appeared to be good, and larvae hatched abundantly in the laboratory. Since the age of the cocoons could not be determined, the parasitism counts were subject to some error. The infestation will probably subside in the forested region but will continue in the farmsteads because of low parasitism.
Outbreaks - 2

60. Dodge, H. R. 1956. Instructions for the control of the tussock moth in northeastern Washington in 1956. USDA For. Serv. Intermt. For. and Range Exp. Stn., Missoula, Mont. 6 p. Unpubl.

Instructions are given for Douglas-fir tussock moth control in small severe outbreaks, such as the farmstead infestations which charaterized the 1953-54 Colville, Washington, epidemic. In these infestations, small groups of fir trees, surrounded by farm land, had severe defoliation and a low rate of parasitism. Control measures include aerial or ground application of DDT or lead arsenate. Timing of application and application procedures are discussed.
Control - 1, 2.

61. Dodge, H. R. 1956. Tussock moth threatens timber. West. Conserv. J. 13(1):36, 40, 42-43, 45, 50.

A popular account is given of a tussock moth outbreak in Washington and Idaho. Life history, population dynamics, natural control factors, and damage are discussed.
Outbreaks - 2

62. Dodge, H. R. 1958. Insect survey program report (Douglas-fir tussock moth, Pinal Mountains, Arizona). USDA For. Ser. Intermt. For. and Range Exp. Stn., Missoula, Mont. 2 p. Unpubl.

Results of a survey of Douglas-fir tussock moth cocoons taken in May 1958, in the Pinal Mountain infestation show: an extremely high ratio of new egg masses compared with old egg masses or total cocoons; a sex ratio of three females per male; total mortality of cocoons at 36.8%; and an average of 200 eggs per mass. The Pinal Mountain infestation apparently contained a population capable of considerable damage in 1958.

Incubation of 35 of the sampled egg masses yielded 75 larvae per mass.
Outbreaks - 2

63. Dodge, H. R., and G. C. Trostle. 1964. Douglas-fir tussock moth. USDA For. Serv. For. Pest Leafl. 86, 7 p.

This leaflet briefly surveys the cycle of Douglas-fir tussock moth outbreaks, the host range, and the evidence of infestation. It includes a description of the larvae and adult moths, the life history and habits, the natural enemies, and the alternatives for chemical control.

General Background

64. Downing, K. B., P. B. Delucchi, and W. R. Williams. 1977. Impact of the Douglas-fir tussock moth on forest recreation in the Blue Mountains. USDA For. Serv. Res. Pap. PNW-224, 14 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Outbreaks - 5

65. Dronka, K. 1974. Znamieniowka tarniowka -- niebezpieczny skodnik sadow jabloniowych. [Rusty tussock moth, a dangerous pest of apple orchards.] Owoce Warz Kwiaty 13(6):10-11. [In Polish.] Translation unavailable.

Related Material - 3

66. Dumbauld, R. K., H. E. Cramer, and J. W. Barry. 1975. Application of meteorological prediction models to forest spray problems. U.S. Army Tech. Note. Dugway Proving Ground, Dugway, Utah. (TECOM Project No. 5-CO-403-000-051.) In Aerial application of insecticides against forest defoliators (chemicals and microbials). Proceedings of workshop held April 23-25, 1974, Univ. Mont., Missoula, p. 32-71. USDA For. Serv., State and Private For., North. Reg., Missoula, Mont.

The report discusses the uses of meteorological prediction models in planning and conducting aerial spray operations with insecticides. The presentation includes a discussion of model inputs and calculations for the 1974 Idaho tussock moth test for determining spray drop-size distribution and spray deposition and concentration at the forest canopy.

Control - 7

67. Eaton, C. B., and G. R. Struble. 1957. The Douglas-fir tussock moth in California. Pan-Pac. Entomol. 33(3):105-108.

Reappraisal of the Hemerocampa species attacking fir indicates that the tussock moth periodically defoliating white fir in California is Hemerocampa pseudotsugata McDunnough. It had been misidentified in that state as H. oslari (Barnes) for nearly 50 years. The identification of specimens collected in 1906 in Mariposa Co. as H. pseudotsugata extends the known range of the Douglas-fir tussock moth to northeastern California.

White fir is the primary host of the Douglas-fir tussock moth in California. It has not been recorded from Douglas-fir. Local outbreaks have periodically occurred in the northern Sierra Nevada but with less severity than in other states.
Taxonomy; Host Relationships - 1

68. Edwards, S. K. 1965. Activity rhythms of lepidopterous defoliators. III. The Douglas-fir tussock moth, Orgyia pseudotsugata (McDunnough) (Liparidae). Can. J. Zool. 43(5):673-681.

This is an extension of earlier work on activity rhythms of lepidopterous defoliators to the Douglas-fir tussock moth. Time of eclosion, larval activity on foliage, adult emergence, and flight were recorded in constant and naturally varying temperature and light regimes.

Egg hatch peaked after the sunrise transition, tapering off as the day progressed. Hatching time apparently did not respond to variation in temperature.

Young larvae were active throughout the day at temperatures above 20°C, but only diurnal activity persisted at a constant temperature of 10°C. Feeding periods paralleled activity.

The dropping of young larvae was timed more by light than by temperature. Two peaks occurred, one after sunrise and another in the

afternoon. The position of the afternoon peak was influenced by temperature.

Late-instar larvae were mainly nocturnal in the constant and varying temperature regimes, and defoliation occurred at night.

Adult emergence and flight of males was greatest about 4 hr before sunset, and there was evidence of mating at the same time of the day. Heightened activity at this time of the day was detected as early as the 1st- and 2nd-instar larvae.

"The possible adaptive value of these rhythms in the insects in nature is discussed."
Biology - 1

69. Elgee, E. 1975. Persistence of a virus of the white-marked tussock moth on balsam fir foliage. Can. For. Serv. Bi-Mon. Res. Note 31(5):33-34.

Results of a study of the persistence of nucleopolyhedrosis virus, which under natural conditions has terminated infestations of the white-marked tussock moth, Orgyia leucostigma (J. E. Smith), in Nova Scotia are reported.

Tests were conducted on balsam fir foliage contaminated either by virus residues of the white-marked tussock moth or spray applications of virus suspensions. The relation between the strength of the suspension and virus persistence to exposure was also studied.

"Results suggest that the virus, deposited on the foliage (naturally or artificially) in the summer, retains sufficient activity through the winter to kill at least some larvae, and that spraying, even when done the previous year, increases larval mortality." Exposure of contaminated foliage to sunlight, precipitation, or both reduces virus activity. "The rate of inactivation depends on the degree of exposure of the branches to

weathering and the period to inactivation depends both on the strength of the suspension and the degree of exposure of the branches to weathering." Related Material - 3

70. Ellefson, P. V. 1974. Douglas-fir tussock moth infestation: a challenge to forestry professionals. J. For. 72(6):326-327, 329.

The paper presents a discussion of the Blue Mountain Douglas-fir tussock moth outbreak (1972-1974), the extent of the present damage, its economic impact, and the alternatives available for control. The USDA Forest Service requested emergency exemption from the EPA ban on DDT, both in 1973 and 1974. In 1974, the EPA granted the exemption provided certain conditions be met before DDT application and that surveys reveal populations capable of causing significant damage if left uncontrolled. Spraying had to be conducted according to certain restrictions established to minimize environmental contamination. The Forest Service control plan is briefly outlined.
Outbreaks - 2; Control - 4

71. Environmental Protection Agency. 1973. The Douglas-fir tussock moth in the Pacific Northwest. A seminar sponsored by the U.S. EPA Washington, D.C. 105 p. Unpubl. (On file: Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg.)

The texts of the addresses given at a seminar on the current Douglas-fir tussock moth pest situation in the Pacific Northwest are presented. The objective of the seminar was to bring together experts from the Federal, State, academic, industrial, and environmental agencies to explore the technical problems and research needs in tussock moth control.

The morning session concentrated on discussions of the current status of the tussock moth outbreaks in Oregon and Washington, the state of present knowledge of tussock moth biology and outbreak cycles, and present strategies for control.

The afternoon session centered on research needs, both in the areas of tussock moth biology and control procedures for outbreak populations.
General Background; Related Material - 2

72. Environmental Protection Agency. 1974. The use of DDT to control the Douglas-fir tussock moth. Fed. Regist. 39(44):8377-8380.

The paper concerns the decision of the EPA on requests of the USDA Forest Service and the States of Oregon and Washington for exemption of the prohibition against the use of DDT to control potential emergency outbreaks of the Douglas-fir tussock moth. Requests were made pursuant to section 18 of the Federal Insecticide, Fungicide, and Rodenticide Act.

The paper reviews the background leading to the requests, the biology of the Douglas-fir tussock moth, the status of the current outbreak and its possible economic impact, possible alternative control methods, and the legal and economic factors underlying the decision of the EPA.

The reasons for granting the exemption to the Forest Service and not to the States of Oregon or Washington, along with the restrictions and requirements accompanying the exemption, are outlined.
Control - 4

73. Eslyn, W. E. 1959. Hemerocampa pseudotsugata McDunnough, a new host for Beauveria bassiana (Balsamo) Vuillemin. J. Insect Pathol. 1(4):434-435.

Mummified pupae of the Douglas-fir tussock moth containing mycelial growth of the fungus Beauveria bassiana (Balsamo) Vuillemin were found under rocks in the Lincoln National Forest, New Mexico, in March 1959. This is a new host record for the fungus. The physical characteristics of the fungus are described. Its possible use in biological control of the Douglas-fir tussock moth is suggested.
Biology - 4

74. Evenden, J. C. 1948. An epidemic of the Douglas-fir tussock moth. Northwest Sci. 22(2):53-59.

This is a brief summary of the 1946 and 1947 reports by the author on the Douglas-fir tussock moth outbreak in northern Idaho and the aerial application of DDT used to control the problem. The paper includes a description of the moth, its means of dissemination, and a brief history of tussock moth epidemics in the Northwest.

The tussock moth epidemic in northern Idaho, the largest ever recorded, is described. By 1946, 350,000 acres were infested and 150,000 were severely defoliated. Surveys in 1946 predicted even greater populations of the tussock moth for 1947.

Aerial application of DDT was timed to effect maximum kill of young larvae and minimum disruption of predacious and parasitic insect populations. A study by the U.S. Fish and Wildlife Service on the environmental impact of DDT showed damage only to some forms of aquatic life.

Larval mortality near 100% was reported.
Outbreaks - 2; Control 2, 3

75. Evenden, J. C., and E. J. Jost. 1946. An outbreak of the Douglas-fir tussock moth (Hemerocampa pseudotsugata) in Latah and Clearwater Counties, Idaho, 1946, a report. USDA Bur. Entomol. and Plant Quar., Intermt. For. and Range Exp. Stn., Missoula, Mont. 22 p. Unpubl.

This report is on the 1946 Douglas-fir tussock moth outbreak in northern Idaho. The study was conducted by the Forest Insect Laboratory at Coeur d'Alene, Idaho, under the direction of the Bureau of Entomology and Plant Quarantine and the USDA Forest Service. The entomological, physical, and economic factors associated with the infestation were evaluated to determine the advisability of control measures. The report

includes a description of the Douglas-fir tussock moth, its seasonal history, and habits.

A survey of the area showed the tussock moth present in about 447,000 acres, and severe defoliation occurred in 150,000 acres. Estimates of the potential 1947 population from studies of egg masses in the field indicated an even greater number of larvae than in 1946. Aerial application of chemical control was recommended. The feasibility of aerial spraying was examined in detail. The entomological, environmental, economic, and social impact of the use of DDT for this control project were explored.
Outbreaks - 2

76. Evenden, J. C., and E. J. Jost. 1947. Tussock moth control, north Idaho, 1947, a report. Intermt. For. and Range Exp. Stn., Missoula, Mont. 28 p. Unpubl.

A detailed report of the organization, methodology, and results of the aerial application of DDT conducted in the spring of 1947 against a serious outbreak of the Douglas-fir tussock moth in northern Idaho. The project, the largest of its kind to date, was conducted with the cooperation of private, State, and Federal timber owners under the direction of the USDA. The Forest Service supervised the fiscal and administrative details and the Bureau of Entomology and Plant Quarantine directed the technical aspects.

DDT was sprayed on 413,469 acres of land. Larval mortality was near 100%. The U.S. Fish and Wildlife Service conducted a survey on the environmental effects of the spray application. Only damage to some aquatic forms was reported.

An appendix includes typical field forms and a photographic summary of the project.
Control - 2, 3

77. Evergreen State College. 1973. Douglas-fir tussock moth in the Northwest: The case against DDT use in 1974. Ecology and chemistry of pollution, Olympia, Wash. 25 p. Unpubl. (On file: Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg.)

An analysis of the status of the Douglas-fir tussock moth outbreak in the Blue Mountains, 1972-1974, and the case against the use of DDT for tussock moth control are presented in a series of papers by members of the Evergreen State College.

The first paper charges that the forest products industry has distorted the situation in their request for use of DDT for tussock moth control. The remaining papers examine each of the alleged distortions and present a detailed rebuttal.
Control - 4

78. Family Tree. 1947. Operation flit gun. Family Tree 11(9), 3 p.

A popular account is given of a control project using DDT for control of the tussock moth. A 300,000-acre infestation was sprayed in 1947. Mortality of tussock moth larvae was considered excellent.
Control - 2

79. Flake, H. W., and R. L. Lyon. 1967. Insecticide tests against larvae of Hemerocampa, new species, a tussock moth that defoliates boxelder in New Mexico. J. Econ. Entomol. 60(2):607-608.

Six insecticides were selected for preliminary laboratory testing against Hemerocampa, n. sp., larvae, a nuisance pest in 1965 on boxelder, Acer negundo L., in southwestern New Mexico. Testing took place in the laboratory in an attempt to find an insecticide suitable for field use. Egg masses were collected and shipped to the laboratory at Berkeley, California. The larvae were reared to 5th instar, and were held during and after treatment in groups of 10. "Larvae were treated individually by applying to the prothoracic region a 1-µl drop of an acetone-insecticide

solution." Pyrethrin, Zectran®, p, p'-DDT, carbaryl, and SD-8530 were sufficiently active to merit additional tests. The insects were highly tolerant to malathion.
Related Material - 3

80. Forestry Research News. 1974. Forest Service reports results of tussock moth research. . . . Several alternatives to DDT appear promising. USDA For. Serv. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg. 5 p. Unpubl.

The highlights of research in 1974 on the Douglas-fir tussock moth are given. "The studies have generally supported the theory of a 3-year cycle between outbreak and decline of tussock moth epidemics, substantiate the effectiveness of DDT in controlling epidemics, and show promise for several chemical and biological alternatives to DDT." Other findings were that "tree mortality and damage were strongly related to the percentage of Douglas-fir in the infested stands, with Douglas-fir hit harder than other species." Trees defoliated in the Blue Mountains were beginning to "green up" and recover.
Control - 1; Related Material - 2

81. Forestry Research, What's New in the West. 1974. A virus that kills tussock moths. USDA For. Serv., p. 4-5, 12-13.

The research by the USDA Forest Service, Forestry Sciences Laboratory, Corvallis, Oregon, to develop microbial control methods against the Douglas-fir tussock moth, is outlined. Both Bacillus thuringiensis and the tussock moth nucleopolyhedrosis virus have been tested with good results. The virus is especially promising as a control agent. Tests for its impact on nontarget organisms have thus far proved negative. Future plans for additional virus field tests are briefly outlined.
Biology - 5, Control - 6

82. Furniss, M. M., and J. A. E. Knopf. 1971. Western tussock moth. USDA For. Serv. For. Pest Leafl. 120, 4 p.

A subspecies of the western tussock moth, Orgyia vetusta gulosa (Boisd.) = (Hemerocampa) is an important defoliator of big game browse plants and fruit trees. The moth occurs in the northwestern United States and in Canada. The appearance of the different stages and the life cycle of the moth are described. Natural enemies of the tussock moth include eight parasites, two predators, and a polyhedral virus. Parasites and predators have reduced the population by 50% in citrus groves and apple orchards. In Idaho, the virus has controlled moth outbreaks.
Related Material - 3

83. Gay, R. L. 1973. Douglas-fir tussock moth infestation in Oregon. An environmental dilemma of national importance. OSPIRG Reports (April), Portland, Oreg. 34 p. Unpubl. (On file: Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg.)

The report presents a detailed case against the USDA Forest Service request for emergency use of DDT to control the Douglas-fir tussock moth outbreak in the Blue Mountains in 1973. Results of OSPIRG research are given to support the contentions that (1) State and Federal forest officials have failed to show that any chemical control is needed, and (2) Zectran is a feasible alternative to DDT should chemical control be necessary. The report contends that (1) the Forest Service estimates of potential defoliation in 1973 were calculated by questionable means, using a defoliation formula without a quantitative basis; (2) the survey technique used to sample populations failed to distinguish properly among populations capable of causing heavy, intermediate, or light damage; and (3) the Forest Service evaluation of Zectran did not accurately reflect its efficacy as an alternative to DDT. Field tests show that Zectran has the necessary toxicity to accomplish high population reduction, especially when applied twice.

The report recommends that resampling should be done to determine if signficant tree mortality will be caused by tussock moth larvae in 1973. If these populations exist, salvage logging should be the first preference

as a control measure. If chemical control must be used, Zectran should be applied.
Control - 4

84. Getzendaner, C. W. 1966. Study of methods and materials for evaluating virus spray deposits. Part IV. In Results of tests to develop operational procedures for controlling Douglas-fir tussock moth with aerial application of polyhedral virus spray. USDA Agric. Res. Serv. and For. Serv., Portland, Oreg. 19 p. Unpubl.

"The fourth phase of cooperative virus spray studies was conducted in June 1965 on the Mt. Hood National Forest, Oregon, in conjunction with phase-two investigations. Objectives were to (1) evaluate the use of fluorescent tracer for assessing aerial spray deposits under forest conditions, (2) determine spray distribution patterns and droplet sizes from the equipment used, and (3) compare the efficiency of various sampling surfaces for determining spray deposits.

"The fluorescent tracer, Calcofluor® white, when used with suitable recovery targets, proved to be a useful material for evaluating spray patterns, distribution, droplet size, and foliage penetration. . . . Spray applied at 1 gal per acre deposited droplets of much more uniform size than applications at 3 gal per acre. . . . Kromekote® paper cards were better than other target materials for visual evaluation of both fluorescent and dye-tagged sprays. Stainless steel plates were best for quantitative measurement of dye-tagged sprays. . . . The Calcofluor white tracer maintains its stability and fluorescence on foliage for long periods if kept dry. It has shown no appreciable deterioration after storage for nearly a year under normal conditions."
Control - 9

85. Gibney, L. C. 1974. The plight of the tussock moth. Environ. Sci. Tech. 8(6):506-507.

A brief overview of the tussock moth problem including the life cycle of the moth, its status as a pest, and a history of tussock moth infestations in the Northwest.

The conditions and restrictions accompanying the 1974 decision by the EPA to grant to the USDA Forest Service an emergency exemption from the prohibition on the use of DDT in tussock moth control are summarized. An egg mass density of one-tenth egg mass per 1,000 in^2 of foliage will be required to establish economic injury. The paper includes a diagram of the fate of DDT in the environment after spraying.

The need for alternative means of control is stressed.
Control - 4

86. Gibson, A. L., and T. T. Terrell. 1955. Preliminary report of Douglas-fir tussock moth infestation in northeastern Washington. USDA For. Serv. Intermt. For. and Range Exp. Stn., Missoula, Mont. 3 p. Unpubl.

A preliminary examination of reported Douglas-fir tussock moth infestations in northeastern Washington was conducted June 27-29, 1955, by members of the Forest Insect Laboratory, Missoula, Montana, at the request of the Pacific Northwest Forest and Range Experiment Station. Infestations occurred in several scattered areas with damage ranging from single trees to 20-acre stands.

The report lists possible control measures and recommended implementation before pupation commenced. Monitoring of present infestation sites was recommended. A second survey was planned by members of the laboratory in late August or September, to determine evidence of expansion of the infestation to intervening stands.
Outbreaks - 2

87. Grace, T. D. 1958. Induction of polyhedral bodies in ovarian tissue of the tussock moth in vitro. Science 128(3318):249-250.

"In a series of experiments primarily set up to test the effects of various concentrations of Eagle's basal medium on the growth of the ovarian tissue of the tussock moth (Hemerocampa leucostigma), polyhedral bodies appeared in some of the cultures after a change was made in the media used. . . . The tissues were obtained from last instar larvae growing on sycamore trees. . . . On gross and microscopic examination, both before and after dissection, no evidence of infection was seen in any of the larvae used. Explants were chosen at random when the cultures were set up. No evidence of infection was noticed in any culture before the change of medium. Only those cultures in which the medium was changed showed infection."

The author postulates "that the larvae used in this experiment carried a latent infection of a polyhedrosis which became manifest after the cultures were subjected to a 'physiological shock' brought about by an abrupt change from one medium to another."
Related Material - 3

88. Graham, D. A. 1972. Testing of improved insecticides for forest pest management. USDA For. Serv. Fact Sheet, Reg. 6, Portland, Oreg. 8 p. Unpubl.

The paper outlines a proposed test of stabilized pyrethrins and Zectran for suppression of the Douglas-fir tussock moth outbreaks. It includes a description of the insect and its life cycle, its status as a pest, a brief history of severe epidemics in the Northwest, and a review of the current outbreaks in central Washington. The possibilities of biological control are outlined.

The report provides background information on toxicity, persistence of breakdown products, and potential hazards of pyrethrins and Zectran. Both insecticides will be given in two applications 10 days apart to ensure the mortality of those larvae emerging after the first treatment. Stabilized pyrethrin at 0.05 lb/acre and Zectran at 0.15 lb/acre will be applied to two 400-acre plots in the infested area of central Washington.

Test plots within the spray areas will be evaluated for pre- and posttreatment larval populations, defoliation occurring in July of 1972 and 1973, and number of egg masses present in October 1972.
Control - 1

89. Graham, D. A. 1975. Douglas-fir tussock moth 1974 operational spraying of DDT. West. For. Conserv. Assoc., Perm. Assoc. Proc. 1974:21-23. Portland, Oreg.

This is the text of an address to the association on the successful 1974 control of the Douglas-fir tussock moth epidemic in the Northwest. Background information is presented on the beginning of the outbreak in 1970, the extent of damage in 1972 and 1973, the search for alternate means of chemical control, and the unsuccessful attempt in 1973 to secure exemption from the EPA ban on the use of DDT. Details of the 1974 effort, which resulted in permission for the temporary use of DDT, are given. The control operation, its personnel, organizational structure, and methods of operation are summarized; 570 people worked on spraying 426,559 acres with DDT at a cost of $2,900,000. Resulting insect mortality was 97% in all areas with the exception of a small area in southern Idaho. The use of DDT despite a predicted population decline in 1975 from natural causes is rationalized on the basis of prevention of the potential damage of the current year's larval population.
Control - 2, 4

90. Graham, D. A., J. Mounts, and D. Almas. 1975. 1974 cooperative Douglas-fir tussock moth control project, Oregon, Washington, and Idaho. USDA For. Serv. Pac. Northwest Reg., Portland, Oreg. 74 p. Unpubl.

This report covers the 1974 Douglas-fir tussock moth control project in the Northwest. Between June 9 and July 25, 426,559 acres of forest land in Oregon, Washington, and Idaho were treated with DDT at 0.75 lb/acre. Application was by helicopter. The background of the Douglas-fir tussock moth infestation, the biology of the moth, and the

biological evaluation of the outbreak population were discussed. DDT was the only chemical that had previously proved to be effective. Although several other chemical and microbial agents had been tested against the tussock moth, the results were not satisfactory or additional large-scale testing was required.

The planning and preparation of the control project, the details of the spray operation, the surveys for insect mortality, the environmental monitoring plans, and the estimates of foliage and timber values saved by the control project were presented. The average postspray mortality of larvae was 98.8%. The control project was evaluated as highly successful.
Control - 2, 3

91. Graham, F., Jr. 1974. The return of DDT - pest control by press release. Audubon 76(5):64-71.

A detailed analysis is presented of the controversy surrounding the USFS request for emergency use of DDT to control the Douglas-fir tussock moth outbreak in the Pacfic Northwest (1972-74).
Control - 4

92. Graham, F., Jr. 1975. Update: moths and DDT. Audubon 77(2):120-121.

An analysis is presented of the controversy surrounding the aerial application of DDT to control the Douglas-fir tussock moth in the Pacific Northwest. The environmental impact of the spray control project is also examined.
Control - 4

93. Grant, G. G. 1975. Extraction and bioassay of the female sex pheromone of white-marked tussock moth, Orgyia leucostigma (Lepidoptera: Lymantriidae). Can. Entomol. 107(3):303-309.

"Factors affecting the extraction and bioassay of the sex pheromone of white-marked tussock moths were evaluated. Dipping the female

pheromone glands in a solvent (preferably hexane) to produce a wash containing active material was a particularly effective and reproducible method of obtaining a potent extract. These were most active if obtained from virgin females less than 2 days old. Extracts from recently mated females were only slightly less active than those from virgin females. Males were most responsive in bioassays when 2 to 3 days old. The maximum percentage of response of males was obtained at $1X10^{-4}$ FE (female equivalents); beyond this concentration the percentage response decreased. Characteristically, extracts lost their potency within 1-3 weeks of preparation. It is suggested that either an inhibitor or the loss of a chemical component of the sex pheromone causes an extract to become inactive."
Related Material - 3

94. Grant, G. G. 1977. Interspecific pheromone responses of tussock moths and some isolating mechanisms of eastern species. Environ. Entomol. 6(5):739-742.

"Laboratory tests with 5 species of Orgyia tussock moths (O. leucostigma (J. E. Smith). O. definita Packard, O. antiqua (L.), O. pseudosugata (McDunnough), and O. cana (=vetusta) Edwards) revealed that all species show some degree of pheromone cross stimulation which ranged from weak (16-41% response) to strong (60%). O. definita showed the most exclusive sex pheromone system because they were strongly stimulated by fewer species and only homospecific males responded strongly to definita females.

"In the laboratory, (Z)-6-heneicosen-11-one, the female sex pheromone of O. pseudotsugata, was sexually stimulating to O. leucostigma and O. antiqua males but not to O. definita males. In electroantennogram tests, O. definita males were 100-fold less sensitive than the other 2 species to this compound. In the field, the chemical attracted O. leucostigma, O. antiqua, and the pine tussock moth, Dasychira plagiata (Walker). Several isolating mechanisms were described which help maintain the species integrity of these sympatric eastern tussock moth species."
Biology - 2, Related Material - 3

95. Grant, G. G., and D. Frech. 1976. Mating disruption of tussock moths by atmospheric permeation with synthetic sex pheromone. Can. For. Serv. Bi-Mon. Res. Notes 32(5):25-26.

The six pheromone of the Douglas-fir tussock moth can sexually stimulate and attract males of the white-marked tussock moth (O. leucostigma) and the rusty tussock moth (O. antiqua). Laboratory experiments were conducted to determine if large concentrations of the Douglas-fir tussock moth sex pheromone can disrupt the mating ability of these species. Four other compounds were tested, including disparlure, the sex pheromone of the gypsy moth. Reduction in mating in the white-marked tussock moth was linearly related to the dosage of tussock moth pheromone used. Percent mating reduction after 6 hr ranged from 34% with 0.1 µg pheromone, to 82% for 100 µg. The mating reduction in the rusty tussock moth was 70% for 100 µg pheromone after 6 hr. Of the four other chemicals tested, only disparlure caused a statistically significant reduction in the white-marked tussock moth mating after 24 hr.
Biology - 2; Related Material - 3

96. Grant, G. G., D. Frech, and D. Grisdale. 1975. Tussock moths: pheromone cross stimulation, calling behavior, an effect of hybridization. Ann. Entomol. Soc. Am. 68(3):519-524.

"Adult crosses, pheromone extract bioassays, and electroantennogram (EAG) tests suggest that three species of tussock moth, Hemerocampa leucostigma (J. E. Smith), H. pseudotsugata McDunnough and H. vetusta (Boisduval), have similar sex pheromones. The same tests also indicate that hybrids from the cross female H. pseudotsugata x male H. leucostigma possess a sex pheromone system more like the female parent than the male parent; that is, the sex pheromone of the female hybrid was like that of female H. pseudotsugata, and the pheromone receptors of the male hybrid were like those of male H. pseudotsugata. On the other hand, the calling periodicity of female hybrids displayed traits of both parents." Most of the males attempted copulation with females of other species, but few

were successful. Differences between pheromones and male sensitivity of the three species and hybrid are discussed.
Biology - 2; Related Material - 3

97. Grant, G. G., and L. McCarty. 1977. Effect of age on calling behavior and mating success of white-marked tussock moths. Can. For. Serv. Bi-Mon. Res. Notes 33(1):2-3.

Described are several factors related to aging that affect mating and fecundity in the white-marked tussock moth, Orgyia leucostigma J. E. Smith. At emergence, the females are ready to mate and contain a full complement of mature eggs. Successful mating is reduced with increasing time after eclosion. Only 33% of 2-day-old females mated in one overnight period, compared to 83% of newly emerged females in the same period.

Decreased mating success of older virgin females is related to decreased pheromone production and decreasing female attractiveness. The pheromone releasing mechanism (i.e., calling behavior) is altered and replaced by oviposition behavior (egg spewing) in older virgin females.

Records of number of eggs deposited by virgin females and percentages of the females calling showed a progressive decline in calling behavior over time as egg deposition increased. Thus the consequence of aging in white-marked tussock moth females is a decreased chance of successful mating.
Related Material - 3

98. Grau, P. A. 1974. Mixing and formulation of Bacillus thuringiensis. In Aerial application of insecticides against forest defoliators (chemicals and microbials). Proceedings of workshop held April 23-25, 1974, Univ. Mont., Missoula, p. 21-26. USDA For. Serv., State and Private Foresty, Northern Region, Missoula, Mont.

This discussion concerns the type of equipment available for mixing Bacillus thuringiensis wettable powders, the effect of storage on the viability of mixed formulations, and the types of additives used in tank mixes and their effect on the residual effectiveness of B.t. in the field. Included is a general review of B.t. and its toxic properties; the formulation Dipel to be used in the Douglas-fir tussock moth control project; and a table on the effects of simulated rainfall on spray-deposit retention of various formulations of Dipel.
Control - 8

99. Grisdale, D. G. 1975. A simple method for removing pupae from cocoons. Can. For. Serv. Bi-Mon. Res. Notes 31(2):9.

The paper describes a method of removing pupae of Malocosoma disstria and Orgyia spp. from cocoons that avoids the allergic responses to larval hairs and parts of the cocoon. Washing the cocoons in a solution of bleach containing 6% available sodium hypochloride dissolves the cocoon silk. After being rinsed in a water bath, the pupae are placed in a screen box and rinsed free of debris. About 2,000 pupae can be separated from their cocoons in 1/2 hr without adverse effects on the future adult moths.
Biology - 6

100. Grissell, E. E. 1973. New species of North American Torymidae (Hymenoptera). Pan-Pac. Entomol. 49(3):232-239.

The description of four new species of Torymidae is presented. They are: Monodontomerus saltuosus Grissell, reared from the Douglas-fir tussock moth; M. clementi Grissell, reared from an anthidiine bee; Torymus frankiei Grissell, reared from a cecidomyiid gall; and T. memnonius Grissell, from a cynipid gall.

The holotype, allotype, and some paratypes will be deposited in the U.S. National Museum. Paratypes will be located in the Canadian National Collection, Ottawa, and the Entomology Museum, U. C. Davis.
Biology - 3

101. Hafez, M., and L. El-Said. 1969. On the bionomics of Orgyia dubia judaea Stgr. (Lepidoptera: Lymantriidae). Bull. Soc. Entomol. Egypt. 53:161-183.

Orgyia dubia judaea Stgr. is found abundantly on wild plants growing on saline soil near the northern coast in U.A.R. The insect can be reared on clover and sweet potatoes. The authors fear that it may become an economic pest. The morphology of all the stages is discussed in detail. Eggs are deposited inside the female cocoon. The species is univoltine. Six species of primary parasites and one species of secondary parasite were captured during the study.
Related Material - 3

102. Hall, D. G. 1947. Tussock moth hits Idaho. Timberman 48(6):46-48.

A popular account is given of a tussock moth outbreak near Moscow, Idaho. The population was expected to increase and infest 350,000 acres during 1948. Control operations using DDT were expected to be undertaken by June 1948.
Outbreak - 2

103. Hard, J. S., J. D. Ward, and S. Ilnytzky. 1977. Douglas-fir tussock moth control on Douglas-fir, 1976. Insectic. and Acaricide Tests 2:113.

Dimilin was applied at three different rates against epidemic Douglas-fir tussock moth populations near Kamloops, B.C. All three Dimilin treatments gave significant control at 35 days, with the greatest mortality occuring from the 2 oz/acre dosage.
Control - 1

104. Harper, J. D. 1974. Forest insect control with Bacillus thuringiensis. Survey of current knowledge. Agric. Exp. Stn., p. 32-34. Auburn Univ., Auburn, Ala.

This chapter discusses the history of control of the Douglas-fir tussock moth with Bacillus thuringiensis, the reasons for success or failure of control projects, and the conditions needed for reproducible control levels of 95% or higher. "Larvae treated in the second or third instar, and large droplet size combined with high droplet density" have produced the best results.
Control - 5

105. Harwood, R. F. 1975. Economics, esthetics, environment, and entomologists: The tussock moth dilemma. Environ. Entomol. 4(2):171-174.

"The author reviews the life cycle and impact of Hemerocampa pseudotsugata McDunnough, and the variety of known and assumed factors involved in the decision to use DDT during 1974 to control the outbreak in Washington, Idaho, and Oregon. Potential alternative control procedures are listed. While the issue is complicated, fault is found in the response of agencies, environmentalists, and entomologists to the serious threat presented by this extensive outbreak of the tussock moth."
Control - 4

106. Hayashi, Y. 1970. Properties of RNA from cytoplasmic-polyhedrosis virus of the white-marked tussock moth, Orgyia leucostigma. J. Invertebr. Pathol. 16(3):451-458.

"When the genome RNA is extracted from the cytoplasmic-polyhedrosis virus of the white-marked tussock moth, Orgyia leucostigma, by the phenol method, it has two components with sedimentation rates of about 15 and 12 S. Their base composition includes adenine and uracil as well as guanine and cytosine. The guanine plus cytosine content was 41.2 percent. Melting temperature of the RNA was about 80°C. in a solution containing 0.0015 M NaCl - 0.00015 M sodium citrate. Most of the RNA was found to be resistant to ribonuclease digestion; some of it was partially sensitive and was presumed to be single-stranded. After enzyme treatment, the 15 and 12 S components of the genome sedimented at about 9 S. From these

findings it is proposed that viral genome RNA from cytoplasmic-polyhedrosis virus is double-stranded."
Related Material - 3

107. Hayashi, Y., and F. T. Bird. 1970. The isolation of cytoplasmic polyhedrosis virus from the white-marked tussock moth, Orgyia leucostigma (Smith). Can. J. Microbiol. 16(8):695-701.

"The procedure for isolating and purifying free and occluded cytoplasmic polyhedrosis virions was improved. The virions are resistant to the enzymes RNase, DNase, trypsin, chymotrypsin, and phospholipase C, and to a detergent, deoxycholate. The use of these enzymes and deoxycholate, in combination with discontinuous and linear sucrose gradients, produced very pure preparations of free virions. Occluded virions were released by dissolving polyhedra in 0.05 M Na_2CO_3 - 0.04 M NaCl for 60 min at room temperature. The composition of the virion was estimated to be about 28% RNA and 72% protein."
Related Material - 3

108. Herman, S. G. 1975. The Douglas-fir tussock moth DDT application of the summer of 1974: Effects of the DDT on nontarget organisms and residue accumulation in vertebrate animals. A progress report-Feb. 1975. West. For. and Conserv. Assoc., Perm. Assoc. Comm. Proc. 1974:18-21. Portland, Oreg.

During a broadly based environmental monitoring program, 13 persons from the Evergreen State College studied DDT residues from the 1974 Douglas-fir tussock control project in the Blue Mountains. Sampling occurred from May 17 to August 7. Plots were set up in spray and nonspray areas. Sampling for aquatic insects showed that where a buffer zone was left adjacent to the stream within the spray areas, stream insects were little affected. One stream that was directly sprayed had no insect life for a month afterward. Arboreal insects, particularly parasitic wasps and flies, showed a drastic population reduction. One stream had a large number of dead sculpin after the spray. Results on small mammal

populations were inconclusive. Counts of passerine birds showed a 24-54% decline after spraying. Brain samples from dead birds showed that death was caused by DDT poisoning. DDT residues increased in all vertebrates studied.
Control - 3

109. Hewson, R., and D. K. Mardon. 1970. Damage to heather moorland by caterpillars of the vapourer moth Orgyia antiqua L. (Lep., Lymantriidae). Entomol. Mon. Mag. 106:82-84.

The vapourer moth is well distributed throughout Britain and occasionally causes damage of commercial importance. A survey was made of an outbreak of damage to heather moorland in 1969. The number of caterpillars, cocoons, and egg masses were counted, and an estimate of defoliation was made. Vaccinium was the preferred food plant. The heather was burned the following year, and the infestation spread to a nearby pine and larch plantation, where the larvae caused some damage.
Related Material - 3

110. Hicks, M. E., D. Swanger, R. E. Pacha, and A. R. Tiedemann. 1976. The effect of the Douglas-fir tussock moth deforestation on microbiological and chemical water quality of damaged watersheds. (Abstr.) Am. Soc. Microbiol., Northwest Branch.

"An assessment of the impact of the insect-caused deforestation on microbiological and chemical water quality parameters was conducted on damaged watersheds, with and without salvage logging, and adjacent unaffected areas."
Outbreaks - 5

111. Hicks, M. E. 1977. Effect of deforestation by the Douglas-fir tussock moth on the quality of streamflow and stream productivity parameters. M.S. thesis. Cent. Wash. State Coll., Ellensburg. 104 p. (No copies available) Unpubl.

"Seven watersheds of three types were examined to determine if deforestation by the Douglas-fir tussock moth and subsequent salvage logging had any effect on stream water quality. Results indicate only seasonal fluctuations and differences among watersheds due to inherent properties of individual watersheds. Increased turbidity levels were detected on logged watersheds which could be correlated with the logging activities."
Outbreaks - 5

112. Hughes, K. M. 1957. An annotated list and bibliography of insects reported to have virus diseases. Hilgardia 26(14):597-629.

Of the lymantriid moths listed, Hemerocampa leucostigma and H. pseudotsugata are listed as having a polyhedrosis virus.
Biology - 5; Related Material - 3

113. Hughes, K. M. 1972. Fine structure and development of two polyhedrosis viruses. J. Invertebr. Pathol. 19(2):198-207.

"Some characteristics of two viruses of the Douglas-fir tussock moth are described. Viral development appears to start in the nuclei of infected cells with the formation of tubes believed to be capsids. Subsequently, the tubes are filled with viral nucleoprotein. Filaments that may be molecules of DNA are illustrated. Objects believed to be defective virus particles, consisting of capsids that contain a subnormal quantity of nucleoprotein, are described. The bearing of these observations on the existence of an 'intimate membrane' is discussed."
Biology - 5

114. Hughes, K. M. 1976. Notes on the nuclear polyhedrosis viruses of tussock moths of the genus Orgyia (Lepidoptera). Can. Entomol. 108(5):479-484.

"Three western species of tussock moths of the genus Orgyia are all susceptible to infection by the same two nuclear polyhedrosis viruses.

An eastern species of Orgyia is also affected by these viruses. In the western states, the natural occurrence of the two viruses appears to be limited to definite geographic areas. Infectivity of the viruses for hosts outside the genus Orgyia is not known. One report of such cross-infectivity could not be substantiated. Bodies which appear to be composed of viral materials but which are not normal virus particles are sometimes found occluded in polyhedra."
Biology - 5; Related Material - 3

115. Hughes, K. M., and R. B. Addison. 1970. Two nuclear polyhedrosis viruses of the Douglas-fir tussock moth. J. Invert. Pathol. 16(2):196-204.

"Two nuclear polyhedrosis viruses affecting the Douglas-fir tussock moth, Hemerocampa pseudotsugata, are described. One induces formation of polyhedral bodies containing single rod-shaped virus particles, each within its own envelope. The other produces polyhedra with bundles of several rods within a common envelope. The same tissues of the host are affected by both viruses, although not equally. Mean lengths of the rods of the two types differ. One type of virus has been found in only a few geographic locations." After three passages of each virus through insects, no reversion to the alternate type was observed.
Biology - 5

116. Ilnytzky, S., J. R. McPhee, and J. C. Cunningham. 1977. Comparison of field-propagated nuclear polyhedrosis virus from Douglas-fir tussock moth with laboratory produced virus. Can. For. Serv. Bi-Mon. Res. Notes 33(1):5-6.

A nuclear polyhedrosis virus from the white-marked tussock moth, Orgyia leucostigma (J. E. Smith), was propagated in the field (Kamloops, B.C.) using 36 Douglas-fir trees infested with a population of 30-150 larvae of the Douglas-fir tussock moth, Orgyia pseudotsugata (McD.). Larvae were infected in the 4th and 5th instars. The first recorded deaths occurred 10 days after virus spray application. On the 14th day postspray, 7,000 larvae were shaken from the trees and processed, yielding 188 g of powder with 4 billion polyhedra/g.

The field-propagated virus was tested against the laboratory-produced virus (propagated on white-marked tussock moth) on 2-ha plots infested with Douglas-fir tussock moth larvae. Two aerial sprays produced an application rate of 125 billion polyhedra/ha.

Comparisons between pre- and postspray larval populations showed similar mortality rates for both field- and laboratory-propagated virus preparations and that control could be obtained from the 125 billion polyhedra/ha dosage.

The advantages and disadvantages of field- and laboratory-propagation methods are discussed.
Control - 6

117. Interagency Tussock Moth Steering Committee. 1973. The Douglas-fir tussock moth problem in the Northwest. Status, impacts, and alternatives for 1974. Portland, Oreg. 18 p. Unpubl.

An informal question-and-answer format is used to inform the public concerning the status of the Douglas-fir tussock moth outbreak in the Northwest, which began in 1972. Maps and tables of areas of defoliation and proposed treatment sites are presented. The alternatives for control are explained along with the rationale for the use of DDT and its possible impact on the environment. Criteria for control recommendations are outlined. The assessment of actual need for control in 1974 must await the results of the USDA Forest Service laboratory report in March on the natural virus levels in egg masses and the effects of predators, parasites, and overwintering stress on larval emergence.
Control - 4

118. Iwai, P. J., and M. E. Martignoni. 1975. Preparation of suspensions of nucleopolyhedrosis virus of the Douglas-fir tussock moth for field application. In Aerial application of insecticides against forest defoliators (chemicals and microbials). Proceedings of workshop held April 23-25, 1974, Univ. Mont., Missoula, p. 19-20. USDA For. Serv., State and Private Forestry, Northern Region, Missoula, Mont.

A description of the preparation of suspensions of nucleopolyhedrosis virus of the Douglas-fir tussock moth is presented along with the method for computing dosage rates, techniques for handling and storage of the suspensions, and the sampling procedure used to determine pre- and posttreatment viral infectivity.
Control - 6

119. Jahn, E., and K. Kotschy. 1973. Zum Auftreten des Schlehenspinners, Orygia antiqua L. (Lepidoptra: Lymantriidae) bei Schwaz in Tirol (Osterreich). [Observations on the outbreak of Orgyia antiqua L. (Lepidoptera: Lymantriidae) near Schwaz, Tyrol (Austria).] Ber. Naturwiss. Med. Ver. Innsb. 60:225-231.

A description is given of a mass outbreak of Orgyia antiqua L., which occurred on an avalanche slope at altitudes of 1 400-1 600 m above sea level near Schwaz, in Tyrol. The larvae defoliated Vaccinium vitis ideae, V. myrtillus, Rhododendron ferrugineum, and Larix eropaea. They also partially infested cultivated spruces (Picea excelsa). The duration of larval development was 3-4 months. Snowfall may be responsible for latency during larval stages. The last-instar larvae were killed by a nuclear polyhedrosis virus, which collapsed the population. The 3rd-instar and older larvae proved to be resistant to insecticides applied as fogs (gama HCH) and liquid solutions (gama HCH and phosphoric acid-metasystox).
Related Material - 3

120. Johnsey, R. 1965. The Douglas-fir tussock moth in eastern Washington, 1964. Resour. Manage. Rep. 3, 11 p. April 1965. Wash. Dep. Nat. Resour.

"An aerial survey conducted in the summer of 1963 detected 40-50 farm woodlots in eastern Washington on which fir trees (primarily Douglas-fir) were being defoliated by the Douglas-fir tussock moth." Another survey conducted in the early summer of 1964 showed 72 infestation centers affecting 17,700 acres. Samples of egg masses were taken to

determine the expected population. Virus was present in all larval samples analyzed. Most of the tussock moth populations subsequently collapsed from virus infection. The new/old egg mass ratio was 1:1 or greater on 2,420 acres, and the populations were expected to increase.
Outbreaks - 2

121. Johnson, D. W., and J. S. Hadfield. 1975. Defect in Douglas-fir and grand fir top-killed by the Douglas-fir tussock moth. USDA For. Serv. R-6, Div. State and Priv. For., Portland, Oreg. 10 p. Unpubl.

"Examination in 1974 of felled Douglas-fir and grand firs top-killed by the Douglas-fir tussock moth during the 1963-1965 Burns, Oregon, outbreak showed grand fir had more visible defect than Douglas-fir. Decay was minimal in both species." Woodstaining fungi and bacteria were the most prevalent organisms isolated.
Host Relationships - 2, 3; Outbreaks - 5

122. Johnson, P. C. 1948. Natural decline of tussock moth infestations in the Inland Empire. (Abstr.) Northwest Sci. 22(1):16.

Outbreaks of the tussock moth were detected in 1947, on 10,000 acres near Colville, Washington, and on 20,000 acres near Orofino, Idaho. The incidence of parasitism had become so great by the final instar, that satisfactory natural control of the larvae was assured. Polyhedral virus disease, combined with parasites, effectively curtailed further development.
Outbreaks - 2

123. Johnson, P. C., and D. A. Ross. 1967. Douglas-fir tussock moth, Hemerocampa (Orgyia) pseudotsugata McDunnough. In Important forest insects and diseases of mutual concern to Canada, the United States, and Mexico. Dep. For. Rural Dev., p. 105-107. Ottawa, Can.

This report summarizes the damage, hosts, life history, and control measures used against the Douglas-fir tussock moth.
General Background

124. Johnson, P. C., and D. A. Ross. 1973. La chenille a houppes du sapin de Douglas Hemerocampa (Orgyia) pseudotsugata McDunnough; Douglas-fir tussock moth. Publ. Dep. Environ. Can. For. Serv. 118F:110-112.
Article unavailable.

125. Keen, F. P. 1929. Tussock moth menace. Timberman. 30:108.

A popular account of the Douglas-fir tussock moth which includes: its first appearance as a pest in Vernon, B.C., in 1920; the areas under attack in the U.S.; a description and life cycle of the insect; the possibility of control and the need for further study of all aspects of the Douglas-fir tussock moth problem.
General Background

126. Keen, F. P. 1952. Insect enemies of western forests. U.S. Dep. Agric. Misc. Publ. 273 (Rev.), p. 90-93.

The history of outbreaks, the life cycle and description of stages, the feeding habits, the parasites and predators, and the alternatives of chemical control of the Douglas-fir tussock moth are presented.
General Background; Biology - 1, 3; Control - 1

127. Kelley, S. A., and W. J. Rompa. 1973. Public opinions about controlling the 1973 Douglas-fir tussock moth outbreak. USDA For. Serv. Pac. Northwest Reg., Div. Timber Manage., Portland, Oreg. 27 p. Unpubl.

An analysis is presented of public opinion concerning the USDA Forest Service environmental statement for the Douglas-fir tussock moth pest-management plan for controlling the Oregon-Washington outbreak of 1972-1973. The Codinvolve System for analyzing public input, devised by

Clark, Hendee, and Stanky of the Forest Service, was used to classify public response to methods of control preferred, and the reasons for the choice indicated. Responses were classified according to type of input (letter, petition, form letter, and so on), locality of respondent (rural or urban, infested or uninfested area), and the basis of interest of the respondent (such as sportsman, resource industry user).

Control alternatives examined were: DDT; biological chemicals other than DDT; harvest of damaged timber; or nonintervention. The use of DDT was supported by the majority of the respondents in both the infested and uninfested areas, primarily to prevent economic damage to the timber industry and the loss of watershed and scenic values of the area.

Appendices include tables on form of response, classification of respondent, and control preferences of concerned organizations in the area.

Control - 4

128. Ketcham, D. E., and K. R. Shea. 1977. USDA combined forest pest reasearch and development program. J. For. 75(7):404-407.

"Late in 1974 the U.S. Department of Agriculture activated the Combined Forest Pest Research and Development Program to provide technology for minimizing intolerable losses for the southern pine beetle, Dendroctonus frontalis (Zimm.), Douglas-fir tussock moth, Orgyia pseudotsugata (McD.), and gypsy moth, Porthetria dispar (L.). Participating are departmental agencies, State agricultural experiment stations and forestry organizations, universities, and industry. This is the first time an interagency research program has been administered directly from the office of the Secretary of Agriculture. Significant progress has been made during the first three years." The organization and administration of the program are detailed.

Related Material - 2

129. Klock, G. O., and C. Huang. 1977. Some early effects of conifer defoliation on microclimate. (Abstr.) Agron. Abstr., p. 181. Am. Soc. Agron., Madison, Wis.

"A reduction in canopy as a result of insect defoliation was simulated on two 0.4-ha experimental plots in a mixed Abies grandis-Pseudotsuga menziesii stand near Lake Wenatchee, Washington. The plots were defoliated with an aerial application of Paraquat® in July 1976. Loss of needles and understory foliage from the treatment stand caused an immediate reduction in use of soil water by the plants as evidenced by the lower rate of soil water depletion when compared with a control stand during the late summer. Maximum daytime air temperatures at the 10- and 100-cm heights increased immediately after defoliation while soil surface temperatures decreased. In the following spring both daytime air and soil surface temperatures were warmer in the defoliated stand while nighttime minimum air temperatures were frequently lower. Changes in air and soil temperatures are attributed to solar energy redistribution within the forest stand and modification of the forest floor albedo and thermal constants by needle fall."
Outbreaks - 5

130. Klock, G. O., and T. L. Jones. 1976. Physical disturbance of soil by salvage logging in the Oregon Blue Mountains. (Abstr.), Annual Mtg. Northwest Scientific Assn., Chaney, Wash. p. 27. Northwest Sci.

"A survey of soil disturbance was made during 1975 on five major areas that appeared to be representative of recent salvage logging of Douglas-fir tussock moth-infested areas in the Oregon Blue Mountains. Except for isolated occurrences, these operations have not had a severe detrimental physical impact on the soil resource. Slight soil disturbance from tractors (disturbance of mineral soil less than 2-3 cm deep) averaged about 17% of the logged areas, with a range of 10-23%. Severe soil disturbance averaged about 25% (range 19-29%), leaving about 58% undisturbed. This level of disturbance is similar to that by tractor logging of green timber in this region. Research supported by Douglas-Fir Tussock Moth Program."

131. Knox, D. A. 1970. Tests of certain insect viruses on colonies of honey bees. J. Invertebr. Pathol. 16(1):152.

This is an extension of the research reported by Cantwell et al., 1966 (J. Invertebr. Pathol. 8: 228-233) concerning the effect of nine different insect viruses on honey bee colonies. Included in the tests is the nuclear polyhedrosis virus of the Douglas-fir tussock moth. No differences were observed between treated colonies and untreated controls. Test of a pathogen's impact on beneficial insects are required before potential candidates for biocontrol can be used in large-scale field experiments.

Control - 6

132. Kohler, S. 1977. Ground application of four insecticides on Douglas-fir tussock moth and western spruce budworm populations in Montana. Mont. Dep. Nat. Resour. Conserv., Div. For., Insect and Dis. Rep. 77-1, 9 p.

Report unavailable.

Control - 1

133. Kohler, S. 1977. Douglas-fir tussock moth detection and survey using pheromone-baited sticky traps, 1976. Mont. Dep. Nat. Resour. Conserv., Div. For., Insect and Dis. Rep. 77-2, 7 p.

Report unavailable.

Biology - 2; Outbreaks - 2, 3.

134. Krygier, J. T., L. Streeby, J. M. Witt, and J. Capizzi. 1973. The Douglas-fir tussock moth. The problem, alternatives, and impact. Oreg. State Univ. Ext. Serv. EC 821 (Rev.), 16 p.

The extension circular delineates for the public the status of the Blue Mountain tussock moth outbreak of 1972-1973 in Washington and Oregon. The life cycle of the insect, its capabilities as a pest, the extent of present defoliation, and the forecast for potential damage in 1973 are presented. The cycle of outbreaks appears to follow a 3-year pattern,

with the 3rd year (in this case, 1973) a period of natural population decline. Comparisons made between the estimated insect mortality and resultant reduction of defoliation with natural population decline or with chemical control by DDT show an estimated 12-369 million board feet of timber can be saved in 1973 with the use of DDT. Variation in number of board feet is dependent on the method used in making the estimate. Both the economic and environmental impact of the use of DDT is examined. The major environmental risk will be the reduction of certain populations of birds and fishes.

The circular is updated with the March 1973 report from the U.S. Forestry Lab at Corvallis, on the virus incidence in the overwintering egg masses. The virus level is lower than anticipated, and the figures for potential defoliation in 1973 have to be adjusted accordingly. Outbreaks - 2; Control - 4

135. Kulman, H. M. 1971. Effects of insect defoliation on growth and mortality of trees. Ann. Rev. Entomol. 16:289-324.

One hundred seventy-four studies of tree mortality and increment reduction related to measured amounts of insect and artificial defoliation are reviewed. Discussion of individual case studies is organized by defoliating insect. Included is a brief section of defoliation of white fir by the Douglas-fir tussock moth.

The need to relate measurement of defoliation, growth, and mortality to a complex of factors is examined. Flower production, respiration and photosynthetic efficiency of the foliage, tree age and species, season of the year, age, exposure, and crown location of the foliage all affect foliage growth, development, and response to defoliation.

Factors affecting selection of trees for experimental controls are outlined, as well as problems encountered in pre- and postdefoliation growth measurements. Trees escaping defoliation make poor controls if

factors affecting the defoliator population independently affect tree growth and mortality.
Outbreaks - 5

136. Lachenmeier, R. R. 1974. DDT and the tussock moth: The EPA in a crisis situation. Environ. Law (Winter):135-184.

The EPA's refusal to allow an emergency application of DDT against the Douglas-fir tussock moth in 1973 drew criticism in light of the widespread defoliation that occurred in the Blue Mountain infestation in the summer of 1973. This paper attempts to determine the background against which the decision was made and to analyze, criticize, and recommend changes in the EPA decisionmaking process. The life cycle and natural history of the moth, the status of the current outbreak in the Blue Mountains, the alternatives for control, and the history of the EPA control over the use of DDT are reviewed.

The USDA Forest Service Environmental Impact Statement is examined in depth, as are the reasons behind the EPA's refusal to allow the use of DDT for Douglas-fir tussock moth control, and the possibilities of political considerations influencing this decision. The article recommends that the EPA enter early in the investigation of surrounding situations where a potential exists for an EPA ruling, to ensure that the agency is in full possession of the facts.

An addendum examines the 1974 reversal by the EPA in granting an exemption from the ban on DDT for Douglas-fir tussock moth control.
Control - 4

137. Lavenseau, L. 1972. Quelques aspects de la biologie d'Orgyia antiqua L. (Lepidoptere, Lymantriidae). [Some aspects of the biology of Orgyia antiqua L. (Lepidoptera, Lymantriidae).] Soc. Linn. de Bord. Bull. 2(10):217-234.

Translation unavailable.
Related Material - 3

138. Lessard, E. D. 1974. Climatic, host tree, and site factors affecting the population dynamics of the Douglas-fir tussock moth, Orgyia pseudotsugata (McDunnough). M.S. thesis, Univ. Wash., Seattle. 69 p.

This study was initiated to analyze present and past infestations of the Douglas-fir tussock moth, and equate climatic conditions, as well as host tree susceptibility, to changes in tussock moth populations. Fifty-five infested sites were studied. Measurements of slope, aspect, elevation, and stand composition were taken. Radial sections were taken from 10 infested Douglas-fir for laboratory analysis. These were x-rayed and an oblique sequence was used to analyze growth patterns from 1955 to 1964. Leader growth was substantially reduced because of defoliation, and the leader increased in dominance relative to the rest of the tree. Climatic release may be an important factor in the population dynamics of the tussock moth, since each infestation was preceded by 1 or more years of below-normal precipitation. The number of years of below-normal precipitation is correlated with the number of acres infested during the outbreak. Stands on drier sites are more susceptible to tussock moth attack than stands on wetter sites. The quality of the foliage increases and host resistance decreases when the tree is under water stress in drought conditions. These factors may explain the sudden release of tussock moth populations because of their favorable effect on the larvae. A generalized model is given showing the interaction of population density, precipitation, and host foliage quantity and quality, as well as host susceptibility.
Host Relationships - 3; Outbreak - 4

139. Linn, J. D., and A. I. Bischoff. 1966. Progress report on the evaluation of the effects on fish and wildlife of the Douglas-fir tussock moth control project in California--1965. Calif. Dep. Fish and Game, Rep. 3, 13 p. Unpubl.

Approximately 58,000 acres of forest land were sprayed with DDT in 1965, for control of the Douglas-fir tussock moth. A surveillance program

was conducted to determine the effects of DDT on nontarget fish and wildlife. The two phases to the evaluation were general observation of direct effects during the spray operation and residue studies. Residue levels were found for fish, aquatic insects, water, terrestrial insects, foliage, and birds and mammals. No evidence was found of direct mortality in birds, mammals, or fish. But heavy mortality was found in aquatic insects. Residues on forage increased from the spray, but analysis of samples taken 2 months after spraying showed a rapid decline in residue levels. A considerable increase of residue occurred in deer and chickadees.
Control - 3

140. Livingston, R. L. 1973. 1973 test of Sevin-4-oil for control of Douglas-fir tussock moth. State of Idaho, Dep. Lands, For. Pest Rep. No. 3, 5 p.

Tests of Sevin-4-oil were conducted in 1973 in northern Idaho against the Douglas-fir tussock moth in an effort to find an alternative to DDT. Aerial application of 1 lb/acre of Sevin on 60-acre plots resulted in a 65.5% corrected mortality but good foliage protection. Low mortality appeared to be the result of low spray deposit rather than low toxicity of the insecticide. Further testing is recommended.
Control - 1

141. Livingston, R. L. 1974. Possible causes for the unexpected decline of the Douglas-fir tussock moth in 1974. (Speech presented at the Nov. 1974 Meeting of the Intermt. Forest Pest Action Council, 3 p.) Unpubl.

Presented is a summary of opinions concerning the possible causes of the unexpected decline in population at the Blue Mountain Douglas-fir tussock moth outbreak. The opinions are unsupported by data and are derived from onsite observation or from speculation. Some areas sampled in June 1974 in Washington, Idaho, and Oregon had populations lower than predicted from the fall 1973 egg-mass survey. Among the suggested reasons

for the decline are: low egg viability; egg parasites; reduced larval vigor from poor egg quality; egg hatch out of synchrony with bud flush; higher virus incidence in the spring (1974); aphid epidemic produced excess honey dew, trapping larvae; larval predators; and inaccurate predictions from 1973 surveys.
Outbreaks - 4

142. Livingston, R. L., and G. Daterman. 1977. Surveying for Douglas-fir tussock moth with pheromone. Bull. Entomol. Soc. Am. 23(3):172-174.

Efforts to survey the Douglas-fir tussock moth population with female sex pheromone traps to detect incipient outbreak populations are described. A two-phase program was designed, first, to determine if pheromone traps could better define the geographic distribution of the tussock moth; and second, to develop a trapping system that would provide advance warning of population increases. Pheromone traps have detected low level population throughout most of the host type area. Population assessment, however, has been hampered by the fact that all traps captured moths regardless of population density. Lower doses of pheromone are needed to correlate numbers of tussock moths captured with numbers of larvae detected in field surveys.
Biology - 2; Outbreaks - 2, 3

143. Livingston, R. L., and S. Tunnock. 1973. Biological evaluation of existing Douglas-fir tussock moth populations in northern Idaho to determine damage potential for 1973. Idaho Dep. Public Lands, For. Pest Rep. 2, 6 p. Unpubl.

Current tussock moth egg populations were surveyed in northern Idaho to determine their potential for causing serious tree defoliation in the spring and summer of 1973. Egg masses were collected to evaluate the incidence of nucleopolyhedrosis virus in the population. Heavy populations were found in 4 of 28 plots examined, intermediate populations in 3 plots, and only cocoons were found in the remaining 4 of the 11

plots with egg masses or cocoons. Only one old egg mass was found in all of the plots. The populations were believed to be in the release phase of an outbreak and expected to cause extensive damage in 1973.
Outbreaks - 2

144. Luck, R. F., and D. L. Dahlsten. 1967. Douglas-fir tussock moth (Hemerocampa pseudotsugata) egg mass distribution on white fir in northeastern California. Can. Entomol. 99:1193-1203.

"The distribution of Douglas-fir tussock moth (Hemerocampa pseudotsugata) egg masses on white fir (Abies concolor (Gord. & Glend.) Lindl.) was studied in three areas of northern California. In each area 100 trees between 4.5 and 8.4 inches in diameter were stratified into five defoliation classes and four crown classes, giving a total of 20 classes per study area with five trees per class. Trees were divided into four crown levels and examples were taken at each of the cardinal directions at each level. Two branches comprised a sample unit in the top half of the tree (eight branches per level) and one branch was the sample unit in the bottom half of the tree (four branches per level). Egg masses were recorded per 10 ft^2 of foliage or branch area. Eighty % or more of the egg masses were found in the bottom half of the crown. This percentage in the bottom half of the crown increased on trees with heavy defoliation or with increased exposure of the crown. Of the four possible sources of variation considered in this study, crown level, defoliation class, and crown class were significant, but cardinal direction was not. A sampling method is proposed on the basis of the information gathered in this investigation."
Host Relationships - 1; Outbreaks - 3, 4

145. Ludeman, W. W., and R. L. Livingston. 1974. Reevaluation of certain 1974 Douglas-fir tussock moth control spray and spray-option areas in north Idaho. State Idaho, Dep. Lands, For. Pest Rep. No. 4, 8 p.

The results of a population survey conducted spring 1974, to reevaluate the potential defoliation on areas previously designated as targets for control projects and to examine new areas that may contain

populations that meet spray criteria, are presented. Based on egg mass densities and estimates of present defoliation, each of the areas was rated for its defoliation hazard, and spray boundaries were adjusted accordingly.
Outbreaks - 2

146. Lyon, R. L., S. J. Brown, and C. E. Richmond. 1967. Insecticides tested on new tussock moth ... defoliator found in Montana. USDA For. Serv. Res. Note PSW-161, 4 p. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.

"A pine tussock moth, identified as Dasychira sp. near/= grisefacta Dyar, was found for the first time in Montana in 1965. Larvae were reared on ponderosa pine foliage in the laboratory. Six insecticides were tested by topical application on fourth-instar larvae. Contact toxicity at LD_{90}, in descending order, was as follows: pyrethrins, Zectran, malathion, DDT, SD-8530, and carbaryl."
Related Material - 3

147. Lyon, R. L., and H. W. Flake, Jr. 1966. Rearing Douglas-fir tussock moth larvae on synthetic media. J. Econ. Entomol. 59(3):696-698.

"A procedure was developed for rearing larvae of Douglas-fir tussock moth, Hemerocampa pseudotsugata McDunnough, in large numbers on a synthetic medium for use in laboratory testing of insecticides. The insects were reared from the egg stage generally to the 4th to 7th instar, depending on testing needs. The larvae appeared normal in every way, reaching a weight of about 300 mg before pupation. An initial high loss from nuclear-polyhedrosis virus in the 3rd instar was avoided by soaking the eggs with a 10%-formaldehyde solution. Mortality during the larval stage on media was about 10%. Three thousand larvae were reared per week at a cost (excluding overhead) of about $15.00. At least 25,000 larvae could be reared weekly by one person working full time."
Biology - 6

148. Lyon, R. L., H. W. Flake, Jr., and L. Ball. 1970. Laboratory tests of 55 insecticides on Douglas-fir tussock moth larvae. J. Econ. Entomol. 63(2):513-518.

"Fifty-five insecticides were tested for their toxicity to larvae of the Douglas-fir tussock moth, Hemerocampa pseudotsugata McDunnough. The 10 most active insecticides in descending order of average toxicity at LD_{90} were: pyrethrins, Dursban® (0,0 diethyl 0-3,5,6-trichloro-2-pyridyl phosphorothioate), Zectran® (4 dimethylamino-3,5-xylyl methylcarbamate), dichlorvas, GC-6506 (dimethyl p-(methythio) phenyl phosphate), aminocarb, tetramethrin, allethrin, Bayer 37298 (0-ethyl 0-2,4,5-trichlorophenyl ethylphosphonothiode), and DDT. Four of the 10 insecticides--pyrethrins, Dursban, Zectran, and DDT, have been field tested recently with varying results. Several insecticides were examined in the laboratory in more detail in different formulations for such characteristics as rate of toxic action and residual activity."
Control - 1

149. McComb, D. 1965. Entomological evaluation of the Douglas-fir tussock moth in eastern Oregon. USDA For. Serv. Pac. Northwest Reg. 6, Portland, Oreg., 12 p. Unpubl.

"Defoliation by the Douglas-fir tussock moth was heavy on 32,000 acres of Douglas-fir and true firs on the Malheur National Forest during 1964. Feeding was light to moderate on an additional 10,000-15,000 acres, Malheur and Ochoco National Forests. Larval populations were high during September, and larval mortality from virus was low except in the Gold Hill area. Results of a new-to-old egg ratio survey made during October indicated a large increase in defoliation and moth populations would occur during 1965 in all areas except Gold Hill where the population was expected to remain static."
Outbreaks - 2

150. McComb, D. 1966. Dursban and Zectran pilot control study for Douglas-fir tussock moth. USDA For. Serv. Pac. Northwest Reg. 6, Portland, Oreg., 6 p. Unpubl.

Dursban and Zectran insecticides were applied by helicopter at the rate of 1/4 lb/gal cycle oil per acre to a mixed stand of ponderosa pine and Douglas-fir in the Malheur National Forest, in 1965. Measurements were taken of spray coverage and larval mortality. Larval mortality was poor. Occurrence of a polyhedrosis virus between the 3rd and 10th day postspray, prevented attributing larval mortality to insecticides. One month after spray application, field surveys encountered large numbers of larvae and some defoliation.
Control - 1

151. McComb, D. 1973. Biological evaluation of Douglas-fir tussock moth -- Oregon and Washington 1972-1973. USDA For. Serv. Div. Timber Manage. Reg. 6, Portland, Oreg., 32 p. Unpubl.

Entomological evaluation surveys were undertaken during the fall of 1972 in the known tussock moth activity centers and in adjacent host-tree areas in Oregon and Washington. The primary objectives of the survey were to locate and delineate areas of tussock moth activity, determine the degree of damage, measure the density and trend of moth population in each area, and collect egg masses for a survey of virus disease incidence. The evaluation procedure combined aerial and ground-detection surveys and sampling of egg masses. During the ground surveys, determinations were made of egg-mass densities, new-to-old egg-mass ratios, egg-mass size, and the presence of predators and parasites.

The population trends and the need for control are discussed for each outbreak area. Upon determination of the amount and distribution of virus from the incidence surveys, a reevaluation was undertaken in each unit where control had originally been recommended for 1973.

The report includes a list of the host trees, a description of tussock moth damage, and a history of the current outbreak.
Outbreaks - 2

152. McDunnough, J. C. 1921. New British Columbia tussock moth, Hemerocampa pseudotsugata McD. Can. Entomol. 53(3):53-56.

The taxonomic description of the Douglas-fir tussock moth is presented, including a description of the egg stage, the five larval stages, and the adult male and female. Description was based on specimens reared from egg masses collected on Douglas-fir by W. B. Anderson (the original discoverer of the species) in Chase, B.C., spring 1920. The species had been identified by E. H. Blackmore of the B.C. Provincial Museum as H. vetusta gulosa. Based on differences in larval coloration and host plant preference, however, the moths collected by Anderson can be distinguished from both H. vetusta and H. gulosa, and therefore recognized as a new species.
Taxonomy

153. McDunnough, J. C. 1938. Check list of the Lepidoptera of Canada and the United States of America. Part I. Macrolepidoptera. Mem. South. Calif. Acad. Sci. 1:1-272.

A complete list of the known species of Lepidoptera in Canada and the United States is presented. Hemerocampa pseudotsugata McDunnough is included.
Taxonomy

154. McGregor, M. D., S. Tunnock, J. E. Dewey, and W. M. Ciesla. 1974. Pilot control project of nucleopolyhedrosis virus and Bacillus thuringiensis to control Douglas-fir tussock moth populations in Idaho - 1974. USDA For. Serv. North. Reg., Insect Dis. Rep. 74-26, 11 p. Div. State Priv. For., Missoula, Mont.

"A pilot control project designed to evaluate two microbial insecticides, the bacterium Bacillus thuringiensis and a nucleopolyhedrosis virus, against epidemic populations of Douglas-fir tussock moth was planned for two test sites in northern Idaho in 1974." The population in the proposed study area was sampled to determine if the Douglas-fir tussock moth outbreak in Idaho met criteria for a definitive

project with virus and bacteria. These criteria are: relatively high larval densities; population in a release phase; and low levels of natural virus associated with overwintering eggs. Sample data revealed larval populations at too low a level to support a definitive test at either test site and the project was cancelled. Monitoring of the population was continued to determine the effects of natural factors on a declining tussock moth population. Field-collected larvae were laboratory reared to determine mortality factors. Forty-nine percent emerged as adults, 36.7% died of unknown causes, 9.2% died from hymenopterous parasites, 1.8% from dipterous parasites, and 3.4% from virus. The nucleopolyhedrosis virus was not the major factor in population decline.

Several problems in the formulation of microbial insecticides are discussed.
Control - 5, 6

155. McLean, H. E. 1966. Twenty days in June . . . the cautious war. Am. For. 72(3):28-31, 49, 50.

A popular account of the DDT spray control project in the Malheur National Forest (Oregon) against an outbreak of the Douglas-fir tussock moth. The infestation was first discovered in 1963 and reached outbreak proportions by 1964. Fifty thousand pounds of DDT was aerially applied to 60,000 acres of Douglas-fir and white fir, between June 10 and July 1, 1965. Helicopters were used to apply the chemical to increase the precision of spray placement and minimize danger to cattle and ranches in the area. The spray project was under the control of the USDA Forest Service. The effects on both domestic and wild animals of possible DDT contamination were monitored. Postspray sampling revealed 98% mortality of Douglas-fir tussock moths in the treated areas.
Control - 2, 3

156. Maksymiuk, B. 1975. Pattern of use and safety aspects in application of insect viruses in agriculture and forestry. In Baculoviruses for insect pest control: Safety considerations, p. 123-127.

M. D. Summers, R. Engler, L. A. Falcon, and P. V. Vail, eds. Am. Soc. Microbiol.

A general discussion is presented of the safety aspects of virus formulation and field application against arthropods. Discussed are: application strategies, types of formulations and equipment, amounts of virus used, and comparisons of patterns of field use between agriculture and forest control projects. The discussion of safety aspects of application covers formulations and storage, equipment sanitation, and application drift hazards. Problems of virus preparation for specific insects such as the Douglas-fir tussock moth are mentioned.
Control - 6, 9

157. Maksymiuk, B., P. A. Boving, R. D. Orchard, and R. G. Winterfeld. 1968. Biological evaluation of helicopter spray equipment for applying polyhedrosis virus to control the Douglas-fir tussock moth. USDA For. Serv. and Agric. Res. Serv. Prog. Rep., 38 p. Pac. Northwest For. and Range Exp. Stn. and Agric. Eng. Res. Div., Corvallis, Oreg. Unpubl.

A series of helicopter spray tests were conducted near Corvallis, Oregon, as part of an effort to develop an operational procedure for control of the Douglas-fir tussock moth with polyhedrosis virus. The tests were designed to determine the effects on larval mortality of various application rates and spray atomizations.

"Two spray systems were tested. The ultralow-volume (ULV) spray system was calibrated to produce a spray atomization of 106 um mass median diameter (mmd) and an application rate of 0.2 gal per acre (gpa). The low-volume (LV) spray system was calibrated to produce spray atomization of 355 um mmd and application rates of 1.0 and 2.0 gpa. Mortalities were recorded until pupation. Distribution of spray deposit across the spray swath was determined."

The tests revealed that the ULV spray system can reduce application rates tenfold without decreasing insect mortality. Only one-half the

amount of virus was used for the application rate of 0.2 gpa as compared to either 2.0 and 1.0 gpa. "ULV application showed the most potential for field use considering biological effectiveness, spray distribution, plant coverage, simplicity of equipment, low weight of spray load, . . . and reduction in cost."
Control - 9

158. Maksymiuk, B., and J. Neisess. 1975. Physical properties of Bacillus thuringiensis spray formulations. J. Econ. Entomol. 68(3):407-410.

The effectiveness of water-base suspensions of Bacillus thuringiensis Berliner is increased by the addition of surfactants such as wetting agents, thickening agents, antievaporants, stickers, and protectants. Twelve commercially prepared, experimental B.t. spray formulations were tested and their physical properties evaluated. Emphasis was placed on selecting the most stable formulations for aerial application against forest defoliating insects.

"Four Thuricide®-HPC and four Dipel formulations were stable, while four Dipel formulations readily separated into layers during short storage. Maywood, whey, and corn oil surfactants increased the viscosity, which resulted in more stable formulations. Maywood surfactant also increased spread of formulations on foliage.

"Cargill's insecticide base (molasses) adjuvant resulted in the higher acidity of spray formulations as compared to polyethylene glycol. The various additives did not significantly improve sticking or retard evaporation of spray formulations. All formulations flowed through experimental spray equipment satisfactorily, were adequately atomized and produced consistent droplet size spectra." Little difference occurred in physical properties between Dipel and Thuricide formulations. The main criterion that would readily distinguish between formulations was the uniformity of suspensions of B. thuringiensis.
Control - 5, 8

159. Maksymiuk, B., and R. D. Orchard. 1974. Techniques for evaluating Bacillus thuringiensis and spray equipment for aerial application against forest defoliating insects. USDA For. Serv. Res. Pap. PNW-183, 13 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

"The most promising Dipel and Thuricide forestry spray formulations and spray equipment were studied to improve aerial application techniques and the effectiveness of Bacillus thuringiensis against forest insects."

The spray formulations and spray equipment produced satisfactory drop-size spectra and spray-deposit patterns. It was found that selected applications of B.t. demonstrated high control potential for the Douglas-fir tussock moth, Orgyia pseudotsugata (McD.), and the western spruce budworm, Christoneura occidentalis Freeman. The mean corrected larval mortality of the Douglas-fir tussock moth was 88% for the 100-ft and 78% for the 200-ft spray swath widths using Dipel. For the Thuricide treatment, the mean corrected larval mortality of the Douglas-fir tussock moth was 94% for the 100-ft and 87% for the 200-ft swath widths; the mean corrected larval mortality of the western spruce budworm was 100% for the 100-ft and 98% for the 200-ft swath widths. Higher deposits of B.t. almost completely prevented insect defoliation to test trees.
Control - 5, 8

160. Maksymiuk, B., R. D. Orchard, R. A. Waite, and J. Neisess. 1972. Aerial application of polyhedrosis virus against the Douglas-fir tussock moth: Equipment, formulation, meteorological monitoring, spray deposit and drift assessment. Part II. In Results of field experiments for controlling Douglas-fir tussock moth with aerial application of polyhedrosis virus and associated studies. USDA For. Serv. Prog. Rep., 22 p. Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg. Unpubl.

"This report summarizes the results of the preliminary spray tests conducted at the airport, Corvallis, Oregon, and the field test carried

Douglas-fir tussock moth." The airport tests corrected spray equipment deficiencies, and determined spray atomization, swath width, and spray deposit patterns.

The field test in California, showed a "wide variation in the amount of spray deposit both within and among individual trees. Quantitative spray-deposit assessment data showed that the foliage samples contained almost twice the amount of deposit on the Iron Mountain plot as compared to the Plummer Ridge plot. This difference is highly significant. It can be explained by the difference in precision of the spray application mainly due to swath markings and general location of plot. The amount of spray drift was highly significant in all control plots.

Due to insufficient larval mortality, no attempt was made to correlate it with the quantity of spray deposit."
Control - 9

161. Manis, H. C., and W. E. Shull. 1946. Tussock moth control. Univ. Idaho Coll. Agric. Mimeogr. Leafl. No. 95, 1 p. Agric. Exp. Stn. and Ext. Div., Moscow.

Report unavailable.
Control - 1

162. Markin, G. P., and H. Wilcox III. 1977. Douglas-fir tussock moth ground spray tests, 1974. Insectic. and Acaricide Tests 2:113-114.

Ground tests of 15 insecticides, each at 3 different rates, were conducted in the Wallowa-Whitman National Forest, from June 21 to July 10, 1974, to discover a replacement for DDT for control of the Douglas-fir tussock moth. "Based on the results of the tests (plus additional data) two materials, Orthene® 75S and TH-6040, were recommended for further field testing."
Control - 1

163. Martignoni, M. E. 1967. Separation of two types of viral inclusion bodies by isopycnic centrifugation. J. Virol. 1(3):646-647.

Nucleopolyhedrosis virus (NPV) inclusion bodies and cytoplasmic polyhedrosis virus (CPV) inclusions from larval Douglas-fir tussock moths can be separated and purified from mixed suspensions by centrifugation because of a small difference in the density of the inclusion bodies. "The inclusions are driven by centrifugal force to their isopycnic level in a sucrose density-gradient column." The centrifugations were performed in vacuo at 1°C by a BD-2 ultracentrifuge equipped with high-speed, horizontal swinging bucket rotors. "The fractionation procedure consisted of four steps."

Examination of the resulting two suspensions by dark-field microscopy showed each fraction contained only inclusions of one or the other type. Infectivity tests of the two fractions performed on tussock moth larvae showed only a trace (5.3%) of contaminating CPV in the NPV fraction and no NPV in the CPV fraction.

Isodensity levels for the virus inclusions were determined at 1.261 for NPV and 1.279 for CPV inclusion bodies.
Biology - 5; Control - 6

164. Martignoni, M. E. 1972. Production, safety evaluation, and infectivity titer assay of nucleopolyhedrosis virus preparation for field application. Part I. In Results of field experiments for controlling Douglas-fir tussock moth with aerial application of polyhedrosis virus and associated studies. USDA For. Serv. Prog. Rep., 13 p. Pac. Northwest and Range Exp. Stn., Corvallis, Oreg. Unpubl.

"A nucleopolyhedron preparation sufficient for treating 206 acres of fir forest at 10^{11} viral inclusion bodies per acre was produced by a simplified procedure. The method consisted of three principal steps:
(1) propagation of the virus in Douglas-fir tussock moth larvae;
(2) recovery of the inclusion bodies by homogenizing the larval tissues

and by passage of the suspension through a series of sieves; and (3) enrichment of the inclusion-body suspension by centrifugation in a sucrose solution.

"Tests to determine the safety of the viral agents for bees, fish, and mammals were completed, and gave no indication that the preparation would be unsafe for use as an insecticide. The tests were reviewed by public-health virologists. Routine production control tests confirmed that pathogenic agents (such as Shigella and Salmonella) were absent from the batch actually used in the field."

Infectivity titer of the suspension was determined by bioassay with larvae of the Douglas-fir tussock moth. Median lethal dose was 208 PIB/g larval weight. LD_{90} was estimated at 580 PIB/larvae. Pre- and postspray samples collected from the spray system nozzles showed comparable LD_{50} values when bioassayed with tussock moth larvae, demonstrating good field activity of the virus suspensions. Actual polyhedron counts of field samples were 3-13% lower than theoretically expected, possibly because of sedimentation.
Control - 6

165. Martignoni, M. E. 1972. A rapid method for the identification of nucleopolyhedron types. J. Invertebr. Pathol. 19(2):281-283.

Two nucleopolyhedron morphotypes occur in diseased Douglas-fir tussock moth larvae; single-rod virus types and bundle-rod virus types. Observation of the polyhedron dissolved in an alkali solution by dark-field microscopy gives a rapid method of discerning the ratio of the two types present in a virus suspension. Dissolved virus bundles appear as bright granules in fast Brownian movement within the outer polyhedron membrane, while the contents of the single-rod virus polyhedra appear homogeneous. Optimum area of observation of the dissolved polyhedra is found in the pH gradient formed against Tris buffer. Only freshly dissolved polyhedra can be easily identified. After a few minutes in alkaline solution, the contents of the polyhedra of both types precipitate.

A 0.02 M NaOH with 1% hydroxyethyl cellulose solution and a 0.02 M Tris buffer at pH 7.2 were used. A virus suspension was smeared on a microscope slide and let dry. One drop each of the Tris buffer and the alkaline solution were placed on a cover slip, joined together, and inverted on the slide. The slide was immediately examined.
Biology - 5; Control - 6

166. Martignoni, M. E., J. P. Breillatt, and N. G. Anderson. 1968. Mass purification of polyhedral inclusion bodies by isopycnic banding in zonal rotors. J. Invertebr. Pathol. 11(3):507-510.

Isopycnic separation of nucleopolyhedra from homogenates of larval tissue of several lepidopteran species has been performed in sucrose density-gradient columns by high-speed, horizontal swinging bucket rotors. By adaptation of the procedure for use with zonal rotors, large volumes of homogenate can be processed to produce gram amounts of pure nucleopolyhedra. The procedure could be used in decontaminating industrial batches of nucleopolyhedra if bacterial contaminants and allergens or both were undesirable.
Biology - 5; Control - 6

167. Martignoni, M. E., and P. J. Iwai. 1968. Determination of nucleopolyhedron counts and size-frequency distributions by means of a Coulter transducer. USDA For. Serv. Res. Note PNW-85, 14 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

"Coulter counts of nucleopolyhedra in purified suspensions and in suspensions containing varying amounts of impurities (up to 7.9% in the size range of the inclusion bodies) gave results in good agreement with counts performed with the traditional microscopic counting chamber." With the electronic procedure, large series of preparations can be rapidly processed. The advantages and disadvantages of the automated procedure are outlined. "Polyhedron counts of suspensions containing large amounts of impurities (such as raw tissue homogenates) gave unreliable results by electronic as well as microscopic procedures. In such cases, biological assay remains the only reliable method for the determination of infectivity titers."

With the model B Coulter counter, size-frequency distributions of batches of nucleopolyhedra could be established based on large numbers of particles.
Biology - 5; Control - 6

168. Martignoni, M. E., and P. J. Iwai. 1977. A catalog of viral diseases of insects and mites. 2d ed. USDA For. Serv. Gen. Tech. Rep. PNW-40, 27 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg. (1st ed., 1975.)

"This computer-based catalog lists over 640 species of insects and mites, each reported to have one or more of 21 viral diseases or disease groups, for a total of about 1,000 host-virus records." Hosts are listed both in taxonomic sequence in one list, and alphabetically by specific names in a second list.
Biology - 5

169. Martignoni, M. E., and P. J. Iwai. 1977. Peroral bioassay of technical-grade preparations of the Douglas-fir tussock moth nucleopolyhedrosis virus (Baculovirus). USDA For. Serv. Res. Pap. PNW-222, 12 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

"The potency of industrial preparations of viruses for control of injurious insects can be estimated reliably only by means of biological assay. We describe a simple, yet sensitive peroral bioassay procedure for technical-grade preparations of nucleopolyhedrosis virus. This procedure has been accepted by the Forest Service and the U.S. Environmental Protection Agency as the standard method for assaying industrial virus preparations for control of the Douglas-fir tussock moth."
Biology - 5; Control - 6

170. Martignoni, M. E., and P. J. Iwai. 1977. Thermal inactivation characteristics of two strains of nucleopolyhedrosis virus

(Baculovirus subgroup A) pathogenic for Orgyia pseudotsugata. J. Invertebr. Pathol. 30(2):255-262.

"Two nucleopolyhedrosis viruses of the Douglas-fir tussock moth, Orgyia pseudotsugata, one with a single nucleocapsid per envelope (SV) and one with multiple nucleocapsids per envelope (BV) are inactivated by a first-order reaction at 55° and 60°C. BV is the more thermostable of the two viruses: at both test temperatures, it has a lower inactivation rate than SV. BV is also the more virulent of the two viruses, with respect to acute course of the disease and severity of the histological lesions. The greater thermostability of BV and the acute course of the disease caused by this pathogen support the choice of BV as the virus most suitable for industrial production and field use."
Biology - 5

171. Martignoni, M. E., P. J. Iwai, and J. P. Breillatt. 1971. Heterogeneous buoyant density in batches of viral nucleopolyhedra. J. Invertebr. Pathol. 18(2):219-226.

"Nucleopolyhedron preparations of the bundle virus strain, obtained from large volumes of tissue homogenates of Hemerocampa pseudotsugata larvae, contain populations of inclusion bodies which differ with regard to their buoyant density in isopycnic sucrose gradients. The heavier polyhedra contain higher numbers of virus rods per polyhedron as well as higher numbers of rods per virus bundle. Polyhedra of the single-rod virus strain occlude larger virus rods and band at higher density than bundle virus polyhedra with similar numbers of virus rods. This fact favors the hypothesis that the single-rod and the bundle virus strains are distinct entities. This study includes a determination of the sedimentation constants of two polyhedron fractions, a mathematical simulation of the sedimentation behavior of nucleopolyhedra in isopycnic sucrose gradients, and an empirical analysis of the sedimentation of a polyhedron fraction. These data are intended to provide further criteria for improving the purification of polyhedral inclusion bodies in Anderson's zonal rotors."
Biology - 5; Control - 6

172. Martignoni, M. E., P. J. Iwai, K. M. Hughes, and R. B. Addison. 1969. A cytoplasmic polyhedrosis of Hemerocampa pseudotsugata. J. Invertebr. Pathol. 13(1):15-18.

"Histochemical and histological studies of midguts of larvae of the Douglas-fir tussock moth, Hemerocampa pseudotsugata, infected with cytoplasmic polyhedrosis virus showed that the viral inclusion bodies formed in apicobasally oriented rows in goblet and columnar cells of the epithelium. Electron micrographs of ultrathin sections of infected cells in the late stages of the disease revealed that the cytoplasmic polyhedra were surrounded by high numbers of virus particles, adjacent to the surface of the inclusion bodies. Biological assay gave an LD_{50} estimate of 104 polyhedra/g larval weight. In our samples, the mean volume of the inclusion bodies was 7.7 μ^3 and the mean diameter of the virus particles was 56 mμ."
Biology - 5

173. Martignoni, M. E., P. J. Iwai, and L. J. Wickerham. 1969. A candidiasis in larvae of the Douglas-fir tussock moth, Hemerocampa pseudotsugata. J. Invertebr. Pathol. 14(1):108-110.

A yeast isolated from the alimentary tract of a laboratory-reared larva of the Douglas-fir tussock moth was classified as Candida zeylanoides (Castellani) Langeron and Guerra (designated strain Y-7043) on the basis of cell and colony morphology, carbon assimilation reactions, and sugar fermentation.

Infectivity tests of yeast cells from 2-day-old surface colonies on 4th-instar tussock moth larvae resulted in a slight inhibition of growth with low inoculative doses and a high mortality with high doses. No pathognomonic symptoms of the candidiasis appeared in the tussock moth larvae. The frequency of yeast cells in the fresh feces served as a diagnostic test. The yeast multiplies abundantly in the slightly acidic hindgut of the larvae.

"C. zeylanoides, strain Y-7043, appears to be a conditioned enteropathogenic microorganism for larvae of H. pseudotsugata." Secondary etiological factors may have influenced both its appearance in the laboratory and the results of the infectivity tests. Lowered resistance in the host is often required for successful colonization by certain yeasts. Both the larvae from which the yeast strain was isolated and the larvae used for the tests were reared on an artificial diet. Because artificial diets may lower resistance in laboratory-reared insects, the yeast may cause disease in the laboratory where it would not do so in the field.

Biology - 4

174. Martignoni, M. E., and R. L. Langston. 1960. Supplement to an annotated list and bibliography of insects reported to have virus diseases. Hilgardia 30(1):1-39.

This supplement to Hughes's (1957) "Annotated List and Bibliography" adds 473 references to the 259 of the original list. Almost all the papers have been seen in the original or in photostatic copy. Translators were consulted when needed. Papers in Japanese and Russian included in the supplement were available in translation or contained a complete translated summary. They form only a small portion of the papers in those two languages available on this subject.

An attempt was made to distinguish between nuclear polyhedrosis and cytoplasmic polyhedrosis whenever the information was available. Both a host list and a list of general references is included.

Biology - 5

175. Mason, R. R. 1967. Evaluation of a Douglas-fir tussock moth population near Aztec Peak, Arizona. USDA For. Serv. Prog. Rep., 10 p. Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg. Unpubl.

"An evaluation was made in 1967 of an incipient outbreak of the Douglas-fir tussock moth in the Sierra Ancha Mountains of Arizona.

Purposes of the evaluation were to assess the suitability of the area for a field test of a virus introduced to control the tussock moth." The secondary objectives were to test methods of sampling eggs and larvae, especially at low population levels and to study dynamics of a natural tussock moth population through one or more generations. The populations were sampled three times during the season; twice during the larval stage and once in the egg stage. Major findings of the study follow.

Larval populations in 1967 were variable but low at all 10 permanent sample points. Fall egg populations indicated a substantial increase in population might occur in 1968. Significant defoliation could be expected in one 40-acre area, where heavy egg populations indicated potential outbreak status. The rest of the area under observation would still have relatively low populations. The highest populations were at a level suitable for virus test, but occurred over too small an area for adequate experimental design. Continued study is recommended to provide data on population trends and information on the mechanisms of population fluctuation.
Outbreaks - 4

176. Mason, R. R. 1969. Sequential sampling of Douglas-fir tussock moth populations. USDA For. Serv. Res. Note PNW-102, 11 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

"Sequential plans have been constructed for sampling eggs and larvae of the Douglas-fir tussock moth. The plans are a standardized method for making quick ground surveys of incipient outbreaks. They are designed to be applied independently at selected points in a suspected infestation for distinguishing currently innocuous populations from those having outbreak potential. The sequential schemes are recommended primarily for sampling tussock moth larvae in the early instars."

The basic sample unit is a collection of branches taken representatively from a tree. Population size is the density of young larvae or eggs per 1,000 in^2 of branch area (square inches occupied by

foliage on a branch). A two-class sequential scheme set class limits of 10 or less 1st-instar larvae or eggs per 1,000 in^2 of branch area for light populations; and 20 or more 1st-instar larvae or eggs for heavy populations with high outbreak potential. Sample points consist of about 1-acre areas from which trees are randomly selected and sampled.

Data used in developing the sequential sampling methods in this paper were taken from tussock moth infestation on white fir and may not be representative of infestations in other host species.
Host Relationships - 1; Outbreaks - 3

177. Mason, R. R. 1970. Development of sampling methods for the Douglas-fir tussock moth, Hemerocampa pseudotsugata (Lepidoptera: Lymantriidae). Can. Entomol. 102(7):836-845.

"Methods were developed to standardize sampling of the Douglas-fir tussock moth. Population density was estimated in terms of the number of eggs or larvae per 1,000 in^2 of branch area of Abies concolor (Gord. and Glend.) Lindl. The density of eggs and larvae varied significantly in different parts of the tree crown. In an outbreak, egg masses were concentrated on inside branches near the bottom of the crown, but in light populations they were most common on outside branches in the top of the crown. Larvae were found over the entire tree, but they were especially concentrated on foliage in the top. Mean density of larvae in the middle crown was representative of the whole tree. Egg density is estimated from whole branches sampled representatively from three crown levels; however, density of larvae is estimated accurately from 17-in twig samples taken from just the middle crown. Because eggs are clumped in masses and larvae are dispersed over the foliage, larval density can be estimated with much less sampling than can egg density for the same precision."
Host Relationships - 1; Outbreaks - 3

178. Mason, R. R. 1972. Analysis of population density after virus treatment of a natural outbreak of the Douglas-fir tussock moth. Part III.

In Results of field experiments for controlling Douglas-fir tussock moth with aerial application of polyhedrosis virus and associated studies. USDA For. Serv. Prog. Rep., 12 p. Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg. Unpubl.

"Estimates of tussock moth population density were made five times during the larval cycle on virus-treated and untreated test plots. Purposes of the measurements were to compare population trends and survival on the treated with the untreated plots. Life tables were also constructed using the mortality data provided from laboratory rearings. Major findings of the study are as follows: Sampling methods were adequate for evaluating the test and consistently gave a realistic appraisal of the natural population. Most standard errors were within 15% of the mean. Population trends and survival over the course of larval development were similar on both virus-treated and untreated plots. Larval density dropped sharply early in the cycle and then declined gradually to pupation. Overall larval survival was about 18%.

"In a life table analysis, virus disease accounted for 6% of the mortality on treated plots and 2.5% of the mortality on untreated plots. The largest proportion of mortality (over 80%) on all plots was not identified."
Control - 6

179. Mason, R. R., ed. 1973. Newsletter. Douglas-fir Tussock Moth Research Committee. Corvallis, Oreg. No. 1-Mimeogr.

The Douglas-fir Tussock Moth Research Committee is an informal group of entomologists, organized in 1972 to coordinate tussock moth field research in 1973. Its major function is to circulate information through these periodic newsletters which briefly describe the current research activity and report early research results.
Related Material - 2

180. Mason, R. R. 1974. Population change in an outbreak of the Douglas-fir tussock moth, Orgyia pseudotsugata (Lepidoptera: Lymantriidae), in central Arizona. Can. Entomol. 106(11):1171-1174.

The population growth and natural decline of an isolated outbreak of the Douglas-fir tussock moth is described. The investigation was conducted from 1967 to 1971 on an infestation near Aztec Peak, Arizona.

Data from this study support the general observation that outbreaks pass through a 3-year cycle of population release, peak, and decline. "Growth rate of populations was independent of larval density in the 1st year, but thereafter became a reciprocal function of density, terminated by complete population collapse at the end of the 3rd year. Through correlation analyses, it was found that density of small larvae accounted for a large proportion of the change in population density between years. . . . The close relation between larval density in any two successive years indicates that the outbreak developed from a population that was resident in the area for at least two years. This suggests that, at low densities, dispersal of small larvae is primarily in local redistribution in the stand and does not result in significant long-distance spread of the population the same year. Variation in densities between localities must reflect differences in natural environmental factors which influence rates of increase during release and ultimate population levels reached in the peak phase."
Outbreaks - 4

181. Mason, R. R. 1976. Life tables for a declining population of the Douglas-fir tussock moth in northeastern Oregon. Ann. Entomol. Soc. Am. 69(5):948-958.

"Changes in population density and their causes were quantified on 22 sample plots representing 4 different defoliation intensities in a Douglas-fir tussock moth outbreak. Density of larvae was extraordinarily high at the beginning of feeding in June 1973. Thereafter, populations either declined sharply or completely collapsed on all of the plots

studied. Measurable larval populations of the subsequent generation were found on only six plots in June 1974, and these had virtually disappeared by midsummer. Rate of decline was variable under different conditions but appeared to be predictable from the level of past defoliation. In general, the decline rate was faster on heavily or moderately defoliated plots than on lightly or previously undefoliated plots. Population collapse was the result of a multitude of natural factors operating in compensating ways against the high-density outbreak. It was characterized by an increase in the effect of numerous mortality factors including virus disease, insect parasites, predators, starvation, and larval dispersion, as well as changes in population quality and structure resulting in lower fecundity, and egg quality and a change in sex ratio. The largest proportion of mortality occurred early in the larval cycle and was probably because of losses from natural dispersion and predation; however, other factors may have had an equal or greater effect on ultimate collapse of the population although they accounted for less total mortality."

Outbreaks - 4

182. Mason, R. R. 1977. Advances in understanding population dynamics of the Douglas-fir tussock moth. Bull. Entomol. Soc. Am. 23(3):168-171.

A brief review is presented of the methods of Douglas-fir tussock moth population survey and the results of the studies of population dynamics. Both the conventional method for sampling insect populations and a new technique for estimating low population densities are described. Population surveys have revealed: that the Douglas-fir tussock moth is present in low numbers in most of its natural host type; that outbreaks occur with some periodicity, although not always in the same stand; and that populations are regulated at low levels by a complex of mortality factors including predation by birds and parasitism and predation by other arthropods. Although factors leading to population release have not yet been elucidated, much of the information on population dynamics has been incorporated into models.

Outbreaks - 3, 4

183. Mason, R. R. 1977. Sampling low density populations of the Douglas-fir tussock moth by frequency of occurrence in the lower tree crown. USDA For. Serv. Res. Pap. PNW-216, 8 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

"A new method is described for rapidly estimating the larval density of low-level populations. Densities of 1.0 or fewer larvae per 1,000 in^2 (0.64 m^2) of branch area in the midcrown of host trees can be predicted from the proportion of sample units that are infested in the lower tree crown. This procedure is an improvement over the conventional midcrown sampling method because observations can be made in the more accessible lower crown without clipping and measuring branches. The technique is especially applicable to low-level populations which require the examination of large amounts of foliage to estimate larval density." Outbreaks - 3

184. Mason, R. R., and J. W. Baxter. 1967. Studies of the biology and behavior of the Douglas-fir tussock moth, 1966. USDA For. Serv. Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg., 28 p. Unpubl.

"Studies were initiated in the summer of 1966 on the biology and behavior of the Douglas-fir tussock moth in a declining outbreak in northern California. An unusually late spring frost killed most of the new tip growth on white fir branches and deprived young larvae of their preferred food. The situation prompted a number of short experiments on food quality in the laboratory and larval behavior in a natural forest environment. . . .

"All larval instars fed more on new foliage than on old. Old needles were almost totally unacceptable to early instar larvae but were fed upon by late instars. When new fir foliage was not available in the field, larvae often migrated to pine, where they fed on new needles. However, in the laboratory, new fir foliage, when available, was favored over new pine foliage.

"Lack of acceptable food for early instar larvae stimulated wandering in the laboratory. . . . When larvae were fed only frost-damaged foliage which contained no new growth, a large number died, apparently of starvation. Survivors on damaged foliage were stunted and developed slower than larvae that were fed normal foliage.

"Female moths reared in the laboratory contained an average of 200 eggs per individual, but this was considerably higher than the average number of eggs per mass in the field. . . .

"Larvae tend to avoid high light intensities and temperatures by remaining on the underside of branches and needles that are exposed to the sun. Most activity and feeding by late-instar larvae occurred in the evening, night, and early morning. . . . Early instar larvae usually concentrated in the vicinity of new buds; later instars fed further back on the branch as the season progressed."
Biology - 1; Host Relationships - 1

185. Mason, R. R., and J. W. Baxter. 1970. Food preference in a natural population of the Douglas-fir tussock moth. J. Econ. Entomol. 63(4):1257-1259.

"Food selection by larvae of Hemerocampa pseudotsugata McDunnough was studied in an outbreak on white fir, Abies concolor (Gordon and Glendenning) Lindley, in northern California." Larval feeding preference in relation to age of foliage was determined by categorizing each branch into (1) new foliage, branch tip including all new growth plus 3 inches of woody twig and old foliage; and (2) old foliage, the remainder of the branch. New foliage of white fir, when it was available, was preferred over old foliage, especially by young larvae, but old needles became more acceptable as larvae matured and new foliage was depleted. Given a preference test between fir or ponderosa pine in the laboratory, larvae strongly favored new foliage of white fir. However, new foliage of pine was as attractive as old foliage of white fir. "A shortage of preferred food stimulated mobility among early instars. When larvae were fed only

frost-damaged foliage which contained no new growth, many died, apparently from starvation." Mortality of larvae on damaged fir was 74%. The highest death rates occurred in the 3rd and 4th instars.
Biology - 1; Host Relationships - 1

186. Mason, R. R., R. C. Beckwith, and H. G. Paul. 1977. Fecundity reduction during collapse of a Douglas-fir tussock moth outbreak in northeast Oregon. Environ. Entomol. 6(5):623-626.

"Fecundity of tussock moth populations varied among plots after the 1st year (1972) of conspicuous tree defoliation and declined sharply after a 2d year (1973) of defoliation. Degree of defoliation in the 1st year had no significant effect on egg production, although fewest eggs per mass were produced in the most severely defoliated areas. Severe tree defoliation in the 1st year significantly affected quality of the filial generation. Field populations that had not already collapsed naturally had a 30% drop in fecundity after the 2d yr of defoliation. The conclusion is that fecundity was influenced by many factors, food-related and otherwise, in the outbreak. Tree defoliation had its greatest effect at exceptionally high population densities when the favored current needles were destroyed early in the summer, placing surviving larvae under a food stress for much of their development."
Biology - 1, Outbreaks - 4, 5

187. Mason, R. R., and C. G. Thompson. 1971. Collapse of an outbreak of the Douglas-fir tussock moth, Hemerocampa pseudotsugata (Lepidoptera: Lymantriidae). USDA For. Serv. Res. Note PNW-139, 10 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

"An outbreak population of the Douglas-fir tussock moth on white fir in northern California was studied during the summer of its collapse." Eight study points were established, three in transitional zones of less than 30% defoliation and five in the center of the heaviest defoliation (more than 30%). Mortality of larvae from parasites and disease was determined from laboratory rearings of field-collected larvae.

The survivorship curves were constructed for larvae, one from data from the heavily infested area and the second from the points in the lightly infested area. A general life table for eggs and larvae was prepared by pooling data from all study points. "The major cause of the collapse was a natural epizootic of virus disease in larval population. However, a late spring frost which destroyed much of the preferred food of the early-instar larvae may have also contributed significantly. . . . Two species of ichneumonid parasites were responsible for most of the larval parasitism recorded. . . . Density of early-instar larvae declined more sharply in heavy than in light population areas, which suggests that larval survival was partially density-dependent."
Outbreaks - 4

188. Mathers, W. G. 1949. Douglas-fir tussock moth. Can. Dep. Agric. For. Insect Invest. Bi-Mon. Prog. Rep. 5:4.

In previously recorded outbreaks of the Douglas-fir tussock moth in British Columbia, heavily infested areas seldom exceeded 1,000 acres. In the 1948 outbreak in the Kamloops Forest District, infested areas of 2,500-3,000 acres were found. Field surveys of larvae and cocoons indicated a sharp population decline with heavy larval mortality from disease and parasitism. Dipterous and hymenopterous parasites were numerous in heavily infested areas. Most commonly observed Hymenoptera were Hyposoter spp. and Pimpla pedalis. Very few egg masses were found in the November 1948 survey. A continued Douglas-fir tussock moth outbreak in 1949 is not deemed likely.
Biology - 3; Outbreaks - 2

189. Meyer, H., and R. Lyon. 1966. Instar observations of the Douglas-fir tussock moth. 10 p. Unpubl. (On file: Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.)

Variations in number and length of larval instars in the Douglas-fir tussock moth were studied in the laboratory. Measurements were made of head-capsule width and larval length. Range of the

head-capsule widths overlapped in the 4th-6th instars, preventing the use of this character to detect instars. Little could be concluded from the measurements of larval length. The larval growth pattern was erratic. The time spent in a given instar varied, as did the number of instars (5-7). Long periods of growth in the 6th instar were observed. All larvae maturing to adults after seven instars were female, and 70% of the five-instar larvae were males.
Biology - 1

190. Migunda, J. 1970. Charops sp. (Hymenoptera: Ichneumonidae) a larval parasite of Orgyia mixta Snell. E. Afr. Agric. For. J. 36(2):231-233.

Investigations of the African tussock moth, Orgyia mixta Snell. in a Pinus radiata D. Don plantation in Kenya, revealed an abundance of larvae parasitized by the ichneumonid, Charops sp. Field-collected larvae reared in the laboratory were 100% parasitized in the 4th-6th instars, 50% parasitized in the 3rd instar, and virtually without parasites in the 1st and 2nd instars. Larvae are parasitized in the late stages of the 3rd instar, and mature parasite larvae emerge from the 5th or 6th instar of the host leaving behind the empty larval skin of the moth. Larval Charops sp. then attach to a support, spin a cocoon, and pupate. Duration of the egg-to-larval stage is about 3 weeks, and the pupal stage about 13 days. Adult longevity ranges from 3-4 days. Hyperparasitism by a chalcid Brachymeria sp. was common in the field but nonexistent in the laboratory.
Related Material - 3

191. Mills, J. 1974. Forest management: NACA discusses the tussock moth and gypsy moths and DDT. Nat. Pest Control Oper. News 34(8):18-19.

The controversy concerning the control of the Douglas-fir tussock moth by DDT is discussed. The life cycle of the moth, its method of dispersion, the effects of population outbreaks on host trees, the safety and health hazards posed both by the insect and its defoliating activity, and the estimated acreage affected and timber lost are outlined. Public opinion polls on control of the current outbreak in Idaho, Oregon, and

Washington, show strong support for the use of DDT. The reasons behind the EPA's decision to grant an emergency authorization for the use of DDT are briefly detailed. The emphasis is on problems encountered in making forest management decisions.
Control - 4

192. Morris, O. N. 1963. A nuclear polyhedrosis of Orgyia pseudotsugata: causative agent and histopathology. Can. J. Microbiol. 9(6):899-900.

This paper presents the results of a study on the causative agent and histopathology of the virus disease that affects field populations of the Douglas-fir tussock moth. The causative agent is a nuclear polyhedrosis virus with an average diameter of 1.5 μm. Early 4th-instar larvae were fed 10^8 polyhedra, and the histopathology of the disease followed in a series of larvae examined every 48 hr. The course of the infection is similar to nuclear polyhedrosis infections in other Lepidoptera. Within 4 days, the fat body cells exhibited an increase in nuclear size and coagulation of nuclear chromatin. On the 6th day, polyhedral bodies appeared in the fat body, hypodermis, and trachea. The host died on the 8th day. Breakdown of fat body, hypodermis, and tracheal matrix occurred. Blood cells and the nervous system were heavily infected.
Biology - 5

193. Morris, O. N. 1963. Pathogenicity of three commercial preparations of Bacillus thuringiensis Berliner for some forest insects. J. Insect Pathol. 5(3):361-367.

Three commercial preparations of Bacillus thuringiensis Berliner (Biotrol®, Thuricide, and Bakthane® L69) were laboratory tested against larvae of five forest insects. Because crystalline inclusions have a more immediate toxic effect than spores, a method for approximating the ratio of spores to crystals in commercially prepared B.t. is presented. Larvae used in the tests were all field-collected 3rd and 4th instars. "All three preparations demonstrated high pathogenicity for the satin moth, Stilpnotia salicis (Linnaeus), moderate pathogenicity for the

western oak looper, Lambdina fiscellaria somniara (Hulst.), and relatively low pathogenicity for the western hemlock looper, Lambdina fiscellaria lugubrosa (Hulst.), and the western tent caterpillar, Malocosoma pluviale (Dyar)." Biotrol was moderately pathogenic for Orgyia pseudotsugata, the Douglas-fir tussock moth, but Bakthane L69 and Thuricide showed low pathogenicity. "Fifty % mortality occurred in 3-4 days for S. salicis and in 6-7 days for the remainder, except for M. pluviale, in which case this figure was not reached even after 7 days."
Control - 5

194. Morris. O. N. 1963. Pathogens recovered from forest insects in British Columbia, 1947-1963. Can. Dep. For. Interim Res. Rep. 25 p. For. Entomol. and Pathol. Lab., Victoria, B.C. Unpubl.

A list of the pathogens recovered from forest insects in British Columbia between 1947 and 1963, compiled from the records accumulated by the late S. M. Sager, D. A. Fetherstonhaugh, and O. N. Morris. Identification of fungi was confirmed by the staff of the Insect Pathology Research Institute, Sault St. Marie, Ontario. About 11,000 insect specimens, representing 159 species, were examined for pathogens. Table 1 lists the pathogens, hosts, location, and year of collection. Table 2 lists the number of insects examined and the number found infected with one or more pathogens.
Related Material - 3

195. Morris, O. N. 1963. The natural and artificial control of the Douglas-fir tussock moth, Orgyia pseudotsugata (McDunnough), by a nuclear polyhedrosis virus. J. Insect. Pathol. 5(4):401-414.

"Field populations of the Douglas-fir tussock moth . . . in the interior of British Columbia, Canada, are infected with a nuclear polyhedrosis virus. Eighty-eight to 100% of the laboratory reared 3rd-instar larvae died from the virus when larvae were fed Douglas-fir foliage . . . dipped in a suspension containing 10^7 to 10^9 polyhedra/ml.

"In field studies, a high incidence of the disease was present in young larvae and this increased to 100% in samples of late-instar larvae. Although many parasites are known to attack the tussock moth, control by these agents in the present study appeared negligible, as was control by disease organisms other than the virus. A high incidence of advanced virus infection in the early instars suggested that a certain proportion may have been infected by the transovum transmission of the virus. Indications are that factors, other than density-dependent ones, were operative in this epizootic. The number of cocoons found at the end of the season was extremely low. There is good evidence to suggest that the virus is the main cause for the population collapse frequently observed in this species.

"Results of artificial dissemination of a virus suspension show that storage of virus material in the wet state for 7 years reduced the virulence of the virus for field application. Fresh virus material, sprayed as a suspension containing 107 polyhedra/ml of 1.0% Lovo, produced 90% mortality in recovered larvae."
Biology - 5; Control - 6

196. Morris, O. N. 1970. Precocious development of adult characteristics in virus infected Lepidoptera. J. Invertebr. Pathol. 16(2):173-179.

Precocious development of antennae, mouthparts, adult-type forelegs, and partial fusing of ocelli were recorded in Douglas-fir tussock moth and oak looper larvae infected by nuclear polyhedrosis virus. Larvae were laboratory reared from field-collected eggs and infected in the 4th instar. The larvae ceased feeding after the teratological alterations appeared and death occurred about a week later. "During the progressive stages of pathogenesis, the amount of aldehyde-fuchsin-stainable neurosecretory products decreased in the larval brain, but increased in the corpora allata." There may have been a direct or indirect inhibition of the corpora allata by the virus, which prevented the production and release of enough juvenile hormone for maintenance of the larval state.

The study suggests "that virus infections in insect populations may affect the hormone balance and timing of hormone activity, resulting in prothetelic conditions, cessation of feeding, and death."
Biology - 5

197. Morris, O. N. 1972. Susceptibility of some forest insects to mixtures of commercial Bacillus thuringiensis and chemical insecticides, and sensitivity of the pathogen to the insecticides. Can. Entomol. 104(9):1419-1425.

"Experiments were designed to determine the effects of low doses of some insecticides on the viability and physiological characteristics of commercial Bacillus thuringiensis (Berliner) as a prelude to studies on the susceptibility of lepidopterous forest defoliators to mixtures of bacteria and insecticides." Insecticides used were: pyrethrum, malathion, phosphamidon, Zectran, and Butacide®. "The results show that the insecticides tested had no effect on viability or physiological integrity of the bacteria."

Combinations of bacteria and insecticides at various concentrations and formulations were tested on field-collected larvae of Halisidota argentata, Malacosoma disstria, Hyphantria cunea, and Orgyia pseudotsugata. "Bacteria-insecticide combination effects varied from strongly antagonistic to strongly supplemental, depending on insecticide or Thuricide formulations and concentrations and on the relative susceptibility of the test species to either agent applied separately. . . . Among O. pseudotsugata, malathion at 10^{-5} and pyrethrum at 10^{-3} dilutions were weakly supplemental to B.t. used at 10^{-3} dilution. All other insecticide treatments appeared to be subadditive or antagonistic. In general, combination effects were more often supplemental at the higher B.t. concentration."

Treatment with B.t. generally produced a drastic reduction in feeding activity and a further reduction was evident among larvae treated with B.t. and chemical insecticide compared with controls.
Control - 1, 5

198. Morris, O. N. 1973. Dosage-mortality studies with commercial Bacillus thuringiensis sprayed in a modified Potter's tower against some forest insects. J. Invertebr. Pathol. 22(1):108-114.

"Dosage mortality tests were carried out with commercial Bacillus thuringiensis (B.t.) (Dipel) against various instars of the spruce budworm, Choristoneura fumiferana, the white-marked and Douglas-fir tussock moths, Hemerocampa leucostigma and Orgyia pseudotsugata, and the gypsy moth, Porthetria dispar. Dipel was applied as a dilute (10^{-2}) molasses suspension onto artificial diet surface in a spray tower designed to simulate aerial application. Probit analysis of the results showed that LD_{50}'s expressed both in terms of gallons deposited per acre and as spores and crystals deposited per cm^2, increased with larval age for all species. The spruce budworm was the most sensitive to the bacteria, followed in decreasing order of sensitivity by the white-marked tussock moth, Douglas-fir tussock moth, and the gypsy moth. The mean slopes for all instars of the four species were 1.6, 3.1, 2.6, and 2.2 respectively, indicating that the assay of B.t. on artificial medium was good. The relatively low slope for spruce budworm is explained by its peculiar feeding habits. Among all species tested, bacteria-treated larvae gained weight at a considerably reduced rate compared with untreated ones. Reduction in weight resulting from lowered feeding activity intensified as dosage rates increased. The implication of this in terms of mortality assessments in microbial control operations is discussed.

"It is suggested that 0.02 gal ($4x10^6$ International Units) of Dipel Molasses deposited per acre may achieve economic control of 4th-6th instar budworm and 1st-2nd instar gypsy moths. A deposit rate for 2nd-5th instar white-marked and Douglas-fir tussock moths appeared to be in the vicinity of 0.01 gal ($2x10^6$ IU) per acre."
Control - 5; Related Material - 3

199. Morris, O. N. 1975. Susceptibility of the spruce budworm, Choristoneura fumiferana, and the white-marked tussock moth, Orgyia leucostigma, to Bacillus thuringiensis: chemical insecticide combinations. J. Invertebr. Pathol. 26(2):193-198.

"Bacillus thuringiensis mixed with the organophosphate insecticides, fenitrothion (Sumithion®), Gardona®, and Orthene, or the synthetic pyrethroid, SBP 1382, was incorporated into synthetic diet and fed larvae of the spruce budworm, Choristoneura fumiferana, and the white-marked tussock moth, Orgyia leucostigma." All larvae were disease-free, 4th-instar reared in the laboratory. "Mortality was highest when larvae were fed combinations of low concentrations of the insecticides and low to moderate concentrations of the pathogen. The data indicated that applications of a B.t. dosage expected to produce about 45% mortality of the 3rd- and 4th-instar larvae of the spruce budworm combined with a dosage of fenitrothion causing about 40% mortality or a dosage of Orthene causing from 5-25% mortality should result in low budworm survival. With a B.t. dosage causing 20-60% mortality combined with a fenitrothion dosage causing 15-50% mortality or a sublethal dosage of Gardona, a low survival rate of young white-marked tussock moth larvae may be expected." No additive effect appeared for the B.t. - pyrethrum (SBP 1382) combination for either species of moth.
Related Material - 3

200. Mounts, J. 1976. 1974 Douglas-fir tussock moth control project. J. For. 74(2):82-86.

"In June and July of 1974, 427,000 acres of Douglas-fir and grand fir timberlands in Oregon, Washington, and Idaho were treated with DDT to control the Douglas-fir tussock moth. This was the largest all-helicopter forest spray project ever carried out in the United States and required cooperation by many State and Federal agencies, universities, and private landowners. Almost total insect mortality occurred immediately after treatments were applied. Defoliation ceased almost completely, and a high proportion of foliage was saved." The development of the outbreak, the planning and application of control measures, the effects on timber, and the impact on wildlife are described.
Control - 2

201. Mounts, J., D. McComb, S. W. Meso, L. F. Kline, and G. C. Trostle. 1973. Cooperative tests of chemical insecticides for control of the Douglas-fir tussock moth - 1973. USDA For. Serv. Reg. 6, Portland, Oreg. 41 p. Unpubl.

Four insecticides were tested in the Blue Mountain (Oregon-Washington) Douglas-fir tussock moth outbreak in 1973, in an attempt to find a replacement for DDT. The chemicals tested were: Zectran, at two dosage rates; Dylox, at two dosage rates; Sevin; and BEM. Application was by helicopter.

Populations were surveyed before treatment to determine density levels, areas of infestation, and virus incidence. Each chemical was tested at four independent outbreak areas, with relatively high tussock moth populations. Populations were sampled repeatedly after treatment. Assessments of spray deposit, foliage retention, and effects on nontarget insects were made. Environmental monitoring covered water quality, small mammal populations, and aquatic populations. Individual insecticide tests are covered separately in the report as are operational procedures and personnel.

"Results of the tests were highly variable and somewhat inconclusive." Larval mortality with Zectran, Dylox, and Sevin was high but the amount of foliage saved was not satisfactory. BEM gave poor results on larval mortality, possibly from too low an application rate. Control - 1

202. National Forest Products Association. 1973. The tussock moth epidemic: Why chemicals are needed to control forest pests. Natl. For. Prod. Assoc., Washington, D.C. 6 p. (Insert to Oct. 26, 1976, Newsletter.)

The background is given of a tussock moth outbreak in progress in the Northwest during 1973. Arguments in favor of the use of DDT to control the epidemic are presented. These include the inability of any

other control practice to check the epidemic, the proved effectiveness of DDT against the tussock moth, and the danger of fire hazard from dead trees and a possible 30-60 year setback in the forest management of the region if the epidemic is left uncontrolled.
Control - 4

203. Neisess, J., G. P. Markin, and R. Schaefer. 1976. Field evaluations of acephate and Dimilin against the Douglas-fir tussock moth. J. Econ. Entomol. 69(6):783-786.

"Efficacy of acephate at 1.0 and 0.5 lb AI/2 gal per acre against Orgyia pseudotsugata (McDunnough) was compared to DDT at 0.75 lb AI/gal per acre on replicated 20-acre plots in 1974. Acephate at 1.0 lb AI/gal per acre and Dimilin [1-(4-chlorophenyl)-3-(2,6-difluorobenzoyl) urea] at 0.25 lb AI/gal per acre were evaluated on replicated 150-acre plots in 1975. In both experiments, all treatments caused significant reduction in larval populations. In 1974, the 1.0 lb acephate treatment resulted in population reductions that were comparable to the DDT treatment; however, the larval knockdown was faster for DDT. Both acephate and Dimilin provided excellent population control and foliage protection in 1975."
Control - 1, 2

204. Neisess, J., and M. J. Stelzer. 1975. Tests of microbial insecticides. West. For. and Conserv. Assoc., Perm. Assoc. Comm. Proc. 1974:15-16, Portland, Oreg.

Various formulations of a nucleopolyhedrosis virus (NPV) and Dipel, a commercial Bacillus thuringiensis were evaluated in 1973, against the Douglas-fir tussock moth. In the 1974 field season, a followup evaluation of the 1973 test was made to determine long-term effectiveness, and to investigate further new B.t. formulations and application strategies. The effectiveness of these tests is reported.
Control - 5, 6

205. Northwest Forest Pest ACTION Council and the College of Forestry, University of Washington. 1960. Douglas-fir tussock moth, Hemerocampa pseudotsugata McD. (Manual for) Forest Pest Short Course, March 23-25, 1960. Northwest For. Pest ACTION Council and Coll. For., Univ. Wash., Seattle. 3 p.

A description of the life cycle, physical characteristics, damage, and control of the Douglas-fir tussock moth is outlined.
General Background

206. Odera, J. A. 1972. A defoliator of pines, Orgyia hopkinsi (Lepidoptera: Lymantriidae) in Turbo, Kenya. Can. Entomol. 104(3):355-360.

"Sporadic outbreaks of many pine defoliators, including Orgyia hopkinsi Coll., have occurred in many pine plantations in Kenya in the last 20 years. A recent outbreak of O. hopkinsi is reported from young plantations in Turbo. Distribution, hosts, and epidemiology of the insect are discussed. The stages, life history, and habits are described. Eggs are laid on the bark close to pupation sites or on the pupal cases. The larvae feed on the foliage and pupate following the 5th instar." Migration occurs in the larval stage. Early instars are passively distributed by wind when they drop from trees by silken strands. Later instars actively migrate by crawling to nearby trees. The life cycle lasts 76-94 days with four generations per year. The generations overlap and larvae are present continuously. Two species of parasites, Pimpla mahalensis Grib. and Pimpla sp. (Hymenoptera: Ichneumonidae), have been recorded. Other factors of control are examined. A 2.5% solution of DDT is recommended for chemical control.
Related Material - 3

207. Ortiz, E., and J. Templado. 1975. Los cromosomas de cuatro especies de limantridos (Lep. Lymantriidae). [The chromosomes of four lymantriid species] EOS REV ESP Entomol. 49(1-4):225-232. [In Spanish.]

The results of a cytological study of four species of Lymantriidae, Orgyia trigotephras Boisd., Leucoma salicis L., Lymantria dispar L., and Euproctis chrysorrhoea L. are presented. The first and last species have not been studied before. All specimens are from central Spain. The geographical distribution, life cycle, and host of each species is briefly mentioned. The morphology and movement of chromosomes in mitosis and meiosis was studied in the larval, prepupal, and pupal stages in all four species. The chromosome numbers are as follows: O. trigotephras, n = 29; Leucoma salicis, n = 30; Lymantria dispar, n = 31; E. chrysorrhoea, n = 14. Although several species in the family Lymantriidae have been examined, the number is too small to make conclusive deductions on chromosomal variation in this group.
Related Material - 3

208. Page, M., and R. L. Lyon. 1973. Insecticides applied to western tussock moth reared on artificial diet: Laboratory tests. J. Econ. Entomol. 66(1):53-55.

"Eighteen insecticides were tested on 4th-instar larvae of Hemerocampa vetusta (Boisduval). Eleven insecticides were highly toxic; pyrethroids were the most toxic. Six other insecticides gave toxicity indexes between 48 and 68. Four were slightly more toxic than DDT. Two of the insecticides killed less than 50% of the test population at the highest dose tested, 1,000 µg/g body weight. Although the western tussock moth has been reported to have five larval stages, six were observed. Larvae that molted to the 6th instar were usually female."
Related Material - 3

209. Palmer, L. 1976. Tussock moth report. Pac. Search 10(7):15.

A brief report on the status of the Douglas-fir tussock moth as a pest and the background of the Expanded Douglas-fir Tussock Moth Research and Development Program is presented. Some of the preliminary results of the program's researchers are given.
Related Material - 2

210. Patterson, J. E. 1938. Moths invade play area. West. Trees, Parks and For. 1:7.

An account is given of a 1935-37 infestation of Oslar's tussock moth, Hemerocampa oslari Banner, near the Mammoth Lakes in California. White-fir and Jeffrey pine were heavily defoliated, but red fir in the same stand was not attacked. The population crashed in 1937 from wilt disease and heavy predation.
Related Material - 3

211. Percy, J. E., E. J. Gardiner, and J. Weatherston. 1971. Evidence for a sex pheromone in female Orgyia leucostigma (Lepidoptera: Lymantriidae). Can. Entomol. 103(5):706-712.

"The results of behavioral, chemical, and histological studies are reported showing the presence of a sex attractant in female Orgyia leucostigma J. E. Smith. A method of bioassaying the attractancy of the female moths by the use of 4-ft-long glass tubes is given. Extraction of female abdominal tips with dichloromethane yields material biologically active when tested on male O. leucostigma.

"The pheromone producing gland is a dorsally situated, crescent-shaped structure formed by modification of the epidermal cells in the intersegmental membrane between the eighth and ninth abdominal segments. The glandular cells are goblet-shaped and are arranged in an unusual manner."
Related Material - 3

212. Perkins, R. F., and R. E. Dolph, Jr. 1967. Operational and entomological report on 1965 Burns project for Douglas-fir tussock moth control. USDA For. Serv. Pac. Northwest Reg. Insect Dis. Control Branch, Portland, Oreg. 28 p. Unpubl.

"The 1964 cooperative forest aerial survey recorded over 41,000 acres of true fir and Douglas-fir defoliated by the Douglas-fir tussock moth on the Malheur and Ochoco National Forests." A biological evaluation indicated an increasing population and that biological agents were not sufficient to control it. A control project was begun with aerial application of DDT. Discussed in this report are the operational procedures, logistics, personnel and equipment, contract obligations, spraying procedure, and the mortality of the tussock moth. Maps of the spray area are included. The project was described as a success.
Control - 2

213. Perlman, F., E. Press, J. A. Googins, A. Malley, and H. Poarea. 1976. Tussockosis: reactions to Douglas-fir tussock moth. Ann. Allergy 36:302-307.

"An unusually heavy infestation of the tussock moth resulted in a high incidence of symptoms affecting the skin and mucous membranes of those exposed to high concentrations of particulate matter of this insect. Extensive epidemiological studies proved these manifestations to be both toxic and allergic. The authors have given this condition the name, Tussokosis. Clinical and immunological studies including in vitro procedures and direct patient testing confirmed the allerginicity, as well as the nonspecific irritation of material from this moth."
Related Material - 1

214. Pierce, J. R. 1964. Douglas-fir tussock moth infestations in northern California - 1964. USDA For. Serv. Reg. 5, San Francisco, Calif. Unpubl.

Report unavailable.
Outbreaks - 2

215. Pierce, J. R. 1970. Biological evaluation. Douglas-fir tussock moth infestations in California - 1970. USDA For. Serv. Pac. Southwest Reg., San Francisco, Calif. 13 p. Unpubl.

Douglas-fir tussock moth infestations were detected in four areas of California in 1970; the largest was 100,000 acres, and the remaining three were of minor importance. White fir was the preferred host, but some damage was done to other species in the same stands. Sequential sampling was used to evaluate the population based on egg mass numbers. Of the 159 points sampled, 40 were in the threatening or intermediate class, in the largest infested area. Pupal parasitism was about 81%. Two of the smaller areas had increasing populations. Further sampling is recommended to evaluate the need for control measures. Testing of new control chemicals is also needed.
Outbreaks - 2

216. Portland Metropolitan Environmental Education Council (Tussock Moth Education Committee). [n.d.] The tussock moth issue. Portland Metrop. Environ. Educ. Counc., 59 p.

This is a simulation game about the current tussock moth control issue, geared for secondary schools. The process in this study is a series of activities focusing on a current environmental issue or situation. It was developed because of the need to engage students in the study of current problems and issues relating to environment and resource use. The activities combine the elements of role playing with a simulated decisionmaking process or simulation game.
Control - 4

217. Prebble, M. L., and K. Graham. 1945. The current outbreak of defoliating insects in coast hemlock forests of British Columbia. Part I. Description of outbreak and damage. B. C. Lumberman 29(2):25-24, 42, 44, 46, 48.

Conspicuous defoliation was first noticed in the hemlock forests in 1940 and 1941, in small scattered areas in the southern part of the coast regions of British Columbia. By 1943, defoliation was noticeable throughout the hemlock stands of southwest Vancouver Island. Up to and including 1944, the black-headed budworm has been the most numerous, widespread, and destructive forest pest but three other defoliating insects, including the western rusty tussock moth, increased in abundance

in 1944. The life cycle, gross morphology, hosts, distribution, and damage are given for all four insects. These populations are thought to build up in place instead of spreading localized infestations.
Related Material - 3

218. Priesner, E. 1975. Electroantennogram responses to female sex pheromones in five genera of Lymantriidae (Lepidoptera). Z. Naturforsch. Sect. C. Biosci. 30(5):676-679.

"Sex pheromones of European species of Lymantria, Euproctis, Stilpnotia, Orgyia, and Dasychira (Lymantriidae) have been cross-checked by recording male electroantennogram (EAG) responses to excised female pheromone glands. Within the same genus, there was invariably full reciprocity of the gland effects. Between different genera, however, in all species combinations investigated, the males strongly preferred their own species. From this pattern, it is concluded that the major pheromone constituents are different for the five genera. In accordance with these results, several species of Lymantria are either known or supposed to produce the same sexual attractant, cis-7,8-epoxy-2-methyloctadecane (disparlure), whereas for one species of Orgyia the sex pheromone was recently identified (Smith et al., Science 188.63 [1975]) as cis-6-heneicosen-11-one. None of the additional lymantriid pheromones have yet been chemically defined. In EAG screening tests, some species of this family were specifically responsive to hydrocarbons related to cis-7,2-methyloctadecene, the olefinic precursor of disparlure."
Related Material - 3

219. Richards, W. C., and Y. Hayashi. 1970. Detection of natural infection by cytoplasmic polyhedrosis virus (CPV) occurring in midgut cells of the white-marked tussock moth larvae. J. Invertebr. Pathol. 16:280-281.

The paper reports on a radiotracer technique to detect natural infection by cytoplasmic polyhedrosis viruses (CPV) in insects. The experimental insects used were field-collected larvae of Orgyia leucostigma from a population in which virus infection was suspected.

Fifth-instar larvae were fed on a synthetic diet containing uridine-3H to label the RNA of any developing virons. The midguts were dissected, incubated at 0-4°C for 30 days, and the material for analysis isolated by the method for CPV purification. The radioactive profiles and absorbance at 260 nm of free, uridine-3H-labeled CPV virions (control) and of the isolated material were compared. The absorbance peak of the isolated material was lower than the control, but the radioactivity profiles were similar. This gives evidence for a natural infection of CPV in O. leucostigma that can be detected by this method.
Related Material - 3

220. Riotte, J. C. E. 1967. Anmerkungen zur Nomenklatur einiger europäischer und nordamerikanischer Arten der Gattung Orgyia (Lepidoptera, Lymantriidae). [Remarks about the nomenclature of several European and North American species of the genus Orgyia (Lepidoptera, Lymantriidae).] Dtsch. Entomol. Z. 14(1/2):163-168. [In German.]

"The correct application of the specific names antiqua and recens in the lymantriid genus Orgyia is discussed. This was necessary because of frequent, recent confusion regarding the two species. The 'scarce vapourer' is Orgyia recens Hubner and the 'vapourer' is Orgyia antiqua Linnaeus as shown by Lempke (1950).

"The North American species of the genus Orgyia were separated into two genera first by Dyar (1897). The new genus, Hemerocampa, was erected on the basis that species were to be assigned to the genus if two pairs of spurs were present on the hind tibia. However, Dyar himself (1902) violated this system by incorrectly separating the species concerned into their respective genera. Thereafter no distinction has been made between Orgyia and Hemerocampa. Bryk (1934), Schauss In Seitz (1940), and McDunnough (1921 and 1938) treated all species concerned as Hemerocampa, except antiqua. Schauss made the additional error of saying that Hemerocampa had only one pair of spurs on the hind tibia, the opposite condition to Dyar's proposal, and thereby further confused the matter. Forbes (1948) seems to have arrived at a satisfactory solution to the problem by placing those species with two pairs of spurs on the hind

tibia in the subgenus Hemerocampa of the all-comprising genus Orgyia. The author is in agreement with this view.

"Here, dorsal tufts on the adult moths are used for the first time as a further criterion in assigning the species of Orgyia to the appropriate subgenus. The male genitalia are homogenous in both subgenera."
Related Material - 3

221. Roberts, P. H., and J. C. Evendon. 1949. Controlling the tussock moth. In Trees, USDA Yearbook of Agriculture 1949. p. 436-442. Washington, D.C.

The details of the control project initiated against the 1946-47 Douglas-fir tussock moth outbreak near Moscow, Idaho, are outlined. Included is a description of the life cycle, economic stage, and method of dissemination of the insect. The USDA Forest Service and the Bureau of Entomology and Plant Quarantine joint survey in late 1946 reported a present infestation of 350,000 acres and a potential loss of more than 100 million dollars if not controlled. Aerial application of DDT between May 20 and June 30, 1947, was recommended. The control project, administered by the USDA, included numerous government and private agencies. A total of 413,409 acres in Idaho and Washington were sprayed between May 22 and July 2, 1947. No live larvae were found in the treated area 1 week after spraying. Monitoring of the environmental impact of the DDT application by the Fish and Wildlife Service revealed no serious effects on birds, mammals, or fish, but a marked reduction in fish-food organisms occurred.
Control - 2

222. Robertson, J. L., L. M. Boetler, R. M. Russell, and N. E. Savin. 1978. Variation in response to insecticides by Douglas-fir tussock moth, Orgyia pseudotsugata (Lepidoptera: Lymantriidae), populations. Can. Entomol. 110(3):325-328.

"Selected insecticides were topically applied to different populations of the Douglas-fir tussock moth, Orgyia pseudotsugata (McDunnough). For each insecticide, the hypothesis of equal response curves was rejected by the likelihood ratio test. Even for two successive generations of the same populations, the hypothesis of equality was not accepted for some insecticides. Chemical control programs directed at different populations of this insect may be adversely affected by such variations."
Control - 1

223. Robertson, J. L., and R. L. Lyon. 1973. Douglas-fir tussock moth: contact toxicity of 20 insecticides applied to the larvae. J. Econ. Entomol. 66(6):1255-1257.

"Twenty chemicals were tested for their toxicity to 4th-instars of Hemerocampa pseudotsugata McDunnough. Eleven were more toxic than the standard mexacarbate, at both LD_{50} and LD_{90}." They are listed in decreasing order of toxicity at both LD_{50} and LD_{90}. "Data were also obtained on the effect of posttreatment holding conditions and on the effect of dye tracers and stabilizing adjuvants on the insecticidal activity of pyrethrins." Dyes and stabilizers do not affect the insecticidal activity of the pyrethrins used.
Control - 1

224. Roettgering, B. H. 1971. Biological evaluation. The Douglas-fir tussock moth in California - 1971. USDA For. Serv., San Francisco, Calif. 19 p. Unpubl.

In 1970, populations of the Douglas-fir tussock moth were detected in four separate stands of white fir in the Cascade and Sierra Nevada Mountain ranges. Evaluation of the infestations showed they would persist and in some locations increase in population in 1971.

In July 1971, a ground survey for early instar tussock moth larvae was conducted in fifteen areas with a history of Douglas-fir tussock moth activity, to detect incipient infestations. The survey employed Mason's

(1969) sequential sampling technique and a beating cloth technique to determine the presence or absence of the moth. Aside from the four infestations discovered in 1970, no unknown infestation with outbreak potential was detected.

Shortly after the 1971 survey, severe defoliation was detected on a total of 3,800 acres of white fir in two areas, and incipient infestations were discovered in three additional areas. Of the 11 population centers that formed in 1971, only two were found as part of the organized detection survey. All of the remaining were found by foresters and woods workers in conjunction with their work activities.

The 11 centers were surveyed in October-November of 1971. Egg masses were collected and sent to the USDA Forest Service laboratory at Corvallis, Oregon, for virus and egg viability reports. A resume of the information available on the classification of the Douglas-fir tussock moth populations in each of the 11 infested areas is given. The report makes several recommendations for further statewide surveys of tussock moth populations.
Outbreaks - 2

225. Roettgering, B. H. 1972. The Douglas-fir tussock moth in California - 1972. USDA For. Serv., San Francisco, Calif. 5 p. Unpubl.

This is a report on the continuation of the 1971 Douglas-fir tussock moth detection and population trend survey conducted in the white fir belt of the Cascade and Sierra Nevada Mountain Range in California. The 1972 survey season began in June and ended in September. Nine areas of infestation where the moth had caused noticeable damage were detected. Color aerial photographs of the infestations were taken in October to help evaluate the extent of the damage. Four areas were visited in November to survey overwintered egg masses and the extent of defoliation. Egg masses collected from these areas were sent to the Forestry Sciences Laboratory in Corvallis for disease diagnosis. Three maps detailing the position of the infestation area are appended.
Outbreaks - 2

226. Rohrmann, G. F. 1977. Characterization of N-polyhedrin of two baculovirus strains pathogenic for Orgyia pseudotsugata. Biochemistry 16(8):1631-1634.

"N-polyhedrin of inclusion bodies of two nucleopolyhedrosis viruses of Orgyia pseudotsugata were characterized. Alkali-dissolved N-polyhedrin from both virus strains was of similar size and consisted of a 12S molecule of 209,000 daltons. Eight subunits of about 26,000 daltons were found to form the 12S molecules. N-polyhedrin from both viruses showed two main antigens by immunodiffusion. The subunits appear to possess one antigen, and upon formulation of the 12S molecule, a new antigen is created. Both the subunit and 12S antigens from the two virus strains were shown to be antigenically related. The 12S molecule of both viruses also appears to possess a minor antigen unique to each virus."
Biology - 5

227. Rohrmann, G. F., and G. S. Beaudreau. 1977. Characterization of DNA from polyhedral inclusion bodies of the nucleopolyhedrosis single-rod virus pathogenic for Orgyia pseudotsugata. Virology 83(2):474-478.

"A nucleotide sequence complexity of $88.5X10^6$ was determined for the DNA of the nucleopolyhedrosis single-rod (unicapsid) virus of Orgyia pseudotsugata using optical renaturation. In addition the genome size was determined to be $85X10^6$ by comparison of EcoR1 restriction endonuclease fragments with markers of known size using agarose gel electrophoresis. A G+C concentration of 44% for the viral DNA was estimated from its melting properties and buoyant density in CsCl. Evidence from buoyant density in CsCl indicates that DNA which is occluded in the polyhedral matrix but not associated with virions is of viral origin."
Biology - 5

228. Rohrmann, G. F., J. W. Carnegie, M. E. Martignoni, and G. S. Beaudreau. 1977. Characterization of the genome of the nucleopolyhedrosis bundle virus pathogenic for Orgyia pseudotsugata. Virology 80(2):421-425.

"By reassociation kinetics the DNA from the nucleopolyhedrosis bundle virus of Orgyia pseudotsugata was found to have a nucleotide sequence complexity of approximately $86X10^6$ daltons using both optical renaturation and S_1 nuclease assay to follow the renaturation. The molecular weight of the viral DNA by sedimentation analyses was determined to be $96X10^6$. The viral DNA has a T_m as 76.9° which corresponds to a guanine plus cytosine base composition of 54%."
Biology - 5

229. Rohrmann, G. F., R. H. McParland, M. E. Martignoni, and G. S. Beaudreau. 1978. Genetic relatedness of two nucleopolyhedrosis viruses pathogenic for Orgyia pseudotsugata. Virology 84(1):213-217.

"DNA from two nucleopolyhedrosis viruses pathogenic for Orgyia pseudotsugata showed no common patterns when restriction endonuclease fragments of both DNAs were compared by agarose-gel electrophoresis. Furthermore, DNA-DNA hybridization indicated at most 1% homology between DNAs from the two viruses."
Biology - 5

230. Ross, D. A., and J. Arrand. 1968. Douglas-fir tussock moth in British Columbia. Can. Dep. For., Insect and Dis. Surv., For. Pest Leafl. 9, 3 p. For. Res. Lab., Victoria, B.C.

This is a fact sheet on the Douglas-fir tussock moth in British Columbia that includes a brief history of outbreaks, list of hosts, area of distribution, description of the insect, its life history, a description of the damage, and methods of control. Malathion, 25% wettable powder at 2 lbs/100 gal of water is the recommended chemical control.
General Background

231. Ross, S. A., and D. Evans. 1954. Annotated list of forest insects of British Columbia, Part I - Lasiocampidae, Saturniidae, Liparidae. Entomol. Soc. B. C. Proc. 51:40-43.

"This is the first in a series of annotated lists of insects collected or reared by personnel of the Forest Insect Survey in British Columbia since 1937. . . . Precise collection localities are noted only where less than five scattered locality records are listed for a given species; otherwise, broad distribution categories are used. . . . Brief descriptions, generally of the full-grown larvae are included in the annotated list where such stages are known to one or both of the writers." Hemerocampa pseudotsugata is listed, along with a larval description and a brief history of outbreaks in British Columbia.
Taxonomy

232. Rossmoore, H. W., L. Elder, and E. A. Hoffman. 1970. Susceptibility of larvae of Hemerocampa leucostigma to several varieties of crystalliferous bacteria. J. Invertebr. Pathol. 16(1):102-106.

"Twelve isolates belonging to six H-antigen serotypes were evaluated for their effectiveness against Hemerocampa leucostigma larvae. All except one, Bacillus finitimus var. finitimus, produced high levels of mortality in four days. In addition, we found no difference in susceptibility to Bacillus thuringiensis var. thuringiensis among 1st- through 5th-instar larvae."
Related Material - 3

233. Rossmoore, H. W., and E. A. Hoffman. 1971. The effect of ^{137}Cs radiation on growth, development, and mortality of the larvae of the tussock moth, Hemerocampa leucostigma. J. Invertebr. Pathol. 17(2):277-281.

"Larvae and pupae of Hemerocampa leucostigma were irradiated in a ^{137}Cs Radcell and observed for effects on growth, development, and mortality. Irradiated larvae were half of control weight 10 days postradiation." No differences appeared in head-capsule size. "Although pupae were extremely resistant, relatively low doses to larvae prevented emergence. LD_{100} of first instars was 30 kr, while that of third instars was 85 kr. No delay in median time to pupation was noted."
Related Material - 3

234. Rossmoore, H. W., and E. A. Hoffman. 1971. The effect of gamma radiation on larval resistance to Bacillus thuringiensis infection. J. Invertebr. Pathol. 17(2):282-283.

Some of the relations between radiation dose and the susceptibility of Hemerocampa leucostigma larvae to Bacillus thuringiensis infection are examined. Various combinations of radiation and spore-crystal dosages, route of administration, and variety of pathogen were used. No effect of radiation on susceptibility to B.t. was discerned. When postradiation time for bacteria infection was extended to 10 days, however, resistance to B.t. infection was depressed. Percent larval survival was 74.1 for the controls and 56.7 for the radiation-treated larvae.
Related Material - 3

235. Ruggles, A. G. 1917. The white marked tussock moth. Minn. Off. State Entomol. Circ. 42, 4 p. St. Paul, Minn.

The circular describes the white-marked tussock moth, Hemerocampa leucostigma, its life history, natural factors controlling its population, and a method of mechanical control by the physical removal of overwintering egg masses. The insect is cited as primarily a pest of shade trees.
Related Material - 3

236. Sager, S. M. 1958. Studies on the epizootiology of a virus disease in the Douglas-fir tussock moth, (Hemerocampa pseudotsugata McD.). Interim Rep. Can. Dep. Agric., For. Biol. Div., For. Biol. Lab., Victoria, B.C. 27 p. Unpubl.

"The larval tussock moth population at Cascade, B.C., during the summer of 1955, appeared to be in an advanced stage of a polyhedrosis virus epizootic. A relatively high evidence of the disease was present in the young larvae and increased to 100% in samples of late-instar larvae. Other disease organisms and parasites were found in negligible amounts, but birds or other predators may have been effective in helping to reduce the larval populations. A survey at the end of the season

showed the number of cocoons to be extremely low, and the prediction seemed reasonable that the 1956 tussock moth population would be negligible.

"A high incidence of advanced virus infections in the early-instar larvae suggested that a certain proportion may have been transovarially infected; a later increase in incidence of infection may have been the result of larva-to-larva transmission of the disease. Regions of the Cascade outbreak with comparatively high larval densities showed slightly higher rates of infection and mortality from the virus than did areas of lower density. . . .

"Virus inclusion bodies found associated with ants and parasites in the Cascade outbreak area gave some evidence that these insects may act as a means of dissemination of the virus.

"Small scale virus dissemination tests were attempted and the results indicated that increasing the concentration of virus spray increased larval mortality."
Biology - 5; Control - 6

237. Sager, S. M. 1960. On the transtadial transmission of insect viruses. J. Insect Pathol. 2(3):307-309.

Observations on seven species of Lepidoptera indicate that complete transtadial transmission of insect viruses does occur in their respective hosts. Nuclear polyhedrosis and granulosis viruses were studied. In Hemerocampa pseudotsugata, Orgyia antiqua, and Lambdina fiscellaria, polyhedral inclusions were found in every stage except the egg. In Hemerocampa, this was confirmed by infectivity tests.
Biology - 5; Related Material - 3

238. Schreuder, G. F. 1977. An approach to evaluating effects of alternative controls for Douglas-fir tussock moth. Bull. Entomol. Soc. Am. 23(3):178-179.

The socioeconomic impact of a variety of control strategies, ranging from no control to the use of chemical or microbial controls are being incorporated into a model. The model concentrates on the impacts on wood production, the hydrological system, wildlife and fish, recreational activities, and fire incidence.
Control - 11

239. Schroeder, J. E. 1973. The Douglas-fir tussock moth: An impact statement relating to private lands in northeastern Oregon. Oreg. State For. Dep., Salem, Oreg. 17 p. Unpubl.

"This statement describes the impact of the Douglas-fir tussock moth infestation in northeastern Oregon as it has affected the State and privately owned lands for which the Department of Forestry has statutory responsibility." The problem is discussed in terms of the economic and aesthetic losses resulting from tussock moth defoliation.
Outbreaks - 5

240. Scribner, W. A. 1965. Report of operations. Potlatch tussock moth control project, 1965. State of Idaho Coop. Board For., Off. State For., Boise, Idaho. 29 p. Unpubl.

The planning, organization, and operation of the Potlatch tussock moth control project of 1965 is described. DDT at 3/4 lb/acre was applied to 86,533 acres of forest. Environmental monitoring was undertaken by the Fish and Game Department. Mortality of larvae was high, and the project was considered successful. Recommendations for improvement of control projects of this type are included.
Control - 2, 3

241. Shea, K. R. 1975. Progress on integrated pest management: Douglas-fir tussock moth, gypsy moth, and southern pine beetle. Soc. Am. For. Proc. 1975 Natl. Conv., p. 218-223. Washington, D.C.

The creation of the Combined Forest Pest Research and Development Program, its organization and administration, and its objectives, status, and plans are outlined. The cooperative effort to develop pest management systems for the Douglas-fir tussock moth, the southern pine beetle, and the gypsy moth is planned for completion within 3-5 years at an estimated cost of $46.8 million.
Related Material - 2

242. Shea, P. J. 1977. Testing of chemical and microbial insecticides for safety . . . some techniques. Bull. Entomol. Soc. Am. 23(3):176-178.

The effects of chemical and microbial insecticides on nontarget organisms have been examined for Bacillus thuringiensis, the Douglas-fir tussock moth nucleopolyhedrosis virus, Dimilin, Orthene, and Sevin-4-oil. Both laboratory and field tests were conducted using a variety of animals. The impact on terrestrial and aquatic insects, mammals, and birds was monitored using several techniques. The results of the studies on microbial insecticides indicate that neither B.t. nor the tussock moth virus poses a threat to the environment. The results of the chemical studies are not completely analyzed as yet.
Control - 1, 5, 6

243. Shepard, R. F. 1976. Douglas-fir tussock moth: Review of 1975-76 field experiments, pilot trials and operational projects, Kamloops, B.C. West. For. Conserv. Assoc., p. 67, Perm. Comm. Proc., Portland, Oreg.

In 1975-76, the Douglas-fir tussock moth polyhedrosis virus, Bacillus thuringiensis, Orthene, and Dimilin were field tested against the Douglas-fir tussock moth in Kamloops, B.C. Orthene was the most effective in preservation of new foliage, but its short residual life made timing of application critical. Dimilin achieved a greater population reduction but less foliage protection. The virus was very effective in population control, reducing it to innocuous levels. B.t. neither sufficiently

reduced the population nor provided foliage protection. The environmental impact of these control agents on nontarget organisms was examined.
Control - 1, 5, 6

244. Silver, G. T. 1962. Province of British Columbia, forest insect survey. Annu. Rep. For. Insect Dis. Surv. 1961, p. 107-119, Can. Dep. For., For. Entomol. and Pathol. Branch, Ottawa, Ont. Unpubl.

Among the various insects discussed, the Douglas-fir tussock moth was infecting part of the Okanagan Valley, with moderate to severe defoliation at some places. "Infestations include single isolated trees, small open-grown stands around agricultural buildings, and compact stands of Douglas-fir up to 20 acres in extent." Egg counts indicate that severe defoliation might occur in some stands in 1962. Mortality from a polyhedrosis virus infection was discovered in several late-instar larvae and pupae, on each of the larger infestations.

The rusty tussock moth was reported as being numerous on Vancouver Island.
Outbreaks - 2

245. Silver, G. T., and D. A. Ross. 1963. Province of British Columbia, forest insect conditions. Annu. Rep. For. Insect Dis. Surv., 1962, p. 107-123, Can. Dep. For., For. Entomol. and Pathol. Branch, Ottawa, Ont. Unpubl.

"The Douglas-fir tussock moth epidemic continued for the second successive year in the North Okanagan and at Hedley." Experimental control was carried out with DDT or malathion. Virus was sprayed from the ground and reduced the population considerably.
Outbreaks - 2; Control - 1, 2, 6

246. Smith, F. W. 1977. The effects of Douglas-fir tussock moth defoliation on stand dynamics. M.S. thesis. Univ. Wash., Seattle. 50 p. Unpubl.

Unavailable.
Outbreaks - 5

247. Smith, R. G., G. E. Daterman, and G. D. Daves, Jr. 1975. Douglas-fir tussock moth: sex pheromone identification and synthesis. Science 188(4183):63-64.

"The sex pheromone of the Douglas-fir tussock moth, Orgyia pseudotsugata (McD.), has been isolated and identified as (Z)-6-heneicosen-11-one. This compound and its E isomer have been synthesized and are highly potent in laboratory bioassays and field trials." At certain concentrations, the synthetic Z isomer was preferred over the extracted compounds of tussock moth females.
Biology - 2

248. Smith, R. G., G. D. Daves, Jr., and G. E. Daterman. 1975. Synthesis of (Z)-6-heneicosen-11-one. Douglas-fir tussock moth sex attractant. J. Org. Chem. 40(11):1593-1595.

"The synthesis of (Z)-6-heneicosen-11-one, the principal component of the sex attractant of the Douglas-fir tussock moth and the corresponding E isomer are described. The stereochemistries of the products were determined by selective reductions of the common intermediate, 6-heneicosyn-11-ol. The lower limits of isomeric purity of the products, determined by gas chromatographic analysis of the corresponding epoxides, was greater than 97% and 98% for the Z and E isomers, respectively."
Biology - 2

249. Sorenson, R. 1973. Between the devil and DDT: A report on the current tussock moth infestation. Pac. Search 8(3):12-15.

An analysis is presented of the controversy concerning the use of DDT to control the Douglas-fir tussock moth outbreak of 1972-73 in the Pacific Northwest. The life history of the insect, biological control agents, the cyclic pattern of outbreaks, and the insect's capacity for destruction are briefly outlined. The history of the present infestation and the pros and cons of the EPA refusal to grant the USDA Forest Service request for emergency use of DDT are explored.
Control - 4

250. Sower, L. L., and G. E. Daterman. 1977. Evaluation of synthetic sex pheromone as a control agent for Douglas-fir tussock moths. Environ. Entomol. 6(6):889-892.

"Synthetic pheromone evaporated from controlled-release applicators substantially reduced the ability of male Douglas-fir tussock moth, Orgyia pseudotsugata (McDunnough), to locate females and mate in the field. Dosages of 0.05-5.0 mg/ha/day were tested; the 2 strongest treatments of 1.0 and 5.0 mg/ha/day were the most effective. The disruption effect was relatively greater with traps baited with live females than with traps baited with synthetic pheromone. Catches of males in traps increased with increased height of traps above the 1.5-m treatment level up to 18.3 m."
Biology - 2, Control - 10

251. Stairs, G. R. 1971. Use of viruses for microbial control of insects. In Microbial control of insects and mites, p. 97-124. H. D. Burges and N. W. Hussey, ed. Acad. Press, London and New York.

The host-virus relations and the use of viruses in both long-range and short-range pest control is discussed for several important pest species. A brief paragraph on the Douglas-fir tussock moth mentions the susceptibility of the larvae to a nucleopolyhedrosis virus. Attempts at testing NPV control of the tussock moth larvae were hampered by the presence of an epizootic in the test population. Sufficient information

was obtained to indicate that epizootics can be initiated in incipient outbreak populations.
Control - 6

252. Stark, R. W. 1973. Statement. Symposium on the status of knowledge on the Douglas-fir tussock moth. EPA, Nov. 16, 1973, p. 106-115, Seattle, Wash.

Although the Douglas-fir tussock moth is one of the most destructive defoliators in the Western United States, only 26 scientific papers have been written on it, and only 6 of these deal with basic research. The author concludes that the tussock moth should be given a higher research priority. Four areas of knowledge need extensive research; the impact of damage to the forest and economy, the population dynamics, regulatory tactics and strategies, and the development of an integrated pest management program. He believes a commitment from the USDA Forest Service and the EPA for a sustained research program is needed.
Related Material - 2

253. Steinhaus, E. A. 1951. Report on diagnosis of diseased insects, 1944-1950. Hilgardia 20(22):629-678.

This paper presents a general and summarized report on the diagnosis for 575 accessions of dead and diseased insects, plus 27 accessions of healthy insects examined for symbiotes, received at the Laboratory of Insect Pathology, Division of Biological Control, in Berkeley, California, between August 1, 1944, and December 31, 1950.

Several new species of viruses, bacteria, fungi, protozoa, and symbiotes are recorded. The findings of some small research projects include: observations of several new and previously recognized virus infections; results of an attempt to grow insect viruses in embryonated hen eggs; reisolation and redetermination of the bacterium responsible for widespread epizootics among grasshoppers; a reevaluation of the pathogenic effects of so-called Bacillus "C" for scale insects; new host and locality data for several important entomophagous fungi and protozoa;

and new records regarding certain intracellular and caecal symbiotes of insects.

The Douglas-fir tussock moth larvae sent from Troy, Oregon, suffered from polyhedral virus infection.
Biology - 5

254. Steinhaus, E. A., and G. A. Marsh. 1962. Report of diagnoses of diseased insects, 1951-1961. Hilgardia 33(9):349-490.

This report presents the findings of laboratory diagnoses of diseased insects during the period of January 1, 1951, to December 31, 1961. The diagnoses reported are brief statements as to the source of the diseased insect and the etiology of its disease. A new approach to diagnosis uses more precise procedures, more detailed forms for recording data, and a more efficient method of collecting data. Douglas-fir tussock moth larvae were found to have polyhedrosis virus in two out of five samples analyzed.
Biology - 5

255. Stelzer, M. J. 1972. Epizootiological investigation. Part IV. In Results of field experiments for controlling Douglas-fir tussock moth with aerial application of polyhedrosis virus and associated studies. USDA For. Serv. Prog. Rep., 8 p. Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg. Unpubl.

"An aerial application of the polyhedrosis virus of the Douglas-fir tussock moth was tested in 1971 on the Eldorado National Forest. The virus was applied by helicopter at a dosage of 100 billion polyhedra in 1 gal of a water-based formulation per acre. Two plots, each of about 40 acres in area, were sprayed.

"Periodic posttreatment evaluations showed only low levels of virus mortality, ranging from 2-12% of the larval population, resulted from the treatment. Inadequate spray coverage, improper timing, and inactivation

of the virus by ultraviolet radiation are postulated as the causes for the low rates of infection induced by the treatment.

"An assessment of surviving tussock moth population on the Eldorado National Forest is essential to determine whether or not the virus becomes established or provides effective control in 1972."
Control - 6

256. Stelzer, M., J. Neisess, J. C. Cunningham, and J. R. McPhee. 1977. Field evaluation of baculovirus stocks against Douglas-fir tussock moth in British Columbia. J. Econ. Entomol. 70(2):243-246.

"Aerial applications of three baculovirus stocks were tested against Orgyia pseudotsugata (McDunnough) in British Columbia in June 1975. A dosage of 100 billion polyhedra/acre, formulated in a molasses and a nonmolasses formulation and applied at 1 or 2 gal/acre, provided population control and excellent foliage protection. Larvae collected from the treated areas 5 days after spraying showed virus infection rates that ranged from 60-87%. With the exception of one treatment that was applied under extremely adverse meteorological conditions there were no significant differences between virus treatments. Population densities were reduced by more than 90% at 21 days posttreatment, and no evidence of survival to the pupal stage was found on the virus-treated areas."
Control - 6

257. Stelzer, M. J., J. Neisess, and C. G. Thompson. 1975. Aerial application of nucleopolyhedrosis virus and Bacillus thuringiensis against the Douglas-fir tussock moth. J. Econ. Entomol. 68(2):269-272.

"Efficacy of application of a nucleopolyhedrosis virus (NPV) and Dipel (Bacillus thuringiensis Berliner) against Orgyia pseudotsugata (McDunnough) was determined on replicated field plots of 20 acres in size. Population reductions exceeded 95% at 35 days on plots treated with NPV dosages of 100×10^9 and at 100×10^{10} polyhedra/acre in 2 gal/acre of 25% molasses formulation. Application of Dipel at 1 lb/acre in 25% molasses was as effective as the NPV. These treatments also

provided excellent foliage protection, with estimated defoliation below 25%. In contrast, Dipel formulated in Biofilm failed to reduce larval densities to a satisfactory level or to prevent severe defoliation."
Control - 5, 6

258. Stevens, R. E. 1957. Control of an infestation of the Douglas-fir tussock moth with DDT aerial spray. Calaveras and Tuolumne Counties, California. USDA For. Serv., Calif. For. and Range Exp. Stn., Berkeley, Calif. 13 p. Unpubl.

An aerial spray operation was implemented on July 31 and August 1 and 2, 1956, for control of the Douglas-fir tussock moth in Calaveras and Tuolumne Counties, California. Nearly 10,000 acres were sprayed with DDT in seven separate units. The infestation was closely monitored in 1955 to determine the need for control in 1956. "Postspray appraisals, based primarily on assessment of feeding damage and an intensive search for new egg masses, indicated that satisfactory control was achieved."
Control - 2

259. Strickler, G. S. 1975. DDT residue accumulation and decline in kidney fat of lambs grazing sprayed forest range. USDA For. Serv. Res. Note PNW-256, 6 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

"DDT residues in fat of weaner lambs grazing 1, 2, 6, 10, and 14 weeks (five treatment groups) in forests sprayed with DDT for Douglas-fir tussock moth control increased rapidly up to 2 weeks, then decreased. After removal of lambs to unsprayed feed for 14 to 22 weeks, fat residues declined, but only those in the 1- and 2-week treatments fell significantly below the 5 ppm tolerance level."
Control - 3

260. Strickler, G. S., and P. J. Edgerton. 1970. Monitoring DDT residues on forage plants following a forest insect control program. Pestic. Monit. J. 4(3):106-110.

"The amount of DDT reaching understory vegetation grazed by cattle, deer, and elk, and the DDT residues in herbage samples of sedge, lupine, and sagebrush were determined for one prespray and three postspray sampling dates up to 1 year following aerial application of DDT for forest insect control. The DDT was applied at the start of the livestock grazing period. Ground-level DDT dosage ranged from 3-78% of the designated 3/4 lb/acre rate. . . . Residue in species plot samples from the first two postspray dates were significantly related to ground-level dosage. Cycling of DDT was not indicated; a greater elk sedge residue 1 year after spraying was attributed to differences in sampling. Associated DDT residues in cattle and big game are briefly discussed."
Control - 3

261. Stoszek, K. J. 1977. Factors influencing tree and stand susceptibility to Douglas-fir tussock moth attack. Bull. Entomol. Soc. Am. 23(3):171-172.

A report on studies undertaken in 1972-74 to determine the probability that a given stand will suffer defoliation by the Douglas-fir tussock moth. Both ground and aerial survey procedures were used to assess the physiographic edaphic and phytoceonotic characteristics of the site; and the species composition, structure, and vigor of the stand. Preliminary results indicate that: stands on ridge tops and upper slopes have significantly higher defoliation; defoliation increased with tree age; and grand fir was more susceptible to defoliation than Douglas-fir. Several other factors, such as aspect, elevation, canopy structure, and number of stories also influence the probability of tussock moth defoliation.
Outbreaks - 5

262. Sugden, B. A. 1957. A brief history of outbreaks of Douglas-fir tussock moth, Hemerocampa pseudotsugata McD., in British Columbia. Entomol. Soc. B. C. Proc. 54:37-39.

Douglas-fir tussock moth outbreaks are listed and analyzed. Results of analysis indicate outbreaks have recurred at intervals in a limited part of B.C., mostly in open-grown stands of Douglas-fir. They build up quickly in a few suitable sites, last for a short period, and then collapse. In a few localities where an outbreak has never been recorded, a small population always persists.
Outbreaks - 1

263. Swaine, J. M. 1917-1918. The control of the white-marked tussock moth. Rep. Soc. Prot. Plants, 10 p. (On file: Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg.)

The white-marked tussock moth is a serious native defoliator of hardwoods in the Mountain Provinces of Canada. An outbreak was expected the summer of 1918 [after this report]. A description of the stages of the moth's life cycle, the life history, and type of injury of the moth is given. Preventive control, i.e., maintaining healthy trees, is listed as the primary means of controlling the white-marked tussock moth. The egg and larval stages are the best targets for applications of artificial control. Destruction of egg masses during dormant months is an effective control method, as is spraying the larvae with arsenate compounds. Banding the trees with tanglefoot will prevent reinfestation from any wandering larvae.
Related Material - 3

264. Swaine, J. M., and G. E. Sanders. 1918. The white-marked tussock moth and its control on shade trees and ornamental trees. Can. Dep. Agric. Entomol. Branch, Circ. 11, 12 p.

The white-marked tussock moth can be controlled by destroying the egg masses, either by removal or painting with creosote, and by spraying larvae with arsenate compounds and banding the trees with sticky tape to prevent larval migration. For control in orchards, a paste of lead arsenate or arsenate of lime is used. A description of the life stages and biology of the moth is included.
Related Material - 3

265. Tarrant, R. F., D. G. Moore, W. B. Bollen, and B. R. Loper. 1972. Pesticides in soil. DDT residues in forest floor and soil after aerial spraying, Oregon--1965-68. Pestic. Monit. J. 6(1):65-72.

"One month after aerial application of DDT (12 oz/acre) to an eastern Oregon forest, 3 oz/acre of DDT residues (DDT, its isomers and metabolites--DDD, DDE, p,p'-DDT, and o,p'-DDT) were detected in the forest floor; 3 years later, the DDT content had decreased by more than 50%, and had not leached into the surface mineral soil.

"At the time of spraying, water from two streams draining the sprayed area had a total DDT content of about 0.3 ppb. This low concentration decreased rapidly to levels below limits of analytical detection. No effect of the spraying was noted on soil microbial populations, nitrification rate, or amount of nitrate nitrogen in the soil.

"Of the 12 oz of DDT applied per acre, about 26% reached the ground surface initially; and over 36 months, about 6% more was brought to the ground in litterfall. Thus, approximately one-third of the sprayed chemical reached the forest floor. The need for more efficient aerial methods of chemical application is evident."
Control - 3

266. Teakle, R. E. 1973. A nuclear polyhedrosis virus of the painted apple moth (Orgyia anartoides (Walker)). Queensland J. Agric. Anim. Sci. 30(2):179-190.

"A disease of the painted apple moth (Orgyia anartoides (Walk.)) caused by a nuclear-polyhedrosis virus was investigated. The virus is described on the basis of its morphology and pathology and the influence of larval age and size of virus dosage on incubation period." In tests of cross-infectivity, viruses from O. anartoides and O. australis demonstrated identical serological reactions and reciprocal cross-infectivity.

"The nuclear polyhedrosis virus studied in the current work is a virulent pathogen. The habit of O. anartoides of depositing eggs in clumps and the gregarious tendency displayed by early instar larvae favors early cross-transmission of the virus." Larvae of early instars are more susceptible to the virus. Cross-transmission is favored by the lack of mobility of the wingless female adult. Thus the distribution of this insect is usually restricted to individual trees.
Related Material - 3

267. Templado, J. 1974. Biological observations on Orgyia trigotephras Biosd. (Lep., Lymantriidae). Bol. Estac. Cent. Ecol. 3(6):63-67.

Article unavailable.
Related Material - 3

268. Terrell, T. T. 1955. Douglas-fir tussock moth outbreak in northeastern Washington. Season of 1955. USDA For. Serv. Intermt. For. and Range Exp. Stn., Missoula, Mont. 3 p. Unpubl.

An infestation of the Douglas-fir tussock moth which had been moderately active for several years in northeastern Washington, developed into a serious outbreak in 1955. In September, 1955, an aerial survey was made of the infested Douglas-fir forests by the Missoula Forest Insect Laboratory. Stevens County contained the heaviest infestations, with small scattered spots of infestation in Spokane and Pend Oreille Counties. "Altogether, 87 separate areas of infestation, ranging from single infested trees to as much as 2,000 acres of tree defoliation, were mapped during the flights." The history of the infestation, and the methods used to survey damage are presented.
Outbreaks - 2

269. Thomas, J. W., and D. C. McClusky. 1974. Effects of aerial application of DDT for tussock moth control on nestling survival of mountain bluebirds and house wrens. USDA For. Serv. Res. Pap. PNW-185, 37 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

The EPA approval of the use of DDT against the Douglas-fir tussock moth in 1974 was contingent upon intensive environmental monitoring to determine the impact on nontarget organisms. The present study was undertaken to assess if DDT application had adverse, short-term effects on reproductive performances of insectivorous birds. The study was limited to cavity-nesting, insectivorous birds such as mountain bluebirds, western bluebirds, and house wrens.

Birds were encouraged to nest in specially constructed nest boxes in spray and nonspray areas. The boxes were checked at intervals from 2-21 days to determine: clutch size, condition of eggs; number of young hatched, their condition and approximate age; and number of young fledged. Reproductive success was measured by comparisons of mean number of eggs per clutch, egg fertility, nestling mortality, and number of young fledged between spray and nonspray areas.

DDT reaching the ground was monitored with oil-sensitive cards in the spray area only.

No detrimental, short-term effects on clutch size or nestling survival of the selected species of birds were detected by this study. Control - 3

270. Thompson, C. G. 1966. Tests to determine effectiveness of different virus dosages and concentrations. In Results of test to develop operational procedures for controlling Douglas-fir tussock moth with aerial application of polyhedral virus spray. USDA Agric. Res. Serv. and For. Serv., Portland, Oreg. 27 p. Unpubl.

"A simulated field test was conducted during the summer of 1965 to determine virus spray dosage and concentrations required for control of the Douglas-fir tussock moth. Specific objectives were to determine the effectiveness of three different virus polyhedra rates applied by helicopter in 1 gal and in 3 gal of spray per acre. The optimum timing of application was also investigated. Spray was applied by helicopter at

5-weekly intervals to potted trees, which were subsequently colonized with larvae to determine pathogenicity of the different treatments. . . .

"Applications of 1, 5, and 50 billion polyhedra in 1 gal/acre were as effective, or slightly better, than applications of the same virus rates in 3 gal/acre. The applications were more effective with increasing virus rate. Only the rate of 50 billion polyhedra per acre was sufficiently effective to indicate a satisfactory control potential. Applications were most effective against 2nd-instar larvae. Larvae from egg masses collected in northern California were apparently more susceptible to infection on Douglas-fir than on grand fir.

"Following an initial wave of polyhedrosis resulting directly from virus applications, waves of polyhedrosis occurred at about 2-week intervals. These latter waves were apparently due to natural contagion and spread of the disease from those dying as a direct result of the application."
Control - 6

271. Thompson, C. G. 1975. Comparison of environmental stresses between field and insectary populations. In Baculoviruses for insect pest control: Safety considerations, p. 158. M. D. Summers, R. Engler, L. A. Falcon, and P. V. Vail, eds. Am. Soc. Microbiol.

Two comments are offered concerning the use of virus for Douglas-fir tussock moth control. First, the amount of virus applied for control is minimal compared to the amount naturally produced by the larvae moth during an epizootic. Secondly, the stress on laboratory-reared insects is much less than the stress suffered by field populations. Thus the possible favoring of mutant virus strains from laboratory-stressed insects can be discounted.
Biology - 5; Control - 6

272. Thompson, C. G., J. Neisess, and H. O. Batzer. 1977. Field tests of Bacillus thuringiensis and aerial application strategies on western

mountainous terrain. USDA For. Serv. Res. Pap. PNW-230, 12 p. Pac. Northwest For. Range Exp. Stn., Portland, Oreg.

Control - 5, 8

273. Toliver, M. E. [n.d.] Bionomics of egg parasitoids of the Douglas-fir tussock moth in the Southwestern United States. Unpubl. Lit. Rev. Study Plan (On file: Rocky Mt. For. and Range Exp. Stn., Albuquerque, N.M. 34 p.

The primary objective of the study plan presented is the determination of the role of egg parasitism by Telenomus californicus and Baryscapus sp. in endemic and epidemic populations of the Douglas-fir tussock moth in the Southwest. The secondary objectives include: determination of egg parasites and other mortality factors acting on the Douglas-fir tussock moth in the Southwest, description of the life history of T. californicus and Baryscapus sp., determination of effects of egg mass exposure on parasitism, description of the parasite-parasite interactions, description of parasite-host interactions, and the determination of effects of Bacillus thuringiensis and nucleopolyhedrosis virus on T. californicus and Baryscapus sp.

The study plan contains a detailed literature review covering the Douglas-fir tussock moth life history, natural enemies, and history of outbreaks.

A research schedule and cost estimates are included.

Biology - 3

274. Torgersen, T. R. 1977. Identification of parasites of the Douglas-fir tussock moth, based on adults, cocoons and puparia. USDA For. Serv. Res. Pap. PNW-215, 28 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

"A key for the identification of egg, larval, and pupal parasites of the Douglas-fir tussock moth is supplied. Determinations are based on features of adult parasites, their cocoons, or puparia. Notes on additional diagnostic characters and biologies are also given."
Biology - 3

275. Tucker, R. K., and D. G. Crabtree. 1970. Handbook of toxicity of pesticides to wildlife. U.S. Resour. Publ. No. 84, p. 88-89.

The acute oral toxicity summary of the nucleopolyhedrosis virus of the Douglas-fir tussock moth is presented. LD_{50}s for mallard ducks, pheasants, house sparrows, albino rabbits, and mule deer are given.
Control - 6

276. Tunnock, S. 1962. Biological evaluations of three Douglas-fir tussock moth infestations in northern Idaho, 1961. USDA For. Serv., Div. State and Priv. For. Reg. 1, Missoula, Mont. 7 p. Unpubl.

Cocoon samples were collected from three infested sites in northern Idaho to determine the status of the infestation. Cocoons were examined for egg masses, adult emergence, and pupal mortality. High ratios of current egg masses to older masses in two areas indicated a probable population increase for 1962. Female moths were slightly more abundant than males in all three areas. Dipterous parasites were found inside pupae more frequently than hymenopterous parasites.
Outbreaks - 2

277. Tunnock, S. 1963. Douglas-fir tussock moth infestations in northern Idaho and northwestern Montana, 1963. USDA For. Serv., Div. State and Priv. For. Reg. 1, Missoula, Mont. 5 p. Unpubl.

In October 1963, biological evaluations of several Douglas-fir tussock moth infestation sites in Montana and Idaho were made to determine their growth potential for 1964. Cocoon samples were collected to determine: ratio of old to current egg masses, successful adult emergence, causes of pupal mortality, and percent and kind of

parasitization. The probable infestation trends for 1964, based on percentages of current egg masses and pupal mortality, are presented for each infestation site.
Outbreaks - 2

278. Tunnock, S. 1963. Trends of Douglas-fir tussock moth infestations in northern Idaho and Colbert, Washington, 1962. USDA For. Serv., Div. State and Priv. For. Reg. 1, Missoula, Mont. 7 p. Unpubl.

Aerial surveys of nine centers of Douglas-fir tussock moth infestation in northern Idaho and northeastern Washington were made in 1962 to determine the extent of defoliation. Biological evaluation of the tussock moth population intensity was made during October to determine the population trend for 1963. Cocoon samples were collected and examined for egg masses, adult emergence, and causes of pupal mortality. Dipterous parasites were found inside pupae more often than hymenopterous parasites.

Population trends for each area are listed individually, based on the percentage of current egg masses and on pupal mortality.
Outbreaks - 2

279. Tunnock, S. 1964. Status and trends of Douglas-fir tussock moth infestations in northern Idaho and northwestern Montana. USDA For. Serv., Div. State and Priv. For. Reg. 1, Missoula, Mont. 10 p. Unpubl.

Biological evaluations of the major Douglas-fir tussock moth outbreaks in Idaho and Montana were made during October 1964 to determine their status and trend in 1965. Cocoon samples were examined for percent of current to old egg masses and pupal mortality. The results are listed in tabular form for each infestation site.

A history of tussock moth outbreaks in the Northwest and a summary of the life history of the moth is included.
Outbreaks - 2

280. Tunnock, S. 1965. Evaluation of Douglas-fir tussock moth infestations in northern Idaho and northwestern Montana, 1965. USDA For. Serv., Div. State and Priv. For. Reg. 1, Missoula, Mont. 5 p. Unpubl.

"Douglas-fir tussock moths caused various degrees of defoliation during 1965 in 50 acres south of Polson, Montana; in three 10- to 40-acre areas south of Elmo, Montana; and within 225,000 acres in Benewah and Latah Counties, Idaho. These infestations were examined during October 1965 to determine the ratio of current egg masses to old and to evaluate the effects of natural mortality factors. No current egg masses were found in Montana and only a few were collected in Idaho. Observations showed that the infestations had died out. Factors responsible for this were nuclear polyhedrosis virus, parasites, and aerial applications of DDT in Idaho."
Outbreaks - 2

281. Tunnock, S. 1966. A pilot test to control Douglas-fir tussock moth by an aerial application of nuclear polyhedrosis virus during 1965. USDA For. Serv., Div. State and Priv. For., Reg. 1, Missoula, Mont. 17 p. Unpubl.

"The effectiveness of a nuclear polyhedrosis virus obtained from diseased Douglas-fir tussock moth larvae was tested during the summer of 1965. A helicopter was used to spray 1,220 acres at the rate of 1 billion polyhedra in 1 gal of water per acre when most larvae were 2nd instars. Larvae, collected before treatment and at weekly intervals after treatment, were reared on artificial media in plastic cups at an insectary until they died from polyhedrosis, were killed by other agents, or emerged as adults.

"Mortality from polyhedrosis was consistently higher in an untreated area than in a treated area. Therefore, the application of 1 billion polyhedra per acre did not significantly decrease the Douglas-fir tussock moth population. Mortality from other diseases, parasites, and unknown agents was not above 17.6% during any of the collection periods.

Hymenopterous and dipterous parasites caused most of this mortality. Five species of wasps killed 96.7% of the parasitized larvae.

"Some adult emergence occurred in each collection. However, many adults were malformed, which indicated that they may have been infected with virus. No current egg masses could be found in treated and untreated areas during the fall of 1965."
Control - 6

282. Tunnock, S. 1973. The Douglas-fir tussock moth in the northern region. A cartographic history of the outbreaks from 1928 to 1973. USDA For. Serv., Div. State and Priv. For., Missoula, Mont. Report 73-27, 18 p.

"The Douglas-fir tussock moth, Orgyia pseudotsugata (McD.), periodically defoliates Douglas-fir, true firs, and other host trees in forests of the United States. In the northern region, these infestations occur about once every decade.

"This history covers the earliest recorded outbreak in northeastern Washington from 1928 to 1930 and includes information about outbreaks in northern Idaho and eastern Washington from 1944 to 1947, northeastern Washington and northern Idaho from 1950 to 1955, northern Idaho and western Montana from 1961 to 1975, and the current outbreak in northern Idaho, northeastern Washington, and western Montana which began in 1970.

"These outbreaks usually last from 2-4 years in forested areas and typically go through a buildup phase the 1st year, an outbreak phase the 2nd year, and a declining phase the 3rd year due to parasites and/or polyhedrosis virus. Exceptions are: It may take an outbreak 2 years to build up, or occasionally natural control agents can cause a population collapse at the end of the 2nd year."
Outbreaks - 1

283. Tunnock, S. 1974. Impact of egg viability, egg parasitism and virus on 1974 Douglas-fir tussock moth defoliation potential in western Montana. USDA For. Serv. North. Reg. Insect and Dis. Rep. 74-11. 4 p. Div. State and Priv. For., Missoula, Mont.

"Douglas-fir tussock moth egg mass studies during winter 1974 indicate that natural factors such as low egg viability, egg parasitism, and virus do not alter the potential for heavy defoliation in two sections south of Frenchtown and one section northwest of Lolo, Montana." The percent virus infection was low from the egg masses and ranged from 1.0 to 5.3. More than 30% virus in an area is needed to classify it as a low risk from the standpoint of potential damage.
Outbreaks - 2

284. Tunnock, S. 1975. Impact of egg viability, egg parasitism, and virus on 1975 Douglas-fir tussock moth defoliation potential in the lower Flathead Valley, Montana. USDA For. Serv. North. Reg. For. Environ. Prot. Rep. 75-9, 7 p. Div. State and Priv. For., Missoula, Mont.

"Evaluation of Douglas-fir tussock moth, Orgyia pseudotsugata, egg masses collected from an outbreak area in the lower Flathead Valley indicated that overall egg viability was relatively high, egg parasitism was low, and virus infestation averaged 7.1% northwest of Polson, 17.9% south of St. Ignatius, and 57.0% west of Ravalli. In the three areas, a total of 2,240 acres may be visibly defoliated in 1975, and light defoliation may be scattered over an additional 5,600 acres. The outbreak is expected to decline due to natural causes by the end of 1975."
Outbreaks - 2

285. Tunnock, S., J. E. Dewey, S. Kohler, and S. Hagland. 1974. Evaluation of a Douglas-fir tussock moth outbreak in the lower Flathead Valley, Montana. USDA For. Serv. North. Reg. Insect and Dis. Rep. 74-24, 10 p. Div. State and Priv. For., Missoula, Mont.

"An aerial survey during 1974 revealed approximately 5,000 acres of various degrees of Douglas-fir tussock moth, Orgyia pseudotsugata McD., defoliation in the lower Flathead Valley. An egg mass survey was made in September to determine the potential for damage in 1975." The number of new egg masses/1,000 in^2 of foliage, the ratio of old to new egg masses, and the number of cocoons per egg mass were calculated. Plots containing 0.1 or more new egg masses/1,000 in^2 of foliage were considered "high risk", and control may be advisable. Based on the survey, significant defoliation was predicted on 2,880 acres.
Outbreaks - 2

286. Tunnock, S., J. E. Dewey, R. Lood, and R. L. Livingston. 1973. Status of Douglas-fir tussock moth infestations in the northern region, 1973. USDA For. Serv. North. Reg. Insect and Dis. Rep. 73-23a, 9 p. Div. State and Priv. For., Missoula, Mont.

Aerial surveys of Douglas-fir tussock moth infestation sites in Washington, Idaho, and Montana were conducted in July-August of 1973 to detect the extent of defoliation. The surveys revealed a total of 127,000 acres of aerially visible damage. Damage occurred in two separate patterns. Most of the outbreaks were characterized by partial defoliation of varying intensities occurring over entire hillsides or stands. The stands were predominately grand fir. The other type of infestation associated with pure stands of young Douglas-fir, was characterized by heavily defoliated clusters of trees (1/2-50 acres); some almost completely defoliated.

Maps of defoliated areas are included.
Outbreaks - 2

287. Tunnock, S., and R. L. Livingston. 1974. Potential Douglas-fir tussock moth damage in northern Idaho in 1974 based on a 1973 fall egg mass survey. USDA For. Serv. North. Reg. Insect and Dis. Rep. 74-4, 26 p. Div. State and Priv. For., Missoula, Mont.

"An epidemic of the Douglas-fir tussock moth was detected in northern Idaho in 1972. In 1973, aerial surveys showed that nearly 100,000 acres contained various degrees of visible defoliation. An egg mass survey of five reporting units made in the fall of 1973 determined potential for damage in 1974. Based on new egg mass densities and new-to-old egg mass ratios, damage is predicted to be sufficiently high to warrant control on 34,138 acres in the Coeur d'Alene unit, 64,779 acres in the St. Joe unit, 4,433 acres in the Clearwater unit, 4,762 acres in the Craigmont unit, and 33,501 acres in the NezPerce unit. Total acres qualifying for treatment are 141,613. In addition, some damage might occur on 81,554 acres within the five units. These areas will be further evaluated to determine if they qualify for treatment."
Outbreaks - 2

288. Tunnock, S., R. L. Livingston, and W. E. Bousfield. 1974. Impact of egg viability, egg parasitism, and virus on 1974 Douglas-fir tussock moth defoliation potential in northern Idaho. USDA For. Serv. North. Reg. Insect and Dis. Rep. 74-9, 10 p. Div. State and Priv. For., Missoula, Mont.

Egg masses collected fall 1973 in northern Idaho were studied to assess the effects of egg viability, egg parasitism, and virus infection on the defoliation potential of the area. Egg masses were stored overwinter and incubated in February; the surviving larvae were reared. Dead larvae were examined for virus polyhedra. The percent nonviable eggs ranged from 0.3-68.9, and egg parasitism ranged from 0-14.9% (two species of Hymenoptera were recovered). Virus incidence was generally low. The acreage to be treated for tussock moth control was adjusted according to the findings of this survey.
Outbreaks - 2

289. U.S. Department of Agriculture. Douglas-Fir Tussock Moth Program. 1975. Douglas-Fir Tussock Moth Newsletter.

The Douglas-Fir Tussock Moth Newsletter is a monthly publication covering the current activities of the program. It includes reports on program meetings, a calendar of events, progress reports on tussock moth research, reports on current research on other forest pests, lists of recent publications, and articles on program personnel.
Related Material - 2

290. U.S. Department of Agriculture, Agricultural Research Service and Forest Service. 1966. Results of tests to develop operational procedures for controlling Douglas-fir tussock moth with aerial application of polyhedral virus spray. USDA Agric. Res. Serv. and For. Serv., Portland, Oreg. Unpubl.

A four-part report on the cooperative tests in 1965 by the Agricultural Research Service and the Forest Service to develop operational procedures for application of water-based polyhedrosis virus sprays in Douglas-fir tussock moth control. Each part is abstracted separately and filed under the author. For abstracts, see the following authors: C. W. Getzendaner; C. G. Thompson; K. H. Wright and R. R. Mason; and V. D. Young.
Control - 6, 9

291. U.S. Department of Agriculture, Forest Service. 1966. Prospectus for a joint research administrative effort to develop and test a method for using a nuclear polyhedrosis virus against the Douglas-fir tussock moth. USDA For. Serv. Pac. Northwest For. and Range Exp. Stn. and Reg. 6, Portland, Oreg. 9 p. Unpubl.

The present prospectus is an expansion of a previous outline of steps for operational testing of the nuclear polyhedrosis virus into a proposal indicating the scope of the undertaking and estimating the funds, manpower, facilities, and time needed to carry out the project. "The proposal calls for combining regular research, survey, and control efforts and supplementing them with funds to speed operational testing of the nuclear polyhedrosis virus as a control agent." The test will be

conducted in 1967, or "as soon thereafter as a suitable area becomes available."
Control - 6

292. U.S. Department of Agriculture, Forest Service. 1971. Douglas-fir tussock moth in California forests 1970-1971. Calif. Reg. Pam.

A Douglas-fir tussock moth epidemic was reported in several locations in California in 1970. This publication discusses the history of past outbreaks, ecological factors leading to outbreaks, the life cycle and damage, and possible control methods.
General Background

293. U.S. Department of Agriculture, Forest Service. 1972. Results of field experiments for controlling Douglas-fir tussock moth with aerial application of polyhedrosis virus, and associated studies. USDA For. Serv., Prog. Rep. Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg. Unpubl.

This is a six-part report on the 1971 field test of nuclear polyhedrosis virus spray application for control of the Douglas-fir tussock moth. A stand of white fir in the Eldorado National Forest, California, served as the test site. Each report is abstracted separately. For abstracts see the following authors: D. L. Dahlston and R. F. Luck; B. Maksymiuk; M. E. Martignoni; R. R. Mason; R. D. Orchard; M. J. Stelzer; R. A. Waite; and B. E. Wickman.
Control - 6, 9

294. U.S. Department of Agriculture, Forest Service. 1973. Environmental statement, Douglas-fir tussock moth pest management plan, Oregon and Washington - 1973. USDA For. Serv. Pac. Northwest Reg., Portland, Oreg. 205 p. Unpubl.

"The USDA Forest Service proposed a pest management program for integrating natural biological control agents, silvicultural practices, and chemicals to minimize forest resource losses, particularly timber and

recreational values. This objective will be accomplished by: (1) harvest cutting of affected areas of commercial-size timber where serious tree damage has been and is expected to occur and where economic, environmental, and other factors warrant; (2) chemically treating affected high-use, high value recreational areas with Zectran on an operational test basis; (3) and reforestation of all affected areas where necessary." The proposed Zectran treatment will be at a dosage of 0.15 lb/acre in two aerial applications.

"The environmental impact of the proposed action and the alternatives are considered and evaluated." Plans for environmental monitoring are presented.

The appendices include an entomological evaluation of the pest population status in Oregon and Washington in 1972-73 and comments received on the tussock moth outbreak and possible control from interested persons and agencies.
Control - 1

295. U.S. Department of Agriculture, Forest Service. 1973. USDA-USDI Environmental Statement. Cooperative Douglas-fir tussock moth management plan. Idaho-Oregon-Washington. USDA For. Serv., Pac. Northwest Reg., Portland, Oreg. 301 p. Unpubl.

The USDA Forest Service proposed to treat chemically an estimated 650,000 acres of Douglas-fir tussock moth-infested forest land in Oregon, Washington, and Idaho in the spring of 1974. The environmental impact of the proposed DDT treatment is evaluated.

The statement covers: the appraisal of the forest situation, the biology of the Douglas-fir tussock moth, the history of destructive epidemics, proposed DDT control plan, the environmental monitoring plan, the impact on the environment of DDT application, the unavoidable adverse effects of DDT, the benefits of DDT use, the alternatives to control with DDT, and public response to the proposed DDT control project.

The appendices include: the entomological evaluation of the pest status in Oregon, Washington, and Idaho in 1973, the cost-benefit analysis, and the Pest Action Council's Resolution and problem analysis on the Douglas-fir tussock moth outbreak.
Control - 2, 3

296. U.S. Department of Agriculture, Forest Service. 1974. Douglas-fir tussock moth project - 1974. Oregon-Washington-Idaho. USDA For. Serv. Insect and Dis. Control, Reg. 6, Portland, Oreg. 18 p. Unpubl.

This report on the Douglas-fir Tussock Moth Control Program was submitted to the Environmental Protection Agency as required by the February 28, 1974, Order authorizing the emergency use of DDT for tussock moth control.

The location, quantity, times, and places of aerial application are included. A treatment summary for each Project Unit showing the date treated, the number of gallons applied, and the acres treated by numbered spray blocks is also included. A summary of the Dylox and Sevin-4-oil treatments is given. Accounts of insecticide accidents that occurred during the operation are included.
Control - 1, 2

297. U.S. Department of Agriculture, Forest Service. 1974. Environmental Analysis. Douglas-fir tussock moth, microbial insecticide pilot tests. USDA For. Serv. North. Reg., Missoula, Mont. 31 p. Unpubl.

The USDA Forest Service proposes to pilot test two biological control agents, Bacillus thuringiensis and a nucleopolyhedrosis virus, on the Douglas-fir tussock moth outbreak in northern Idaho, to obtain data leading to the possible registration of one or both. A pilot test is proposed on 17,500 acres. The tussock moth is predicted to cause defoliation on 104,000 acres in 1974.

The report examines the impact of the Douglas-fir tussock moth on timber stands if left uncontrolled, the favorable and unfavorable environmental effects of control with virus or B.t., and the alternative control measures available.

Appended is a work plan for pilot tests, a history of pest epidemics and suppression activities, an entomological evaluation of the epidemic, and background information on the microbial agents.
Control - 5, 6

298. U.S. Department of Agriculture, Forest Service. 1974. Project plans for the 1974 tussock moth control project. USDA For. Serv., Pac. Northwest Reg., Insect and Dis. Control Branch, Portland, Oreg. 106 p. Unpubl.

This report gives detailed plans for a proposed control project against the Douglas-fir tussock moth in 1974. The area will be sprayed with 3/4 lb of DDT in 1 gal of No. 2 fuel oil and auxiliary hydrocarbon solvent per acre. About 376,000 acres will be sprayed in Oregon and Washington. Application will be made from helicopters flying in tandem with an observation helicoper supervising. Areas will be released for control according to the results of natural virus and egg viability tests completed in March 1974. The report details the organization and duties of project personnel; the project procedures; the communications, meteorological, and environmental monitoring plans; and the safety plans for all phases of the project. General provisions in contracts for insecticide mixing and spraying are presented.

The sampling procedure and data analysis to measure population survival, assess foliage saved, measure the number of egg masses in the fall after treatment, and determine the success of treatment in preventing top-kill and tree mortality is outlined. Appended are lists of terminology used, tagging techniques, a sample of all forms used for recording data, sample organization charts, monitoring procedures for residues in the environment, and emergency phone numbers.
Control - 2

299. U.S. Department of Agriculture, Forest Service. 1974. Situation statement, Douglas-fir tussock moth, Oregon-Washington-Idaho. May 23, 1974. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg. 8 p. Unpubl.

An analysis of the tussock moth outbreak in the Northwest is presented. Subjects considered are the host life cycle, biological evaluation, environmental statements, the role of the DFTM Interagency Steering Committee, treatment plans for 1974, and research currently being done on control of the tussock moth.
Outbreaks - 2; Control - 2; Related Material - 2

300. U.S. Department of Agriculture, Forest Service. 1974. Proceedings. Workshop -- Aerial application of insecticides against forest defoliators (chemicals and microbials). Univ. Mont., Missoula. April 23-25, 1974. USDA For. Serv., State and Private Forestry, North. Reg., Missoula, Mont. 128 p.

A series of discussions is presented on the problem of improving aerial spray technology to provide effective aerial application of insecticides against forest defoliators. It includes discussions on mixing and formulation of chemicals, selection of aircraft, meteorological prediction models for spray-deposit assessments, sampling and monitoring techniques, and safety and disposal systems for toxic chemicals.

Articles by W. E. Bousfield; P. R. Canutt; R. K. Dumbauld, H. E. Cramer, and J. W. Barry; P. A. Grau; and P. J. Iwai and M. E. Martignoni are abstracted separately.
Control - 7

301. U.S. Department of Agriculture, Forest Service. 1974. USDA Environmental statement. Cooperative Douglas-fir tussock moth pest management plan. USDA For. Serv., Pac. Northwest Reg., Portland, Oreg. 335 p. Unpubl.

In accordance with the requirements of the EPA, the USDA Forest Service prepared a statement on the environmental impact of the proposed treatment with DDT of the Douglas-fir tussock moth outbreak in Washington, Oregon, and Idaho. The statement covers all affected lands to be treated regardless of ownership.

The statement covers: the appraisal of the forest situation, the biology of the Douglas-fir tussock moth, the history of destructive epidemics, the proposed DDT control plan, the environmental monitoring plan, the impact on the environment of DDT application, the unavoidable adverse effects of DDT, the benefits of DDT use, the alternatives to control with DDT, the public response to the proposed DDT control project, and the supporting research and development programs for a Douglas-fir tussock moth pest management plan.
Control - 2, 3

302. U.S. Department of Agriculture, Forest Service. [n.d.] Saving the forests. Burns project, tussock moth control. USDA For. Serv., Malheur, Ochoco Natl. For. 4 p. Unpubl.

A popular account is given of plans for a forest pest control spray project in the Malheur and Ochoco National Forests, against the Douglas-fir tussock moth. Histories of past outbreaks and the present one are briefly examined. The present and potential economic loss from defoliation, the acres to be sprayed, the groups approving the control project, and the surveillance efforts to be carried out for possible effects of the spray on other resources are reviewed.
Control - 2

303. U.S. Department of Agriculture, Forest Service and Cooperators. 1974. Interim report. Douglas-fir tussock moth research and pilot test program season of 1974. USDA For. Serv., Pac. Northwest For. and Range Exp. Stn., Portland, Oreg. 24 p. Unpubl.

After a concise examination of the history and status of the current Douglas-fir tussock moth outbreak in Oregon, Washington, and Idaho (Blue Mountains), 1972-1974, this report concentrates on a summary of the about 30 studies initiated in 1974 on the population dynamics of the moth and its control. Fourteen of these studies are summarized separately in the Appendix

Findings of particular significance at this point in the research program are: for a given locality, the present outbreak conformed to the 3-year cycle; tree mortality was related to the percentage of Douglas-fir in the infested stand; tests of microbial insecticides, nucleopolyhedrosis virus, and Bacillus thuringiensis showed promise for control; pilot tests of Sevin-4-oil at 2 lb/acre gave effective control, and Dylox also appeared promising but more testing is needed. DDT was more effective against the tussock moth than any other material tested, and a reduced dosage of 1/2 lb/acre was as effective as the standard 3/4 lb/acre. Small-scale aerial tests of Orthene gave promising results for further testing; in ground-application screening tests of 14 new insecticides, five gave over 90% control, with two compounds, Phosvel® and FMC-33297, reducing population levels by 99%; the natural sex attractant of the tussock moth has been identified, synthesized, and field tested with excellent results as a field sampling technique. Biology - 2; Outbreaks - 4; Control - 1, 2, 5, 6; Related Material - 2

304. U.S. Department of Agriculture, Forest Service, and Cooperative State Research Service. 1976. The tussock moth program. USDA For. Serv. and Coop. State Res. Serv. Pam.

"The USDA Expanded Douglas-fir Tussock Moth Research and Development Program is a 3-year effort (1975-1977) designed to solve problems caused by periodic outbreaks of the Douglas-fir tussock moth in western conifer forests. Major goals of the program are to: (1) implement methods that are presently available to reduce damage caused by the tussock moth outbreaks, and (2) develop the new knowledge necessary to prevent or suppress future outbreaks." This pamphlet discusses the need for new control methods, the past status of the tussock moth, the expected

accomplishments of the program, and the means by which the objectives will be accomplished.
Related Material - 2

305. U.S. Department of Agriculture, Forest Service and Cooperative State Research Service. 1976. Tussock moth program progress report. USDA For. Serv. and Coop. State Res. Serv. Pam.

This pamphlet discusses the purpose and background of the Douglas-fir tussock moth program and reports on the progress made in each of its five main phases. Researchers have learned that the natural sex pheromone of the moth can be used to detect low-level populations. They have developed techniques for sampling low-level populations, explored the predator-parasite complex attacking the moth, studied the relation of outbreaks to forest conditions, tested chemical alternatives to DDT, experimented with microbial insecticides, and developed improved methods of aerial application of insecticides.
Related Material - 2

306. U.S. Department of Agriculture, Forest Service and Cooperative State Research Service. 1977. Tussock moth program progress report. USDA For. Serv. and Coop. State Res. Serv. Pam.

This pamphlet discusses the purpose and background of the Douglas-fir Tussock Moth Program and reports on the progress made in each of the five main phases of the program. The sex attractant of the tussock moth is being used to provide better survey techniques and thus a better understanding of population dynamics. Site factors are being analyzed to elucidate the relation of outbreaks to forest conditions. Chemical and microbial insecticides are being tested to develop new methods of suppression and regulation. A conceptual economic model has been developed to determine the socioeconomic impact of the tussock moth. A pest-management system will result from a synthesis of the first four phases.
Related Material - 2

307. Van Dyke, W. 1974. The Douglas-fir tussock moth. The situation as of January 1974. OSPIRG Reports. 40 p. Unpubl.

The paper reports the research undertaken by OSPIRG to determine the necessity of the USDA Forest Service request for use of DDT to control the Blue Mountain outbreak in 1973 and 1974. OSPIRG concludes that DDT would not have prevented a large proportion of the damage that occurred in 1973 because more than half of the severe damage was in areas where it was not anticipated by the Forest Service surveys and thus not included in the proposed spray areas. It charges that tests of alternative chemical insecticides were poorly handled and the results equivocal. OSPIRG contends that the Forest Service has not established either that DDT is the most effective control against the Douglas-fir tussock moth or that the Blue Mountain infestation warrants control by DDT based on accurate assessments of population trends.

OSPIRG recommends that: areas already severely damaged should not be considered for control; a new population survey and a revised estimate of potential damage is needed; areas for spray treatment should be chosen on the basis of data demonstrating significant potential damage; the EPA should require verification of the efficacy of DDT against the moth; and the Forest Service should demonstrate that gains from DDT use offset potential hazards.
Control - 4

308. Volck, W. H. 1907. The California tussock moth. Univ. Calif., Coll. Agric. Bull. 183:191-215. Agric. Exp. Stn., Berkeley, Calif.

Preliminary studies of a tussock moth affecting apple trees in California are presented. Although the moth was not identified, its life history and the feeding habits of the larvae are well described. Young larvae feed on both the foliage and the newly formed fruit. Older larvae are strictly foliage feeders. Rearing of collected larvae and pupae yielded a number of parasites including a tachinid fly, several species of ichneumonid wasps, other parasitic wasps and a chalcid wasp. Eggs are

attacked by a hymenopteran (Telenomus orgyia Ash.) and the larvae of a dermestid beetle. Disease was scarce.

Control by chemicals is difficult because the larvae are relatively resistant to arsenic compounds. First-instar larvae are the most susceptible. Contact poisons were ineffective. The only reliable control is hand removal of the overwintered egg masses. If the larvae emerge before egg mass removal, a secondary control measure is beating the trees to force the larvae to fall and attaching a sticky band to the tree trunk to prevent reascent of the larvae.
Related Material - 3

309. Waite, R. A. 1977. Spread factors of pesticidal spray formulations on Kromekote cards. USDA For. Serv. Res. Note PNW-286, 7 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

"To determine spherical drop size from a known spot size on a particular sampling surface it is necessary to know the spread factor for droplets of pesticide formulations." Preparations of the Douglas-fir tussock moth nucleopolyhedrosis virus, NPV, were among the formulations tested.
Control - 7, 8, 9

310. Washburn, R. I., and W. E. Cole. 1960. The use of virus to control tussock moth. USDA For. Serv. Prog. Rep., 11 p. Intermt. For. and Range Exp. Stn., Ogden, Utah. Unpubl.

This study attempted to determine susceptibility of various tussock moths to the Douglas-fir tussock moth virus, approximate dosage required for establishment, and expected mortality curve from the various dosages tested. In addition, it was intended to develop practical means of propagating the virus so that an adequate supply would be available for field tests.

"Supplies of virus can be maintained or increased in the laboratory by spraying immature tussock moth larvae with a virus solution at the rate of 1 million polyhedra per ml, 1/12 ml per cage; optimum virus concentration tested was 10 million polyhedra per ml, 1/12 ml per cage. Infected immature larvae yielded approximately 50 million and mature larvae yielded about 300 million polyhedra per individual.

"The virus was established when applied at the rate of 10 million polyhedra per acre against a tussock moth infestation on bitterbrush. Excellent control can be obtained the same year with an application of 50 million polyhedra per acre."

This work showed that tussock moths infesting bitterbrush in Nevada, white fir in New Mexico, and Douglas-fir in southern Idaho were susceptible to the virus stock.
Control - 6

311. Watt, K. E. F. 1968. A computer approach to analysis of data on weather, population fluctuations, and disease. In Biometeorology, p. 145-159. W. P. Lowry, ed. Proc. 28th Ann. Biol. Colloq., 1967. Oreg. State Univ. Press, Corvallis.

Using historical records from interior British Columbia, a correlation was found between mean monthly temperature during July and August and numbers of the Douglas-fir tussock moth.
Biology - 1

312. Wear, J. F., and W. J. Buckhorn. 1955. Organization and conduct of forest insect aerial surveys in Oregon and Washington. USDA For. Serv., Pac. Northwest For. and Range Exp. Stn., Portland, Oreg. 41 p. Unpubl.

This report describes the organization and conduct of annual forest insect aerial reconnaissance surveys of the 49,000,000 acres of forested lands in Oregon and Washington as now practiced by the Division of Forest Insect Research of the Pacific Northwest Forest and Range Experiment

Station and its cooperators. Surveys for the Douglas-fir tussock moth are conducted from July 1 to September 1.
Outbreaks - 2

313. Webb, W. L., and J. J. Karchesy. 1977. Starch content of Douglas-fir defoliated by the tussock moth. Can. J. For. Res. 7(1):186-188.

"Defoliation by the Douglas-fir tussock moth (Orgyia pseudotsugata (McDunnough)) resulted in a reduction of total tree reserve energy in the form of starch, proportional to the intensity of defoliation. This reduction was significantly less on a site with faster growing trees."
Outbreaks - 5

314. Webb, W. L., and K. Kilpatrick. 1976. Defoliation of Douglas-fir in a tussock moth outbreak near Kamloops, B.C. In Proc. Symp. Terr. Aquat. Ecol. Stud. Northwest, March 26-27, p. 135-143. East. Wash. State Coll., Chaney.

"Refoliation of trees defoliated by the Douglas-fir tussock moth is likely related to bud incidence and available tree reserve energy. In this paper, we present data on the variation in bud incidence and variation in starch content for both defoliated and undefoliated Douglas-fir. Some of the data show a decline in bud incidence with increased defoliation, and show also a linear decline in foliar starch with increased defoliation."
Outbreaks - 5

315. Weeds Trees and Turf. 1975. Aerial war on two fronts: tussock and gypsy moths. Weeds Trees and Turf 14(3):16-17, 28, 30.

A popular account is given of the control projects on the tussock and gypsy moth outbreaks. DDT was used effectively on the tussock moth outbreak in Washington, Oregon, and Idaho and Dylox was used on the gypsy moth, on small, widely scattered tracts in Pennsylvania.
Control - 2

316. Wellenstein, Von G., and K. Fabritius. 1973. Beobachtungen am Schlehenspinner (Orgyia antiqua L.) und seinen Parasiten. (Observations of Orgyia antiqua L. and its parasites) Anz. Schaedlingskd. Pflanzenschutz 46(2):24-30. [In Ger.]

The first appearance in large numbers of Orgyia antiqua in the spruce forest of southern Germany gave the opportunity of observing this insect pest and its parasitoids under field and laboratory conditions. In warm regions and years, this insect has 2 generations a year.

The older larvae bear poison hairs. Extended handling of the cocoon cause severe irritation (urticaria).

The outbreak of Orgyia antiqua in middle-European forests occurs in intervals from 50 to 60 years, with no preference for any one area. High populations in the same stand for several years are seldom encountered. A loss of increment results from a high population density. The outbreaks generally occur in the center of closed forests.

In the study area (about 7 km north of Bad Wurzbach, Baden-Wurttemberg), the authors found 48.4% females in the second generation, and a pupal mortality of 4.4%. The number of eggs laid was higher in the center than in the peripheral zones of the infestation.

The most important parasitoids were Coccygomimus turionellae (L.) (pupae), Phobocampe crassiuscula (Grav.) (larvae), and Telenomus dalmanni (Ratz.) (eggs). The density of the population of these parasitoids has been studied in heavily infested as well as in lightly populated areas.

The systematics, host species, life cycle, sexual index, and the behavior of the parasitoid Telenomus dalmanni are described.
Related Material - 3

317. Wernz, J., and G. P. Markin. 1977. Flow rates and characteristics of Dimilin, Dylox 1.5, Orthene 75S, and Sevin 4-oil. USDA For. Serv.,

Res. Note PNW-300, 16 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Tests of aerial application of insecticides for Douglas-fir tussock moth control require knowledge of the flow rate of each chemical through the spray nozzle. Standardized equipment was used to evaluate the flow rates for Dimilin, Dylox 1.5, Orthene 75S, and Sevin 4-oil at five pressures and four temperatures with three standard T-jet nozzles. "Physical properties of settling, density, and viscosity and handling characteristics are also discussed."
Control - 7

318. Wert, S. L., and B. E. Wickman. 1968. White fir stands killed by tussock moth . . . 70 mm color photography aids detection. USDA For. Serv. Res. Note PSW-168, 5 p. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.

An aerial survey technique to determine the extent and severity of white fir damage after defoliation by the Douglas-fir tussock moth is described. Large-scale, 70-mm aerial photography was used to increase detection accuracy and allow for stereoscopic viewing of the film in an uncut roll. Aerial photographs were taken of three separate sites at the tussock moth infestation in the Modoc National Forest, California. Comparisons were made between field assessments of tree crown conditions and interpretations from aerial photographs of selected 0.2-acre plots within the test sites. Interpreters of the aerial photographs were able to detect dead white fir trees with a high degree of accuracy but were less able to distinguish the degree of top-kill or thin foliage compared with ground estimates of the same trees. With more training, the interpreters could more accurately detect top-kill and thin foliage crowns.
Host Relationships - 1; Outbreaks - 5

319. Wert, S. L., and B. E. Wickman. 1970. Impact of Douglas-fir tussock moth . . . color aerial photography evaluates mortality. USDA For.

Serv. Res. Pap. PSW-60, 6 p. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.

Large-scale, 70-mm aerial photography was tested as a method of measuring white fir mortality and crown conditions after defoliation by the Douglas-fir tussock moth in the Warner Mountains, California. The surveys took place 3 years after a serious outbreak of the moth. In addition, the use of small-scale (1:8,000), 9-by-9 inch format, color aerial photographs to map and stratify insect damage was examined.

Ground surveys of the areas to be photographed were made both as a check against the photographs and to provide sample data for estimating total white fir damage in the area. "Comparisons of the photo interpretations with a sample ground cruise gave high correlations (0.78 to 0.95) for tree mortality and top-kill, and an estimate of mortality made from photos was within 5% of the ground cruise estimate."
Host Relationships - 1; Outbreaks - 5

320. Wickman, B. E. 1958. Mortality of white fir following defoliation by the Douglas-fir tussock moth in California, 1957. USDA For. Serv. Calif. For. and Range Exp. Stn. Res. Note 137, 4 p. Berkeley, Calif.

The 1954-56 Douglas-fir tussock moth infestation of white fir in the Stanislaus National Forest covered seven scattered blocks and 10,000 acres. A study conducted in 1957 of tree mortality on selected plots in the infestation sites showed 21% of the trees were killed on heavily defoliated plots. One-fourth of the mortality was caused by defoliation alone, the other defoliated trees were killed by bark beetles. Only trees 50-100% defoliated were killed. Damage to trees less than 50% defoliated resulted in reduced growth.

The plots will be checked annually in August until 1960.
Host Relationships - 1; Outbreaks - 5

321. Wickman, B. E. 1963. Mortality and growth reduction of white fir following defoliation by the Douglas-fir tussock moth. USDA For. Serv. Res. Pap. PSW-7, 15 p. Pac. Southwest For. and Range Exp. Stn., Berkeley, Calif.

"Damage caused by the Douglas-fir tussock moth was studied in white fir stands in California. The data collected were from the Stanislaus infestation of 1954-56 and the Inyo infestation of 1934-38. Mortality of white fir was caused by defoliation alone and by a combination of defoliation and attacks by cambium-mining beetles. More small trees were killed than large ones. In the most heavily defoliated stands, 20% of the saw-timber volume (11,071 fbm per acre) died in the 5 years immediately after the end of the Stanislaus outbreak. Twenty-nine % of the volume (10,595 fbm per acre) was killed in the 5 years after the Inyo outbreak.

"Top damage in the Stanislaus infestation was most severe in the heavily defoliated trees; 12% of them being top-killed as a result of tussock moth feeding. Many small trees suffered temporary top dieback, but later grew new leaders. Loss of radial growth was pronounced and similar for both infestations. The loss was most noticeable in trees more than 30% defoliated. Defoliation had an immediate effect upon white fir growth, and when feeding stopped, growth increased immediately. Differences in growth between top, midcrown, and base were noticeable before and after defoliation. In almost every case the base was growing more slowly and the magnitude of loss was proportionately greater in the upper crown."

Growth losses of merchantable white fir combined with mortality totaled 12,184 fbm per acre, or more than one-fifth of the original stand volume.

Host Relationships - 1; Outbreaks - 5

322. Wickman, B. E. 1972. Preliminary report on the effects of Douglas-fir tussock moth larval populations on defoliation of white fir. Part V. In Results of field experiments for controlling Douglas-fir

tussock moth with aerial application of polyhedrosis virus and associated studies. Progress Report. USDA For. Serv., Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg. 9 p. Unpubl.

"Estimates of white fir defoliation by tussock moth larvae were made through the 1971 growing season on the Iron Mountain plots and on an undefoliated plot at Alder Ridge. Purposes of the measurements were to correlate defoliation with population levels. The major findings of this exploratory work are as follows. Sampling methods must be improved for estimating defoliation. There was no measurable difference in defoliation on the Iron Mountain treated and untreated plots, but there was a significant difference with a nearby nondefoliated plot. Larval populations in the 35 per 1,000 in^2 of foliage category cause significant foliage removal through one growing season. This relates to visual crown estimates which showed that 75% of the sample trees on the Iron Mountain plots suffered "light" defoliation. Quantitative data was obtained on white fir foliage production which will be valuable for future energy flow models of fir trees and their foliage consumers."
Outbreaks - 4, 5

323. Wickman, B. E. 1975. Research on population dynamics and impact in the Blue Mountains. West. For. Conserv. Assoc., Perm. Assoc. Proc. 1974:15. Portland, Oreg.

A brief synopsis of the tussock moth research underway at the Pacific Northwest Forest and Range Experiment Station, Corvallis, Oregon, is presented. The population dynamics of the Douglas-fir tussock moth have been studied in depth at the extensive outbreak in the Blue Mountains to determine the nature of population change, natural mortality factors, and tree damage under natural conditions.
Outbreaks - 4

324. Wickman, B. E. 1976. Douglas-fir tussock moth egg hatch and larval development in relation to phenology of grand fir and Douglas-fir in northeastern Oregon. USDA For. Serv. Res. Pap. PNW-206, 13 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

"Bud burst, shoot elongation, egg hatch, and larval development were studied on six areas in a 1973 infestation in the Blue Mountains." The study sites were located at various elevations in both pure stands of grand fir and Douglas-fir and in mixed stands. "Bud development was similar for both tree species except on the lower elevation plot where Douglas-fir bud burst preceded grand fir by several days. . . ."

"Bud burst and egg hatch were found to be closely related to accumulated degree-days, and peak egg hatch occurred after all buds had burst and shoots were 50% or more elongated." First egg hatch occurred at 80-100% bud burst on grand fir and 70-97% bud burst on Douglas-fir. "Larval development closely followed shoot elongation. This synchrony of host and insect phenology provides an easily observable field event for monitoring Douglas-fir tussock moth development."
Biology - 1; Host Relationships - 2, 3

325. Wickman, B. E. 1976. Phenology of white fir and Douglas-fir tussock moth egg hatch and larval development in California. Environ. Entomol. 5(2):316-322.

"The phenology of bud burst and shoot elongation of the host tree and egg hatch and larval development were studied on three areas in a 1972 infestation. Bud burst and egg hatch (of the Douglas-fir tussock moth) were found to be closely related to accumulated degree-days, and peak egg hatch occurred when 77-97% of the buds had burst." Complete dispersal of the larvae from the egg masses and extensive feeding occurred after 100% of the buds had burst. "Larval development then closely followed shoot elongation."
Biology - 1; Host Relationships - 1

326. Wickman, B. E. 1977. Douglas-fir tussock moth egg hatch and larval development in relation to phenology of white fir in southern Oregon. USDA For. Serv. Res. Note PNW-295, 9 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

The relation between bud burst and shoot elongation in white fir and egg hatch and larval development in the Douglas-fir tussock moth was studied in two areas near Fort Klamath, Oregon. "The study areas had low populations of the Douglas-fir tussock moth. Bud burst was found to be closely related to accumulated degree-days, and peak egg hatch occurred after all buds had burst and shoots were 40% elongated. Larval development then closely followed shoot elongation." The phenological relations for tussock moth egg hatch and larval development on white fir in California and on grand fir and Douglas-fir in northeastern Oregon are similar to those indicated by this study.
Biology - 1; Host Relationships - 1

327. Wickman, B. E. 1977. Observations on spider predation of early instar larvae of Douglas-fir tussock moth, Orgyia pseudotsugata (McDunnough) (Lepidoptera: Lymantriidae). Pan-Pac. Entomol. 53:46.

On one occasion a medium-sized spider (about 6-8 mm long) removed and apparently stung two newly hatched Douglas-fir tussock moth larvae. On two other occasions, medium-sized spiders (5-8 mm) were seen opening tussock moth eggs and eating the larvae that were ready to emerge.
Biology - 3

328. Wickman, B. E., R. R. Mason, and H. G. Paul. 1975. Flight, attraction, and mating behavior of the Douglas-fir tussock moth in Oregon. Environ. Entomol. 4(3):405-408.

"Continuous observations and measurements were made of adult flight, mating, and oviposition of Orgyia pseudotsugata McDunnough over a 31-h period in eastern Oregon. Male flight started at 1,000 (P.S.T.), gradually increased to a peak period at ca. 1700, and concluded at 1930. This coincided with peak mating activity with the wingless females. Oviposition occurred immediately after mating." Females were observed mating more than once, on several occasions after ovipositing most of their eggs. Some females oviposited without mating. "Virgin females attached to sticky traps were very effective for attracting and capturing

male moths. The female sex pheromone offers a possible technique for early detection of Douglas-fir tussock moth populations."
Biology - 1, 2

329. Wickman, B. E., R. R. Mason, and C. G. Thompson. 1973. Major outbreaks of the Douglas-fir tussock moth in Oregon and California. USDA For. Serv. Gen. Tech. Rep. PNW-5, 18 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

"Case histories of five tussock moth outbreaks that occurred in California and Oregon between 1935 and 1965 are discussed. Information is given on the size and duration of the outbreaks, the presence of natural control agents and the damage caused. Most of the outbreaks were eventually treated with DDT. However, enough information was available from untreated portions to show the probable trend of natural events in the absence of direct control. Repeated patterns observed in each of the outbreaks enabled certain generalizations to be made about natural population behavior and tree impact.

"All infestations followed a 3-year cycle with inconspicuous to minimal defoliation the first year, severe foliage loss the second year, and ultimate collapse of the population by the end of the third year. The most severe tree damage occurred in the second year. Additional loss of foliage before population collapse in the third year was usually of minor importance in terms of total impact. Although other natural factors were involved, a virus disease appeared to be the principal cause of insect mortality during collapse."
Outbreaks - 1

330. Wickman, B. E., and D. A. Renton. 1975. Evaluating damage caused to a campground by Douglas-fir tussock moth. USDA For. Serv. Res. Note PNW-257, 5 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

The impact of Douglas-fir tussock moth defoliation on recreational values was studied at the Stowe Reservoir campground, Modoc National Forest. Tree mortality and top-kill of white fir were tallied and evaluated. "Cleanup costs for hazardous trees and dead tops amounted to $23.75 per camp unit. When esthetic values were assigned to trees, the insect damage costs increased to $126.88 per camp unit. Campground trees should be assigned some replacement value rather than their timber value to aid the pest management specialist in determining the level and kind of suppression technique to be applied against a given pest."
Host Relationships - 1; Outbreaks - 5

331. Wickman, B. E., and R. F. Sharpf. 1972. Decay in white fir top-killed by Douglas-fir tussock moth. USDA For. Serv. Res. Pap. PNW-133, 9 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

"Stands heavily defoliated in 1936-37 by the Douglas-fir tussock moth, Hemerocampa pseudotsugata McD., at Mammoth Lake, California, were studied to determine the incidence and extent of decay in top-damaged trees. This was done by dissecting the tops of trees felled during logging. Comparisons were made with white fir in a nearby logged area that was not defoliated during the old outbreak. Few decay organisms were isolated from trees top-killed by Douglas-fir tussock moth. However, old top damage and a condition known as wetwood were common in the infested area. Wetwood was found in 17 of 21 top-damaged trees in the infested area and in one of 50 trees in the uninfested area. We conclude therefore, that in east-side Sierra Nevada white fir stands, the threat of defect is not economically serious in large trees that will be logged within 35-40 years after top-damage."
Host Relationships - 1; Outbreaks - 5

332. Wickman, B. E., G. C. Trostle, and P. E. Buffam. 1973. Douglas-fir tussock moth. USDA For. Serv. For. Pest Leafl. 86, 6 p. (Rev.)

This leaflet covers a brief history of the Douglas-fir tussock moth infestations; the outbreak cycle; a description of the damage of the

larvae; a description, life history and preferred hosts of the moth; and the alternatives of natural and chemical control.
General Background

333. Williams, C. B., Jr. 1974. Field test of four insecticides against the Douglas-fir tussock moth in Oregon. West. For. and Conserv. Assoc., Perm. Assoc. Comm. Proc. 1973:77-83. Portland, Oreg.

"In the spring and early summer in 1973, Federal and State resource agencies tested four insecticides on epidemic populations of the Douglas-fir tussock moth (Orgyia pseudotsugata) in the egg and early larval stages." Application was by helicopter. Insecticides and dosage rates applied were: Bioethanomethrin (BEM) at 0.01 lb/acre; carbaryl (Sevin) at 1 lb/acre; trichlorfon (Dylox) at 1 lb/acre; and mexacarbate (Zectran) at 0.15 lb/acre. Field dosages were determined from laboratory toxicity tests and dosages registered for similar species of defoliating moths. Zectran and Dylox were tested in single and double applications, BEM and Sevin by a single application.

Results of the tests were highly variable and inconsistent. Some of the variability in mortality resulted from increases in population densities during the tests, because spraying was done before all larvae had hatched. Poor or highly variable spray deposit and coverage further increased the variability of the population data.

Results of the test apparently do not provide sufficient information to evaluate the performance of the four materials against the Douglas-fir tussock moth. More field testing with different spray strategies is needed.
Control - 1

234. Wolf, K. 1975. Evaluation of the exposure of fish and wildlife to nuclear polyhedrosis and granulosis viruses. In Baculoviruses for insect pest control: Safety considerations, p. 109-111. M. D. Summers, R. Engler, L. A. Falcon, and P. V. Vail, eds. Am. Soc. Microbiol.

Suggestions for testing the impact of the Douglas-fir tussock moth polyhedrosis virus on nontarget organisms by the use of tissue cultures and in vivo experiments are presented. Attempts to replicate the virus in cell cultures of both fish and amphibians have given negative results.
Control - 6

335. Wright, K. H. 1975. An expanded research and development program for the Douglas-fir tussock moth -- 1975 to 1978. West. For. Conserv. Assoc., Perm. Assoc. Proc. 1974:24-30. Portland, Oreg.

An accelerated 3-year research program has been designed by the USDA, to detect, predict, and manage populations of the Douglas-fir tussock moth. From 1975 to 1978, members of the Forest Service and the Cooperative State Research Services will work to develop an integrated pest management system.

This paper summarizes the objectives, organization, and plans of the tussock moth cooperative research and development program.
Related Material - 2

336. Wright, K. H. 1977. The Douglas-fir tussock moth research and development program. Bull. Entomol. Soc. Am. 23(3):167-168.

The background of the creation of the Combined Forest Pest Research and Development Program and its organization and management are presented. Douglas-fir tussock moth program planning is briefly detailed and the five main phases of investigation are described. A short description of the Douglas-fir tussock moth and its status as a pest is included.
Related Material - 2

337. Wright, K. H., and R. R. Mason. 1966. Field tests at Mt. Hood, Oregon, to determine performance of water virus sprays. Part II. In Results of tests to develop operational procedures for controlling Douglas-fir tussock moth with aerial application of polyhedral virus spray. USDA Agric. Res. Serv. and For. Serv., Portland, Oreg. 36 p. Unpubl.

"Helicopter tests were undertaken in June, 1965, on the Mt. Hood National Forest to further knowledge on how to apply water sprays of the type used for applying polyhedral virus of the Douglas-fir tussock moth. Specific objectives were to determine (1) the amount and distribution of water spray deposited under varying forest conditions when applied at the rate of 1 and 3 gal/acre, and (2) efficacy of using fluorescent tracer material for evaluating spray distribution."

The average dye spray recovery in tree crowns was 0.30 and 0.63 gal/acre, respectively, from trees sprayed at the rate of 1 and 3 gal/acre, and 0.14 and 0.60 gal/acre was recovered on the ground beneath the canopy. Coverage at the 3-gal rate was consistently more uniform. No significant difference occurred in the amount of dye spray recovered within trees from top, middle, and lower crowns. "Average deposits of fluorescent spray on sample cards at top, midcrown, and lower crown was 45, 30, and 25% respectively of the total deposited on the trees. Differences between top and other positions were statistically significant. This is in variance with findings from dye spray."

"In general, the fluorescent tracer material (Calcofluor white) worked well as a tagging material. Fluorescent materials are advantageous over dyes for ease of assessing spray coverage in the field. Droplets fluoresced brightly for 1 month after application."
Control - 9

338. Young, V. D. 1966. Development of equipment and methods for applying virus water sprays. Part I. In Results of tests to develop operational procedures for controlling Douglas-fir tussock moth with aerial application of polyhedrosis virus spray. USDA Agric. Res. Serv. and For. Serv., Portland, Oreg. 21 p. Unpubl.

The results of tests of equipment development and spray formulation are reported. Physical factors influencing droplet size are reviewed. A helicopter mounted with a 29-foot boom equipped with 37 nozzles was tested for effects of nozzle size, and type, and speed of application on deposit spectrum. Formulation tests centered on the discovery of a

sticker that would not affect colorimeter readings of a dye tracer incorporated into the solution. Corn syrup proved to be the most compatible. Appendices include the results of helicopter nozzle calibration tests, spray pattern data, and spray deposition cards.
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GPO 986-261

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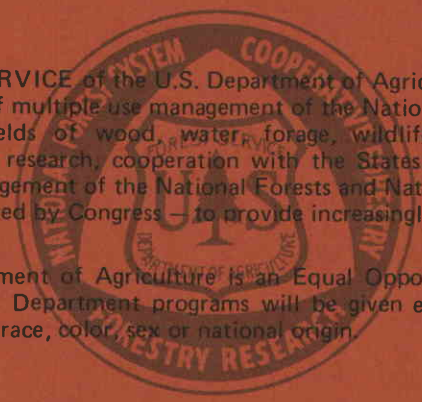

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