NON-TARGET IMPACTS OF THE HERBICIDE GLYPHOSATE

A COMPENDIUM OF REFERENCES AND ABSTRACTS

4TH EDITION

INFORMATION REPORT
APPLIED MAMMAL RESEARCH INSTITUTE

RATIONALE AND BACKGROUND

The original concept of a compendium of references and abstracts outlining the "non-target impacts of the herbicide glyphosate" arose from the apparent incomplete and scattered sources of information on this subject. A common complaint from both lay and professional people is: "What research has been done on non-target impacts of glyphosate and how do we access this information?" In fact, from the computerized literature search which was conducted to identify studies of non-target impacts of glyphosate, the information in this fourth edition of the compendium was extracted from several thousand references covering environmental impacts, toxicology, efficacy, and human health. Thus, there is considerable literature base for glyphosate and this compendium evolved as a means of providing, in as complete a manner as possible, a collection of titles and abstracts of articles reporting on the non-target impacts of this herbicide.

As compilers of this document, we have conducted research on the non-target effects of glyphosate over the past 18 years. This work has focused primarily on small mammal populations in forestry and agriculture. Additional work was conducted on black-tailed deer, fish, daphnids, and diatoms (algae) as part of a major field study. To date, with coworkers, there are 18 journal publications outlining our work on the non-target impacts of glyphosate. Much of our earlier work on mammals is summarized in the chapter "Effects of Glyphosate on Selected Species of Wildlife: from the book "The Herbicide Glyphosate" published in 1985.

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was 2,4-D, which allows vigorous sprouting. We sampled available browse in glyphosate and 2,4-D treated stands. Three years after spraying, the glyphosate stands averaged only half the available browse as the 2,4-D stands. While sensitivity to 2,4-D differs markedly among woody plant species, glyphosate kills woody species more uniformly. Grass and raspberries are not controlled one year after spraying because glyphosate has no residual effects. We could not measure longterm effects in this study because glyphosate was not used in this region before 1981. This report covers only the first half of a 2-year study.

34. **Lautenschlager, R. A. 1993. *Effects of conifer release with herbicides on wildlife. (A review with an emphasis on Ontario's forests).* VMAP Forest Research Information Paper No.111 . Ontario Ministry of Natural Resources, Sault Ste. Marie, Ontario.**

See Biodiversity and Habitat Restoration Section.

35. **———. 1986. "*In*: Is Good Forestry Good Wildlife Management? J. Bissonette (ed.) ." *Forestry, herbicides, and wildlife.* Maine Agriculture Experimental Station, University of Maine, Orono. Miscellaneous Publication No. 689. pp. 299-307.**

At present application rates, herbicide conifer release in the northeast probably affects wildlife populations little. However, if herbicide conifer release increases greatly, it will: reduce the ability of treated areas to support moose (*Alces alces*) and small mammal populations for a short period following treatment; at most cause a short term reduction of deer (*Odocoileus virginianus*) and hare (*Lepus americanus*) populations, which are more likely to benefit within a few years after application; and benefit warblers and associated bird species normally found in the spruce/fir (*Picea* spp./*Abies balsamea*) forest. Although herbicide conifer release could benefit a variety of forest wildlife, forestry herbicides have developed an unjustified negative reputation. That reputation is based on: environmental fears and generalizations developed in the 1960's; herbicides' incorrect association with other, more toxic, chemicals (e.g., insecticides); and the inability of some resource workers and the media (and therefore the public) to distinguish among the variety of pesticides. To help eliminate this confusion it is imperative that resource professionals use "pesticide" only when a more specific term (insecticide, herbicide, fungicide etc.) is inappropriate.

36. **———. 1991. *Response of wildlife in northern ecosystems to conifer release with herbicides.* Cooperative Forestry Research Unit , University of Maine, Orono, Maine. Information Report 26. 12 p.**

See Birds Section.

* 37. **———. 1992. Effects of conifer release with herbicides on moose: browse production, habitat use, and residues in meat. *Alces* 28: 215-22.**

Six studies, 5 in spruce plantations and 1 in naturally regenerated spruce-fir stand, have examined the effects of conifer release with herbicides on moose browse production and habitat use. Both were reduced in plantations and naturally regenerated spruce-fir stands for up to 4 growing seasons after treatment. Only 1 study, in a naturally regenerated stand, examined long-term effects, and there forage production on all treated areas exceeded production on controls 8 growing seasons after treatment. Although feeding studies and residues in digestive tracts show that animals consume some glyphosate while feeding, herbicides were not found in the flesh of game animals (moose, deer, hare) taken from within or near areas released with glyphosate.

38. **———. 1993. Response of wildlife to forest herbicide applications in northern coniferous ecosystems. *Canadian Journal of Forest Research* 23: 2286-99.**

Reviewed studies of the effects of forest herbicide applications on wildlife often lacked replication, pretreatment information, and (or) were conducted for only one or two growing seasons after treatment. Because of these problems, as well as the use of dissimilar sampling techniques, study conclusions have sometimes been contradictory. A review of eight studies of the effects of herbicide treatments on northern songbird populations in regenerating clearcuts indicates that total songbird populations are seldom reduced during the growing season after treatment. Densities of species that use early successional brushy, deciduous cover are sometimes reduced, while densities of species which commonly use more open areas, sometimes increase. A review of 14 studies of the effects of herbicide treatments on small mammals indicates that like songbirds, small mammal responses are species specific. Some species are unaffected, while some select and others avoid herbicide-treated areas. Only studies that use kill or removal trapping to study small mammal responses show density reductions associated with herbicide treatment. It seems that some small mammal species may be reluctant to venture into disturbed areas, although residents in those areas are apparently not affected by the disturbance. Fourteen relevant studies examined the effects of conifer release treatments on moose and deer foods and habitat use. Conifer release treatments reduce the availability of moose browse for as long as four growing seasons after treatment. The degree of reduction during the growing season after treatment varies with the herbicide and rate used. Deer use of treated areas remains unchanged or increases during the first growing season after treatment. Eight years after treating a naturally regenerated spruce-fir stand browse was three to seven times more abundant on treated than on control plots (depending on the chemical and rate used). Forage quality (nitrogen, ash, and moisture) of crop trees increased one growing season after the soil-active herbicide simazine was applied to control competition around outplanted 3-year-old balsam fir seedlings.

39. **———. 1997. Effects of alternative conifer release treatments on small mammals in northwestern Ontario. *Forestry Chronicle* 73 (in press).**

Density changes were quantified in populations of small mammals responding to different conifer release treatments [manual (brushsaw) cutting; mechanical (Silvana selective) cutting; aerial-applied herbicides (Release® (a.i. triclopyr), Vision® (a.i. glyphosate)); and no treatment (control)]. Nearly 4,000 individual small mammals were captured and released during the first two years of this study. The most commonly captured were deer mice (*Peromyscus maniculatus*), redback voles (*Clethrionomys gapperi*), and common shrews (*Sorex cinereus*). Short-tailed (*Blarina brevicauda*), black-backed (*S. arcticus*) and pygmy (*S. hoyi*) shrews; eastern (*Tamias striatus*) and least (*T. minimus*) chipmunks; meadow voles (*Microtus pennsylvanicus*); short-tailed weasels (*Mustela erminea*); and meadow jumping mice (*Zapus hudsonius*) were fairly common. During the first growing season after treatment deer mouse densities were highest on Release®, Silvana, and brushsaw plots, and lower on control and Vision® plots. Redback vole densities were highest and very similar on control, brushsaw, and Silvana plots, intermediate on Vision® plots, and lowest on the Release®-treated plots. At this time eastern chipmunk densities were highest on Vision® and control plots, intermediate on brushsaw and Silvana plots, and lowest on Release®-treated plots. One growing season post-treatment, small mammal responses to proposed alternative conifer release treatments varied somewhat, but were similar to responses to the standard (Vision® herbicide) conifer release treatment.

40. **Lautenschlager, R. A., C. Hollstedt, and F. W. Bell. 1995. Effects of herbicide, manual, and annual release of young jack pine on vegetation and small mammals in northwestern Ontario. *Second International Conference on Forest Vegetation Management*, Rotorua, New Zealand. R.E. Gaskin, J.A. Zabkiewicz (compilers), FRI Bulletin No. 192. pp. 149-50.**

This study documents the effects of standard aerial herbicide (glyphosate) application, annually repeated herbicide applications and a proposed alternative (brushsaw cutting) for conifer release in jack pine systems in northwestern Ontario. Treatments increased survival and growth of planted pine, but their effects on resident small mammals were species specific. Redback voles and eastern chipmunks were reduced, deer mice were unaffected, and least chipmunks increased following herbicide treatments. Manual brushsaw cutting did not reduce small mammal populations less, or for a shorter period, than traditional aerial release treatments.

41. **Legris, J., and G. Couture. 1991. *Résidus de glyphosate dans le gibier (lièvre, orignal et cerf de Virginie) suite à des pulvérisations en milieu forestier en 1988.* Ministère des Forêts, Service des analyses environnementales, Gouvernement du Québec. 91-3016. 24 p.**

In 1988 the forests sector of the ministère de l'Énergie et des Resources looked into the possible contamination of game animals resulting from the use of glyphosate in softwood plantation maintenance operations in public forests. The glyphosate was applied at 1.5 kg AI/ha.

Samples of snowshoe hare (*Lepus americanus*), moose (*Alces alces*) and white-tailed deer (*Odocoileus virginianus*), shot inside or close to the treated areas, were collected in the vicinity of Rimouski and Matane. Sampling was done in October, during hunting season and approximately two months after the treatments had been applied (In August). Flesh, liver, kidney, urine, stomach content and feces samples were removed from 19 hares. Flesh, liver and kidney samples were taken from 16 dead moose. Only one white-tailed deer flesh sample was obtained.

For the three species under study, 31 of the 32 flesh samples showed no detectable residue. The detection threshold for these analysis was 0.050 µg/g (wet weight). The only positive value (0.146 µg/g) was found in a moose flesh sample. However, this reading may be the result of accidental contamination during the sampling procedure and may have been caused by the presence of moose hairs on the sample.

Stomach content samples were taken from 17 hares. Six of these showed glyphosate residues ranging from 0.084 to 0.262 µg/g. These concentrations represent less than 20% of the glyphosate that may be found in vegetation approximately two months after treatment. Analysis of the 18 liver samples revealed no trace of residue. Analysis of the 19 kidney samples revealed only one positive value (0.208 µg/g). Two of the seven urine samples contained glyphosate (109 and 142 µg/L). Residues ranging from 0.174 to 3.52 µg/g were found In 13 of the 15 feces samples. None of the 16 moose liver samples or nine kidney samples showed any detectable residue.

The results therefore indicate that glyphosate can be ingested through treated vegetation and is mainly eliminated through the urinary and fecal tracts. In general, these results concur with the observations reported in the literature.

Given the product's mode of action, its characteristics, and the low residue levels found in the samples, we do not anticipate any particular impact on the species studied. The generalized absence of detectable residues in the flesh, liver and kidneys seems to confirm that the risk of contamination from the consumption of these meats is very low.

42. **Léveillé, P., J. Legris, and L. Deschenes. 1996. *Exploratory study of glyphosate residues in small mammals after an aerial forestry application.* B-102. Gouvernement du Québec, Ministère des Ressources naturelles, Québec.**

In general, species used in this study turned out to be good indicators of the presence of residues shortly after treatment. The deer mouse (*Peromyscus maniculatus*), the red-backed vole (*Clethrionomys gapperi*) and the gray shrew (*Sorex cinereus*) did indicate the presence of residues. The grand shrew (*Blarina brevicauda*) never did show any detectable residues. Residue levels were of the order of 1 ppm or less, 15 days after treatment. At 45 days after treatment, residues were detected less frequently. Residue levels found are similar to those previously reported in the literature. Based on available Information, these residue levels do not constitute a risk of either acute or subchronic toxic effects for these small mammals, nor for their predators.

43. **Lloyd, R. A. 1989. *Assessing the impact of glyphosate and liquid hexazinone on moose browse species in the Skeena Region. B.C.*, Third year report. Ministry of Environment, Fish and Wildlife Branch, Smithers, B.C..**

This report is presented In three parts. Part A shows how herbicide impact may be described as the range of effects produced on a given species in a given area. The range of effects possible on one individual In the first year following treatment were Light, Moderate, Severe, Very Severe or Dead. The term "damage assessment" was used to portray the percentage of individuals of a given species in each category. In general, Light, Moderate and some Severe individuals were found to recover, whereas Dead, Very Severe and some Severe Individuals did not. Thus, when a site is assessed by this method, it Is possible to show not only the range of damage, but also the expected degree of recovery.

Part B describes how moose utilization of an area depends on herbicide impact. Moose were found to browse Light or Moderate plants, not Severe, Very Severe or Dead. Thus, where most browse plants were Light or Moderate, the area will continue to be useful to moose; where most were Severe, Very Severe or Dead, much of its value is lost. Herbicide residues in treated browse were up to 73 µg/g 4 weeks after treatment, and undetectable the following year. Toxic effects on moose seem unlikely

Part B also shows that willow and red-osier dogwood are comparatively resistant to glyphosate, and may generally be expected to show 25-60% recovery when sprayed at 1.8-2.1 kg a.i./ha. Aspen, cottonwood, maple and birch are much less resistant and may show over 90% mortality under the same conditions. Invasions of herbaceous pioneer species sometimes occurred in the second year after treatment; this seemed typical of moist sites which suffered heavy impact. This suggests that application rates of 1.8-2.1 kg a.i./ha are too high and are causing unnecessarily severe damage to non-target browse and non-browse plants.

Part C makes some recommendations as to how impact on browse species may be minimized. Most of these involve using a lower concentration, and not treating entire areas at once.

44, ———. 1990. ***Assessing the impact of glyphosate and liquid hexazinone on moose browse species in the Skeena region. Addendum.*****, B.C. Ministry of Environment, Fish and Wildlife Branch, Smithers, B.C..**

The impact of herbicide treatment on moose habitat can be approached from two different directions; namely, changes in browse availability and composition which are directly attributable to herbicide use, and changes in the way that moose utilize a treated area. Damage assessments demonstrate herbicide impact on shrub species, especially browse species, in the year following treatment. Some further mortality of severely impacted plants can be expected in the second year and, at least for willows and Douglas maple, in the third year as well.

At Smithers Landing, 3 1/2 years after treatment, moose utilization as determined from track counts was approximately eight times higher in the control area than in the treated. There are approximately twice as many live willow stems in the control area as in the treated, although the areas were probably similar prior to treatment. It seems that herbicide use did diminish the value of the treated area as moose habitat, and that the decrease was not solely correlated with browse abundance. In future, herbicide impact on moose habitat should also be considered in terms of habitat selection and not only in terms of browse.

Out of fifteen sites first surveyed in 1987 and 1988, eleven showed vigorous herbaceous growth at least in some parts of the cutblock. Herbaceous growth was most obvious in moist areas where most of the shrub vegetation existing prior to treatment had been killed. The commonest species were fireweed and grasses, especially *Elymus glaucus, Calamagrostis canadensis, Festuca* spp. and *Bromus vulgaris*. This could give rise to concern from both forestry and wildlife management perspectives. Shrub establishment from seed was not observed at any of the sites visited.

45. ———, 1990. ***Impact on vegetation after operational Vision treatment at varying rates in the Skeena region.*** **B.C. Ministry of Environment, Fish and Wildlife Branch, Smithers, B.C.**

Four cutblocks each received Vision treatments at various application rates in August 1988. The Blunt Fire, an established mixed brush community to 6 m tall, received 2, 3, 4 and 4.5 litres of formulated product per hectare; Taltapin Lake, an established mixed brush community on a dry site, received 3, 4 and 5 l/ha; Tachek Creek, a rehab site completing its second growing season after mechanical disturbance and broadcast burn, received 3 and 5 l/ha; and Pinkut Creek, an established mixed brush community on a dry-to-moist hillside site received 3 and 5 l/ha. A 4 l/ha treatment was also applied to Pinkut Creek but could not be clearly distinguished in the field. Data have been gathered before treatment and one year after treatment. Damage sustained seemed to depend on site conditions as well as on application rate. Vegetation and site conditions were rarely uniform even within a site, especially at Taltapin Lake and Pinkut Creek.

At the Blunt Fire, little impact was seen after most treatments on willow and red-osier dogwood; considerable impact was seen on aspen, cottonwood, Sitka alder and fireweed; and very high impact was seen on birch and thimbleberry. The 4.5 l/ha and 2 l/ha rates caused the most impact; the 3 l/ha and 4 l/ha caused least.

At Taltapin Lake, none of the treatments caused extensive damage. Some plants were showing signs of stress prior to treatment. Little impact was seen on willow of Sitka alder after treatment at 3 l/ha or 5 l/ha; aspen showed more impact, especially at 4 l/ha. Fireweed showed 35%-40% reduction in percent cover at 3 l/ha and 5 l/ha. Vegetation was comparatively tall and dense in the 3 l/ha, and comparatively sparse in the 4 l/ha unit. The 4 l/ha caused the most impact and the 3 l/ha caused the least

At Tachek Creek, considerable impact was seen on all species, especially black twinberry, aspen and Sitka alder. Impact was somewhat less on willow and red-osier dogwood. Little difference