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Thomas P. Sullivan
Department of Forest Sciences, Faculty of Forestry, University of British Columbia, Vancouver, British Columbia, Canada

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THOMAS P. SULLIVAN, Department of Forest Sciences, Faculty of Forestry, University of British Columbia, Vancouver, British Columbia, Canada V6T 1W5

ABSTRACT: The use of diversionary food is an ecological method to reduce feeding damage by wildlife to forest and agricultural crops. The red squirrel (*Tamiasciurus hudsonicus*) feeds on the vascular tissues of young lodgepole pine (*Pinus contorta* var. *latifolia*) and this damage is particularly severe in intensively managed stands. Aerial application of sunflower seed on an operational scale significantly reduced damage by squirrels. This result was achieved in three different ecological zones in the interior of British Columbia, Canada. The food shortage apparently experienced by these rodents during the May-June damage period can be accommodated by an artificial food source such as sunflower seeds. Cost of this operational program is $0-$45/ha and is a worthwhile expense even if required annually for 5-10 years to protect the $2,000+/ha invested in intensively managed pine stands. Adaptation of this technique is discussed with respect to understanding the sociological aspects essential to successful application of research results.

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INTRODUCTION

Provision of an artificial alternative food or lure crop as a diversionary food is an ecological method to reduce feeding damage by wildlife to forest and agricultural crops. This approach has had considerable success in alleviating waterfowl depredation to cereal crops in North America (see review by Knittle and Porter 1988). Use of supplemental feeding for the management of other vertebrate pests has received little attention because it is perceived as being of limited usefulness and effectiveness with relatively high costs. However, Marsh and Salmon (1992) stress the need for research and development in this field to complement the great interest and desire for ecologically sound and sustainable forest and agricultural practices.

The red squirrel (*Tamiasciurus hudsonicus*) is a common inhabitant of boreal and temperate coniferous forests of North America. Mature stands of conifers, particularly spruce (*Picea* spp.) and pine (*Pinus* spp.) are preferred habitat, providing seed from cone crops as a major food source for this sciurid (C. Smith 1968, M. Smith 1968, Rusch and Reeder 1978). However, stands of juvenile lodgepole pine (P. *contorta* var *latifolia*) covering burned or cutover forest land in western North America also support populations of red squirrels, often at densities comparable to mature stands (Sullivan and Moses 1986). In these stands, squirrels often feed on vascular tissues by debarking young lodgepole pine trees during May to early July (Sullivan and Sullivan 1982a). Feeding on vascular tissues, as well as fungi, buds, and shoots appears to occur when coniferous seed is in short supply. Barking damage by red squirrels in young lodgepole pine can occur in managed naturally regenerated stands or plantations (Sullivan and Sullivan 1982a, Sullivan and Vyse 1987).

Since this damage occurs during a relatively short period in the spring when food is presumably in short supply, would provision of diversionary food reduce tree damage? This question was answered by Sullivan and Klenner (1992) who reported that both manual and aerial applications of sunflower seed significantly reduced feeding damage to lodgepole pine trees by squirrels. In addition, Klenner and Sullivan (1992) concluded that the population density of resident red squirrels did not increase when diversionary food was added.

What, then, are the operational implications of using sunflower seeds as a diversionary food for red squirrels in young lodgepole pine forests? This paper discusses the research, development, and application phases of an operational system for large-scale provision of diversionary food. Logistics, costs, and sociological considerations are included in the application phase of this operational system.

MATERIALS AND METHODS

Study Areas

The study areas where the field testing and operational use of a diversionary food for red squirrels were conducted are given in Klenner and Sullivan (1992) and Sullivan and Klenner (1992).

Distribution of Sunflower Seed

Sunflower seeds were chosen as the alternative food since they are available commercially and closely simulate conifer seed, the principal food source for red squirrels. Sunflower seeds have an energy content of 6.82 kcal/g (Mrosovsky 1966) which is similar to those of interior spruce (*Picea glauca* x *Picea engelmannii*) (7.11 kcal/g), lodgepole pine (6.83 kcal/g), and Douglas fir (*Pseudotsuga menziesii*) (7.13 kcal/g (C. Smith 1968).

Sunflower seed was applied at an operational scale in 1991. Sunflower seeds were uniformly distributed by helicopter at a rate of 20.0 kg/ha over 200 ha at the West Fire (Quesnel), 120 ha at McGregor Creek (Vernon-1) and 120 ha at Bigg Creek (Vernon-2) during the period 3-5 May. Untreated blocks of lodgepole pine were available as controls at the West Fire and McGregor Creek study areas. However, due to the limited area (120 ha) of pine stands at Bigg Creek, a control block for this operational treatment had to be located at McGregor Creek where a large area (900 ha) of stands was available.

Assessment of Feeding Damage

Feeding damage to lodgepole pine was assessed according to the sampling design and statistical analysis outlined in Sullivan and Klenner (1992).

Table 1. Intensity of feeding damage to lodgepole pine crop trees in control and treatment blocks after operational applications of sunflower seed. Sample size in parentheses.

Study area and block	Average number of wounds/tree	Average class of partial girdling
Quesnel		
Control (200)	0.50	1.20
Treatment (200)	0.08	1.00
Vernon-1		
Control (200)	0.52	1.16
Treatment (200)	0.09	1.07
Vernon-2		
Control (200)	2.04	1.66
Treatment (200)	0.10	1.00

RESULTS AND DISCUSSION

Feeding Damage and Diversionary Food

Application of sunflower seeds on a large-scale (operational) basis in 1991 significantly ($F_{1,4} = 16.7$; $P = 0.02$) reduced damage by squirrels in treatment stands at the three study areas (Fig. 1). Cumulative incidence of damage prior to this experiment was similar ($F_{1,4} = 0.7$; $P = 0.47$) in control (average of 64.8% of trees attacked) and treatment (average of 71.2% of trees attacked) stands (Fig. 1). Intensity of feeding damage in 1991 also followed the pattern of reduced attack by squirrels where an alternative food was provided (Table 1).

Availability of an alternative food clearly reduced feeding on lodgepole pine trees during the damage period. This result was achieved in three different ecological zones or regions: Interior Cedar Hemlock, Montane Spruce and Engelmann Spruce-Subalpine fire, and Sub-boreal Spruce. Squirrels presumably do not require some essential nutrient present in pine vascular tissues. They apparently experience a food shortage during May and June which can be accommodated by an artificial food source such as sunflower seeds.

The choice of sunflower seeds as a diversionary food is supported by studies using these seeds to mimic "mast years," with squirrel abundance on food-supplemented areas increasing 3 to 4 times over that of controls (Sullivan 1990, Klenner and Krebs 1991). Thus, an abundant food supply of high nutritive value was preferred b> squirrels over the vascular tissues of lodgepole pine. A similar result was recorded for sunflower seed mixed with Douglas fir (Sullivan 1979) or lodgepole pine seed (Sullivan and Sullivan 1982b) in seed predation studies with the deer mouse. In these latter studies and mat by Klenner and Sullivan (1992), the target populations either changed little or increased in abundance only temporarily on food-supplemented areas.

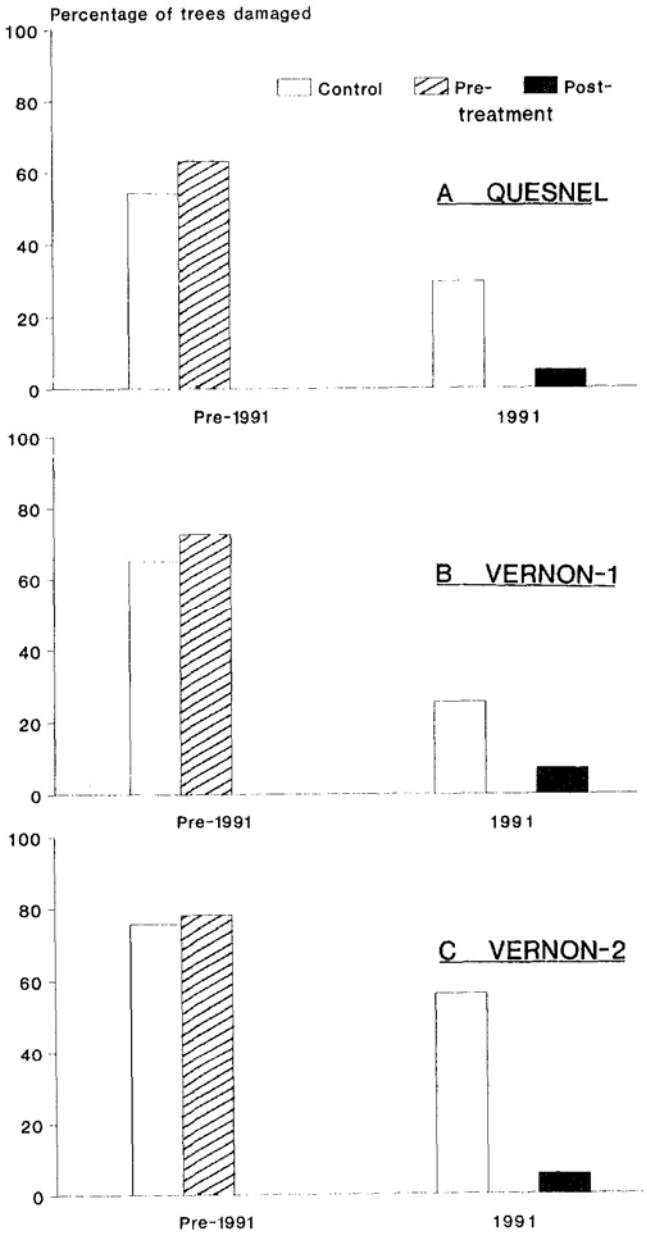

Figure 1. Percentage of lodgepole pine crop trees attacked by red squirrels in experiment 3 testing operational application of sunflower seeds as an alternative food at Quesnel, Vemon-1 (McGregor Creek), and Vernon-2 (Bigg Creek) study areas.

MANAGEMENT IMPLICATIONS

Application of Diversionary Food

In terms of application, the aerial method, with its uniform distribution, makes the sunflower seed readily available to squirrels and other seed-eating species at both an individual animal and population level. Costs are similar to manual application, but from a logistical perspective, manual is not nearly as efficient Seed must be applied in late April or early May to be effective in reducing damage. Clearly, if several stands require protection, then aerial application would be the more efficient method to cover large areas as quickly as possible.

The question of how many years lodgepole pine trees require protection is of critical importance. Squirrels begin attacking pine at an average d.b.h. of 6 cm (Sullivan and Sullivan 1982a) and this feeding appears to decline at about 20 cm d.b.h. (Sullivan, in prep.). Some trees of ≥20 cm d.b.h. are still attacked but the amount of feeding is small, particularly with respect to percentage of stem circumference girdled. Another factor, in addition to diameter, is bark thickness which is likely related to tree vigor (and hence phloem thick-

Table 2. Costs of aerial application of sunflower seed to lodgepole pine stands on an *operational basis per ha* at Vemon and Quesnel study areas in 1991.

	Vernon		Quesnel
	Bigg Creek [a]	McGregor Creek [b]	West Fire [c]
Sunflower seed (retail)	$27.55	$27.55	$25.21
Helicopter and seeding bucket	$16.89	$13.36	$14.21
Supervision and organization [d]	$1.33	$1.33	$1.25
Total	$45.77	$42.24	$40.67

Note: Number of ha treated [a]120, [b]120, [c]200; [d]one person-day @ $160/day

Table 3. Factors influencing adoption or adaptation of an innovation (new technology or system) by an organization (after Callaham 1984).

- Users (managers must want innovation
- All parties must accept and be compatible with the innovation and associated changes
- Adequate funding and infrastructure must be in place to carry out innovation
- Resistance to innovation and value systems of individuals and organizations must be dealt with skilfully and tactfully
- Climate of trust and willingness to accept challenge and risk
- Demonstration areas are essential
- Effective person-to-person communication, informal linkages of people with ideas

ness) and age, with fast-growing trees having thinner bark.

Therefore, a management strategy may be to enhance tree growth to reach beyond the 20-cm d.b.h. threshold as quickly as possible. Diversionary foods could be used to protect trees during the intervening vulnerable years. Costs of annual food supplementation for several years would be offset by the protection provided for these intensively managed and highly valuable pine stands.

Logistics and Costs

The cost of aerial application of sunflower seed to lodgepole pine stands on an operational basis ranged from $40.67 to $45.77 per ha which includes seed, helicopter time, and organization/ground assistance (Table 2). Thus, considering the $2,000+/ha invested in intensively managed (planting, weeding/brushing, thinning, and fertilization) stands of lodgepole pine, an additional expenditure of $40 to $50/ha per year to protect that investment is clearly reasonable. Even if this seeding program is required for five ($200-$250/ha) or ten years ($4O0-$500/ha), this effort would still be worthwhile. As already discussed, there is an endpoint (20 cm d.b.h.) beyond which protection of trees from squirrel feeding is no longer necessary. If we assume intensively managed stands of pine were protected from squirrel damage by seeding for ten years from age 20 to 30, the cost would be $400-$500/ha but the 30-year-old stand of pine would by then represent an investment of considerably more than $2,000/ha.

Application of Research Results

Application of research results is the sociological phase of vertebrate pest management which *must* be coupled with the biological phase if results are to be successfully applied. Understanding the application of new technology has been well reviewed by Callaham (1984). A summary of relevant factors that influence adoption or adaptation of an innovation are listed in Table 3. Individuals doing applied research who truly want to see the application of their work to a management problem should study the review by Callaham (1984) as well as other references on this important but much neglected subject.

Essential to the adoption of an innovation, which is an alternative approach in vertebrate pest management, are three additional key elements: the research results must be simple, credible, and timely (Callaham 1984, Bunnell 1989). With respect to diversionary foods and red squirrels, the concept and technique are simple, there is scientific credibility from replicated field experiments at both research and operational scales, and the concept and application are timely. Clearly, as reviewed by Marsh and Salmon (1992), there is a great need and desire for ecologically sound methods to manage vertebrate pests as a part of sustainable forest and agricultural practices.

The Future?

Diversionary foods offer an opportunity to reduce a vertebrate pest damage problem and enhance wildlife habitat in managed forests. Clearly, several species of seed-eating rodents and birds should benefit from application of sunflower seeds to these lodgepole pine stands which are susceptible to feeding damage by red squirrels. This combination provides a good example of integrated management of forestry and wildlife.

Enhancing wildlife populations and crop production on the same site has been historically difficult in North America. Thus, I hope that this example will help change the attitude of people working with vertebrate pests and encourage them to use their imagination and develop a willingness to try new approaches.

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