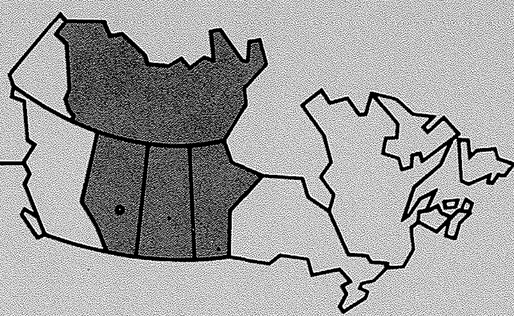
Government of Canada
Gouvernement du Canada

Canadian Forestry Service
Service canadien des forêts

Snowshoe hares and forest plantations: a literature review and problem analysis

A. Radvanyi



Information Report NOR-X-290
Northern Forestry Centre

The Northern Forestry Centre (NoFC) of the Canadian Forestry Service is responsible for fulfilling the federal role in forestry research, regional development, and technology transfer in Alberta, Saskatchewan, Manitoba, and the Northwest Territories. The main objectives of the center are research and regional development in support of improved forest management for the economic, social, and environmental benefit of all Canadians. Since 1982 the center has also assumed responsibility for the implementation of federal-provincial forestry agreements and employment stimulation programs in the forestry sector.

One of six regional centers, two national forestry institutes, and a headquarters unit, NoFC is located in Edmonton, Alberta, and has district offices in Prince Albert, Saskatchewan, and Winnipeg, Manitoba. Until joining Agriculture Canada in 1984 under a Minister of State (Forestry and Mines), the Canadian Forestry Service was part of Environment Canada.

Cover photo: courtesy of C. Gordon, Canadian Wildlife Service, Edmonton.

SNOWSHOE HARES AND FOREST PLANTATIONS: A LITERATURE REVIEW AND PROBLEM ANALYSIS

A. Radvanyi

INFORMATION REPORT NOR-X-290

NORTHERN FORESTRY CENTRE
CANADIAN FORESTRY SERVICE
1987

Catalogue No. Fo46-12/290E
ISBN 0-662-15628-5
ISSN 0704-7673

This publication is available at no charge from:

Northern Forestry Centre
Canadian Forestry Service
5320 - 122 Street
Edmonton, Alberta
T6H 3S5

Radvanyi, A. 1987. *Snowshoe hares and forest plantations: A literature review and problem analysis*. Can. For. Serv., North. For. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-290.

ABSTRACT

Snowshoe hare damage to forest plantations in the Canadian prairie provinces is studied through an extensive literature review. Interrelationships of habitat and snowshoe hare populations are examined. Eleven general methods of snowshoe hare damage control based on silvicultural treatments and population controls are presented and examined. Several avenues of research needed to improve snowshoe hare damage control procedures are suggested.

RESUME

Les dommages causés par le lièvre d'Amérique aux plantations forestières des provinces canadiennes des Prairies font l'objet d'une étude bibliographique exhaustive. Les relations entre l'habitat et les populations de lièvres sont examinées. Onze moyens de limiter les dommages grâce à des traitements sylvicoles et à la réduction des populations sont présentés et examinés. Plusieurs pistes de recherche sont proposées en vue de mieux limiter les dommages causés par le lièvre d'Amérique.

CONTENTS

NOTE

The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by the Canadian Forestry Service.

INTRODUCTION

As forest renewal requirements grow, the potential for financial loss due to hare damage increases and the need for practical and effective risk assessment and control strategies assumes greater importance. For example, it was recently estimated[1] that total investment from 1975 to 1985 in spruce-related silviculture in the prairie provinces (site preparation, planting, seeding, and tending) on sites with hare damage potential was 92.4 million dollars. The investment is increasing yearly as reforestation programs continue to grow.

This current literature review and problem analysis examines three main aspects of the snowshoe hare (*Lepus americanus*) problem in the prairie region:

1. the nature of hare impact on regional forests,
2. hare damage risk assessment potential and methods, and
3. hare control strategies.

The points are addressed on the basis of ecological principles, a substantial body of scientific literature, and the experience of the author. The results form a basis for future application and adaptation to find practical solutions to a growing problem in boreal forest management.

SNOWSHOE HARE HABITS, NEEDS, AND MOVEMENTS

Snowshoe hares forage on the bark and twigs of coniferous and deciduous trees and shrubs during winter and on leafy herbaceous plants during summer. Avoiding open areas, they prefer habitats that provide dense vegetative cover 1-2 m above ground level. A mosaic of early and late successional stages in close proximity are most preferred. In such habitats, snowshoe hares use the dense stands of late successional conifers for shelter and move up to several hundred metres into adjacent early successional stands for an abundance of food. Thus, a close proximity of coniferous cover, clear-cut areas, and diversity of habitat types (habitat interspersion) are prime requisites of ideal snowshoe hare habitat. Clear-cutting forestry practices and forest fires in the boreal forests of the prairie provinces have created early successional stages ideally suited for hare habitat. Such stands have increased from 50 000 ha to 70 000 ha annually between 1975 and 1980 in the prairie provinces.[2]

Fundamental to a description of snowshoe habitat, activity, and dispersal is the concept of edge effect (de Vos 1964; Conroy et al. 1979; Wolff 1980; Pietz and Tester 1983). Edge effect is augmented by current forestry practices of harvesting using a checkerboard pattern or long narrow cut blocks. Most hare activity occurs close to or in lowland coniferous communities. Activity is generally higher in area of habitat interspersion, such as along the edges of clear-cut or plantation sites, than in the center of these communities. Slash piles remaining near the perimeter of clear-cut operations provide obstruction refugia for foraging hares. High densities of snowshoe hares are generally not found further than 200-400 m from conifer cover (Keith 1974; Keith et al. 1984) and are less likely to be found in solidly canopied areas than in areas with high habitat interspersion. Heavy edge utilization of clear-cut areas or young plantation sites relate directly to the perimeter-area ratio. The more irregular the boundary or the smaller the total area, the greater the portion susceptible to hare damage. Snowshoe hares do not use plantations extensively in winter until the trees have attained sufficient height to provide a critical 60% conifer foliage cover value at 1-3 m above ground.[3] Because snowshoe hares do not dig through snow for food, young conifers, once covered with snow, are protected.

The principal winter food of snowshoe hares in Alberta consists of buds, twigs, and bark of aspen (*Populus tremuloides*), willow (*Salix* spp.), birch (*Betula* spp.), and rose (*Rosa* spp.) (Meslow and Keith 1971). As snow depth increases, the height above ground level at which a hare feeds also increases. Hares can reach and clip stems 60 cm above ground and snow level, and generally feed on stems up to 1.5 cm in diameter (Keith et al. 1984). Parker (1984) used summer live trapping, winter pellet counts, and assessment of twig browsing to

[1] Brace, L.G. 1984. Report to Regional Reforestation Technical Committee (RRTC) in Brandon, Manitoba. Unpublished report. Data based on Brace and Golec (1982).

[2] Brace, L.G.; Ball, W.J. 1982. The impact of snowshoe hares on commercial forests in the prairie provinces of Canada. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Unpublished report.

[3] Parker, G.R. 1985. Canadian Wildlife Service, Maritimes Region. Personal communication.

assess abundance of snowshoe hares. All three measures of habitat showed hares preferred plantations 11-16 years old. Hares selected against very young plantations and mature spruce-fir forests, thus emphasizing the primary needs of cover and availability of diverse browse species.

Snowshoe hares are fairly sedentary. Although not territorial, they do occupy well-defined home ranges that overlap considerably. The area of the home range may vary seasonally with population density and social pressures. Wolff (1980) estimated that the home range of snowshoe hares in Alaska did not exceed 10-12 ha. Approximately 50% of a hare's seasonal movements may take place in an area less than one hectare. Dense spruce stands or willow-alder thickets provide cover in winter, while more open habitats in summer allow hares to shift their habitat seasonally to change their diet. The home ranges of males and females do not differ significantly. Other estimates of snowshoe hare home range include 20-30 acres (8-12 ha) (Seton 1928), 10 acres (4 ha) (Grange 1932), 19-25 acres (7.5-10 ha) (Adams 1959), and 14.5 acres (5.9 ha) (O'Farrell 1965). The home range generally includes a variety of habitat types centering on dense conifers for cover and extending to nearby cut or burned areas for a rich diversity of deciduous and coniferous browse.

Low-growing conifer cover, whether in lowland or upland terrain, appears to be the key local determinant of snowshoe hare distribution (Aldous and Aldous 1944; Keith and Windberg 1978; Conroy et al. 1979; Buehler and Keith 1982). Seasonal shifts in habitat use appear to be linked to changing food and cover requirements but have one prominent physical attribute in common — the presence of low, dense woody cover. The latter fulfills a triple function in snowshoe hare survival by providing the source of winter food, protection from predators through concealment and physical obstruction, and shelter from inclement weather.

Movements on a broader scale between preferred refugia and more open habitat are related to population pressures and the characteristic 10-year cycle (Keith 1963; Wolff 1980, 1981). At low population density, snowshoe hares can survive throughout the winter in the refugia virtually free from predation. When the population increases to a point where overwinter food (woody browse) becomes a limiting factor in the refugia, hares, particularly juveniles, are forced to move into suboptimal habitats. Thus, during the low phase of the snowshoe hare cycle, hares are found only in the insular refugia. During high population levels, hare distribution is ubiquitous and the species is found in all suitable habitats. Suboptimal habitats may have more food seasonally, but in such habitats there is less cover and hares are more exposed to predation. As suitable habitats become more completely filled, the animals have nowhere else to go. The population becomes physiologically stressed and participates in mass movements during winter when food is limited, thus resulting in starvation, heavy losses to predation, and population decline.

TWO BASIC APPROACHES TO SNOWSHOE HARE DAMAGE CONTROL

Resolution of the snowshoe hare problem centers around two fundamental concepts, as listed below.

A. **Silvicultural treatments**, wherein the basic needs of cover protection from predators and a diversity of plant food items are effectively made less available to snowshoe hares on the plantation sites for as long as it takes for the young trees to grow beyond the reach of hares. The following silvicultural treatments are discussed in detail in this report:

1. *Habitat manipulation*—prescribed burning and thorough scarification to remove or minimize snowshoe hare cover and food sources. Area configuration to provide the least edge effect. Effective 1-2 years.
2. *Herbicide application* over several years after scarification and planting. Aerial application over established plantations should provide several more years of reduced snowshoe hare cover and food.
3. *Use of larger seedlings* with good height growth potential to improve chances of growing beyond the range of hare damage, and treat stands to encourage rapid height and diameter growth.
4. *TMTD-rabbit repellent treatment* of seedlings in nursery prior to transplant. Effective until next growing season (approximately 1 year).
5. *Physical barriers for individual seedlings*—use of 0.6-cm (¼-inch) repellent-treated mesh tubing cover or polyethylene sleeves over transplanted seedling for approximately 1 year.
6. *Physical barriers for plantations*—rabbit-proof fencing to exclude snowshoe hares from valuable plantation area. Highly effective but expensive.

B. **Population control**, particularly during peak population years when the greatest damage to forest regeneration is likely to occur. The following population control methods are discussed in detail in this report:

1. *Toxic baiting (poisoning)*—strychnine-adhesive sprays, strychnine-treated apple baits, oats, barley, carrot, alfalfa; poisoned salt-impregnated pegs; poisoned salt blocks. Timing critical; hazardous to nontarget species.

2. *Removal by shooting, trapping, snaring, night-lighting.* Can be effective if commenced before population buildup. Selective targeting, no secondary effects.

3. *Provision of alternate foods*—hay, lure crops. May attract even more hares into area.

4. *Chemosterilants*—difficulties with bait acceptance. Critical timing and dosage. Often requiring in-hand treatment—impractical in field.

5. *Biological control*—predators. Largely ineffective during peak population years. Myxomatosis—hazardous, nonselective, unacceptable to public.

Silvicultural Treatments

Habitat manipulation

Several measures may alleviate the impact of snowshoe hare damage to forest plantation seedlings. During years of low population in the hare cycle, the animals remain close to the preferred refugia of mature forest stands, where sufficient cover and food exist. The open habitats of the cutover areas are generally avoided, and damage to plantation seedlings during such years is minimal. During peak years, population pressures force the juvenile hares to move into suboptimal habitats such as cutovers, early successional areas, and newly established plantations. Hare damage to young, unprotected seedlings may be extensive during several years just before and after peak populations. The quantity of cull material and slash remaining after cutting, the degree of scarification or burn achieved, and the rapidity of early successional development directly effect the amount of cover and food available to snowshoe hares in such suboptimal habitats.

Reduction of the amount of cover against predators must be a prime requisite in successful establishment of a forest plantation. Thorough scarification or prescribed burning largely removes both slash and early successional vegetation for at least 1 year. Clear-blading into windrows, as suggested by Sullivan and Moses (1985), does not remove protective cover for snowshoe hares, but rather increases by many fold the characteristic edge effect favored by these animals.

Herbicide application

Because of the slow growth of conifer seedlings in prairie latitudes, additional years of protection against clipping damage by snowshoe hares are needed until seedlings attain heights beyond the reach of hares. Reduction of vegetation cover by application of appropriate herbicides may give seedlings 1, 2, or more years of protection against snowshoe hare damage (Borrecco 1976; Greaves 1978). Additional research is required to determine the possibility of extending this period of protection even further by reapplication of herbicides in subsequent years.

Use of larger seedlings and repellent treatments

Bare-root and container-grown coniferous stock currently used for reforestation in the prairie provinces is fairly slow-growing; for example, records for 10-year height growth of container stock in Alberta and Saskatchewan indicate averages of 1, 2, and 2.3 m for white spruce (*Picea glauca* (Moench) Voss), lodgepole pine (*Pinus contorta* var. *latifolia* Engelm.), and jack pine (*Pinus banksiana* Lamb.), respectively. Conventional bare-root stock (3–0 spruce and 2–0 pine) may do 20% better. Under ideal conditions for site preparation and crop release and using high-quality stock, the same heights might be achieved in 6–8 years.[4] Considering that hares can reach 0.6 m and snow depths may average 0.6 m in many areas, planted trees are vulnerable to clipping for long periods of time, even if planted at the low point of a 10-year hare cycle. Advantage should be taken of the faster growth rate of seedlings in the protected cultured environment of a tree nursery. For example, instead of 2–0 stock, larger seedlings grown 2 years in seedbeds and 2 or more additional years in transplant beds could be used in establishing plantations, or larger container stock or combined container transplant stock with more rapid height growth potential could be produced.

[4] Personal communication with L.G. Brace. 1986. Northern Forestry Centre, Edmonton, Alberta.

Hartwell (1969) referred to unpublished work by D.L. Campbell, who conducted a study in 29-in. (73.7 cm) Douglas-fir (*Pseudotsuga* Carr.) stock grown 2 years in a seedbed and 2 years in a transplant bed. Stock was exposed to a large number of snowshoe hares in an enclosure. After 4 months, the large seedlings sustained no reduction in average height, while whole seedlings grown only 2 years in the seedbed sustained a 14% reduction in average height.

Both lodgepole pine and jack pine are subject to girdling and other stem damage by hares. Sullivan (1984) found that such damage was significantly reduced as diameter increased, and was essentially eliminated for trees over 60–80 mm in diameter. Stem damage risk to pine can be reduced by planting trees with rapid diameter-growth potential and by stand treatments that favor larger trees or encourage rapid diameter growth.

As an additional measure of protection, seedlings could be treated with hare repellents before being planted in the field. Three repellent compounds applicable to woody plants to protect them against rabbit damage are trinitrobenzene-aniline (TNBA), zinc dimethyldithiocarbamate cyclohexylamine (ZAC), and tetramethyl thiuram disulphide (TMTD) (Besser and Welch 1959; Burns 1961; Walters and Soos 1961; Duffield and Eide 1962; Radwan and Dodge 1965; Hooven 1966; Bullard and Campbell 1968; Dodge 1969; Radwan 1969; Black and Hooven 1978). TMTD, a dithiocarbamate fungicide (Thiram), appears to be the most promising of the various spray repellents against hares and rabbits. It is nonphytotoxic. Besser and Welch (1959) reduced hare damage by 82% using TMTD on Douglas-fir seedlings in western Washington; Walters and Soos (1961) achieved 94% reduction in damage in B.C., and Hooven (1966) 93% in Oregon. The repellent is applied as a spray to dormant seedlings in nursery seedbeds prior to fall planting. One-half gallon of TMTD spray formulation is sufficient to treat 1000 2–0 seedlings in nursery beds and provides 11–22 mg of protectant per seedling. Application of TMTD protective spray to 2–0 seedlings cost at that time about 60 cents per seedling.

Hartwell (1969) exposed small and large untreated and TMTD-treated Douglas-fir seedlings to snowshoe hares in an enclosure where small seedlings had been decimated by hares. The small seedlings had been grown for 2 years in a seedbed; large seedlings had grown 2 years in a seedbed and 2 years in a transplant bed. After 4 months, 88% of the small untreated seedlings, 94% of the large untreated seedlings, and 4% of the large treated seedlings had been clipped by hares. After 6 years, 76% of the large treated stock survived, but only 52% of the large untreated stock survived. Furthermore, the large treated stock averaged 40.6 cm (16 inches) more height growth than did the large untreated stock. The difference was attributed mainly to the initial protection provided by the repellent, which enabled the terminal shoots to grow rapidly above the reach of hares.

A 1958 test applied TMTD to black and white spruce plantings. Less than 2% suffered hare clipping damage, while more than half of the untreated spruce were damaged.[5]

Repellent sprays applied to seedlings prior to field transplant are generally effective for approximately 1 year. New growth after the first winter in the field is unprotected by the treatment and is vulnerable to hare damage. Provision of additional years of protection to valuable research plantings by respraying of individual seedlings during subsequent years in the field does not appear to have been tried and may merit consideration.

Systemic repellents have been studied as a possible way to accord protection to the entire plant, including new growth material, over several years. Rediske and Lawrence (1962) tested the use of selenium both as a surface and a systemic repellent. The selenium coating proved to be effective against rabbits. In the selenate (SeO_4) systemic form, foliage containing 5000 mg/kg (0.5%) of the selenium caused test animals to develop an aversion to seedlings receiving this treatment. With snowshoe hares, a 0.5% selenate solution coating was more effective in preventing damage than standard 10% thiram coating. In later studies Rediske and Lawrence (1964) considered selenium somewhat toxic to Douglas-fir seedlings when applied in concentrations sufficient to cause repellency. Octamethylpyrophosphoramide (OMPA), an organic phosphate systemic, was found to be less toxic to Douglas-fir seedlings, and at 400 mg/kg converted to a toxic substance in the liver of the test animal to produce a repellent aversion action. To cause such an action, a rabbit would have to consume 100 grams of seedling material with a tissue concentration of 500 mg/kg OMPA.

Repellents such as SKOOT or AA PROTECT, which contain N-butylmercaptan, a chemical in skunk or

[5] Krafting, L.W. 1958. Deer and hare repellent studies in Minnesota and Wisconsin, 1957–58. Fish Wildl. Serv., Univ. Minnesota, St. Paul, Minnesota. Unpublished report.

mink odor, have been tested to deter rabbit browsing, but without wide acceptance (Thompson 1953; Pepper 1976).

Application of fecal odors of bobcat and mountain lion to preferred foliage of black-tailed deer reduced browsing by 51% and 27%, respectively, but the inefficiency of procuring sufficient quantities of such fecal materials precluded widespread use of such repellents (Melchiors and Leslie 1985).

The compound 3-propyl-1,2-dithiolane, obtained from stoat anal glands and mixed with petroleum ether, suppressed hare feeding on lodgepole pine seedlings during a 5-week early spring field trial in British Columbia. Continuing research is centered on perfecting a longer-lasting, slow-release predator odor repellent to control snowshoe hare, small rodent, and black-tailed deer damage to forest seedlings (Sullivan and Crump 1984, 1985). Once perfected, the synthetic preparation will be enclosed in microscopic glass tubules that will be scattered aerially over areas to be protected from hare damage. While the procedure may offer protection for several years, Sullivan admits little can be expected in the line of repellency from the technique once the tubules are buried under snow.[6]

Two repellents tested against Leporidae—Emol and Repentol-6—have proven highly effective in protecting trees in Europe and may merit field testing against snowshoe hares in Canadian forest plantations (Szukiel 1981). As well, R-55, a carbamate repellent applied to black walnuts, completely deterred digging up of nuts by black squirrels in a plantation study in Ontario and may be a worthy candidate as a snowshoe hare repellent if applied as a spray to plantation seedlings.[7]

While growth rates comparable to west coast Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco.) cannot be achieved for spruce or pine in our climate, the advantage of larger initial seedling size, particularly if combined with the protection of an effective repellent, may enable plantation seedlings to escape the devastating damage of the first high hare population peak.

Physical barriers to protect seedlings

The use of 30–92 cm wire screen cylinders supported by stakes and placed over individual seedlings provides effective protection against clipping damage by snowshoe hares. Because of the expense factor, however, the approach may not be acceptable in protecting seedlings on large plantations.

Inexpensive and effective plastic mesh (Campbell 1969; Black and Hooven 1978; Baer 1980) and polyethylene sleeves (Mason and Davidson 1964) placed over individual seedlings at time of planting have proven effective against hare and deer damage. Various-sized mesh was tested, with the ¼-in. size proving most effective. Both the seedlings and the netting can be treated with repellent. Treatment of the netting allows use of moderately phytotoxic chemicals that cannot be applied directly to the seedlings. The cost of net tubing was approximately 5 cents per seedling. The cost of polyethylene sleeves cut from large rolls was approximately $2 per thousand. Natural deterioration of the sleeves occurs quickly after one season of exposure.

Close mesh fencing 90–125 cm high and buried at least 15 cm in the ground has been used extensively and has proven most effective in excluding rabbits and hares from orchards, crops, and plantations as well as other mammalian predators (Nichols 1951; Johnson 1964; Canada Agriculture 1965; Evans et al. 1970; Fitzwater 1972; Pepper 1976; Wade 1982; Knight 1983). To be entirely effective in excluding snowshoe hares, the fence structure must exceed maximum snow depth, follow soil topography closely, avoid barriers such as stumps, rocks, and snow drifts, and be frequently patrolled and repaired. Only extremely valuable crops can justify the high costs involved in the fencing procedure—more than $2,000 per mile of crop edge (Knight 1983). Kverno (1964) quotes 1964 pricing for rabbit fencing at $56 per acre to enclose a 30-acre (12 ha) plot or $10.53 per acre ($26.75 per ha) to enclose a 1-square-mile (252-ha) area. Hundreds of kilometres of rabbit-proof fencing used in rabbit control in Australia are erected, maintained, and patrolled by the state (Nichols 1951). If properly installed, fencing is the most effective and longest-lasting method of protecting young plantations against snowshoe hare damage.

Population Control

Toxic baiting

Massive poisoning programs to control rabbit and hare populations have been carried out for more than 30 years in New Zealand and Australia with moderate

[6] Personal communication with T.P. Sullivan, 1985.

[7] Radvanyi, A. 1973. Coulson Tract small mammals and their effective control. Environ. Can., Can. Wildl. Serv., Edmonton, Alberta. Unpublished progress report.

success, using such poisons as sodium monofluoroacetate (1080), arsenic trioxide, strychnine, and zinc phosphide (Tomlinson 1970; Peters 1972; Batcheler 1974; Fennessy and Mykytowycz 1974; Godfrey 1974; Nelson 1978; Oliver et al. 1982). Other methods have included use of anticoagulants to control jackrabbits (*L. californicus*) in the U.S.A. (Johnson 1964; Evans et al. 1970; Johnston 1978; Oliver and Wheeler 1978; Wheeler and Oliver 1978; Barnes et al. 1982; Knight 1983).

Aerial application of 1080 poison to carrot, oat, and raspberry flavored apple jam is considered the only successful method of controlling animal pests such as rabbits in New Zealand at the present time. Approximately 750 000 ha are poisoned annually at a cost of between $2.50 and $8.00 per ha with a resultant kill of at least 90% of the target pest species (Nelson 1978). Earlier, Godfrey (1974) indicated 1080 baits applied to 600 000 acres (236 220 ha) annually cost $5 million per year, equivalent to 1.5 New Zealand dollars per capita or 50 cents per acre ($1.27 per ha). There are problems with this method, however; because the poisoned animals are seldom removed, they constitute a hazard, particularly to dogs. Further, quail, deer, and feral goats feed on the poisoned oats and carrot bait. Secondary poisoning of hawks, ferrets, and domestic cats does occur, but few such animals are found. Rabbits show no aversion to 1080 on carrot baits. Approximately one quarter of the rabbits do not take the bait and therefore survive (Batcheler 1974; Peters 1976).

Two procedures are followed using the 1080-oats bait: 1) prebaiting for several days using nontreated grain, followed by presentation of 1080-treated grain; 2) the "one-shot" approach, in which no prebaiting is applied. Instead, bait consisting of 99% nonpoisoned oats is mixed with 1% oats that have been vacuum-impregnated with 1080 solution and dried. Each poisoned oat grain contains about 4.5 mg of 1080 (about three times the lethal dose for an adult rabbit).

A variation on the 1080-carrot or oat poisoning technique is to mix the toxicant with a sticky substance and spread the mixture onto the floor or opening of a rabbit burrow (Fennessy and Mykytowycz 1974). The rabbits are poisoned as a consequence of licking the sticky poison material from their feet.

Another mode of 1080 application in rabbit control relies on the appetite of these animals for salt (Fennessy and Mykytowycz 1974; Myers 1975). Soft wooden pegs impregnated with 1080-laced sodium chloride and sodium bicarbonate are avidly sought and chewed upon by rabbits, with lethal results. Rabbit numbers continue to drop even after treated pegs are removed as rabbits continue to feed on pegs taken into burrows. This method is inexpensive and easy to apply; treated pegs cost approximately 5 cents each, and thousands can be prepared at a time in small commercial pressure cookers.

While the use of 1080 is largely banned from pest control measures in North America, other poisons used in rodent control may have application in reducing snowshoe hare numbers. Zinc phosphide is registered for control of several vertebrate pest species, such as field and orchard mice, pocket gophers, and rats. Zinc phosphide largely meets the desired characteristics of an ideal rodenticide as outlined by Hood (1972): 1) it is a toxicant well accepted by target species; 2) it is selectively toxic to target species; 3) it is safe to handle by humans; 4) it causes no secondary hazards; 5) it is slow acting to minimize bait shyness; 6) it causes painless and nonviolent death; 7) it decomposes into harmless products; 8) it is nonaccumulative; 9) it is not translocated in vegetation; 10) it can be counteracted by an antidote; 11) it is economical; and 12) it is registered by the Environmental Protection Agency and the Food and Drug Agency.

Zinc phosphide is insoluble in water and alcohol and only slightly soluble in alkalis and oils. It decomposes in the presence of acids and alkalis to produce zinc oxide or salts and phosphine, a highly toxic, colorless gas with a garlic-like odor. Upon ingestion, zinc phosphide reacts with the dilute acids of the gastrointestinal tract and produces phosphine, which enters the bloodstream. Chronic exposure to phosphine may cause nausea, vomiting, diarrhea, tightness of chest, coughing, headaches and dizziness, thirst, back pains, coldness and stupor, fainting, convulsions, paralysis, and coma. No secondary poisoning is caused unless the predator consumes the stomach contents of the prey (Hood 1972).

An alternate poison, strychnine, is widely used in rabbit control (Johnson 1964; Evans et al. 1970; Knight 1983). The toxicant can be applied to carriers such as alfalfa leaves, oats, milo, barley, and sorghum heads for use in jackrabbit control. Johnson (1964) recommended 3-4 days prebaiting with oil of anise applied to rolled barley and then use of 2% strychnine alkaloid on barley bait.

Effective control of jackrabbits has been achieved using the second-generation anticoagulants Diphacinone (Johnston 1978), Pindone (Oliver and Wheeler 1978), Brodifacoum (Kaukeinen 1982), and Bromadinalone (Knight 1983). Wheeler and Oliver (1978) found

Pindone stayed on an oat bait under moist climatic conditions better than 1080. Rabbits subjected to Pindone anticoagulant poisoning experienced widespread hemorrhaging throughout the muscles of the posterior aspect of both hind legs, massive leakage of blood into the abdominal cavity, hemorrhaging in muscles around the rib cage and in the submandibular region, and numerous small subcutaneous hemorrhages over the body, pericardium, and cerebral regions and exterior orifices. Chlorophacinone and Diphacinone are two other indandione derivatives that may have rabbit control applications.

Johnston (1978) lists the cost of preparation of 0.005% diphacinone-treated barley sufficient to service 100 bait stations used in jackrabbit control at 12 cents per rabbit killed (cost of poison and grain only).

Whether poisoned baits are applied aerially or dispersed along furrows from ground vehicles (Griffith and Evans 1970a), the bait is readily available to both target and nontarget avian and mammalian species. Killed rabbits and hares are not always picked up and disposed of. Incidents of direct kill or secondary poisoning of nontarget scavengers are seldom reported. The use of poisoned-bait feeder stations, such as those designed for rodent control and used by the Canadian Wildlife Service, limit access by larger mammals and birds to the poisoned bait (Radvanyi 1974, 1980). A need exists for designing and experimentation with a similar feeder station device applicable for hare control studies.

Physical removal of hares

Numerous physical means of diminishing rabbit and hare populations, particularly during peak population periods, have been reported with various and sometimes contradictory results. Williams et al. (1964), Johnson (1964), Griffith and Evans (1970b), McCabe (1981), Williams (1983), and Knight (1983) maintain shooting, particularly if coupled with a team approach using vehicular night-lighting, is a proven effective method for preventing rabbit damage for forests and crops, and can remove a high percentage of the hare population. On the other hand, others maintain that even heavy shooting by groups accounts for less than a 5% population reduction[8] (Evans et al. 1970).

Shooting as a control measure is made more difficult by the close association of snowshoe hares to dense vegetation and a primarily crepuscular and nocturnal activity pattern (Keith 1964). Vehicular spot-lighting and shooting may be effective on flat rangeland terrain but of limited value on agricultural or forested lands. The excessive social pressure of peak population years forces greater travel that may negate the effectiveness of created vegetation-free zones of up to 400 m (¼-mile) wide around plantations. Nightly excursions by jackrabbits may exceed 3 or more kilometres (Evans et al. 1970). Thus even the vegetation-free barriers fail to keep jackrabbits from damaging crops. McCabe (1981) found shooting of cottontail rabbits was only an in-year control measure, influencing rabbit populations in subsequent years only if a high proportion of female animals were shot. Reduction of snowshoe hares from plantation sites may also be prone to massive influx of animals from larger surrounding areas during peak population years, thus negating the effectiveness of shooting as a control method. If shooting is employed as a population control procedure, it should be started several years before peak populations are reached.

While trapping, snaring, and netting may be useful in population marking studies, they are slow and ineffective as a method of population control (Johnson 1964; Keith 1965; Keith and Meslow 1968; Shepherd et al. 1978). Field rabbits do not respond readily to apple and green vegetable baits, which do not remain palatable under field conditions.

Provision of alternate food

Provision of alternate foods to lure animals from feeding on trees has long been practiced (Aldous and Aldous 1944). Fallen pine foliage and slash resulting from manual spacing operations can provide hares with alternate sources of food with little resultant tree barking crop damage during the first winter after spacing (Sullivan 1984). The weight of heavy snowfall accumulation on tree branches and larger deciduous saplings may bend significant additional browse material within reach of winter snowshoe hare populations (Pruitt 1970; Telfer 1974; Pease et al. 1979). Supplying extra food for snowshoe hares and deer, however, might attract more animals to the area than would normally be present (Aldous and Aldous 1944; Dasmann et al. 1967; Sullivan and Sullivan 1982; Sullivan 1984). Provision of supplemental winter food failed to prevent damage by jackrabbits to grain and hay crops (Borrecco 1976).

---

[8] Personal communication with L.B. Keith. 1982.

Chemosterilants

Balser (1964a) outlined the following advantages to be derived from the use of antifertility agents:

1. It is more practical to prevent birth than to exterminate animals fully grown and established.

2. Often animals compensate for mortalities by increasing reproduction. Suppressing reproduction prevents such compensatory increases.

3. Use of toxic agents usually develops an aversion in target animals, thus reducing effectiveness of the toxic agents. A readily acceptable antifertility agent eliminates this factor and permits a higher percentage of the animals to be baited.

4. Nontoxic antifertility agents are safer and more readily accepted by the public, thus enabling more effective control.

To be suitably effective, an antifertility agent should:

1. be effective in a single dose on either sex at several stages of reproduction;

2. have a wide margin of safety between effective and lethal doses;

3. be stable, inexpensive, and effective in doses under 500 mg for practical field application;

4. be tasteless, odorless, or capable of being masked to avoid aversion to baits;

5. should be without side effects; and

6. have sterility effect for one breeding season or one year.

While the concept of limiting animal populations by interfering with the reproductive process merits consideration, administration to and acceptance by animals of antifertility agents outside the laboratory environment have been problematical. The method has been used in attempts to control reproduction of rodent pests such as Norway rats (*Rattus norvegicus*), roof rats (*Rattus rattus*), ground squirrels (*Citellus* spp.), and house mice (*Mus musculus*) (Howard and Marsh 1969; Marsh and Howard 1969); of captive meadow voles (*Microtus pennsylvanicus*) (Storm and Sanderson 1970); of canids (Jackson 1953; Balser 1964b; Linhart and Enders 1964); of rabbits, mink, and cattle (Greenwald 1957; Balser 1964b); of deer (Matschke 1976, 1977a, b; Harder and Peterle 1974), and of wapiti (Greer et al. 1968). Synthetic estrogens have been administered to female animals orally, by subcutaneous injection, intramuscular implants, or as intravaginal mechanical devices.

The varying success that chemosterilants have had in interfering with reproduction in a wide spectrum of animal species leaves as questionable the merits of the method as a procedure for controlling snowshoe hare populations in their natural environment. Inclusion of mestranol, a synthetic estrogen, into the bait of wild Norway rats led to initial interrupted reproduction followed by aversion (Howard and Marsh 1969; Marsh and Howard 1969; Storm and Sanderson 1970). Diethylstilbestrol (DES) incorporated in tallow baits prevented reproduction in wild foxes provided one or more baits were taken during the period 9 days before and 10 days after mating (Linhart and Enders 1964). DES included in the feed of white-tailed deer failed to prevent pregnancy due to aversion toward the treated feed (Matschke 1977b). Subcutaneous implantation of estrogen (DES) or a synthetic progestin (DRC 6246) into white-tailed deer 1 month before the breeding season proved effective in inhibiting reproduction (Matschke 1977a). Insertion of intravaginal mechanical devices failed, however, to prevent pregnancy in females of the same species (Matschke 1976). Harder and Pertele (1974) encountered an aversion toward DES when they attempted to incorporate the antifertility agent into a corn feed or by insertion of DES tablets into quartered apples to control reproduction in white-tailed deer. Nor did intramuscular injection of DES into elk already 2.5 to 5 months pregnant arrest most of the pregnancies (Greer et al. 1968).

The estrogen antagonist drug CN-55, 945-27, produced by Parke-Davis Research Laboratories, administered on a corn diet at approximately 20 times the antifertility potency of mestranol, prevented pregnancy in all treated female Norway rats (Gwynn and Kurtz 1970). The authors suggest that in natural habitats, the drug might be included in drinking water or used in a powdered form in runways to be picked up on the feet and undersides of target animals and ingested during grooming.

Whereas the prevention of pregnancy by treatment of the female is highly dependent upon the timing of the treatment, an antifertility agent influencing the male of the species may be more worthwhile. U-5897 (trade name Epibloc), a chlorohydrin, causes reversible antifertility effects in male monkeys, guinea pigs, and white rats. The compound causes formation of a lesion in the caput epididymis that completely blocks passage of sperm to the exterior. While the drug sterilized Norway and laboratory rats, it had little value on Polynesian rats (Kennelly et al. 1970; Ericsson et al. 1971; Ericsson 1982).

Other antispermatogenic compounds used in vertebrate pest control include ethyleneimide derivatives, triethylenemelamine (TEM), triethylenethiophosphoramide (thio-TEPA), Myleran, a methanesulfonate, glyzophrol, and nitrofurnes (Marsh and Howard 1970).

Three daily 15-μg injections of 17B estradiol benzoate can interrupt pregnancy in rabbits at any time during the first 7 days after mating. Normally, blastocysts are evenly spaced throughout the length of the cornu by the 7th day postcoitum. The estrogen induces death of the embryos in utero by abnormal spacing of the blastocysts, thus crowding the embryos at the cervical and ovarian ends of the uterus. Interruption depends, therefore, upon the stage of development in the reproductive tract. Initially, degeneration of blastocysts occurs through the estradiol-induced reduced deposition of the mucin layer by the tubal epithelium. Later implantation and postimplantation death occurs at the 96-h stage from abnormal spacing of the blastocysts (Greenwald 1957).

Another potentially useful approach applicable to managing reproduction in herbivores may rely on use of plant products that interfere with reproduction. Fifty plant families, genera, and species have been documented as having antifertility effects on males and females (Kirkpatrick and Turner 1985).

Chemosterilants may be an effective, nonlethal method of limiting reproduction in some pest species but not in others. Several of the antifertility compounds may merit further research in controlling snowshoe hare populations on limited high-value study areas. Further refinements on bait acceptance at a time coincident with commencement of breeding are needed. Frigid temperatures would negate the use of carrot or apple carriers of antifertility agents to prevent normal first litters, although corn or alfalfa hay may be acceptable substitutes.

Biological control

Biological control considers the role of predators and diseases as limiting agents of population size. Common predators of snowshoe hares in Alberta include lynxes (*Lynx canadensis*), coyotes (*Canis latrans*), long and shorttailed weasels (*Mustela frenata* and *M. erminea*), great horned owls (*Bulbo virginianus*), goshawks (*Accipiter gentilis*), and red-tailed hawks (*Buteo jamaicensis*). To a lesser degree, feral dogs and cats, great gray owls (*Stix nebulosa*), sharp-shinned and Cooper's hawks (*Accipiter striatus* and *A. cooperi*), broad-winged hawks (*Buteo platypterua*), marsh hawks (*Circus cyaneus*), and ravens (*Corvus corvax*) also prey upon the snowshoe hare population (Brand et al. 1975).

The impact of predators becomes increasingly important as a mortality factor depressing the population decline in the 10-year cycle once initiated by overwinter food shortage and low juvenile survival. Studies by Nellis and Keith (1968), Nellis et al. (1972), and Wolff (1980) suggest a 1-2 year lag in the lynx cycle with respect to the hare cycle. Because of this lag period, predation can be expected to have but minor impact on hare populations during peak cycle years.

Methods for dramatically reducing rabbit and hare populations have been adopted in Australia and New Zealand (Nichols 1951; Ratcliffe et al. 1952; Herman 1953; Tomlinson 1970; Fennessey and Mykytowycz 1974; King and Wheeler 1981; Waithmann 1981; Williams 1983). During the 1860s, the European rabbit (*Oryctolagus cuniculus*) had been introduced. With lush vegetation and a near complete lack of controlling predators, the rabbit thrived and spread across the country. By the turn of the century it became a pest competing with livestock for pasture, damaging agricultural crops, and accelerating landscape erosion. By 1950 there were about 750 million rabbits in Australia. In 1951 the virus disease myxomatosis was introduced from South America. Myxomatosis, carried by several species of mosquitos, dramatically reduced the huge rabbit population (Douglas 1981). The European rabbit flea (*Spillopsyllus cuniculus*) was introduced into Australia to aid in the spread of myxomatosis through the rabbit population. Myxomatosis proved less successful in New Zealand, but massive poisoning programs carried out there by a large number of municipal pest control authorities or boards reduced rabbit numbers, at least in the main agricultural areas.

The accidental release of myxomatosis in England and Europe, transmitted by the rabbit flea, wiped out 99% of the total rabbit population (Moore 1970; Vaughn 1979; Ross and Tittensor 1981). Whereas in Australia and New Zealand the rabbit had become a pest, in Europe it had been a source of sport hunting. Myxomatosis occurs naturally in some lagomorph populations in California but at such low levels that there is no evidence of effective control (Marsh and Salmon

1981). Fear that the disease may not be specific for pest species alone has led to reluctance to introduce myxomatosis or exotic predators into other wildlife populations in North America (Howard 1967).

ANTIHERBIVORY DEFENSE OF PLANTS

A third approach to snowshoe hare damage control, antiherbivory defense of plants, is still at the experimental stage. The following is a discussion of progress in this area.

The staple winter diet of hares consists primarily of small-diameter lateral and terminal twigs of conifer and deciduous trees and a wide variety of shrubs. During summer hares feed on herbaceous plants and grasses. Severe clipping damage may result not only in deformation and marked reductions in height growth, but, if combined with bark girdling damage, may also kill young trees.

While a wide variety of tree species are fed upon, a select preference for certain food species appears to exist while others are avoided by browsers such as deer and snowshoe hares. The possible cause of avoidance of browsing on particular species, and the possibilities of encouraging propagation of these species, have been examined by several researchers. Different genotypes of Douglas-fir, for example, vary widely in their susceptibility to browsing (Radwan 1972, 1975). It has been postulated that if the resistance characteristics were genetically transmittable through breeding, they could be used in selective rearing of Douglas-fir trees resistant to deer and hare browsing (Dimock 1974; Dimock et al. 1976; Dickmann 1978). Clones with high resistance to deer browsing have lower dry matter and cellulose digestibility, essential oils with greater inhibitory action on rumen microbial function, higher content of fat, total phenols, flavanols, and leucoanthocyanins, and lower levels of chlorogenic acids than do genotypes preferred by deer. Factors or combinations of factors responsible for preferential browsing differences have not been determined.

Subsequent studies (e.g., Radwan and Ellis 1975) indicated clonal Douglas-fir foliage resistant to deer browsing produced more terpenes than did browse-susceptable clonal foliage. Conifers contain terpenes and other compounds that inhibit rumen microbial function in ungulates (Oh et al. 1968), making conifer needles relatively unpalatable even though they are an abundant source of maintenance energy during winter. Caecal digestion in rabbits is possibly also interfered with by rumen toxins (Fox 1978).

Animals browsing on Douglas-fir have a strong preference for young growing tips of branches rather than for mature needles (Maarse and Kepner 1970). As the new growths emerge in the spring, they possess little or none of the acyclic oxygenated monoterpenes (citronellal, citronellol, citronellyl acetate, geranyl acetate, and linalool). These compounds increase in amount as the needles mature. The palatable young growing tips of Douglas-fir foliage also have lower concentrations of monoterpene alcohols and carbonyl compounds, which are highly inhibitory to the functioning of rumen microorganisms in deer and sheep.

Many browse species of plants have evolved chemical defense mechanisms against herbivorous damage such as perpetrated by snowshoe hares (Oh et al. 1968; Fox 1978; Bryant 1981a, b, 1983). Certain woody plant species and genotypes are more resistant to attack than others; for example, late successional evergreen browse species like black spruce (*Picea mariana* (Mill.) B.S.P.) and alder (*Alnus* B. Ehrh.) are more resistant than early successional willows, aspen, or birch. The resistant species are also of extremely low nutritive value. Bryant (1981b) maintains palatability of snowshoe hare browse is related less to nutritive content than to the presence or absence of plant secondary constituents that serve a defensive function. For example, ether-soluble resins found in mountain birch (*B. pubescens*) are repellent to Norwegian mountain hare. Certain ether-soluble compounds have antimicrobial activity in the gut of hares; these resins have evolved as a consequence of hare browsing. Subarctic birches have internode resin glands in those growth stages that are subject to snowshoe and mountain hare predation. The juvenile-growth-stage twigs of a browse species contain considerably higher concentrations of ether-soluble substances than do mature-growth-stage twigs. The foliar and floral buds of green alder (*Alnus crispa* (Ait.), Alaska paper birch (*Betula neoalaskana* Sarg.), and balsam poplar (*Populus balsamifera* L.) are extremely rich in ether-soluble substances and are, therefore, less browsed. The resins thus serve a defensive function against hare browsing; even starving snowshoe hares refuse to eat the extremely resinous foliage and foliar buds of Alaska paper birch.

Following heavy browsing, certain plants, particularly willow, revert to a juvenility stage by producing adventitious shoots. These new juvenile growths have increased production of phenolic substances and resins that serve as defensive functions against additional snowshoe hare browsing. The adventitious shoots of preferred browse species are less palatable to snowshoe hare than the mature-growth-stage twigs of either alder or black spruce. Snowshoe hares almost totally avoid eating adventitious shoots of willow if the growth is less than 4 years old. After that, the shoots are highly palatable.

Bryant (1981b) offers an alternate causal relationship to the Keith model of snowshoe hare cycles. Keith bases the population crash on feeding of snowshoe hares beyond the carrying capacity of the environment followed by lowered reproduction and juvenile survival and increased predation. Bryant (1981b), however, places emphasis on browsing by snowshoe hares during the late decline and early peak phase that causes depletion of the supply of small-diameter, mature-growth twigs of browse species that make up the snowshoe hare's staple winter diet. This excessive browsing causes the production of adventitious shoots, which are highly unpalatable to hares. Thus, peak- and decline-phase hare populations are forced to feed upon less-preferred browse species' adventitious shoots and to girdle preferred browse species. Consequently, the hare population crashes even though the total supply of small-diameter twigs has not been completely depleted. Because of this defensive response to hare browsing via reversion to juvenility and increased production of phenolic substances and resins, the new browse is unusable by snowshoe hares for approximately 2–3 years following its production, and the growth rate of a postcrash snowshoe hare population is subject to a time-delayed density-dependent negative feedback of sufficient magnitude to generate a 10-year cycle.

Secondary compounds in plants have both toxicological and behavioral effects on many groups of organisms, including not only herbivorous insects, mammals, reptiles, and mollusks, but also nematodes, viruses, bacteria, and fungi. The development of chemical defenses, extensively studied by Feeny (1976), Levin (1976), Edmunds and Alstad (1978), and Coley (1980, 1983), has been a coevolutionary process with a variety of predators, parasites, and pathogens matching tolerance and adaptivity at each progressive step. The evolution of defence mechanisms of plants and the parallel adaptive processes of herbivores are ongoing procedures. Any plan to culture clonal varieties largely immune to snowshoe hare damage must recognize potential parallel adaptiveness on the part of the herbivore.

Antiherbivore defense mechanisms, as currently understood, still do not offer the prospects of a panacean solution to snowshoe hare damage, particularly in the element of large monocultural environments such as conifer plantations.

ASSESSMENT OF SNOWSHOE HARE DAMAGE RISK POTENTIAL

The second objective of this review is to examine what environmental factors, if present singly or in combination, may be considered conducive to extensive snowshoe hare damage to forest plantations in the prairie provinces. This complex subject can perhaps best be reviewed by examination first of the cyclical nature of snowshoe hare populations within their range and secondly in the principal requirements of individuals within the species in relation to food, shelter, dispersal, and limiting factors.

As indicated earlier, snowshoe hares occur throughout the boreal forests of North America. In the northern part of its range, the population fluctuates in an approximate 10-year cycle. In the western United States at the southern limit of the range, the population is almost noncyclical. Here, the discontinuity or patchiness of preferred spruce-fir habitats, the competition with several conspecific lagomorphs, the continuous presence of predators, and the resultant low survival of dispersers into suboptimal habitats combine to prevent buildup of the hare population (Wolff 1977, 1981). Leopold (1933) suggested that the amplitude of hare population cycles was higher on large, continuous blocks of range than on small, dispersed, or discontinuous blocks.

Within its range, suitable hare habitats may be termed preferred or optimal, suboptimal, or marginal, depending upon the degree of availability of food and shelter and the probability of survival. During the high of the cycle, hares can occur in all suitable habitats including marginal. During the low phase of the cycle, hares are found only in the most preferred habitats or refugia. With population growth and before the carrying capacity of the area is reached, hares disperse from the refugia into suboptimal habitats. The late low-density phase of the population cycle is marked by an increase in reproductive rate and a decrease in mortality (an increase in survival of dispersing adult and juveniles and a decrease in predation). As the population continues to rise, individuals (predominantly juveniles) are forced to move into marginal areas further removed from continuous dense canopy cover of the preferred habitat (Meslow and Keith 1968). When all suitable habitats are filled and the population continues to grow beyond the carrying capacity, surplus animals have nowhere else to go and undertake massive frustrated dispersal. Under winter conditions such animals suffer heavily from starvation and predation.

As snowshoe hares increase beyond the carrying capacity, a temporary destruction of the habitat and a 2-3 year lowering of the carrying capacity occurs, initiating a sharp decline or crash in the population (Keith 1974; Pease et al. 1979; Wolff 1980). As the food supplies are reduced by peak hare populations, the interaction between malnutrition and low temperatures is intensified. Individuals spend longer periods of time exposed while searching for food. Decreased quality and quantity of food, and increased expenditure of energy looking for food, increase chances of predation as hares move between habitats. During the 3rd and 4th years of the decline, open willow, mature birch, and aspen stands are vacated. During the low phase of the cycle, hares are again found only in the preferred habitats or refugia.

During winter months, individual adult snowshoe hare consume approximately 300 g of browse daily (Bookout 1965; Pease et al. 1979). Normally these consist of twigs and stems whose basal diameters range from 3–4 mm or less. The small-diameter terminal portions of willow and alder are richer in protein, calcium, magnesium, potassium, and zinc than are the larger-diameter, more proximal portions of the same browse stems (Wolff 1980). During peak population years, when availability of browse becomes a limiting factor, hares revert to browsing on twigs up to 15 mm in diameter—an indication of food stress. There is a direct correlation between undernutrition and consumption of larger diameter twigs. Hares feeding on stems with diameters of 6–15 mm have to consume considerably more browse to attain the essential nutrients and spend more time foraging than if they were feeding on twigs of 3-mm diameter (Wolff 1980).

RECOMMENDATIONS TO MINIMIZE SNOWSHOE HARE DAMAGE TO FOREST PLANTATIONS

Habitat Manipulation

In the briefest of terms, reduction of snowshoe hare damage can result from a "no cover—no rabbits" approach, which means that in each stage of plantation establishment, heavy emphasis must be placed on elimination of protective cover and an abundant diversified food supply for snowshoe hares. A thorough scarification process, with or without prescribed burning, can minimize the availability of slash piles or windrows as obstruction forms of cover. Site preparation and planting should take place as soon after harvesting as practical, before the invasion of pioneer species takes place. An annual application of herbicides could be applied after planting to reduce ground cover further within the critical lower metre and to discourage growth of adventitious shoots. Chemical, manual, and mechanical techniques can also be employed subsequent to planting and regrowth of competing vegetation to reduce cover and winter food supplies for snowshoe hares. Habitat manipulation practices should be continued until the plantation trees have outgrown the reach of snowshoe hares atop the maximum snow depth. With slow growth in our conifer species, this could mean habitat manipulation during two or more snowshoe hare cycles.

Larger Seedlings

To attain the fastest growth possible on the plantation sites, consideration should be given to planting of extra-large seedlings. For example, 2–0 stock transplanted into the ideally cultured habitat of nursery beds for two additional years or more should attain greater height growth than 2–0 stock planted directly into plantation sites. Because of the preference of snowshoe hares for nitrogen-fertilized seedlings, this form of fertilizer should be used only modestly during the additional transplant years. Also, because pine stem girdling by hares decreases significantly with increasing diameter, treatments that encourage diameter growth or favor large trees will tend to minimize this type of damage.

Physical Barriers

Seedlings planted into plantation sites must be protected against snowshoe hare damage until a height of approximately 152 cm (60-in.) is attained. The ideal form of protection (but perhaps also the most costly) is rabbit-proof fencing. Even after set up, such fencing requires periodic inspection and maintenance. Should fencing prove too costly, individual seedlings should be protected using wire mesh cylindrical screens or annual fall applications of a proven repellent spray, until leader shoots are out of reach of foraging hares. Plastic sleeves or ¼-in. (0.6 cm) repellent-treated plastic mesh can accord protection against rabbit damage during the 1st year, but retreatment will be required in subsequent years. While TMTD appears to be the repellent most favored in North America, other repellents, such as Emol and Repentol from Poland and R-55 blended with Rhoplex AC-33 adhesive, should be accorded laboratory and field trials here.

Population Control

Starting several years before the next expected peak in showshoe hare populations, an active program of shooting all rabbits and hares on or near plantations could be carried out. Whether by use of a bounty system or assignment of designated areas, individual shooters should each be able to reduce hare numbers greatly on an up to 1000-acre (405 ha) sector. The objective would be to prevent natural peak population levels from being reached. Leaving carcasses where shot in the field should serve to encourage predators. Where runways clearly indicate extensive use by hares, shooting should be supplemented by use of snares.

Research Needs

The snowshoe hare damage problem has existed for decades. Yet even an extensive review of the scientific literature yields no proven formula as to how to cope with such damage in the field. Many of the suggestions for control are gleaned from studies of other problem animals and other environmental situations. A research program to develop control methods applicable specifically to the snowshoe hare is needed. Such a program should examine laboratory and field facets dealing with improved site preparation and planting stock performance, habitat manipulation (including herbicides), ground and aerial application of hare repellents, systemics, species-specific poisons, bait acceptance and aversions, poisoned bait feeder stations applicable to snowshoe hare control, and oral acceptance of chemosterilants. Very few, if any, of these approaches appear to have been adopted or pursued by forestry agencies in Canada to protect their extensive plantations. A team approach, including expertise in silviculture, plant ecology, soils, small mammal biology, chemistry, and economics, is fundamental to development of a viable solution to the snowshoe hare damage problem. Preventative measures may require years of experimentation to perfect the workable procedures (e.g., Sullivan's (1985) research on slow release predator odors).

REFERENCES

Adams, L. 1959. An analysis of a population of snowshoe hares in northwestern Montana. Ecol. Monogr. 29:141–170.

Aldous, C.M.; Aldous, S.E. 1944. The snowshoe hare—a serious enemy of forest plantations. J. For. 42:88–94.

Baer, N.W. 1980. Tree guard tubes to reduce rabbit damage to shelterbelt trees in South Dakota. Tree Plant. Notes 31:6–8.

Balser, D.S. 1964a. Antifertility agents in vertebrate pest control. Pages 133–137 *in* Proc. Second Vertebr. Pest Conf., March 4–5, 1964, Anaheim, Calif.

Balser, D.S. 1964b. Management of predator populations with antifertility agents. J. Wildl. Manage. 28:352–358.

Barnes, V.G., Jr.; Anthony, R.M.; Evans, J.; Linsey, C.D. 1982. Evaluation of zinc phosphide bait for pocket gopher control on forest land. Pages 219–225 *in* Proc. Tenth Vertebr. Pest Conf., February 23–25, 1982, Monterey, Calif.

Batcheler, C.L. 1974. Modelling for research on chemical control of mammals in New Zealand. Pages 233–237 *in* W.V. Johnson, ed. Proc. Sixth Vertebr. Pest Conf., March 5–7, 1974, Anaheim, Calif.

Besser, J.F.; Welch, J.F. 1959. Chemical repellents for the control of mammal damage to plants. Trans. N. Am. Wildl. Conf. 24:166–173.

Black, H.C.; Hooven, E.F. 1978. Animal damage control. Pages 195–198 *in* B.D. Cleary, R.D. Greaves, and R.K. Herman, eds. Regenerating Oregon's forests. Oregon State University Extension Service, Corvallis, Oregon.

Bookout, T.A. 1965. The snowshoe hare in Upper Michigan—its biology and feeding coaction with white-tailed deer. Michigan Dep. Conserv. Res. Dev. Rep. 38.

Borrecco, J.E. 1976. Controlling damage by forest rodents and lagomorphs through habitat manipulation. Pages 203–210 *in* C.C. Siebe, ed. Proc. Seventh Vertebr. Pest Conf., March 9–11, 1976, Monterey, Calif.

Brace, L.G.; Golec, P.J. 1982. Silviculture statistics for Canada, 1975–80. Environ. Can., Can. For. Serv., North. For. Res. Cent., Edmonton, Alberta. Inf. Rep. NOR-X-245.

Brand, C.J.; Vowles, R.H.; Keith, L.B. 1975. Snowshoe hare mortality monitored by telemetry. J. Wildl. Manage. 39:741–747.

Bryant, J.P. 1981a. Hare trigger. Nat. Hist. 90:46-53.

Bryant, J.P. 1981b. The regulation of snowshoe hare feeding behavior during winter by plant antiherbivore chemistry. Pages 720-731 *in* K. Myers and C.D. MacInnes, eds. Proc. World Lagomorph Conf., August 1979., Univ. Guelph, Guelph, Ontario.

Bryant, J.P. 1983. Pinosylvin methyl ether deters snowshoe hare feeding on green alder. Sci. 222:1023-1025.

Buehler, D.A.; Keith, L.B. 1982. Snowshoe hare distribution and habitat use in Wisconsin. Can. Field-Nat. 96:19-29.

Bullard, R.W.; Campbell, D.L. 1968. Evaluation of adhesives for foliar application of chemicals. For. Sci. 14:39-44.

Burns, R.M. 1961. Rabbit repellents in north Mississippi. Tree Plant. Notes 45:19-22.

Campbell, D.L. 1969. Plastic fabric to protect seedlings from animal damage. Pages 87-88 *in* H.C. Black, ed. Proc. Symp. Wildl. Reforestation Pac. Northwest. Oregon State University, Corvallis, Oregon.

Canada Agriculture. 1965. Control of mice, rabbits and deer in orchards. Publ. 1115. Ottawa, Ontario.

Coley, P.D. 1980. Effects of leaf age and plant life history patterns on herbivory. Nature 284:545-546.

Coley, P.D. 1983. Herbivory and defensive characteristics of tree species in a lowland tropical forest. Ecol. Monogr. 53:209-223.

Conroy, M.J.; Gysel, L.W.; Dudderar, G.R. 1979. Habitat components of clear-cut areas for snowshoe hares in Michigan. J. Wildl. Manage. 43:680-690.

Dasmann, R.F.; Hubbard, R.L.; Longhurst, W.M.; Ramstead, G.I.; Harn, J.H.; Calvert, E. 1967. Deer attractants: An approach to deer damage problems. J. For. 65:564-566.

de Vos, A. 1964. Food utilization of snowshoe hares on Manitoulin Island, Ontario. J. For. 62:238-244.

Dickmann, D.I. 1978. Marked differences among poplar clones in winter browsing damage by cottontail rabbits. Can. J. For. Sci. 8:351-354.

Dimock, E.J. 1974. Animal resistant Douglas-fir: how likely and how soon? Pages 95-101 *in* H.C. Black, ed. Wildl. For. Manage. Pac. Northwest. Oregon State University, Corvallis, Oregon.

Dimock, E.J.; Silen, R.R.; Allen, V.E. 1976. Genetic resistance in Douglas-fir to damage by snowshoe hare and black-tailed deer. For. Sci. 22:106-121.

Dodge, W.E. 1969. Protective measures—a review of chemical, mechanical, and other means of controlling damage by animals. Pages 60-62 *in* H.C. Black, ed. Proc. Symp. Wildl. Reforestation Pac. Northwest. Oregon State University, Corvallis, Oregon.

Douglas, G.W. 1981. Ecological and economic aspects of control in the introduced rabbit in Victoria, Australia. Pages 822-829 *in* K. Myers and C.D. MacInnes, eds. Proc. World Lagomorph Conf., August 1979, Univ. Guelph, Guelph, Ontario.

Duffield, J.W.; Eide, R.P. 1962. Application of rabbit repellent to coniferous planting stock in the Pacific northwest. J. For. 60:109-111.

Edmunds, G.F.; Alstead, D.M. 1978. Coevolution in insect herbivores and conifers. Sci. 199:941-945.

Ericsson, J.R. 1982. Alpha-chlorophydrin (Epibloc): a toxicant-sterillant as an alternative in rodent control. Pages 6-9 *in* R.E. Marsh, ed. Proc. Tenth Vertebr. Pest Conf., February 23-25, 1982, Monterey, Calif.

Ericsson, R.J.; Downing, H.E.; Marsh, R.E.; Howard, W.E. 1971. Bait acceptance by rats of microencapsulated male sterilant alpha-chlorohydrin. J. Wildl. Manage. 35:573-576.

Evans, J.E.; Hegdal, P.L.; Griffith, R.E., Jr. 1970. Methods of controlling jackrabbits. Pages 109-116 *in* Proc. Fourth Vertebr. Pest Conf., March 3-5, 1970, West Sacramento, Calif.

Feeny, P. 1976. Plant apparency and chemical defenses. Rec. Adv. Phytochem. 10:1-42.

Fennessy, B.V.; Mykytowycz, R. 1974. Rabbit behaviour research in Australia and its relevance in control operations. Pages 184-197 *in* W.V. Johnson, ed. Proc. Sixth Vertebr. Pest Conf., March 5-7, 1974, Anaheim, Calif.

Fitzwater, W.D. 1972. Barrier fencing in wildlife management. Pages 49-55 *in* R.E. Marsh, ed. Proc. Fifth Vertebr. Pest Conf., March 7-9, 1972, Fresno, Calif.

Fox, J.F. 1978. Forest fires and the snowshoe hare—Canada lynx cycle. Oecologia (Berl.) 31:349-374.

Godfrey, M.E.R. 1974. The European rabbit problem in New Zealand. Pages 106-111 *in* W.V. Johnson, ed. Proc. Sixth Vertebr. Pest Conf., March 5-7, 1974, Anaheim, Calif.

Grange, W.B. 1932. Observations on the snowshoe hare, ***Lepus americanus phaenotus*** Allen. J. Mammal. 13:1-19.

Greaves, R.D. 1978. Competing vegetation. Pages 190-191 *in* B.D. Cleary, R.D. Greaves, and R.K. Herman, eds. Regenerating Oregon's forests. Oregon State University Extension Service, Corvallis, Oregon.

Greenwald, G.S. 1957. Interruption of pregnancy in the rabbit by the administration of estrogen. J. Exp. Zool. 135:461-481.

Greer, K.R.; Hawkins, W.W., Jr.; Catlin, J.E. 1968. Experimental studies of controlled reproduction in elk (wapiti). J. Wildl. Manage. 32:368-376.

Griffith, R.E., Jr.; Evans, J. 1970a. A vehicle mounted bait dispenser. Pages 117-119 *in* Fourth Vertebr. Pest Conf., March 3-5, 1970, West Sacramento, Calif.

Griffith, R.E., Jr.; Evans, J. 1970b. Capturing jackrabbits by night lighting. J. Wildl. Manage. 34:637-639.

Gwynn, G.W.; Kurtz, S.M. 1970. Acceptability and efficacy of an antisterility agent in wild Norway rats. J. Wildl. Manage. 34:514-519.

Harder, J.D.; Peterle, T.J. 1974. Effect of diethylstilbestrol on reproductive performance of white-tailed deer. J. Wildl. Manage. 38:183-196.

Hartwell, H.D. 1969. Control of damage by snowshoe hares in forest plantations. Pages 80-81 *in* H.C. Black, ed. Proc. Symp. Wildl. Reforestation Pac. Northwest. Oregon State University, Corvallis, Oregon.

Herman, C.M. 1953. A review of experiments in biological control of rabbits in Australia. J. Wildl. Manage. 17:482-486.

Hood, G.A. 1972. Zinc phosphide—a new look at an old rodenticide. *In* R.E. Marsh, ed. Proc. Fifth Vertebr. Pest Conf., March 7-9, 1972, Fresno, Calif.

Hooven, E.F. 1966. A test of thiram on two rabbit-infested areas in Oregon. Tree Plant. Notes 79:1-3.

Howard, W.E. 1967. Biological control of vertebrate pests. Pages 137-157 *in* Proc. Third Vertebr. Pest Conf., March 7-9, 1967, San Francisco, Calif.

Howard, W.E.; Marsh, R.E. 1969. Mestranol as a reproductive inhibitor in rats and voles. J. Wildl. Manage. 33:403-408.

Jackson, W.F. 1953. Management of canine mismating with diethylstilbestrol. Calif. Vet. 7:22, 29.

Johnson, W.V. 1964. Rabbit control. Pages 90-95 *in* Proc. Second Vertebr. Pest Conf., March 4-5, 1964, Anaheim, Calif.

Johnston, J.C. 1978. Anticoagulant baiting for jackrabbit control. Pages 152-153 *in* W.E. Howard, ed. Proc. Eighth Vertebr. Pest Conf., March 7-9, 1978, Sacramento, Calif.

Kaukeinen, D. 1982. A review of the secondary poisoning hazard potential to wildlife from the use of anticoagulant rodenticides. Pages 151-158 *in* R.E. Marsh, ed. Proc. Tenth Vertebr. Pest Conf., February 23-25, 1982, Monterey, Calif.

Keith, L.B. 1963. Wildlife's ten-year cycle. University of Wisconsin Press, Madison, Wisconsin.

Keith, L.B. 1964. Daily activity pattern of snowshoe hares. J. Mammal. 45:626-627.

Keith, L.B. 1965. A live snare and tagging snare for rabbits. J. Wildl. Manage. 29:877-880.

Keith, L.B. 1974. Some features of population dynamics in mammals. Proc. Int. Congr. Game Biol. Stockholm 11:17-58.

Keith, L.B.; Meslow, E.C. 1968. Trap response by snowshoe hares. J. Wildl. Manage. 32:795-801.

Keith, L.B.; Windberg, L.A. 1978. A demographic analysis of the snowshoe hare cycle. Wildl. Monogr. 58:70.

Keith, L.B.; Cary, J.R.; Ronstad, O.J.; Brittingham, M.C. 1984. Demography and ecology of a declining snowshoe hare population. Wildl. Monogr. 90:43.

Kennelly, J.J.; Garrison, M.V.; Johns, B.E. 1970. Laboratory studies of the effect of U-5897 on the reproduction of wild male rats. J. Wildl. Manage. 34:508-513.

King, D.R.; Wheeler, S.H. 1981. Ecology of the rabbit in western Australia. Pages 858-869 *in* K. Myers and C.D. MacInnes, eds. Proc. World Lagomorph Conf., August 1979, Univ. Guelph, Guelph, Ontario.

Kirkpatrick, J.F.; Turner, J.W. 1985. Chemical fertility control and wildlife management. Bioscience 35:485-491.

Knight, J.E. 1983. Jackrabbits. Pages 75-80 *in* R.M. Timm, ed. Prevention and control of wildlife damage. Great Plains Agricultural Council Wildlife Resources Committee, Cooperative Extension Service, University of Nebraska, Lincoln, Nebraska.

Kverno, N.B. 1964. Forest animal damage control. Pages 81-89 *in* Proc. Second Vertebr. Pest Conf., March 4-5, 1964, Anaheim, Calif.

Leopold, A. 1933. Game management. Charles Scribner and Sons, New York, N.Y.

Levin, D.A. 1976. The chemical defense of plants to pathogens and herbivores. Annu. Rev. Ecol. Syst. 7:121-159.

Linhart, S.B.; Enders, R.K. 1964. Some effects of diethylstilbestrol on reproduction of captive red foxes. J. Wildl. Manage. 28:358-363.

Maarse, H.; Kepner, R.E. 1970. Changes in composition of volatile terpenes in Douglas-fir needles during maturation. J. Agric. Food Chem. 18:1095-1101.

Marsh, R.E.; Howard, W.E. 1969. Evaluation for mestranol as a reproductive inhibitor of Norway rats in garbage dumps. J. Wildl. Manage. 33:133-138.

Marsh, R.E.; Howard, W.E. 1970. Chemosterilants as an approach to rodent control. Pages 55-63 *in* Proc. Fourth Vertebr. Pest Conf., March 3-5, 1970, West Sacramento, Calif.

Marsh, R.E.; Salmon, T.P. 1981. The control of jackrabbits in California agriculture. Pages 842-857 *in* K. Myers and C.D. MacInnes, eds. Proc. World Lagomorph Conf., August 1979, Univ. Guelph, Guelph, Ontario.

Mason, R.R.; Davidson, F.R. 1964. Protecting pine seedlings from rabbits with polyethylene sleeves. J. For. 62:751-752.

Matschke, G.H. 1976. Non-efficacy of mechanical birth control devices for white-tailed deer. J. Wildl. Manage. 40:792-795.

Matschke, G.H. 1977a. Fertility control in white-tailed deer by steroid implants. J. Wildl. Manage. 41:731-735.

Matschke, G.H. 1977b. Microencapsulated diethylstilbestrol as an oral contraceptive in white-tailed deer. J. Wildl. Manage. 41:87-91.

McCabe, R.A. 1981. The cottontail rabbit for recreation and control. Pages 899-906 *in* K. Myers and C.D. MacInnes, eds. Proc. World Lagomorph Conf., August 1979, Univ. Guelph, Guelph, Ontario.

Melchiors, A.M.; Leslie, C.A. 1985. Effectiveness of predator fecal odors as black-tailed deer repellent. J. Wildl. Manage. 49:358-362.

Meslow, E.C.; Keith, L.B. 1968. Demographic parameters of a snowshoe hare population. J. Wildl. Manage. 32:812-834.

Meslow, E.C.; Keith, L.B. 1971. A correlation analysis of weather versus snowshoe hare population parameters. J. Wildl. Manage. 35:1-15.

Moore, N.W. 1970. New factors controlling populations of land vertebrates in Great Britain. Pages 9-14 *in* Proc. Fourth Vertebr. Pest Conf., March 3-5, 1970, West Sacramento, Calif.

Myers, K. 1975. Utilization of appetite for sodium salt to control rabbit populations by poisoning. Aust. Wildl. Res. 2:135-136.

Nellis, C.H.; Keith, L.B. 1968. Hunting activities and success of lynxes in Alberta. J. Wildl. Manage. 32:718-722.

Nellis, C.H.; Wetmore, S.P.; Keith, L.B. 1972. Lynx-prey interactions in central Alberta. J. Wildl. Manage. 36:320-329.

Nelson, P.C. 1978. Agricultural pests destruction movement in New Zealand. Pages 154-157 *in* W.E. Howard, ed. Proc. Eighth Vertebr. Pest Conf., March 7-9, 1978, Sacramento, Calif.

Nichols, J.E. 1951. Rabbit control in Australia: problem and possibilities. Nature 168(4283):932-934.

O'Farrell, T.P. 1965. Home range and ecology of snowshoe hares in interior Alaska. J. Mammal. 46:406-418.

Oh, H.K.; Jones, M.B.; Longhurst, W.M. 1968. Comparison of rumen microbial inhibition resulting from various essential oils from relatively unpalatable plants species. Appl. Microbiol. 16:39-44.

Oliver, A.J.; Wheeler, S.H. 1978. The toxicity of the anticoagulant Pindone to the European rabbit *Oryctolagus cuniculus* and the sheep *Ovis aries*. Aust. Wildl. Res. 5:135-142.

Oliver, A.J.; Wheeler, S.H.; Gooding, C.D.; Bell, J. 1982. Changes in bait acceptance by rabbits in Australia and New Zealand. Pages 1011-1103 *in* R.E. Marsh, ed. Proc. Tenth Vertebr. Pest Conf., February 23-25, 1982, Monterey, Calif.

Parker, G.R. 1984. Use of spruce plantations by snowshoe hare in New Brunswick. For. Chron. 60:162-166.

Pease, J.L.; Vowles, R.H.; Keith, L.B. 1979. Interaction of snowshoe hares and woody vegetation. J. Wildl. Manage. 43:43-60.

Pepper, W.H. 1976. Rabbit management in woodlands. Her Majesty's Stationery Office, London, U.K. For. Comm. Leafl. 67.

Peters, J.A. 1972. Vertebrate pests in New Zealand: research and control. Pages 101-103 *in* R.E. Marsh, ed. Proc. Fifth Vertebr. Pest Conf., March 7-9, 1972, Fresno, Calif.

Peters, J.A. 1976. Contamination of forest ecosystems by sodium fluoroacetate (Compound 1080). Pages 307-315 *in* C.C. Siebe, ed. Proc. Seventh Vertebr. Pest Conf., March 9-11, 1976, Monterey, Calif.

Pietz, P.J.; Tester, J.R. 1983. Habitat selection by snowshoe hares in north central Minnesota. J. Wildl. Manage. 47:686-696.

Pruitt, W.O., Jr. 1970. Some ecological aspects of snow. Pages 83-99 *in* Ecology of the subarctic region. Paris, UNESCO.

Radvanyi, A. 1974. Small mammal census and control on a hardwood plantation. Pages 9-19 *in* W.V. Johnson, ed. Proc. Sixth Vertebr. Pest Conf., March 5-7, 1974, Anaheim, Calif.

Radvanyi, A. 1980. Control of small mammal damage in the Alberta oil sands reclamation and afforestation program. For. Sci. 26:687-702.

Radwan, M.A. 1969. TMTD wild mammal repellent: review and current status. For. Sci. 15:439-445.

Radwan, M.A. 1972. Differences between Douglas-fir genotypes in relation to browsing preferences by black-tailed deer. Can. J. For. Res. 2:250-255.

Radwan, M.A. 1975. Genotype and season influence chlorogenic acid content in Douglas-fir foliage. Can. J. For. Res. 5:281-284.

Radwan, M.A.; Dodge, W.E. 1965. Effective application rates of TMTD rabbit repellent to Douglas-fir seedlings in the nursery. Tree Plant. Notes 72:7-9.

Radwan, M.A.; Ellis, W.D. 1975. Clonal variation in monoterpene hydrocarbon of vapors of Douglas-fir foliage. For. Sci. 21:63-67.

Ratcliffe, F.N.; Myers, K.; Fennessy, B.Y.; Calaby, J.H. 1952. Myxomatosis in Australia, a step toward the biological control of the rabbit. Nature 170(4314):7-11.

Rediske, J.H.; Lawrence, W.H. 1962. Selenium as a wildlife repellent for Douglas-fir seedlings. For. Sci. 8:142-148.

Rediske, J.H.; Lawrence, W.H. 1964. Octamethylpyrophosphoramide (OMPA) as a systemic animal repellent for Douglas-fir seedlings. For. Sci. 10:93-103.

Ross, J.; Tittensor, A.M. 1981. Myxomatosis in selected rabbit populations in southern England and Wales 1971-1977. Pages 830-833 *in* K. Myers and C.D. MacInnes, eds. Proc. World Lagomorph Conf., August 1979, Univ. Guelph, Guelph, Ontario.

Seton, E.T. 1928. Lives of game animals. Doubleday, Doran and Company, Inc. Garden City, N.Y.

Shepherd, R.C.H.; Nolan, I.F.; Edmonds, J.W. 1978. Review of methods to capture live wild rabbits in Victoria. J. Wildl. Manage. 42:179-184.

Storm, G.L.; Sanderson, G.C. 1970. Effect of mestranol and diethylstilbestrol on captive voles. J. Wildl. Manage. 34:835-843.

Sullivan, T.P. 1984. Effects of snowshoe hare damage on juvenile lodgepole pine. Implications for spacing natural stands. B.C. Minist. For. Res., Victoria, B.C. Note 94.

Sullivan, T.P.; Crump, D.R. 1984. Influence of mustelid scent-gland compounds on suppression of feeding by snowshoe hares (*Lepus americanus*). J. Chem. Ecol. 10:1809-1821.

Sullivan, T.P.; Crump, D.R. 1985. Influence of predator odours on the feeding behaviour of herbivores. Fourth Int. Theriol. Cong., August 13-20, 1985, Edmonton, Alberta. Abstr. 609. Session S20.

Sullivan, T.P.; Moses, R.A. 1986. Demographic and feeding responses of a snowshoe hare population to habitat alteration. J. Appl. Ecol. 23(1):53-64.

Sullivan, T.P.; Sullivan, D.S. 1982. Barking damage by snowshoe hares and red squirrels in lodgepole pine stands in central British Columbia. Can. J. For. Res. 12:443-448.

Szukiel, E. 1981. Repellents for protecting trees against browsing by Leporidae. Page 888 *in* K. Myers and C.D. MacInnes, eds. Proc. World Lagomorph Conf., August 1979, Univ. Guelph, Guelph, Ontario.

Telfer, E.S. 1974. Vertical distribution of cervid and snowshoe hare browsing. J. Wildl. Manage. 38:944-948.

Thompson, H.V. 1953. The use of repellents for preventing mammal and bird damage to trees and seeds. For. Abstr. 14:129-136.

Tomlinson, A.R. 1970. The organization of rabbit control (*Oryctolagus cuniculus*) in western Australia. Pages 188-194 *in* Proc. Fourth Vert. Pest Conf., March 3-5, 1970, West Sacramento, Calif.

Vaughan, J.A. 1979. The influence of the rabbit flea on the selection of attenuated strains of myxoma virus. Pages 834-841 *in* K. Myers and C.D. MacInnes, eds. Proc. World Lagomorph Conf., August 1979, Univ. Guelph, Guelph, Ontario.

Wade, D.A. 1982. The use of fences for predator damage control. Pages 24-33 *in* R.E. Marsh, ed. Proc. Tenth Vertebr. Pest Conf., February 23-25, 1982, Monterey, Calif.

Waithman, J. 1981. Rabbit control in Australia: history and future requirements. Pages 880-887 *in* K. Myers and C.D. MacInnes, eds. Proc. World Lagomorph Conf., August 1979, Univ. Guelph, Guelph, Ontario.

Walters, J.; Soos, J. 1961. The relative efficiency of three hare-repellents in protecting Douglas-fir seedlings. For. Chron. 37:22-28.

Wheeler, S.H.; Oliver, A.J. 1978. The effect of rainfall and moisture on the 1080 and Pindone content of vacuum-impregnated oats used for control of rabbits *Oryctolagus cuniculus*. Austr. Wildl. Res. 5:143-149.

Williams, J.M. 1983. The impact of biological research on rabbit control policies in New Zealand. Acta. Zool. Fenn. 174:79-83.

Williams, R.M.; Darwin, J.H.; Wodzicki, K. 1964. Effectiveness of rabbit and hare control by night-shooting. N.Z. J. Sci. 7:367-386.

Wolff, J.O. 1977. Habitat utilization of snowshoe hares (*Lepus americanus*) in interior Alaska. Ph.D. dissertation. Univ. Calif., Berkeley, Calif.

Wolff, J.O. 1980. The role of habitat patchiness in the population dynamics of snowshoe hares. Ecol. Monogr. 50:111-130.

Wolff, J.O. 1981. Refugia, dispersal and geographic variation in snowshoe hare cycles. Pages 441-449 *in* K. Myers and C.D. MacInnes, eds. Proc. World Lagomorph Conf., August 1979, Univ. Guelph, Guelph, Ontario.