**From: Chappell, H.N., G.F. Weetman, and R.E. Miller, editors. 1992. Forest fertilization: sustaining and improving nutrition and growth of western forests. Institute of Forest Resources Contrib. 73. College of Forest Resources, Univ. of Washington, Seattle.**

Chapter 16

# Forest Fertilization and Wildlife

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*ABSTRACT.* Direct and indirect effects of forest fertilization on wildlife were evaluated through a literature review. Operational applications of urea were found to pose minimal hazards to animal species studied to date. Forage quality and quantity were generally improved in fertilized forest stands, and were often further enhanced when fertilization was combined with stand thinning. Wildlife feeding damage to conifer seedlings and saplings may increase because of fertilization, particularly in stands already susceptible to damage. Since fertilization increases the rate of vegetative succession and interacts with other stand management practices to affect vegetation, the impacts on wildlife and biological diversity generally should be considered from a large-scale (mosaic of stands) perspective.

Forest fertilization is an operational practice designed to improve the growth of several tree species in the Pacific Northwest. Since aerial application of fertilizer makes nutrients available to all trees, plants, and wildlife in a given ecosystem, this practice may affect wildlife directly by exposure to nutrients in their concentrated form immediately after application, and indirectly through growth enhancement of plant species. In addition, fertilization may increase wildlife feeding damage to conifer seedlings and saplings.

Rochelle (1981) reviewed literature up to 1979 on the effects of forest fertilization (urea) on wildlife with particular emphasis on the Pacific Northwest. This chapter updates current knowledge of forest fertilization-wildlife relationships. To provide as comprehensive a review as possible, we have included information from other forested areas of North America and Europe.

## Direct Effects of Fertilization on Wildlife

Toxicity, palatability, and availability in the environment are all factors that influence the direct hazard of fertilizers (specifically urea) to wildlife.

### *Toxicity*

Acute toxicity levels of urea, expressed as $LDL_0$ (lowest dose, administered by any route other than inhalation, reported to cause mortality) and $LD_{50}$ values, are listed for several vertebrates in Table 1. Amphibians and domestic animals appear to be the most susceptible to urea poisoning. For example, oral $LDL_0$ values as low as 28.5 to 88.0 mg/kg have been reported for sheep (Repp et al. 1955; Kromann et al. 1973). The mechanism of toxicity is the conversion of urea to ammonia and carbon dioxide in the presence of the enzyme urease. This particular enzyme is produced by bacteria found in the digestive systems of both ruminants and simple-stomached animals (Visek 1962), as well as in the soil (Conrad 1942).

As discussed by Rochelle (1981), after large intakes of urea by ruminants, ammonia in excess of that which can be metabolized is liberated (Repp et al. 1955). This results in a rapid pH change in the rumen, and the mortality of rumen microbes. Since the liver cannot detoxify excess ammonia, ammonia becomes elevated in peripheral blood.

Important to note is the relation between urea toxicity and intake rate. Use of low concentrations of urea (up

**Table 1—Acute toxicity levels ($LDL_0$ and $LD_{50}$ mg/kg) of urea for some laboratory animals. From Sax and Lewis (1989).**

| Species | Oral | Subcutaneous | Intravenous |
|---|---|---|---|
| Rat | 14,300 | 8,200 | 5,300 |
| Mouse | 11,500 | 9,200 | 4,600 |
| Dog | — | 3,000 | 3,000 |
| Rabbit | — | 3,000 | 4,800 |
| Goat or sheep | 511 | — | — |
| Pigeon | — | 14,800 | — |
| Frog | — | 600 | — |

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to 3%) as a nitrogen supplement to ruminant feeds serves as an inexpensive nontoxic source of protein for animal production (Hale 1956). As a food source, urea is converted to ammonia and then to microbial protein and amino acids by rumen microbes. Microbial protein is subsequently made available through its digestion in the abomasum and small intestine of the ruminant.

Although urea is not considered hazardous under normal use, in laboratory testing it has been found to be a skin irritant, may have effects on fertility by an intraplacental route, and has some mutagenic properties (Sax and Lewis 1989).

Municipal sewage and pulp and paper sludges have also been used as forest fertilizers. Concerns have been raised regarding the potential toxicity of heavy metals to wildlife, but so far no significant effects have been reported (Anderson 1983; Campa et al. 1986; Woodyard et al. 1986; Thiel et al. 1989).

### *Palatability*

Little new information is available on the palatability of urea to forest wildlife beyond Rochelle's (1981) review. As reported by Postovit (1976*a*), acceptance of pelletized urea by the deer mouse (*Peromyscus maniculatus*) was negligible in laboratory and field trials. Similar negative results were obtained for Japanese quail (*Coturnix coturnix*) (Postovit 1976*b*). In addition, toxic effects were not observed in either species fed diets in which urea pellets could be discriminated against in normal feeding trials. Urea in water solution presented to deer mice where it could not be selected against produced symptoms of intoxication at concentrations of 0.75 M and 1.0 M (Postovit 1976*a*). Toxic symptoms disappeared within one day when animals were fed normal water and roughage, whereas mice kept on urea solutions died. The concentrations of dissolved urea causing toxicity in these experiments were probably higher than would be encountered in the field where a fertilization program had been conducted.

Urea pellets, which could not be discriminated against, fed to quail in increasing concentrations resulted in decreased food uptake. Although production and hatchability of eggs declined for some treatments, no symptoms of toxicity were observed. Some weight losses occurred, but these were reversible; survival of chicks produced by hens fed urea was unaffected.

### *Availability in the Environment*

Availability of urea in the forest environment determines its potential hazard to wildlife. Dissipation rates of urea in the field depend on application rate, vegetation density, soil moisture, and precipitation pattern (Postovit 1976*a*). Field rate applications of fertilizer in closed canopy conifer plantations under conditions of high humidity, high soil moisture, and frequent rainfall should result in 18 to 36 hours of urea availability as a food source.

Considering that urea must be consumed for several days to produce reversible toxic symptoms, and it dissipates rapidly under field conditions, forest fertilization with urea is unlikely to adversely affect mammals or gallinaceous birds. Fertilizer spills at storage or transfer facilities are probably the greatest potential wildlife hazard. Several instances of cattle having died after feeding on exposed piles of urea are known in the Pacific Northwest, although not documented. Cases of poisoned domestic stock from accidental urea spills have been reported in the literature in other countries (Maksimovic and Jesenik 1979; Abdullah et al. 1986). Clearly, these situations are easily avoided with careful handling and storage and prompt cleanup of spilled fertilizer.

## Indirect Effects of Fertilization on Wildlife

Indirect effects arise from fertilization-induced changes in vegetation, including increased growth, nutritive quality, and palatability of forage plants and changes in the plant species composition of the vegetative cover. Altered rates of vegetative succession may also affect forest wildlife.

### *Forage Production*

As reviewed by Rochelle (1981), increased quantities of deer (*Odocoileus* spp.) forage following fertilization have been reported; the majority of work has been conducted in pine (*Pinus* spp.) plantations in the southeastern United States. In the Pacific Northwest, Stanek et al. (1979) reported a decrease in biomass of salal (*Gaultheria shallon*) and bracken fern (*Pteridium aquilinum*) after fertilization of Douglas-fir (*Pseudotsuga menziesii*). This decrease was presumably related to greater overstory shading as a result of fertilization. In stands thinned or thinned and fertilized, more light was able to reach the understory, thereby increasing the biomass of these species relative to untreated stands.

Total forage available for white-tailed deer (*O. virginianus*) was 1.8 (summer) to 2.7 (winter) times greater in thinned than unthinned loblolly pine (*P. taeda*) plantations in Alabama (Hurst et al. 1982). Fertilization with urea further increased forage production 1.5 times in both thinned and unthinned stands, and this general effect lasted for at least one year. A similar result was recorded for thinned and fertilized pine stands in Mississippi (Brooks 1979; Campo 1980). In upland broad-leaved stands in Arkansas, nitrogen (ammonium nitrate) application significantly increased the amount of wildlife forage produced by thinning (Snyder et al. 1985).

In another study of fertilized pine plantations in Mississippi, Wolters and Schmidtling (1975) reported lower overall numbers of browse plants but a substantial increase in numbers of desirable browse plants. This change in vegetative species composition also improved habitat quality for deer in terms of the greater accessibility provided by the reduction in understory. Fertilization with triple superphosphate significantly increased browse production on forest land in North Carolina (King and Cherry 1976; Hazel 1976).

Forest fertilization with municipal sewage sludge in Michigan resulted in heavier browsing of treated than untreated vegetation by white-tailed deer and elk (*Cervus elaphus canadensis*) (Campa et al. 1986). Sludge treatment of loblolly pine plantations in South Carolina increased the understory biomass (McLeod et al. 1986). The herbaceous component showed the greatest response, but increases in the shrub and woody components indicated a potential long-term effect. These authors were concerned that increased heavy metal concentrations in understory vegetation on treated plots may reduce the food quality for wildlife.

### *Nutritive Quality of Forage*

In general, most studies have reported improvement in some parameters of nutritive quality of wildlife forage following fertilization. In the Pacific Northwest, Oh et al. (1970) reported significant increases in crude protein in fertilized Douglas-fir seedlings in northern California. Nitrogen content (% dry weight) of salal and bracken fern increased in fertilized Douglas-fir stands on Vancouver Island, British Columbia (Stanek et al. 1979).

Other studies reported significant increases in protein content but inconsistent results with respect to dry matter digestibility (Segelquist and Rogers 1975; King and McKee 1978). Forage quality was mainly improved through increased phosphorus after fertilization with phosphate in South Carolina pine plantations (Wood 1986). Crude protein content more than doubled and reached 20% in dry matter in reindeer (*Rangifer tarandus*) after forest fertilization in Sweden (Ahman and Ahman 1984).

In sludge-treated plots in Michigan broad-leaved forest, crude protein content of forages was greater than in untreated plots (Campa et al. 1986). The nitrogen content of forbs, shrubs, and grasses and overall forage production increased in sludge-fertilized clearcuts in Washington (Anderson 1983). The increase in forage production was a result of a great proliferation of cool-season grasses, which resulted in heavy use of sludge sites by deer in late autumn, winter, and early spring.

### *Forage Selection and Tree Damage*

Clearly, palatability of plants as wildlife food often improves following fertilization (Rochelle 1981). This is a desirable goal from a wildlife management perspective but may interfere with forest productivity if tree growth and survival are adversely affected.

Forage selection in terms of outplanted nursery-grown seedlings and natural-regeneration seedlings of lodgepole pine (*P. contorta*) and interior spruce (*Picea glauca* x *Picea engelmannii*) clearly indicated a preference by meadow (*Microtus pennsylvanicus*) and long-tailed voles (*M. longicaudus*) for fertilizer-grown seedlings in west-central British Columbia (Sullivan and Martin 1991) (Table 2). Significant increases in deer use, as indicated by pellet group deposition and feeding on Douglas-fir seedlings, were recorded by Oh et al. (1970). Similar results were observed in western Washington for wildlife (deer, snowshoe hare, and blue grouse) feeding on fertilized Douglas-fir seedlings (USDA Forest Service 1970). Young Douglas-fir trees (0.7-1.7 m tall) fertilized with nitrogen or phosphorus were examined one year after treatment, and those given only nitrogen fertilizer were more heavily browsed by deer (Crouch and Radwan 1981). This effect disappeared in the second year but suggests that nitrogen, in particular, may predispose trees to feeding damage. Radwan et al. (1974) examined the rate of deer browsing of nursery-grown seedlings fertilized with different nitrogen sources (ammonium sulfate, calcium nitrate, urea) but detected no differences attributable to source.

In Finland, the number of Scots pine (*P. sylvestris*) seedlings damaged by elk was higher on N- than P-fertilized plots (Laine and Mannerkoski 1980). Phosphorus also increased occurrence of elk damage, but this

**Table 2—Percentage survival from vole attack of naturally grown and planted fertilizer-treated seedlings of lodgepole pine and interior spruce. From Sullivan and Martin (1991).**

| | Pine | | | Spruce | |
|---|---|---|---|---|---|
| Plantation | Natural | Planted | Plantation | Natural | Planted |
| A | 96.7(60)** | 72.0(82) | C | 100.0(14)· | 79.2(53) |
| B | 72.0(93)** | 28.1(32) | D | 97.1(34)* | 83.1(77) |

**$p < 0.01$; * $p < 0.05$; significant difference by chi-square.
·$p = 0.07$.

was confounded by better growth and size of P-fertilized seedlings. Potassium had no effect on seedling growth or occurrence of damage. A similar result was reported for moose (*Alces alces*) damage to N-fertilized Scots pine (Löyttyniemi 1981). There were no consistent correlations between other nutrients (phosphorus, potassium, calcium, magnesium) and browsing damage, although phosphorus and calcium contents in needles of damaged trees were slightly higher than in those of undamaged trees. Löyttyniemi (1981) concludes that in regions with persistent browsing damage, nitrogen fertilization should be avoided or postponed until trees have grown beyond the stage most susceptible to damage.

The incidence of squirrel feeding on slash pine (*P. elliottii*) cones in Florida was significantly higher on fertilized than unfertilized trees (Asher 1963). Similarly, higher levels of rodent feeding on terminal buds of Pacific silver fir (*Abies amabilis*) saplings in western Washington following fertilization were recorded by Gessel and Orians (1967).

The influence of fertilization on feeding attacks to lodgepole pine saplings by snowshoe hare (*Lepus americanus*) and red squirrel (*Tamiasciurus hudsonicus*) in north-central British Columbia is shown in Table 3 (Sullivan and Sullivan 1982). Clearly, these herbivores prefer fertilized lodgepole pine stems to those in nonfertilized or unmanaged stands. Similar results were reported by Brockley and Sullivan (1988), where significantly more severe squirrel damage (i.e. ≥ 50% of stem circumference girdled) occurred in fertilized than unfertilized plots. Damage intensity tended to be directly related to fertilizer application rate. Brockley (1989) reported that three years after fertilization, the favorable effects on a stand volume basis were partly negated by feeding damage from red squirrel.

A major question arose from these studies: are all fertilized stands of lodgepole pine susceptible to severe feeding damage by red squirrel? Of 23 stands in interior British Columbia that had been operationally fertilized, 5 had severe levels of damage. However, all of these damaged stands were already susceptible to attack prior to fertilization for other reasons (e.g., extensive areas of young stands, high squirrel populations) (Sullivan et al. 1992). It is likely that fertilized stands of pine on moist sites where tree growth may be vigorous are potentially susceptible to attack, particularly if other factors of stand susceptibility are involved.

**Table 3—Incidence of damage, complete girdling, and intensity of feeding on lodgepole pine saplings by snowshoe hare and red squirrel. From Sullivan and Sullivan (1982).**

| | Snowshoe Hare | | | Red Squirrel | | |
|---|---|---|---|---|---|---|
| | Control | Thinned | T + F | Control | Thinned | T + F |
| Incidence (%) | 58.8 | 63.3 | 53.6 | 14.3 | 30.9 | 38.9 |
| Complete girdling (%) | 3.9 | 6.4 | 10.0 | 0.0 | 0.0 | 6.9 |
| Intensity of feeding ($cm^2$) | 27.4 | 46.2 | 92.2 | 42.3 | 41.6 | 66.9 |

T + F = thinned and fertilized.

*Information and Research Needs*

There have been several studies documenting the responses of vegetation and wildlife to fertilization since the review of this subject by Rochelle (1981). Most studies have generally supported the predicted (Lawrence 1969) positive influences of fertilization and other silvicultural treatments on carrying capacities of managed forests for forage production and ungulates. However, wildlife management now includes all species in a quest to manage for biological diversity in managed forests. Thus the influence of fertilization and other forestry practices on diversity should be the focus of future research. Again, as discussed by Rochelle (1981), individual silvicultural activities in managed stands must be examined within the context of the entire landscape, which is a mosaic of stands of different ages and stocking levels.

There is a need to investigate manipulation of the fertilization regime in tree seedling nurseries to perhaps reduce feeding damage by herbivores. In addition, operational applications should be adjusted with respect to timing of treatments to avoid susceptible stands in space and time.

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