III.1 Introduction

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Grasshopper integrated pest management (GHIPM) is the preferred alternative for grasshopper control listed in the 1987 Environmental Impact Statement for the 17 Western States with rangeland. In conducting the U.S. Department of Agriculture (USDA) cooperative grasshopper control programs, it is necessary to meet the requirements of environmental protection laws, especially the National Environmental Policy Act, the Endangered Species Act, and laws to protect surface and ground water.

Three of the registered methods for the cooperative programs use liquid insecticide formulations. Although the amount of active ingredient applied has been reduced by using ultralow-volume spray techniques, these pesticides can still affect the ecosystem. Grasshopper sprays blanket the rangeland habitat and expose nontarget animal life to the chemicals. Though the spray programs effectively reduce grasshopper densities in the short term, effects on nontarget species and rangeland ecology need to be evaluated. Some aspects deserve continued monitoring after USDA's GHIPM Project ended in 1994.

Use of dry baits for grasshopper control, with less potential for unintended effects on nontarget life, was investigated in the field. Grasshopper baits carrying chemical or biological control materials have great promise for use in environmentally sensitive areas. Also, new candidate grasshopper control methods and materials, such as diflubenzuron and *Beauveria bassiana,* were examined for effects on American kestrels (sparrowhawks) in field studies of nestlings and fledglings. These materials appear to have little, if any, direct toxicity to birds.

Several field and laboratory studies of GHIPM materials or methods have been conducted since the inception of the GHIPM Project in 1987. Birds have received the most attention because they are usually more susceptible than mammals to direct toxicity and to indirect ecological changes, such as loss of insect food. Studies have varied from determining total avian population response following large-scale grasshopper control programs (on areas greater than 10,000 acres) to physiological and behavioral measurements in individual birds sublethally exposed to GHIPM materials.

Two species of endangered fish have been studied intensively for toxicity of malathion and carbaryl. Effects on nontarget invertebrates (both aquatic and terrestrial) were also investigated. Other GHIPM Project-sponsored environmental impact studies included (1) avian and mammalian brain and blood cholinesterase measurements, (2) use of American kestrels and killdeer as bioindicators of possible effects on closely related endangered species, (3) effectiveness of bird predation for regulating grasshopper population densities, (4) postspray pesticide residue concentrations in environmental samples and biota (fauna and flora), (5) results of aquatic field monitoring of spray treatments, (6) small mammal live-trapping recapture tests, and (7) field experiments to investigate the indirect effects (loss of food base) on productivity of nesting birds associated with application of malathion and Sevin® 4-Oil liquid sprays and carbaryl bait. Preliminary results of golden eagle postfledging survival after aerial spray of Sevin 4-Oil to nest areas are also reported in this Environmental Monitoring and Evaluation section.

The important question of potential effects on endangered plant species and their insect pollinators is addressed in a summary of several studies. Authors also discuss untreated buffer-zone requirements to protect endangered plants, aquatic habitats, nests of endangered birds such as peregrine falcons, and other environmentally sensitive sites.

Knowledge of GHIPM relationships to nontarget life and rangeland ecology is critical for successful grasshopper population management. The days are long past when estimating the grasshopper kill was the only concern while other effects of a spray program were ignored. For many years, aldrin, dieldrin, and other organochlorine compounds were extremely efficient at killing grasshoppers, but USDA stopped using those pesticides in the mid 1960's because of their effects on nontarget life. Organochlorine pesticides harmed wild mammals, migratory birds, endangered raptors, reptiles, aquatic life, and western rangeland ecosystems (McEwen 1982).

Dieldrin, for example, is a stable compound that circulated through food chains and ecosystems for years and was highly toxic to all fish and wildlife. The Environmental Protection Agency criterion for chronic dieldrin contamination in fresh water is only 0.0019 parts per billion (Nimmo and McEwen 1994), but the bioconcentration factor in aquatic life can be 49,000 times the level of contamination in the water (Moriarity 1988). Animals exposed to sublethal organochlorine contamination may be unable to reproduce—particularly many fish species, fish-eating birds, and endangered raptors—and may also be more vulnerable to disease, pathogens, predators, and other stresses.

The insecticides currently registered for GHIPM programs are not only less toxic to terrestrial nontarget wildlife (McEwen 1982, Stromborg et al. 1984, Smith 1987) but also much less persistent in the environment than organochlorine chemicals. Today's grasshopper insecticides soon degrade into biologically inactive compounds that do not circulate through food chains (U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1987). The primary questions to be answered concerning the current control materials are (1) significance of sublethal toxic effects on birds, mammals, and fish, particularly cholinesterase inhibition; (2) degree of hazard to endangered fish, wildlife, and plants, and other species of concern; (3) indirect effects due to reduction of insect or invertebrate food supply; (4) effects on nontarget insects, including pollinators of endangered plants; and (5) evaluation of wildlife population effects related to wide area GHIPM treatments. The answers to these questions are more difficult to determine than the relatively simple wildlife carcass counts and pesticide residue analyses that were used to investigate the old organochlorine pesticides.

The current, more comprehensive, investigations of sublethal and indirect effects reflect the need to determine the complex ecological impacts of GHIPM on nontarget life. The findings support GHIPM strategy, including recognition that healthy, vigorous, rangeland ecosystems are the most permanent solutions to range grasshopper problems in the long term.

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