Twenty-Five Year (1982-2007) History of Lodgepole Pine Dwarf Mistletoe Animal Vectors and Ethephon Control on the Fraser Experimental Forest in Colorado

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Abstract

This is a summary of the 25-year history of studies of mammal and bird vectors of lodgepole pine dwarf mistletoe (Arceuthobium americanum), ethephon control of dwarf mistletoe, and the ecology of the most important dwarf mistletoe vector, the gray jay (Persisoreus canadensis), on the USDA Forest Service, Fraser Experimental Forest (FEF) in Colorado. This paper is dedicated to the memory of the late Dr. Frank Hawksworth who was a plant pathologist and international authority on dwarf mistletoes at the Rocky Mountain Research Station who inspired this study. It is also presented in celebration of the 100th anniversary of the USDA Forest Service Experimental Forests in 2008.

The Fraser Experimental Forest (FEF) Study Area—The 36-sq mile FEF, in the Arapaho National Forest, is located 6 miles southwest of Fraser, in Grand Co. It is administered by the Rocky Mountain Research Station (RMRS) headquartered in Fort Collins, CO. The elevation of the Forest ranges from 8,800 to 12,804 ft.

The USDA Forest Service dedicated the FEF in 1937 as an outdoor laboratory to research sub-alpine forests representative of much of the central and southern Rocky Mountains. In 1978, the Forest was designated a World Biosphere Reserve by the United Nations, one of many worldwide dedicated to the study and conservation of the diversity and integrity of plant and animal communities within natural ecosystems. Forest Service Experimental Forests and Biosphere Reserves, by their nature, are strategic places for carrying out long-term ecological and environmental studies such as reported here.

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Dwarf Mistletoe Studies

Impact of Dwarf Mistletoes—In the western United States dwarf mistletoes have a greater impact on forests than any other pathogen, decreasing growth rates, distorting tree form, reducing wood quality and killing trees. It has been estimated that over 29 million acres are infested in western forests and Alaska with 164 million cubic feet of wood lost annually. Lodgepole pine dwarf mistletoe causes major economic timber production losses through tree deformity and mortality.

Lodgepole Pine Dwarf Mistletoe Animal Vector Study Initiated in 1982—This study was initiated in 1982 when I was a Forest Service Research Plant Pathologist with the North Central Research Station (NCFES), now the Northern Research Station, St. Paul, MN, and by the late Frank Hawksworth (figure 1) of the RMRS, Fort Collins, CO. Over a period of years this study evolved into a series of other studies as new research questions developed during the course of the study.

Animal Vectors of Lodgepole Pine Dwarf Mistletoe Identified—The objective of our study was to identify animal vectors of lodgepole pine dwarf mistletoe and to determine their importance in the establishment of new infection centers that could not be explained by normal spread of sticky mistletoe seeds shot up to 50 feet, or more, by explosive fruits. We used small mammal traps, ear tags, bird mist nets, cell traps, banding, and radio telemetry to document how mistletoe seeds were carried by vectors beyond the normal seed dispersal range of infected trees.

Our study identified ten bird and four mammal vectors of lodgepole pine dwarf mistletoe seed. They included the gray jay, Steller's jay (figure 1), mountain chickadee, dark-eyed junco, hermit thrush, American robin, Yellow-rumped warbler, saw-whet owl, Townsend's solitaire, three-toed woodpecker, least chipmunk, golden-mantled squirrel, red squirrel, and pine marten.

We found that birds and mammals, foraging in infected lodgepole pine, become inadvertent targets of explosive, sticky mistletoe seeds that can stick to feathers or fur. Although such events are rare, a sufficient proportion of birds (27%) carried dwarf mistletoe seeds to make some dispersal probable. As animals move about the forest, or clean their bodies, mistletoe seeds can be deposited on healthy lodgepole pine where they sometimes germinate causing new infections.

Figure 1. Frank Hawksworth and a Steller's Jay in 1982 with a dwarf mistletoe seed on its tail feather, Fraser Experimental Forest, CO.

Silvicultural Control of Small Satellite Pockets of Dwarf Mistletoe Can Reduce Spread—Vector study results explained how new satellite infection centers become established in healthy stands far-removed from main infection centers. Dwarf mistletoe plants are dioecious, so a female and male plant would have to become established within pollination range to develop a satellite infection. Although satellite infection centers are relatively scarce, the explosive mechanism of seed dispersal utilized by dwarf mistletoes enables them to intensify and spread rapidly from a newly established center.

The most practical management plan for controlling new infection centers is to find them through periodic, systematic land or aerial surveys and removing them. This can be done by cutting infected trees and a buffer strip of about two chains of adjacent trees that may be harboring latent infections not yet showing signs and symptoms. Follow-up surveys 5 to 10 years after eradication efforts will determine whether all infected trees were removed.

This management action is recommended to effectively prevent, or slow the spread of dwarf mistletoe from small, isolated infected pockets found in otherwise healthy, merchantable stands.

Chemical Control of Dwarf Mistletoe Using Ethephon Applied by Ground Sprayers Reduced Seed Dispersal up to 4 Years; Helicopter Spray was Ineffective—A chemical control method was tested on the FEF in the 1980s in cooperation with Forest Pathologists David Johnson, USDA Forest Service, Forest Pest Management, Lakewood, CO and Kathy Robbins of NCFES, both now retired. The objective of this work was to determine whether small pockets of infected trees could be saved and adjacent healthy trees protected by treating infected trees with ethephon, a growth regulator. It acts by releasing ethylene, a plant hormone, which is absorbed by the plant and interferes in the growth process. It is found in nature and, among other things, causes tree leaves to abcise at the end of a growing season. We thought it might do the same to mistletoe shoots. It did.

Ethephon at 2,500 ppm in water with a spreader applied by ground sprayers was effective in causing mistletoe shoots, flowers, and fruits to drop off trees (figure 2), thereby, significantly reducing seed dispersal for up to 4 years after treatment. However, it does not kill the parasite's endophytic system in the host tissue, so shoots often re-sprout in 3 to 5 years. As a result, frequent ethephon treatments would be required to effectively manage this disease making it economically unfeasible to use under forest conditions.

Ethephon treatments using ground sprayers can be used to slow the development and spread of dwarf mistletoe in high value trees located in campgrounds, small parks, golf courses, and around buildings.

Presumably, the reduction in dwarf mistletoe shoots can also reduce the drain on the host tree's nutrients from being directed to the parasite. Because of these benefits it was registered with the Environmental Protection Agency for this use.

Figure 2. Lodgepole pine dwarf mistletoe before (left) and several days after (right) being sprayed with ethephon growth regulator on the Fraser Experimental Forest, CO.

Aerial applications of ethephon by helicopter were not effective in controlling lodgepole pine dwarf mistletoe under forest conditions.

Ethephon research results stimulated many other studies of this growth regulator on other dwarf mistletoe species achieving similar results.

Dwarf Mistletoe Benefits Wildlife—Later, looking though the eyes of a wildlife biologist rather than those of a forest pathologist, having switched disciplines in 1986, I found that control of dwarf mistletoe may not be the best management action to take in all situations, especially in terms of overall ecosystem health and diversity.

While dwarf mistletoes are a major cause of tree deformity and mortality in affected coniferous stands throughout the northern hemisphere causing significant economic damage, the resulting dead and declining trees have a positive affect on many wildlife species who use the trees for nesting, shelter and food in insects attracted to such trees.

Mistletoes create canopy openings providing conditions suitable for plant species not ordinarily found in dense, healthy stands which in turn attract a variety of animal species. Mistletoe shoots are eaten by some mammal and bird species. Insects are abundant in affected trees attracting a wide variety of insect eating birds such as woodpeckers, nuthatches, and warblers as we saw on the FEF. In addition, there are several species of raptors and songbirds that nest in witches' brooms of various dwarf mistletoe species.

Based upon the FEF study and related studies, mistletoes have been found to play a positive role in creating more compositional (both plant and animal), structural, and functional diversity in the forest. Whether this is good or bad depends upon the management objectives for any given forest stand. For example, if timber management for forest products is a primary objective, dwarf mistletoe control is essential when economically feasible. If wildlife management, species diversity, and wildlife viewing are the primary objectives, control may not be essential and may even be detrimental to some wildlife, especially in marginal or non-commercial stands.

Gray Jay Studies

Early study results found that the gray jay is one of the most important vectors of lodgepole pine dwarf mistletoe on the FEF. As a result, later work began to focus on gray jay movements, longevity, health, site fidelity, and vector ecology to better understand this species. During the course of these later studies, it became clear that the gray jay, a year-round resident of the Forest, is an integral part of the ecosystem,

maybe even a keystone species. This species is a remarkable, highly intelligent, long-lived, territorial bird with amazing survival tactics and communication skills.

I found the ecology of the gray jay so interesting in its own right that I continued research on this species as a Forest Service Volunteer since my retirement in 1994 as has my wife, Mary Lou, also a Forest Service Volunteer.

With the help of NCFES Biological Technician Leanne Egeland, now with the USDA Forest Service Forest Health Management Unit, Gunnison, CO, we have studied gray jays on the FEF for 25 consecutive years starting in 1982. This study is believed to be the longest continuous study of gray jays in the United States.

Figure 3. Manuel Martinez with a 17-year-old gray jay on the Fraser Experimental Forest, CO, the oldest gray jay recorded in the United States according to the USGS Bird Banding Laboratory.

Banding Reveals Long-lived, Territorial Gray Jays — We banded and released 668 individual gray jays on the FEF over the 25 years. We used over 40 mist-net trapping locations to capture birds, each located about ½ mile apart centered on the FEF Headquarters. The average weight of these birds was 73 grams, average wing length 153 mm and average tail length 142 mm.

We handled a total of 1,891 new and retrapped gray jays over the 25 years of our study. Many were retrapped and released many times, often at the same location, or at a nearby location, where they were originally banded. These results showed adult birds are highly site specific and territorial.

Fifty-seven of the banded gray jays achieved long-lived status of between 8 and 17 years of age (table 1). In fact, FEF has the distinction of having had the oldest recorded living gray jay in the wild. It was recaptured on 30 Aug 2002, 17 years after it was originally banded on 16 Aug 1985 (figure 3). This is a U.S. record for gray jay longevity according to the USGS Bird Banding Laboratory.

The record gray jay was originally banded at the FEF Headquarters as a hatch-year bird on 16 Aug 1985. It dispersed about 2 miles away and was retrapped and released on its new territory on 8 Sept 1998, 10 Sept 1999, 8 Sept 2000 and was last caught on 30 Aug 2002. The bird's weight remained normal over the years ranging between 69 and 73 grams.

Table 1. Minimum age class of 668 individual gray jays trapped, banded, and released on the Fraser Experimental Forest, Grand Co., CO from 1982 to 2007.

Minimum Age	No. Individuals
0 (Hatch Year)	203
1	212
2	72
3	34
4	24
5	28
6	18
7	20
8	22
9	11
10	8
11	6
12	6
13	0
14	1
15	2
16	0
17	1
Grand Total	668 Gray Jays

Gray Jays Year-round Residents on the FEF—Study results revealed a relatively long life span and high site fidelity for resident adult gray jays that live in permanent all-purpose territories in the sub-alpine forests where they live under extreme winter weather conditions at high elevations of around 9,000 to 11,000 feet. The bird survives these harsh conditions because it has a rather unique way of preserving food.

Gray jays possess two large mandibular salivary glands, one on each side near the base of the bill. The jay shapes its food into an oval pellet, or bolus, with its tongue and permeates it with saliva. The sticky saliva is used to glue food pellets to vegetation during the non-winter months where they dry to form a hard protective covering around the food. What's more remarkable, gray jays can remember where they store most of their food enabling them to survive the long, harsh winters on the FEF.

FEF Home to an Estimated 682 Gray Jays—In 2005, 39 gray jays on the FEF were color-banded by Jennifer Berg (now Jennifer Lansing), an MS student at the University of Colorado—Denver under the direction of Professor Diana Tomback, and followed to determine habitat use. The purpose of the study was to create a method to predict carrying capacities for birds by using Geographic Information System techniques by using our available information on gray jay distribution, habitat use, and territorial sizes. Based upon this work, Berg (Lansing) and Tomback estimated there is a population of about 682 gray jays on the 36-sq mile FEF.

Polymerase Chain Reaction (PCR) Technique used to Sex Gray Jays for the First Time—The plumage of female and male gray jays is identical, so we were unable to sex the birds in the field. For the first time in 2005, blood samples were used to identify the sex of gray jays using PCR. Avian sexing PCR uses the fact that male and female birds have different genes or chromosomes, much like mammals.

So far, we have been able to determine the sex of 74 gray jays, 38 males and 36 females. As a control, the PCR method was used to correctly sex four red-shafted flickers and one hairy woodpecker that can also be sexed by plumage in the field.

As this data base develops, it can serve as a basis for studying genetic parentage, relationships, and dispersal of related gray jays on the FEF.

Introduced West Nile Virus (WNV) Threatens Gray Jays in 2003 —An outbreak of the introduced mosquito-borne WNV in 2003 posed a threat to the gray jay population on the FEF as well as to humans throughout Colorado. More humans (2947) were infected in Colorado in 2003 than any other state and 63 of those people died.

Zoonotic pathologist Kurt Reed M.D. of the Marshfield Clinic Research Foundation (MCRF) now Professor of Pathology, Northwestern University School of Medicine joined our research team in 2003 to study the impact of WNV on gray jays. He took blood samples from 296 gray jays from 2003 to 2007. We do not as yet have the results of 60 samples taken in 2007. The other 236 blood samples tested negative for WNV antibodies except for two gray jays (band nos. 9822-51941 and 9822-52036) that tested positive with high WNV antibody titers of @1:20 and @1:40, respectively.

Jays are highly susceptible to the virus and many individuals may have died before they could develop protective antibodies and before we could find them in the field where they can be quickly picked up by scavengers. However, circumstantial evidence as follows showed a major decline in the jay population that we hypothesized was caused by WNV.

The population of gray jays on the FEF had been healthy for at least 21 years, but something was different about the birds in 2003. They were more difficult to trap and far fewer birds were trapped than in the previous 4 years despite similar trapping effort. There was a 37% decrease in the number of birds netted in 2003 (N=74) compared to 2002 (N=117). There was an overall 33% decline in the capture rate over the previous 4 years, 1999 to 2002, compared to 2003. We are not sure whether WNV mortality was the cause of this decline, but our WNV blood test results hinted that WNV might have been the cause. As WNV waned in CO after 2003, the gray jay population on the FEF rebounded in 2005 and 2006 by 16% and 22%, respectively.

WNV outbreaks, like other arboviruses, are cyclical in nature. We might be able to further strengthen our hypothesis that WNV was the cause of the population decline by making observations during the next WNV outbreak in Colorado. If and when that will happen is an unknown, but that is why long-term studies are so valuable for ecological research.

Mountain Pine Beetle (Dendroctonus ponderosae) Outbreak Threatens Gray Jay Habitat in 2007 and Kills Mistletoe-infected Lodgepole Pine—Without normally cold recent winters to kill off their larvae and sustained drought to predispose the trees to attack, native mountain pine beetles had infested up to 90 percent of older lodgepole pine stands in Colorado by 2007. Recent aerial surveys reveal that dead and dying lodgepole acreage has grown to 1.5 million in Colorado since the first signs of outbreak in 1996.

The beetle threatens esthetics of recreational areas and valuable home sites, forest products, watersheds, and wildlife habitat for some species, but a boon for others like woodpeckers. The drying dead trees present a serious fire risk.

Until fire control was initiated about 100 years ago, fire was a natural control of dwarf mistletoes. It appears that the recent mountain pine beetle tree mortality is having a similar natural control affect in that it is killing thousands of mistletoe-infected trees, trees that otherwise would intensify the spread of dwarf mistletoe.

By 2007, the pine beetle outbreak had killed thousands of older lodgepole pine in prime gray jay habitat on the FEF. The impact of this significant tree mortality on gray habitat and populations, as well as on other wildlife, is yet to be determined—a major reason to continue this long-term study on the FEF.

When we initiated this study in 1982, we thought for sure that dwarf mistletoe was the worst possible pest threat to lodgepole pine and that it warranted significant research and control. So 25 years later, it now begs the question which pest, dwarf mistletoe or mountain pine beetle, is more important to the health of lodgepole pine, the forest, and to the ecosystem in the long run? Only long-term research can answer this question—one more reason to make sure our Forest Service Experimental Forests are preserved for long-term studies.

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Study Publications

The following papers, listed in chronological order, have been published based on information gathered in all, or in part, during the FEF study. In addition to these publications, numerous progress reports were issued over the past 25 years.

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