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Department of
Agriculture

Marketing and
Regulatory
Programs

Animal and
Plant Health
Inspection
Service

Rangeland Grasshopper and Mormon Cricket Suppression Program

Final Environmental Impact Statement—2002

Contents

Preface

Several changes to assist readers have been made from the draft to this Final Rangeland Grasshopper and Mormon Cricket Suppression Program Environmental Impact Statement (EIS). This document has two sections as follows:

- The first section consists of chapters 1 through 6, and the references cited in those chapters are listed in chapter 7.
- The second section contains the appendices. Appendix A provides additional background information, appendix B is an environmental risk assessment, and appendix C is the environmental fate and transport modeling. The references cited in those appendices are listed in appendix D. Appendix F has been added and contains the public comments received by the Animal and Plant Health Inspection Service (APHIS) on the draft EIS as well as APHIS' responses to those comments.

FIGURE 1-1: Grasshopper Control - circa 1930s—Spreading bait by hand (Photo Credit USDA-APHIS)

Executive Summary

This final programmatic environmental impact statement (EIS) describes actions available to the United States Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS) to suppress grasshopper and Mormon cricket populations that have reached a level of economic infestation on rangeland in the 17 Western States.[1] This EIS examines the environmental effects of two suppression alternatives that use insecticides and a no action alternative.

Rangeland is a complex ecosystem, and grasshoppers are a natural part of rangeland ecosystems. (The term "grasshoppers" in this document refers to both grasshoppers and Mormon crickets unless differentiation is needed.) Rangeland is also an important agricultural resource that is used mainly for livestock production. In some years, grasshoppers become serious pests when populations reach high densities. These outbreaks can destroy rangeland forage and devastate rangeland habitats.

There are rangeland management actions that are intended to prevent or drastically reduce grasshopper outbreaks. While APHIS can provide technical assistance and expertise regarding grasshopper management actions, the responsibility for implementing land management practices lies with Federal, State, and private land managers. Therefore, management practices are not available for APHIS to implement and are not analyzed in this EIS.

Grasshopper populations may build up to levels of economic infestation despite even the best land management and other efforts to prevent outbreaks. At such a time, a rapid and effective response may be requested and needed to reduce the destruction of rangeland vegetation, or in some cases, to also prevent grasshopper migration to cropland adjacent to rangeland. This EIS analyzes the alternatives available to APHIS when a Federal land management agency or State agriculture department (on behalf of a State, a local government, or a private group or individual) requests APHIS to suppress economically damaging grasshopper populations. APHIS is authorized under the Plant Protection Act (PPA) (7 United States Code (U.S.C.) § 7701 *et seq.*) to protect rangeland from economic infestations of grasshoppers.

Purpose of and Need for the Proposed Action

This environmental impact statement (EIS) is prepared in accordance with the requirements under the National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. § 4321 *et seq.*) and the NEPA procedural requirements promulgated by the Council on Environmental Quality,

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[1] Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming.

USDA, and APHIS. This document considers the potential for environmental impacts from APHIS grasshopper suppression programs in all or part of 17 Western States.

Rather than a specific proposed action, this EIS analyzes environmental impacts associated with programmatic actions related to grasshopper suppression. These environmental impacts are based on new information and technological advances that have occurred since the completion of the Rangeland Grasshopper Cooperative Management Program, Final Environmental Impact Statement—1987.

This programmatic document contains information that can be used by APHIS and Federal land management agencies when preparing the NEPA documentation for their proposed actions. The methods for using this information in such documents include adoption, combining, incorporation by reference, and tiering (see chapter 1).

Alternatives Available to APHIS to Protect Rangeland From Grasshopper Outbreaks

APHIS conducts surveys for grasshopper populations on rangeland in the Western United States, provides technical assistance on grasshopper management to land owners/managers, and cooperatively suppresses grasshoppers when direct intervention is requested and deemed necessary.

The need for rapid and effective suppression of grasshoppers when an outbreak occurs limits the options available to APHIS. The application of an insecticide within all or part of the outbreak area is the response available to APHIS to rapidly suppress or reduce (but not eradicate) grasshopper populations and effectively protect rangeland. The following alternatives are available to APHIS and analyzed in this EIS.

Alternative 1: No Action

Under Alternative 1, APHIS would not fund or participate in any program to suppress grasshopper infestations. Some Federal land management agencies, State agriculture departments, local governments, or private groups or individuals would likely conduct their own suppression programs against grasshoppers.

Alternative 2: Insecticide Applications at Conventional Rates and Complete Area Coverage

Alternative 2 is generally the approach that APHIS has used for many years. The insecticide APHIS would consider under this alternative includes carbaryl, diflubenzuron, and malathion. Carbaryl and malathion are insecticides that have traditionally been used by APHIS. The insect growth regulator, diflubenzuron, is also included in this alternative. Applications would cover all treatable sites within the infested area (total or blanket coverage) per label directions. The application rate analyzed under this alternative are as follows:

- 16 fluid ounces (0.50 pound active ingredient (lb a.i.)) of carbaryl spray per acre,
- 10 pounds (0.50 lb a.i.) of 5 percent carbaryl bait per acre,
- 1.0 fluid ounce (0.016 lb a.i.) of diflubenzuron per acre, or
- 8 fluid ounces (0.62 lb a.i.) of malathion per acre.

Alternative 3: Reduced Agent Area Treatments (RAATs)

Alternative 3 is a recently developed grasshopper suppression method in which the rate of insecticide is reduced from conventional levels, and treated swaths are alternated with swaths that are not directly treated. The RAATs strategy relies on the effects of an insecticide to suppress grasshoppers within treated swaths while conserving grasshopper predators and parasites in swaths not directly treated. Either the insecticide carbaryl, diflubenzuron, or malathion would be considered under this alternative at the following application rate:

- 8 fluid ounces (0.25 lb a.i.) of carbaryl spray per acre,
- 10 pounds (0.20 lb a.i.) of 2 percent carbaryl bait per acre,
- 0.75 fluid ounce (0.012 lb a.i.) of diflubenzuron per acre, or
- 4 fluid ounces (0.31 lb a.i.) of malathion per acre.

The area not directly treated (untreated) under the RAATs approach is not standardized. In the past, the area infested with grasshoppers that remains untreated has ranged from 20 to 67 percent. This EIS analyzed the reduced pesticide application rates associated with the RAATs approach, but assumed pesticide coverage on 100 percent of the area because there is no way to predict in this EIS how much area will actually be left untreated.

Rather than suppress grasshopper populations to the greatest extent possible, the goal of this alternative is to suppress grasshopper populations to a desired level.

Environmental Consequences

Alternative 1: No Action

Under Alternative 1, APHIS would not fund or participate in any program to suppress grasshoppers infestations. Despite implementing the best land management practices, Federal land management agencies, State agriculture departments, local governments, or private groups or individuals may not effectively combat outbreaks in a coordinated effort. In these situations, grasshopper outbreaks could develop and spread unimpeded. Unsuppressed outbreaks can destroy rangeland forage, devastate rangeland habitats, threaten crops, and become a public nuisance.

Another potential scenario, if APHIS does not participate in any grasshopper suppression programs, is that some Federal land management agencies, State agriculture departments, local governments, or private groups or individuals may attempt to conduct widespread grasshopper programs. Without the technical assistance and program coordination that APHIS can provide to grasshopper programs, it is possible that a large amount of insecticides, including those APHIS considers too environmentally harsh but labeled for rangeland use, could be applied, reapplied, and perhaps misapplied in an effort to suppress or even locally eradicate grasshopper populations.

Alternative 2: Insecticide Applications at Conventional Rates and Complete Area Coverage

Under Alternative 2, APHIS would participate in grasshopper programs with the option of using one of the insecticides carbaryl, diflubenzuron, or malathion, depending upon the various factors related to the grasshopper outbreak and the site-specific characteristics. The use of an insecticide would occur at the conventional rates. With only rare exceptions, APHIS would apply a single treatment in an outbreak year that would blanket affected rangeland areas in an attempt to suppress grasshopper outbreak populations by a range of 35 to 98 percent, depending upon the insecticide used.

Treatments made during grasshopper outbreaks, when densities can be 60 or more per square meter, still leave a number of grasshoppers that may be higher than the number of grasshoppers found in a normal year. Detailed information about the consequences of insecticide applications under this alternative can be found in chapter 5, Environmental Consequences, and in appendix B.

Carbaryl: Carbaryl is of moderate acute oral toxicity to humans. The mode of toxic action of carbaryl occurs through inhibition of acetylcholinesterase (AChE) function in the nervous system. This inhibition is reversible over time if exposure to carbaryl ceases. EPA has classified carbaryl as a “possible human carcinogen.” However, it is not considered to pose any mutagenic or genotoxic risk.

Potential exposures to the general public from conventional application rates are infrequent and of low magnitude. These low exposures to the public pose no risk of direct toxicity, carcinogenicity, neurotoxicity, genotoxicity, reproductive toxicity, or developmental toxicity. The potential for adverse effects to workers are negligible if proper safety procedures are followed, including wearing the required protective clothing. Carbaryl has been used routinely in other programs with no reports of adverse health effects. Therefore, routine safety precautions are expected to provide adequate worker health protection.

Carbaryl is of moderate acute oral toxicity to mammals. Carbaryl applied at Alternative 2 rates is unlikely to be directly toxic to upland birds, mammals, or reptiles. Field studies have shown that carbaryl applied as either ultra-low-volume (ULV) spray or bait at Alternative 2 rates posed little risk to killdeer, vesper sparrows, or golden eagles in the treatment areas. AChE inhibition at 40 to 60 percent can affect coordination, behavior, and foraging ability in vertebrates. Multi-year studies conducted at several grasshopper treatment areas have shown AChE inhibition at levels of no more that 40 percent with most at less than 20 percent. Carbaryl is not subject to significant bioaccumulation due to its low water solubility and low octanol-water partition coefficient.

Carbaryl will most likely affect nontarget insects that are exposed to ULV carbaryl spray or that consume carbaryl bait within the grasshopper treatment area. Field studies have shown that affected insect populations can recover rapidly and generally have suffered no long-term effects, including some insects that are particularily sensitive to carbaryl, such as bees. The use of carbaryl in bait form generally has considerable environmental advantages over liquid insecticide applications: bait is easier than liquid spray applications to direct toward the target area, bait is more specific to grasshoppers, and bait affects fewer nontarget organisms than sprays.

Should carbaryl enter water, there is the potential to effect the aquatic invertebrate assemblage, especially amphipods. Field studies with carbaryl concluded that there was no biologically significant effect on aquatic resources, although invertebrate downstream drift increased for a short period after treatment due to toxic effects. Carbaryl is moderately toxic to most fish.

Diflubenzuron: The acute oral toxicity of diflubenzuron formulations to humans ranges from very slight to slight. The most sensitive indicator of exposure and effects of diflubenzuron in humans is the formation of methemoglobin in blood.

Potential exposures to the general public from Alternative 2 rates are infrequent and of low magnitude. These low exposures to the public pose no risk of methemoglobinemia, direct toxicity, neurotoxicity, genotoxicity, reproductive toxicity, or developmental toxicity. Potential worker exposures are higher than the general public but are not expected to pose any risk of adverse health effects.

Because diflubenzuron is a chitin inhibitor that disrupts insects from forming their exoskeleton, organisms without a chitinous exoskeleton, such as mammals, fish, and plants are largely unaffected by diflubenzuron. In addition, adult insects, including wild and cultivated bees, would be mostly unaffected by diflubenzuron applications. Among birds, nestling growth rates, behavior data, and survival of wild American kestrels in diflubenzuron treated areas showed no significant differences among kestrels in treated areas and untreated areas. The acute oral toxicity of diflubenzuron to mammals ranges from very slight to slight. Little, if any, bioaccumulation of diflubenzuron would be expected.

Diflubenzuron is most likely to affect immature terrestrial insects and early life stages of aquatic invertebrates. While this would reduce the prey base within the treatment area for organisms that feed on insects, adult insects, including grasshoppers, would remain available as prey items. Many of the aquatic organisms most susceptible to diflubenzuron are marine organisms that would not be exposed to rangeland treatments. Freshwater invertebrate populations would be reduced if exposed to diflubenzuron, but these decreases would be expected to be temporary given the rapid regeneration time of many aquatic invertebrates.

Malathion: Malathion is of slight acute oral toxicity to humans. The mode of toxic action of malathion occurs through inhibition of AChE function in the nervous system. Unlike carbaryl, AChE inhibition from malathion is not readily reversible over time if exposure ceases. However, strong inhibition of AChE from malathion occurs only when chemical oxidation results in formation of the metabolite malaoxon. Human metabolism of malathion favors hydroxylation and seldom produces much malaoxon.

Potential exposures to the general public from conventional application rates are infrequent and of low magnitude. These low exposures to the public pose no risk of direct toxicity, neurotoxicity, genotoxicity, reproductive toxicity, or developmental toxicity. Potential worker exposures are higher, but still have little potential for adverse health effects except under accidental scenarios. Malathion has been used routinely in other programs with no reports of adverse health effects. Therefore, routine safety precautions are expected to continue to provide adequate protection of worker health.

EPA has recently reviewed the potential for carcinogenic effects from malathion. EPA's classification describes malathion as having "suggestive evidence of carcinogenicity, but not sufficient to assess human carcinogenic potential." This indicates that any carcinogenic potential of malathion cannot be quantified based upon EPA's weight of evidence determination in this classification. The low exposures to malathion from program applications would not be expected to pose carcinogenic risks to workers or the general public.

Malathion is of slight acute oral toxicity to mammals. There is little possibility of toxicity-induced mortality of upland birds, mammals, or reptiles, and no direct toxic effects have been observed in field studies. Malathion is not directly toxic to vertebrates at the concentrations used for grasshopper suppression, but it may be possible that sublethal effects to nervous system functions caused by AChE inhibition may lead directly to decreased survival. AChE inhibition at 40 to 60 percent affects coordination, behavior, and foraging ability in vertebrates. Multi-year studies at several grasshopper treatment areas have shown AChE inhibition at levels of no more than 40 percent with most at less than 20 percent. Field studies of birds within malathion treatment areas showed that, in general, the total number of birds and bird reproduction were not different from untreated areas. Malathion does not bioaccumulate.

Malathion will most likely affect nontarget insects within a treatment area. Large reductions in some insect populations would be expected after a malathion treatment under Alternative 2. While the number of insects would be diminished, there would be some insects remaining. The remaining insects would be available prey items for insectivorous organisms, and those insects with short generation times may soon increase.

Malathion is highly toxic to some fish and aquatic invertebrates; however, malathion concentrations in water, as a result of grasshopper treatments, are expected to be low presenting a low risk to aquatic organisms, especially those organisms with short generation times.

Alternative 3: Reduced Agent Area Treatments (RAATs)

Under Alternative 3, either the insecticide carbaryl, diflubenzuron, or malathion would be used at a reduced rate and over reduced areas of coverage. Rarely would APHIS apply more than a single treatment to an area per year. The maximum insecticide application rate under the RAATs strategy is reduced 50 percent from the conventional rates for carbaryl and malathion and 25 percent from the Alternative 2 rate for diflubenzuron. Although this strategy involves leaving variable amounts of land not directly treated, the risk assessment for this document (appendix B) assumed 100 percent area coverage because not all possible scenarios could be analyzed. However, when utilized in grasshopper suppression, the amount of untreated area in RAATs often ranges from 20 to 67 percent of the total infested area but can be adjusted to meet site-specific needs.

Applying the RAATs strategy during grasshopper outbreaks, when densities can be 60 or more per square meter, still leave a density of grasshoppers that may be higher than the density of grasshoppers found in a normal year. Grasshopper mortality using a RAATs strategy has been shown to range from 75 to 95 percent. Detailed information about the consequences of insecticide applications under this alternative can be found in chapter 5, Environmental Consequences, and appendix B.

Carbaryl: Potential exposures to the general public and workers from RAATs application rates are lower than those from conventional application rates, and adverse effects decrease commensurately with decreased magnitude of exposure. These low exposures to the public pose no risk of direct toxicity, carcinogenicity, neurotoxicity, genotoxicity, reproductive toxicity, or developmental toxicity. The potential for adverse effects to workers is negligible if proper safety procedures are followed, including wearing the required protective clothing. Routine safety precautions are expected to provide adequate protection of worker health at the lower application rates under RAATs.

Carbaryl will most likely affect nontarget insects that are exposed to liquid carbaryl or that consume carbaryl bait. While carbaryl applied at a RAATs rate will reduce susceptible insect populations, the decrease will be less than under Alternative 2 rates. Carbaryl ULV applications applied in alternate swaths have been shown to affect terrestrial arthropods less than malathion applied in a similar fashion.

Direct toxicity of carbaryl to birds, mammals, and reptiles is unlikely in swaths treated with carbaryl under a RAATs approach. Carbaryl bait also has minimal potential for direct effects on birds and mammals. Field studies indicated that bee populations did not decline after carbaryl bait treatments, and American kestrels were unaffected by bait applications made at a RAATs rate. Using alternating swaths will furthermore reduce adverse effects because organisms that are in untreated swaths will be mostly unexposed to carbaryl.

Carbaryl applied at a RAATs rate has the potential to affect invertebrates in aquatic ecosystems. However, these affects would be less than effects expected under Alternative 2. Fish are not likely to be affected at any concentrations that could be expected under Alternative 3.

Diflubenzuron: Potential exposures and adverse effects to the general public and workers from RAATs application rates are commensurately less than conventional application rates. These low exposures to the public pose no risk of methemoglobinemia, direct toxicity, neurotoxicity, genotoxicity, reproductive toxicity, or developmental toxicity. Potential worker exposures pose negligible risk of adverse health effects.

Because diflubenzuron is a chitin inhibitor that disrupts insects from forming their exoskeleton, organisms without a chitinous exoskeleton, such as mammals, fish, and plants are largely unaffected by diflubenzuron. Diflubenzuron exposure at Alternative 3 rates are not hazardous to terrestrial mammals, birds, and other vertebrates. Insects in untreated swaths would have little to no exposure, and adult insects in the treated swaths are not susceptible to diflubenzuron's mode of action. The indirect effects to insectivores would be negligible as not all insects in the treatment area will be affected by diflubenzuron.

Diflubenzuron is most likely to affect immature terrestrial insects and, if it enters water, will affect early life stages of aquatic invertebrates. While diflubenzuron would reduce insects within the treatment area, insects in untreated swaths would have little to no exposure. Many of the aquatic organisms most susceptible to diflubenzuron are marine organisms that would not be exposed to rangeland treatments. Freshwater invertebrate populations would be reduced if exposed to diflubenzuron, but these decreases may be temporary given the rapid regeneration time of many aquatic invertebrates.

Malathion: Potential exposures to the general public and workers from RAATs application rates are of a commensurately lower magnitude than conventional rates. These low exposures to the public pose no risk of direct toxicity, neurotoxicity, genotoxicity, reproductive toxicity, or developmental toxicity.

Potential risks to workers are negligible if proper safety procedures are adhered to, including the use of required protective clothing. Malathion has been used routinely in other programs with no reports of adverse health effects. The low exposures to malathion from program applications are not expected to pose any carcinogenic risks to workers or the general public.

Malathion applied at a RAATs rate will cause mortalities to susceptible insects. Organisms in untreated areas will be mostly unaffected. Field applications of malathion at a RAATs rate and applied in alternate swaths resulted in less reduction in nontarget organisms than would occur in blanket treatments. Birds in RAATs areas were not substantially affected. Should malathion applied at RAATs rates enter water, it is most likely to affect aquatic invertebrates. However, these effects would soon be compensated for by the surviving organisms given the rapid generation time of most aquatic invertebrates and the rapid degradation of malathion in most water bodies.

Species of Concern: This EIS has examined the effects of grasshopper suppression programs on three specific species, or groups of species, that are of concern in the Western United States. These species or groups were selected as examples of species that are found on rangeland habitats.

Sage grouse, which is a species of concern to land management agencies, has been in a state of decline throughout most of its entire range. Sage grouse can be present in grasshopper suppression areas, and grasshoppers can be a food item for sage grouse chicks. There is little likelihood that the insecticide APHIS would use to suppress grasshoppers would be directly or indirectly toxic to sage grouse. Treatments would typically not reduce the number of grasshoppers below levels that are present in nonoutbreak years. If grasshoppers were in short supply, sage grouse chicks may consume other insects. Grasshopper suppression would also conserve rangeland vegetation that may be used by sage grouse.

There are numerous biological control agents used to control invasive plants on Western rangeland. For example, species of flea beetles are used to control leafy spurge that threatens many rangeland habitats. Some of these same rangeland habitats may be locations where the grasshopper program is conducted, thus these biological control agents would likely be exposed to the insecticide used for grasshopper control. Field studies on the effects of grasshopper suppression programs on flea beetles demonstrated that after an initial decline in flea beetle populations immediately following after a grasshopper treatment, flea beetle populations recovered to pretreatment levels after 1 year.

Populations of threatened or endangered species in grasshopper suppression areas would be at a greater risk, because of the small number of individuals. Studies on two federally listed endangered fish species concluded that carbaryl and malathion posed no greater hazard to those endangered species than to species not listed as endangered. A programmatic consultation on the threatened and endangered species and their habitats that occur in the 17 Western States is presently underway. Protective measures will be developed that, when implemented, will ensure that threatened and endangered species and their habitats will not be adversely affected.

Cumulative Impacts: As this is a programmatic environmental document, the cumulative impacts of the program on the environment would best be considered when a site-specific environmental document is prepared for a particular grasshopper program. Grasshopper programs could occur on rangelands in any of the 17 Western States. The location, magnitude, and characteristics of a treatment area where APHIS is requested to carry out an insecticide program would need to be defined in order to determine the past, present, and foreseeable future actions that have or will occur in the program area.

Socioeconomic Impacts: This EIS considers the qualitative social and economic linkages regarding action taken or not taken against grasshopper outbreaks. Livestock owners, crop growers, and the general public (consumers of agricultural products) are among the social groups that, in various ways, would be economically adversely impacted under the No Action alternative. These socioeconomic impacts could result from the extensive damage to rangelands and associated resources from grasshopper outbreaks and the availability of funding by private individuals and government agencies to carry out efforts against outbreaks.

Under Alternative 2, socioeconomic impacts would be realized from the use of insecticides at conventional rates and complete area coverage. The socioeconomic impacts under this alternative would result from the timing and success of the treatments, the potential for adverse or beneficial environmental impacts, and the cost of the treatments.

Under Alternative 3, the socioeconomic impacts would be realized from the use of insecticides at reduced rates and reduced area coverage. The socioeconomic impacts would result from the timing and success of treatment methods used, the potential for adverse or beneficial environmental impacts from the reduced use of insecticides and area treated, and the decreased cost and greater economic benefits from using insecticide at reduced rates and area coverage.

Other Environmental Considerations: This EIS also addresses concerns about program actions on the following environmental considerations: environmental justice, the protection of children, cultural resources and events, endangered species, and monitoring.

In accordance with Executive Order (E.O.) 12898, APHIS will consider the potential for disproportionately high and adverse human health or environmental effects on minority populations and low-income populations for any of its actions related to grasshopper suppression programs. The appropriate environmental documentation for a site-specific program will include environmental justice considerations.

APHIS has also developed agency guidance for its programs to follow to ensure the protection of children as required by E.O. 13045. Information about the exposure risks to children from carbaryl, diflubenzuron, and malathion used for grasshopper suppression is discussed in appendix B of this EIS. The risk assessment concluded that the likelihood of children being exposed to insecticides used for grasshopper suppression is very slight and that no disproportionate adverse effects to children are anticipated over the negligible effects to the general population.

The potential for impacts that could occur from grasshopper suppression activities to cultural and historical sites and artifacts, as well as cultural events, will be considered in site-specific environmental documents. In addition, APHIS will confer with land managers and tribal authorities to protect cultural resources and events.

In order to comply with the Endangered Species Act of 1973, APHIS is preparing a biological assessment that will be used in a programmatic consultation with the Fish and Wildlife Service and the National Marine Fisheries Service. The consultation process will address the impacts of grasshopper suppression on federally listed (and proposed) species and their habitats that occur in all or part of the 17 Western States. Through this process protection measures will be developed that, when implemented, will ensure that grasshopper suppression activities will not adversely affect those species or their habitats.

Monitoring could involve an evaluation of the efficacy of the grasshopper treatments, the safety of program personnel, and environmental monitoring to assure that insecticides are applied in accordance with the labels and sensitive sites and species are protected. If environmental monitoring is conducted, a monitoring plan will describe the types of samples to be collected. Additional information regarding the effects of grasshopper suppression programs on the environment can be found in the Grasshopper Integrated Pest Management Program User Handbook that is available at: www.sidney.ars.usda.gov/grasshopper/index.htm.

TABLE 1-1: Road warning sign (Photo Credit - USDA-APHIS)

I. Purpose of and Need for the Proposed Action

Grasshoppers and Mormon crickets are part of rangeland ecosystems, serving as a food source for wildlife and playing an important role in nutrient cycling. (The term “grasshopper” used in this environmental impact statement (EIS) refers to both grasshoppers and Mormon crickets, unless differentiation is necessary.) Many grasshoppers are strong fliers, often moving from rangeland to cropland and other vegetation where they can cause severe damage (Pfadt, 1994). Mormon crickets, although flightless, are also capable of moving long distances in large groups. (For more information about the biology of grasshoppers, see chapter 2, section D.)

Grasshoppers have a potential for sudden and explosive population increases, resulting in outbreaks. Such outbreaks produce high densities of grasshoppers and intense competition for the available food supply, which may cause damage to rangeland and nearby crops. Loss of wildlife habitats also may result from outbreaks. (For more information about damage caused by grasshoppers, see chapter 2, section E.) To date, there are no simple ecological explanations to predict grasshopper outbreaks (Belovsky *et al.*, 1996).

Despite the best land management efforts to prevent outbreaks, grasshopper populations may build to levels of economic infestation where direct intervention may be the most viable option to suppress grasshopper populations. Not all grasshopper species are damaging; therefore, action to protect rangeland resources is not always required when grasshopper populations increase. When a rapid and effective response to a developing grasshopper outbreak is required, a Federal land management agency or a State agriculture department (on behalf of a State, a local government, or a private group or individual) may request assistance from the Animal and Plant Health Inspection Service (APHIS) to suppress rangeland grasshopper populations. APHIS has the authority, according to the Plant Protection Act (PPA) (7 United States Code (U.S.C.) § 7701 *et seq.*) and subject to the available funds, to treat Federal, State, or private lands that have economic infestations of grasshoppers. (See footnote 2 in this chapter for a definition of economic infestation.)

The U.S. Department of Agriculture (USDA), APHIS, has prepared this EIS, Rangeland Grasshopper and Mormon Cricket Suppression Program, Final Environmental Impact Statement, to comply with the National Environmental Policy Act of 1969 (NEPA), as amended (42 U.S.C. § 4321*et seq.*), the Council on Environmental Quality (CEQ) Regulations for Implementing the Procedural Provisions of NEPA (40 Code of Federal Regulations (CFR) §§ 1500–1508), the USDA NEPA regulations (7 CFR Part 1b), and the APHIS NEPA regulations (7 CFR Part 372).[1] This EIS analyzes the potential for impacts on the human environment from APHIS' use of any of three insecticides analyzed in this EIS to protect rangeland from economically damaging grasshopper infestations.

The CEQ NEPA implementing regulations state that an EIS shall "briefly specify the underlying purpose and need to which the agency is responding in proposing the alternatives including the proposed action" (40 CFR § 1502.13). This EIS does not respond to a new action or proposal but looks at new information and technological advances to a broad program for treating grasshopper infestations when site-specific action is required.

New information and technological advances in the use of insecticides for grasshopper infestations have occurred since the preparation of the Rangeland Grasshopper Cooperative Management Program, Final Environmental Impact Statement—1987 (1987 EIS) (see appendix A for information about grasshopper programs and the 1987 EIS). There is a need to generally consider the potential for environmental impacts from the program and proposed changes to the program. The CEQ NEPA implementing regulations (40 CFR § 1502.4(c)) state "When preparing statements on broad actions. . . , agencies may find it useful to evaluate the proposal(s) in . . . the following way: . . . (3) By stage or technological development including federal or federally assisted research, development or demonstration programs for new technologies which, if applied, could significantly affect the quality of the human environment. Statements shall be prepared on programs and shall be available before the program has reached a stage of investment or commitment to implementation likely to determine subsequent development or restrict later alternatives." The analysis of the treatments for grasshopper infestations needs to be updated based on new information and technological advances on the insecticides used and proposed for use and the methods by which the insecticides can be applied.

According to the authority delegated under section 417 of the PPA (7 U.S.C. § 7717), APHIS may be requested to work in conjunction with a Federal land management agency or a State agriculture department (on behalf of a State, a local government, or a private group or individual) to treat areas that are infested with grasshoppers when they reach a level of economic infestation.[1] In satisfying this mandate, APHIS may be asked to carry out actions using insecticides to reduce grasshopper populations. The analysis of the potential for

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[1] This document is also intended to satisfy the order of the United States District Court for the District of Idaho, dated January 9, 2001, dismissing a case (Civ. No. 00-337-E-BLW) pursuant to the Stipulation of the parties calling, in part, for APHIS to "issue a revised and updated Environmental Impact Statement for the Rangeland Grasshopper Cooperative Management Program." *See* Rule 41(a) STIPULATION TO DISMISS, the ORDER OF DISMISSAL, as well as the documented history of the proceeding, at http://www.id.uscourts.gov/wconnect/wc.dll?usdc_racer~get_case_jb~4:0-cv-337~~ALL+DOCUMENTS~~PUID+NOBILL.

environmental impacts of APHIS' suppression programs includes a new insecticide and technological advances for the purpose of responding to grasshopper outbreaks.

This programmatic EIS closely follows the recommended standard format for this type of environmental document, as provided by CEQ NEPA implementing regulations 40 CFR §§ 1500–1508. This EIS discusses the (1) purpose of and need for the action, (2) alternatives considered, (3) affected environment, and (4) potential for environmental impacts from the alternatives. This EIS also includes other required sections, such as references used; a list of preparers; a list of agencies, organizations, and persons to whom copies of the EIS was sent; and an index. In adhering to CEQ's guidelines, an attempt has been made to keep the required sections concise (not encyclopedic) and written so that both the decision makers and the public can readily understand this EIS (40 CFR § 1502.10).

Readers who may have questions that are relevant to rangeland grasshopper programs but that are outside the scope of this EIS should refer to appendix A. Appendix A includes supplemental information to this EIS, such as an historical overview of grasshopper programs in the United States, information about cooperator roles in grasshopper programs, a discussion about the difference in grasshopper management and suppression programs, and alternative approaches to grasshopper management that are outside the scope of this EIS. Readers who may want more technical information about the use of insecticides to suppress rangeland grasshoppers should refer to appendix B. Appendix B contains the detailed and technical risk assessment that supports chapter 5, Environmental Consequences. Additionally, appendix C has been added to this EIS. Appendix C is the environmental fate and transport modeling conducted on the three insecticides APHIS may use during a grasshopper program.

This EIS includes analysis of those activities that APHIS is authorized to conduct, which includes the conduct of surveys and the use of insecticides for the suppression of grasshoppers. APHIS conducts

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1 The "level of economic infestation" is a measurement of the economic losses caused by a particular population level of grasshoppers or Mormon crickets to the infested rangeland. This value is determined on a case-by-case basis with knowledge of many factors including, but not limited to, the following: economic use of available forage or crops; grasshopper species, age, and density present; rangeland productivity and composition; accessibility and cost of alternative forage; and weather patterns. In decision making, the level of economic infestation is balanced against the cost of treating to determine an "economic threshold" below which there would not be an overall economic benefit for the treatment. Short-term economic benefits accrue during the years of treatments, but additional long-term benefit may accrue and be considered in deciding the total value gained by a treatment. Additional losses to rangeland habitat and cultural and personal values (e.g., esthetics and cultural resources), although they may also be a part of decision making, are not part of the economic values in determining the necessity for treatment.

these activities at the request of a Federal land management agency or a State agriculture department (on behalf of a State, a local government, or a private group or individual).

The NEPA implementing regulations address the issue of how other agencies may use this programmatic document. The most obvious way in which another Federal agency may use this document is through the technique known as "incorporate by reference." "Agencies shall incorporate material into an environmental impact statement by reference when the effect will be to cut down on bulk without impeding agency and public review of the action. The incorporated material shall be cited in the statement and its content briefly described. . . ." (40 CFR § 1502.21). There is also a technique known as "adoption," under which "An agency may adopt a Federal draft or final environmental impact statement or portion thereof provided that the statement or portion thereof meets the standards for an adequate statement under these regulations." (40 CFR § 1506.3). A Federal agency may also "combine" documents. In 40 CFR § 1506.4 it states that "Any environmental document in compliance with NEPA may be combined with any other agency document to reduce duplication and paperwork."

A last method is tiering (40 CFR §1502.20). "Agencies are encouraged to tier their environmental impact statements to eliminate repetitive discussions of the same issues and to focus on the actual issues ripe for decision at each level of environmental review (40 CFR § 1508.28).

Whenever a broad environmental impact statement has been prepared (such as a programmatic or policy statement) and a subsequent statement or environmental assessment is then prepared on an action included within the entire program or policy (such as a site specific action) the subsequent statement or environmental assessment need only summarize the issues discussed in the broader statement and incorporate discussions from the broader statement by reference and shall concentrate on the issues specific to the subsequent action. The subsequent document shall state where the earlier document is available (40 CFR § 1508.28)."

This document is not restricted to the actions of a single agency; rather, it deals with a program, treating it by stage of technological development (40 CFR § 1502.4(c)(3)), in which other Federal agencies, States, or private citizens may cooperate, as needed, in more localized operations.

This EIS supercedes the Rangeland Grasshopper Cooperative Management Program, Final Environmental Impact Statement—1987.

The following table summarizes the similarities and differences between alternatives in the 1987 EIS and this EIS.

TABLE 1-1. Alternatives Analyzed in the 1987 and 2002 Grasshopper Environmental Impact Statements

1987 EIS

Alternative 1 - No Action

Alternative 2 - Chemical Controls

- ULV[1] Sprays
  - Acephate: 0.094 lb a.i./acre[2]
  - Carbaryl: 0.50 lb a.i./acre
  - Malathion: 0.58 lb a.i./acre
- Bait
  - Carbaryl:0.50 lb a.i./acre

Alternative 3 - Integrated Pest Management (IPM)

- ULV Sprays
  - Acephate: 0.094 lb a.i./acre
  - Carbaryl: 0.50 lb a.i./acre
  - Malathion: 0.58 lb a.i./acre
- Bait
  - Carbaryl: 0.50 lb a.i./acre
- Biological Control Agents
- Combined Chemical/Biological Control Bait
- Other IPM strategies including: range management, database development and predictive modeling, environmental evaluation

2002 EIS

Alternative 1 - No Action

Alternative 2 - Insecticide Applications at Conventional Rates and Complete Area Coverage

- ULV Sprays
  - Carbaryl: 0.50 lb a.i./acre
  - Diflubenzuron: 0.016 lb a.i./acre
  - Malathion: 0.62 lb a.i./acre
- Bait
  - Carbaryl: 0.50 lb a.i./acre

Alternative 3 - Reduced Agent Area Treatments (RAATs)

- ULV sprays applied onto 33 to 50% of treatment area, for example, application to 100-foot swaths alternating with 100- to 200-foot untreated swaths
  - Carbaryl: 0.25 lb a.i./acre maximum
  - Diflubenzuron: 0.012 lb a.i./acre maximum
  - Malathion: 0.31 lb a.i./acre maximum
- Bait applied onto 33 to 50% of treatment area, for example, application to 100-foot swaths alternating with 100- to 200-foot untreated swaths
  - Carbaryl: 0.20 lb a.i./acre

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[1] Ultra-low-volume

[2] Pound of active ingredient per acre

II. Background

A. Scope and Focus of This Environmental Impact Statement

On August 14, 2000, the Animal and Plant Health Inspection Service (APHIS) published in the *Federal Register* (FR) (65 FR 49533) a notice of its intent (appendix E) to prepare an environmental impact statement (EIS) relative to the agency's activities to suppress rangeland grasshoppers and Mormon crickets (the term "grasshoppers" used in this document refers to both grasshoppers and Mormon crickets, unless differentiation is needed). This EIS is written to comply with the National Environmental Policy Act (NEPA) (42 United States Code (U.S.C.) § 4321 *et seq.* and the Council on Environmental Quality's NEPA implementing regulations (40 Code of Federal Regulations (CFR) §§ 1500–1508). It is designed to—

1. examine the environmental effects of alternatives available to APHIS for the suppression of rangeland grasshoppers,
2. inform the public about the environmental effects of APHIS' rangeland grasshopper suppression activities,
3. be used for planning and decisionmaking, andp
4. provide a document to which APHIS can tier site-specific analyses and environmental documents on grasshopper suppression activities. The information contained in the EIS can be used by Federal land management agencies when preparing their environmental documents. Federal land management agencies can adopt (§ 1506.3), combine (§ 1506.4), incorporate by reference (§ 1502.21), or tier (§ 1502.20) their activities to the data in this EIS.

Since the preparation of the Rangeland Grasshopper Cooperative Management Program, Final Environmental Impact Statement—1987, (1987 EIS) (USDA, APHIS, 1987b), new information and technological advances in insecticide treatments for grasshopper infestations have occurred. This EIS is a programmatic analysis that focuses specifically on insecticide treatments, current and proposed, for rangeland grasshopper programs. A rangeland grasshopper program could occur in any of the following 17 Western States: Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming.

New Information and Technological Advances

a. The Grasshopper Integrated Pest Management Program—The Grasshopper Integrated Pest Management (GHIPM) Program was established as a result of the 1987 EIS to study the feasibility of using integrated pest management (IPM) for managing grasshoppers. IPM includes biological control, chemical control, rangeland management, environmental monitoring and evaluation, modeling and population dynamics, and decision support tools. The results of the study have been provided to managers of public and private rangeland and are available at: www.sidney.ars.usda.gov/grasshopper/index.htm. The major objectives of the program were to (1) manage grasshopper populations in study areas, (2) compare the effectiveness of an IPM program for rangeland grasshoppers with the effectiveness of a standard chemical control program on a regional scale, (3) determine the effectiveness of early sampling in detecting incipient grasshopper infestations, (4) quantify short- and long-term responses of grasshopper populations to treatments, and (5) develop and evaluate new grasshopper suppression techniques that have minimum effects on nontarget species (Quinn *et al.*, 2000).

This program managed grasshopper populations with several available IPM techniques, described by the preferred alternative grasshopper management tactics outlined in the 1987 EIS. These techniques included (1) providing more detailed surveys of grasshopper populations so that small areas of infestations could be defined, (2) treating small areas of infestations (“hot spots”) rather than the larger areas of infestation traditionally treated, and (3) using control methods other than the conventional large-scale aerial applications of insecticidal sprays.

The program included data gathering during the first year, testing of range improvement techniques during a 5-year period after the data gathering, database development and predictive modeling, environmental evaluation, and economic research. The program was designed to provide data that would be used for improving APHIS’ ability to determine environmental effects of its use of insecticides and to refine its program operations accordingly.

b. Acephate, Carbaryl, and Malathion—Since APHIS’ 1987 analysis of the potential for environmental impacts from the insecticides used for rangeland grasshopper control (USDA, APHIS, 1987b), updated information about the potential impacts from carbaryl and malathion on human health and nontarget species has become available. Specifically, information about the carcinogenicity, revised data on the reference doses of carbaryl and malathion, synergism of the program insecticides with other insecticides, and new information about carriers and inert ingredients used with the insecticides are analyzed in this EIS. The summary of the updated analysis on these insecticides can be found in chapter 5, Environmental Consequences, and an in-depth analysis of these insecticides can be found in appendix B. After the 1987 EIS was written, the registration of acephate for use on rangeland was not renewed; therefore, it can no longer be considered for use in rangeland grasshopper programs.

d. Use of Diflubenzuron—Information about the potential use of the insecticide diflubenzuron for grasshopper infestations has become available. Diflubenzuron is an insect growth regulator that affects the formation of chitin which is essential for the development of insect exoskeletons. Although the mode of action for diflubenzuron is different than the mode of action for both carbaryl and malathion, the term "insecticide" used in this document refers to carbaryl, diflubenzuron, and malathion.

Diflubenzuron primarily affects the immature stages of insects that need chitin to form cuticles or shells and, therefore, could be used during early growth stages of grasshoppers. The potential for APHIS' use of diflubenzuron in grasshopper programs warrants analysis of its environmental impacts. The summary of the analysis on this insecticide can be found in chapter 5, Environmental Consequences, and an in-depth analysis of this insecticide can be found in appendix B.

e. Alternative Treatment Strategy—An alternative treatment strategy, referred to in this EIS as Reduced Agent Area Treatments (RAATs), for grasshopper suppression has been researched and developed. This strategy allows application of a treatment at a reduced rate and in alternating land swaths (thus using less insecticide). Therefore, this strategy results in conservation of nontarget biological resources, including predators and parasites of grasshoppers, in the areas not directly treated. In addition, this approach reduces the likelihood that insects will develop resistance to pesticides. This EIS analyzes RAATs as a new alternative for APHIS activities involving insecticide treatments in grasshopper programs. See chapter 3, Alternatives, for more information about this treatment strategy.

2. Inform the Public

This EIS will provide the interested public with a programmatic analysis of the potential for environmental impacts from alternatives available to APHIS to suppress rangeland grasshopper infestations.

3. Aid in Planning and Decision making

This EIS provides analyses of potential environmental impacts of alternatives based on new information and technological advances since 1987 and will serve as an aid to the program manager responsible for making a decision on a proposed action at the site-specific level.

4. Provide a Basis for Site-specific Analysis

This EIS provides an overview of insecticides and approaches available to APHIS for grasshopper suppression and the potential for environmental impacts from their uses. This EIS can be used as a basis for tiering site-specific environmental analyses when APHIS is requested to suppress grasshopper outbreaks. In addition, Federal land management agencies can use this information when preparing their environmental documents. They can adopt, combine, incorporate by reference, or tier their activities to the data in this EIS.

B. APHIS' Authority in Grasshopper Programs

APHIS has authority under the Plant Protection Act (PPA) (7 U.S.C. § 7701) to take actions to control and minimize the economic, ecological, and human health impacts that harmful plant pests can cause. APHIS protects U.S. agriculture and forests and other natural resources from devastation that could occur from harmful pest species.

Section 417 of the PPA (7 U.S.C. § 7717) authorizes efforts to minimize the economic impacts of grasshoppers. Section 417(a) states that subject to the availability of funds, the Secretary "shall carry out a program to control grasshoppers and Mormon crickets on all Federal lands to protect rangeland."

Section 417(c)(1) states that "Subject to the availability of funds pursuant to this section, on request of the administering agency or the agriculture department of an affected State, the Secretary, to protect rangeland, shall immediately treat Federal, State, or private lands that are infested with grasshoppers or Mormon crickets at levels of economic infestation, unless the Secretary determines that delaying treatment will not cause greater economic damage to adjacent owners of rangeland." Section 417(c)(2) states, "*OTHER PROGRAMS.*—In carrying out this section, APHIS shall work in conjunction with other Federal, State, and private prevention, control, or suppression efforts to protect rangeland."

C. APHIS' Role in Grasshopper Programs

APHIS conducts surveys for grasshopper populations on rangeland in the Western United States, provides technical assistance on grasshopper management to land owners/managers, and cooperatively suppresses grasshoppers when direct intervention is necessary. APHIS would only treat grasshoppers when requested and needed. In some cases APHIS rangeland treatments protect not only the rangeland, but reduce the likelihood that the grasshoppers will move from the rangeland onto crops and other lands that border rangeland.

APHIS' role in direct intervention of grasshopper infestations is to use insecticide treatments to reduce grasshopper populations to a level below that which constitutes an economic infestation. APHIS' treatment alternatives analyzed in this EIS (see chapter 3, Alternatives) generally are carried out in conjunction with and complement Federal, State, and private efforts to prevent, control, or suppress grasshopper outbreaks. When a harmful grasshopper infestation reaches a level of economic infestation, direct intervention may be the most viable option to protect rangeland.

APHIS surveys grasshopper populations. Survey information is used by APHIS and land managers/owners to assess whether treatments may be warranted. Treatments must be requested from a Federal land management agency or a State agriculture department (on behalf of a State, a local government, or a private group or individual) that has jurisdiction over the land before APHIS could begin to consider a treatment. Upon request, APHIS would then make a site visit to determine whether APHIS action is warranted by assessing various factors relevant to the infestation. These factors include, but are not limited to, the pest species, synchronous timing of the biological stages of the pest species, timing of treatment, cost benefits of conducting the action, and ecological considerations. Grasshopper surveys, conducted at certain times of the year, may show the potential for large grasshopper populations. Based on survey results, State and Federal officials may initiate early coordination of local programs and request APHIS assistance in a timely and effective cooperative effort. Appendix A contains more detailed information regarding grasshopper programs.

D. General Description and Biology of Target Organisms

Grasshoppers and crickets are closely related insects—both belong to the order Orthoptera. Mormon crickets are a flightless species of long-horned grasshopper. Grasshoppers occur throughout the North American continent and around the world; however, Mormon crickets are mostly found in the Great Basin and other areas of the Western United States. Nearly 400 species of grasshoppers are known to inhabit 17 Western States. Of these, approximately 20 or more species commonly cause damage to rangeland, grasses, and surrounding crops. Most of the economically damaging species are rather small or intermediate in size. Although as many as 15 to 45 grasshopper species may be found in an area, only a few cause economic damage. However, when all the species are combined they can each provide a portion of the overall economic damage. It is very important to note that each species alone may not cause much damage but when combined can cause extensive damage.

Grasshoppers are relatively large insects with quite distinct appearances. Long-horned grasshoppers make up the family Tettigoniidae.

Short-horned grasshoppers, also known as true grasshoppers, are named for their relatively short antennae and make up the family Acrididae. The Mormon cricket, also a member of the Tettigoniidae family, is classified as *Anabrus simplex.* Mormon crickets (actually wingless, long-horned grasshoppers) are included in this EIS because they have periodically caused extensive damage to lands in the Western United States (Pfadt, 1994).

1. Grasshoppers and Mormon Crickets

Grasshopper species vary in densities and dominance depending on the soil, vegetation, topography, and use of a habitat. They are generally grouped into grass feeders, forb feeders, or mixed feeders. Some species of grasshoppers will eat almost any vegetation, while other species are more selective (Pfadt, 1994). Grasshopper habitats may change because of the differential effects of weather, parasites, disease, or insecticidal treatments. It is thought that increases in the abundance of food and habitat or decreases in natural enemies are just as likely to trigger population explosions. Food sources and preferences may change during outbreaks.

Most grasshoppers are highly mobile with jumping hind legs and strong wings. They have short, relatively thick antennae, which are rarely longer than half of the body. The female's ovipositor is short, often barely visible. Most grasshopper species are strong fliers as adults, although a few have only wing pads and do not fly. Some species have brightly colored wings; however, these species are usually not economically damaging. Some species of grasshoppers can be considered beneficial, feeding on other invertebrates or plant forms that are not consumed by other users of the rangeland. Grasshoppers range in length from less than 1 inch to 3 inches.

2. Life Cycles

The Mormon cricket is flightless but highly mobile. From the time it is half grown, the cricket is capable of migrating great distances in a single day. Mormon crickets have long, thin antennae, usually longer than the body. Like all members of the order Orthoptera, the grasshopper life cycle includes three stages of development: the egg, the nymph, and the adult. Each species appears to possess a unique set of ecological and physiological adaptations that allow it to grow, survive, and reproduce in its environment. The habitat plays an important role in providing nutritive food plants, adequate living space, satisfactory soil conditions for the eggs, and favorable biotic relationships for all the life stages. Generally, only one generation a year is produced except in the northern regions where eggs may occasionally require as many as 2 years to fully develop, depending upon species and climatic conditions. In warmer areas, such as in Kansas, *Melanoplus sanguinipes* may produce a smaller, second generation each year.

In a normal life cycle (see figure 2–1), eggs are laid late in the summer and fall and enter a stage of inactive development known as diapause. The embryos remain physiologically active as transfer of nutrient materials from the yolk into the embryonic fat body and tissue continues. Cold temperatures slow or end this process, and the embryos enter into a dormant stage. In spring, when temperatures warm above threshold levels, the egg embryos continue their development.

The egg-laying habits of grasshoppers differ and, having mated with a male of her species, the female digs a small hole in the soil with her ovipositor and deposits the first group of eggs. Once egg laying begins, the female continues to mate and deposit eggs regularly for the rest of her life. The number of eggs laid may range from 3 pods per week to 1 pod every 1 to 2 weeks, and each pod may contain as many as 15 to 100 eggs. Grasshopper egg pods vary not only in the number of eggs they contain but also in their size, shape, structure, and where they are laid. Incubation of eggs may begin immediately after being deposited in the soil, depending upon climatic temperatures.

Newly-hatched grasshoppers are capable of standing upright and being able to hop away from danger immediately after shedding their embryonic membrane. The young grasshoppers are active and begin feeding on green and nutritious host plants. A young grasshopper must shed (molt) its soft exoskeleton to grow and mature to an adult stage. The exoskeleton is composed of protein and polysaccharide called chitin. As the grasshoppers grow and develop they molt at intervals, changing their structures and form. Depending on species and sex, grasshoppers molt four to six times during their nymphal or immature life, and depending on weather conditions, the various molts may require 30 to 40 days to complete. Mormon crickets vary from grasshoppers in that they pass through seven nymphal instars and may take 60 to 90 days to complete their molting. The insect stage between molts is referred to as an instar. When the last instar molts, the exoskeleton hardens and the insect becomes an adult and is ready to mate and reproduce (Pfadt, 1994).

E. Damage Caused by Grasshoppers

Some grasshoppers cut grass stems and blades, eating only a part. Some eat closer to the ground than livestock and feed primarily on the growing part of grasses. Other species may cut off seed stalks, thus eliminating seed production and making soil erosion more likely to occur in denuded areas. Such changes may lead to soil degradation, the interruption of nutrient cycles, and the loss of important plant species or seed production that can lead to irreversible changes that reduce the amount and diversity of rangeland habitats. Soil damage causes erosion and also disrupts nutrient cycling, water infiltration, seed germination, and other ecological processes that are important components of rangeland ecosystems. Grasshoppers waste approximately six times as much foliage as they consume. Grasshoppers that invade cropland often develop on adjacent

rangeland. In contrast to cropland, the value of forage produced on rangeland is of less value (Pfadt, 1994).

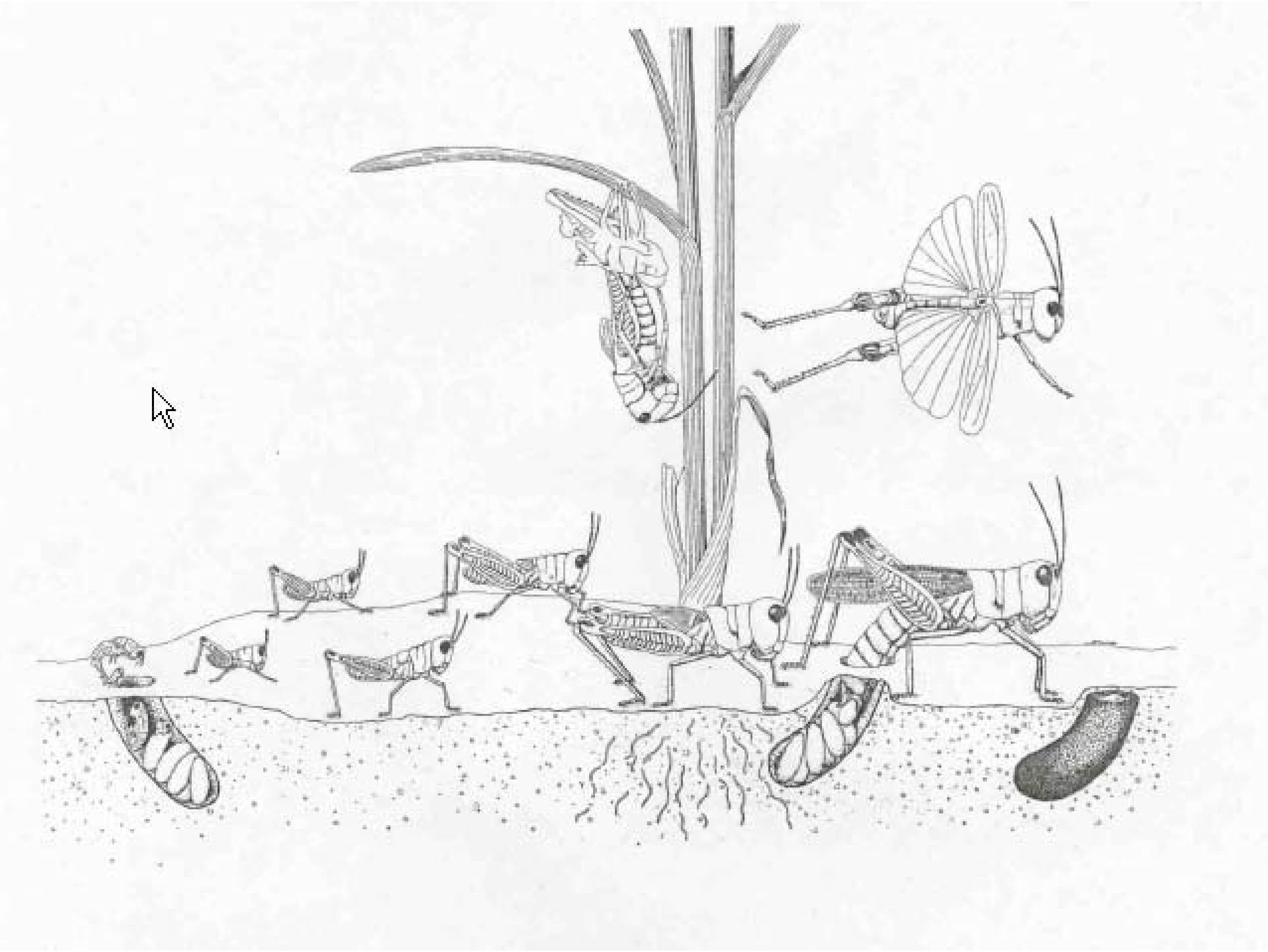

FIGURE 1-1: The life cycle of the bigheaded grasshopper, Aulocara elliotti (Thomas). during summer in bare spots of grassland, the female deposits, at intervals, batches of eggs. As soon as the eggs are laid, they begin embryonic development and reach an advanced stage in which they enter diapause and pass the winter. In spring the eggs complete embryonic development and hatch. The young grasshopper sheds a serosal skin, the exoskeleton hardens, and the nymph begins to feed and grow. After molting five times and developing through five instars in 30 to 40 days, it becomes an adult grasshopper with functional wings. The adult female matures groups of six to eight eggs at a time and deposits them in the soil at intervals of 3 to 4 days for the duration of her short life. (This figure is reproduced from the introduction to "Field Guide to Common Western Grasshoppers", by Robert E. Pfadt, 1994, and is reprinted with permission.)

FIGURE 1-2: Surveying grasshoppers using the sweep-net technique. (Photo credit USDA-APHIS)

III. Alternatives

The purpose of this environmental impact statement (EIS) is to analyze, in a programmatic manner, the environmental impacts anticipated from grasshopper and Mormon cricket suppression activities undertaken by the Animal and Plant Health Inspection Service (APHIS). (The term "grasshopper" used in this document refers to both grasshoppers and Mormon crickets, unless differentiation is needed.) The approach APHIS uses to suppress grasshoppers is only one of many approaches that are a part of grasshopper management. APHIS is fully aware that many other strategies can be taken to manage grasshopper populations—many of those strategies were investigated through the APHIS-funded integrated pest management (IPM) program, and the information has been transferred to land managers (see appendix A). However, implementing these strategies is not within the purview of APHIS. Rather, these strategies are best implemented and normally studied in the context of rangeland management programs by the respective land managers of Federal, State, and local governments and private groups and individual landowners who have stewardship over the lands.

The need for immediate treatments limits the options that are available to APHIS. The best grasshopper management strategies are preventative in nature and are long-term efforts that are designed to head off, rather than combat, outbreaks. They do not achieve the rapid reduction of grasshopper populations that is needed when devastating outbreaks occur. The response that most rapidly and effectively reduces grasshopper populations is the application of insecticides. This response, the application of insecticides within all or part of an outbreak area, is the response available to APHIS that rapidly suppresses (but does not eradicate) grasshopper outbreaks and effectively protects rangeland habitats and adjacent crops.

The following alternatives describe the options available to APHIS in fulfilling its mandate to carry out control programs for grasshopper infestations to protect rangeland. A No Action alternative is also included.

A. Alternative 1: No Action

Under this alternative, APHIS would not fund or participate in any program to suppress grasshopper infestations. Some Federal land management agencies, State agriculture departments, local governments, or private groups or individuals would likely conduct their own grasshopper treatments, but APHIS would not be involved with any suppression activities.

B. Alternative 2: Insecticide Applications at Conventional Rates and Complete Area Coverage

Under this alternative, the application of insecticides, typically at the rates described in the Rangeland Grasshopper Cooperative Control Management Program, Final Environmental Impact Statement—1987 (1987 EIS) and covering all treatable sites within the infested area (total or blanket coverage), has historically been the most common approach used to reduce grasshopper populations.

The insecticides APHIS considers using under this alternative are carbaryl, diflubenzuron, and malathion. Carbaryl and malathion are insecticides that have traditionally been used by APHIS. Diflubenzuron, an insect growth regulator, is also included in this alternative. Although diflubenzuron's mode of action is very different than the mode of action for carbaryl and malathion, the term "insecticide" used in this document refers to carbaryl, diflubenzuron, and/or malathion.

Carbaryl, diflubenzuron, and malathion are all currently registered for use and labeled by the U.S. Environmental Protection Agency (EPA) for rangeland grasshopper treatments. All applications of these insecticides by APHIS personnel will be conducted in strict adherence to the label directions. The insecticides could be applied aerially or by ground equipment. The application rates analyzed in this alternative are 16 fluid ounces (0.50 pound active ingredient) of carbaryl spray per acre, 10 pounds (0.50 pound active ingredient) of 5 percent carbaryl bait per acre, 1.0 fluid ounce (0.016 pound active ingredient) of diflubenzuron per acre, and 8 fluid ounces (0.62 pound active ingredient) of malathion per acre.

The traditional goal of grasshopper treatments, especially prior to the Grasshopper IPM Program, was often to suppress grasshoppers to the greatest possible extent (Foster, 1996). Recent studies by Foster *et al.* (2000) have shown that the insecticides to be used as part of the suppression programs at conventional rates reduce grasshopper populations at 14 days after treatment by the following percentages: carbaryl spray at 96 to 97 percent reduction; carbaryl bait 35 to 85 percent reduction; diflubenzuron at 98 percent reduction; and malathion at 89 to 94 percent reduction.

Because this is a programmatic document, issues associated with a specific site will need to be addressed in site-specific documents for a given treatment area, or in other documents prepared in accordance with other Federal, State, or local laws.

C. Alternative 3: Reduced Agent Area Treatments (RAATs)

This alternative is a recently developed approach to grasshopper suppression that uses insecticides at low rates with a reduction in the area treated. The Reduced Agent Area Treatments (RAATs) strategy relies on the effects of an insecticide to suppress grasshoppers within treated swaths and the conservation of grasshopper predators and parasites in swaths not directly treated (untreated).

For more than 20 years, various studies by APHIS have suggested that reduced rates of insecticides could provide acceptable levels of grasshopper suppression (Foster *et al.*, 1979, 1989; Reuter *et al.*, 1993; Reuter and Foster, 1996), although none of these findings were implemented in the field. The concept of reducing the area of coverage while also applying less insecticide per treated acre was developed in 1995, with the first field tests of RAATs in Wyoming (Lockwood and Schell, 1997). The potential economic advantages of this method were proposed by Larsen and Foster (1996) and empirically demonstrated by Lockwood and Schell (1997). Widespread efforts to communicate the advantages of RAATs across the Western States were undertaken in 1998 and have continued on an annual basis. The viability of this method at operational scales was initially demonstrated by Lockwood *et al.* (2000) and subsequently confirmed by Foster *et al.* (2000). The first government agencies to adopt RAATs in their grasshopper suppression programs were the Platte and Goshen County Weed and Pest Districts in Wyoming, who also funded research at the University of Wyoming to support the initial studies in 1995. This method has now been used by government agencies and private landowners in eight Western States.

The insecticides APHIS considers using under this alternative are carbaryl, diflubenzuron, and malathion. All these insecticides are currently registered for use and labeled by EPA for rangeland control of grasshoppers, have been demonstrated to be effective, and would be used by APHIS personnel in strict adherence to the label. The RAATs rates analyzed in this document are 8 fluid ounces (0.25 pound active ingredient) of carbaryl spray per acre; 10 pounds (0.20 pound active ingredient) of 2 percent carbaryl bait per acre; 0.75 fluid ounce (0.012 pound active ingredient) of diflubenzuron per acre; and 4 fluid ounces (0.31 pound active ingredient) of malathion per acre. It has been demonstrated that an acceptable level of grasshopper control can be achieved by reducing application rates to typically one-half the rates used in conventional control programs (Lockwood *et al.*, 2000) and applying the insecticides to only a portion of the land. Because the entire range of application rates under the RAATs approach is not known, the analyses of this alternative will only consider the above application rates, which are the maximum rates used under this alternative. (See chapter 5, Environmental Consequences, and appendix B.)

An important part of the RAATs alternative is the amount of area that is not directly treated (untreated). The concept of leaving intermittent swaths untreated is designed to both reduce cost and conserve nontarget, biological resources, including predators and parasites of grasshoppers, that are in the untreated areas. There is no standardized percentage of area that is left untreated. The proportion of land treated in a RAATs approach is a complex function of the rate of grasshopper movement, which is a function of developmental stage, population density, and weather (Narisu *et al.*, 1999, 2000), as well as the properties of the insecticide (insecticides with longer residuals allow wider spacings between treated swaths). Foster *et al.* (2000) left 20 to 50 percent of their study plots untreated, while Lockwood *et al.* (2000) left 20 to 67 percent of their treatment areas untreated. Because there is no standardized area that is untreated for biological conservation purposes, this document will assume complete, 100 percent coverage at the rates under the RAATs alternative in order to assess environmental impacts. This will be a substantial overestimation of the amount of insecticide applied in every RAATs strategy, and the analyses in this document will represent the worst-case scenario for this alternative. (See chapter 5, Environmental Consequences, and appendix B.)

The goal of grasshopper suppression under the RAATs alternative is to economically and environmentally suppress grasshopper populations to a desired level rather than to reduce those populations to the greatest possible extent. The efficacy of a RAATs strategy in reducing grasshoppers is, therefore, less than conventional treatments. The efficacy of insecticide treatments under the RAATs alternative also is variable. Foster *et al.* (2000) reported that grasshopper mortality using RAATs was reduced 2 to 15 percent from conventional treatments, depending on the insecticide, while Lockwood *et al.* (2000) reported 0 to 26 percent difference in mortality between conventional and RAATs areas.

Not every conceivable combination of reduced rates and partial spray coverages are analyzed under this alternative. The absolute rates and areas covered will be described in site-specific documents, such as environmental assessments, when there is a need for action to be taken against grasshoppers. Setting the desired level of suppression in advance and conducting programs to meet that predetermined goal may be practical when using a RAATs approach (Larsen, personal communication, 2001). Indeed, the flexibility in application rates and treatment area will allow for decisions to be made on a case-by-case basis based on the economic and environmental considerations and the level of grasshopper mortality desired for a specific location.

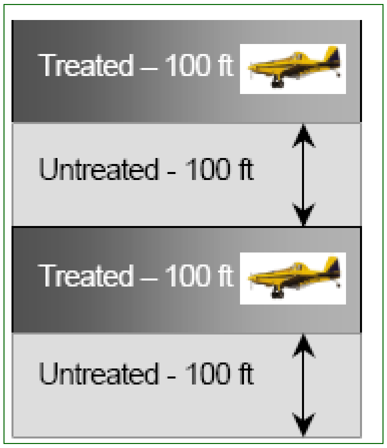

FIGURE 1-1: Diagram of a Reduced Agent Area Treatment showing treated swaths alternating with untreated swaths. In this example, the amount of the area that is reduced by 50%.

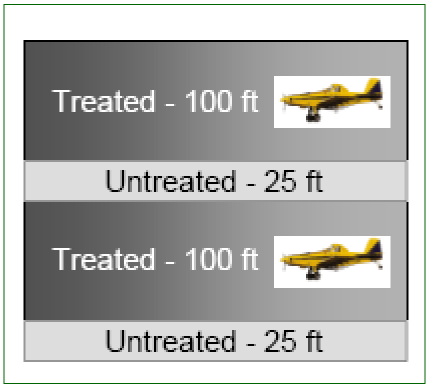

FIGURE 1-2: Diagram of a Reduced Agent Area Treatment showing treated swaths of 100 ft. alternation with untreated swaths of 25 ft. In this example, the amount of the area that is treated is reduced by 20%.

IV. The Affected Environment

The environment potentially affected by the Animal and Plant Health Inspection Service (APHIS) grasshopper and Mormon cricket suppression program is the rangeland of the 17 Western States as follows: Arizona, California, Colorado, Idaho, Kansas, Montana, Nebraska, Nevada, New Mexico, North Dakota, Oklahoma, Oregon, South Dakota, Texas, Utah, Washington, and Wyoming. (The term “grasshoppers” used in this document refers to both grasshoppers and Mormon crickets, unless differentiation is needed.) These vast rangeland areas are a valuable natural resource providing grazing for domestic livestock, food and habitat for a variety of plant and wildlife species, and recreational resources for the public.

A substantial threat to the animal and plant productivity of these rangeland areas is the proliferation of grasshopper populations. Grasshoppers have been a serious pest in the Western States since early settlement. Conditions favoring the hatching and survival of large numbers of grasshoppers can cause outbreak populations. The resulting damage to vegetation may be so severe that all grasses and forbs are destroyed, and plant growth is retarded for several years. The consequences are reduced grazing for livestock; loss of food and habitat for plants and wildlife, including endangered and threatened species; and soil erosion, possibly resulting in decreased water quality.

Programs to suppress economically damaging grasshopper infestations could occur on any of the rangeland within the 17 Western States. APHIS sometimes cooperates in grasshopper suppression programs when requested by a Federal land management agency or a State agriculture department (on behalf of a State, a local government, or a private group or individual). APHIS’ involvement in grasshopper programs could include conducting surveys, providing technical advice, and applying insecticides.

This environmental impact statement (EIS) is a programmatic document for APHIS’ grasshopper suppression programs that potentially could occur on rangeland within seven general regions as identified by Bailey (1980) (see figure 4–1). When there is a need to suppress damaging grasshopper populations, a site-specific environmental document identifying the area of a proposed treatment program will be prepared. This document will include the specific characteristics of the rangeland areas and will contain an analysis of the potential effects of the program on the environment of the treatment area.

The analysis of site-specific characteristics of a program may include the following considerations:

- Potential effects of the program on human health
    - workers and
    - the general public (see chapter 5, Environmental Consequences);
- Potential effects on nontarget species
    - terrestrial vertebrates and invertebrates, including bees,
    - aquatic organisms,
    - plants, and
    - endangered and threatened plants and wildlife (see chapter 5, Environmental Consequences);
- Socioeconomic issues, such as the effects on
    - livestock owners,
    - crop growers,
    - beekeepers, and
    - recreationists, and (see chapter 5, Environmental Consequences);
- Special considerations for certain populations, such as
    - minorities and low-income populations and
    - children (see chapter 6, Other Environmental Considerations).

The impacts of APHIS suppression programs will differ from one rangeland area to another because of differences in physical characteristics or certain biological elements. Bailey (1980) has identified seven ecoregions within the 17 Western States, as shown in figure 4–1.

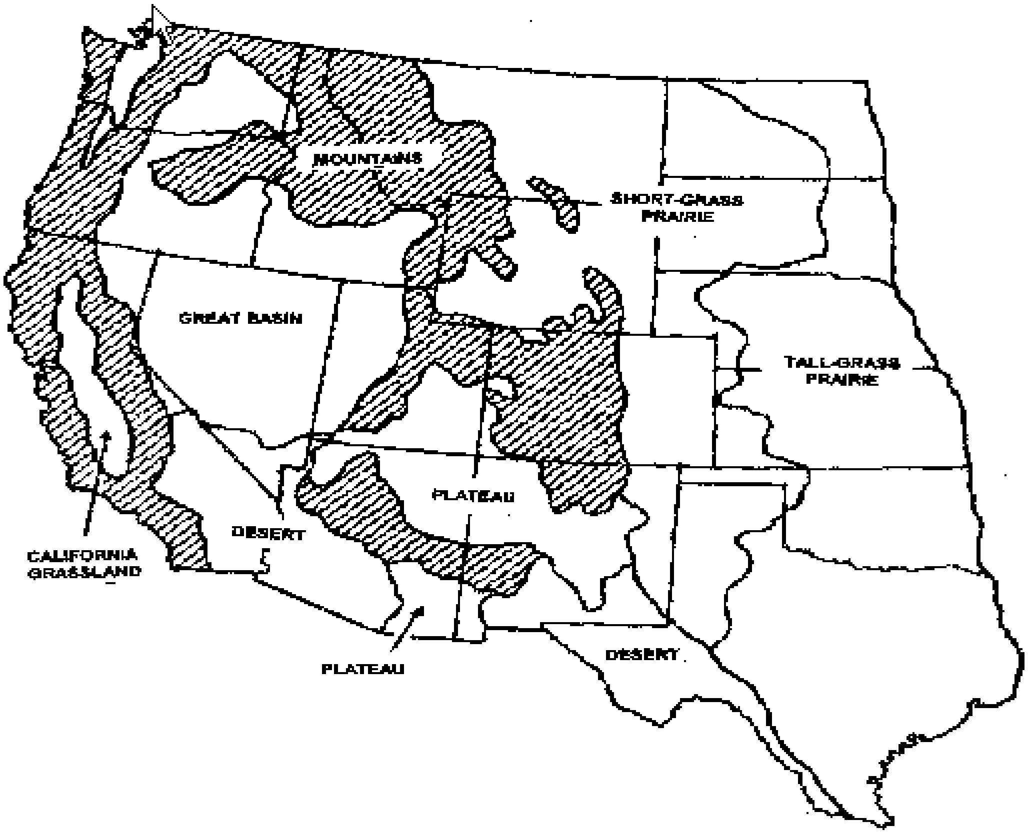

FIGURE 1-1: The Seven ecoregions of the Western United states. (Source: Baile, R.G. 1980)

The Tall-grass Prairie region is a contiguous grassland that lies between the deciduous forests of the east and the short-grass prairie of the west, on the flat-to-rolling-hill land of the central lowland. Elevation gradually increases from about 500 feet above sea level in the east to about 1,500 feet in the west. The northern boundaries extend into Canada, and the southern boundaries extend through southeastern Texas.

The climate varies widely in this region. The length of the frost-free season varies from less than 120 days in the north to almost 300 days in the south. Annual precipitation ranges from 15 inches in the north to 30 inches in the south. In general, more precipitation occurs in the warmer months of the year. Drought periods are less frequent and less severe near the eastern forest than in more westerly areas. Annual average temperatures range from 40 °F in the north to 55 °F in the central portion to 70 °F in the south.

The Short-grass Prairie region lies in a broad belt that slopes gradually eastward from an altitude of 6,000 to 8,000 feet in the Wyoming Basin within the eastern Rocky Mountains to 1,500 feet in the Central States where it gives way to the tall-grass prairie. The mixed-grass prairie is included in the eastern portion of the analysis region and represents a transition zone between the tall-grass and short-grass prairies.

This region is characterized by rolling plains and table lands of moderate relief. It includes the areas known as the Great Plains and Wyoming Basin. The most striking feature of the region is the phenomenal flatness of the interstream areas, which make up a great expansive flood plain or alluvial slope.

The climate is semiarid and the total supply of moisture is low. Precipitation ranges from 10 inches in the north to more than 25 inches in the south. Evaporation usually exceeds precipitation. Winters are cold and dry; summers are warm to hot. The frost-free season ranges from fewer than 100 days in the north to more than 200 days in parts of Texas. Average annual temperatures range from 40 to 60 °F.

The Plateau region includes two separate (noncontiguous) geographical areas: the Colorado Plateau in Arizona, New Mexico, and Utah, and the Mexican Highlands located between the American Desert on the west and the Chihauhuan Desert on the east. The topography covers high, grassy mountains of the Mexican plains as well as the table lands and mountains of the Colorado Plateau. Local relief is from 500 feet to more than 3,000 feet in some of the deeper canyons that dissect these table lands, and volcanic mountains rise 1,000 to 3,000 feet above the plateau surfaces. Stream valleys are narrow and widely spaced.

The high elevations of this region produce moderate mean temperatures. However, summer days are hot and extremely cold weather occurs in winter. The annual average temperatures range from 40 to 55 °F in the plateau region and from 55 to 70 °F on the Mexican plains. Normal rainfall occurs in winter; summer rains occur as occasional, sudden thunderstorms. Average annual precipitation ranges from 10 to 20 inches on the Colorado Plateau. The Mexican Highlands are semiarid and have less rainfall.

The Desert region includes the Chihuahuan Desert in southern New Mexico and western Texas and the American Desert in California, Arizona, Nevada, and Utah. The topography is characterized by extensive plains from which isolated mountains and buttes rise abruptly. Elevations range from 280 feet below sea level to 11,000 feet above sea level in some mountain ranges. The only permanent water bodies are a few large rivers that include the Colorado, Rio Grande, and Pecos Rivers. Washes, dry most of the year, fill with water following a rain.

Summers are long and high temperatures prevail. Though winters are moderate, the region is subject to occasional frosts and freezing temperatures. Average annual temperatures range from 50 to 75 °F. Summer rains occur as torrential storms; in winter, the rains are more gentle and widespread. In the Colorado and Mojave Deserts of southeastern California, there are virtually no summer rains. Average annual precipitation ranges from 2 to 20 inches. The evaporation rate in summer is very high.

The Great Basin region occupies the area between the Rocky Mountains on the east and the Sierra Nevada Range on the west, its elevation varying from mountainous regions to low elevations along the Snake River plain. This includes areas in Nevada, Utah, southern Idaho, Washington, and Oregon. Much of this intermountain area has numerous separate interior basins, and only a small portion of it drains to the sea. Except for the Snake River and its tributaries in the Snake River plain, streams in this region are generally intermittent. Many mountains rise steeply from the semiarid, sagebrush-covered plains.

Summers are hot; winters are fairly moderate. The average annual temperature is 40 to 55 °F. Spring comes early except at the higher elevations. Total annual precipitation averages only 5 to 20 inches; almost no rain falls during the summer months except in the mountains.

The California Grassland region lies within the Central Valley of California, a flat alluvial plain between the Sierra Nevada and the coast ranges. Elevations range from sea level to 500 feet. This area has broad, nearly level valleys bordered by sloping alluvial fans, slightly dissected terraces, and the lower foothills of the surrounding uplands. Large undrained basins are in the south.

The precipitation of this region is characterized by winter rainfall. Except near the coast, summers are hot and the winters mild. Annual rainfall ranges from 6 inches in the upper San Joaquin Valley to nearly 30 inches along the coast. Potential evaporation during the warmest months is often much greater than the precipitation. Annual temperatures average 60 to 67 °F in much of the area. Northern temperatures fall as low as 55 °F.

The Mountain region encompasses the wide variety of mountainous areas in the Western United States. The Pacific and Sierra Forests and California chaparral extend down the west coast while the Rocky Mountains, Columbian Forest, and Upper Gila Mountains dissect the central region. The mountain environments are characterized by high, steep, rugged slopes. Many areas are glaciated; others are volcanic. Plateaus of dissected, horizontally layered rocks are found in the Rocky Mountains and Upper Gila Mountains.

The climates vary considerably with altitude. Temperature decreases and precipitation increases with rising elevations. Winter produces the most precipitation and much of it falls in the mountains as snow. Average rainfall ranges from 10 inches in the semiarid Rockies to 150 inches in the humid Pacific Northwest.

Overall, temperatures are moderate, although severe winters are characteristic of the northernmost regions. Average temperatures range from 35 to 55 °F in most areas. The southern coastal region is somewhat warmer.

The parameters examined in a site-specific document will include human populations—particularly the populations potentially at risk in the APHIS grasshopper suppression program (workers and the general public), soils, vegetation (both native and introduced plants and agricultural crops), terrestrial wildlife (including endangered and threatened terrestrial wildlife species), water resources and aquatic life (including endangered and threatened aquatic species), and land uses and cultural resources.

V. Environmental Consequences

This chapter summarizes the potential effects that the Animal and Plant Health Inspection Service's (APHIS) grasshopper and Mormon cricket program treatments could have on the human environment. Unless specifically stated otherwise in this chapter, the word "grasshopper" refers to both grasshoppers and Mormon crickets. These effects are described in detail in appendix B, Environmental Risk Assessment for Rangeland Grasshopper Suppression Programs—Insecticides, which is a more thorough risk assessment of program treatments on the environment. This chapter concentrates on the potential ecological impacts described during the APHIS Grasshopper Integrated Pest Management (GHIPM) Program (USDA, APHIS, 1996) and the human health information analyzed in Appendix B. This information from the GHIPM Program is considered pertinent because most of the studies were conducted during actual APHIS grasshopper suppression programs or under field conditions that closely followed the APHIS procedures used for grasshopper suppression.

The available toxicity data from research on given pesticides is limited to a finite number of wildlife species. The determination of risk to a given species from potential program action is made by selection of toxicity data for that species or the most closely related surrogate species. The review of the quality of data from available research may influence the decision, made by a diverse team of scientists, to select a given study or specific data for a given surrogate species over other available data. The surrogate data were selected to best represent the species risk based upon the consensus of the team. This approach may not always portray the most sensitive outcome, but it is designed to provide the decisionmaker with a realistic description of impacts of potential program alternatives. This information allows the risk manager to make an informed decision about differences in potential impacts among available alternatives to the program. The literature citations in this chapter supplement the literature citations in appendix B.

A. Environmental Consequences of Alternative 1: No Action

Under Alternative 1, No Action, APHIS would not fund or participate in any program to suppress grasshoppers. Even with the implementation of the best land management practices, if APHIS does not participate in any grasshopper suppression programs, Federal land management agencies, State agriculture departments, local governments, or private groups or individuals may not effectively combat outbreaks in a coordinated effort. In these situations, grasshopper outbreaks would develop and spread unimpeded.

Grasshoppers in unsuppressed outbreaks would consume agricultural and nonagricultural plants. The damage caused by grasshopper outbreaks could also pose a risk to rare, threatened, or endangered plants that often have a low number of individuals and limited distribution. Habitat loss for birds and other wildlife and rangeland susceptibility to invasion by nonnative plants are among the consequences that would likely occur should existing vegetation be removed by grasshoppers.

Loss of plant cover due to grasshopper consumption will occur. Plant cover may protect the soil from the drying effects of the sun, and plant root systems hold the soil in place that may otherwise be eroded or lost to erosion.

Another potential scenario, if APHIS does not participate in any grasshopper suppression programs, is that some Federal land management agencies, State agriculture departments, local governments, or private groups or individuals may attempt to conduct widespread grasshopper programs. Without the technical assistance and program coordination that APHIS can provide to grasshopper programs, it is possible that a large amount of insecticides, including those APHIS considers too environmentally harsh but labeled for rangeland use, could be applied, reapplied, and perhaps misapplied in an effort to suppress or even locally eradicate grasshopper populations. It is not possible to accurately predict the environmental consequences of the no action alternative because the type and amount of insecticides that could be used in this scenario are unknown.

B. Background Information on Alternative 2 and Alternative 3

The objective of a grasshopper suppression program is to reduce grasshopper populations below an economically damaging level. The suppression methods APHIS uses rely on either one of three insecticides: carbaryl, diflubenzuron, and malathion. These insecticides can be applied according to two separate strategies presented as Alternatives 2 and 3. Alternative 2 is the conventional strategy that uses insecticide rates described in the Rangeland Grasshopper Cooperative Management Program, Final Environmental Impact Statement—1987 (1987 EIS) (USDA, APHIS, 1987b) and applies those insecticides in a complete coverage of the treatment area. Alternative 3, Reduced Agent Area Treatments (RAATs), is a recently developed approach to grasshopper suppression that significantly lowers the amount of insecticide used by reducing both (1) the insecticide application rate and (2) the amount of area treated with insecticide.

Because diflubenzuron is an insecticide that was not included in the 1987 EIS, some sections in this chapter contain proportionately more information on the use and effect of diflubenzuron than is presented for either carbaryl or malathion. This does not indicate that APHIS has a preference for one insecticide over another. The decision on which pesticide to use for grasshopper suppression treatments depends on a variety of factors which are described in greater detail in the following sections.

1. Insecticides Used by APHIS

A number of insecticides are labeled by the U.S. Environmental Protection Agency (EPA) for use against grasshoppers on rangeland but are not considered by APHIS for use. APHIS chooses and approves insecticides based on (1) effective performance against grasshoppers on rangeland and (2) minimal or negligible impact on the environment and nontarget species (Foster and Reuter, 1996).

Carbaryl, diflubenzuron, and malathion are the insecticides APHIS would use in the rangeland grasshopper program based on several factors, including efficacy, cost, and environmental concerns. These three insecticides are all labeled by EPA for rangeland use. Although diflubenzuron's mode of action is very different than the mode of action for carbaryl and malathion, the term "insecticide" used in this document usually refers to carbaryl, diflubenzuron, and/or malathion.

When direct intervention is requested by land managers, APHIS' role in the suppression of grasshoppers is achieved through insecticide application. Generally APHIS would apply either carbaryl, diflubenzuron, or malathion one time to a treatment site. There may, however, be situations where it is appropriate to use one insecticide or formulation in one part of a treatment area and a different insecticide or formulation in another part of that same treatment area with all applications conducted according to the label directions. For example, ultra-low-volume malathion may be used over the majority of a treatment area, but areas of special consideration may be treated with carbaryl bait. Should these situations occur, no area would be treated with more than one insecticide, nor would insecticides be mixed or combined.

a. Carbaryl—Carbaryl is a carbamate, broad spectrum, insecticide that has many commercial uses for insect control on fruits, vegetables, ornamental plants, field crops, and forage crops. The mode of action for carbaryl occurs primarily through acetylcholinesterase (AChE) inhibition which affects transmission of the nerve impulses across the nerve synapse. This inhibition is reversible over time if exposure to carbaryl ceases. Carbaryl is active both as a contact and a stomach poison, although ingestion results in a greater level of mortality.

Carbaryl is of moderate acute oral toxicity to humans. EPA has classified carbaryl as a "possible human carcinogen" based on an increased incidence of vascular tumors in a chronic study of male mice exposed at 46 mg/kg/day (1000 parts per million (ppm)) (EPA, 1993). However, carbaryl is not considered to pose any mutagenic or genotoxic risk based upon the weight of evidence.

Carbaryl is of moderate acute oral toxicity to mammals. It is slightly toxic to birds, slightly toxic to reptiles and amphibians, severely toxic to most terrestrial invertebrates, and of low phytotoxicity to most plants. Carbaryl is moderately toxic to fish and very highly toxic to aquatic invertebrates.

Carbaryl can be used effectively both early and late in the season to treat grasshoppers over a broad range of climatic conditions. Carbaryl is short-lived in rangeland ecosystems, but carbaryl is more persistent than malathion. The half-life of carbaryl in soil ranges from 7 to 28 days. Carbaryl is not expected to have detectable runoff or any leaching to groundwater; its half-life in freshwater ranges from 1 to 6 days. Insecticidal properties of carbaryl persist on exposed green plant surfaces from 3 to 10 days and perhaps longer. The main carbaryl metabolites and degradation products are considerably less toxic than carbaryl, the parent compound. The effects of carbaryl used for grasshopper suppression are described in greater detail in the following sections for Alternatives 2 and 3.

b. Diflubenzuron—Diflubenzuron is an insect growth regulator that is used against a number of crop and forest insect pests. The mode of action for diflubenzuron is very different than the mode of action for carbaryl or malathion.

Carbaryl and malathion are active against a broad spectrum of insects in both the adult and immature stages. When applied in liquid form, carbaryl and malathion are less selective and have a greater impact on nontarget insects in treatment areas. However, the growth-regulating insecticide, diflubenzuron, has a narrower spectrum of activity. Diflubenzuron causes mortality to immature insects by inhibiting chitin formation, which is a different mode of action than carbaryl or malathion. At very low doses, diflubenzuron selectively inhibits the ability of immature insects to synthesize chitin at the time of molting which prevents insects from forming their exoskeleton, or outer shell, causing death due to cuticle rupture or starvation. Diflubenzuron is primarily a stomach poison to immature insects. Because diflubenzuron is effective against immature insects, diflubenzuron can most effectively be used early in the treatment season. In many cases, the “window of opportunity” for applying diflubenzuron may be earlier than for carbaryl or malathion.

The acute oral toxicity of diflubenzuron to humans ranges from very slight to slight. The most sensitive indicator of exposure and effects of diflubenzuron in humans is the formation of methemoglobin.

Diflubenzuron's acute oral toxicity to mammals ranges from very slight to slight. Higher organisms that contain chitin or polysaccharides similar to chitin (such as birds and mammals) seem unaffected (Eisler, 2000). The toxicity of diflubenzuron is much greater to immature invertebrates whose required chitin production is inhibited by this insecticide. Diflubenzuron is highly toxic to larval stages of insects but is not toxic to adult insects that have already formed their exoskeleton. In addition to grasshoppers, other terrestrial insects such as beetle larvae, lepidopteran larvae, and chewing herbivorous insect larvae are susceptible to diflubenzuron. Larval stages of aquatic arthropods, especially crustaceans, are sensitive to the effects of diflubenzuron, although fish are not.

Diflubenzuron has low mobility and leachability in soils, and has a half-life in soils of 7 to 19 days. Degradation is most rapid when soil bacteria are abundant and when small-particle formulations are applied, as would be done for grasshopper suppression. Diflubenzuron usually persists in water for only a few days. High organic and sediment loadings along with elevated pH and temperature are the conditions whereby diflubenzuron most rapidly degrades. When applied to terrestrial plants, diflubenzuron tends to remain adsorbed with little or no absorption or translocation from plant surfaces. Metabolites of diflubenzuron are rapidly degraded, and it is unlikely that there would be sufficient exposure to these products to cause adverse toxicological effects. The effects of diflubenzuron used for grasshopper suppression are described in greater detail in the following sections for Alternatives 2 and 3.

c. Malathion—Malathion is an organophosphate, broad spectrum insecticide that has been widely used for many years in commercial agriculture, public health, and in homes and gardens. The mode of action for malathion is similar to carbaryl in that malathion primarily acts as an AChE inhibitor. Malathion acts as both a contact insecticide and a stomach poison, although ingestion results in a greater percentage of mortality. Malathion is recommended for use against grasshoppers during warm and dry conditions (Foster and Onsager, 1996a), and the quick action of malathion will result in mortality before grasshoppers mature and lay eggs. Because malathion is fast acting and has less persistence than carbaryl, it is preferred in situations where older-stage grasshoppers are present and limiting the egg-laying capacity of grasshoppers is a primary concern.

Malathion is of slight acute oral toxicity to humans. The mode of toxic action of malathion occurs through inhibition of AChE function in the nervous system. Unlike carbaryl, this reaction that results in inhibition from malathion is not readily reversible over time if exposure ceases. However, strong inhibition of AChE from malathion occurs only when chemical oxidation occurs to form the metabolite malaoxon. Human metabolism of malathion favors hydroxylation and seldom produces much malaoxon.

EPA has recently reviewed the potential for carcinogenic effects from malathion. EPA's classification describes malathion as having "suggestive evidence of carcinogenicity, but not sufficient to assess human carcinogenic potential." This indicates that any carcinogenic potential of malathion cannot be quantified based upon EPA's weight of evidence determination in this classification (EPA, 2000).

Malathion is of very slight to moderately acute oral toxicity to mammals. It is slightly to moderately toxic to birds. While malathion is not directly toxic to vertebrates at the concentrations used for grasshopper suppression, it may be possible that sublethal effects to nervous system functions caused by AChE inhibition may lead indirectly to decreased survival. Malathion is moderately to severely toxic to terrestrial invertebrates and of low phytotoxicity to most plants. Malathion is slightly to very highly toxic to fish, highly toxic to aquatic stages of reptiles and amphibians, and moderately to very highly toxic to aquatic invertebrates. Appendix B contains more information on the effects of malathion to aquatic organisms.

Malathion is short-lived in virtually all components of the environment. The half-life in soil and on foliage ranges from 1 to 6 days. Malathion does not penetrate much below the soil surface and is unlikely to leach into groundwater; its half-life in freshwater ranges from 6 to 18 days. Increased toxicity associated with malathion may be brought about through oxidation to malaoxon and isomerization to isomalathion. Neither chemical is persistent and should not present a problem to humans as long as proper storage and handling procedures are followed. The effects of malathion used for grasshopper suppression are described in greater detail in the following sections for Alternatives 2 and 3.

APHIS Insecticide Application Techniques

An insecticide used for grasshopper suppression can be applied in either of two different forms: liquid ultra-low-volume (ULV) sprays or solid-based baits. Depending upon the area requiring treatment, both forms have advantages and disadvantages. Habitat diversity, topographical features, meteorological conditions, economic concerns, and environmental considerations all have important roles in choosing the best form of treatment (Foster and Onsager, 1996a). Both ULV sprays and baits can be distributed by aerial or ground applications. Aerial applications are typical for treatments over large areas. Some grasshopper outbreak locations are economically or logistically accessible only by aircraft, while other locations may be best treated by ground applicators. Ground applications are most likely to be made when treating localized grasshopper outbreaks or for treatments where the most precise placement of insecticide is desired.

An important aspect of protecting humans from the effects of an insecticide used for grasshopper suppression is that APHIS will not conduct any suppression program unless requested to do so by the responsible land management agency. Those agencies have their own procedures for protecting humans that APHIS will abide by. APHIS also conducts stakeholder meetings involving the wide range of land managers, land owners, and the public before any suppression programs are conducted; and where health and safety issues can be addressed at these meetings. In addition, APHIS complies with all product label requirements for human health and safety including the Worker Protection Standard (40 Code of Federal Regulations (CFR) § 170).

Baits—Baits have been used for grasshopper control since the late 1800s (Foster, 1996). The most common form of bait used today is wheat bran, similar to the product found in grocery stores for human consumption, that has been impregnated with carbaryl. A small amount of additives also may be mixed with bait to extend the product shelf life or assist in applying the product evenly. Other bait formulations include rolled whole grain and pelleted products that are impregnated with an insecticide. Commercial bait products containing carbaryl are currently marketed but are no longer registered for use on rangeland. The carbaryl bait used for grasshopper suppression is prepared by mixing the appropriate amount of SEVIN® XLR PLUS carbaryl insecticide with a cereal grain substrate as recommended on the current Section 3 label.

In general, baits have considerable environmental advantages over liquid insecticide applications. Compared to sprays, baits are easier to direct toward the target area than sprays, are much more specific toward grasshoppers, and affect fewer nontarget organisms than sprays (Foster, 1996). For example, bees (both cultivated and wild) are likely to be susceptible to some liquid insecticidal sprays (Tepedino, 1996) while baits appear to be safe for bees and other insect pollinators (McEwen *et al.,* 1996a).

However, grasshopper species vary considerably in their inclination to feed on wheat bran and other bait formulations and in their susceptibility to carbaryl-treated bait (Onsager *et al.,* 1996). Bait applications, in general, yield less grasshopper mortalities than liquid sprays. Baits are usually more expensive per unit area than aerially applied treatments.

b. Ultra-low-volume (ULV) Applications—ULV applications are defined as any application of 0.5 gallon, or less, per acre. Liquid sprays, especially when applied at ULV rates, have several desirable characteristics when considering grasshopper suppression. For example, ULV applications typically produce a quicker, higher, and more predictable grasshopper mortality rate than bait applications (Fuller *et al.*, 1996). Generally, contract costs are substantially lower for applying sprays than baits (Foster and Onsager, 1996b).

When applying ULV treatments, it is vital to control spray distribution to avoid drift or the off-target movement of material (Sanderson and Huddleston, 1996). Drift can become a critical factor in protecting environmentally sensitive areas. Drift is also unsatisfactory from a program standpoint because drift results in less insecticide landing in the treatment area, which reduces program efficiency and economy.

Various carriers and adjuvants are used to enhance ULV insecticide applications. These are primarily natural and synthetic oils. One adjuvant that may be used with insecticides considered for use by APHIS is canola oil, a vegetable oil commonly found in grocery stores. Canola oil may be a grasshopper attractant and feeding stimulant that increases the effectiveness of the insecticide; however, canola oil may become rancid if stored for extended periods of time and become unsuitable for use. In general, vegetable oils drift more than petroleum-based oils. The amount of oil used will be at the labeled rate. The label for diflubenzuron currently allows for, but does not mandate, the use of emulsified vegetable or paraffinic crop oil. The maximum rate that oil would be applied for grasshopper suppression is 10 ounces of oil per acre. The risk of toxic effects from oil at this rate is extremely low. Unless a concentrated spill should occur, the amount of oil applied to a given area is unlikely to be in high enough concentrations to affect nontarget organisms.

3.Insecticide Application Rates

All APHIS grasshopper treatments using carbaryl, diflubenzuron, and malathion would be conducted in strict adherence with the EPA-approved label directions. The insecticide application rates used by APHIS will, in many cases, be substantially less than the rates that can be used by private landowners conducting their own grasshopper programs. For example, the rates for malathion in Alternative 2, the conventional rates used by APHIS, are 33 percent lower than the maximum allowable rate (table 5–1). In Alternative 2, carbaryl and malathion will be applied at the conventional rate analyzed in the 1987 EIS (USDA, APHIS, 1987b). The application rates for Alternative 3, RAATs will all be reduced from the Alternative 2 rates by 50 to 60 percent for carbaryl and malathion and 25 percent for diflubenzuron (table 5–1).

Table 5–1.Insecticide Label Rates for Rangeland Grasshopper Suppression

TABLE 1-1: Insecticide Label Rates for Rangeland Grasshopper

Rates for Various Uses	Carbaryl Spray (lb a.i./acre)[1]	Carbaryl Bait (lb a.i./acre)[1]	Diflubenzuron (lb a.i./acre)[1]	Malathion (lb a.i./acre)[1]
Maximum label rate for grasshopper	1.0	0.50	0.016	0.91
Alternative 2 (conventional APHIS rate)	0.50	0.50	0.016	0.62
Alternative 3 (RAATs rate)	0.25	.20	0.012	.31

[1] lb a.i./acre = pound of active ingredient per acre

APHIS typically applies either carbaryl, diflubenzuron, or malathion one time to a treatment site. Retreatments seldom occur for both scientific and economic reasons. The goal of a treatment is to reduce grasshopper populations to below those levels that cause economic damage. A single treatment is intended to sufficiently reduce grasshopper populations, and there should be no need for another treatment. In addition, while a single treatment must be cost-effective, there are very few situations where multiple treatments would be cost-effective. An exception could be that migrating Mormon crickets may sometimes require a second treatment.

C. Environmental Consequences of Alternative 2: Insecticide Applications at Conventional Rates and Complete Area Coverage

Under this alternative, an insecticide application, typically at the rates described in the 1987 EIS (USDA, APHIS, 1987b) and covering all treatable sites permitted by the label and within the infested area (total or blanket coverage), has historically been the most common approach used in grasshopper programs.

The insecticide APHIS would use under this alternative includes carbaryl, diflubenzuron, or malathion. Carbaryl and malathion are insecticides that APHIS has traditionally used. Diflubenzuron, an insect growth regulator, is also included in this alternative. Although diflubenzuron's mode of action is very different than the mode of action for carbaryl and malathion, the term "insecticide" used in this document refers to carbaryl, diflubenzuron, and/or malathion.

Carbaryl, diflubenzuron, and malathion all currently are registered for use and labeled by EPA for rangeland grasshopper treatments and have been demonstrated to be effective. Applications of these insecticides could be done aerially or by ground equipment, and APHIS personnel would conduct the treatments in strict adherence to the label directions. The application rates analyzed in this document are 16 fluid ounces (0.50 pound active ingredient) of carbaryl spray per acre, 10 pounds (0.50 pound active ingredient) of 5 percent carbaryl bait per acre, 1.0 fluid ounce (0.016 pound active ingredient) of diflubenzuron per acre, and 8 fluid ounces (0.62 pound active ingredient) of malathion per acre.

The goal of grasshopper treatments, especially prior to the GHIPM Program, was often to suppress grasshoppers to the greatest possible extent (Foster, 1996). Recent studies by Foster *et al.* (2000) have shown that following the use of insecticides at conventional rates (and the labeled rate for diflubenzuron) grasshopper populations are reduced at 14 days after treatment by the following percentages: carbaryl spray at 96 to 97 percent reduction, carbaryl bait at 35 to 85 percent reduction, diflubenzuron at 98 percent reduction, and malathion at 89 to 94 percent reduction. During grasshopper outbreaks when grasshopper densities can be 60 or more per square meter (Norelius and Lockwood, 1999), grasshopper treatments that have a 90 to 95 percent mortality still leave a number of grasshoppers (3 to 6) that is generally greater than the average number found on rangeland, such as in Wyoming, in a normal year (Schell and Lockwood, 1997).

1. Carbaryl

Direct and Indirect Toxicity—Carbaryl is an AChE inhibitor. For vertebrates, such as birds, AChE is essential for normal nervous system functions. A moderately severe AChE inhibition of 40 to 60 percent affects coordination, behavior, and foraging ability. Such inhibition can lead to death from weather, predators, or other stresses of survival in the wild. The effects of lower AChE levels are still open to question regarding biological significance. In samples collected over a period of several years from multiple grasshopper treatment areas, not a single bird or mammal was found to have more than a 40 percent AChE inhibition, and only a few individuals over the course of the entire study had an AChE inhibition as high as 20 percent (McEwen *et al.*, 1996a). Fish exposed to carbaryl showed no inhibition of AChE (Beyers *et al.*, 1994). At the carbaryl ULV application rate in Alternative 2, there is very little possibility of toxicity-caused mortality of upland birds, mammals, or reptiles, and none has been observed (McEwen *et al.*, 1996a). Carbaryl is not subject to significant bioaccumulation due to its low water solubility and low octanol-water partition coefficient (Dobroski *et al.*, 1985).

Human Health—EPA has classified carbaryl as a “possible human carcinogen” based on an increased incidence of vascular tumors in a chronic study of male mice exposed at 46 milligrams/kilograms/day (mg/kg/day) (1000 ppm) (EPA, 1993). Carbaryl, however, is not considered to pose any mutagenic or genotoxic risk based upon the weight of evidence.

Potential exposures to the general public from conventional application rates are infrequent and of low magnitude. These low exposures to the public pose no risk of direct toxicity, carcinogenicity, neurotoxicity, genotoxicity, reproductive toxicity, or developmental toxicity. Potential worker exposures are higher and have the potential for adverse effects if proper safety procedures, including required protective gear, are not used. Carbaryl has been used routinely in other programs with no reports of adverse health effects. Therefore, routine safety precautions are anticipated to continue to provide adequate protection of worker health.

Immunotoxic effects from carbaryl exposure are generally expected at concentrations much higher than those from grasshopper applications, but individuals with allergic or hypersensitive reactions to the insecticide or other chemicals in the formulated product could be affected. These individuals are advised to avoid treatment areas at the time of application until the insecticide has time to dry on the treated vegetation.

c. Terrestrial Invertebrates—Applications of broad spectrum insecticidal sprays can cause large reductions in populations of both target arthropods (grasshoppers) and nontarget arthropods immediately after treatment. Insects that are active during treatments or that feed on moribund grasshoppers have the greatest potential for exposure to insecticides. Insects of this type include ground beetles, darkling beetles, blister beetles, spiders (especially wolf spiders), field crickets, foraging bees, and ants.

Catangui *et al.* (1996) assessed the impact of grasshopper suppression programs that used ULV carbaryl at Alternative 2 rates on nontarget arthropods in South Dakota. There were no substantial reductions in the numbers of ants, spiders, predatory beetles, or scavenger beetles from 7 to 76 days after treatment. Even after 1 year, no substantial reductions in soil surface-associated arthropods were detected. That study also found that flying nontarget arthropods such as pollinator bees, predators, and parasites showed no substantial reductions either immediately after carbaryl treatments or 1 year later. Swain (1986) conducted a field study on the effects of grasshopper treatments on nontarget arthropods and reported that malathion was initially more detrimental than either ULV carbaryl or carbaryl bait, but there was no indication of long-term effects on the arthropod complex.

Carbaryl bait applications affect only species that consume the baits directly or prey that have consumed the baits (Quinn, 1996). These species include darkling beetles, ground beetles, field crickets, and ants. Bait applied at Alternative 2 rates for grasshopper suppression did not cause any long-term effects on those species (Quinn, 1996). There are many reasons for this lack of long-term effects, including resiliency of populations.

d. Terrestrial Vertebrates—No toxic signs of bird mortality were observed during studies on killdeer populations in North Dakota when carbaryl ULV sprays were applied at Alternative 2 rates (McEwen *et al.*, 1996a). Killdeer foraging effectiveness increased in the carbaryl treatment area, probably in response to the presence of dead and moribund grasshoppers. The quantitative risk assessment in appendix B established that the estimated carbaryl dose that rangeland birds would accumulate, by both direct exposure and indirectly through diet, in grasshopper treatment areas is well below a toxic dose.

However, in some areas the reduced number of invertebrates necessary for bird survival and development may result in birds having less available food. In these cases, birds either will have less than optimal diets or will travel to untreated areas for suitable prey items causing a greater foraging effort and a possible increased susceptibility to predation.

Golden eagles are a protected species and also are designated as a "species of concern" by wildlife conservation and land management agencies. This bird also has special significance for some Native American tribes. Golden eagles nest in remote rangeland areas and can be found on areas requiring grasshopper suppression treatments. A study of carbaryl sprayed directly over golden eagle nests at the Alternative 2 rate found that there was little risk to nesting golden eagles (McEwen *et al.*, 1996b).

The effects of carbaryl bait applied at Alternative 2 rates on vesper sparrow nestling growth and survival were investigated in North Dakota (McEwen *et al.*, 1996a). Vesper sparrow survival, growth, and fledgling rates were not affected by the bait treatments around the nesting areas, and there was no difference in any of the productivity parameters between vesper sparrow nests on treated and untreated sites (Adams *et al.*, 1994).

Live trapping studies of small rodent populations (primarily deer mice) in areas treated with carbaryl showed no posttreatment decreases in number of animals (McEwen *et al.*,1996a).

By contrast, Martin *et al.* (2000) reported the effects of the carbamate insecticide, carbofuran, on two species of upland birds. Although grasshopper populations were reduced by more than 90 percent, the rate of prey delivery, nestling weight and size, and total arthropod biomass delivered to nestlings in the treated areas were no different than in the untreated areas. The number of grasshoppers in nestling diets was significantly decreased, although the total number of food items was similar in both treated and untreated areas.

e. Aquatic Organisms—Beyers and McEwen (1996) intensively studied six freshwater ponds exposed to carbaryl. The only evidence of direct mortality was to pond-dwelling amphipods, and that was observed in only one of the six ponds. Amphipods are known to be extremely sensitive to carbaryl. All other aquatic invertebrates and other taxa in the six ponds appeared to be unaffected by the exposure to carbaryl.

Studies by Beyers *et al.* (1995) were conducted in the Little Missouri River during a drought year when insecticide exposure to aquatic organisms was high because the insecticides were less diluted by the river water. Of the many effects on aquatic organisms measured, the only negative impact detected was an increase in invertebrate drift during the first 3 hours of carbaryl application. Sampling later that same day showed that the increase in invertebrate drift was transient and undetectable after 3 hours. The overall conclusion was that the grasshopper suppression program had no biologically significant effect on aquatic resources.

Toxicity tests conducted on two fish, the Colorado squawfish, renamed the Colorado pikeminnow, and bonytail chub, using carbaryl and malathion exposures that simulated field conditions after a grasshopper treatment indicated in their laboratory experiments that carbaryl was several times more toxic than malathion to those fish (Beyers and Sikoski, 1994).

2. Diflubenzuron

Under Alternative 2, diflubenzuron would be applied at the rate of 1.0 fluid ounce (0.016 pound active ingredient) per acre, using ULV sprays that provide complete coverage within the treatment area. A grasshopper mortality rate of up to 98 percent after 2 weeks could occur, although mortalities may be less. In addition to grasshoppers, diflubenzuron also would have the greatest effect on other immature terrestrial insects and early life stages of aquatic invertebrates.

a. Direct and Indirect Toxicity—Because of its mode of action and low toxicity, diflubenzuron would not be toxic to or directly affect humans, terrestrial wildlife, plants, or fish at the application rate in Alternative 2. The highest potential for exposure to diflubenzuron would be to insectivorous (organisms that consume insects) vertebrates such as birds, rodents, and reptiles that may be exposed to diflubenzuron treatments and then consume considerable quantities of grasshoppers, other rangeland invertebrates, and/or plants that contain diflubenzuron. Yet, the quantitative risk assessment in appendix B has demonstrated that vertebrates have a negligible risk of adverse toxicological effects from full coverage treatments using diflubenzuron. The assessment of 12 representative species demonstrated that diflubenzuron accumulation at Alternative 2 rates is many orders of magnitude below a lethal dose.

McEwen *et al.* (1996b) exposed wild American kestrels in north-central Colorado to diflubenzuron rates that were 50 percent greater than the estimated rates that kestrels would be exposed to under Alternative 2. No statistically significant differences were detected in nestling growth rates, behavior data, or survival among treated and untreated kestrels. Fledgling survival for the kestrels treated with diflubenzuron was lowered for 1 year, but in the subsequent year no statistically substantial differences were observed between treated and control fledglings. Little, if any, bioconcentration or bioaccumulation would be expected for any animals (Booth, 1978). The rapid metabolism and lack of bioconcentration indicate that only acute toxic effects would be expected for diflubenzuron exposures (Opdycke *et al.*, 1982).

In addition to direct toxicity, there is a concern that wildlife and other species that feed upon grasshoppers and other insects would be indirectly affected because there would be fewer insects left in a treatment area for insectivores to consume. Because diflubenzuron is most effective against immature insects, adult insects in the treatment area would be largely unaffected and still available to insectivorous species for consumption.

b. Human Health—Potential exposures to the general public from conventional application rates are infrequent and of low magnitude. These low exposures to the public pose no risk of methemoglobinemia, direct toxicity, neurotoxicity, genotoxicity, reproductive toxicity, or developmental toxicity. Potential worker exposures are higher but are not expected to pose any risk of adverse health effects.

Immunotoxic effects from exposure to diflubenzuron or formulation ingredients, if treatment-related, only could occur at concentrations much higher than those from grasshopper applications, but individuals with allergic or hypersensitive reactions to the insecticide or formulation ingredients could be affected. These individuals are advised to avoid treatment areas at the time of application until the insecticide has time to dry on the treated vegetation.

c. Terrestrial Invertebrates—Diflubenzuron applied at the rate and coverage in Alternative 2 has a minimal impact on many insects common to rangeland ecosystems and is mostly limited to larval insects that are exposed to the spray or ingest diflubenzuron. Adult insects and spiders would not be affected. Predatory invertebrates that consume grasshoppers affected by diflubenzuron are not affected by the toxicant (Lockwood *et al.*, 2001). In addition, any reductions in nontarget insects are of short duration, typically measured in days. This is most likely a result of nontarget insects not being in early life (larval) stages during the exact time diflubenzuron is applied or exhibiting a behavior (such as being nocturnal or burrowing) and, therefore, not exposed to this insecticide.

Catangui *et al.* (1996) assessed the impact of grasshopper suppression programs that used diflubenzuron at Alternative 2 rates on nontarget arthropods in South Dakota. In general, there were no significant reductions in the numbers of ants, spiders, predatory beetles, or scavenger beetles from 7 to 76 days after treatment. Even after 1 year, no substantial reductions in soil surface-associated arthropods were detected. That study also found that flying nontarget arthropods such as pollinator bees, predators, and parasites were not substantially reduced either immediately after diflubenzuron treatments or 1 year later.

Bees, such as honey bees and leafcutter bees, are insects of special concern because they pollinate crops. In the Western United States more than 2,500 species of native bees are found that may be specialized pollinators for many noncultivated flowering plants, including threatened and endangered species (Tepedino, 1996). However, diflubenzuron has been shown to adversely affect honey bees only at dietary concentrations much higher and for time periods much longer than the concentrations and exposure periods than in grasshopper treatment areas. Diflubenzuron application rates as high as 0.3125 lb a.i./acre (Schroeder, *et al.*, 1980) and 0.357 lb a.i./acre (Emmett and Archer, 1980) resulted in no effects on adult bee mortality and brood production. Therefore, diflubenzuron can be applied at the rates and coverage in Alternative 2 without substantially affecting adult honey bees.

d. Terrestrial Vertebrates—Chitin or chitin-like substances are not as important to terrestrial mammals, birds, and other vertebrates as chitin is to insects; therefore, the chitin-inhibiting properties of diflubenzuron will have little to no direct toxic impact on vertebrates. However, indirect effects may occur after diflubenzuron applications under the conditions of Alternative 2, such as reductions in the food base for insectivorous wildlife species, especially birds. As stated above, diflubenzuron is practically nontoxic to birds, including those birds that ingest moribund grasshoppers resulting from diflubenzuron applications, as described in Alternative 2.

While immature grasshoppers and other immature insects can be reduced up to 98 percent in areas covered with diflubenzuron, some grasshoppers and other insects remain in the treatment area. Although the density of grasshoppers and other insects may be low, it is most likely sufficient to sustain birds and other insectivores until insect populations recover. Those rangeland birds that feed primarily on grasshoppers may switch to other diet items. However, in some areas the reduced number of invertebrates necessary for bird survival and development may result in birds having less available food. In these cases, birds will either have less than optimal diets or travel to untreated areas for suitable prey items, causing a greater foraging effort and a possible increased susceptibility to predation. It also should be noted that suppressing grasshopper populations conserves rangeland vegetation that often is important habitat to rangeland wildlife. Habitat loss is frequently the most important factor leading to the decline of a species, and reducing grasshopper densities can be an aid in reducing habitat loss.

e. Aquatic Organisms—Although diflubenzuron has relatively few effects on most nontarget terrestrial organisms, the same is not the case for aquatic organisms, especially freshwater crustaceans and immature aquatic insects. Arthropods, including crabs, crayfish, lobsters, shrimp, daphnids, mayflies, stoneflies, barnacles, copepods, and horseshoe crabs, that are in developing stages can be adversely affected by diflubenzuron (Eisler, 2000). Many aquatic invertebrates have short life cycles and produce offspring several times a year. Aquatic vertebrates, such as fish, are not directly susceptible to diflubenzuron. Reductions in the invertebrate food base would likely be readily compensated by other food items.

Diflubenzuron used for grasshopper suppression in Alternative 2 is unlikely to cause long-term damage to aquatic ecosystems in the Western United States. Many of the organisms most susceptible to diflubenzuron, such as marine invertebrates, do not occur in rangeland ecosystems. While some aquatic invertebrate populations could temporarily decrease if exposed to diflubenzuron, this decrease would not likely be permanent because aquatic invertebrates regenerate rapidly, and the populations would have the potential to recover quickly.

3. Malathion

a. Direct and Indirect Toxicity—Malathion is an AChE inhibitor. For vertebrates such as mammals and birds, AChE is essential for normal nervous system functions. A moderately severe AChE inhibition of 40 to 60 percent affects coordination, behavior, foraging ability, and can lead to death from weather, predators, or other stresses of survival in the wild. The effects of lower AChE levels are still open to question regarding biological significance. In samples collected over several years from multiple grasshopper treatment areas, not a single bird or mammal was found to have more than a 40 percent AChE inhibition, and only a few individuals over the course of the entire study had an AChE inhibition as high as 20 percent (McEwen *et al,* 1996a). At the malathion ULV application rate in Alternative 2, there is very little possibility of toxicity-caused mortality of upland birds, mammals, or reptiles, and none has been observed (McEwen *et al.*, 1996b). Bioconcentration factors for fish range from 7.36 in lake trout to 34.4 in willow shiners. The concentration in fish tissues decreases readily and consistently with decreasing concentrations of malathion in water. No concerns about bioaccumulation are anticipated for grasshopper suppression programs (HSDB, 1990; Tsuda *et al.*, 1989).

b. Human Health—Potential exposures to the general public from conventional application rates are infrequent and of low magnitude. These low exposures to the public pose no risk of direct toxicity, neurotoxicity, genotoxicity, reproductive toxicity, or developmental toxicity. Potential worker exposures are higher, but still have no potential for adverse health effects except under accidental scenarios. The risks to workers under accidental scenarios are minimized if proper safety procedures, including required protective gear, are used. Malathion has been used routinely in other programs with no reports of adverse health effects. Therefore, routine safety precautions are anticipated to continue to provide adequate protection of worker health.

EPA has recently reviewed the potential for carcinogenic effects from malathion. Their classification describes malathion as having "suggestive evidence of carcinogenicity, but not sufficient to assess human carcinogenic potential." This indicates that any carcinogenic potential of malathion cannot be quantified based upon the weight of EPA's evidence determination in this classification (EPA, 2000). The low exposures to malathion from program applications would not be expected to pose any carcinogenic risks to workers or the general public.

Immunotoxic effects from malathion exposure may be expected at concentrations much higher than those from grasshopper applications, but individuals with allergic or hypersensitive reactions to the insecticide or formulation ingredients could be affected.

c. Terrestrial Invertebrates—Applications of broad spectrum insecticidal sprays can cause large reductions in populations of both target arthropods (grasshoppers) and nontarget arthropods immediately after treatment. Insects that are active during treatments or that feed on moribund grasshoppers have the greatest potential for exposure to insecticides. Insects of this type include ground beetles, darkling beetles, blister beetles, spiders (especially wolf spiders), field crickets, foraging bees, and ants.

A field study (Quinn, 1996) on the effects of malathion applied at Alternative 2 rates to suppress grasshoppers summarized that there is little evidence that grasshopper control treatments cause any long-term effects on nontarget arthropods. Swain (1986) conducted a field study on the effects of grasshopper treatments on nontarget arthropods and reported that malathion was initially more detrimental than either ULV carbaryl or carbaryl bait, but there was no indication of long-term effects on the arthropod complex.

d. Terrestrial Vertebrates—A 3-year field study of indirect effects of malathion applied at Alternative 2 rates on nesting birds was conducted in Idaho (McEwen *et al.*, 1996b). In the malathion treatment area, total invertebrate availability for foraging birds was significantly reduced. However, nesting birds switched their diets to the remaining insects and reproduced as successfully as birds on untreated comparison plots, as also reported by Howe *et al.* (1996) and (2000).

McEwen *et al.* (1996a) reported about the general response of total bird populations to grasshopper treatments. The total number of birds of all species within a treatment area did not change after treatments with the exception of the western meadowlark, a highly insectivorous species.

Presumably the decrease in western meadowlark was due to reduced food availability because there was no evidence of toxic signs in the meadowlarks that remained in the treatment area, no dead birds were found, and the birds temporarily moved to untreated areas where food was more available.

An alternative explanation not supported by Howe *et al.* (1996) is that meadowlarks could possibly have moved to untreated areas and died, or birds may have died on the treated plots but were scavenged, or moribund birds were predated upon before observations occurred.

Howe *et al.* (1996) determined the effects of malathion applied at Alternative 2 rates for grasshopper suppression on reproduction of passerine birds in shrubsteppe habitat in southern Idaho. Malathion had no observable direct effects on Brewer's sparrow and sage thrasher. There was a significant reduction in food items, but nestling growth and survival were not severely affected and the indirect effects on those birds were only marginal.

In some areas, the reduced numbers of invertebrates necessary for bird survival and development may result in birds having less available food. In these cases, birds will either have less than optimal diets or travel to untreated areas for suitable prey items causing a greater foraging effort and a possible increased susceptibility to predation.

Small mammals, such as rodents, are not affected to the extent birds are affected from an insecticide application. Most small mammals are nocturnal and are often in underground burrows during and immediately after a treatment. This provides more time for the insecticide to dissipate before small mammals are exposed. Deer mice collected from an area treated with malathion had lower residues than did birds from the same sites (McEwen *et al.*, 1996a). Live trapping studies of small rodent populations (primarily deer mice) in areas treated with malathion showed no posttreatment decreases (McEwen *et al.*, 1996a). The risk assessment in appendix B indicates that of the 12 species assessed, the species that are at greatest risk from malathion applied at Alternative 2 rates are bobwhite quail, American kestrel, and Woodhouse's toad.

e. Aquatic Organisms—Acute toxicity of malathion varies widely from slightly toxic to some species of fish to very highly toxic to other species. A direct exposure to malathion in water is toxic to many aquatic invertebrates and may kill sensitive fish species (Beyers and McEwen, 1996). Appendix B contains more information on the effects of malathion to aquatic organisms. Toxicity tests conducted on two fish, the Colorado pikeminnow and bonytail chub, using carbaryl and malathion exposures that simulated field conditions after a grasshopper treatment indicated in their laboratory experiments that carbaryl had severalfold higher mortality than malathion to those fish (Beyers and Sikoski, 1994).

D. Environmental Consequences of Alternative 3: Reduced Agent Area Treatments (RAATs)

The RAATs strategy has two components: insect suppression and conservation biological control. First, treatments made under RAATs rely on grasshopper suppression using insecticides. Grasshoppers in the treated area are directly exposed to insecticides and suffer mortality. Grasshoppers in the areas not directly treated (untreated) may also be exposed to insecticides if drift occurs from the treated areas or if individuals move from the untreated area into the treated area and thus become exposed to the insecticide. Second, RAATs strategy relies on conservation biological control. This means that naturally occurring predators and parasites of grasshoppers are retained in the untreated areas. These predators and parasites remain after treatments and are available to suppress grasshoppers in both the treated and untreated areas.

The insecticide APHIS would use under this alternative would be either carbaryl, diflubenzuron, or malathion. Carbaryl, diflubenzuron, and malathion are all currently registered for use and labeled by EPA for rangeland grasshopper treatments and have been demonstrated to be effective. Applications of these insecticides could be conducted aerially or by ground equipment, and APHIS personnel would conduct the treatments in strict adherence to the label directions. The application rates analyzed in this document are 8 fluid ounces (0.25 pound active ingredient) of carbaryl spray per acre, 10 pounds (0.20 pound active ingredient) of

2 percent carbaryl bait per acre, 0.75 fluid ounce (0.012 pound active ingredient) of diflubenzuron per acre, and 4 fluid ounces (0.31 pound active ingredient) of malathion per acre.

The goal of grasshopper suppression under the RAATs alternative is to economically and environmentally suppress grasshopper populations to a desired level rather than to reduce those populations to the greatest possible extent. The efficacy of the RAATs alternative in reducing grasshoppers is therefore less than conventional treatments. The RAATs efficacy is also variable. Foster *et al.* (2000) reported that grasshopper treatment mortality using RAATs was reduced 2 to 15 percent from conventional treatments while Lockwood *et al.* (2000) reported 0 to 26 percent difference in mortality between the conventional and RAATs alternatives. During grasshopper outbreaks when grasshopper densities can be 60 or more per square meter (Norelius and Lockwood, 1999), grasshopper treatments that have a 90 to 95 percent mortality still leave a number of grasshoppers (3 to 6) that is generally greater than the average number found on rangeland, such as in Wyoming, in a normal year (Schell and Lockwood, 1997).

The risk assessment (appendix B) used reduced application rates, but assumed 100 percent coverage because there is no way of knowing how much area will be left untreated. In certain circumstances, untreated areas may receive an unintended, small amount of insecticide from adjacent treated areas, so complete coverage was used for our analyses. Therefore, the actual effects associated with grasshopper suppression programs, according to RAATs, are likely to be less severe than described in the risk assessment. The untreated areas in RAATs may also be viewed as protected areas that play a vital role in protecting nontarget species (Winks *et al.*, 1996).

1. Carbaryl

a. Human Health—EPA has classified carbaryl as a “possible human carcinogen” based on an increased incidence of vascular tumors in a chronic study of male mice exposed at 46 mg/kg/day (1000 ppm) (EPA, 1993). Carbaryl, however, is not considered to pose any mutagenic or genotoxic risk based upon the weight of evidence.

Potential exposures to the general public from RAATs application rates are lower than those from conventional application rates, and adverse effects decrease commensurately with decreased magnitude of exposure. These low exposures to the public pose no risk of direct toxicity, carcinogenicity, neurotoxicity, genotoxicity, reproductive toxicity, or developmental toxicity. Potential worker exposures are higher and have the potential for adverse effects if proper protective gear is used. Carbaryl has been used routinely in other programs with no reports of adverse effects. Therefore, routine safety precautions are anticipated to provide adequate protection of worker health at the lower application rates under RAATs.

Immunotoxic effects from carbaryl exposure are generally expected at concentrations much higher than those from grasshopper applications, but individuals with allergic or hypersensitive reactions to the insecticide or formulation ingredients could be affected. These individuals are advised to avoid treatment areas at the time of application until the insecticide has time to dry on the treated vegetation.

b. Terrestrial Invertebrates and Vertebrates—A decrease in susceptible invertebrate populations is evident when carbaryl is applied at rates under the RAATs alternative. The immediate effect of a treatment results in a more limited predator avoidance by susceptible insects and easier foraging for insectivorous species that are within the treatment areas or that may migrate into the treated area from untreated areas. The decreases in populations of susceptible insects following carbaryl applications are expected to be minimal with rapid colonization of the treated areas from surrounding untreated areas. Using alternating swaths and reducing rates even lower as part of a RAATs strategy will further limit the adverse effects to nontarget insect populations, thereby minimizing any potential adverse effects on foraging insectivorous vertebrates.

A carbaryl bait study applied at Alternative 3 rates for grasshopper suppression in North Dakota (George *et al.*, 1992) indicated that low rate carbaryl bait applications have minimal potential for direct toxic effects on birds and mammals, but may have limited indirect effects on species that depend on arthropod groups for food or seed dispersal. Also, that study found that Halictid bees, which are the primary pollinators of some native plants, did not decline after the bait treatments.

AChE inhibition at 40 to 60 percent affects coordination, behavior, and foraging ability in vertebrates. This could lead to death from weather, predators, or other stresses of survival in the wild. Studies over several years for multiple grasshopper treatment areas have shown AChE inhibition at levels of no more than 40 percent with most at less than 20 percent (McEwen *et al.*, 1996a). After a RAATs application, live grasshoppers often remain at a higher density than grasshopper populations present in nonoutbreak years and, thus, they are available as prey to insectivores.

McEwen *et al.* (1996b) studied the effects of carbaryl bait applied at Alternative 3 rates to American kestrel nests. No adverse effect was noted on the treated nests, and all kestrel nestlings fledged normally.

Field applications of carbaryl spray at Alternative 3 rates and applied in alternate swaths resulted in less reduction to nontarget organisms than did blanket applications. Under a RAATs strategy, carbaryl affects arthropods less than malathion (Lockwood *et al.*, 2000). The effect of carbaryl on bird populations in RAATs areas was similar to the effect of malathion RAATs, although malathion perhaps had a greater suppressive effect on populations (Norelius and Lockwood, 1999). Carbaryl is not subject to significant bioaccumulation due to its low water solubility and low octanol-water partitian coefficient (Dobroski *et al.*, 1985).

c. Aquatic Organisms—Carbaryl has the potential to affect invertebrates in aquatic ecosystems but is unlikely to affect vertebrates such as fish at any concentrations that could be expected under Alternative 3. Although invertebrate populations may be reduced, these changes would not be permanent. Over a few months it is likely that most, if not all, invertebrate populations have a chance to recover to pretreatment levels.

Diflubenzuron

Under Alternative 3, the maximum rate that diflubenzuron would be applied is 0.75 fluid ounce (0.012 pound active ingredient) per acre using ULV sprays. In addition, the area treated is currently 50 percent of the total suppression area, but this amount is not standardized and may decrease substantially. Other RAATs applications cover only 33 percent of the suppression area, and it may be possible to achieve acceptable grasshopper reduction by treating an even smaller area. Because not every possible combination of reduced rates and reduced areas could be analyzed, this section is based on only the maximum RAATs rate of 0.75 fluid ounce and 100 percent coverage. Although this is not a realistic RAATs scenario, this rate/area combination represents the maximum insecticide burden and subsequent environmental effects that could be realized under Alternative 3. Grasshopper mortality of 75 to 95 percent after 2 weeks would be expected to occur.

a. Human Health—Potential exposures and adverse effects to the general public from RAATs application rates are commensurately less than conventional application rates. These low exposures to the public pose no risk of methemoglobinemia, direct toxicity, neurotoxicity, genotoxicity, carcinogenicity, reproductive toxicity, or developmental toxicity. Potential worker exposures are higher, but are not expected to pose any risk of adverse health effects.

Immunotoxic effects from exposure to diflubenzuron or formulation ingredients, if treatment-related, could only occur at concentrations much higher than those from grasshopper applications, but individuals with allergic or hypersensitive reactions to the insecticide or formulation ingredients could be affected. These individuals are advised to avoid treatment areas at the time of application until the insecticide has time to dry on the treated vegetation.

b. Direct and Indirect Toxicity—Because of its mode of action and low toxicity, diflubenzuron would not be toxic to or directly affect humans, terrestrial wildlife, plants, and fish at the application rate under Alternative 3. The lower application rate under Alternative 3 results in commensurately lower overall exposures. Although the highest potential for exposure to diflubenzuron would be to insectivorous (organisms that consume insects) vertebrates such as birds, rodents, and reptiles that consume considerable quantities of grasshoppers and other rangeland invertebrates that contain diflubenzuron after a treatment, the overall risk to insectivores would be less than the negligible risk posed in Alternative 2. The quantitative risk assessment in Appendix B has demonstrated that vertebrates have a very negligible risk of adverse toxicological effects from full coverage treatments using diflubenzuron. None of the 12 representative species assessed in Appendix B would accumulate an amount of diflubenzuron that even begins to approach a lethal dose under Alternative 3.

In addition to direct toxicity, there is a concern that nontarget species that feed upon grasshoppers and other insects would be indirectly affected because there would be fewer insects left in a treatment area to consume. Because diflubenzuron is most effective against immature insects, adult insects in the treatment area would be largely unaffected and still available to insectivorous species.

c. Terrestrial Invertebrates—Diflubenzuron applied at Alternative 3 rates will have a minimal impact on many insects common to rangeland ecosystems. Not all insects in the area treated will be affected because adult insects are unaffected by diflubenzuron. In addition, immature insects in the untreated areas will have little exposure to diflubenzuron and can move into the treated area and become adults after diflubenzuron has degraded.

Although protected in brood chambers, larval honey bees, leafcutter bees, and native rangeland bees in the treatment area will be indirectly exposed to even the reduced rates of diflubenzuron in Alternative 3. Adult bees are not likely to be affected because contact with diflubenzuron does not directly affect adult insects, and the dietary uptake of small amounts of diflubenzuron in the treatment area is brief. Diflubenzuron application rates as high as 0.3125 lb a.i./acre (Schroeder *et al.*, 1980) and 0.357 lb a.i./acre (Emmett and Archer, 1980) resulted in no effects on adult bee mortality and brood production. Bees in the untreated areas would not be affected even if they later enter the treated area.

d. Terrestrial Vertebrates—Chitin or chitin-like substances are not as important to terrestrial mammals, birds, and other vertebrates as chitin is to insects; therefore, the chitin-inhibiting properties of diflubenzuron will have little to no direct toxic impact on vertebrates. However, indirect effects may occur after diflubenzuron applications under RAATs, such as reductions in the food base for insectivorous wildlife species, especially birds. As stated above, diflubenzuron is practically nontoxic to birds, including those birds that ingest moribund grasshoppers resulting from diflubenzuron applications described in Alternative 3. Little, if any, bioconcentration or bioaccumulation would be expected for any animals (Booth, 1978). The rapid metabolism and lack of bioconcentration indicate that only acute toxic effects would be expected for diflubenzuron exposures (Opdycke *et al.*, 1982).

Grasshopper densities are reduced less in RAATs than in conventional treatments. Therefore, grasshoppers remain not only in the treatment area but the untreated area as well. In many cases, the level of grasshoppers after RAATs is as large, if not larger, than grasshopper populations in nonoutbreak years. For example, grasshopper densities during outbreaks can be greater than 50 per square yard. Reducing those populations by 90 percent would leave 5 grasshoppers per square yard in the treated area. This density may be more grasshoppers than in normal years. Norelius and Lockwood (1999) reported that grasshopper densities remaining after a grasshopper treatment were above the average found on Wyoming rangeland. The remaining grasshoppers can sustain birds and other insectivores until insect populations recover.

Rangeland birds also may temporarily switch to diet items other than grasshoppers. In years when grasshopper levels are naturally low, rangeland birds are forced to find alternative food items. It should also be noted that suppressing grasshopper populations conserves rangeland vegetation that often is important habitat to rangeland wildlife. Habitat loss is frequently the most important factor leading to the decline of a species.

Reducing grasshopper densities can be an aid in reducing habitat loss. While perennial plants may remain defoliated for only one growing season, Pfadt (1994) attributed high grasshopper densities to the defoliation and death of 11 species of native shrubs as well as forbs and grasses.

e. Aquatic Organisms—Diflubenzuron used for grasshopper suppression under Alternative 3 is unlikely to cause long-term damage to aquatic ecosystems in the Western United States. Although diflubenzuron can adversely affect aquatic crustaceans, insects, and other arthropods, the rapid regeneration time for these organisms ensures rapid recolonization. Diflubenzuron is not toxic to fish. Fish that feed on arthropods whose populations may be reduced by diflubenzuron may increase their feeding on other diet items until the more preferred invertebrate populations recover.

Malathion

a. Human Health—EPA has recently reviewed the potential for carcinogenic effects from malathion. EPA's classification describes malathion as having "suggestive evidence of carcinogenicity, but not sufficient to assess human carcinogenic potential." This indicates that any carcinogenic potential of malathion cannot be quantified based upon EPA's weight of evidence determination in this classification (EPA, 2000).

Potential exposures to the general public from RAATs application rates are of a commensurately lower magnitude than conventional rates. These low exposures to the public pose no risk of direct toxicity, neurotoxicity, genotoxicity, reproductive toxicity, or developmental toxicity. Potential worker exposures are higher than for the general public, but still have no potential for adverse health effects except under accidental scenarios. The risks to workers under accidental scenarios are minimized if proper protective gear is used. Malathion has been used routinely in other programs with no reports of adverse health effects. Therefore, routine safety precautions are anticipated to continue to provide adequate protection of worker health. The low exposures to malathion from program applications would not be expected to pose any carcinogenic risks to workers or the general public.

Immunotoxic effects from malathion exposure are generally expected at concentrations much higher than those from grasshopper applications, but individuals with allergic or hypersensitive reactions to the insecticide or formulated ingredients could be affected. These individuals are advised to avoid treatment areas at the time of application until the insecticide has time to dry on the treated vegetation.

b. Terrestrial Invertebrates and Vertebrates—The toxic effects of malathion from RAATs application rates cause decreases in susceptible invertebrate populations. The immediate effect of a treatment results in prey insects having a more limited predator avoidance. After treatments, foraging may be easier for insectivorous species, both within the suppression areas or those that migrate into the treated area from untreated areas. The decreases in populations of susceptible insects following malathion applied at Alternative 3 rates are expected to be minimal with rapid colonization of the treated areas from surrounding untreated areas. Using alternating swaths and reducing rates even lower as part of a RAATs strategy will further limit the adverse effects to nontarget insect populations, minimizing any potential adverse effects on foraging insectivorous vertebrates.

AChE inhibition at 40 to 60 percent affects coordination, behavior, and foraging ability in vertebrates. This could lead to death from weather, predators, or other stresses of survival in the wild. Studies over several years for multiple grasshopper treatment areas have shown AChE inhibition at levels of no more than 40 percent with most inhibition at less than 20 percent (McEwen *et al.,* 1996a). After a conventional treatment, live grasshoppers often remain at a higher density than grasshopper populations present in nonoutbreak years, and thus they are available as prey to insectivores. Bioconcentration factors for fish range from 7.36 in lake trout to 34.4 in willow shiners. The concentration in fish tissues decreases readily and consistently with decreasing concentration of malathion in water. No concerns about bioaccumulation are anticipated for grasshopper suppression programs (HSDB, 1990; Tsuda *et al.*, 1989).

Field applications of malathion at Alternative 3 rates and applied in alternate swaths resulted in less reduction in nontarget organisms than would occur with blanket applications. However, arthropods in malathion RAATs areas were affected more than those in the carbaryl RAATs areas (Lockwood *et al.*, 2000). The effect of malathion on bird populations in RAATs areas was similar to the effect of carbaryl RAATs areas, although malathion perhaps had a greater suppressive effect on populations (Norelius and Lockwood, 1999). It should be noted that although adult birds can migrate into untreated areas, this activity could possibly result in decreased foraging success and increased predation on chicks.

c. Aquatic Organisms—Aquatic field studies on the effects of malathion applied at Alternative 3 rates have not been conducted by APHIS. However, based on the risk assessment in appendix B, malathion applied for grasshopper suppression is most likely to affect aquatic invertebrates, especially amphipods and cladocerans. These effects would soon be compensated for by the survivors, given the rapid generation time of most aquatic invertebrates and the rapid degradation of malathion in water. Organisms that normally feed on aquatic invertebrates would likely switch temporarily to an alternate food source. If no alternate food source is available, the rapid generation time of invertebrates means that the affected population would quickly recover to pre-exposure levels, or in flowing waters, upstream drift would result in recolonization before the predator populations would be permanently affected. Therefore, malathion applied at Alternative 3 rates would not likely cause long-term effects on the aquatic ecosystem.

E. Species of Concern

This section will describe the effects of grasshopper treatments on three species of concern in the Western United States. These species are provided as three examples of the many species of concern found on rangeland habitats. Species of concern, including federally listed endangered and threatened species, will also be addressed during consultation with the Fish and Wildlife Service and/or the National Marine Fisheries Service as well as in site-specific documents, such as environmental assessments, that will be prepared in conjunction with grasshopper program activities.

Sage Grouse

Grasshoppers and sage grouse are a natural part of rangeland ecosystems in the Western United States. Sage grouse is the largest grouse in North America and is known for the stunning mating ritual of the males that has been considered one of the continent's great wildlife spectacles (Weidensaul, 2001). Sage grouse, a species of concern to land management agencies, have been in a state of decline throughout most of their entire range. Currently, the Washington State population of the sage grouse is a candidate for listing under the Endangered Species Act (ESA), with habitat loss as a major factor in their decline.

The organophosphorous insecticides, dimethoate and methamidophos, applied to crops can adversely affect sage grouse (Blus *et al.*, 1989). A carbamate insecticide, carbofuran, can also effect wildlife (Forsyth and Westcott, 1994). APHIS neither uses those insecticides nor applies those insecticides to crops as part of the grasshopper program. Although malathion is also an organophosphorus insecticide and carbaryl is a carbamate insecticide, malathion and carbaryl are much less toxic to birds than are dimethoate, methamidophos, or carbofuran. The risk assessment in appendix B analyzed sage grouse as an indicator species. The risk assessment concluded that malathion and carbaryl used for grasshopper treatments under Alternative 2 would not directly affect sage grouse, and Alternative 3, when 50 to 75 percent less malathion and carbaryl would be applied, would have even less of a potential to affect sage grouse.

Sagebrush leaves and buds comprise the vast majority (up to 99 percent) of sage grouse diet in the winter. Even in summer, sage grouse live in close association with sagebrush, but succulent forbs and other plants predominate the diet. In the spring, however, sage grouse chicks consume a wide variety of foods, including insects that are necessary for their growth and survival (Johnson and Boyce, 1990; Drut *et al.*, 1994).

Grasshoppers can be diet items for sage grouse chicks. During grasshopper outbreaks when grasshopper densities can be 60 or more per square meter (Norelius and Lockwood, 1999), grasshopper treatments that have a 90 to 95 percent mortality still leave a density of grasshoppers (3 to 6) that is generally greater than the average density found on rangeland, such as in Wyoming, in a normal year (Schell and Lockwood, 1997). Even though grasshoppers may be less available to sage grouse, behavioral changes, such as switching to other diet items or increased foraging time, may help compensate for the lack of grasshoppers (Howe *et al.*, 2000).

Although most grasshoppers do not directly damage sagebrush, Pfadt (1994) described that grasshopper nymph densities of 100 to 3,000 per square yard resulted in the defoliation and death of 11 species of native shrubs, as well as forbs and grasses. Furthermore, the grasshopper damage disrupted the natural biodiversity of the plant community and opened the land to soil erosion and invasion by noxious weeds. Despite attempts to reduce these outbreaks, one outbreak in Nevada that began in 1938 lasted until 1951 (Pfadt, 1994).

Forbs and other rangeland vegetation are also important sage grouse diet items, especially for juveniles. It is likely that in outbreak conditions grasshoppers cause a widespread destruction of forbs. In those situations when grasshopper densities exceed the ability of predators to control population size (including immature sage grouse), the remaining grasshoppers represent a competitive threat to the food base of juvenile sage grouse.

A temporary reduction in the available food for immature sage grouse is only one of a multitude of threats facing sage grouse. Fire is a threat to physically destroy sagebrush. Rangeland fires can be a natural event, a land management tool, a result of human carelessness, or even an attempt to control grasshoppers. Regardless of the cause, fire directly removes sagebrush habitat for sage grouse until the sagebrush has revegetated. Other causes of habitat loss include livestock grazing, human development (e.g., building roads, housing, and power lines), and anything that serves to fragment or degrade sagebrush habitat. Permanent habitat losses are a greater threat to sage grouse than are grasshopper treatments. Reducing grasshopper numbers in a given area should also increase the number of other plants that sage grouse consume in the spring and summer.

In conclusion, grasshopper suppression programs reduce grasshoppers and at least some other insects in the treatment area. Sage grouse, both adults and chicks, are likely to be present in some areas when grasshopper treatments are made, and grasshoppers can be a food item for sage grouse chicks. There is little likelihood that the insecticides APHIS would use to suppress grasshoppers would be toxic to sage grouse, either by direct exposure to the insecticides or indirectly through immature sage grouse eating moribund grasshoppers. Because grasshopper numbers are so high in outbreak years, treatments would not likely reduce the number of grasshoppers below levels present in normal years. Should grasshoppers be unavailable in small, localized areas, sage grouse chicks may consume other insects, which sage grouse chicks probably do in years when grasshopper numbers are unusually low. By suppressing grasshoppers, rangeland vegetation is available for use by other species, including sage grouse, and rangeland areas are less susceptible to invasive plants that may be undesirable for sage grouse habitat. Habitat degradation and removal by fire, grazing, and human development presents longer lasting and more serious threats to sage grouse survival than temporary insect reductions.

2.Biological Control Agents

There are numerous biological control agents being used for the control of invasive weeds. The potential effect of the use of insecticides is of concern, and this will be addressed when site-specific environmental documentation is prepared. One study has been conducted to determine the effects of program insecticides on flea beetles, *Aphthona nigrisutus* and *A. lacertosa.* They are used to control leafy spurge, an invasive weed that is spreading on rangeland and other ecosystems in Western States. Because leafy spurge infestations can occur on rangeland where damaging grasshopper populations may require treatment, *Aphthona* beetles could be exposed to insecticides.

Foster *et al.* (2001) determined the effect of grasshopper suppression programs on flea beetles addressing issues such as how much flea beetle mortality grasshopper program insecticides cause and how long it takes for flea beetles to return to pretreatment levels. In laboratory tests diflubenzuron produced no substantial flea beetle mortality; malathion spray produced moderate (25 to 41 percent) mortality; and carbaryl spray produced an 86 to 96 percent mortality. Field evaluations showed that diflubenzuron resulted in 18 percent mortality at 1-week posttreatment and a full recovery to pretreatment levels 2 weeks after treatment. Carbaryl bait resulted in a 17 percent mortality, carbaryl spray resulted in a 60 to 82 percent mortality, and malathion resulted in a 21 to 44 percent mortality. In these field evaluations at 1 year after treatment, adult *Aphthona* populations in 23 of 24 plots had surpassed pretreatment levels.

3.Threatened and Endangered Species

A concern when considering the environmental effects of insecticides used for grasshopper suppression is that threatened or endangered species may be particularly susceptible either directly or indirectly to the effects of those insecticides. Populations of endangered and threatened species would be at greater risk, because of the small number of individuals, than nonlisted species should the endangered or threatened species have an acute sensitivity to program insecticides. In some cases, the removal of only a few individuals could drastically impact the potential for endangered species to survive, whereas other species are better able to compensate when a small portion of the population is affected. Endangered and threatened species are being examined in a programmatic section 7 consultation in accordance with the ESA (see chapter 6.D.).

In order to assess the impacts of grasshopper suppression programs on endangered aquatic organisms, studies were conducted on two federally listed endangered species: the Colorado pikeminnow and the bonytail chub. Each of these species was exposed to carbaryl and malathion at concentrations that could incidentally be in water within grasshopper treatment areas. These fish were chosen because of experimental availability and the historic occurrence of these species within the Colorado River Basin, which covers a large portion of the affected environment. In addition, the timing of grasshopper suppression programs coincides with the early life stages of these fish. These life stages may be particularly vulnerable to insecticide exposure and are found in shallow, nearshore habitats where insecticides typically do not become as dilute as in mainstream areas.

Beyers and Sikoski (1994) reported that Colorado pikeminnow and bonytail chub were relatively tolerant of carbaryl and malathion. These endangered fish are roughly as sensitive to insecticides as are fathead minnows (Beyers and McEwen, 1996), a fish commonly found throughout North America. In addition to direct toxicity, the effects of carbaryl and malathion on AChE levels in Colorado pikeminnow were measured by Beyers and Sikoski (1994). These studies point out that carbaryl and malathion used for grasshopper suppression pose no greater hazard to endangered or threatened species than to species not listed as endangered or threatened. Indirect effects, such as a reduction in the number of invertebrate food items, would also affect endangered as well as species not endangered.

F. Cumulative Impacts

Cumulative impact, as defined by the Council on Environmental Quality's National Environmental Protection Act implementing regulations (40 CFR § 1508.7) "is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."

This EIS is a programmatic environmental document for APHIS' grasshopper suppression programs that involve the application of insecticides. It is the effects of the use of insecticides that will be added to the past, present, and future actions that have or will occur in the action area when considering cumulative impacts. Grasshopper program treatments could occur on rangeland in any of the 17 Western States. The cumulative impact of the application of pesticides, as well as other actions, in these same areas will be considered on a site-specific basis when a treatment program is proposed for a grasshopper infestation. Application of pesticides could be carried out by Federal land management agencies, State departments of agriculture, local governments, or private groups or individuals. The location and magnitude of a treatment area in which APHIS is involved need to be defined in order to determine the cumulative impacts.

APHIS cooperates in a grasshopper program at the request of Federal land management agencies or State agriculture departments. Once APHIS determines that an area requires treatment, the specifics of that treatment area will be known. At this time that cumulative impacts will be examined in the environmental document that is prepared.

G. Socioeconomic Impactsbah

This section discusses the potential qualitative social and economic impacts that could result from the alternatives analyzed in this EIS:

1. No Action
2. Insecticide Applications at Conventional Rates and Complete Area Coverage, and
3. Reduced Agent Area Treatments (RAATs) in response to a grasshopper infestation.

Under Alternative 1, APHIS would not participate in any grasshopper suppression programs. The socioeconomic impacts of APHIS not taking any action could result from (1) the extent of damage to rangeland and associated resources from grasshopper infestations and (2) the availability of funding by private individuals or other government agencies (Federal, State, and local) to carry out efforts against outbreaks.

Under Alternative 2, APHIS would apply an insecticide treatment at the recommended conventional rate to an entire block of land, completely blanketing an area to minimize grasshopper damage. The socioeconomic impacts of APHIS using insecticide under this alternative would result from (1) the timing and success of chemical methods used, (2) the potential for adverse or beneficial environmental impacts from this alternative to reduce grasshopper populations, (3) the costs of the insecticides and their application, and (4) the resulting economic benefits of using insecticides at conventional rates to treat an entire infestation area.

Under Alternative 3, APHIS would apply an insecticide treatment at a reduced (less than full) rate and in alternating swaths to an infested area to alleviate grasshopper damage. The socioeconomic impacts of APHIS' use of an insecticide at a reduced rate and reduced area coverage would result from (1) the timing and success of the treatment method used, (2) the potential for adverse or beneficial environmental impacts from the reduced rate and reduced area coverage, and (3) the decreased cost and greater economic benefits from using an insecticide at the reduced rate and on less land area. Foster *et al.* (2000) conducted a 3-year study of grasshopper control carrying out treatments at conventional rates and treatments at reduced rates (RAATs approach) using the insecticides carbaryl, diflubenzuron, and malathion. The findings of the study generally concluded that the RAATs strategies "can substantially reduce the amount of pesticide applied per treated acre, the amount of infested area requiring treatment and the overall cost of control actions while demonstrating higher economic returns than conventional treatments. RAATs techniques offer a great potential for managing grasshoppers at an affordable cost while minimally impacting the environment . . . ." (Foster *et al.*, 2000).

1.Livestock Owners

Livestock owners are one of the major social groups that could be economically impacted by grasshopper infestations. Although livestock owners can request APHIS to conduct a grasshopper suppression program through their State department of agriculture, the owners would not make that request unless they were confident the program was cost-effective and economically justified. The chief commercial use of U.S. rangeland is livestock grazing to produce food, fiber, and draft animals (National Research Council (NRC), 1994). Livestock (such as cattle) are raised primarily for meat; however, other products derived from livestock include hides, tallow, insulin, and wool.

a. Alternative 1: No Action—Under the No Action alternative, forage for grazing livestock could be destroyed by a grasshopper infestation. Under this scenario, individual livestock owners may have to lease rangeland in another area and relocate their livestock, find other means to feed them (such as purchasing hay or grain), or sell their livestock early. Individual livestock owners could incur economic losses from personal attempts to control grasshopper damage, leasing alternate grazing rangeland and relocating livestock, or purchasing alternate sources of feed (such as hay) for livestock. However, many outbreaks occur during droughts when other land leases are unavailable and alternate feed is more expensive. Local communities where losses occur would incur an adverse economical impact under this alternative.

b.Alternative 2: Insecticide Applications at Conventional Rates and Complete Area Coverage—Livestock owners comprise the largest social group likely to economically benefit from insecticide treatments used to suppress grasshopper infestations. Range and nonrange grazing are crucial in domestic livestock production. Insecticides used at the conventional control rate and to completely cover an infested area would prevent destruction of most forage for livestock on rangeland and, thus, would be beneficial for the livestock. This treatment method also could economically benefit livestock owners who depend on ample forage for their livestock. However, grasshopper suppression costs for ranchers are estimated to have increased by approximately 30 to 50 percent since the last major outbreak in 1987 (Foster, pers. comm., 2001, and Helbig and Winks, pers. comm., 2001), while the price of cattle is virtually unchanged due to inflation and decreases in Federal subsidies (Lockwood *et al.*, 1999). Large-scale coverage (conventional rates of insecticides used over large land areas) is more costly than it was more than a decade ago. The cost effectiveness of conducting the conventional approach for grasshopper outbreaks would have to be considered on a case-by-case basis in determining the overall economic benefits to livestock owners.

c. Alternative 3: Reduced Agent Area Treatments (RAATs)— Insecticides used at reduced rates and reduced area coverage would suppress grasshopper populations and prevent destruction of most forage for livestock. This alternative would most likely economically benefit livestock owners who depend on ample forage for their livestock. The economics of the RAATs strategy has been studied by both Foster *et al.*, 2000, and Lockwood and Schell, 1997. In summarizing both studies (which used various rates of insecticide below the conventional rates for suppression of rangeland grasshoppers and treated less area), the results concluded that treatment costs, under this alternative, when compared to the costs for conventional treatments for rangeland grasshopper infestations, were reduced as follows: 38 to 62 percent with malathion,

57 to 66 percent with carbaryl, and 56 percent with diflubenzuron. It is apparent from these studies that the RAATs alternative has potential to result in a viable means for suppressing grasshopper infestations below an economic infestation level, could result in sustainable rangeland production, and would reduce economic losses to livestock owners.

2. Crop Growers

Crop growers include another social group that could be economically impacted if rangeland grasshopper infestations occurred near crops. Crops are grown both for human and livestock consumption. Some grasshopper species feed on and destroy crops. If rangeland is dry or vegetation is depleted by grasshoppers, they could move to crops growing near rangeland.

a. Alternative 1: No Action—Under the No Action alternative, crops could be destroyed by grasshoppers if no cooperative control efforts were implemented. Individual growers could incur financial losses from their efforts in attempting to control a grasshopper infestation, their outlay in cultivating the crops, and the loss of crops that they would not be able to harvest and sell. The loss of crops would have an adverse economic effect on local communities.

b. Alternative 2: Insecticide Applications at Conventional Rates and Complete Area Coverage—The use of insecticides under this alternative would suppress a rangeland grasshopper outbreak to some level below an economic infestation, thus providing a level of protection to nearby crops unaffected by an outbreak. Crop growers near rangeland could economically benefit from this alternative in that fewer grasshoppers would remain to move from rangeland to their crops, thus resulting in reduced crop loss.

c. Alternative 3: Reduced Agent Area Treatments (RAATs)— Insecticide used at reduced rate and coverage would suppress a rangeland grasshopper infestation, thus possibly preventing grasshoppers from moving to nearby crops and, consequently, providing crops with some level of protection from an outbreak. Crop growers could economically benefit from this alternative in that a suppressed grasshopper population on rangeland would most likely result in reduced grasshopper movement to crops and reduced crop damage.

3. General Public

Consumer segments of the general public rely on products (such as meat and crops) and byproducts (such as insulin or tallow) from agricultural resources produced on or near rangeland. Consumers could be economically affected by grasshopper infestations.

a. Alternative 1: No Action—In the case of the No Action alternative, some consumer segments of the general public, on a local or regional basis, could incur loss of a sufficient supply of products (e.g., meat and crops) that were not produced because of grasshopper infestations that impact the sources of the products and their byproducts. Demand, which could be placed on other markets for these products and byproducts, could cause increased prices of those items. If livestock owners or crop growers incur the costs for suppressing grasshopper outbreaks, these costs could be passed on to the consumer through higher commodity prices. Consumers of livestock, crops, or byproducts of these commodities could face higher prices. Consumers in the local communities where grasshopper infestations deplete vegetation would incur adverse economic impacts.

b.Alternative 2: Insecticide Applications at Conventional Rates and Complete Area Coverage—Individuals of the general public in regional and local areas could economically benefit from insecticides used against grasshopper infestations at the conventional rate and coverage. The use of insecticides at the full rate and for complete area coverage would reduce grasshopper populations, thereby conserving forage for livestock and possibly preventing grasshoppers from moving to nearby crops that otherwise would be destroyed by them. This alternative would economically benefit consumers of meat, crops, or byproducts of these commodities because markets for these commodities most likely would be minimally affected in that they would not face major decreases in commodities and the costs associated with these commodities most likely would be minimally affected.

c. Alternative 3: Reduced Agent Area Treatments (RAATs)— Individuals of the general public in regional and local areas could economically benefit from insecticides used against grasshopper infestations at a reduced rate and reduced area coverage.

Grasshopper populations on rangeland would be reduced, thus conserving resources for livestock and possibly conserving nearby crops that otherwise could be destroyed by grasshoppers. This alternative could economically benefit consumers of livestock, crops, and byproducts because markets and costs for these commodities would be minimally affected.

4.Beekeepers

Ample and healthy bee populations are economically important to various crop growers and commodity producers. Some beekeepers cultivate bee colonies for the purpose of providing pollination services to crop growers. Producers of various crops and commodities rely on bees for pollination, resulting in increased production. For example, alfalfa seed producers use several bee species in farming practices to increase the yield of alfalfa seeds. Honey producers rely on bees and their hives for honey production. Without the appropriate bee populations in crop and commodity production areas, a decline in pollination would occur, most likely decreasing some crop and commodity production.

a. Alternative 1: No Action—Under the No Action alternative, individuals who rely on bees for their livelihood, such as pollination services, honey producers, and alfalfa seed producers, could incur economic losses. Grasshopper destruction leading to loss of vegetation that bees frequent for food and that they pollinate could adversely impact beekeepers. In addition, the loss of honey bees as a result of precautions not implemented to protect beehives from uncoordinated use of insecticides to protect nearby crops and other agricultural resources from grasshoppers (non-APHIS use of insecticides) also could impact individuals who rely on bees. Some bee species are susceptible to some insecticides and can be protected through moving or protecting cultivated beehive colonies. Individual beekeepers, alfalfa seed producers, or honey producers could be economically impacted under this alternative.

b. Alternative 2: Insecticide Applications at Conventional Rates and Complete Area Coverage—Beekeepers and others who rely on bees for their livelihood could be economically affected more by the use of carbaryl and malathion than by the use of diflubenzuron under this alternative. In areas where bees are required for honey production or alfalfa cultivation, the use of liquid formulations of carbaryl and malathion for grasshopper suppression potentially could impact bee populations, thus impacting individuals who rely on bees for their livelihood. Both carbaryl and malathion are highly toxic to honey bees (Johansen and Mayer, 1990, and Johansen *et al.,* 1983). Diflubenzuron is relatively nontoxic to honey bees (Robinson and Johansen, 1978), especially adults, and thus would not have the potential for adverse impacts that the other two insecticides have.

APHIS will work to protect bees. This will protect both the livelihood of individuals who rely on bees and native bees that may be in a treatment area. Examples of measures that can be implemented to protect bees are notifying beekeepers in advance of any spray programs so that hives can be moved or protected, conducting spray treatments at a time of day when the fewest number of bees would be away from the hive, choosing an insecticide that has a relatively low potential to affect bees, using a bait formulation (when available) instead of a liquid formulation, and strict adherence to label restrictions. Any protective measures that may be implemented to reduce the potential effects of grasshopper suppression activities on bees would best be described in a site-specific environmental document. However, the full coverage application of liquid malathion or carbaryl at conventional rates could temporarily expose some bee populations, especially native bees, and subsequently have some economic impact on producers who depend on bee species for production purposes.

c. Alternative 3: Reduced Agent Area Treatments (RAATs)— Beekeepers and others who rely on bees for their livelihood could be economically affected by insecticides used under the reduced rate and coverage alternative. The use of spray formulations of carbaryl and malathion, even at reduced rates for grasshopper infestations, potentially could impact bee populations that these groups depend upon. However, the use of insecticides at reduced rate and over reduced area of coverage would conserve more wild bees than the use of insecticides at the conventional rate and coverage. As stated in the paragraph above, measures implemented to reduce the effects of grasshopper suppression activities on bees would be best described in a site-specific environmental document. Although the reduced rate and reduced area coverage could impact bee populations resulting in some economic impact on producers, the adverse economic impact will be less than that of the economic impact from the conventional rate and coverage.

5.Recreationists

Public lands, including Federal and State forests, parks, wilderness, and recreational areas are used for a variety of recreational activities, including camping, fishing, and hiking. Some public land may be leased to ranchers for livestock grazing use; however, the socioeconomic impacts to livestock owners is addressed earlier in this section. If infestations occurred near public lands, grasshoppers could impact these lands by feeding on grasses and other vegetation in these areas.

Western rangeland is increasingly used as recreational resources by millions of visitors each year (NRC, 1994). People use rangeland for a variety of recreational activities, including vacations, horseback riding, hiking, picnicking, fishing, hunting, skiing, snowmobiling, and driving off-road vehicles.

a. Alternative 1: No Action—Depending upon the available funding and actions of other government agencies to manage grasshoppers, vegetation on public lands on or near rangeland could be adversely impacted by grasshopper damage if insecticide is needed but not applied before an infestation reaches an economically damaging level. If grasshoppers deplete vegetation on rangeland or public use lands, soil erosion could result and lead to reduction in water quality. This could cause temporary decreases in use of some areas, thereby impacting some recreationists who may then travel to alternate public land locations to carry out their activities. Alternatively, viewing large swarms of grasshoppers may be a source of attraction to some members of the public.

Under this alternative, temporary reduction in or displacement of wildlife species could occur if grasshopper infestations devastate forage and habitat used by game wildlife and other wildlife. Reduction in wildlife habitat and forage could diminish plant and animal diversity, thus resulting in a decrease in wildlife-associated recreation. Less recreational opportunities could result in some economic loss to those who sell licenses, permits, or sporting goods and equipment to recreationists who use public lands for activities, such as hunting, fishing, or bird watching. If lands are denuded from grasshopper infestations, this also could lead to soil erosion and result in sedimentation problems in water, thus adversely affecting game fish. When considering an economic value on consumptive recreational activities, such as hunting or fishing or nonconsumptive recreation, such as bird watching or photography, less recreation means an economic loss (Skold and Kitts, 1996). A loss could be realized for several years until native vegetation and wildlife are able to reestablish, provided they are not displaced.

b. Alternative 2: Insecticide Applications at Conventional Rates and Complete Area Coverage—Recreational users of rangeland or public lands on or near rangeland most likely would not be affected by the use of insecticides at the conventional rate and complete area coverage for grasshopper infestations. Insecticide treatments are short-lived and most likely would impact land uses temporarily. In fact, recreationists would most likely benefit from efforts that will help to protect the natural ecosystems and their resources from grasshopper devastation.

Any protective measures that may be implemented to reduce potential effects of grasshopper suppression activities on recreationists would best be described in a site-specific environmental document. The use of insecticide treatments at conventional rates would most likely reduce loss of natural resources on public land and associated economic losses.

Suppression of economically damaging grasshopper populations using insecticide at the conventional rate and area coverage could help to maintain forage and habitat for wildlife, thus maintaining wildlife populations on lands for recreational purposes. While insecticide use potentially could impact wildlife species, approved treatment options are the result of careful evaluation and selection to determine materials and methods that minimize the threat to the environment (Skold and Kitts, 1996). The environmental monitoring component of past grasshopper control programs (including insecticides used at conventional rates and coverage) has not found adverse effects on wildlife resulting from grasshopper suppression programs (Skold and Kitts, 1996). If grasshopper treatments do not result in wildlife depletion, economic losses from reductions in wildlife-associated recreation most likely would not occur (Skold and Kitts, 1996). Treatments are short-lived and most likely would result in brief closure of areas for recreational purposes and minimal loss of activities to recreationists and minimal economic losses to those who profit from recreation-related sales.

c. Alternative 3: Reduced Agent Area Treatments (RAATs)—The use of insecticide treatments, even at a reduced rate and area coverage, would most likely prevent loss of natural resources on public land and associated economic losses. Insecticide treatments are short-lived and most likely would impact recreational uses briefly. Using less insecticide and treating less land area would be economically advantageous to public land management agencies. Reduced use of insecticide and area coverage results in lower treatment cost than the conventional treatment.

The RAATs alternative most likely would have minimal socioeconomic impact on recreationists who use grasshopper-affected lands for activities such as hunting, fishing, or bird watching or those who sell licenses, permits, or sporting goods to recreationists. While grasshopper infestations can destroy rangeland grasses and other vegetation that wildlife species rely on for forage or habitat, the use of insecticide treatments, even at a reduced rate, would most likely minimize economic damage from grasshoppers to rangeland used for recreation. While insecticides would impact grasshoppers in infested areas, insecticide use according to labels, and at reduced rates and reduced coverage (consistent with scientific and conservation principles) most likely would have minimal, if any, impacts on wildlife populations for recreational purposes. Treatments are short-lived and most likely would result in brief closure of areas for recreational purposes and minimal loss of activities to recreationists and minimal economic losses to those who profit from recreation-related sales.

6.Esthetics of the Natural Environment

Grasshoppers are a food source for some wildlife species and serve as an important role in rangeland nutrient cycling; however, grasshopper infestations can severely affect natural resources that give rangeland its esthetic characteristics. According to Skold and Kitts (1996), rangeland is increasingly recognized as important for its environmental and recreational amenities. Rangeland not only produces tangible products such as forage, wildlife habitat, water, minerals, energy, plant and animal gene pools, recreational opportunities, and some wood products, but also produces intangible products (non-use values), including natural beauty, open space, and the mere existence as a natural ecosystem, that are the result of use (NRC, 1994). Others emphasize biological diversity and the associated potential array of products and services as a distinct intangible product (West, 1993, cited in Skold and Kitts, 1996). Further, rangeland covers vast areas, often contiguously, and thereby possesses the scale necessary for biological diversity of communities, ecosystems, and landscapes (West, 1993, cited in Skold and Kitts, 1996).

a. Alternative 1: No Action—Under the No Action alternative, the use of affected rangeland for esthetics and biological resources could be lost for several years until native vegetation and wildlife are able to reestablish. Loss of native vegetation disturbs natural environments and then provides the opportunity for invasive plant species to outcompete native vegetation. Post-fire revegetation would also be jeopardized. Humans who enjoy these lands for their beauty and wildlife species that use the ecosystems of these lands could be adversely affected by grasshopper destruction. Lost economic benefits (e.g., photography, vacation uses, enjoyment of the natural scenery including wildlife) of enjoying or using these lands for their intangible products could be incurred from uncontrolled grasshopper outbreaks.

b. Alternative 2: Insecticide Applications at Conventional Rates and Complete Area Coverage—Under this alternative, the impact on the use of affected rangeland for esthetics and biological resources could be minor. Treatment activities involving the use of insecticides at conventional rates and complete area coverage are temporary and would most likely impact the use and enjoyment of affected areas for short periods of time. Some loss of economic benefits (e.g., from photography, hiking, and vacation uses) from not being able to enjoy or use these lands for a short duration could occur. Most likely, the long-term benefits of treating these lands for grasshopper infestations outweigh any temporary economic losses.

c. Alternative 3: Reduced Agent Area Treatments (RAATs)—Under this alternative, the socioeconomic impact of grasshopper infested areas, such as rangeland, for esthetics and biological resources could be minor. Treatment activities are temporary and would impact the use and enjoyment of affected areas for a short duration. Minimal loss of economic benefits from not being able to enjoy or use these lands (e.g., from photography, hiking, and vacation uses) could occur for a short duration. Most likely, the long-term economic benefits of using this alternative for grasshopper infestations on these lands outweigh the short-term economic losses. In addition, reduced insecticide use and reduced area coverage under the RAATs alternative would minimally affect the esthetics and biological resources that comprise the natural environment of rangeland.

7. Artificial Surfaces

Some chemicals, including insecticides, can affect artificial surfaces. Malathion could be used as a treatment for grasshopper infestations and is known to damage some paint surfaces (Mabry, 1981, and Mangum, 1981). Artificial surfaces, such as vehicles and signs, painted with metallic acrylic lacquers and baked enamel could be affected by the use of malathion for grasshopper infestations. Some owners of vehicles or signs could be economically impacted from the cosmetic damage malathion could cause. However, certain measures can be taken to avoid damage from malathion on painted surfaces. In areas where this is a concern, malathion surface damage will be addressed in a site-specific environmental document.

a. Alternative 1: No Action—Under the No Action alternative, the extent of insecticide use by others (e.g., State or local agencies or private groups or individuals) is unknown; however, some efforts using insecticides to suppress infestations most likely would occur. Therefore, it is possible that some artificial surfaces could be affected by non-APHIS use of malathion and that vehicle owners and others who own items covered with certain paints could be economically impacted by this alternative. It also has been anecdotally reported that grasshoppers have eaten paint on houses; under this reported scenario, if APHIS takes no action, it is possible that uncontrolled grasshopper infestations could cause economic damage to some painted surfaces.

b. Alternative 2: Insecticide Applications at Conventional Rates and Complete Area Coverage—Under this alternative, some vehicle and sign owners could be economically impacted by the use of malathion for grasshopper infestations. If a vehicle or sign, painted with metallic acrylic lacquer or baked enamel paints, is in or downwind of a treatment site, there is potential for damage to its paint finish from the use of malathion. Damage of this kind is likely to be negligible compared to normal wear on a paint finish from windborne dust and road debris from road travel in rangeland areas. The economic impact to vehicle and sign owners from malathion used under this alternative most likely would be negligible.

It may be necessary to take measures that reduce the potential for malathion to come in contact with certain artificial surfaces. These measures include ensuring that vehicles are not in areas of rangeland treatments, covering susceptible surfaces that are in areas of rangeland treatments, and even choosing a different formulation of program insecticide that will not harm these surfaces. Any protective measures that may be implemented to reduce the potential effects of grasshopper suppression activities on certain artificial surfaces would best be described in a site-specific environmental document in areas where this is a concern.

c. Alternative 3: Reduced Agent Area Treatments (RAATs)—Under the RAATs alternative, the paint on some vehicles and signs could be cosmetically damaged by the use of malathion for grasshopper infestations the same as they could under the conventional treatment alternative. Damage of this kind is likely to be negligible compared to normal wear on a paint finish from windborne dust and road debris from road travel in rangeland areas. With the reduced use of insecticide and area coverage from this alternative, the potential for economic damage to artificial surfaces is decreased. As stated above, for insecticide application at conventional rates and complete coverage, it may be necessary to take measures that reduce the potential for malathion to contact certain artificial surfaces. Any protective measures that may be implemented to reduce the potential effects of grasshopper suppression activities on certain artificial surfaces would best be described in a site-specific environmental document in areas where this is a concern.

VI. Other Environmental Considerations

A. Environmental Justice

Executive Order (E.O.) 12898, Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations, was signed by President Clinton on February 11, 1994 (59 *Federal Register* (FR) 7269). This E.O. requires each Federal agency to make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations. Consistent with this E.O., the Animal and Plant Health Inspection Service (APHIS) will consider the potential for disproportionately high and adverse human health or environmental effects on minority populations and low-income populations for any of its actions related to grasshopper and Mormon cricket suppression programs. (The term “grasshoppers” used in this document refers to both grasshoppers and Mormon crickets, unless differentiation is needed.)

When planning a site-specific action related to grasshopper infestations, APHIS will consider the potential for disproportionately high and adverse human health or environmental impacts of its actions on minority populations and low-income populations in the environmental document for the proposed action. In doing so, APHIS program managers will work closely with representatives of these populations in the locale of planned actions.

In developing site-specific environmental documents, there are nine opportunities in the National Environmental Policy Act (NEPA) process where environmental justice issues can be integrated, as identified and described in detail in the U.S. Department of Agriculture’s (USDA) Departmental Regulation 5600-2, Environmental Justice (USDA, 1997). A few of these opportunities are explained here. The first opportunity would be when the agency defines the action, purpose, need, and area of potential effect. The action proposed by the agency should be clearly defined so that interested parties understand what is being proposed. The agency should identify the purpose of the action and provide justification as to why the action is needed. The area of potential concern should be defined (i.e., physical boundary of area reasonably expected to be affected by the action) so that the agency can include all of the minority and low-income populations within this area in all of its outreach efforts. The second opportunity is during scoping. Once the potentially affected parties are identified, it is important to communicate with and understand the concerns of these groups. Notification should be accomplished by such means as publishing notices in local newspapers and broadcasts on local radio and television stations. This information may need to be translated into the language of minority populations.

Two other opportunities where consideration of minorities and low-income populations can be considered include the analysis of the effects of the alternatives and the development of mitigation to minimize adverse effects. The analysis of impacts should include potential impacts to subsistence consumption and human health as well as the related economic and social effects of the alternatives. When developing mitigation, the concerns and suggestions of minorities and low-income populations should be carefully considered. Once mitigation measures have been developed, there should be followup to ensure they are implemented and are effective.

In past grasshopper programs, the U.S. Department of the Interior's (DOI) Bureau of Land Management (BLM) or Bureau of Indian Affairs (BIA) have notified the appropriate APHIS State Plant Health Director when any new or potentially threatening grasshopper infestation is discovered on BLM lands or tribal lands held in trust and administered by BIA. APHIS has cooperated with BIA when grasshopper programs occur on Native American tribal lands. In future grasshopper programs involving Native American populations, APHIS program managers will work with BIA and contacts established under the APHIS Native American Working Group to communicate information to tribal organizations and representatives when programs have the potential to impact the environment of their communities, lands, or cultural resources.

B. Protection of Children

The increased scientific knowledge about the environmental health risks and safety risks associated with hazardous substance exposures to children and recognition of these issues in Congress and Federal agencies brought about legislation and other requirements to protect the health and safety of children. On April 21, 1997, President Clinton signed E.O. 13045, Protection of Children From Environmental Health Risks and Safety Risks (62 FR 19885). This E.O. requires each Federal agency, consistent with its mission, to identify and assess environmental health risks and safety risks that may disproportionately affect children and to ensure that its policies, programs, activities, and standards address disproportionate risks to children that result from environmental health risks or safety risks. APHIS has developed agency guidance for its programs to follow to ensure the protection of children (USDA, APHIS, 1999).

The human health risk assessment for this environmental impact statement (EIS) analyzed the effects of exposure to children from carbaryl, diflubenzuron, and malathion. Information about the exposure risks to children from these insecticides is discussed in appendix B of this EIS. Based on review of the insecticides and their use in the grasshopper programs, the risk assessment concluded that the likelihood of children being exposed to insecticides is very slight and that no disproportionate adverse effects to children are anticipated over the negligible effects to the general population. Treatments used for grasshopper programs are primarily conducted on open rangelands where children would not be expected to be present during treatment or enter should there be any restricted entry period after treatment. In the preparation of the site-specific environmental documents, an evaluation of the risk of the program exposing children to an insecticide will be conducted. If protection measures are determined to be necessary, they will be implemented.

C. Cultural Resources and Events

The potential for impacts that could occur from program-related activities to cultural and historical sites and artifacts, such as petroglyphs and monuments, and cultural events, such as Native American sun dances, will be considered in site-specific environmental documents, as needed. An example of a concern about a potential program impact to cultural artifacts occurred in 1995. BLM in Wyoming expressed concern about the possibility that a malathion formulation containing oil might have an adverse effect on carbon-dating techniques used for pictographs and petroglyphs. In that particular situation, site-specific protective measures were implemented to mitigate any possible impacts from drift of the insecticide near the petroglyphs.

A program treatment is of short duration and generally would occur once in a program area during the treatment season. Treatments typically do not occur at cultural sites, and drift from a program treatment at such locations is not expected to adversely affect natural surfaces, such as rock formations and carvings. However, to ensure that historical and cultural sites, monuments or buildings, or artifacts of special concern are not adversely affected by program treatments, APHIS will confer with BLM or other appropriate land management agencies at the local level to protect these areas. APHIS also will confer with the appropriate tribal authority and, as needed, with the BIA office at a local level to ensure that the timing and location of a planned program treatment does not coincide or conflict with cultural events or observances, such as sun dances, on tribal lands.

D. Endangered Species Act

Policies and procedures for protecting endangered and threatened species of wildlife and plants were established by the Endangered Species Act (ESA) of 1973, as amended (16 United States Code (U.S.C.) § 1531 *et seq.*). The ESA is designed to ensure the protection of endangered and threatened species and the habitats upon which they depend for survival. Regulations implementing the provisions of the ESA have been issued.

In accordance with section 7 of the ESA, consultation is to be conducted for any action authorized, funded, or carried out by a Federal agency that may affect listed endangered or threatened species or their habitats. APHIS includes proposed species in their consultations. Consultations are conducted with Fish and Wildlife Service (FWS), DOI, for terrestrial species and most aquatic species and with the National Marine Fisheries Service (NMFS), U.S. Department of Commerce, for marine and anadromous species.

The document APHIS prepares to determine the potential impacts of an action on endangered and threatened species and their habitats is a biological assessment (BA). A BA for the grasshopper program (USDA, APHIS, 1987a) was completed in conjunction with the Rangeland Grasshopper Cooperative Management Program, Final Environmental Impact Statement—1987 (USDA, APHIS, 1987b).

APHIS is now preparing the BA that will be used to conduct a new programmatic consultation with FWS and/or NMFS for APHIS' grasshopper suppression programs that may affect listed or proposed endangered or threatened species or their habitats. The BA will evaluate the potential direct and indirect effects of the use of the three insecticides on the endangered and threatened species and their habitats that occur in the 17 Western States. Through the consultation process, protection measures will be developed that, when implemented, will ensure the grasshopper program will not adversely affect endangered or threatened species or their habitats.

E. Monitoring

Monitoring involves the evaluation of various aspects of the grasshopper suppression programs. There are three aspects of the programs that may be monitored. The first is the efficacy of the treatment. APHIS will determine how effective the applications of an insecticide has been in suppressing the grasshopper population within a treatment area.

The second area included in monitoring is safety. This includes ensuring the safety of the program personnel through medical monitoring conducted specifically to determine risks of a hazardous material. Part of such a program could be checking to make sure the proper use of protective equipment is being used, such as long-sleeved or long-legged clothing and respirators, and the implementation of cholinesterase testing to prevent overexposure. (See APHIS Safety and Health Manual (USDA, APHIS, 1998) available online at: www.aphis.usda.gov/mb/aseu/shes/shes-manual.html.)

The third area of monitoring is environmental monitoring (APHIS Directive 5640.1) (USDA, APHIS, 2002). This includes such things as checking to make sure the insecticides are applied in accordance with the labels and sensitive sites and organisms are protected. Should environmental monitoring be conducted, a monitoring plan will describe the where, when, what, and how many samples should be collected. The types of samples collected might include flowing or stationary water, soil, sediment, fish, insects, and vegetation, as well as measuring airborne drift using dye cards. Precision monitoring could be utilized to limit pesticide use to areas where pests actually exist or are reasonably expected and where economically and technically feasible. Samples will be analyzed for insecticide residues, and monitoring reports will be written should monitoring be conducted.

Sensitive sites include habitats of endangered and threatened species, wildlife refuges or preserves, surface water, or other sites of concern to the public. As a result of the consultation conducted in compliance with the ESA, environmental monitoring may be required to ensure adverse impacts to endangered and threatened species or their habitats do not occur. Under NEPA, monitoring would be conducted to ensure compliance with mitigation adopted as part of the decision to conduct a treatment program.

The Grasshopper Integrated Pest Management (IPM) Program has conducted studies on the effects of insecticide treatments on nontarget organisms. This information can be found in the IPM Manual (USDA, APHIS, 1996) which is also available online at: www.sidney.ars.usda.gov/grasshopper/index.htm.

VII. References for Chapters I through VI

Adams, J.S., Knight, R.L., McEwen, L.C., and George, T.L., 1994. Survival and growth of nestling vesper sparrow exposed to experimental food reductions. The Condor 96:739–748.

Bailey, R.G., 1980. Descriptions of the ecoregions of the United States. U.S. Department of Agriculture, Mis. Pub. No. 1391. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1987. Rangeland Grasshopper Cooperative Management Program, Final Environmental Impact Statement—1987. Washington, DC. 221 pp.

Belovsky, G.E., Lockwood, J.A., and Winks, K., 1996. Recognizing and managing potential outbreak conditions. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. IV.8. Washington, DC.

Beyers, D.W., Farmer, M.S., and Sikoski, P.J., 1995. Effects of rangeland aerial application of Sevin-4-Oil® on fish and aquatic invertebrate drift in the Little Missouri River, North Dakota. Archives of Environmental Contamination and Toxicology 28:27–34.

Beyers, D.W., Keefe, T.J., and Carlson, C.A., 1994. Toxicity of carbaryl and malathion to two federally endangered fishes, as estimated by regression and ANOVA. Environmental Toxicology and Chemistry 13:101–107.

Beyers, D.W., and McEwen, L.C., 1996. Grasshopper treatment effects on aquatic communities. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. III.6. Washington, DC.

Beyers, D.W., and Sikoski, P.J., 1994. Acetylcholinesterase inhibition in federally endangered Colorado squawfish exposed to carbaryl and malathion. Environmental Toxicology and Chemistry 13(6):935–939.

Blus, L.J., Staley, C.S., Henny, C.J., Pendleton, G.W., Craig, T.H., Craig, E.H., and Halford, D.K., 1989. Effects of organophosphorus insecticides on sage grouse in southeastern Idaho. Journal of Wildlife Management 53(4):1139–1146.

Booth, G., 1978. Dimilin and the environment. *In* Dimilin chitin inhibitor breakthrough in pest control. Agri-Fieldman and Consultant, Kansas City, KS.

Catangui, M.A., Fuller, B.W., and Walz, A.W., 1996. Impact of Dimilin® on nontarget arthropods and its efficacy against rangeland grasshoppers. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. VII.3. Washington, DC.

Dobroski, C.J., O'Neill, E.J., Donohue, J.M., and Curley, W.H., 1985. Carbaryl: a profile of its behavior in the environment. Roy F. Weston, Inc., West Chester, PA, and V.J. Ciccone and Associates, Inc., Woodbridge, VA.

Drut, M.S., Pyle, W.H., and Crawford, J.A., 1994. Technical Note: diets and food selection of sage grouse chicks in Oregon. Journal of Range Management 47:90–93.

Eisler, R., 2000. Handbook of chemical risk assessment: health hazards to humans, plants, and animals. Lewis Publishers, New York.

Emmett, B.J., and Archer, B.M, 1980. The toxicity of diflubenzuron to honey bee (*Apis melifera* L.) Colonies in apple archards. Plant Pathol. 29:637–183.

EPA—See U.S. Environmental Protection Agency.

Forsyth, D.J., and Westcott, N.D., 1994. Carbofuran residues in grasshoppers and vegetation from aerially sprayed prairie pastures: potential effects on wildlife. Environmental Toxicology and Chemistry, 13(2):299–306.

Foster, R.N., 1996. Baits for controlling rangeland grasshoppers: an overview. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. II.11. Washington, DC.

Foster, R.N., 2001. Handwritten comments from review of preliminary draft environmental impact statement. May 2001.

Foster, R.N., and Onsager, J.A., 1996a. A review of chemical sprays in cooperative rangeland control programs. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. II.4. Washington, DC.

Foster, R.N., and Onsager, J.A. 1996b. Sprays versus baits. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. II.3. Washington, DC.

Foster, R.N., and Reuter, K.C., 1996. Evaluation of rangeland grasshopper controls: a general protocol for efficacy studies of insecticides applied from the air. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. II.2. Washington, DC.

Foster, R.N., Staten, R.T., Reuter, K.C., and Henderson, J.A., 1979. Low rates of Orthene for control of grasshoppers on rangeland. Insecticide and Acaricide Tests 6:137.

Foster, R.N., Reuter, K.C., Walgenbach, D.D., Bohls, R.A., Swain, J.L., and Roland, T.J., 1989. Field comparison for rangeland grasshopper control. Insecticide and Acaricide Tests 14:265–266.

Foster, R.N., Reuter, K.C., Fridley, K., Kurtenback, D., Flakus, R., Bohls, R., Radsick, B., Helbig, J.B., Wagner A., and Jech, L., 2000. Field and economic evaluation of operational scale reduced agent and reduced area treatments (RAATs) for management of grasshoppers in South Dakota rangeland, 1997–1999. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Phoenix, AZ. Available online: http://www.sidney.ars.usda.gov/grasshopper.

Foster, R.N., Reuter, K.C., Winks, K., Reulle, T.E., and Richard, R.D., 2001. Impact of grasshopper treatments on established populations of biological control agents (*Aphthona* spp.) for leafy spurge. Spurgefest II Proceedings. In press.

Fuller, B.W., Catangui, M.A., Boetel, M.A., Foster, R.N., Wang, T., Walgenbach, D.D., and Walz, A.W., 1996. Bran bait or liquid insecticide treatments for managing grasshoppers on croplands adjacent to rangeland or conservation reserve program acreages. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. II.21. Washington, DC.

George, T.L., McEwen, L.C., and Fowler, L.C., 1992. Effects of a carbaryl bait treatment on nontarget wildlife. Environmental Entomology 21:1239–1247.

Hazardous Substances Database, 1990. On-line database. National Library of Medicine, Bethesda, MD.

Helbig, B., and Winks, K., 2001. Personal communications via e-mail to Vicki Wickheiser, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, Riverdale, MD, regarding question about increase in grasshopper control costs for ranchers. Four e-mail messages dated June 14, 2001, and two dated June 18, 2001.

Howe, F.P., Knight, R.L., McEwen, L.C., and George, T.L., 1996. Direct and indirect effects of insecticide applications on growth and survival of nestling passerines. Ecological Applications 6:1314–1324.

Howe, F.P., Knight, R.L., McEwen, L.C., and George, T.L., 2000. Diet switching and food delivery by shrubsteppe passerines in response to an experimental reduction in food. Western North American Naturalist 60:139–154.

HSDB—See Hazardous Substances Database.

Johansen, C.A., and Mayer, D.F., 1990. Pollinator protection: bee and pesticide handbook. Wicwas Press, Cheshire, CT. 212 pp.

Johansen, C.A., Mayer, D.F., Eves, J.D., and Kious, C.W., 1983. Pesticides and bees. Environmental Entomology 12:1513–1518.

Johnson, G.D., and Boyce, M.S., 1990. Feeding trials with insects in the diet of sage grouse chicks. Journal of Wildlife Management 54(1):89–91.

Larsen, J., 2001. Personal communication via telephone to Charles Brown, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, Riverdale, MD.

Larsen, J., and Foster, R.N., 1996. Using Hopper to adapt treatments and costs to needs and resources. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. II.6. Washington, DC.

Lockwood, J.A., and Schell, S.P., 1997. Decreasing economic and environmental costs through reduced area and agent insecticide treatments (RAATs) for the control of rangeland grasshoppers: empirical results and their implications for pest management. Journal of Orthoptera Research 6, November 1997, p. 19–32.

Lockwood, J.A., Latchininshy, A.V., and Sergeev, M.G., 1999. Grasshoppers and grassland health, managing grasshopper outbreaks without risking environmental disaster. Proceedings of the NATO Advanced Research Workshop on Acridogenic and Anthropogenic Hazards to the Grassland Biome, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Lockwood, J.A., Schell, S.P., Foster, R.N., Reuter, C., and Rachadi, T., 2000. Reduced agent-area treatments (RAATs) for management of rangeland grasshoppers: efficacy and economics under operational conditions. International Journal of Pest Management 46(1):29–42.

Lockwood, J.A., Schell, S.P., and Smith, D., 2001. Refining reduced agent and area treatments (RAATs). Proceedings of the National Grasshopper Management Board, January 17–18, Aurora, CO.

Mabry, H.E., 1981. Proposed test schedule for screening pesticides effect on automobile finishes. U.S. Department of Agriculture, internal memorandum.

Mangum, C., 1981. Effect of Staley's bait on automobile paint. U.S. Department of Agriculture, internal memorandum.

Martin, P.A., Johnson, D.L., Forsyth, D.J., and Hill, B.D., 2000. Effects of two grasshopper control insecticides in food resources and reproductive success of two species of grassland songbirds. Environmental Toxicology and Chemistry 19(12):2987–2996.

McEwen, L.C., Althouse, C.M., and Peterson, B.E., 1996a. Direct and indirect effects of grasshopper integrated pest management (GHIPM) chemicals and biologicals on nontarget animal life. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. III.2. Washington, DC.

McEwen, L.C., Petersen, B.E., and Althouse, C.M., 1996b. Bioindicator species for evaluating potential effects of pesticides on threatened and endangered wildlife. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. III.7. Washington, DC.

Narisu, Lockwood, J.A., and Schell, S.P., 1999. A novel mark-capture technique and its application to monitoring the direction and distance of local movements of rangeland grasshoppers (Orthoptera: Acrididae) in context of pest management. Journal of Applied Ecology 36:604–617.

Narisu, Lockwood, J.A., and Schell, S.P., 2000. Rangeland grasshopper movement as a function of wind and topography: implications for pest movement. Journal of Orthoptera Research 9:111–120.

National Research Council, 1994. Rangeland health: new methods to classify, inventory, and monitor rangelands. Committee on Rangeland Classification, Board on Agriculture, National Research Council, National Academy Press, Washington, DC.

Norelius, E.E., and Lockwood, J.A., 1999. The effects of reduced agent-area insecticide treatments for rangeland grasshopper (Orthoptera: Acrididae) control on bird densities. Archives of Environmental Contamination and Toxicology 37:519–528.

NRC—See National Research Council.

Onsager, J.A., Foster, R.N., and Jech, L., 1996. Bait acceptance by different grasshopper species and instars. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. II.12. Washington, DC.

Opdycke, J.C., Miller, R.W., and Menzer, R.E., 1982. Metabolism and fate of diflubenzuron in swine. Journal of Agricultural Food and Chemistry 30:1223–1227.

Pfadt, R.E., 1994. Field guide to common western grasshoppers. Second Edition, Wyoming Agricultural Experiment Station, Bulletin 912, University of Wyoming, Laramie, Wyoming, September 1994. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Washington, DC.

Quinn, M.A., 1996. Impact of control programs on nontarget arthropods. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. III.3. Washington, DC.

Quinn, M.A., Foster, R.N., Cushing, W.J., Hirsch, D.C., Winks, K., and Reuter, K.C., 2000. The North Dakota grasshopper integrated pest management demonstration project, Tech. Bul. No. 1891. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Phoenix, AZ.

Reuter, K.C. and Foster, R.N., 1996. Success with reduced rates of carbaryl, malathion, and acephate sprays. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. II.5. Washington, DC.

Reuter, K.C., Foster, R.N., Jech, L.E., Walgenbach, D.D., Walgenbach, D.R., and Roland, T.J, 1993. Field evaluation of a reduced rate of carbaryl spray on rangeland grasshoppers (Orthoptera: Acrididae). Journal of the Kansas Entomology Society 66(2):231–236.

Robinson, W.S., and Johansen, C.A., 1978. Effects of control chemicals for Douglas-fir Tussock moth *Orgyia pseodotsugata* (McDonnough) on forest pollination (Lepidoptera: Lymantriidae). Melanderia 30:10–56.

Sanderson, R., and Huddleston, E., 1996. Factors affecting application and chemical deposition. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. II.7. Washington, DC.

Schell, S., and Lockwood, J., 1997. Spatial characteristics of rangeland grasshopper population dynamics in Wyoming: implications for pest management. Environmental Entomology 26:1056–1065.

Schroeder, W.J., Sutton, R.A., and Beavers, L.B., 1980. *Diaprepes abbreviatus*: Fate of diflubenzuron and effect on nontarget pest and beneficial species after application to citrus for weevil control. J. Econ. Entomol. 73:637–638.

Skold, M.D., and Kitts, A.W., 1996. Rangeland environmental amenities and grasshopper management programs. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. VII.12. Washington, DC.

Swain, J.L., 1986. Effect of chemical grasshopper controls on non-target arthropods of rangeland in Chaves County, New Mexico. New Mexico State University, Masters Thesis, Las Cruces, New Mexico. December 20, 1996.

Tepedino, V.J., 1996. The reproductive biology of rare rangeland plants and their vulnerability to insecticides. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. III.5. Washington, DC.

Tsuda, T., Aoki, S., Kojima, M., and Harada, H., 1989. Bioconcentration and excretion of diazinon, IBP, malathion, and fenitrothion by willow shiner. Toxicology and Environmental Chemistry 24:185–190.

USDA—See U.S. Department of Agriculture.

U.S. Department of Agriculture, 1997. Departmental Regulation 5600-2, Environmental Justice. December 15, 1997. U.S. Department of Agriculture, Washington, DC.

USDA, APHIS—See U.S. Department of Agriculture, Animal and Plant Health Inspection Service.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1987a. Biological Assessment—Rangeland Grasshopper Cooperative Management Program.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1987b. Rangeland Grasshopper Cooperative Management Program, Final Environmental Impact Statement—1987. U.S. Department of Agriculture, Animal and Plant Health Inspection Service. Washington, DC. 221 pp.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Washington, DC.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1998. Safety and health manual. Safety, Health, and Environmental Staff, Riverdale, MD. February 28, 1998. [online] available: http://www.aphis.usda.gov/mb/aseu/shes/shes-manual.html.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1999. APHIS Directive 5600.3, Evaluating APHIS programs and activities for ensuring protection of children from environmental health risks and safety risks. September 3, 1999. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Riverdale, MD. [online] available: http://www.aphis.usda.gov/library/directives.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 2002. APHIS Directive 5640.1, Environmental monitoring for APHIS pest and disease control and eradication programs. April 19, 2002. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Riverdale, MD.

U.S. Environmental Protection Agency, 1993. Carcinogenicity peer review of carbaryl, 1–napthyl n–methylcarbamate. MRID 421889—01, 02. Memorandum from Ray Landolt, Toxicological Branch II, October 7, 1993, 35 pp.

U.S. Environmental Protection Agency, 2000. Cancer Assessment Document #2. Evaluation of the carcinogenic potential of malathion. Report of the 12 April 2000 meeting and its 29 attachments. April 28, 2000. U.S. Environmental Protection Agency, Washington, DC.

Weidensaul, S., 2001. Sage grouse. Smithsonian Magazine. June 2001.

West, N.E., 1993. Biodiversity of rangelands. Journal of Range Management 46:2-13. *In* Skold, M.D., and Kitts, A.W., 1996. Rangeland environmental amenities and grasshopper management programs. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809, Sec. VII..12. Washington, DC.

Winks, L.K., McEwen, L.C., Foster, R.N., Sampson, M.W., Green, M., and Tepedino, V.J., 1996. Buffer zones: their purpose and significance in grasshopper control programs. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. III.8. Washington, DC.

Appendix A. Background Information on Grasshopper Programs

A. Summary of Grasshopper Programs

U.S. Department of Agriculture (USDA) became involved in grasshopper and Mormon cricket control on Federal rangeland in the 1930s. (The term "grasshoppers" used in this document refers to both grasshoppers and Mormon crickets, unless differentiation is needed.) During that decade, grasshopper infestations covered millions of acres in 17 Western States. Unsuccessful efforts to control grasshopper outbreaks on a local basis proved that grasshoppers needed to be dealt with on a broader basis. In 1934, Congress charged USDA with controlling grasshopper infestations on Federal rangeland. Thereafter, USDA was the lead agency in cooperative efforts among Federal agencies, State agriculture agencies, and private ranchers to control grasshopper outbreaks. USDA's legal authorities to cooperate in those outbreaks came from the Incipient and Emergency Control of Pests Act (1937), the Organic Act of the Department of Agriculture (1944), the Cooperation With State Agencies in the Administration and Enforcement of Certain Laws Act (1962), and the Food Security Act (1985). Most recently, APHIS derives its authority from the Plant Protection Act (PPA).

Efforts against rangeland grasshoppers have evolved over the decades. During the first half of the 20th century, control efforts mostly relied on poison baits. Grasshopper control was mainly conducted to protect crops, but rangeland was treated to save forage and prevent grasshopper movement to nearby cropland. Insecticide sprays sometimes were used but caused concern because they poisoned vegetation, thereby endangering livestock (Parker, 1952).

1940s–1950s

In the late 1940s and early 1950s, several major developments changed grasshopper control. Baits, made from chlorinated hydrocarbon insecticides that acted quickly and had longer residual effects, became available. The formulation of these dry baits made large-scale aerial application much easier. At the same time, sprays of the same compounds were developed and were more effective and less expensive than the bait formulations. Organized large-scale control programs were started for rangeland grasshoppers.

Change in Focus. Prior to 1950, direct financial aid from the government had been available for treatment of cropland and rangeland. In 1950, a State/Federal task force studying grasshopper control recommended that the Federal government drop its involvement with grasshopper control on cropland. The task force reasoned that then-newly developed, relatively inexpensive, effective chemicals—as well as improved application equipment—made it possible for growers to control grasshoppers on higher value cropland than on their own, or with only periodic State assistance. In 1952, State agriculture departments and USDA, through a memorandum of understanding, agreed that cooperative grasshopper control programs would be reserved for rangeland. The federally sponsored cooperative grasshopper control program became focused on rangeland, both private and public.

1960s–1970s

In the early 1960s, the use of ultra-low-volume (ULV) applications (defined as less than 0.5 gallon per acre) of insecticides was refined specifically for grasshopper control in the United States. By 1964, the use of a new organophosphate insecticide, malathion ULV spray, became favored for cooperative rangeland grasshopper control programs.

Problems were realized with the chlorinated hydrocarbon compounds. Their residual features began to accumulate in the food chain, posing a threat to nontarget organisms. In 1962, the use of these compounds was discontinued in cooperative rangeland grasshopper control programs. A formulation of carbaryl became available for use in the cooperative programs in 1962 and was used annually on rangeland through 1967. During that time, control of grasshoppers using carbaryl was not as high or as consistent as with the chlorinated hydrocarbons previously used. There also were compatibility problems between the spray formulations and aerial spraying systems.

The carbaryl formulation was greatly improved by 1972 and replaced the earlier carbaryl formulation used in the cooperative rangeland grasshopper control programs.

1980s and Beyond

By the early 1980s, after several years of research, acephate became available for use in cooperative rangeland grasshopper control programs. By that time, the recommended insecticides for grasshopper control were acephate, carbaryl, and malathion. (Acephate is no longer registered for use on rangeland.)

Until the mid-1980s, the Animal and Plant Health Inspection Service (APHIS) played a lead role in monitoring and controlling destructive grasshopper populations and, thus, managed large-scale cooperative control programs for rangeland grasshoppers. In 1985, heavy grasshopper infestations covered 55 million acres of western rangeland, of which APHIS treated 14 million acres with insecticides. These insecticide treatments were applied aerially to blocks of 10,000 or more acres per treatment (see figure A–1 for acreage treated annually). Although the insecticides used for grasshopper infestations were chosen for their minimal or negligible impact on the environment, the magnitude of the treatments raised concern about the potential effects of insecticides on the environment.

The cost and concerns associated with large-scale applications of insecticides after the major outbreak in the mid-1980s elevated the need for developing new and improved ways to manage grasshoppers. From that need, Congress authorized APHIS to undertake a program for the prevention, suppression, control, or eradication of grasshopper outbreaks. APHIS' goal was to further develop a grasshopper management program to reduce grasshopper outbreaks to noneconomic levels. Thus, the idea for the use of an integrated pest management (IPM) approach developed into the Grasshopper Integrated Pest Management (GHIPM) Program.

In 1987, APHIS completed the Rangeland Grasshopper Cooperative Management Program, Final Environmental Impact Statement—1987 (1987 EIS) in response to the development of an IPM approach for grasshopper control efforts. APHIS' role in the preparation of the EIS was as a lead agency working with three cooperating Federal agencies to prepare and coordinate an environmental analysis of IPM methods for grasshopper control. The 1987 EIS analyzed the potential for environmental impacts from several alternatives that included (1) no action, (2) chemical controls using acephate, carbaryl, both liquid and bait, or malathion in ULV aerial application, and (3) an IPM alternative. APHIS proposed the development of IPM techniques to keep rangeland grasshoppers below economically damaging levels as an alternative to standard grasshopper control programs (USDA, APHIS, 1987).

As stated in the 1987 EIS, the IPM alternative included flexibility in choosing among the then-available insecticide controls (acephate, carbaryl, and malathion) and biological control (*Nosema locustae*, a disease-causing microorganism to a wide range of grasshoppers), and potential future components of an IPM approach that would be tested to determine their effectiveness against grasshopper infestations. The components discussed in the EIS included inflight encapsulation as an alternative delivery method for chemical spray; *Nosema* (after testing at various rates and application times); carbaryl bait; carbaryl/*Nosema* bait mixture; fungal pathogens of grasshoppers and locusts; pathogenic viruses; and cultural/mechanical control methods, such as various techniques of range management (livestock grazing practices and prescribed burning of grasshopper-infested areas) and the physical destruction of grasshopper eggs.

The IPM approach coordinated the use of pest and environmental information along with available pest control methods, including combinations of cultural, biological, and chemical methods. The approach was designed to prevent unacceptable levels of pest damage by the most economical means and with the least possible hazard to people, property, and the environment. The approach was developed to complement initiatives of other agencies, such as range management, water quality, and food safety. The cultural/mechanical component (rangeland management) of the IPM approach involved the cooperative efforts of the U.S. Department of the Interior's (DOI) Bureau of Land Management (BLM), USDA's Forest Service (FS), the Idaho and North Dakota Agricultural Experiment Stations, and livestock producers. The 1987 EIS led to the implementation of an IPM program for grasshopper management, which extended over a 7-year period. An overview of the program and conclusions resulting from the program are provided in section B of this appendix.

Funding and Statutory Changes . During the mid-1980s, APHIS played a lead role in monitoring and controlling grasshopper populations. In 1986, responding to extremely high and destructive grasshopper outbreaks, Congress appropriated $18 million for grasshopper control. Congress also created no-year funding for grasshopper programs by stipulating that approximately $16 million shall remain available until expended. This funding mechanism provided APHIS with immediate access to resources for controlling economically damaging grasshopper populations.

From Fiscal Year (FY) 1987 until FY 1992, Congress appropriated $5 million annually for no-year grasshopper reserve funds. In FY 1990, APHIS received $6.8 million to cooperate with States and individuals to control grasshoppers on lands designated under the Conservation Reserve Program (CRP) and other lands. As high-level damaging grasshopper populations failed to materialize or were kept under control, the no-year grasshopper reserve fund exceeded $16.5 million in 1993.

Beginning in FY 1994, Congressional appropriations for grasshopper programs ceased. The lack of funding has affected long-term management for grasshopper outbreaks; treatments for grasshopper outbreaks since 1994 have utilized mostly the chemical component of IPM. The Office of Management and Budget (OMB) directed APHIS to fund all grasshopper-related activities, surveys, and control from the accumulated no-year reserve. To conserve no-year funds starting in FY 1995, APHIS conducted only crop protection programs, designed to protect high value crops by treating strips of Federal rangeland that border the crops. Crop protection programs provide short-term, immediate control of grasshoppers and do not include long-term rangeland management. The crop protection programs are conducted using a small contingency fund, which must cover other APHIS emergencies. Following the OMB funding directive, APHIS exhausted all grasshopper program resources during FY 1999. In FY 2000, lacking appropriated funding for grasshopper outbreaks, APHIS managed grasshopper outbreaks using contingency funds, as directed by Congress. However, the grasshopper populations were not as high as projected because of weather conditions, and most of the grasshopper control funds were returned to the no-year APHIS contingency fund.

USDA's authority to participate in grasshopper programs now comes from the PPA (7 United States Code (U.S.C.) § 7701 *et seq.*) under section 417 (7 U.S.C. § 7717). This act specifies that APHIS "shall work in conjunction with other Federal, State, and private prevention, control, or suppression efforts to protect rangeland." The act also states that APHIS, "to protect rangeland, shall immediately treat Federal, State, or private lands that are infested with grasshoppers or Mormon crickets at levels of economic infestation, unless the Secretary [USDA] determines that delaying treatment will not cause greater economic damage to adjacent owners of rangeland." APHIS' cost sharing role in grasshopper programs is also reestablished in the act.

Methods for controlling economically damaging grasshopper infestations have evolved over the years and most likely will continue to do so. Improvements in IPM methods for grasshopper control resulting from research and development will lead to the application of more economical methods with less potential for environmental impacts in responding to grasshopper outbreaks, or perhaps ultimately could lead to the prevention of outbreaks.

B. The Grasshopper Integrated Pest Management Program

The GHIPM Program was initiated in 1987 as a 5-year experimental demonstration project. The project's major objectives were (1) the management of grasshopper population densities at two demonstration areas, (2) the evaluation of management techniques, and (3) the development of new rangeland grasshopper management strategies. To achieve those objectives, the program was divided into Field Operations and Field Support Agreements. Field Operations was responsible for the overall program management and the management of grasshopper population densities at two demonstration areas. Field Support Agreements provided evaluation and research for the most effective management of rangeland grasshoppers. The approximate location of the demonstration areas coincided with the DOI BLM Shoshone District in Idaho and the Little Missouri National Grasslands of North Dakota. However, during the program years, most of the grasshopper densities occurred in North Dakota, resulting in most of the research being conducted there.

In furthering the program's overall objectives, additional objectives of the project research in the North Dakota location included (1) comparing the effectiveness of an IPM program for rangeland grasshoppers with the effectiveness of a standard chemical control program on a regional scale, (2) determining the effectiveness of early sampling in detecting incipient grasshopper infestations, (3) quantifying short- and long-term responses of grasshopper populations to treatments, and (4) developing and evaluating new grasshopper suppression techniques that have minimal effects on nontarget species (Quinn *et al*., 2000).

During this program, several available IPM techniques were used to manage grasshopper populations, as described by the preferred alternative grasshopper management tactics outlined in the 1987 EIS. These techniques included (1) providing more detailed surveys of grasshopper populations so that small areas of infestations could be defined; (2) treating small areas of infestations ("hot spots") rather than the minimum 10,000 acres of infestation required under standard grasshopper control programs; and (3) using control methods other than the conventional large-scale aerial applications of insecticidal sprays.

The program included data gathering during the first year, testing of range improvement techniques during a 5-year period after the data gathering, database development and predictive modeling, environmental evaluation, and economic research. The program was designed to provide data that would be used for improving APHIS' ability to determine environmental effects of its program.

The following information summarizes the studies on the treatment components of the GHIPM program from Quinn *et al*., 2000:

***Nosema*-bran Bait Treatments.** A 3-year study of the effect of *Nosema*-bran bait on grasshopper populations suggested that the microbial insecticide has little, if any, effect on grasshoppers either immediately after treatment or in subsequent years.

Carbaryl and Malathion Spray Treatments. Aerial and ground applications of carbaryl and malathion sprays were the most efficacious treatments. Immediate reductions in the total number of grasshoppers at nine blocks treated with these insecticides ranged from 84 to 99 percent.

Carbaryl-bran Bait Studies. Twenty-two evaluation sites were assessed for three aerial application and six ground application experiments to determine the effects of carbaryl-bran bait on grasshoppers. Total populations of grasshoppers were reduced by an average of 44.5 percent at the evaluation sites in the treated areas as compared to a decline of only 3.3 percent at 18 untreated control sites. Ground and aerial applications of the bait had similar short-term effects on total grasshopper populations.

Hot-spot Treatments. The treatment of small areas of grasshopper infestation, or hot spots, with either ground applications of malathion sprays or carbaryl-bran baits was effective in suppressing grasshopper populations. Two applications of carbaryl-bran bait were needed to control grasshoppers in some cases, particularly when densities were very high.

Suppression of Grasshoppers After Treatment. Eighteen field experiments compared grasshopper populations in treated sites and untreated control sites (excluding the *Nosema*-bran bait experiment) 1 year after treatment. Overall, populations at treatment evaluation sites declined by an average of 53.2 percent 1 year after treatment. In contrast, grasshopper densities at untreated control sites increased by an average of 33.6 percent 1 year after treatment. The data suggest that, in general, treatments were effective in suppressing second-year populations of grasshoppers.

Overall Conclusions of the GHIPM Program. The results from the GHIPM Program indicate that incorporating the following more intensive management methods into IPM programs will greatly reduce both the cost of grasshopper control treatments and the amount of insecticide applied to rangeland: (1) increased sampling to delineate more exactly the area of grasshopper infestation, (2) carefully timed treatment applications, and (3) the use of hot-spot treatments with ground applications of either insecticidal sprays or baits (Quinn *et al.*, 2000).

C. Cooperator Roles in Grasshopper Programs

Federal and State land management agencies, State agriculture departments, and private groups or individuals may carry out activities, many of which were identified in the GHIPM Program. Some of these activities are grazing management practices, cultural and mechanical methods, and prescribed burning of rangeland areas. These techniques have been tried with varying success in rangeland management and some have been associated with the prevention, control, or suppression of harmful grasshopper populations on rangeland. A primary goal of grasshopper IPM is to prevent the buildup of populations to damaging levels; however, some periodic outbreaks will occur, and some will require immediate intervention in the form of fast-acting insecticide control (Foster, 1996).

1. Federal Agencies

Rangeland makes up about 770 million acres in the United States, from the wet grasslands of Florida to the desert floor of California (National Research Council (NRC), 1994). Federal agencies own and manage about 43 percent of rangeland in the United States (NRC, 1994). The DOI’s BLM and Bureau of Indian Affairs (BIA) and USDA’s FS manage most of the Federal lands where grasshopper programs have been implemented. BLM manages about 170 million acres, BIA manages about 56 million acres (Helbig, pers. comm., 2001), and FS manages about 40 million acres of rangeland. These agencies develop land management plans that include livestock grazing allotment. APHIS could be requested by any of these Federal agencies to assist with actions to prevent, control, or suppress grasshopper populations. When APHIS cooperates with a Federal agency in these efforts, a division of work is established. Generally, the land management agency (either BLM, BIA, or FS) would prepare an environmental analysis for treatments planned on rangeland under their jurisdiction (USDA, APHIS, 1987).

The PPA (§ 417(d)(1)) authorizes APHIS to pay 100 percent of the cost of grasshopper control on Federal lands to protect rangeland.

2. State and Local Agencies

Less than 7 percent of rangeland is owned by State and local government agencies. State agencies, such as agriculture departments, as well as local governments, could initiate efforts against grasshopper infestations on lands they manage. If a State requests APHIS, through the State agriculture department, to take action against a grasshopper infestation, APHIS would undertake the appropriate environmental process for the action.

In earlier years when funding was available for large-scale programs, an agreement between APHIS and the involved State agency established the division of work and funding. The PPA (§ 417(d)(2)) allows for 50 percent cost-sharing of cooperative actions to control rangeland grasshoppers when State lands are involved.

3. Private Land Owners

More than half of U.S. rangeland is privately owned (NRC, 1994), and these landowners could initiate efforts against grasshopper infestations. They also can request, through the State agriculture department, APHIS' assistance to control grasshopper infestations. The land owner and APHIS could cooperate in actions on private lands, and APHIS would undertake the appropriate environmental process for such actions.

The PPA (§ 417(d)(3)) authorizes APHIS to pay 33.3 percent of the cost of rangeland grasshopper control on private lands.

D. What is Grasshopper Management and How is it Different From Grasshopper Suppression?

Grasshopper management involves a wide variety of actions of which the ultimate goal is to prevent or drastically reduce the adverse impacts of grasshopper outbreaks on rangeland ecosystems and agricultural production. Grasshopper management is primarily the responsibility of rangeland managers whether they are managing Federal, State, tribal, or private lands. It is the land managers who are best able to make decisions and set priorities for actions that will affect the land they steward. APHIS assists in making grasshopper management decisions by providing survey information and technical assistance to the land managers.

Some grasshopper management actions are long-term while other management decisions are implemented in the short-term. Long-term grasshopper management focuses on measures that predict and hopefully prevent devastating outbreaks. Should those long-term measures fail, or should natural forces prevail over human actions, grasshopper outbreaks can develop. It is at this point when short-term measures can be taken to mitigate the effects while sustaining, to the extent possible, those processes that allow long-term management. Short-term grasshopper management actions most often are designed to rapidly reduce the number of grasshoppers within the outbreak area.

A comprehensive grasshopper management program would have several components, including predictive forecasting and population monitoring (survey); informed decisionmaking; and an array of mechanical, biological, and chemical strategies to prevent outbreaks or minimize the damage should outbreaks occur and grasshopper populations threaten rangeland ecosystems and agricultural production.

Despite recent progress by researchers, such as Joern (2000), the ability does not yet exist to accurately predict when and where grasshopper populations will increase to the point that rangeland and cropland resources are at risk (Onsager, 1996). Among the factors that contribute to grasshopper population fluctuations are temperature, precipitation, vegetation, soil qualities, natural enemies, as well as many other parameters—some of which remain to be discovered. The role of temperature in grasshopper egg development was investigated by Fisher *et al.* (1996b). Weather was considered to be a primary factor controlling fluctuations in southern Idaho (Fielding and Brusven, 1996b). The relationships between vegetation and grasshoppers have been described by Lockwood and Lockwood (1991), Joern *et al.* (1996), Joern (1996c and d), and Fielding and Brusven (1996a). However, as more information becomes known, the task of forecasting outbreaks becomes more complex (Joern, 1996a; Belovsky *et al.*, 1996b; Lockwood and Lockwood, 1997).

Land managers may adopt management techniques that, over time, are designed to prevent or lessen the severity of grasshopper outbreaks. The most researched grasshopper management methods involve cultural control and biological control. Each of these methods is considered to be a long-term, preventative approach. The potential to manipulate grasshopper habitat through cultural methods, such as grazing, was discussed by Manske (1996) and Belovsky *et al.* (1996a).

Recently, Onsager (2000) reported that grasshopper outbreaks in the northern Great Plains can be suppressed through grazing management.

The most traditional approaches to grasshopper control have involved physically destroying grasshoppers and grasshopper eggs. For centuries on the African Continent, locust control has been attempted by techniques such as physical harvesting, trampling, or trapping and burying migrating bands in trenches. These techniques have been tried (Lockwood and DeBrey, 1990) on western rangeland but are very labor intensive and unlikely to have any large-scale impact (Panos Institute, 1993). Prescribed burning to physically destroy grasshoppers and remove the vegetation that is their food source is unlikely to be practical on a large scale (USDA, APHIS 1987).

The most reliable way to assess rangeland grasshopper populations is to gather information on species composition, density, and developmental stage by conducting field sampling and surveys. A general description of grasshopper survey methods can be found in Berry *et al.* (1996). It is important to know which grasshopper species are present in any given area because there are about 400 grasshopper species in the Western United States (Pfadt, 1994). A typical rangeland area, over the course of 1 year, has 15 to 40 species (Foster, 1996), but not all grasshopper species cause economic concern. Dysart (1996) ranked grasshopper pest-status and reported that there are about 2 dozen western grasshoppers that can be considered pests to agricultural production.

The total number of grasshoppers in an area is less important than determining the number of pest species per unit area when deciding whether or not control measures are necessary. Information on the stage of development is used to formulate when control measures can be most effectively implemented, because some insecticides are only effective against early life stages of grasshoppers. It is known that grasshopper species have widely varying hatching times (Cushing *et al.*, 1996) and that the same species of grasshopper develops at different times in different geographic locations (Fisher *et al.*, 1996a).

To better understand grasshopper population dynamics, land managers and technical advisors can apply the survey information to data management tools such as maps. Examples of grasshopper maps include a State distribution atlas (Lockwood *et al.*, 1993) and general maps showing grasshopper distribution and density throughout the 17 Western States. (See http://www.aphis.usda.gov/ppq/maps/finalhazard01.jpg for the 2002 Rangeland Grasshopper Hazard Map.) Use of recent technological advances, such as the Global Positioning System (GPS) and geographic information systems (GIS), will increase map accuracy and usefulness (Kemp *et al.*, 1996).

Biological and economic models have been developed to estimate grasshopper population dynamics, forage losses, and changes in cattle feeding regime. These models indicate that grasshoppers cause damage which reduces the weight gain of animals and, because of the reduced overall health of the herd, production (including calving rates) is adversely affected. Grasshopper damage also may change livestock management practices forcing producers to feed hay, sell early, reduce stocking rates, or relocate their herds. Damage caused by grasshoppers goes beyond actual consumption of forage (Pfadt, 1994).

Past experience and survey information have shown that certain rangeland grasshopper species occasionally experience an outbreak and become pests that consume crops and rangeland forage. While most species increase only slightly, some pest grasshopper populations can increase dramatically (Joern and Gaines, 1996).

Biological control is often viewed as a way to reduce pesticide use and has long been considered to be an important component of an IPM approach to control grasshoppers. The development of native biological control agents (predators, parasites, and diseases) was a major focus of the Grasshopper IPM Program. Despite advances in the knowledge on the biological control of grasshoppers reported in the Grasshopper IPM User Handbook (USDA, APHIS, 1996a), no reliable biological control agents have been developed and registered for use by the Environmental Protection Agency. Onsager and Olfert (2000) have reported that there appears to be little potential for augmentation of natural grasshopper parasites or predators, yet those authors also state that there appears to be a great potential for conserving natural enemies.

When land managers are faced with increasing populations of pest grasshopper species, several actions can be taken to reduce, or even eliminate, the damage those populations can cause to rangeland ecosystems. In order to optimize these actions, these strategies must be employed over long time periods. Other actions are more immediate in their effect on grasshoppers. Should all other management techniques fail, insecticides remain the most effective and immediate grasshopper reduction method.

An IPM approach to grasshopper management using intensive surveys and "hot-spot" treatments has been successfully demonstrated in North Dakota by Quinn *et al.* (2000). In order to sustain the limited success of many nonchemical grasshopper control strategies, it would be necessary to apply these management techniques in a uniform fashion. As Joern (1996b) states:

Figure A–1. Grasshopper/Mormon Cricket Treatments (in acres), 1966–2000.

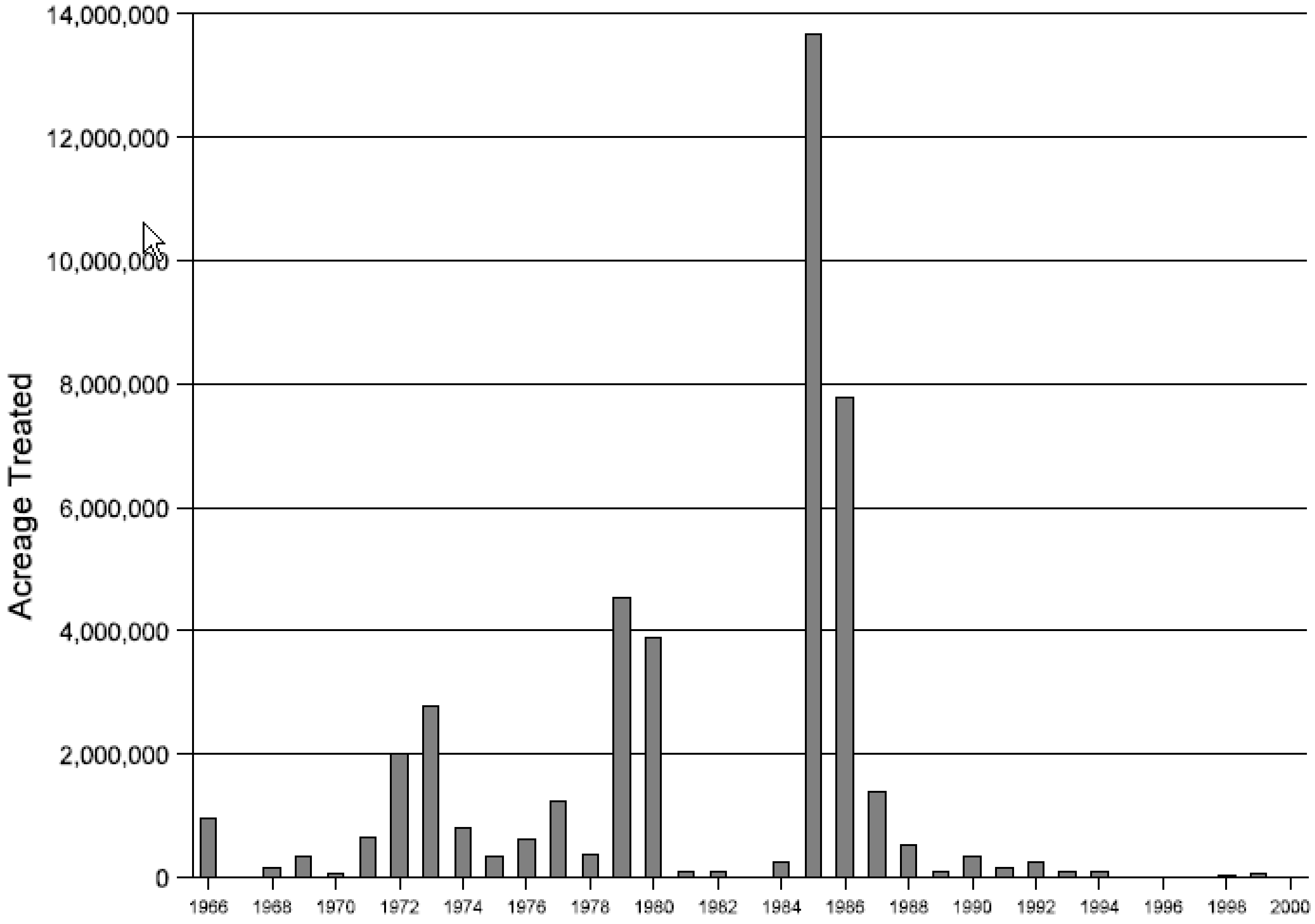

FIGURE 1-1: Background Information on Grasshopper Programs

> "Understanding how grasshopper populations are regulated and how regulation differs between regions of the western rangeland is essential for the development of new control strategies that involve reduced insecticide use, biocontrol agents, and grazing and habitat manipulation."

APHIS is fully aware of IPM strategies—many of which were investigated through the APHIS-funded IPM Program. However, implementing these strategies is not within the purview of APHIS. Rather, these strategies are best implemented and normally studied in the context of rangeland management programs by the respective land managers of Federal, State, private lands. APHIS lacks land management authority.

E. Alternative Approaches to Grasshopper Management

This section describes alternative approaches that have been considered by some to be effective ways to address grasshopper outbreaks and the damage those outbreaks cause. APHIS has not considered these as alternatives to its program.

1. Grasshopper Eradication. This approach would dedicate all efforts toward a planned eradication of grasshopper populations. All efforts would focus on implementing technical assistance, direct control, and methods development to completely eliminate target grasshopper populations in areas where damage has occurred or could occur. Under an eradication approach, all applicable control methods would be utilized.

Eradication is an unsound and impractical consideration both ecologically (Belovsky, 1996) and economically. Grasshoppers play an important role in rangeland ecosystems, as Belovsky *et al.* (1996b) and Belovsky (2000) have indicated. Eradication programs would have major consequences on nontarget species as well. Eradication would require vast Federal, State, and local government funding, as well as large amounts of private funds. Such funding is not likely to occur for grasshopper eradication.

2. Use of Insecticides Not Registered by EPA for Rangeland Use. Some insecticides are used outside of the United States to control grasshoppers and locusts. For example, fipronil has been widely used in Africa and Europe for locust control, and dimethoate and deltamethrin are used in Canada and other countries to control grasshoppers and locusts (Onsager and Olfert, 2000). However, none of those insecticides are currently registered for rangeland use by EPA. Acephate is an insecticide that was analyzed in the 1987 EIS (USDA, APHIS, 1987); however, there is no current EPA registration for the use of this insecticide on rangeland.

3. Damage Compensation—Insurance Program. A Damage Compensation—Insurance Program approach could conceivably replace APHIS program activities with verification and compensation for agricultural losses caused by grasshopper damage. The responsibility for this approach would most likely be an agency other than APHIS. Verification and compensation of grasshopper damage to agricultural crops and rangeland forage could constitute a large undertaking involving complex considerations. A program to make available federally sponsored or subsidized insurance is another mechanism to compensate landowners for grasshopper damage. The insurance system could be similar to Federal crop, hail, or flood insurance programs. The legal and regulatory authority and legislation to implement this alternative does not exist at this time.

4. Land Management Techniques. Land managers and land owners can take several actions in an attempt to prevent or reduce damage from grasshoppers. These preventative actions include cultural, mechanical, and biological methods that must be employed over a long period of time to reach effectiveness. It is the responsibility of the land managers, whether Federal, State, or private, to implement these management techniques. APHIS can assist the land managers with management decisions, but the ultimate responsibility for implementing grasshopper management actions rests with the land managers or land owners.

In some federally managed rangeland, grasshoppers pose a major threat to adjacent, privately owned croplands. Preventing the movement of these grasshoppers from rangeland onto neighboring lands and crops is a consideration land managers can often encounter.

FIGURE 1-2: Road Warning Sign (Photo Credit USDA-APHIS)

Appendix B. Environmental Risk Assessment for Rangeland Grasshopper Suppression Programs—Insecticides

A. Insecticide Risk Assessment Methodology

This section provides information about the basic methodology used to assess risk from the application of insecticides. Application procedures and basic background about the potential human health hazards of the program insecticides are discussed.

1. Human Health Assessment Methods

This section describes the human health effects that are possible from exposure to treatment insecticides that the Animal and Plant Health Inspection Service (APHIS) could apply to suppress grasshoppers on rangeland. The information contained herein summarizes the Human Health Risk Assessment for the APHIS 1996 Rangeland Grasshopper Cooperative Management Program (SERA, 1996) and updates that information. Analyses of the reduced rate applications were completed more recently using the same methodology. The risk assessment of each insecticide (i.e., carbaryl, diflubenzuron, and malathion) consists of:

- an identification of the hazards associated with each agent,
- an assessment of potential human exposure to the agent,
- an assessment of the dose-response relationships of the agent, and
- a characterization of the risks associated with exposure to the agent.

These basic steps, used to prepare the Human Health Risk Assessment (SERA, 1996), are generally recommended by the National Research Council of the National Academy of Sciences in Risk Assessment in the Federal Government, Managing the Process (NRC, 1983) for conducting and organizing risk assessments. In addition, information and analyses have been updated to make the presentation applicable to current program alternatives and application methods.

a. Hazard Identification. Hazard identification is the process of identifying what effects an agent is likely to induce in an exposed population. The hazard of each insecticide was examined by reviewing relevant toxicological and pharmacokinetic data from the published literature, manufacturers' information, specific information from knowledgeable experts in the field, and reliable published information on exposed populations. The assessment was based on an analysis of *in vivo* and *in vitro* data for experimental animals as well as all available human data including epidemiology studies, case reports, and clinical investigations. The hazard of carriers and inert ingredients or possible contaminants in the insecticide formulations was also considered. The relative noncarcinogenic hazard of each treatment method is classified according to the level of severity as defined in table B–1.

In the risk assessment, a review of the toxicological and pharmacokinetics data for each insecticide was presented in the hazard identification and was intended to capture the dose-response and dose-severity relationships. The severity scale used for the risk assessment considered four levels of severity. These levels, defined in table B–1, include the no-observed-effect level (NOEL), no-observed-adverse-effect level (NOAEL), adverse-effect level (AEL), and frank-effect level (FEL). This scale, with minor differences in nomenclature, is used by many government agencies to classify the toxicological effects observed in experimental or epidemiology studies. The analysis involves making judgments about which effects are most relevant to the assessment of human health.

TABLE 1-1: Severity Definitions

Acronym	**Definition**
NOEL	*No-observed-effect level*: No biologically or statistically significant effects attributable to treatment.
NOAEL	*No-observed-adverse-effect level*: Effects that are attributable to treatment but do not appear to impair the organism's ability to function and clearly do not lead to such an impairment.
AEL	*Adverse-effect level*: Signs of toxicity that must be detected by invasive methods, external monitoring devices, or prolonged systematic observations. Symptoms that are not accompanied by grossly observable signs of toxicity.
FEL	*Frank-effect level*: Frank or clinically evident, gross and immediately observable signs of toxicity.

The risk assessment uses common terminology to describe the acute toxicity of individual insecticides. The categories of acute toxicity as defined by the U.S. Environmental Protection Agency (EPA) are provided in table B–2 for description of relative toxicity.

Table B–2. Toxicity Categories

TABLE 1-2: Toxicity Categories

Habitat	Category	Toxicity Criteria

TABLE 1-2: Toxicity Categories

Terrestrial	Severely toxic	LD_{50}[1] _ 50 mg/kg[2]
	Moderately toxic	50 mg/kg $<$ LD_{50} $\leq$ 500 mg/kg
	Slightly toxic	500 mg/kg $<$ LD_{50} $\leq$ 5,000 mg/kg
	Very slightly toxic	5,000 mg/kg $<$ LD_{50} $\leq$ 50,000 mg/kg
Aquatic	Very highly toxic	LC_{50}[3] _ 0.1 mg/L[4]
	Highly toxic	0.1 mg/L $<$ LC_{50} $\leq$ 1.0 mg/L
	Moderately toxic	1.0 mg/L $<$ LC_{50} $\leq$ 10 mg/L
	Slightly toxic	10 mg/L $<$ LC_{50} $\leq$ 100 mg/L
	Practically nontoxic	LC_{50} $>$ 100 mg/L

[1] Oral dose lethal to 50% of test organisms
[2] Milligrams per kilogram
[3] Concentration in water that is lethal to 50% of the test organisms
[4] Milligrams per liter

b. Exposure Assessment. Exposure assessment is the process of estimating the extent to which a population will come in contact with a chemical and the amount of the chemical in various media. Three general steps are involved in assessing population exposures:

- characterizing exposure scenarios,
- estimating levels in environmental media, such as soil, air, water, and vegetation, and
- calculating dose rates.

The exposure scenarios selected were based on how the insecticides are applied and the biological, physical, and toxicological properties of the insecticides. Depending on the insecticide properties and application method, the following were also considered: oral, dermal, inhalation, or combined exposure to the insecticide; exposure of people living in or traversing treated areas and of grasshopper program workers; and acute, subchronic, or chronic durations of exposure.

Three types of exposure scenarios were considered: routine, extreme, and accidental. For routine exposures, assumptions were that the recommended application rates are used, that recommended safety precautions are followed, and that the estimated model parameter values, such as food or water consumption rates and skin surface area, are based on the most likely activities and circumstances. For extreme exposures, assumptions were that recommended procedures and precautions are not followed and that exposure parameters were based on different activities and circumstances that increased the estimate of exposure. For accidental exposures, the assumption was that some form of equipment failure or gross human error occurred. Not all three scenarios were used for each insecticide. The decision to use a particular scenario was based on its applicability to the insecticide being assessed and the need to encompass uncertainties in the exposure.

The Human Health Risk Assessment also considered potential exposed or absorbed doses for individuals of different age groups, that is, adults and young children who may, under certain circumstances, be more vulnerable. Values such as body weights and food consumption rates were taken from standard sources (EPA, OHEA, ORD, 1988).

c.Dose-response Assessment. A dose-response assessment is the process of characterizing the relationship between a known dose of an agent and the incidence of an adverse health effect in an exposed population. It involves estimating the incidence and severity of the effect as a function of dose or exposure to the specific agent. It also takes into account the intensity of the exposure, the age range during exposure, and other variables that might affect the response, such as gender and lifestyle. Extrapolation from high to low dose and from animals to humans is often required (NRC, 1983).

The dose-response assessments used an approach that involved a no-observed-adverse-effect level (NOAEL) and an uncertainty factor. Quantitative toxicological assessments involve deriving an estimate of the dose level that is unlikely to cause adverse health effects in humans. This dose estimate is called the reference dose (RfD). It is derived by taking the experimental no effect (or equivalent) dose associated with the most sensitive effect and applying a series of uncertainty factors to adjust for differences between the experimental design and the conditions for which the RfD is being derived.

d.Risk Characterization. Risk characterization is the process of estimating the incidence of a health effect in a human population under the different conditions of exposure represented in the exposure assessment (NRC, 1983). The risk characterization process detailed by EPA (OERR, 1989) generally was followed. It involved comparing the dose to which humans may be exposed with the RfD. This comparison produces a hazard quotient (HQ) which indicates the level of concern regarding one or more exposure scenarios. Because the RfD represents an exposure that is not expected to cause adverse effects, an HQ of 1 or less would not be a cause for concern.

All relevant routes of exposure (mouth, skin, respiratory tract) were considered in deriving a composite HQ. An HQ greater than 1 (dose exceeds the RfD) was usually associated with a concern about an adverse effect. In some cases, however, uncertainties associated with the hazard identification and exposure assessment required a qualitative judgment to characterize the risk involved.

1. Cumulative Effects

Some exposures, especially to workers, may occur over several days to several months. In addition, and in extremely rare situations, some program activities may be repeated more than once during a year or for several consecutive years under the full coverage control alternative. Such exposures are referred to as cumulative exposures.

Depending on the specific exposure scenario and the nature of the available data, the consequences of cumulative exposures are assessed in a variety of ways. For carcinogenic effects, total dose is assumed to be related directly to risk. Thus, the consequences of two applications at a given rate would be twice those of a single application.

For toxic effects, concern is triggered by exposures that exceed the RfD. Only a limited amount of insecticide would be applied in a given year. Consequently, most exposure scenarios assume maximum application rates. If the RfD is not exceeded by multiple applications at maximum rates, it will not be exceeded by multiple applications at lower rates for comparable intervals. In addition, cumulative effects from exposures to persistent residues of diflubenzuron on vegetation are considered by using RfDs appropriate for chronic or lifetime exposure. If the daily exposure level does not exceed the daily level that would be tolerable for a lifetime, exposure for shorter periods will not present a hazard. It is expected that the program will seldom, if ever, need to retreat any sites within a given season.

2. Connected Actions

Some individuals may be exposed to several treatment types, either in their job as applicators or because more than one type of treatment is used in the areas that they frequent. Such exposures are considered connected actions, that is, one or more actions that an individual may take that could affect the individual's risk to the insecticides used to suppress the grasshopper. In addition, all individuals are exposed to a multitude of chemicals and biological organisms every day in foods, medicines, household products, and other environmental chemicals.

Exposure to multiple chemical or biological agents may lead to interactions that are substantially toxic. For most of the grasshopper insecticides under review, relatively little information pertaining to this issue is available. The information that is available is included in the risk characterization for each insecticide.

3. Information Data Gaps

New data and more complete information are regularly obtained by APHIS about the program insecticides and application methods through independent researchers and monitoring data. This information is then incorporated into risk analyses and applied to environmental assessments prepared for site-specific programs as it is made available.

The insecticides used by APHIS in this program are regulated by EPA. EPA has responsibility for pesticide registration and reregistration under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA, as modified by the Food Quality Protection Act of October 1996). A variety of data, including product and residue chemistry, environmental fate, and human, wildlife, and aquatic toxicity, are required for this process (see 40 Code of Federal Regulations (CFR) 158). EPA uses these data to make regulatory decisions concerning these pesticides.

Data gaps (deficiencies) have been identified by EPA either because registration requirements have changed or because previously submitted data have been ruled inadequate under current registration guidelines. Data gaps are listed in EPA Registration Standards documents for each pesticide. In some cases, data have been submitted since the document and are under review by EPA.

Data considered inadequate for registration purposes, or data not submitted to EPA but available through the literature or other sources, may be adequate to provide indications of potential environmental effects. Because all data needed for a complete evaluation were not available, APHIS used the available data and made extrapolations when necessary.

Nontarget Species Assessment Methods

a. Terrestrial Species. Organisms can be exposed to an insecticide used for grasshopper suppression through several exposure routes. These include dermal contact through direct spray applications as well as contact with contaminated soil and vegetation, ingestion of food and water that contains chemical residues, ingestion from grooming, and inhalation.

The potential risks to nontarget species posed by the grasshopper suppression program were determined quantitatively using a combination of the following: (1) a hazard analysis for each program insecticide, and (2) an exposure assessment based on estimated exposures to species representative of those found in regions where a grasshopper suppression program is likely to occur. Risk to nontarget species was assessed using available toxicological data for representative species. Where toxicological data for representative species were not available, data for suitable surrogate species that exhibit similar biological characteristics were used.

1. Nontarget Species Risk Assessment

A risk assessment, similar to the assessment of risks to human health, was prepared to analyze potential effects of the program insecticides, carbaryl, diflubenzuron, and malathion, on nontarget species.

A multiple-pathway exposure model developed by APHIS (USDA, APHIS, 1993) was used to estimate exposure levels for species through oral (ingestion) and dermal routes. Inhalation is also a route of exposure but to such a slight extent that it was not further considered. The model provides an estimate of total dose to nontarget species and attempts to quantify numerous direct and indirect routes of exposure. In so doing, the model makes assumptions considered a reasonable worst-case scenario. This use of a conservative model increases the likelihood that potential error will be “false positive” rather than “false negative.” (That is, the model is programmed to identify species at great risk, but it is unlikely that any species at risk would not be characterized as such.) Models predict which species may be potentially at risk; they do not predict which species will be definitely at risk from program treatments.

2. Exposure Estimates

Since it is unrealistic to attempt to estimate exposures to suppression insecticides for all species in the grasshopper program area, the analysis presented in this EIS is based on representative species. The species used for analytical purposes herein (see table B–3) are identical to those used in the 1987 EIS (USDA, APHIS, 1987). These species are considered to be adequately representative of bird, mammal, reptile, and amphibian species that inhabit the program area.

Table B–3. Representative Nontarget Terrestrial Species

TABLE 1-3: Representative Nontarget Terrestrial Species

Birds	Mammals	Reptiles and Amphibian
Lark bunting	Grasshopper mouse	Horned lizard
Sage grouse	Blacktail jackrabbit	Eastern yellow-belly racer
Bobwhite quail	Pronghorn antelope	Woodhouse’s toad
American kestrel	Domestic cattle (*Bovine* spp.)	
	Coyote	

Application rates and treatment areas in the grasshopper suppression program can vary considerably. Scenarios are designed to consider the impacts of conventional rates with full coverage and Reduced Agent Area Treatments (RAATs). Full coverage treatments are based upon label rates and complete coverage of infested sites. Although RAATs usually involves lower application rates and alternating swaths (incomplete coverage), it is not possible to analyze all possible combinations that could apply. The scenarios analyze nontarget species that are exposed within the treated swaths. The application rates analyzed for RAATs are considered typical of the rates that would be applied in this suppression program. It is possible for some site-specific programs that reduced rates could be even lower than those analyzed here, plus the reduced rates would be less than the full coverage application rates. Risk assessments will be prepared as part of site-specific program assessments to analyze other application rates and unique conditions at specific sites for suppression programs. Dose estimates were modeled based upon the representative application rates in table B–4.

TABLE 1-4: Representative Application Rates Used to Assess Potential Exposure

Insecticide	**Full Coverage Rate (lb a.i./acre)[1]**	**RAATs (lb a.i./acre)**
Carbaryl	0.50	0.25
Diflubenzuron	0.016	0.012
Malathion	0.62	0.31

[1] pound of active ingredient per acre

Dermal exposures are estimated assuming that the animal is exposed over the entire body surface area at the per acre application rate. Additional exposure is also assumed to occur due to the animal coming in contact with treated vegetation while moving through a treated area. Ingestion is estimated based on a single day's diet of contaminated food items and an estimated daily consumption of contaminated drinking water (USDA, APHIS, 1996b). Diet items and water consumption rates are described in table B–5.

Table B–5. Diet Items and Water Consumption of Nontarget Species [1]

TABLE 1-5: Diet Items and Water Consumption of Nontarget Species[1]

Species	Grass	Insects	Small mammals	Quail	Seeds	Toads	Water
Birds							
◆ Lark bunting		8[2]			1		0.02[3]
◆ Sage grouse		70					0.10
◆ Bobwhite quail		30			4		0.05
◆ American kestrel		52					0.05
Mammals							
◆ Grasshopper mouse		7			2		0.01
◆ Blacktail jackrabbit	300						0.05
◆ Proghorn antelope	2,763						1.00
◆ Domestic cattle (*Bovine* spp.)	11,250						58.00
◆ Coyote		40	320	340			0.80
Reptiles and Amphibian							
◆ Horned lizard		4					0.05
◆ Eastern yellow-belly racer		9				22	0.10
◆ Woodhouse's toad		8					0.10

[1] Estimated daily consumption

[2] Food amount shown in grams

[3] water amount in liters

The dose estimates represent a daily dose of program insecticides for each animal. The dose estimate calculations are based upon the upper limits of exposures in short-grass prairie or rangeland. These calculations overestimate the dose to nontarget terrestrial species that would occur in tall-grass prairies. Studies of differences in potential exposure between short- and tall-grass prairies indicate more than a 50 percent reduction in exposures in the tall grass at the upper limits of exposure (Kenaga, 1973). This difference will be considered in the documentation of any site-specific environmental assessments for programs in tall-grass prairie areas.

Risks to exposed nontarget terrestrial species were calculated quantitatively by comparing the dose estimates to toxicity benchmark values, usually of a surrogate species. The benchmark toxicity value was extrapolated from the laboratory-derived dose determined to be lethal to half of the test organisms (median lethal dose or LD50). Populations of terrestrial species exposed to concentrations of insecticide at less than one-fifth of the LD50 are considered to be at negligible risk of adverse impacts. Populations of terrestrial species exposed to concentrations of insecticide in excess of the LD50 are considered to be at substantial risk of adverse impacts. Moderate risk to exposed populations would be anticipated for exposures between one-fifth of the LD50 and the LD50. In most cases, the dose estimates for the representative species are compared to LD50 values for surrogate species that have been selected based on their biological and metabolic similarities.

3. Field Studies

   One of the goals of the Grasshopper Integrated Pest Management (GHIPM) Program initiated in 1987 was to examine the effects of grasshopper treatments on nontarget organisms and the environment through the use of monitoring and field studies. Field studies were designed to determine not only the direct effects of program treatments, but the indirect impacts as well. For example, insectivorous species can be affected not only by coming in contact with a suppression insecticide or consuming contaminated food items, they also could be subject to indirect impacts due to the loss or alteration of their forage base. In fact, indirect impacts on birds and other insectivorous populations, due to fluctuations in forage base, have been shown to occur during GHIPM field investigations. The information describing the potential consequences for each insecticide is summarized in the sections on Nontarget Species (chapter 5).

b. Aquatic Species. Insecticide labels have protective measures designed to preclude exposures of aquatic organisms to insecticides from program applications. These are intended to prevent program insecticides from entering water bodies under routine applications. These measures do not apply to water bodies such as intermittent streams, vernal pools, cattle tanks, springs, and puddles which are often difficult, if not impossible, to avoid entirely. Insecticide concentrations following direct application to these small bodies of water were calculated. The theoretical insecticide concentrations calculated in this manner provide a conservative (maximized) estimate of exposure should any aquatic species be present. Exposure to aquatic species was equivalent to the potential concentration of insecticide in the organism's habitat, that is, in the ambient water. Potential exposure to representative species in streams, wetlands, and small water bodies was analyzed.

Risks to exposed nontarget aquatic species were calculated quantitatively by comparing the exposure estimates to toxicity benchmark values, usually of a surrogate species. The benchmark toxicity value was extrapolated from the laboratory-derived water concentration determined to be lethal to half of the test organisms (median lethal concentration or LC_{50}). Exposures of aquatic species to concentrations of insecticides less than one-tenth of the LC_{50} are considered to pose negligible risk to the population present. Exposures of aquatic species to concentrations of insecticides in excess of the LC_{50} are considered to pose substantial risk to the population present. Moderate risk to exposed populations would be anticipated for exposures between one-tenth of the LC_{50} and the LC_{50}. In most cases, the exposure estimates for the representative species are compared to LC_{50} values for surrogate species that have been selected based on their biological and metabolic similarities.

3. Potential Hazards and Qualitative Assessment of Insecticide Suppression Agents

a. Carbaryl.

1. Toxic Mode of Action

Carbaryl is a carbamate insecticide. The mode of action of carbamates occurs primarily through acetylcholinesterase (AChE) inhibition (Smith, 1987; Klaassen *et al.*, 1986). The AChE enzyme is responsible for the breakdown (hydrolysis) of acetylcholine, a neurotransmitter that permits the transmission of nerve impulses across the nerve synapse. Carbamates exhibit a reversible pesticide-enzyme binding reaction (carbamylation), which results in gradual decreases in binding as their concentration decreases through metabolism and excretion. Effects of AChE inhibition from carbamates may include weakness, blurred vision, headache, nausea, abdominal cramps, chest discomfort, constriction of pupils, sweating, muscle tremors, and decreased pulse.

2. **Acute and Chronic Toxicity**

Carbaryl is of moderate acute oral toxicity to mammals. The acute LD_{50} is 270 mg/kg for rats (EPA, ECAO, 1984). The acute dermal LD_{50} was reported to exceed 4,000 mg/kg for rats and to exceed 5,000 mg/kg for rabbits (EPA, ECAO, 1984). Low doses can cause skin and eye irritation. The acute inhalation LD_{50} is 721 mg/kg (HSDB, 1987).

Based upon a 1-year dog feeding study, a systemic NOEL of 1.4 mg/kg was determined. The NOAEL for this study was 3.83 mg/kg based upon significant decrease in plasma and brain cholinesterase activity (EPA, OPPTS, 1994). The systemic reference dose (RfD) for carbaryl based upon this study is 0.01 mg/kg/day.

3. Neurotoxicity

Studies of carbaryl neurotoxicity were conducted with hens given subcutaneous injections (Carpenter *et al.*, 1961; Gaines, 1969). Based upon their evaluation of these studies, EPA, OPTS (1980) concluded that carbaryl does not pose any neurotoxic human health hazard. At doses below the current RfD of 0.01 mg/kg/day, no neurological or other adverse systemic effects are anticipated.

4. Immunotoxicity

Some relatively recent studies have suggested that carbaryl may inhibit the normal response of human natural killer cells (Casale *et al.*, 1992) as well as T-cell activity in rats (Casale *et al.*, 1993). Both of these studies involve *in vitro* exposures and cannot be used to quantify any immunologic risk. The toxicology of carbaryl has been studied extensively *in vivo,* and clinical consequences, if any, from any immunologic responses are likely to be encompassed by these study outcomes. The current information suggests that immunotoxic effects from carbaryl could only occur at doses in excess of those resulting in neurological or reproductive effects, so immunotoxic responses are not anticipated to be critical effects from program exposure to carbaryl.

5. Carcinogenicity

Carbaryl has been classified by EPA as a “possible human carcinogen” based on an increased incidence of vascular tumors in a chronic study of male mice exposed at 46 mg/kg/day (1000 parts per million (ppm)) (EPA, 1993). The EPA employs the default linear low dose extrapolation to risk assessments setting the Q_1* value at 1.19×10^{-2} $(\mathrm{mg/kg/day})^{-1}$ based on the mouse vascular tumors. Based upon use of this value in risk assessment of grasshopper programs, the potential for carcinogenicity is less than 1 in a million and much higher applications of carbaryl would be required to pose unacceptable risks of carcinogenicity.

6. Genotoxicity and Mutagenicity

A dominant lethal rat mutation assay was negative at 200 mg/kg (Epstein *et al.*, 1972). Other chromosomal assays have caused some induction of mitotic effects and chromosomal aberrations (EPA, ECAO, 1984). The reproductive effects assessment group of EPA has concluded that data from mutagenicity studies indicate that carbaryl can be classified as a weak mutagen (EPA, OPP, 1984). Carbaryl does not pose any mutagenic risk at program application rates.

7. Reproductive and Developmental Toxicity

A three-generation reproduction study of rats found a NOEL of 200 mg/kg/day (highest dose tested) when carbaryl was administered in the diet (Weil *et al.*, 1973). A teratologic study of beagle dogs determined a NOEL of 3.125 mg/kg/day and the lowest effect level (LEL) of 6.25 mg/kg/day. The defects observed included abdominal fissures, failure of skeletal formation, and the presence of extra toes (Smalley *et al.*, 1968). A set of studies considered dietary and gavage exposure of mice and gavage exposure of rabbits (Murray *et al.*, 1979). The teratogenic NOEL for mice was 1,166 mg/kg/day for dietary exposure and 150 mg/kg/day for gavage (highest doses tested). The maternal NOEL for each exposure to mice, based upon decreased weight gain and cholinesterase inhibition, was determined to be less than 1,166 mg/kg/day for dietary exposure and less than 150 mg/kg for gavage. The teratogenic and maternal NOEL of 150 mg/kg/day was determined for rabbits. Based upon their review of available laboratory studies, EPA, OPP (1984) determined that carbaryl does not constitute a potential human teratogen or reproductive hazard under proper usage.

The interpretation of reproductive risk is equivocal because of the qualitative judgment to derive a provisional RfD. EPA has determined qualitatively that carbaryl poses no teratogenic or reproductive risk to humans. EPA has also concluded that the dog is a poor model to use for teratogenicity testing (EPA, OPTS, 1985). This position was also taken by the National Institute for Occupational Safety and Health (NIOSH) (Cranmer, 1986). In addition, none of the three published reviews (Baron, 1991; Cranmer, 1986; Mount and Oehme, 1981) suggest that carbaryl is a potential human teratogen. However, the basis for this determination is unclear and additional investigation calls these conclusions into question (SERA, 1996). Without further documentation, the position is not sufficiently well supported to allay concern for potential reproductive effects given the number of species in which carbaryl has caused teratogenic effects or death in the embryo or fetus. The provisional RfD determined by EPA for reproductive effects is 0.002 mg/kg/day.

8. Inert Ingredients and Metabolites

The major hydrolytic metabolites of carbaryl are glucaronides andsulfates (Knaak *et al.*, 1965). Most metabolites such as naphthol are considerably less toxic than carbaryl. There has been some concern expressed about the reaction of carbaryl with nitrite under certain circumstances. This may result in the formation of N-nitrosocarbaryl which has been shown to be mutagenic and carcinogenic in laboratory tests (Siebert and Eisenbrand, 1974; Regan *et al.*, 1976).

Although the formulations of carbaryl in some previous programs had oil-based carriers (i.e., Sevin® 4-oil), current programs have converted to water-based carriers (i.e., SEVIN® XLR PLUS). Some information about inert ingredients in these formulations is available, but actual concentrations of inert ingredients was not located. One inert ingredient is propylene glycol or propanediol (antifreeze agent). It degrades readily to carbon dioxide and water in soil and water environments after applications, so actual exposures from the grasshopper suppression program would only be acute. The low exposures to humans would not expect to have human health effects except to those few individuals experiencing allergic contact dermatitis. Program safety procedures preclude applications when unprotected people are present in the treatment area, so any adverse effects from program applications are unlikely. Propylene glycol is practically nontoxic to fish and daphnia (Pillard, 1995). Concentrations of propylene glycol from program application rates would not be anticipated to result in adverse effects to wildlife.

9. Synergistic Effects

The only studies of chemical interactions with carbaryl indicate that toxicity of organophosphates combined with carbaryl is additive not synergistic (Keplinger and Deichmann, 1967; Carpenter *et al.*, 1961).

There may be situations where it is appropriate to use one insecticide or formulation in one part of a treatment area and a different insecticide or formulation in another part of that same treatment area with all applications conducted according to the label directions. For example, ultra-low-volume (ULV) malathion may be used over the majority of a treatment area, but areas of special consideration may be treated with carbaryl bait. Should these situations occur, no area would be treated with more than one insecticide, and there would be no mixing or combination of insecticides.

10. Carbaryl Baits

The nature of the carbaryl baits used to suppress grasshoppers suggests that the bait formulations will be less hazardous than liquid formulations. The carbaryl in the bait formulations is absorbed by the bran or other carrier, and will be less bioavailable, particularly in dermal exposures. The magnitude of this difference, however, cannot be quantified. Although separate exposure assessments are made for workers applying carbaryl baits, these assessments reflect differences in application rates between the baits and the liquid sprays but use the same exposure rate estimates as those used for the liquid formulations. Thus, the quantitative risk assessment for the baits probably overestimate risk; however, the extent of the overestimation cannot be quantified.

Some carbaryl baits include certain additives to preserve the bait (i.e., silica gel) or provide an attractive carrier to the grasshoppers (i.e., n-amyl acetate). The primary concerns with silica gel relate to inhalation of dusts (potential for silicosis). The concentration of silica gel is very low in the formulation. Proper application and adherence to pesticide labels preclude any concern for exposures to silica gel.

N-amyl acetate or "banana oil" can be used as a solvent and flavor additive. It occurs naturally in fruits. N-amyl acetate readily volatilizes to the atmosphere. Biodegradation occurs readily in soil, but there is moderate potential for bioconcentration in aquatic organisms. Although this compound is a primary irritant of skin, eyes, and mucus membranes, the low potential exposures from program applications of carbaryl bait are not expected to result in any adverse effects to humans. Although it may bioconcentrate in aquatic organisms, the toxicity to those species is low relative to the active ingredient (carbaryl) in the formulation.

b.Diflubenzuron.

1. Toxic Mode of Action

Diflubenzuron is classified as an insect growth regulator. Diflubenzuron is toxic to insects through inhibition of chitin synthesis (interference with the formation of the insect's cuticle or shell). The likely mechanism is through blockage of chitin synthetase, the ultimate enzyme in the biosynthesis pathway of chitin (Cohen, 1993). Exposure of insect life stages to diflubenzuron can result in larvicidal and ovicidal effects. The larvae are unable to molt properly due to a lack of chitin in the new cuticle. Exposure of larvae may occur through dermal contact, but the primary route of intoxication is as a stomach poison. Ovicidal effects may occur through direct contact of eggs or through exposure of gravid females by ingestion or dermal routes. The larva develops fully in the egg, but is either unable to hatch or dies soon after hatching due to chitin deficiency in the cuticle. This inhibition of chitin synthesis affects primarily immature insects, but can also affect other arthropods and some fungi. Chitinous algae (diatoms) are not adversely affected by diflubenzuron (Antia *et al.*, 1985). Most other organisms lack chitin and are not affected by exposure to diflubenzuron.

The main sources of uncertainty regarding diflubenzuron risk assessment are estimates of dermal absorption, dose-severity relationships for effects on the blood, and the potential cancer risk. These uncertainties have been addressed by using conservative estimates that are over-protective of human health. The overall quality of the data on diflubenzuron can be categorized as being moderate to good (SERA, 1996).

2. Acute Toxicity

Diflubenzuron has only very slight to slight acute oral toxicity to humans. Acute toxicity through dermal and inhalation routes is also low. There are no reports of skin sensitization from diflubenzuron, and it is only a mild skin and eye irritant.

3. Effects on the Blood/Hematopoietic System

The most sensitive effect from exposure to diflubenzuron is the occurrence of methemoglobinemia, a condition that impairs the ability of the blood to carry oxygen. Hematological effects from exposure to diflubenzuron pose the greatest concern. The formation of substantial amounts of methemoglobin and sulfhemoglobin following exposure to diflubenzuron requires exposures higher than those in the grasshopper suppression program, but some subgroups of the population (i.e., smokers) could be at increased risk due to low viable hemoglobin counts from other nonprogram exposures. Clinical signs of toxicity do not normally begin to occur until the level of methemoglobin exceeds 10 percent in the blood. Levels above 50 percent can be fatal. Studies of chronic exposure to diflubenzuron indicate that hematological effects are the issue of greatest potential concern to humans. The toxic effect resulting from excessive exposure to diflubenzuron is the induction of methemoglobin and sulfhemoglobin. These modified forms of hemoglobin are unable to function normally in the transport of oxygen by blood. The NOEL for the formation of these modified forms of hemoglobin in a 1-year dog-feeding study of diflubenzuron was determined to be 2 mg/kg/day (Duphar, 1985), but actual toxic effects were not noted at this exposure level. Based upon this NOEL, the RfD determined by EPA for hematopoietic effects from diflubenzuron is 0.02 mg/kg/day.

4. Neurotoxicity

Diflubenzuron has been shown to be negative in tests for neurotoxicity (Eisler, 1992; Maas *et al.*, 1981).

5. Carcinogenicity

Diflubenzuron has no reported carcinogenic effects. Neither a 2-year feeding study of rats (Keet, 1984a) nor a 2-year feeding study of mice (Keet, 1984b) found any evidence of carcinogenic effects. Although EPA has not formally classified diflubenzuron, these negative studies indicate that this compound meets the criteria for EPA's group E classification (evidence of noncarcinogenicity).

6. Genotoxicity and Mutagenicity

Diflubenzuron has very limited evidence of mutagenic effects. Diflubenzuron had negative findings in a dominant lethal study of mice (Arnold, 1974), a cell transformation assay, an assay of induction of unscheduled deoxyribonucleic acid (DNA) synthesis (Brusick and Weir, 1977a), transplacental hamster cell transformation assays (Quarles *et al.*, 1980), and Ames mutagenicity assays (Brusick and Weir, 1977b). The only positive finding was in a study of cell transformations that showed weak mutagenic effects in the absence of metabolic activation (Perocco *et al.*, 1993). These mutagenic effects were not observed with metabolic activation. Immunotoxic, mutagenic, and genotoxic effects are only recorded for exposures much higher than would be anticipated in the grasshopper suppression program.

7. Reproductive and Developmental Toxicity

Reproductive and teratogenic effects were not reported in several teratogenicity and multigeneration reproduction studies of mammals conducted by the World Health Organization (1985). Only one study has noted a dose-related decrease in testosterone in chickens (Smalley, 1976), but this study is inconsistent with the full report for the same facility (Kubena, 1982) and with other studies (Cecil *et al.*, 1981).

8. Inert Ingredients and Metabolites

The primary metabolites of diflubenzuron are 4-chlorophenylurea (CPU) and 2,6-difluorobenzoic acid. The acid metabolite is further metabolized by microorganisms in 1 to 2 weeks in soil. The CPU degrades in soil in about 5 weeks. The rapid metabolism and degradation of this metabolite's low concentrations make it highly unlikely that there would be sufficient exposure to cause any of the adverse toxicological effects noted in these studies.

There are various carriers and adjuvants used with diflubenzuron to enhance the pesticide applications. These are primarily synthetic and naturals oils. These inert ingredients may include light and heavy paraffinic oils, polyethylene glycol nonylphenyl ether, alkylaryl polyether-ethanols, vegetable oil surfactants, and canola oil. Food-grade canola oil would not be expected to pose any noteworthy hazards, but some of the heavier oils could affect birds and other wildlife. (Use of formulations that use the paraffinic oils may not be appropriate in some habitats with nesting birds, particularly if endangered or threatened species are present or protection of game birds is an issue.) Although the paraffinic oils have been shown to decrease egg-hatch of nesting birds, these effects have only been observed from spills or exposures higher than are anticipated from program applications. Polyethylene glycol nonylphenyl ether has generally not been of human health concern except for a few cases of allergic contact dermatitis. This should not be an issue if proper program safety precautions are followed. This compound does not persist in natural environments and is unlikely to show bioconcentration of residues.

9. Synergistic Effects

Diflubenzuron is only reported to be synergistic with the defoliant DEF (NLM, 1988). Because the defoliant is unlikely to be applied concurrently with grasshopper suppression treatments, there is minimal risk of synergistic effects. However, diflubenzuron has potential for cumulative or synergistic effects with other (nonpesticidal) compounds known to bind hemoglobin. For example, exposure to cigarette smoke and carbon monoxide from incomplete combustion can result in binding of hemoglobin. Exposure to diflubenzuron after these exposures can result in additional binding of hemoglobin and the greater risk associated with less oxygen transport by blood.

Malathion.

1. Toxic Mode of Action

Malathion is an organophosphate insecticide whose mode of toxic action is primarily through acetylcholinesterase (AChE) inhibition (Smith, 1987; Klaassen *et al.*, 1986). At low doses, the symptoms of AChE inhibition in humans include effects such as nausea, sweating, dizziness, and muscular weakness. The effects of higher doses of malathion may include irregular heartbeat, elevated blood pressure, cramps, convulsions, and respiratory failure. However, AChE inhibition can be measured in blood at levels much below that which causes symptoms; therefore, adverse health effects do not necessarily result from all levels of AChE inhibition.

Complete toxicity data are unavailable for individual formulations of malathion. In these cases, regulatory values established by EPA and other agencies have been based on the toxicity characteristics of the technical grade (or pure) chemical or other similar formulations of the pesticide. It is this information that has been reviewed and incorporated into this hazard assessment of malathion.

2. Acute and Chronic Toxicity

The acute oral toxicity of malathion is slight to humans (DHHS, NIOSH, OSHA, 1978). Malathion's acute toxicity by the dermal route is minimal, and malathion is considered one of the least dermally toxic of the organophosphorus insecticides (EPA, OPP, 1989b). Malathion is a very slight dermal irritant and a slight eye irritant (EPA, OPP, 1989b).

Testing also indicates relatively low chronic toxicity. The human RfD was established at 0.02 (mg/kg/day) based upon no AChE inhibition (NOEL) at a higher concentration (2.3 mg/kg/day) and applying an uncertainty factor of 100 to that study of human exposure (Moeller and Rider, 1962; EPA, OPP, 1989b).

3. Neurotoxicity

Neurotoxicity is any toxic effect on any aspect of the central or peripheral nervous system. Such changes can be expressed as functional changes (such as behavioral or neurological abnormalities) or as neurochemical, biochemical, physiological, or morphological alterations. Malathion poses a neurotoxic risk only as a consequence of inhibition of AChE. Studies of acute delayed neurotoxicity or structural neuropathy have been negative (EPA, OPP, 1989a). The quantitative risk assessment of AChE inhibition analyzes only the neurotoxic risks associated with AChE inhibition.

4. Immunotoxicity

Immunotoxicity is any toxic effect mediated by the immune system, such as dermal sensitivity, or any toxic effect that impairs the functioning of the immune system. Malathion may be immunosuppressive and immunopathologic *in vitro* at high concentrations (Desi *et al.*, 1978; Thomas and House, 1989). More recent studies have shown that malathion may alter immune functions in mammals *in vivo* (Rodgers and Ellefson, 1992). The implications of this information with respect to human immune system toxicity remain unclear.

5. Genotoxicity and Mutagenicity

Genotoxicity is a specific adverse effect on the genome (the complement of genes contained in the haploid set of chromosomes) of living cells that, upon the duplication of the affected cells, can be expressed as a mutagenic or a carcinogenic event because of specific alteration of the molecular structure of the genome. It results from a reaction with DNA that can be measured either biochemically or, in short-term tests, with end points that reflect on DNA damage. DNA is the genetic material of a cell.

Mutagenicity is an adverse effect that produces a heritable change in the genetic information stored in the DNA of living cells. There is some evidence that malathion may pose a genetic hazard at high concentrations based upon some *in vivo* and *in vitro* cytogenetic studies where chromosomal aberrations and reactivity with DNA had a weak association to exposure, but the majority of studies do not support a finding of any genetic hazard from malathion exposure (WHO, IARC, 1983; Griffin and Hill, 1978). The potential risk of clastogenic injury increases if the high doses of malathion formulation contain sufficient impurities. The premium grade malathion is of high purity, and exposures resulting from applications are relatively low compared to the thresholds for genotoxicity. Based upon this, there should be no unacceptable risks of genotoxicity or mutagenicity from program applications of malathion.

6. Carcinogenicity

Carcinogenicity is an adverse effect that causes the conversion of normal cells to neoplastic cells and the further development of neoplastic cells into a tumor (neoplasm). A neoplasm is an altered, relatively autonomous growth of tissue composed of abnormal (neoplastic) cells, the growth of which is more rapid than, and not coordinated with, the growth of other tissues. EPA has classified malathion as having "suggestive evidence of carcinogenicity, but not sufficient to assess human carcinogenic potential." This indicates that any carcinogenic potential of malathion cannot be quantified based upon EPA's weight of evidence determination used in this classification.

Guidelines for the expression of potential carcinogenic hazard are being revised by EPA to accommodate the increased understanding of the nature and causation of cancer. Historically, it was widely believed that cancer was caused by a limited number of discrete chemical, physical, or biological agents. It was assumed that this limited number of carcinogenic agents could be readily determined and regulated to eliminate cancer risks. This assumption that only certain compounds cause cancer led to a nonthreshold approach to regulation. The finding of a positive result for cancer in an acceptable animal study, human study, or through epidemiological study presumed the agent to be a carcinogen. The finding of a negative result for cancer in these studies was interpreted as indicative that the agent was either not carcinogenic or the data were inadequate to classify the carcinogenic potential. This widespread assumption that potential initiation and promotion of cancer related to specific agents led EPA to issue guidelines on September 24, 1986 (51 *Federal Register* (FR) 33992–34054), to rank those agents according to carcinogenic hazard potential based upon the weight of evidence. Under these guidelines, chemical and other agents were identified as human carcinogens (Group A), probable human carcinogens (Group B), possible human carcinogens (Group C), not classifiable (Group D), or having evidence of noncarcinogenicity (Group E). Although this classification based upon positive or negative results could be used readily for regulation of agents, it is widely recognized by the scientific community that this approach does not adequately use the advances in knowledge of carcinogenesis and risk assessment.

Today, scientists recognize that cancer is a highly complex, multifactorial disease caused, in part, by endogenous (intrinsic) metabolic or other imbalances associated with age or genetic makeup and, in part, by a wide variety of exogenous (external) factors including diet, lifestyle, exposure to ionizing radiation, and exposure to chemicals of natural or man-made origin. It is now known that initiation of cancer may be caused by cell damage resulting from excess exposure to one or multiple agents and that promotion of genetic errors from the cell damage may also be caused by conditions or agents other than those causing the initial cell damage. It is also widely recognized that there is a threshold for all agents to cause carcinogenicity, and the threshold for a given agent may be affected by the endogenous and exogenous factors mentioned above. This realization has led to changes in carcinogen regulation by some international organizations. Likewise, EPA has prepared new categories to address these issues and other advances in the understanding of carcinogenesis. Their narrative descriptors of carcinogenic risk for potential agents in the 1999 proposed guidelines on June 25, 1996 (61 FR 32799–32801) include carcinogenic to humans, suggestive evidence of carcinogenicity but not sufficient to assess human carcinogenic potential, not likely to be carcinogenic to humans, and data are inadequate for an assessment of human carcinogenic potential. Classification of pesticides into a given category is based upon a weight of evidence approach. These new rankings recognize the potential risk of all agents to cause cancer, even if the actual occurrence is “not likely.”

Uses of most insecticides in APHIS' grasshopper suppression programs are expected to be classified by EPA under the new guidelines as “not likely to be carcinogenic to humans” or data are inadequate for an assessment of human carcinogenic potential based upon the weight of evidence. As part of EPA’s Pesticide Reregistration process (for all pesticides registered prior to 1984) and in compliance with the Food Quality Protection Act of 1996, it is expected that carcinogenic potential will be reclassified for all chemicals. Depending upon the registration review status, references to carcinogenic potential of pesticides in this document use classifications according to either the 1985 classification or the 1999 proposed guidelines. Based upon existing data including recent reviews, there are no unacceptable risks of carcinogenicity anticipated for this program.

7. Ocular (Eye) Toxicity

Information on the ocular effects of malathion have been based mostly on anecdotal data. Reports from Japan in the early 1970s associated eye disease in a number of people with agricultural use of malathion (as well as other pesticides) at extremely high concentrations (the syndrome was called Saku Disease after the region in which it occurred). A review of the data by the Malathion Public Health Effects Advisory Committee, a committee formed by the California Department of Health Services (CDHS) in 1990, found fundamental flaws in the original study and subsequent papers and determined that the reported association between malathion and eye disease had not been established (CDHS, 1991).

However, because data from various studies have demonstrated adverse ocular effects from other organophosphates, EPA has issued a data call-in to the registrant for ocular toxicity testing of malathion. The study is required to confirm or deny the potential for malathion to cause adverse eye effects.

8. Reproductive and Developmental Toxicity

Reproductive toxicity is any adverse effect that produces changes in the capacity to produce viable offspring, for example, by affecting the reproductive organ systems or hormonal functioning. Developmental toxicity is any adverse effect in the parent or the offspring that produces changes in fetal or neonatal growth and development, including physiological, morphological, biochemical, or behavioral changes.

Reproductive and teratology studies are outstanding data requirements of EPA for reregistration of malathion (EPA, OPTS, 1990). The lowest NOEL determined for these effects from malathion exposure was a developmental NOEL of 25 mg/kg/day in rabbits (EPA, OPP, 1989a). This exposure level is considerably higher than the NOEL for AChE inhibition (0.23 mg/kg/day) analyzed in the quantitative risk assessment, so these effects would not be anticipated unless other effects were noted first.

There are no unacceptable risks of reproductive or developmental toxicity to workers or to the general public from any exposure scenario.

9. Inert ingredients and Metabolites

The main impurities of concern in malathion formulations are isomalathion (95 times as toxic as malathion) and malaoxon (68 times as toxic as malathion) (CDHS, 1991; Aldridge *et al.*, 1979; Ryan and Fukuto, 1985; Fukuto, 1983). Isomalathion formation results from improper storage or handling of malathion formulations. Malaoxon is formed from malathion's oxidation, which has been reported to occur in air and from volatilization from the bait droplets on various surfaces. A recent pilot study by the CDHS (Brown *et al.*, 1991; Brown *et al.*, 1993) found that, following aerial malathion applications, malaoxon and other transformation products were detectable in air and on various test surfaces for hours and, in some cases, days after the treatment. Levels of malaoxon increased, presumably via oxidation of malathion on some test surfaces for the 9 days of the study. However, another study (Ross *et al.*, 1990) indicated that the dermal uptake of a pesticide can be highly dependent on the amount that is bioavailable (i.e., the amount of residue that can be dislodged or assimilated) and that the amount can decrease substantially over a 12-hour period. The variances in test data and the absence of any scientific accord over the interpretation of the results point to the need for further studies in this area. There is some petroleum-based oil that occurs in some ULV formulations. The exposure of birds' eggs and humans to this oil has been shown to have no adverse effects at program application rates.

10. Synergistic Effects

Although the toxicity of malathion may be potentiated by some other organophosphates and carbamates (Knaak and O'Brien, 1960; Cohen and Murphy, 1970), it is impossible to predict multiple exposures and synergism from applications not related to this program. Dichlorvos and naled were not found to be synergistic with malathion, but only additive (Cohen and Ehrich, 1976). Diazinon is synergistic with malathion (Keplinger and Deichmann, 1967). In addition, organophosphate insecticides are routinely used in various public health applications such as mosquito control programs. There is some potential for synergistic effects resulting from the combination of malathion and inadvertent simultaneous pesticide application by the public; however, public notification about program treatments helps to minimize this risk.

B. Insecticide Applications at Conventional Rates and Complete Area Coverage

This section describes the potential consequences of the full coverage suppression alternative to affect human health, environmental quality, and nontarget species. The consequences are based upon the maximum field rates of application of each insecticide anticipated for this program as described in table B–4. The risks to human health are assessed quantitatively and characterized by potential health outcome for each of the program insecticides. The risks to environmental quality of the physical environment are presented qualitatively. Quantitative information about environmental fate and modeling data are provided in the chemical background paper on environmental fate and transport modeling (USDA, APHIS, 1996b; see appendix C). The risks to nontarget species include a review of the hazards of each insecticide, a quantitative presentation of potential risks, and review of the findings of field studies.

1. Efficacy of Insecticide Controls

Grasshoppers and crickets comprise one of the major insect groups capable of a rapid response to habitat disturbance, due in a large part to their high fertility rate, prolific reproduction, and short generation time (Uvarov, 1966). Numerous reports have documented the capacity of grasshopper population "explosions" to cause significant destruction of vegetation (Uvarov, 1977). This aggressive colonization of uninfested (treated) sites by economically damaging grasshoppers assures that no limited program can eradicate these species with control agents alone. Insecticide treatments have only suppressed native grasshopper and cricket populations briefly. Although there are temporary decreases in grasshopper populations on treated sites, studies indicate that there is rapid recolonization of the disturbed (treated) sites by populations from untreated sites nearby (Parmenter *et al.*, 1991). This rapid recolonization also assures that long-term suppression of grasshopper populations at given locations is highly unlikely. The only suggested extinction of a pest grasshopper in North America (Rocky Mountain grasshopper) has been attributed to agricultural destruction of the insect's habitat and the introduction of nonnative species (Lockwood and DeBrey, 1990).

The toxic properties of insecticides remain active against grasshoppers until the active ingredient in the formulated compound degrades. Populations of grasshoppers recover from the toxic effects of these insecticides as the frequency of contact decreases. This generally coincides with decreasing concentrations of the insecticides on the treated site. The selective nature of the insecticide may favor survival of certain species of grasshoppers over other species. This may result in higher populations of resistant species on certain treated sites, but this selective advantage would only last as long as the toxicant remained active. The selective nature of the insecticides determines which grasshopper populations would be affected, and the selection pressure would determine the extent of population reduction and the length of suppression. Although some data about toxicity are available for these agents, not all program insecticides have been tested for efficacy against all species of economically damaging grasshoppers. It is, however, clear from the completed research that application of these chemical agents would not result in any permanent changes in the ecological relationships that exist between grasshopper species and other components of the rangeland.

2. Human Health

Included in this risk assessment are the potential effects on grasshopper program workers, the general public, and groups of people who may be at special or increased risk. The potential high risk group includes those who are sensitive to specific chemicals, those with multiple chemical sensitivity, those whose health status may make them more susceptible to effects, and those whose lifestyles may make them more prone to come into contact with the chemicals in the treatment areas.

a. Carbaryl. For the general public, none of the exposures exceed the systemic RfD of 0.01 mg/kg/day. Therefore, the estimated exposures that might occur to the public as a result of involvement in an event similar to the scenarios that were analyzed are not cause for concern.

For workers, on the other hand, all of the estimated exposure levels associated with the normal application of carbaryl sprays exceeds the RfD, with estimated doses resulting in HQs of 2 to 4000. This variability probably reflects differences in individual work habits (SERA, 1993). Workers who handle insecticides with proper care can reduce their exposure substantially. Conversely, poor work habits can increase exposure substantially.

At the lower and mid-ranges of exposure, it is unlikely that there would be overt signs of toxicity, even when the RfD is exceeded considerably (i.e., by factors of about 40 to 400). There are experimental studies in humans suggesting that doses of up to about 3 mg/kg (Gold *et al.*, 1982) will not be associated with signs of toxicity in humans.

At the high range of occupational exposure (i.e., about 36 mg/kg), the nature of potential adverse effects is less clear. Carbaryl has been used for many years, and reports of occupational poisoning, either published or anecdotal, were not encountered. On the other hand, no rigorous worker monitoring or epidemiology studies were found on the aerial application of carbaryl. Consequently, a precise characterization of risk is not possible. However, with good personal work practices, carbaryl may be handled safely. Poor work practices may present risks, but the likelihood of observing adverse effects cannot be well characterized. If such effects are observed, they would be those that are characteristic of AChE inhibitors.

Under most exposure scenarios, members of the general public do not appear to be at any risk to the potential reproductive effects of carbaryl, even using relatively conservative assumptions. The one exception may be exposure from the consumption of contaminated vegetation immediately after aerial applications. In this case, the upper range of projected exposure exceeds the provisional RfD for reproductive effects by a factor of 1.5. Although the exposure levels would diminish rapidly as the carbaryl degrades and disperses, the initial residues could plausibly result in dose levels that exceed the provisional RfD. The specific instance where this may cause concern would be for individuals either with gardens in the vicinity of a spray application, or for individuals, particularly Native Americans, who might forage for food, herbs, or medicinal plants immediately after an application. However, the provisional RfD is designed to protect against adverse effects from chronic exposure at that level. The rapid degradation and infrequent applications in the grasshopper suppression program would not be routinely (or chronically) expected to result in exposures in excess of the provisional RfD. The only exposures from program applications would be acute and not expected to cause adverse reproductive effects with the short duration of potential exposure.

For workers, under the least conservative exposure assumptions, levels of plausible exposure are far greater than the provisional RfD for reproductive effects. For the application of carbaryl sprays, the central estimate of the absorbed dose, 3.6 mg/kg/day, is in the range of doses associated with fetotoxicity in dogs and the upper range of the estimated absorbed dose, 36 mg/kg/day, is above the level associated with teratogenic effects in dogs.

This does not necessarily mean that teratogenic effects or reproductive impairment in humans can be predicted from or attributed to carbaryl exposure. Nonetheless, standard criteria and procedures are used for estimating the provisional RfD. Plausible levels of exposure are far above this provisional RfD.

1. Cumulative Effects

For the general public, repeated exposure to carbaryl is a relatively minor concern. The risk characterization is based on exposure that is likely to be transient and the RfD is intended to be protective over very prolonged periods of exposure. Applications for suppression of grasshoppers are unlikely to be repeated within a given season and outbreaks are not an annual occurrence, so exposures would be infrequent and effects would only be acute. Because the RfD for neurotoxic effects is not exceeded even in short-term accidental exposures such as direct sprays, it is unlikely that repeated brief exposure, even over several seasons, would lead to neurotoxic effects. Based on estimated exposures from contaminated vegetation, the provisional RfD for reproductive effects is exceeded slightly.

As with the general public, effects that would be associated with repeated exposure to carbaryl are encompassed by the risk assessment. Workers will be exposed to higher doses of carbaryl than the general public will be, and the exposure may occur over a relatively prolonged period of time—during the work week of a treatment season or several treatment seasons. The reproductive studies on dogs differ from the reproductive studies on most other species in that the dose schedule spans the period from conception to birth. While it is not clear that this difference contributes to the apparently higher sensitivity of dogs to the reproductive effects of carbaryl, the use of the data on dogs in characterizing potential risks to workers does encompass an exposure schedule that is similar to that for workers who could be exposed.

2. Connected Actions

Baron (1991) has reviewed the literature regarding the interaction of carbaryl with other compounds. Very little information is available on the interaction of carbaryl with other agents used to control the grasshopper. In a study of acute lethal toxicity, no interactions were apparent with the co-administration of malathion and carbaryl to rats (Carpenter *et al.*, 1961). In a pharmacokinetic study, however, co-administration of these compounds to rats altered the action of both insecticides so that the elimination of carbaryl from gastrointestinal tissues was delayed (Lechner and Abdel-Rahman, 1986).

Many toxicological interactions occur as a result of changes in the metabolism of the toxicant because of the induction or inhibition of an enzyme system, microsomal mixed function oxidase (MFO), which is involved in the metabolism of many different chemicals. Some studies have found that pretreatment with an agent that induced MFO decreased the acute toxicity of carbaryl to mice while pretreatment with an inhibitor of MFO enhanced the toxicity (Neskovic *et al.*, 1978). As with many compounds, carbaryl appears to induce enzymes that are involved in its metabolism.

These data suggest that some compounds, including carbaryl itself, may increase the rate of metabolism of carbaryl and that this may reduce the acute toxicity of the compound. Conversely, other compounds that inhibit carbaryl metabolism may increase the acute toxicity of this compound. It is unclear how or if changes in metabolism would affect the reproductive toxicity of carbaryl.

3. Groups at Special Risk

Very young children (that is, infants less than 6 months old) may be at special risk because they have incompletely developed AChE systems and immature livers and thus reduced MFO activity (ATSDR, 1993). As part of our compliance with Executive Order 13045 (Protection of Children From Environmental Health Risks and Safety Risks), the potential for adverse effects to children was considered carefully. The grasshopper treatments are conducted primarily on open rangeland and croplands where children would not be expected to be present or enter during the restricted re-entry period. Therefore, it is expected that grasshopper suppression applications would not usually be expected to result in exposures to children and that children would not have any adverse effects from these actions that are disproportionately different from the general population.

A small proportion of the population has an atypical variant of plasma cholinesterase. This condition is known to make these individuals sensitive to succinylcholine and may make them more susceptible to exposure to carbaryl as well as other AChE inhibitors. Other groups known to have low plasma AChE levels are long-distance runners, women in early stages of pregnancy, women using birth control pills, individuals with advanced liver disease, alcoholics, individuals with poor nutritional status, and individuals with skin diseases (ATSDR, 1993).

Several studies are available indicating that animals on a protein deficient diet tend to be more sensitive to carbaryl in terms of acute LD_{50} values compared with animals on a diet containing normal levels of protein (Baron, 1991). This sensitivity is probably related to the metabolism of carbaryl. Animals on a protein deficient diet generally will have lower levels of MFO, and, as discussed in the previous section, MFO appears to be involved in the detoxification of carbaryl, at least in terms of acute lethal potency.

b.Diflubenzuron. Values for the highest dose levels that will not induce methemoglobinemia have been derived for both workers and the general public. These values have been compared with estimates of doses derived from the exposure assessment to calculate HQs.

HQs determined for aerial spray workers, for both routine and extreme exposures, were all less than 1, indicating that these workers are not at risk of adverse effects from the grasshopper program operations that use diflubenzuron. Scenarios representing workers involved in accidental exposures also resulted in HQs less than 1 if they washed within 1 hour. Therefore, accidents would not cause concern about the health effects on these workers. Circumstances that prevent a worker from washing until 24 hours after spilling diflubenzuron on the lower legs would be cause for concern. In this case, the HQ could be as high as 40.

A number of scenarios were analyzed to help characterize risk to the general public. The calculated HQs were less than 1 for most of these public exposures; therefore, adverse health effects clearly are not anticipated. The HQs for a few of the extreme scenarios ranged from 1 to 7. Even in these cases, no clinically significant effects are likely. At the highest exposure, increases in certain blood pigments may be detected, but they will not be long lasting.

1. Cumulative Effects

Any cumulative effects from the use of diflubenzuron are likely to be additive if the exposures are in the same treatment season, that is, diflubenzuron is applied twice in one season. Because there is a relatively short "window of opportunity" to suppress grasshoppers using diflubenzuron (early instars), it is highly unlikely that diflubenzuron would be applied twice in one season. No cumulative effects are expected from one year to the next. Therefore, the risks of a single exposure at 7 g a.i./acre is identical to two applications at 3.5 g a.i./acre. Since the risk assessment used maximum application rates in determining risk and any effects are likely to be additive rather than synergistic, cumulative effects due to diflubenzuron essentially have been addressed.

This risk assessment is based on single applications at a rate of 7 g a.i./acre. This approach is used to estimate maximum daily exposure and daily absorbed dose. Because the dispersal rate for diflubenzuron in the environment is relatively fast, multiple applications at lower rates per application will result in risks that are less than those associated with a single application at the maximum approved rate. Given the narrow range of application rates compared with the variabilities and uncertainties in the exposure and dose-response assessments, the risks of toxic effects associated with a single application at less than the maximum rate will be related directly to the application rate. Thus, an application at 3.5 g a.i./acre will entail risks that are approximately one half of those expected at the maximum application rate. Two applications at 3.5 g a.i./acre will entail risks that are less than the risks from a single application at 7 g a.i./acre due to degradation, but greater than a single application at 3.5 g a.i./acre.

2. Connected Actions

No data were found to indicate that exposure to diflubenzuron will affect the way people respond to other insecticides used in the grasshopper suppression program. The most sensitive effect of diflubenzuron, methemoglobinemia, is not associated with exposure to any of the other insecticides. Therefore, the other insecticides are not expected to interact with diflubenzuron or result in an additive response. If other compounds in the environment induce methemoglobinemia, then an additive effect may be noticed. Individuals exposed to combustion smoke or carbon monoxide may be at increased risk of developing methemoglobinemia (Hoffman and Sauter, 1989; Laney and Hoffman; 1992). Also, individuals exposed to high levels of nitrates, in either air or water, will have increased levels of methemoglobin (Woebkenberg *et al.*, 1981) and may be at increased risk from exposure to compounds such as diflubenzuron.

3. Groups at Special Risk

Some individuals are born with a form of congenital methemoglobinemia and may be at increased risk of adverse effects from compounds that induce methemoglobinemia (Barretti *et al.*, 1984). Infants less than 3 months old have higher levels of methemoglobin than do older children or adults (Centa *et al.*, 1985; Khakoo *et al.*, 1993; Nilsson *et al.*, 1990) and may be at increased risk if exposed to diflubenzuron contamination. Some infants with an intolerance to cow's milk or soy protein exhibit methemoglobinemia (Murray and Christie, 1993; Wirth and Vogel, 1988). This condition may decrease the likelihood that those infants would be exposed to diflubenzuron through contaminated milk. Nonetheless, the infants may be at increased risk if exposed to any materials contaminated with diflubenzuron or any compound that induces methemoglobinemia. As with carbaryl, the likelihood of exposure of children to insecticides used in grasshopper suppression programs is very slight, and no disproportionate adverse effects to children are anticipated over the negligible effects of diflubenzuron to the general population.

The most significant exposure scenarios for diflubenzuron involve dermal contact. Individuals with diseased or damaged skin may absorb chemicals such as diflubenzuron at a substantially greater rate than do normal individuals. Those individuals may be at higher risk, but the magnitude of this risk will depend on the type and severity of skin damage.

Other individuals who may be considered at increased risk of exposure to chemicals in general include those with various disease conditions (for example, immunosuppression; immunodeficiency; allergies; and impaired liver, kidney, lung, or other organ functions), the very young or the very old, individuals with poor diets, pregnant women, or individuals suffering from multiple chemical sensitivity. Other than infants and individuals with damaged skin, there are no data to support an evaluation of the sensitivity of such individuals to diflubenzuron.

c. Malathion. For the general public, none of the exposure scenarios involve levels that exceed the RfD and most are far below the RfD. The assessment of inhalation exposure is based on a threshold limit value (TLV) that was normalized for an exposure that would occur over an 8-hour workday, 5 days per week. When normalized for this continuous exposure, this RfD is equivalent to a factor of about 6,000 above plausible levels of estimated exposure. Therefore, although the adjusted TLV does not incorporate additional uncertainty factors for sensitive subgroups or data quality, even very conservative adjustments would not result in HQs of concern.

For workers, estimates of daily absorbed doses that are associated with the maximum application rate of malathion span the RfD: 0.01 mg/kg to 1 mg/kg. The variability in the exposure estimates reflects the variability in the data upon which the assessment is based. Under routine conditions, aerial spray workers may be exposed to doses that result in HQs of from 0.5 to 50. All accidental scenarios, based on the estimated amount of malathion handled per day, result in HQs more than 1 (from 2.5 to 13).

The implications of these HQs greater than 1 are difficult to assess. Although AChE inhibition is possible at the estimated levels of exposure, it is far less certain that these exposure levels would be associated with any signs of toxicity. This is consistent with human experience. Aerial applications of malathion have been conducted since the early 1960s to control grasshoppers and other pests, and signs of severe nervous system impairment have not been reported in the open literature or in unpublished or anecdotal reports. Although the upper range of plausible exposure, 1 mg/kg/day, is above the level that has been demonstrated to cause AChE inhibition in humans, it is well below the range at which adverse effects have been demonstrated.

1. Cumulative Effects

For both workers and the general public, the characterization of risk for most scenarios is based upon the exposure relative to the RfD. Since this RfD value is intended to be protective of daily exposure over a life span, the value is conservative when applied to the grasshopper program in that all exposures will occur over substantially less than a life span. The only exception is the risk characterization for inhalation exposure, which is based on the TLV time-weighted for continuous exposure. Although there are uncertainties to this approach, the very low HQ, 0.0002, suggests that these uncertainties do not affect the characterization of risk. In addition, as with the other exposure scenarios, the concentrations of malathion in air used for the exposure assessment are based on monitoring data collected shortly after a spray. These levels will diminish over time through dispersion and dissipation. Thus, the exposure assessment is conservative. Given these conservative approaches and the lack of any apparent hazard, concern for cumulative effects is minimal.

2. Connected Actions

Relatively little information is available regarding the effects of exposure to malathion with other agents used to control grasshoppers. Keplinger and Deichmann (1967) noted that co-exposure to malathion and carbaryl resulted in a slight increase in the toxicity of the mixture. Another cholinesterase inhibitor, EPN (O-ethyl O-p-nitrophenylbenzenethiophasphonate) also has been reported to have a greater than expected toxicity on co-administration with malathion to rats and dogs (Frawley *et al.*, 1957), although it is not possible to quantify the magnitude or nature (i.e., additive vs. synergistic) of the interaction.

3. Groups at Special Risk

Very young children (that is, infants less than 6 months old) may be at special risk because they have incompletely developed AChE systems and immature livers. As with carbaryl and diflubenzuron, the likelihood of exposure of children to control chemicals used in grasshopper programs is very slight and no disproportionate adverse effects to children are anticipated over the negligible effects of malathion to the general population.

Several other groups may be at special risk to all cholinesterase inhibiting compounds, including malathion. A small proportion of the population has an atypical variant of plasma cholinesterase. This condition is known to make these individuals sensitive to succinylcholine and may make them more susceptible to the effects of exposure to malathion and other AChE inhibitors. Other groups known to have low plasma AChE levels are long-distance runners, women in early stages of pregnancy, women using birth control pills, individuals with advanced liver disease, alcoholics, individuals with poor nutritional status, and individuals with skin diseases (ATSDR, 1993).

For the general public, none of the exposure scenarios involve levels that exceed the RfD, and most are far below the RfD. The assessment of inhalation exposure is based on a TLV that was normalized for an exposure that would occur over an 8-hour workday, 5 days per week. When normalized for this continuous exposure, this reference level is equivalent to a factor of about 6,000 above plausible levels of estimated exposure. Therefore, although the adjusted TLV does not incorporate additional uncertainty factors for sensitive subgroups or data quality, even very conservative adjustments would not result in HQs of concern.

3. Environmental Fate and the Physical Environment

The effects on components of the physical environment may be direct or indirect. Direct impacts to soil, water, or air would include changes in chemistry and composition in such a way as to reduce the ability to support plant and animal growth and survival. Indirect impacts include negative effects on soil and water organisms and microorganisms that play a large role in ecological processes such as nutrient cycling and breakdown of organic matter to include pesticides. It has been shown in many instances that the major factor in the breakdown of organic matter is the presence of microorganisms. Characteristics such as bioaccumulation or bioconcentration of insecticides in vegetation and animals are important environmental quality indicators.

Environmental Fate of Insecticides

The ability of a chemical to affect an environmental component is largely dependent on persistence. The persistence of a chemical will be affected to some extent by certain ambient conditions such as amount of organic material present, temperature, moisture content, and pH. In the case of compounds that bind readily with organic matter, the amount of organic material present in the soil will determine the extent of inhibition to chemical movement. Specific information pertaining to the fate and transport characteristics of grasshopper suppression insecticides can be found in the Hazard Analysis—Rangeland Grasshopper Cooperative Management Program (USDA, APHIS, 1996c). The following paragraphs identify how each specific compound affects components of the physical environment.

Carbaryl.

1. Soil

Carbaryl has a relatively short half-life in soil. The average half-life ranges from 7 days in aerobic soils to 28 days in anaerobic soils (EPA, OPTS, 1985). Carbaryl persistence in soil depends on the pH, moisture content, and microbial activity of the soil. Degradation of carbaryl in soil results primarily from the metabolic activity of microorganisms (Heywood, 1975), but hydrolysis and photolysis also occur. Biodegradation of carbaryl is a principle breakdown mechanism and as much as 80 percent has been shown to mineralize (degrade) within 4 weeks (Howard, 1991).

Soil microorganism densities have been shown to be slightly reduced following carbaryl treatments, with recovery to normal population densities occurring within 3 weeks (Moulding, 1972). Carbaryl bait, due to its application method, will exhibit reduced soil effects relative to spray applications (USDA, APHIS, 1987).

Little transport of carbaryl through runoff or leaching to groundwater is expected due to the low water solubility, moderate sorption, and rapid degradation in soils. There are no reports of carbaryl detection in groundwater and less than 1 percent of carbaryl applied to a sloping plot was detected in runoff (Caro *et al.*, 1974). Groundwater Loading Effects of Agricultural Management Systems (GLEAMS) modeling (Davis *et al.*, 1990) indicates minimal soil movement of carbaryl.

A. Water

Degradation of carbaryl is rapid in both freshwater and saltwater. Carbaryl applied over open freshwater was found to degrade completely in 1 to 2 days (California Department of Fish and Game (CDFG), 1963; Lichtenstein *et al.*, 1966). All carbaryl degraded from seawater in 17 days at 20 °C (Karinen *et al.*, 1967). Kinetic studies determined the half-life for hydrolysis in neutral to alkaline freshwater to be 1.3 to 1.5 days (Wolfe *et al.*, 1978; Aly and El-Dib, 1971). The photolysis half-life in water was determined to be 6.6 days (Wolfe *et al.*, 1978). Carbaryl concentrations following a 1.5-inch rainstorm are projected to have less than 5 parts per billion (ppb) in streams and less than 13 ppb in ponds based upon GLEAMS modeling (USDA, APHIS, 1996b; see appendix C).

B. Air

Carbaryl has a half-life in air of 1 to 4 months. The low vapor pressure of carbaryl makes it unlikely that there will be any volatilization from soil, water, or treated surfaces (Dobroski *et al.*, 1985).

Criteria pollutants (pollutants for which maximum allowable emission levels and concentrations are enforced by State agencies) will be produced by internal combustion engine fuel consumption during suppression application activities. Effects will be localized and minimal compared with other vehicular activities in treatment areas.

C. Vegetation

Carbaryl has a short residual life on plant surfaces. Insecticidal properties are retained for 3 to 10 days (EPA, OPTS, 1985). The major metabolite is 1-naphthol. Although carbaryl is a polar compound, bioconcentration in plants is not of concern due to limited plant uptake relating to the low water solubility and rapid degradation (Nash, 1974).

The effects of carbaryl on vegetation can be either direct toxicity (phytotoxicity) or indirect. Carbaryl can adversely affect plant growth and produce phytotoxic effects at high application rates. However, exposure of vegetation to carbaryl at the proposed program application rates is lower and would not be expected to result in any phytotoxic effects. Indirect effects include the beneficial impact of reducing numbers of grasshoppers that consume vegetation as well as the negative impacts on plant reproduction associated with reduced numbers of plant pollinators. The effects of reduced plant pollinators is discussed in the section entitled Arthropods Pollinator Issues (see section B.4.d. of this appendix).

Carbaryl can adversely affect plant growth and produce phytotoxic effects at certain application rates. However, the application rate used in grasshopper suppression programs is less than would result in phytotoxicity to rangeland vegetation.

D. Animal

Most mammals, including humans, readily break down carbaryl and excrete it in the urine and feces. An estimated 70 to 80 percent is eliminated within 24 hours (Dorough, 1970). Water-soluble metabolites taken up by mammals are also quickly eliminated, mainly in the urine (Casida and Lykken, 1969). Carbaryl is not subject to significant bioaccumulation due to its low water solubility and low octanol-water partition coefficient (Dobroski *et al.*, 1985). Uptake of carbaryl in fish has been detected with 95 percent excreted within 8 hours (Tompkins, 1966).

2. Diflubenzuron

A. Soil

Diflubenzuron has been shown to bind readily with organic matter in soils and is relatively immobile in the environment. GLEAMS modeling indicates no percolation to groundwater, but some transport in runoff is possible. The persistence of diflubenzuron in soils depends a great deal on the presence of microorganisms. The half-life of diflubenzuron under field conditions ranges from 7 days to about 19 days (Nigg *et al.*, 1986).

Some soil dwelling organisms may be at risk from diflubenzuron applications. Reductions in mite populations have been observed following applications of 35 g a.i./ha (Perry *et al.*, 1993). Although soil dwelling species may be at risk, at least one field study suggests decomposition rates are not affected by diflubenzuron (Rockwood, 1995). Toxicological testing concerning fungal, bacterial, and soil invertebrate population effects from exposure to diflubenzuron on soil fertility and productivity has not been published.

B. Water

Diflubenzuron seldom persists more than a few days in water, so the toxic effects from direct exposure anticipated at program locations all would be acute. However, diflubenzuron indirectly entering water on foliage in the fall (cold water temperatures) is more persistent and can result in chronic toxicity to aquatic invertebrates that frequent the leaf packs as grazers (Wimmer *et al.*, 1993). GLEAMS modeling predicts that concentrations of diflubenzuron after a 1.5-inch rainstorm will all be less than 0.1 ppb in streams and ponds. Directly sprayed, 1-foot deep ponds are projected to have diflubenzuron concentrations of less than 6 ppb (USDA, APHIS, 1996b; see appendix C).

C. Air

The vapor pressure of diflubenzuron is relatively low (Wauchope *et al.*, 1992), so exposure to substantial concentrations of diflubenzuron in air is unlikely.

Criteria pollutants (pollutants for which maximum allowable emission levels and concentrations are enforced by State agencies) will be produced by internal combustion engine fuel consumption during suppression application activities. Effects will be localized and minimal compared with other vehicular activities in treatment areas.

D. Vegetation

Diflubenzuron does not directly affect vegetation through any phytotoxic effects, even though it may remain on leaf surfaces for several months following application. Diflubenzuron applied to foliage tends to remain adsorbed to leaf surfaces for several weeks with little or no absorption or translocation from plant surfaces (Eisler, 1992). This persistence on leaves may result in exposure and toxic effects to nontarget species as late as the time of fall foliage drop (Harrahy *et al.*, 1993; Wimmer *et al.*, 1993). Loss from foliage occurs mainly by wind, rain, and shedding of leaves in the fall. Chronic toxicity is possible for animals that feed on leaves or have regular contact with treated leaf surfaces.

E. Animal

Metabolism of diflubenzuron in mammals is rapid (EPA, OPTS, 1987). Diflubenzuron is not well absorbed by skin with only 0.2 percent absorption within 48 hours from shaved skin of a treated rabbit (Keet *et al.*, 1982). Little, if any, bioconcentration or bioaccumulation would be expected for any animals (Booth, 1978). The rapid metabolism and lack of bioconcentration indicate that only acute toxic effects would be expected for diflubenzuron exposures. Metabolism of diflubenzuron by mammals and birds occurs through hydroxylation, conjugation, and cleavage of the urea moiety (Opdycke *et al.*, 1982).

3. Malathion

A. Soil

The persistence of malathion in soils depends primarily on microorganism activity, pH, and organic matter content. The half-life of malathion in natural soil varies from less than 1 day (Walker and Stojanovic, 1973) to 6 days (Neary, 1985). The character of a soil is dependent not only upon its physical and chemical components, but also upon the presence of microorganisms. Breakdown of malathion in soil has been determined to be largely mediated by soil microorganisms. The principle degradation products are monocarboxylic and dicarboxylic acids (Walker and Stojanovic, 1973).

Malathion has been shown in laboratory studies to exhibit slight toxicity to some soil microorganisms. Toxicity to some nitrifying bacteria is variable. Malathion is slightly toxic to *Nitrobacter* sp. and can cause complete inhibition of *Nitrosomas* sp. (Bollen, 1961; Garretson and San Clemente, 1968). Malathion applied to soils has not affected the growth of several fungi or their ability to degrade other pesticides (Anderson, 1981). Malathion application to a forested watershed resulted in no observed effects on bacteria or fungi (Giles, 1970).

Inorganic degradation of malathion may be more important in soils that are relatively dry, alkaline, and low in organic content, such as those that predominate in the western program areas. Malathion is subject to hydrolysis under neutral and alkaline conditions, but is more stable under acidic conditions. It does not penetrate much beyond the soil surface and does not adsorb tightly to inorganic soil particles, although it binds tightly with organic matter (Jenkins *et al.*, 1978). Adsorption to organic matter and rapid degradation make it unlikely that detectable quantities of malathion would leach to groundwater (LaFleur, 1979; HSDB, 1991). Because of agricultural and other uses, low-level background residues of malathion may occur in certain areas.

Modeling of environmental fate of malathion indicates that less than 1 ppb is projected to percolate to a depth of 1 foot in soil, but some runoff is possible with heavy rainstorms (USDA, APHIS, 1996b; see appendix C).

Malathion degradation products also have short half-lives. Malaoxon, the major malathion degradation product of concern in soil, has half-lives of 4 and 5 days in soils of pH 7.2 and 8.2, respectively (Paschal and Neville, 1976).

B. Water

Surface water contamination may occur from direct applications or runoff from treated plants and soils, particularly if a rainfall occurs soon after application. Degradation of malathion in water is mostly by photolysis (decomposition induced by light), microbial degradation under acidic conditions, and chemical transformations under alkaline conditions (Wolfe *et al.*, 1977). The half-life of malathion in water with pH values from 5 to 8 ranges from 6 to 18 days (Paris and Lewis, 1973). The half-life of malathion was calculated from program monitoring data for natural waters during the 1997 Medfly Cooperative Eradication Program in Florida to be 8 hours in a retention pond and 32 hours in the Hillsborough River (USDA, APHIS, 1997). Half-life in seawater at pH 8 was 2.6 days (Horvath, 1982). Malathion in chlorinated swimming pool water degrades readily to the more toxic metabolite malaoxon. The half-life of malaoxon in chlorinated swimming pool water has been determined to be 37 hours (CDFA, 1991). Monitoring of four aerial bait spray applications in the 1991 study showed no cumulative concentrations of malathion or malaoxon in freshwater or chlorinated swimming pools. Because of agricultural and other uses, low-level background residues of malathion may be present in water in certain areas.

Various sources have set different water quality criteria for malathion in freshwater and saltwater habitats. EPAs chronic water quality criterion for malathion is 0.1 µg/L (equivalent to

0.1 part per billion) for both freshwater and saltwater. This criterion is near or below the limit of detection for malathion using standard analytical techniques. By comparison, the CDFG water quality criteria for malathion (based on acute exposure) are 3.54 µg/L for freshwater and 10 µg/L for saltwater (CDFG, 1982). The criteria for aquatic life are quite a bit lower than for human drinking water—CDHS has established a Health Advisory Level of 160 µg/L for malathion in human drinking water (CDHS, 1991).

Some directly sprayed water within the treatment area could have malathion concentrations exceeding the EPA chronic freshwater and saltwater criteria immediately following malathion aerial application; however, program applications are not made to water bodies. The concentrations of malathion in unprotected freshwater bodies immediately after treatment during the 1997 Cooperative Medfly Eradication Program in Florida ranged from below the detection limit (less than 0.1 ppb) to 460 ppb (USDA, APHIS, 1997). Environmental fate modeling predicted that in directly sprayed water bodies greater than 6 feet deep, malathion concentrations immediately after spraying were 11 µg/L or less. Shallow water bodies were estimated to have higher concentrations (e.g., greater than 64 µg/L in water less than 1-foot deep). The modeling data are consistent with monitoring data from past programs. Malathion concentrations in aquatic habitats would decrease readily over time because of the chemical degradation, biological metabolism, and water flow into and out of the water body. Modeling predicts that malathion concentration decreases rapidly in flowing water and in water bodies with drainage outlets. For shallow water bodies in which CDFG water quality criteria may be exceeded for a short time, natural degradation processes make it unlikely that chronic exposures could result from program activities.

Malathion is predicted to occur in ponds and streams at concentrations less than 10 ppb following a 1.5-inch rainstorm within 24 hours after an application of 8 oz a.i./acre. Directly sprayed ponds of 1-foot in depth are projected to have concentrations as high as 224 ppb (USDA, APHIS, 1996b; see appendix C).

C. Air

Because of malathion's low volatility, high concentrations are unlikely to be detected in air. However, because of agricultural and other uses, low-level background residues of malathion may be present in the air at certain locations. The atmospheric vapor phase half-life of malathion is 1.5 days (HSDB, 1990).

Criteria pollutants (pollutants for which maximum allowable emission levels and concentrations are enforced by State agencies) will be produced by internal combustion engine fuel consumption during suppression application activities. Effects will be localized and minimal compared with other vehicular activities in treatment areas.

D. Vegetation

The effects of malathion on vegetation can be either direct toxicity (phytotoxicity) or indirect. The half-life of malathion on foliage ranges from 1 to 6 days (Matsumara, 1985; Nigg *et al.*, 1981; El-Refai and Hopkins, 1972). Indirect effects include the beneficial impact of reducing numbers of grasshoppers that consume vegetation as well as the negative impacts on plant reproduction associated with reduced numbers of plant pollinators. The effects of reduced plant pollinators is discussed in the section entitled Arthropod Pollinator Issues (see B.4.d of this appendix).

Malathion can adversely impact plant growth and produce phytotoxic effects at certain application rates. However, program application rates are lower than would result in phytotoxicity to rangeland vegetation.

E. Animal

Metabolism of malathion in mammals occurs primarily by hydrolytic cleavage to yield urinary metabolites such as malathion monoacid that are readily excreted (WHO, IARC, 1983). The half-life of malathion in humans was determined to be 3 hours and 90.2 percent of the total dose is excreted in the urine (Feldmann and Maibach, 1974). This accounts for the lack of bioaccumulation in mammals. The primary metabolism in insects occurs by oxidation to form malaoxon, a more potent inhibitor of acetylcholinesterase and a more toxic compound (O'Brien, 1957). This accounts for the greater toxicity to insects and high efficacy of malathion. Bioconcentration factors for fish range from 7.36 in lake trout to 34.4 in willow shiners (HSDB, 1990; Tsuda *et al.*, 1989). The concentration in fish tissues decreases readily and consistently with decreasing of malathion in water. No concerns about bioaccumulation are anticipated for grasshopper suppression programs.

4. Nontarget Terrestrial Species

4. Carbaryl.

1. Potential Hazards

A. Mammals

Carbaryl is of moderate acute oral toxicity to mammals. The acute oral LD50 is 270 mg/kg for rats. The acute dermal toxicity is low with an LD50 in excess of 4,000 mg/kg for rats and in excess of 5,000 mg/kg for rabbits (EPA, ECAO, 1984).

B. Birds

Carbaryl is slightly toxic to birds. The acute oral LD_{50} of carbaryl to avian species ranges from 707 mg/kg to 3,000 mg/kg (Hudson *et al.*, 1984). A number of studies have reported no effects on bird populations in areas treated with carbaryl (Richmond *et al.*, 1979; McEwen *et al.*, 1962; Buckner *et al.*, 1973). Some applications of carbaryl were found to cause depressed AChE levels (Zinkl *et al.*, 1977; Gramlich, 1979). This temporary inhibition of AChE may reduce the ability of the birds to avoid predation and conduct adequate foraging.

AChE inhibition at 40 to 60 percent affects coordination, behavior, and foraging ability in vertebrates. This could lead to death from weather, predators, or other stresses of survival in the wild. Studies over several years for multiple grasshopper treatment areas have shown AChE inhibition at levels of no more than 40 percent with most at less than 20 percent (McEwen *et al.*, 1996).

C. Reptiles and Amphibians

Data about effects of carbaryl to these organisms is limited to toxicologic information about the bullfrog. The acute oral LD_{50} of carbaryl to bullfrogs is greater than 4,000 mg/kg (Hudson *et al.*, 1984). This indicates that carbaryl is probably slightly toxic to most of these species.

D. Terrestrial Invertebrates

Carbaryl, in its action as an insecticide, is severely toxic to many insects. Honey bees are particularly sensitive to carbaryl (Atkins *et al.*, 1981). Carbaryl applied to turfgrass at labeled rates decreased earthworms by 60 to 99 percent (Potter *et al.*, 1990). Spiders are not severely affected in carbaryl-treated fields, and recovery occurs within 3 weeks after spraying (Shepard and Sterling, 1972; Barrett, 1968). Carbaryl is severely toxic to predatory mites, but less toxic to phytophagous mites (Bartlett, 1968).

2. Quantitative Risk Assessment

The output from terrestrial vertebrate exposure modeling of doses from carbaryl full coverage treatments is summarized in table B–6. The highest potential doses to representative vertebrates are shown for the lark bunting, grasshopper mouse, horned lizard, and Woodhouse's toad. These insectivorous species consume considerable quantities of grasshoppers and other rangeland invertebrates, so they would be expected to receive higher doses than omnivores, herbivores, and vertebrate carnivores. The highest potential doses of carbaryl to wildlife species would be received by the target insects (grasshoppers and crickets) and other nontarget invertebrates present within the treatment areas.

TABLE 1-6: Estimated Daily Doses of Carbaryl from Full Coverage Treatments to Vertebrate Nontarget Species and Corresponding Reference Levels

Representative	Estimated Dose (mg/kg)	Reference Dose		Reference Species
		1/5 LD_{50}	LD_{50}	
Birds				
Lark bunting	66.97	156	780	Sharp-tailed grouse
Sage grouse	11.90	156	780	Sharp-tailed grouse
Bobwhite quail	48.93	458	2290	Japanese quail
American kestrel	43.20	156	780	Sharp-tailed grouse
Mammals				
Grasshopper mouse	60.37	55	275	Mouse
Blacktail jackrabbit	11.67	142	710	Rabbit
Pronghorn antelope	5.97	40	200	Mule deer
Domestic cattle *(Bovine* spp.)	2.51	40	200	Mule deer
Coyote	3.47	30	150	Cat
Reptiles and Amphibians				
Horned lizard	66.38	156	780	Sharp-tailed grouse
Eastern yellow-belly racer	12.80	800	4,000	Bullfrog
Woodhouse’s toad	62.95	156	780	Sharp-tailed grouse

Based upon the quantitative calculations of doses of carbaryl to vertebrate species, most animals have negligible risk of adverse toxicological effects from full coverage treatments. The only species that shows greater risk is the grasshopper mouse, which has a potential dose just in excess of 1/5 of the LD_{50}. The risk to this species would be characterized as moderate, but this dose is at the lower end of the moderate effects and would not be expected to permanently affect local populations within the treated areas.

The toxic effects of carbaryl full coverage treatments will be most evident as decreases in susceptible invertebrate populations. The immediate effect of a treatment results in more limited predator avoidance by susceptible insects within the treatment area and easier foraging for insectivorous species there. This is followed by rapid decreases in population density of the susceptible species and the need for more widespread foraging by the insectivorous species. The decrease in populations of susceptible insects following carbaryl treatments is expected to be temporary with rapid recolonization of the treated areas from surrounding range and croplands.

3. Field Studies

The use of Sevin® 4-Oil, at the formulation rate of 1.25 lbs a.i./acre, has demonstrated little possibility of toxicity-caused mortality of upland birds, mammals, or reptiles, and none has been observed as part of the grasshopper IPM monitoring effort (McEwen *et al.*, 1996). These observations are consistent with the modeling results for carbaryl shown in table B-6, which indicate negligible impact on representative mammalian, bird, and reptile species due to carbaryl treatments.

4. Community Effects

Most potential community effects in terrestrial habitats appear to relate to the reduction in insect populations. Reduction of the insect populations on sites treated with carbaryl in New Jersey was correlated to reduced bird populations (Moulding, 1972). Removal of insects has been suggested as cause for bird migrations (Doane and Schaefer, 1971).

Field studies in North Dakota were conducted to determine the effects of Sevin® 4-Oil treatment on killdeer populations. At treatment rates of 0.5 and 0.4 lb a.i./acre, no toxic signs and no mortality were observed in the killdeer population. Effects on foraging and diet of the killdeer were examined by both direct observation and analysis of stomach contents (Fair *et al.*, 1995b). The insect capture rate by foraging killdeer increased during the 2-day period after treatment when affected insects were easily obtainable (Fair *et al.*, 1995a). There were no other differences or changes in food habits observed.

5. Carbaryl Bait Treatments

Bait treatments were not analyzed as part of the modeling effort. The methodology used to model the exposures was not considered to be applicable in determining exposures to carbaryl baits.

The modeling results determined in this analysis are based on ULV applications of treatment chemicals and take into account various transport mechanisms that are not applicable to carbaryl bait treatments.

There are several factors, however, that could favor the use of carbaryl bait treatments. Carbaryl incorporated into bran flakes or other solid media acts only upon ingestion by the organism and is considered to be a more selective and environmentally benign than other chemical control means (Peach *et al.*, 1994). This suppression method may offer a viable alternative when grasshopper treatment is required in close proximity to endangered and threatened species, water bodies, or other sensitive sites. The inert ingredients known to be present in bait formulations (e.g., silica gel and n-amyl acetate) occur at low concentrations or pose less risk than the active ingredients in the formulated product (see section A.3.a.(8)) on inert ingredients and metabolites of carbaryl).

As part of the grasshopper IPM monitoring studies, a test was conducted in North Dakota of the effect of carbaryl bait on the nestling growth and survival of vesper sparrow (Adams *et al.*, 1994). This study was designed to simulate the treatment of a small grasshopper infestation with carbaryl bait. There was no difference reported in any of the productivity parameters between nests on treated and untreated sites (Adams *et al.*, 1994). Adult sparrows on treated sites had to forage farther from the nests to obtain food but did so successfully (McEwen *et al.*, 1996). Any effects on nontarget species due to bait treatments can be considered indirect; that is, the prey populations are affected, while no direct toxicity to the nontarget species is likely to occur.

b.Diflubenzuron.

1. Potential Hazards

A. Mammals

Diflubenzuron is slightly to very slightly toxic to mammals (Maas *et al.*, 1981). The acute oral median lethal dose of technical diflubenzuron to mice and rats is 4,640 mg/kg. The acute dermal median lethal dose to rats is 10,000 mg/kg and to rabbits is 4,000 mg/kg (Eisler, 2000).

B. Birds

Diflubenzuron is slightly to very slightly toxic to birds. The acute oral median lethal dose of diflubenzuron to birds ranges from 3,762 mg/kg for red-winged blackbird to in excess of 5,000 mg/kg for bobwhite quail and mallard duck (Willcox and Coffey, 1978). The primary concern for bird species has related to the effects of decreases in insect populations from insecticide applications on insectivorous species rather than to the direct toxicity to birds from diflubenzuron exposure.

C. Reptiles and Amphibians

No information was located about toxicity of diflubenzuron to reptiles or amphibians, but it is likely that diflubenzuron is of low toxicity to these species based upon the selective nature of the toxic mode of action. Based upon this, the relative toxicity of diflubenzuron to these species is anticipated to be similar to that of mammals and birds.

D. Terrestrial Invertebrates

Toxicity of diflubenzuron to terrestrial arthropods varies, but most species show adverse effects at high exposures. The most evident toxic effects occur when diflubenzuron is ingested immediately prior to molting. As a result, diflubenzuron is moderately to severely toxic to larval stages (molting stages) of terrestrial insects, but is practically nontoxic to most adult stages such as adult honey bees (Kuijpers, 1989). Immature grasshoppers, beetle larvae, lepidopteran larvae, and chewing herbivorous insects are the most susceptible. The acute toxicity from topical exposure of the first instar caterpillar of the large white butterfly (*Pieris brassicae*) is 2.5 µg/insect or 1.07 mg/kg (Sinha *et al.*, 1990). Honey bees, parasitic wasps, predatory insects, and sucking insects show greater tolerance to diflubenzuron exposure. Diflubenzuron is moderately toxic to spiders and mites. However, diflubenzuron is only slightly to very slightly toxic to earthworms.

E. Plants and Microorganisms

Phytotoxicity has not been found to be of any concern to green plants when diflubenzuron is applied at the recommended rates of application. Most fungi contain chitin and, therefore, may be affected by diflubenzuron. Some fungi have shown growth inhibition at 50 ppm, but most species have not (Booth, 1978). The no-observed effect concentration for phytotoxicity in duckweed is 190 µg/L (Thompson and Swigert, 1993).

2. Quantitative Risk Assessment

The output from terrestrial vertebrate exposure modeling of doses from diflubenzuron full coverage treatments is summarized in table B–7. The highest potential doses to representative vertebrates are shown for the lark bunting, grasshopper mouse, horned lizard, and Woodhouse's toad. These insectivorous species consume considerable quantities of grasshoppers and other rangeland invertebrates, so they would be expected to receive higher doses than omnivores, herbivores, and noninsect carnivores. The highest potential doses of diflubenzuron to wildlife species would be received by the target insects (grasshoppers and crickets) and other nontarget invertebrates present within the treatment areas.

Based upon the quantitative calculations of doses of diflubenzuron to vertebrate species, all vertebrates have negligible risk of adverse toxicological effects from full coverage treatments. The toxic effects of diflubenzuron full coverage treatments will be most evident as decreases in susceptible invertebrate populations. The immediate effect of a treatment results in more limited predator avoidance by susceptible insects within the treatment area and easier foraging for insectivorous species there. This is followed by rapid decreases in population density of the susceptible species and the need for more widespread foraging by the insectivorous species. The decrease in populations of susceptible insects following diflubenzuron treatments is expected to be temporary with rapid recolonization of the treated areas from surrounding range and croplands. The specificity of the toxic mechanism of action of diflubenzuron results in adverse effects to fewer susceptible species (primarily immature grasshoppers, beetle larvae, lepidopteran larvae, and chewing herbivorous insects) than carbaryl or malathion (general oral and dermal toxicants to all insects). This results in fewer insect populations affected and less effect on foraging of insectivorous vertebrates for diflubenzuron treatments than for the other grasshopper suppression insecticides.

TABLE 1-7: Estimated Daily Doses of Diflubenzuron from Full Coverage Treatments to Vertebrate Nontarget Species and Corresponding Reference Levels

Representative Species	Estimated Dose	Reference Dose 1/5 LD_{50}	LD_{50}	Reference Species
Birds				
◆ Lark bunting	4.25	752	3762	Red-winged blackbird
◆ Sage grouse	0.60	>1000	>5000	Mallard duck
◆ Bobwhite quail	2.21	>1000	>5000	Bobwhite quail
◆ American kestrel	2.15	>1000	>5000	Mallard duck
Mammals				
◆ Grasshopper mouse	3.44	928	4640	Mouse
◆ Blacktail jackrabbit	0.59	928	4640	Rabbit
◆ Pronghorn antelope	0.26	928	4640	Rabbit
◆ Domestic cattle *(Bovine* spp.)	0.11	928	4640	Rabbit
◆ Coyote	0.23	928	4640	Rabbit
Reptiles and Amphibians				
◆ Horned lizard	2.41	752	3762	Red-winged blackbird
◆ Eastern yellow-belly racer	1.15	752	3762	Red-winged blackbird
◆ Wooehouse’s toad	16.56	752	3762	Red-winged blackbird

3. Field Studies

Diflubenzuron is unique among the grasshopper suppression insecticides in that it is not a cholinesterase inhibitor; that is, it is not a neurotoxin but acts as a growth regulator. The mode of insecticidal action of diflubenzuron is described in detail in the Hazard Analysis—Rangeland Grasshopper Cooperative Management Program (USDA, APHIS, 1996c). Because of its mode of action, diflubenzuron is more target-specific and can be expected to pose a reduced threat to nontarget species relative to the other grasshopper suppression insecticides.

A. Invertebrates

Previously conducted research, as well as field studies carried out as part of the grasshopper IPM project, indicate that diflubenzuron spares most terrestrial nontarget arthropods (Catangui *et al.*, 1996). Results of these studies indicate that the effects of diflubenzuron normally range from nonexistent to slight. Any reductions in nontarget populations have been shown to be of short duration, usually measured in days.

Grasshopper IPM field studies have shown diflubenzuron to have a minimal impact on ants, spiders, predatory beetles, or scavenger beetles. There was no significant reduction in populations of these species from 7 to 76 days after treatment. Although ant populations exhibited declines of up to 50 percent, these reductions were temporary, and population recovery was described as immediate (Catangui *et al.*, 1996).

No significant reductions in flying nontarget arthropods, including honey bees, have been reported. Within 1 year of diflubenzuron applications in a rangeland environment, no significant reductions of bee predators, parasites, or pollinators were observed for any level of diflubenzuron treatment (Catangui *et al.*, 1996).

B. Vertebrates

Modeling results described in this EIS indicate that there is little or no direct impact on mammalian species as a result of diflubenzuron applications. Results of field studies reinforce these results. Acute dosages of diflubenzuron were found to have no direct effects on terrestrial wildlife (McEwen *et al.*, 1996). Although indirect effects do occur as a result of reduced populations of prey for insectivorous species, these impacts have been shown to be temporary.

IPM monitoring studies have shown the effects of suppression insecticides on small mammals such as mice and squirrels to be slight. Since many of these species are nocturnal, they are not as readily exposed to spray treatments as other larger mammals or birds (McEwen *et al.*, 1996).

c. Malathion.

1. Potential Hazards

A. Mammals

The acute oral toxicity of malathion is very slight to moderate for mammals. The acute oral median lethal doses of malathion range from 250 mg/kg in rabbits to 12,500 mg/kg in rats. The acute toxicity of malathion by the dermal route is one of the lowest of the organophosphorus insecticides (EPA, OPP, 1989b).

B. Birds

Malathion is slightly to moderately toxic to birds. The acute oral median lethal doses range from 150 mg/kg to chickens (EPA, 1975) to 1,485 mg/kg to mallard ducks (Hudson *et al.*, 1984). The 5-day dietary median lethal concentrations for wild birds all exceed 2,500 ppm (Smith, 1987).

Several reproductive and developmental studies have been conducted with birds. The lowest median lethal dose to chicken embryos (eggs) was 3.99 mg per egg for 4-day embryos (Greenberg and LaHam, 1969). The median lethal concentration for field applications of malathion to mallard duck eggs was found to be 4.7 lbs a.i./acre (Hoffman and Eastin, 1981). No effect on reproductive capacity of chickens was found at dietary concentrations as high as 500 ppm in feed (Lillie, 1973).

C. Reptiles and Amphibians

The toxicity of malathion is relatively low to adult reptiles and amphibians, but is highly toxic to the immature aquatic stages. Studies of adult salamanders and lizards exposed to field applications (up to 6 oz a.i./acre) of malathion found no observable adverse effects and no AChE inhibition (Baker, 1985; McLean *et al.*, 1975). The 96-hour median lethal concentration of malathion is 420 µg/L for tadpoles of Fowler's toad and 200 µg/L for tadpoles of the western chorus frog (Mayer and Ellersieck, 1986).

D. Terrestrial Invertebrates

Malathion is moderately to severely toxic to terrestrial invertebrates. The median lethal concentration of malathion to earthworms ranges from 0.27 to 13.5 µg/cm^2 (Roberts and Dorough, 1985). The median lethal dose to honey bees is 0.709 µg per bee (Atkins *et al.*, 1973). Median lethal concentrations of malathion to insects range from 23 mg/kg for carpenter ants (Gibson and Scott, 1989) to 124.1 mg/kg for lacewings (Pree *et al.*, 1989). A lowest effect level based upon increased excretion and decreased tissue protein content was determined for snails to be 5 ppm malathion (Sivaiah and Ramano Rao, 1978).

E. Plants and Microorganisms

Malathion has low phytotoxicity to most plants. Concentrations above field application rates are required for adverse effects to conifers, clover, and pea plants (Ilnytzky and Marshall, 1974; Archer, 1971; Chakraborti *et al.*, 1983).

2. Quantitative Risk Assessment

The output from terrestrial vertebrate exposure modeling of doses from malathion full coverage treatments is summarized in table B–8. The highest potential doses to representative vertebrates are shown for the lark bunting, grasshopper mouse, horned lizard, and Woodhouse's toad. These insectivorous species consume considerable quantities of grasshoppers and other rangeland invertebrates, so they would be expected to receive higher doses than omnivores, herbivores, and noninsect carnivores The highest potential doses of malathion to wildlife species would be received by the target insects (grasshoppers and crickets) and other nontarget invertebrates present within the treatment areas.

TABLE 1-8: Estimated Daily Doses of Malathion from Full Coverage Treatments to Vertebrate Nontarget Species and Corresponding Reference Levels

		Reference Dose		
Representative Species	**Estimated Dose**	**1/5 LD_{50}**	**LD_{50}**	**Reference Species**
Birds				
Lark bunting	79.20	81	403	Horned lark
Sage grouse	13.91	30	150	Chicken
Bobwhite quail	56.67	30	150	Chicken
American kestrel	50.46	30	150	Chicken
Mammals				
Grasshopper mouse	71.80	115	775	Mouse
Blacktail jackrabbit	13.65	50	250	Rabbit
Pronghorn antelope	6.96	11	53	Cattle
Domestic cattle (*Bovine* spp.)	2.90	11	53	Cattle
Coyote	3.50	72	360	Dog
Reptiles and Amphibians				
Horned lizard	77.14	465	2324	Carolina anole
Eastern yellow-belly racer	15.16	30	150	Chicken
Woodhouse’s toad	74.02	30	150	Chicken

Based upon the quantitative calculations of doses of malathion to vertebrate species, many animals are at negligible risk of adverse toxicological effects from full coverage treatments. The species that are at greater risk include the bobwhite quail, American kestrel, and Woodhouse's toad. The risk to these species would be characterized as moderate. Although their doses are at the lower end of the moderate effects, some individuals of these species could suffer mortality. The mortality would be considerably less than 50 percent and recovery of the populations of these species within the treatment area from these adverse effects would be expected to be rapid.

The toxic effects of malathion full coverage treatments will be most evident as decreases in susceptible invertebrate populations. The terrestrial invertebrates are likely to have depressed populations for a given period of time following spraying. The treatment area and number of treatments will influence the ability of the population to become reestablished, but in most every case application is made only once. The ability to reestablish the population is also influenced by the distance from the treatment area to similar, untreated habitats containing potential colonists, and the ability of these potential colonists to disperse. The immediate effect of a treatment results in more limited predator avoidance by susceptible insects within the treatment area and easier foraging for insectivorous species there. This is followed by rapid decreases in population density of the susceptible species and the need for more widespread foraging by the insectivorous species. The decrease in populations of susceptible insects following malathion treatments is expected to be temporary with rapid recolonization of the treated areas from surrounding range and croplands.

3. Field Studies

The grasshopper IPM Program investigated the effects of malathion. A 3-year study was conducted to determine the indirect effects of malathion on nesting birds in Idaho (Howe, 1993). Although the total invertebrate availability was significantly reduced by standard malathion spray applications (0.5 lb a.i./acre), nesting birds were shown to switch their diets to the remaining insects and reproduce as successfully as birds on untreated control plots. Adults had to forage longer on treated plots, and nestlings demonstrated an increased propensity for parasitic blowfly infestations. Either of these indirect effects might impact survival in some situations. However, this particular field study did not show these particular effects to be significant. Prespray grasshopper densities were relatively low (1 to 4 per square yard) on all plots and were significantly reduced in the post spray period. This probably made the food availability test even more rigorous than would be posed by an actual operational grasshopper suppression project, where prespray densities are much higher and even post spray grasshopper densities usually exceed 1 or 2 per square yard (McEwen *et al.*, 1996).

The results of field studies involving malathion are consistent with the modeling results shown in table B–8.

A. Arthropod Pollinator Issues

The majority of rangeland plants require insect-mediated pollination. Native, solitary bee species are the most important pollinators on western rangeland (Tepedino, 1979). Potential negative effects of insecticides on pollinators are of concern because a decrease in their numbers has been associated with a decline in fruit and seed production of plants. This decline may have repercussions throughout the rangeland food chain. Rangeland species populations that depend on plants for food may be indirectly affected due to changes in vegetation patterns (Alston and Tepedino, 1996).

Malathion and carbaryl are broad spectrum insecticides and are both considered to be highly toxic in their effects on bees (Johansen and Mayer, 1990, Johansen *et al.*, 1983). Contact sprays can be very toxic to small, native bees because of direct contact with the insecticide or insecticide residue. More selective insecticides are desirable in order to reduce the negative effects on bee populations (Alston and Tepedino, 1996). Although negative effects of diflubenzuron on honey bees have been demonstrated at high application levels and relatively long periods of exposure, these application rates far exceed the prescribed rate for grasshopper suppression. Diflubenzuron application rates as high as 0.125 to 0.25 lb a.i./acre resulted in no effects on adult mortality and brood production (Robinson and Johansen, 1978). Therefore, applications of diflubenzuron are preferable over carbaryl or malathion at locations where pollinating bees are active.

Any negative effects of grasshopper program insecticides on bee populations may also be mitigated by the use of carbaryl bran baits. Studies with carbaryl bran bait have found no sublethal effects on adults or larvae (Peach *et al.*, 1994). There appears to be little cause for concern that any carbaryl eaten by foraging adult females from the nectar of open flowers will affect any aspect of reproduction (Alston and Tepedino, 1996).

5. Nontarget Aquatic Species

Aquatic organisms are protected from exposure to program chemicals by the protective operational measures and adherence to insecticide labels. These measures are intended to prevent program insecticides from entering water bodies under conventional applications. The site-specific protective measures may include (1) prohibiting direct application to water bodies, (2) no-spray buffer zones around water bodies, (3) restrictions to application when rain is forecast, and (4) measures to reduce pesticide drift during aerial applications.

However, despite the protective measures, there is still a potential for aquatic organisms to be exposed to program insecticides. Water bodies cannot be completely protected from insecticide applications because human error in insecticide application, unaccounted drift, and runoff from treated areas would all result in insecticides entering water. This section describes the effects to aquatic organisms that may be exposed to program insecticides.

a. Carbaryl.

1. Fish

Carbaryl is moderately toxic to most fish. The 96-hour median lethal concentration of carbaryl ranges from 0.35 mg/L in a static test of yellow perch to 39 mg/L in a flow-through test of bluegill (Mayer and Ellersieck, 1986). Species of catfish and minnow are generally 10 times more tolerant than salmonids. Acetylcholinesterase depression in brook trout has been observed following 1 lb/acre treatments, but AChE levels returned to normal within 48 hours (Hurlbert, 1978).

2. Aquatic Invertebrates

Carbaryl is very highly toxic to all aquatic insects and highly to very highly toxic to most aquatic crustaceans. The toxicity from 96-hour static tests ranged from 1.7 µg/L in the stonefly, *Pteronarcella badia*, to 1.9 mg/L in the shrimp, *Procambarus* sp. (Mayer and Ellersick, 1986). Treated streams may have a 50 to 100 percent reduction in aquatic insect populations (Burdick *et al.*, 1960), and recolonization may require up to 30 months after spraying (Gibbs *et al.*, 1984). Treatments with carbaryl may enhance aquatic algae growth (Murray and Guthrie, 1980).

3. Qualitative Assessment and Field Studies

Laboratory studies indicate that in aquatic ecosystems carbaryl would mostly affect the invertebrates and have little to no effect on the vertebrates. Based on the values included in the chemical background paper on environmental fate and transport modeling (USDA, APHIS, 1996b; see appendix C), carbaryl concentrations in water would be expected to range from 5 ppb in a stream receiving runoff from a treated area to 184 ppb in a shallow body of water directly sprayed with carbaryl. At those concentrations, the organisms that are at high risk and that are most likely to be found in the affected environment are cladocerans (*Daphnia* spp.). The amphipods (*Gammarus* spp.) and stonefly larvae (*Pteronarcys* sp., *Pteronarcella* sp., *Isogenus* sp.) are at moderate (streams) to high risk (ponds/wetlands).

Chironomid midges and fish such as trout, salmon, minnows, catfish, and bluegills are at negligible to low risk of adverse effects from carbaryl applications at the expected exposure rates.

In an ecological risk assessment, Sheehan *et al.* (1992) predicted the effects of carbaryl on nontarget organisms in aquatic ecosystems. According to their analysis, carbaryl would cause a 30 to 80 percent reduction in the invertebrate populations in prairie ponds. The populations would be expected to recover to normal levels in about 5 months. Carbaryl would potentially eliminate the most sensitive invertebrates, such as amphipods, for an extended period; chironomids (midges) would become dominant in the ponds, and there would be seasonal reductions in the invertebrates available as food for waterfowl.

Carbaryl's effects on nontarget aquatic organisms have been reported from field studies on prairie ponds (Beyers and McEwen, 1996) and the Little Missouri River (Beyers *et al.*, 1995) that were done in association with grasshopper control programs. These pond-monitoring studies showed that amphipod abundance declined in all ponds exposed to carbaryl. However, other taxa in the ponds were not affected (Beyers and McEwen, 1996).

In the Little Missouri River study (Beyers *et al.*, 1995), the maximum mean carbaryl concentrations were 85.1 ppb in a drought year and 12.6 ppb in a nondrought year. When the carbaryl concentrations were highest, invertebrate drift (invertebrates dislodged from the river bottom) was more variable in the Little Missouri River than at a reference site. This response was not considered to be biologically significant because natural events can cause greater effects than those attributed to the insecticide, and because only a small part of the Little Missouri River was affected. No effects were noticed in the fish in the Little Missouri River.

Carbaryl has the potential to affect the invertebrate assemblages in aquatic ecosystems. Although invertebrates may be reduced or possibly eliminated locally, these changes would not be permanent. Over the course of several months, it is likely that most, if not all, invertebrates would recover to levels that existed prior to the exposure to carbaryl. However, the loss of aquatic insects as food items for fish through carbaryl treatments has been associated with decreases in fish (DOI, FWS, 1986).

b. Diflubenzuron.

1. Fish

Toxicity of diflubenzuron to aquatic organisms varies by taxa. Diflubenzuron is slightly to practically nontoxic to fish. The median lethal concentration of diflubenzuron in water ranges from 10 mg/L for smallmouth bass to 660 mg/L in bluegill sunfish (Willcox and Coffey, 1978; Julin and Sanders, 1978).

2. Aquatic Invertebrates

Diflubenzuron is slightly to practically nontoxic to fish, aquatic snails, and most bivalve species. It is very highly toxic to most aquatic insects, crustaceans, horseshoe crabs, and barnacles. The median lethal concentration of diflubenzuron in water to immature stages of aquatic insects ranges from 0.5 µg/L in the mosquito *Aedes nigromaculatum* (Miura and Takahashi, 1974) to 57 mg/L in the perlodid stonefly *Skwala* sp. (Mayer and Ellersieck, 1986). The median lethal concentration of diflubenzuron in water to crustaceans ranges from 0.75 µg/L in *Daphnia magna* (Majori *et al.*, 1984) to 2.95 µg/L in the grass shrimp *Palaemonetes pugio* (Wilson and Costlow, 1986). The median lethal concentration of diflubenzuron in water to the snail *Physa* sp. is greater than 125 mg/L (Willcox and Coffey, 1978).

3. Qualitative Assessment and Field Studies

Although diflubenzuron has been shown to produce relatively benign effects to most terrestrial arthropods, the same is not the case for aquatic organisms, particularly freshwater crustaceans and aquatic insects. Tadpole shrimp, clam shrimp, water fleas, copepods, cladocerans, mayfly naiads, and midge larvae all showed temporary population reductions following diflubenzuron treatments (0.1 lb a.i./acre) (Miura and Takahashi, 1974, 1975). Adult aquatic beetles, spiders, and mosquito fish were not affected by diflubenzuron even at the highest rates tested. These results are consistent with the mode of action of diflubenzuron in that it effects primarily insects in immature life stages.

Effects on invertebrates in aquatic ecosystems depend upon the exposure and type of water body. In freshwater lakes, ponds, and marshes, the types of invertebrates most susceptible to diflubenzuron are amphipods (scuds), cladocerans, some midges, caddisflies, and mayflies (Ali and Mulla, 1978a, b; Apperson *et al.*, 1978; Eisler, 1992; Fischer and Hall, 1992; Hansen and Garton, 1992; Sundaram *et al.*, 1991). In flowing water ecosystems, diflubenzuron application rates of 0.4 to 0.8 oz a.i./acre reduced numbers of dipterans as well as cladocerans, copepods, mayfly nymphs, corixids, and springtails (Eisler, 1992). In particular, cladocerans (*Daphnia* sp.) and caddisflies (*Clistoronia* sp.) are at high risk of adverse effects from full coverage applications of diflubenzuron. Mayflies (*Callibaetis* sp.), amphipods (*Gammarus* sp.), and some midges (*Tanytarsus* sp.) are at moderate risk. Dragonfly larvae, stonefly larvae, aquatic beetles, crayfish, bivalves, chironomid midges, and snails are at low risk.

Vertebrates in freshwater ecosystems are not directly susceptible to diflubenzuron (Eisler, 1992). Fish such as trout, salmon, catfish, bluegill, and perch are at low risk from full coverage applications. However, when preferred food items of fish are reduced by diflubenzuron, the fish may respond by switching to other prey until the preferred items have returned to pretreatment abundances (Apperson *et al.*, 1978; Colwell and Schaefer, 1980).

In marine and brackish ecosystems, the grass shrimp, mysid shrimp, and crabs are at high risk from exposures to diflubenzuron at full coverage application rates. Other species such as snails and bivalves are at low risk. In one study, blue crabs were reduced nearly 50 percent after diflubenzuron was applied in a tidal pool (Hester *et al.*, 1986). However, it is unlikely that the grasshopper program would occur in marine or brackish water areas that support aquatic organisms such as crabs.

Diflubenzuron used for the grasshopper suppression program is unlikely to cause long-term damages to aquatic ecosystems. Some aquatic invertebrate assemblages could temporarily decrease if exposed to diflubenzuron. However, this decrease would not be permanent because of the rapid generation time of aquatic invertebrates.

Residues of insecticides entering flowing water (i.e., creeks) dissipate more readily than in ponds due to constant movement of water from upstream that lowers the potential exposure concentration. There are some aquatic insects that are at potential risk in ponds. The dissipation of insecticide residues in creeks diminishes the likelihood of exposure relative to ponds. Risks to wildlife species in creeks are generally negligible from program use of diflubenzuron.

c. Malathion .

1. Fish

The acute toxicity of malathion varies widely from slightly toxic to some species of fish to very highly toxic to other species. The median lethal concentration of malathion in water ranges from 10 µg/L for the common shiner (Domanik and Zar, 1978) to 38,000 µg/L for the Indian catfish (Singh and Singh, 1980). An analysis of the relative toxicity of malathion to taxonomic families (Macek and McAllister, 1970) determined that the least susceptible families include the catfish and minnows, and the most susceptible families include trout, salmon, perch, and sunfish.

2. Aquatic Invertebrates

Malathion is moderately to very highly toxic to most aquatic invertebrates. The median lethal concentration of malathion ranges from 0.5 µg/L in the scud (Mayer and Ellersieck, 1986) to 3,000 µg/L in the aquatic sowbug (Johnson and Finley, 1980). The median lethal concentration of malathion to insects ranges from 0.69 µg/L in the stonefly nymph to 385 µg/L in snipe fly larvae (Mayer and Ellersieck, 1986). The median lethal concentration of malathion to a bivalve is 12 µg/L (Mane *et al.*, 1984). A No Effect Concentration was determined for mud snail to be 22,000 µg/L (Eisler, 1970). Decreases in primary production and increases in respiration were found in aquatic phytoplankton at as low as 16 µg/L, but no effects on long-term survival were observed at concentrations as high as 200 mg/L (Rajendran and Venugopalan, 1983; Saha and Singh, 1981).

3. Qualitative Assessment and Field Studies

Malathion residues in water would vary according to the size of the water body and the amount of malathion applied. The amount of water-borne malathion residue that aquatic organisms would potentially be exposed to could range from 4.5 ppb in runoff water to 224 ppb in a directly sprayed small water body (USDA, APHIS, 1996b; see appendix C).

Malathion toxicity to aquatic organisms has been reported by Mayer and Ellersieck (1986). According to these laboratory studies, the aquatic organism most sensitive to malathion is the amphipod, *Gammarus*, which has a 96-hour LC_{50} of <1 ppb. Therefore, amphipod populations would be reduced if water was exposed to full coverage treatments. Other species at high risk from malathion full coverage applications in standing water include cladocera (*Daphnia* sp.), caddisflies (*Limnephilus* and *Hydropsyche* sp.), and damselfly larvae (*Lestes* sp.). Other insect larvae in flowing water such as stonefly larvae (*Pteronarcys*, *Pteronarcella*, and *Isoperla* sp.) are at moderate risk. In addition, snipe fly larvae (*Atherix* sp.) and shrimp (*Palaemonetes* sp.) are at moderate risk. Water sowbugs (*Asellus* sp.) are at low risk.

Fish are anticipated to show low to moderate risk from malathion in full coverage applications. Fish such as bluegill in shallow, standing water are at moderate risk, but catfish and largemouth bass are at low risk. Malathion in flowing waters would be rapidly diluted to concentrations that would not affect fish such as trout present in those waters. The greatest malathion concentrations and risk is to those species that inhabit ponds less than 1-foot deep that are directly sprayed.

A study of the effects of malathion applications in a worst-case scenario was conducted at Stewart's Creek in Alabama ((Kuhajda *et al.*, 1996). This study included surveillance of fish and aquatic invertebrate populations. The applications were made to cotton fields up to the edge of the creek bed. The conclusion based upon their data was that no adverse acute or long-term effects of malathion were evident in either the fish or aquatic invertebrate communities based upon numbers of individuals, numbers of taxa, and diversity indices over the 3-year study period. Based upon this study, it is anticipated that any applications of malathion in grasshopper programs, designed to avoid water, would not be expected to have any adverse acute or long-term effects on fish and aquatic invertebrates.

Malathion applied for grasshopper suppression could affect invertebrates, especially amphipods in aquatic ecosystems. These effects would soon be compensated for by the survivors, given the rapid generation time of most aquatic invertebrates and the rapid degradation of malathion in water. Therefore, malathion used for the grasshopper suppression program would not be likely to cause long-term, lasting effects to aquatic ecosystems. Organisms that feed on amphipods would likely switch temporarily to an alternate food source. If no alternate food source is available, the rapid generation time of amphipod assemblages means that the amphipod population would likely recover to pretreatment levels before the predator populations would be permanently affected.

Consequences of the Reduced Agent Area Treatments Alternative (RAATs)

This section describes the potential consequences of the reduced agent area treatments alternative to affect human health, environmental quality, and nontarget species. The consequences are based upon the representative field rates of application of each insecticide anticipated for this alternative as described in table B–4. The risks are assessed quantitatively and likelihoods of occurrence characterized. Relative risks of insecticide applications are characterized by comparison to comparable outcomes from the full coverage alternative to provide adequate information for informed decisions about potential risk. Basic hazard information already presented in the human health section (A.3.) and in the hazard and field studies descriptions (B.5.) is not repeated in this section except when this information pertains specifically to potential insecticide impacts under the RAATs.

1. Efficacy of Chemical Controls

Recent studies by Foster *et al.* (2000) have shown that the three insecticides APHIS could apply at conventional rates reduced grasshopper populations at 14 days after treatment by the following percentages: carbaryl spray, a 96 to 97 percent reduction; carbaryl bait, 35 to 85 percent reduction; diflubenzuron, a 98 percent reduction; and malathion, an 89 to 94 percent reduction.

The goal of grasshopper suppression under the RAATs alternative is to economically and environmentally suppress grasshopper populations to a desired level rather than to reduce those populations to the greatest possible extent. The efficacy of the RAATs alternative in reducing grasshoppers is therefore less than conventional treatments. The RAATs efficacy is also variable. Foster *et al.* (2000) reported that grasshopper treatment mortality using RAATs was reduced 2 to 15 percent from conventional treatments while Lockwood *et al.* (2000) reported 0 to 26 percent difference in mortality between the conventional and RAATs alternatives.

2. Human Health

The human health risks for each insecticide under RAATs alternative are similar to those under the full coverage suppression treatments, but the risk is diminished commensurate with the anticipated decreases in exposure. This section presents the risks relative to the reference doses for each insecticide and relative to comparable application scenarios under the full coverage suppression treatments for comparison of human health effects between the alternatives.

a. Carbaryl.

The lower application rates analyzed for the RAATs alternative result in lower potential for exposure than the full coverage suppression treatments. Therefore, just as with the general public under the full coverage suppression treatments, no exposures under the RAATs alternative exceed the systemic RfD of 0.01 mg/kg/day. Likewise, the estimated exposures that might occur to the public as a result of involvement in an event similar to the scenarios that were analyzed are not cause for concern.

For workers, on the other hand, all of the estimated exposure levels associated with the conventional application of carbaryl ULV exceed the RfD, with estimated doses resulting in HQs of 1 to 2000. This variability probably reflects differences in individual work habits

(SERA, 1993). In other words, workers who handle insecticides with proper care can reduce their exposure substantially. Conversely, poor work habits can increase exposure substantially.

At the lower and mid-ranges of exposure, it is unlikely that there would be overt signs of toxicity, even when the RfD is exceeded considerably (i.e., by factors of about 20 to 2,000). There are experimental studies in humans suggesting that doses of up to about 3 mg/kg (Gold *et al.*, 1982) will not be associated with signs of toxicity in humans.

At the high range of occupational exposure (i.e., about 18 mg/kg), the nature of potential adverse effects is less clear. Carbaryl has been used for many years, and reports of occupational poisoning, either published or anecdotal, were not encountered. On the other hand, no rigorous worker monitoring or epidemiology studies were found on the aerial application of carbaryl. Consequently, a precise characterization of risk is not possible. However, with good personal work practices, carbaryl may be handled safely. Poor work practices may present risks, but the likelihood of observing adverse effects cannot be well characterized. If such effects are observed, they would be those that are characteristic of AChE inhibitors.

Under all exposure scenarios, members of the general public do not appear to be at any risk to the potential reproductive effects of carbaryl, even using relatively conservative assumptions. Unlike the exposures under the full coverage treatments, exposure from the consumption of contaminated vegetation immediately after aerial applications under the RAATs alternative does not exceed the provisional RfD for reproductive effects of carbaryl. The exposure levels would diminish rapidly as the carbaryl degrades and disperses after application, so there are no concerns about exposures to the general public from applications under RAATs.

For workers, under the least conservative exposure assumptions, levels of plausible exposure are far greater than the provisional RfD for reproductive effects. For the application of carbaryl ULV, the central estimate of the absorbed dose, 1.8 mg/kg/day, is in the range of doses associated with fetotoxicity in dogs and the upper range of the estimated absorbed dose, 18 mg/kg/day, is above the level associated with teratogenic effects in dogs.

This does not necessarily mean that teratogenic effects or reproductive impairment in humans can be predicted from or attributed to carbaryl exposure. Nonetheless, standard criteria and procedures are used for estimating the provisional RfD. Plausible levels of exposure are far above this provisional RfD.

The lower application rate under the RAATs strategy results in commensurately lower overall exposures. The rapid degradation of carbaryl and infrequent program applications makes it unlikely that high enough doses to induce cumulative toxic responses could occur to workers and the general public. Proper protective measures and routine monitoring can prevent excessive exposures and adverse effects to workers. Although effects from connected actions and effects to groups at special risk remain possible, the lower potential exposures resulting from actions taken under this alternative make these effects less likely than under the full coverage suppression alternative.

b. Diflubenzuron. The same reference doses derived for methemoglobinemia protection under the full coverage control treatments derived for both workers and the general public are used for comparison to the estimates of dose from the exposure assessment at the RAATs rate to calculate hazard quotients for each exposure scenario.

HQs determined for aerial spray workers, for both routine and extreme exposures, were all less than 1, indicating that these workers are not at risk of adverse effects from grasshopper program operations that use diflubenzuron. Scenarios representing workers involved in accidental exposures also resulted in HQs less than 1 if they washed within an hour. Therefore, accidents would not cause concern about the health effects on these workers. Circumstances that prevent a worker from washing until 24 hours after spilling diflubenzuron on the lower legs would be cause for concern. In this case the HQ could be as high as 20.

A number of scenarios were analyzed to help characterize risk to the general public. The calculated HQs were less than 1 for most of these public exposures; therefore, adverse health effects clearly are not anticipated. The HQs for a few of the extreme scenarios ranged from 1 to 5. Even in these cases, no clinically significant effects are likely. At the highest exposure, increases in certain blood pigments may be detected, but they will not be long-lasting.

The lower application rate under the RAATs alternative results in commensurately lower overall exposures. Although cumulative effects, effects from connected actions, and effects to groups at special risk remain possible, the lower potential exposures resulting from actions taken under this alternative make these effects less likely than under the full coverage control alternative.

c. Malathion. For the general public, none of the exposure scenarios under the RAATs alternative involve levels that exceed the RfD and most are far below the RfD. The assessment of inhalation exposure is based on a TLV that was normalized for an exposure that would occur over an 8-hour workday, 5 days per week. When normalized for this continuous exposure, this reference level is equivalent to a factor of about 6,000 above plausible levels of estimated exposure. Therefore, although the adjusted TLV does not incorporate additional uncertainty factors for sensitive subgroups or data quality, even very conservative adjustments would not result in HQs of concern.

For workers, estimates of daily absorbed doses that are associated with the maximum application rate of malathion span the RfD: 0.006 mg/kg to 0.6 mg/kg. The variability in the exposure estimates reflects the variability in the data on which the assessment is based. Under routine conditions, aerial spray workers may be exposed to doses that result in HQs of from 0.3 to 30. All accidental scenarios, based on the estimated amount of malathion handled per day, result in HQs more than 1 (from 2 to 8).

The implications of these HQs greater than 1 are difficult to assess. Although AChE inhibition is possible at the estimated levels of exposure, it is far less certain that these exposure levels would be associated with any signs of toxicity. This is consistent with human experience. Aerial applications of malathion have been conducted in previous years to control grasshoppers and other pests, and signs of severe nervous system impairment have not been reported in the open literature or in unpublished or anecdotal reports. Although the upper range of plausible exposure, 0.6 mg/kg/day, is above the level that has been demonstrated to cause AChE inhibition in humans, it is well below the range at which adverse effects have been demonstrated.

The lower application rates under the RAATs alternative result in commensurately lower overall exposures. The rapid degradation of malathion and infrequent program applications makes it unlikely that high enough doses to induce cumulative toxic responses could occur to the general public. Proper protective measures and routine monitoring can prevent excessive exposures and adverse effects to workers. Although effects from connected actions and effects to groups at special risk remain possible, the lower potential exposures resulting from actions taken under this strategy make these effects less likely than under the full coverage control strategy.

3. Physical Environment

The impacts to the physical environment from the RAATs alternative are expected to be similar, but of less intensity than those from the full coverage treatments. Projections of the intensity are all based upon output using the Forest Service Cramer Barry Grim (FSCBG) (Curbishley and Skyler, 1989) and GLEAMS modeling as described in the environmental fate background paper (USDA, APHIS, 1996b; see appendix C).

The primary environmental fate considerations for carbaryl relate to water issues. Carbaryl is unlikely to percolate to groundwater, but may occur in runoff waters following rainstorms. The concentrations following a 1.5-inch rainstorm are predicted to be 3 ppb in streams and 8 ppb in 6-foot-deep ponds. Directly sprayed 1-foot-deep ponds are projected to have carbaryl concentrations from 84 to 112 ppb. The program protective measures are designed to avoid direct treatment of water bodies, so these concentrations are not expected when monitoring most control programs. Carbaryl has low vapor pressure, and volatilization to the atmosphere is minimal. The rapid rate of degradation, metabolism, and excretion of carbaryl results in minimal capacity to bioconcentrate or bioaccumulate. Concentrations in organisms generally decrease consistent with the rapid rate of metabolism and degradation.

Diflubenzuron concentrations in most components of the physical environment are expected to be low and its persistence minimal. Diflubenzuron is not predicted to enter groundwater. Concentrations in streams and ponds receiving runoff following a 1.5-inch rainstorm are projected to be well below 0.1 ppb, and most aquatic habitats should not be adversely affected by runoff. Directly sprayed ponds of 1-foot in depth are predicted to have concentrations of less than 3 ppb, which could affect the more sensitive nontarget aquatic species. Diflubenzuron is readily metabolized by animals but is persistent on leaf surfaces where it can bioaccumulate. This persistence on vegetation results in residues from leaves falling into water in fall and exposing aquatic organisms throughout the winter (Wimmer, *et al.*, 1993). These conditions are unlikely to occur in most rangeland and croplands where the grasshopper program will occur.

Malathion is unlikely to persist in any component of the physical environment. Rapid degradation, metabolism, and excretion prevent bioconcentration and bioaccumulation. Malathion is not expected to reach groundwater in detectable concentrations. Concentrations of malathion in waters receiving runoff from a 1.5-inch rainstorm are predicted to be 6 ppb in 6-foot-deep ponds and less than 3 ppb in streams. Directly sprayed 1-foot-deep ponds are projected to have concentrations as high as 137 ppb. The program procedures and adherence to pesticide labels are designed to avoid direct treatment of water bodies, so these concentrations are not expected when monitoring grasshopper suppression programs.

4. Nontarget Terrestrial Species

The assessment of nontarget terrestrial species concentrates on quantitative calculations of exposures to vertebrate species from the RAATs alternative and the potential for toxic effects from those exposures. These effects are less than those anticipated from full coverage treatments. Some qualitative statements are given about the effects on invertebrate populations from applications and how these lower exposures under RAATs application affect predators and other organisms that depend upon invertebrates for prey or other needs.

a. Carbaryl. The output from terrestrial vertebrate exposure modeling of doses from carbaryl at RAATs rates is summarized in table B–9. The highest potential doses to representative vertebrates are shown for the lark bunting, grasshopper mouse, horned lizard, and Woodhouse's toad. These insectivorous species consume considerable quantities of grasshoppers and other rangeland invertebrates, so they would be expected to receive higher doses than omnivores, herbivores, and vertebrate carnivores. The highest potential doses of carbaryl to wildlife species would be received by the target insects (grasshoppers and crickets) and other nontarget invertebrates present within the treatment areas.

Based upon the quantitative calculations of doses of carbaryl to vertebrate species, vertebrate animals are at negligible risk of adverse toxicological effects from the RAATs alternative. Unlike at the full coverage treatments, even populations of the grasshopper mouse are at low risk of adverse effects from the RAATs alternative.

The toxic effects of carbaryl from the RAATs alternative will be most evident as decreases in susceptible invertebrate populations. The immediate effect of a treatment results in more limited predator avoidance by susceptible insects within the treatment area and easier foraging for insectivorous species there. This is followed by rapid decreases in population density of the susceptible species and the need for more widespread foraging by the insectivorous species. The decrease in populations of susceptible insects following carbaryl treatments is expected to be temporary with rapid recolonization of the treated areas from surrounding range and croplands. The use of alternate swaths as part of the RAATs alternative will be expected to increase the rate of recolonization and result in less drastic fluctuations in nontarget insect populations within the treatment areas following carbaryl applications.

TABLE 1-9: Estimated Daily Doses of Carbaryl from Reduced Agent Area Treatments to Vertebrate Nontarget Species and Corresponding Reference Levels

		Reference Dose		
Representative Species	Estimated Dose	1/5 LD_{50}	LD_{50}	Reference Species
Birds				
Lark bunting	40.85	156	780	Sharp-tailed grouse
Sage grouse	7.26	156	780	Sharp-tailed grouse
Bobwhite quail	29.85	458	2,290	Japanese quail
American kestrel	26.35	156	780	Sharp-tailed grouse
Mammals				
Grasshopper mouse	36.83	55	275	Mouse
Blacktail jackrabbit	7.12	142	710	Rabbit
Pronghorn antelope	3.64	40	200	Mule deer
Domestic cattle (*Bovine* spp.)	1.53	40	200	Mule deer
Coyote	2.12	30	150	Cat
Reptiles and Amphibians				
Horned lizard	40.49	156	780	Sharp-tailed grouse
Eastern yellow-belly racer	7.81	800	4,000	Bullfrog
Woodhouse’s toad	38.40	156	780	Sharp-tailed grouse

b. Diflubenzuron. The output from terrestrial vertebrate exposure modeling of doses from diflubenzuron from the RAATs alternative is summarized in table B–10. The highest potential doses to representative vertebrates are shown for the lark bunting, grasshopper mouse, horned lizard, and Woodhouse's toad. These insectivorous species consume considerable quantities of grasshoppers and other rangeland invertebrates, so they would be expected to receive higher doses than omnivores, herbivores, and vertebrate carnivores. The highest potential doses of diflubenzuron to wildlife species would be received by the target insects (grasshoppers and crickets) and other nontarget invertebrates present within the treatment areas. The use of alternate swaths as part of the RAATs alternative will be expected to increase the rate of recolonization and result in less drastic fluctuations in nontarget insect populations within the treatment areas following diflubenzuron applications.

Table B–10.Estimated Daily Doses of Diflubenzuron from Reduced Agent Area Treatments to Vertebrate Nontarget Species and Corresponding Reference Levels

TABLE 1-10: Estimated Daily Doses of Carbaryl from Reduced Agent Area Treatments to Vertebrate Nontarget Species and Corresponding Reference Levels

		Reference Dose		
Representative Species	**Estimated Dose**	**1/5 LD_{50}**	**LD_{50}**	**Reference Species**
Birds				
Lark bunting	3.19	752	3762	Red-winged blackbird
Sage grouse	0.45	>1000	>5000	Mallard duck
Bobwhite quail	1.66	>1000	>5000	Bobwhite quail
American kestrel	1.61	>1000	>5000	Mallard duck
Mammals				
Grasshopper mouse	2.58	928	4640	Mouse
Blacktail jackrabbit	0.44	928	4640	Rabbit
Pronghorn antelope	0.20	928	4640	Rabbit
Domestic cattle (*Bovine* spp.)	0.08	928	4640	Rabbit
Coyote	0.17	928	4640	Rabbit
Reptiles and Amphibians				
Horned lizard	1.81	752	3762	Red-winged blackbird
Eastern yellow-belly racer	0.86	752	3762	Red-winged blackbird
Woodhouse’s toad	12.42	752	3762	Red-winged blackbird

c. Malathion. The output from terrestrial vertebrate exposure modeling of doses from malathion from the RAATs alternative is summarized in table B–11. The highest potential doses to representative vertebrates are shown for the lark bunting, grasshopper mouse, horned lizard, and Woodhouse's toad. These insectivorous species consume considerable quantities of grasshoppers and other rangeland invertebrates, so they would be expected to receive higher doses than omnivores, herbivores, and vertebrate carnivores. The highest potential doses of malathion to wildlife species would be received by the target insects (grasshoppers and crickets) and other nontarget invertebrates present within the treatment areas.

Based upon the quantitative calculations of doses of malathion to vertebrate species, most animals are at negligible risk of adverse toxicological effects from the RAATs alternative. The species that are at greater risk include the bobwhite quail, American kestrel, and Woodhouse's toad. Although the risk to these species would be characterized as moderate, their potential doses are at the lower end of the moderate effects. It is considerably less likely that any individuals of these species at risk would suffer mortality from the use of the RAATs alternative than from the full coverage alternative. However, neurological effects from exposure to malathion could affect feeding efficiency, predator avoidance, and other necessary survival techniques of those species.

TABLE 1-11: Estimated Daily Doses of Malathion from Reduced Agent Area Treatments to Vertebrate Nontarget Species and Corresponding Reference Levels

Representative Species	Estimated Dose	Reference Dose 1/5 LD_{50}	LD_{50}	Reference Species
Birds				
Lark bunting	48.31	81	403	Horned lark
Sage grouse	8.49	30	150	Chicken
Bobwhite quail	34.57	30	150	Chicken
American kestrel	30.78	30	150	Chicken
Mammals				
Grasshopper mouse	43.80	115	775	Mouse
Blacktail jackrabbit	8.33	50	250	Rabbit
Pronghorn antelope	4.25	11	53	Cattle
Domestic cattle (*Bovine* spp.)	1.77	11	53	Cattle
Coyote	2.14	72	360	Dog
Reptiles and Amphibians				
Horned lizard	47.06	465	2324	Carolina anole
Eastern yellow-belly racer	9.25	30	150	Chicken
Woodhouse’s toad	45.15	30	150	Chicken

The toxic effects of malathion from the RAATs alternative will be most evident as decreases in susceptible invertebrate populations. The immediate effect of a treatment results in more limited predator avoidance by susceptible insects within the treatment area and easier foraging for insectivorous species there. This is followed by rapid decreases in population density of the susceptible species and the need for more widespread foraging by the insectivorous species. The decreases in populations of susceptible insects following malathion treatments under the RAATs alternative are expected to be minimal with rapid recolonization of the treated areas from the surrounding range and croplands. The use of alternate swaths and reduced application rates as part of the RAATs alternative will further limit the adverse effects to nontarget insect populations and thereby, minimize any potential adverse effects on foraging of insectivorous vertebrate species.

Nontarget Aquatic Species

This section describes the potential risks to nontarget species from the RAATs alternative. The risk and the likelihood of occurrence is characterized qualitatively. Basic toxicological information and results of field studies were described in the section covering consequences of full coverage treatments to nontarget aquatic species. This information will not be repeated here except as it can be directly applied to the RAATs alternative.

a. Carbaryl. Laboratory studies indicate that in aquatic ecosystems carbaryl would mostly affect the invertebrates and have little to no affect on the vertebrates. Based on the predicted water concentrations included in of the chemical background paper on environmental fate and transport modeling (USDA, APHIS, 1996b; see appendix C), carbaryl concentrations in water would be expected to range from 3 ppb in a stream receiving runoff from a treated area to 112 ppb in a shallow body of water directly sprayed with carbaryl. At those concentrations, cladocerans (*Daphnia* spp.) are at moderate (streams) to high (ponds) risk. The amphipods (*Gammarus* spp.) and stonefly larvae (*Pteronarcys* sp., *Pteronarcella* sp., *Isogenus* sp.) in ponds and streams are at moderate risk. Chironomid midges and fish such as trout, salmon, minnows, catfish, and bluegills are at negligible to low risk of adverse effects from carbaryl applications at the expected exposure rates.

Carbaryl has the potential to affect the invertebrate assemblages in aquatic ecosystems, but is unlikely to affect vertebrates such as fish at any concentrations that could be expected in the water. Although invertebrate populations may be reduced, these changes would not be permanent. Over the course of several months, it is likely that most invertebrates would recover to levels that existed prior to the exposure to carbaryl. The use of alternate swaths as part of the RAATs alternative will be expected to further decrease exposure of aquatic species from the low effects under the conventional alternative. This decreased exposure will coincide with commensurate increases in rates of recolonization and decreases in the fluctuation of populations of aquatic organisms.

b. Diflubenzuron. Effects on invertebrates in aquatic ecosystems depend upon the exposure and type of water body. Modeling results indicate that concentrations vary from 0.01 ppb in streams receiving runoff water following rainfall to 4.3 ppb in a 1-foot deep body of water receiving a direct application. In particular, caddisflies (*Clistoronia* sp.) in ponds are at high risk of adverse effects from full coverage applications of diflubenzuron. Mayflies (*Callibaetis* sp.) and cladocerans (*Daphnia* sp.) in streams are at moderate risk. Dragonfly larvae, stonefly larvae, aquatic beetles, crayfish, bivalves, chironomid midges, amphipods (*Gammarus* sp.), and snails are at low risk.

Fish such as trout, salmon, catfish, bluegill, and perch are at low risk from the RAATs alternative. However, when preferred food items of fish are reduced by diflubenzuron, the fish may respond by switching to other prey until the preferred items have returned to pretreatment abundances (Apperson *et al.*, 1978; Colwell and Schaefer, 1980).

In marine and brackish ecosystems, the grass shrimp, mysid shrimp, and crabs are at high risk from exposures to diflubenzuron at reduced agent area treatment rates. Other species such as snails and bivalves are at low risk. However, it is unlikely that grasshopper program activities would occur in marine or brackish water areas that support aquatic marine or estuarine organisms.

Diflubenzuron used for the grasshopper suppression program is unlikely to cause permanent, long-term damages to aquatic ecosystems. Populations of some aquatic invertebrates could temporarily decrease if exposed to diflubenzuron, but the rapid generation time of these aquatic invertebrates would ensure rapid recolonization. The use of alternate swaths as part of the RAATs alternative will be expected to further decrease exposure of aquatic species from the low effects under the conventional alternative. This decreased exposure will coincide with commensurate increases in rates of recolonization and decreases in the fluctuations of populations of aquatic organisms.

Residues of pesticides entering flowing water (i.e., creeks) dissipate more readily than in ponds due to constant movement of water from upstream that lowers the potential exposure concentration. There are some aquatic insects that are at potential risk in ponds. The dissipation of pesticide residues in creeks diminishes the likelihood of exposure relative to ponds. Risks to wildlife species in creeks are generally negligible from program use of diflubenzuron.

c. Malathion. Malathion residues in water would vary according to the size of the water body and the amount of malathion applied. The amount of water-borne malathion residue that aquatic organisms would potentially be exposed to could range from 2.8 ppb in runoff water in a stream to 137 ppb in a directly sprayed small water body.

As with the full coverage treatments, amphipod populations (*Gammarus* sp.) and cladocera *(Daphnia* sp.) would be reduced from treatments applied under the RAATs alternative. However, other species such as caddisflies (*Limnephilus* and *Hydropsyche* sp.), damselfly larvae (*Lestes* sp.), and stonefly larvae (*Pteronarcys*, *Pteronarcella*, and *Isoperla* sp.) are at moderate risk. Snipe fly larvae (*Atherix* sp.), shrimp (*Palaemonetes* sp.), and water sowbugs (*Asellus* sp.) are at low risk.

All fish are anticipated to show low risk from malathion in RAATs applications. Malathion in flowing waters would be rapidly diluted to concentrations that would not affect fish present in those waters. The greatest malathion concentrations and risk is to those species that inhabit ponds less than 1-foot-deep that are directly sprayed. This could affect species such as minnows that occur in shallow ditches and temporary standing water bodies.

A study of the effects of malathion applications in a worst-case scenario was conducted at Stewart's Creek in Alabama (Kuhajda *et al.*, 1996). This study included surveillance of fish and aquatic invertebrate populations. The applications were made to cotton fields up to the edge of the creek bed. The conclusion based upon their data was that no adverse acute or long-term effects of malathion were evident in either the fish or aquatic invertebrate communities based upon numbers of individuals, numbers of taxa, and diversity indices over the 3-year study period. Based upon this study, it is anticipated that any applications of malathion in grasshopper programs, designed to avoid water, would not be expected to have any adverse acute or long-term effects on fish and aquatic invertebrates.

Malathion applied for grasshopper suppression could affect invertebrates, especially amphipods and cladocerans in aquatic ecosystems. These effects would soon be compensated for by the survivors, given the rapid generation time of most aquatic invertebrates and the rapid degradation of malathion in water. Therefore, malathion applied at reduced agent area treatment rates would not be likely to cause long-term, lasting effects to aquatic ecosystems. Organisms that feed on amphipods would likely switch temporarily to an alternate food source. If no alternate food source is available, the rapid generation time of amphipod assemblages means that the amphipod population would likely recover to pretreatment levels before the predator populations would be permanently affected. The use of alternate swaths as part of the RAATs alternative will be expected to further decrease exposure of aquatic species from the low effects under the conventional alternative. This decreased exposure will coincide with commensurate increases in rates of recolonization and decreases in the fluctuations of populations of aquatic organisms.

Appendix C. Environmental Fate and Transport Modeling for Grasshopper Insecticides

Methodology

A. Residues on Vegetation and Soil/Litter Surface. The Forest Service Cramer Barry Grim (FSCBG) model simulates aerial dispersion of insecticides using the initial insecticide droplet size distribution, aircraft speed, aircraft type, and meteorological conditions to calculate the trajectory of a falling droplet of insecticide. The spatial area modeled includes all of the spray area (spray block) and a portion of the area adjacent to the spray block. The average mass of insecticide within the spray block was calculated, as well as the maximum, minimum, and standard deviation. Based on typical application rates, three rates of application were used for carbaryl (0.375, 0.400, and 0.500 pound active ingredient/acre (lb a.i./acre)), two rates of application were used for diflubenzuron (0.0078 and 0.0156 lb a.i./acre), and one rate of application was used for malathion (0.61 lb a.i./acre). Carbaryl, diflubenzuron, and malathion residues were estimated by modeling a single application as well as a second application at the same rate 1 week later. This model does not apply to ground applications of the insecticides.

The parameter values chosen, mostly from handbooks on aerial application equipment and from insecticide labels, represent the environmental conditions and equipment commonly encountered during a spray program (table C–1). However, many combinations of aircraft, spray equipment, and meteorological conditions were not addressed. Residues predicted by FSCBG generally represent those expected from aerial spraying. Site-specific conditions may cause actual residues to deviate from those predicted using the parameter values given in table C–1.

The parameters that substantially affect model output include release height, wind speed, aircraft speed, aircraft type, and application rate (Teske and Curbishley, 1990). Although the model is not very sensitive to changes in temperature or humidity, it is very sensitive to wind speed and release height (Teske *et al.*, 1991). The wind was modeled as a 2 miles per hour (mph) crosswind perpendicular to the flight lines. This wind speed was selected to result in the maximum deposition on vegetation and the soil surface. Greater wind speeds would cause more of the insecticide to drift away from the target area, whereas lower wind speeds would not allow the proper amount of turbulent mixing required for even coverage. A 4.92-foot story canopy was used to simulate a rangeland with sagebrush. The release height above the canopy varied among the insecticides (45 feet for carbaryl, 50 feet for diflubenzuron, and 25 feet for malathion). The actual release height can range from 25 to 50 feet in the grasshopper program. These release heights were selected to give the most even coverage of insecticide given the aircraft, nozzle type, and wind speed. The model was run in the "near wake" mode of FSCBG to calculate the percentage of the insecticide on the soil surface or in the canopy.

TABLE 1-1: Forest Service Cramer Barry Grim (FSCBG) Model Parameters

Parameters	Carbaryl	Diflubenzuron	Malathion
Wind speed (mph)	2	2	2
Wind direction (°)	90	90	90
Temperature (°F)	60	60	60
Humidity (%)	85	85	85
Release height (ft)	45	50	25
Emission rate (fl oz/acre)	12/12.8/16	3/7	8
Active fraction	0.49	0.90	0.95
Aircraft type	Turbo Thrush	Cessna 188	Cessna 188
Nozzle type	8010	8001	8001
Swath width (ft)	125	75	75
Aircraft speed (mph)	100	100	100
Density of carrier (g/cm^3)	0.999	1.19	1.23
Canopy type	1.5 m brush	1.5 m brush	1.5 m brush
Model type	◆ Near Wake ◆ No evaporation	◆ Near Wake ◆ Evaporation	◆ Near Wake ◆ Evaporation

The model has been validated in the field using data obtained from an aerial application of the insecticide Asana® XL to a seed orchard (Teske *et al.*, 1991). The validation results suggest that FSCBG adequately represented the spray system, although during the validation runs the model generally over predicted the average insecticide mass within the spray block by 12.9 percent.

Several factors contribute to uncertainty in the results of the aerial dispersion model. Small differences in release heights resulted in large differences in the estimated concentrations of the insecticides. Since it is unlikely that a pilot would maintain a constant altitude during aerial application, the actual deposition may deviate from the model predictions. Meteorological conditions (wind, temperature, and relative humidity) vary throughout a spray application and may also affect deposition, although this variation is not considered by FSCBG. FSCBG assumes, unrealistically, that the canopy is homogeneous throughout the spray block. Even when using the same configuration of aircraft and spray equipment, these factors combine to create more variability in observed residue levels than predicted by the model. In addition, different spray equipment, aircraft, and aircraft speeds can be expected to produce dissimilar distributions of residues. Despite the uncertainties associated with the model, it produces reasonable results when compared to monitoring results and can simulate residue levels following application rates for which no monitoring data are available.

B. Degradation of Insecticides on Vegetation Over the Growing Season

Carbaryl residues have a half-life on vegetation of 7 days, resulting in a 50 percent reduction after 1 week Groundwater Loading Effects of Agricultural Management Systems (GLEAMS). Diflubenzuron residues decrease over time due to degradation of the insecticide on vegetation. Diflubenzuron residues were determined for leaves immediately after application and at the end of the growing season. The half-life of diflubenzuron used in the GLEAMS model is 27 days, resulting in a 16 percent reduction in residues after 1 week. Malathion residues have a half-life on vegetation of 1 to 2 days on onions and 3 to 4 days on lettuce. The half-life used in this analysis in the GLEAMS model was 3 days, resulting in a 80 percent reduction after 1 week.

C. Insecticide Concentrations

1. Insecticide Concentration on Leaves and in Leaf Litter

A. Insecticide Concentration on Leaves

Insecticide concentration on leaves was not explicitly calculated. Carbaryl and malathion residues are not expected to persist throughout the growing season, in contrast to diflubenzuron which will persist. If diflubenzuron is applied before leaves have fully expanded, concentration will decrease over the growing season, as leaf weight and surface area increase as the leaves expand. In an eastern deciduous hardwood, an average of 46 percent of the original residue remained on the upper canopy leaves at leaf-drop, while 62 percent remained on lower canopy leaves (Wimmer *et al.*, 1993).

B. Insecticide Concentration in Leaf Litter

Of the three proposed program insecticides (carbaryl, diflubenzuron, and malathion), only diflubenzuron is predicted to persist in leaf litter. Diflubenzuron may persist in leaf litter for the growing season following application; however, the concentration was not explicitly calculated.

2. Insecticide Concentration in Soil

Concentrations of carbaryl, diflubenzuron, and malathion in the soil were estimated with the GLEAMS model. Model parameters were selected from insecticide profiles included with GLEAMS (table C–2). The soil parameters were selected to maximize runoff following a storm, giving a conservative estimate of insecticide concentrations in receiving waters. The soil was a sandy loam covered with fair quality rangeland. Of the treatment area, 70 percent was covered with vegetation and 30 percent was bare soil. Comparing insecticide runoff 24 hours after application from a simulated treatment area containing only bare soil to a vegetated treatment area, resulted in a lower runoff concentration in bare soil for diflubenzuron, whose soil half-life was less than its foliar half-life. Otherwise, the bare soil treatment area had slightly greater insecticide runoff concentrations than the vegetated area. The greatest insecticide concentration in runoff water occurs when soils have high Soil Conservation Service (SCS) runoff coefficients, poor quality vegetative cover, high proportions of clay, high proportion of impervious surfaces within the watershed, and steep slopes.

TABLE 1-2: Summary of Groundwater Loading Effects of Agricultural Management Model (GLEAMS) Input Parameters

Input Parameters	Carbaryl	Diflubenzuron	Malathion
Insecticide Data			
Number of insecticides	1	1	1
Water solubility (mg/L)	120	0.08	130
Foliar half-life (days)	7	27	3
Soil half-life (days)	10	10	1
Partitioning coefficient	300	10000	1800
Initial concentration on foliage	0	0	0
Initial concentration on soil	0	0	0
Fraction available for washoff	0.55	0.05	0.9
Coefficient of uptake by plants	0	0	0.4
Depth of incorporation (inches)	0.3937	0.3937	0.3937
Fraction of insecticide applied to foliage	0.7	0.7	0.7
Fraction of insecticide applied to soil	0.3	0.3	0.3
Hydrology Data			
Irrigation	No	No	No
Area of field (acre)	61.776	61.776	61.776
Effective saturated conductivity below rooting zone	0.1181	0.1181	0.1181
Effective saturated conductivity above rooting zone (inches/hr)	0.3937	0.3937	0.3937
Fraction of plant available water	0.5	0.5	0.5
Soil evaporation	3.5	3.5	3.5
SCS Curve	82	82	82
Slope	0.1	0.1	0.1
Field length/width ratio	1.0	1.0	1.0
Effective rooting depth (inches)	12	12	12
Soil porosity (cc^3/cc^3)	0.43	0.43	0.43
Soil field capacity (cm/cm)	4.724	4.724	4.724
Wilting point (cm/cm)	0.30	0.30	0.30
Organic matter content	2.25	2.25	2.25
Soil type	Silty clay	Silty clay	Silty clay
Percent Clay	45	45	45
Percent Silt	45	45	45
Specific surface area clay (m^2/g)	20	20	20
Soil erodibility factor	0.495	0.495	0.495
Erosion Data			
Soil loss ratio	0.4	0.4	0.4
Contouring factor	0.5	0.5	0.5
Manning’s n	0.06	0.06	0.06

Following application, insecticides remained in the upper soil layer (0.39 inch) until a rainfall event. Rainfall (1 inch, 1.5 inch, or 2.5 inch) on the day of spraying or the following day resulted in detectable insecticide concentrations in the lower soil layers. Malathion, at an application rate of 9.753 ounces (oz) a.i./acre, resulted in the highest soil concentrations (2.65 parts per million (ppm)) following a rainfall event. Higher concentrations of insecticides could be expected in soils with low SCS runoff coefficients, excellent quality vegetative cover, and gentle slopes. Arid conditions would tend to increase insecticide concentrations in soil and decrease them in runoff water.

3. Insecticide Concentration in Waters

A. Insecticide Concentration in Directly Sprayed Waters

Insecticides are not applied directly to large bodies of water in grasshopper programs. Inevitably, however, small water bodies such as streams, vernal pools, cattle tanks, springs, and puddles are inadvertently sprayed. In order to provide a conservative (maximized) estimate of exposure, insecticide concentrations following direct application to these small water bodies are calculated. The pond was assumed to be cylindrical in shape. The concentration was determined by calculating the total residue falling on the surface and then dividing the mass by a volume of water, which varied according to depth of the water body. Mixing was assumed to be instantaneous. The stream was assumed to be triangular in cross section. The total mass of insecticide falling on the surface of a 3.28-foot long segment was calculated. Concentration was determined by dividing this mass by the volume of water in a 3.28-foot long stream segment.

B. Insecticide Concentration in Aquatic Sediments

Concentrations of diflubenzuron in the sediments were assumed to be 2 percent of the concentration in the water column based on a monitoring study by Kingsbury *et al.* (1987).

C. Metabolic Products of the Insecticides (4-chloroaniline and Malaoxon)

Concentrations of 4-chloroaniline in the water column were assumed to be 10 percent of the water column concentration of diflubenzuron based on monitoring following diflubenzuron treatment of a flooded pasture (Schaefer *et al.*, 1980). Malathion in chlorinated water bodies (swimming pools) readily metabolizes to malaoxon. Malaoxon concentrations in non-chlorinated waters are much lower than malathion concentrations.

D. d. Insecticide Concentration in Runoff Water

The GLEAMS model was used to estimate the insecticide concentration in runoff water from a sprayed watershed. Model parameters were selected to simulate the highest concentrations of insecticide that could reasonably be expected to provide a worst case scenario for aquatic organisms.

Parameter estimates were obtained from soil surveys, agricultural Insecticide handbooks, and from the GLEAMS insecticide data files (table C–2). For the simulation, the vegetation canopy coverage was assumed to be 70 percent. Insecticide was applied to fair-condition[1] rangeland on a soil of hydrologic group D, thus minimizing infiltration and maximizing runoff to provide a conservative estimate of risk for aquatic organisms.

Three different storm intensities were simulated (1 inch, 1.5 inch, or 2.5 inch). Insecticide concentrations in the 1-inch storm were negligible. Maximum concentrations of insecticides in runoff water were observed when a 1.5-inch rainstorm occurred shortly after application. (This scenario was selected for the analysis.) Although more runoff was produced with the 2.5-inch storm, the insecticide concentrations in the runoff water, stream, and pond were lower than that observed with the 1.5-inch storm.

Many parameter values used in the GLEAMS model (i.e., slope, cover type, and soil composition) are site-specific; therefore, insecticide concentration in runoff from particular sites may be different from values predicted by the model. The GLEAMS model results used in this analysis could be considered a worst case scenario for silty clay soils. Therefore, the concentration of insecticide used in this analysis probably overestimates actual concentrations in many sites. This type of estimate is useful in the risk analysis because it sets an upper limit on the expected response of aquatic organisms to insecticide applications in the field.

E. e. Insecticide Concentrations in Waters Receiving Runoff

Insecticides are not applied directly to large bodies of water, although small rangeland water bodies may inadvertently receive a direct spray or drift. For the purposes of this analysis, the concentration of insecticides in a small stream,

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[1] Refers to SCS runoff curve, i.e., poor, fair, good, and excellent.

directly sprayed, was determined as a worst case scenario. The concentration of insecticides in a small stream and shallow pond receiving runoff from the sprayed area, but not directly sprayed, were also determined.

The surface-water model used in this analysis to estimate insecticide concentrations in streams and ponds was developed specifically to analyze the effects of nonpoint runoff in a watershed after aerial spraying. This model contains few site-specific parameters, and is used only to give an approximate estimate of insecticide in streams or ponds receiving runoff. Concentrations of insecticide at specific sites can reasonably be expected to vary from model predictions. The model predicts the concentration of insecticides in a stream and a pond in a small watershed (5,760 acres, or 9-square miles (mi^2). The entire watershed was assumed to be sprayed with insecticide. The watershed consists of a 2.1-mile-long stream that drains 52.2 percent of the watershed before emptying into a 1,227-foot-diameter pond. The remaining 47.8 percent of the watershed drains directly into the pond via overland flow. The length of the stream was determined to be the average length of a second order stream draining a watershed of 3,008 acres (or 4.7 mi^2) (van der Leeden *et al.*, 1990). The surface area of the pond was determined by calculating the surface water body size for a watershed of 5,760 acres (or 9 mi^2) using the average basin-to-lake ratio of 212 to 1 reported by Reckhow and Chapra (1983). The simulated pond is 6.56 feet deep. Water enters the pond from overland runoff and from the stream. Water leaves the pond through a drainage outlet and from evaporative loss. Water loss due to evaporation is based on the evaporation rate (van der Leeden *et al.*, 1990) and the available surface area for evaporation (i.e., surface area of the pond). The water level of the pond is assumed to be constant, and the outflow from the pond varies with stream inflow.

The model assumes that the stream has a base flow rate of 3.60 meters (m) per second and an initial depth of 0.76 m at base flow. These values were selected because similar values have been reported for a second order stream of that length (van der Leeden *et al.*, 1990). The stream channel was modeled as a triangular area; the depth and width vary, depending on the volume of water in the stream. The stream is assumed to be twice as wide as it is deep, making the cross-sectional area equivalent to depth squared.

The model simulates the change in insecticide concentration, calculates the average concentration, and the maximum concentration over each 24-hour period within the first 96 hours following a rainstorm. Insecticide concentration was calculated at each of the 1-second time steps until 96 hours had elapsed. The model may overestimate insecticide concentrations due to the assumption that all insecticide on impervious surfaces is carried into surface waters via runoff. Considerable uncertainty exists regarding the actual amount of insecticide that is not bound to organic impervious surfaces, such as asphalt. Some of the insecticide may not be available for transport via runoff water.

At the first time step, the stream depth at base flow was used to calculate the cross-sectional area of the stream. The volume of water in the stream was calculated using the following equation:

V~=~l~times~xa #

ALIGNL where: #

STACKALIGN {

~~~V~&=~volume~of~water~\in~stream~(m^3)#

~~~l~&=~stream~length~(m)#

~~~xa~&=~cross-sectional~area~of~stream~(m^2)}

The volume of the stream is altered by the new volume of base flow entering the stream, the volume of runoff entering the stream, and the volume of water leaving the stream as discharge into the pond. With no runoff, the volume of base flow entering the stream is balanced by the volume of water discharged into the pond such that the stream volume does not change. When runoff occurs, the stream volume increases. Stream volume is calculated at each time step after the first using the following equation, which also accounts for runoff entering, volume of base flow entering, and volume of discharge leaving the stream:

V_t~=~V_{t-1}~+~V_{RO}~+~V_{BF}~-~V_{SD}#

ALIGNL where:#
~~~

```
STACKALIGN {

~~~V_t~&=~volume~(m SUP 3)#

~~~V_{t-1}~&=~volume~at~previous~time~step~(m^3)#

~~~V_{RO}~&=~runoff~volume~entering~stream~(m^3)#

~~~V_{BF}~&=~base~flow~volume~(m^3)#

~~~V_{SD}~&=~stream~discharge~volume~(m^3)

}
```

The depth of the stream was calculated at each iteration after the first time step, using the following equation, assuming a stream channel twice as wide as it is deep:

```
d~ =~   sqrt{{V} OVER l}#

ALIGNL where: #

STACKALIGN {

~~~d~&=~depth~(m)#

~~~V~&=~volume~of~stream~(m^3)#

~~~l~&=~stream~length~(m)

}
```

Stream velocity and overland flow velocity were calculated with the following equation (Newberry, 1984):

```
v~ =~ {SQRT m~times~(p over xa) VERT 70 {2 OVERSM 3}} over {n}#
```

```
ALIGNL where:#

STACKALIGN {

~~~v~&=~velocity~(m/s)#

~~~p~&=~wettable~perimeter~of~stream~(m)#

~~~xa~&=~cross-sectional~area~of~stream~(m^2)#

~~~n~&=~Manning's~n#

~~~m~&=~slope

}
```

The maximum overland velocity in the model was determined by the highest overland flow velocity (greater than 0.61 m/second) reported for a land use type of residential dwellings and grass (USDA, SCS, 1983). When the velocity calculated by the model exceeded the maximum reported velocity, the simulated velocity was taken to be the maximum value.

The model assumes that there are no impervious areas (roads, high-density residential housing, commercial areas, or urbanized areas). The volume of runoff produced was determined by the following equations (USDA, SCS, 1983):

```
S~=~(1000 over SCS) - 10#

ALIGNL where: #

STACKALIGN {

~~~S~&=~runoff~parameter~derived~\from~~SCS~runoff~curve~number#

~~~SCS~&=~the~SCS~runoff~curve~number~for~a~particular~cover~class#

~~~98~&=~SCS~Impervious~areas~(pavement)#

~~~61~&=~SCS~Pervious~areas~(good~grass)~

}
```

```
 Runoff~=~{sqrt{R~-~(0.2~times~S)}} over {R~+(0.8~times~S)}~times~
0.0254#

ALIGNL where: #

STACKALIGN {

~~~Runoff~&=~runoff~produced~(cm)#

~~~R~&=~rainfall~(inches)#

~~~S~&=~runoff~parameter~derived~from~SCS~runoff~curve

}
```

The model simulates the effect of insecticides entering a pond and stream by means of overland runoff after a relatively large storm event 24-hours after application. The initial insecticide concentrations in the pond and stream 6 hours after application were assumed to be zero. Insecticide concentrations are expected to increase in the pond and stream as the overland flow enters them.

The surface-water model was designed to provide a generalized representation of insecticide transport in an aquatic system. This approach was selected over a more detailed site-specific model because of the difficulty in extrapolating from site-specific models to the geographically diverse program area. The predictions of the surface-water model are useful for comparing the expected concentrations of the insecticides; however, any spray may result in aquatic concentrations that differ from the model results because of site-specific factors. Ponds less than 6.56 feet deep are likely to have higher insecticide concentrations than the simulated pond; whereas larger, deeper ponds are likely to have lower insecticide concentrations.

The model assumes homogeneous and instantaneous mixing; thus it simplifies the hydrological conditions of a stream. Consequently, there is uncertainty regarding the residence time of insecticide in the stream. In reality, the concentration of insecticide in a pond or stream is likely to vary spatially. Insecticide residence time would vary if the model assumption of equal inflow and outflow of water in the pond were violated. Results of this model reflect the average insecticide concentration observed rather than the maximum concentration (table C–3). The maximum concentration persists for very short time periods (less than 6 hours). There are no toxicological data to determine whether the response of an organism to varying insecticide concentrations is more similar to that organism's response to the average concentration or the maximum concentration encountered. Therefore, in this analysis, the average concentration was used.

TABLE 1-3: Carbaryl Bran Bait Estimated Environmental Residues

DEBUG-1 Application Rate 0.2 lb a.i. /acre	
Expected residue based on application rate (lb/acre)	0.1814
DEBUG-1 Application Rate 0.02 lb a.i. /acre	
Expected residue based on application rate (lb/acre)	0.01814
DEBUG 5% Application Rate 0.5 lb a.i. /acre	
Expected residue based on application rate (lb/acre)	0.4536
DEBUG 5% Application Rate 0.05 lb a.i. /acre	
Expected residue based on application rate (lb/acre)	0.04536

II. Results and Discussion

As expected, modeling results indicated the highest residues were associated with the highest of the application rates examined. Applying insecticide twice, rather than once, results in residue levels similar to those from a higher application rate used once (table C–4).

TABLE 1-4: Multiple Applications of Pesticide Within the Same Year

Carbaryl 0.5 lb a.i./acre	
Surface residues (lb/acre)	0.7328
Upper (0-1 cm) soil layer concentration from GLEAMS (ppm)	1.6467
Middle (1-6 cm) soil layer concentration from GLEAMS (ppm)	0.3092
Lower (6-12 cm) soil layer concentration from GLEAMS (ppm)	0.0282
Concentration in runoff water (1.5 inch storm) (ppm)	0.1266
Concentration in percolating water (1.5 inch storm) (ppm)	0.0073
Carbaryl 0.4 lb a.i./acre	
Surface residues (lb/acre)	0.5863
Upper (0-1 cm) soil layer concentration from GLEAMS (ppm)	1.4067
Middle (1-6 cm) soil layer concentration from GLEAMS (ppm)	0.2684
Lower (6-12 cm) soil layer concentration from GLEAMS (ppm)	0.0243
Concentration in runoff water (1.5 inch storm) (ppm)	0.1018
Concentration in percolating water (1.5 inch storm) (ppm)	0.0058
Carbaryl 0.375 lb a.i./acre	
Surface residues (lb/acre)	0.5496
Upper (0-1 cm) soil layer concentration from GLEAMS (ppm)	1.3128
Middle (1-6 cm) soil layer concentration from GLEAMS (ppm)	0.2505
Lower (6-12 cm) soil layer concentration from GLEAMS (ppm)	0.0226
Concentration in runoff water (1.5 inch storm) (ppm)	0.0950
Concentration in percolating water (1.5 inch storm) (ppm)	0.0054
Malathion 9.753 oz a.i./acre	
Surface residues (lb/acre)	0.5573
Upper (0-1 cm) soil layer concentration from GLEAMS (ppm)	2.6669
Middle (1-6 cm) soil layer concentration from GLEAMS (ppm)	0.0523
Lower (6-12 cm) soil layer concentration from GLEAMS (ppm)	0.0007
Concentration in runoff water (1.5 inch storm) (ppm)	0.0801
Concentration in percolating water (1.5 inch storm) (ppm)	0.00003

A. Carbaryl. Carbaryl is more likely to be transported offsite in runoff water than through percolation to the groundwater as suggested by GLEAMS modeling. Concentrations of carbaryl are predicted to be at least one order of magnitude greater for runoff water than percolating water (table C–5). Streams are predicted to have carbaryl concentrations of under 5 parts per billion (ppb), and ponds 6.56 feet deep are predicted to have less than 13 ppb in the 24 hours following runoff from rom a 1.5-inch rainstorm. Directly sprayed water bodies (1 foot deep) are predicted to have carbaryl concentrations that range from 138 to 184 ppb, depending on the application rate. Higher carbaryl concentrations occur in the upper soil layer (0 to 0.3937 inch) than the lower ones (0.3937 to 4.72 inches). Aerial dispersion modeling indicates most of the residues will be intercepted by the vegetation canopy, if there is one.

TABLE 1-5: Carbaryl Estimated Environmental Residues

Application Rate 0.5 lb a.i. /acre	
Expected residue based on application rate (lb/acre)	0.4536
Vegetation mean residue from FSCBG (lb/acre)	0.4871
Soil/Litter surface residue beneath vegetation from FSCBG (lb/acre)	0.1843
Upper (0-1 cm) soil layer concentration from GLEAMS (ppm)	1.2986
Middle (1-6 cm) soil layer concentration from GLEAMS (ppm)	0.1752
Lower (6-12 cm) soil layer concentration from GLEAMS (ppm)	0.0123
Concentration in runoff water (1.5-inch storm) (ppm)	0.1593
Concentration in percolating water (1.5-inch storm) (ppm)	0.0030
Average concentration in 0.76 m stream (ppb)	5.33
Average concentration in 2 m pond (ppb)	12.04
Directly sprayed water body 1 foot deep (ppb)	184.00
Directly sprayed water body 3.28 feet deep (ppb)	56.04
Application Rate 0.400 lb a.i. /acre	
Expected residue based on application rate (lb/acre)	0.3629
Vegetation mean residue from FSCBG (lb/acre)	0.3895
Soil/litter surface residue beneath vegetation from FSCBG (lb/acre)	0.1735
Upper (0-1 cm) soil layer concentration from GLEAMS (ppm)	1.0436
Middle (1-6 cm) soil layer concentration from GLEAMS (ppm)	0.1407
Lower (6-12 cm) soil layer concentration from GLEAMS (ppm)	0.0199
Concentration in runoff water (1.5-inch storm) (ppm)	0.0754
Concentration in percolating water (1.5-inch storm) (ppm)	0.0024
Average concentration in 0.76 m stream (ppb)	4.28
Average concentration in 2 m pond (ppb)	9.68
Directly sprayed water body 1 foot deep (ppb)	147.00
Directly sprayed water body 3.28 feet deep (ppb)	44.83
Application Rate 0.375 lb. a.i. /acre	
Expected residue based on application rate (lb/acre)	0.3402
Vegetation mean residue from FSCBG (lb/acre)	0.3651
Soil/litter surface residue beneath vegetation from FSCBG (lb/acre)	0.1627
Upper (0-1 cm) soil layer concentration from GLEAMS (ppm)	0.9740
Middle (1-6 cm) soil layer concentration from GLEAMS (ppm)	0.1314
Lower (6-12 cm) soil layer concentration from GLEAMS (ppm)	0.0092
Concentration in runoff water (1.5-inch storm) (ppm)	0.0704
Concentration in percolating water (1.5-inch storm) (ppm)	0.0022
Average concentration in 0.76 m stream (ppb)	4.00
Average concentration in 2 m pond (ppb)	9.03
Table C–5, continued.	
Directly sprayed water body 1 foot deep (ppb)	138.00
Directly sprayed water body 3.28 feet deep (ppb)	42.03

B. Carbaryl Bran Bait. Carbaryl residues resulting from bran bait applications (table C–3) are higher than those resulting from application of liquid carbaryl at the two lower application rates (table C–5). However, the residue is confined to the bran bait and is not found on vegetation or soil without the bait. Applying carbaryl in bait greatly reduces the number of organisms exposed to carbaryl. DEBUG 5 percent at 0.5 oz a.i./acre results in the highest carbaryl residues of the bran bait products used.

C. Diflubenzuron. GLEAMS does not predict any percolation of diflubenzuron to the groundwater; however, some transport off site is predicted in runoff water (table C–6). Streams and ponds in the treated watershed receiving runoff water following a 1.5-inch storm are predicted to have diflubenzuron concentrations less than 0.1 ppb. At the low application rates used, even directly sprayed water bodies of 1-foot depth are predicted to have less than 6 ppb of diflubenzuron. Diflubenzuron concentrations in the soil are predicted to be greatest in the upper layer (0 to 0.3937 inch). Aerial dispersion modeling indicates most of the residues will be intercepted by the vegetation canopy, if there is one. Due to its persistence on vegetation, much of the diflubenzuron in the canopy can be expected to persist through leaf drop and beyond. Leaf litter in sprayed areas contains measurable diflubenzuron residues for more than one growing season (Wimmer, 1994a).

An extensive monitoring study of diflubenzuron residues was conducted in a mixed hardwood forest in West Virginia following application with 0.5 oz a.i./acre (Wimmer *et al.*, 1993). Residues are reported throughout the growing season in both upper and lower canopy leaves. Insecticide concentrations in the litter in field studies (greater than 1 ppm spring, 1 ppm autumn, 1994) are similar to those estimated through modeling (1.4 ppm spring, 1.2 ppm autumn) (Wimmer, 1994b, unpublished data).

TABLE 1-6: Diflubenzuron Estimated Environmental Residues

Application Rate 0.0156 lb a.i. /acre	
Expected residue based on application rate (lb/acre)	0.0142
Vegetation mean residue from FSCBG (lb/acre)	0.0150
Soil/litter surface residue beneath vegetation from FSCBG (lb/acre)	0.0020
Upper (0-1 cm) soil layer concentration from GLEAMS (ppm)	0.040803
Middle (1-6 cm) soil layer concentration from GLEAMS (ppm)	0.000140
Lower (6-12 cm) soil layer concentration from GLEAMS (ppm)	0.000000
Concentration in runoff water (1.5 inch storm) (ppm)	0.000292
Concentration in percolating water (1.5 inch storm) (ppm)	0.000000
Average concentration in 0.76 m stream (ppb)	0.017
Average concentration in 2 m pond (ppb)	0.008
Directly sprayed water body 1 foot deep (ppb)	5.74
Directly sprayed water body 3.28 feet deep (ppb)	1.75
Application Rate 0.0078 lb a.i./acre	
Expected residue based on application rate (lb/acre)	0.0071
Vegetation mean residue from FSCBG (lb/acre)	0.0075
Soil/litter surface residue beneath vegetation from FSCBG (lb/acre)	0.0009
Upper (0-1 cm) soil layer concentration from GLEAMS (ppm)	0.020401
Middle (1-6 cm) soil layer concentration from GLEAMS (ppm)	0.000070
Lower (6-12 cm) soil layer concentration from GLEAMS (ppm)	0.00000
Concentration in runoff water (1.5 inch storm) (ppm)	0.000146
Concentration in percolating water (1.5 inch storm) (ppm)	0.00000
Average concentration in 0.76 m stream (ppb)	0.008
Average concentration in 2 m pond (ppb)	0.019
Directly sprayed water body 1 foot deep (ppb)	2.87
Directly sprayed water body 3.28 feet deep (ppb)	0.87

Malathion. GLEAMS predicts a very low concentration of malathion (>1 ppb) in water percolating to the groundwater. Some transport off site is predicted in runoff water (table C–7) resulting in malathion concentrations of 10 ppb or less in ponds and streams in the treated watershed receiving runoff water following a 1.5-inch storm. Directly sprayed water bodies of 1-foot depth are predicted to have 224 ppb of malathion. Malathion concentrations in the soil are predicted to be greatest in the upper layer (0 to 0.3937 inch). Aerial dispersion modeling indicates most of the residues will be intercepted by the vegetation canopy, if there is one.

TABLE 1-7: Malathion Estimated Environmental Residues

Application Rate 0.61 lb a.i. /acre	
Expected residue based on application rate (lb/acre)	0.5529
Vegetation mean residue from FSCBG (lb/acre)	0.5137
Soil/litter surface residue beneath vegetation from FSCBG (lb/acre)	0.2183
Upper (0-1 cm) soil layer concentration from GLEAMS (ppm)	2.6480
Middle (1-6 cm) soil layer concentration from GLEAMS (ppm)	0.0518
Lower (6-12 cm) soil layer concentration from GLEAMS (ppm)	0.0007
Concentration in runoff water (1.5 inch storm) (ppm)	0.0795
Concentration in percolating water (1.5 inch storm) (ppm)	0.00003
Average concentration in 0.76 m stream (ppb)	4.51
Average concentration in 2 m pond (ppb)	10.2
Directly sprayed water body 1 foot deep (ppb)	224.00
Directly sprayed water body 3.28 feet deep (ppb)	68.00

Multiple Applications. Carbaryl and malathion may potentially be applied to the treatment area twice in a season, with 7 days separating the two applications. Two applications would be considered if there was rainfall immediately following the first application. A second carbaryl application results in about a 30 percent increase in carbaryl concentrations in the upper soil layer (0 to 0.3937 inch), a 90 percent increase in the middle soil layer (0.3937 to 2.36 inches), and over a 200 percent increase in the lower soil layer simulated (2.36 to 4.72 inches) (table C–4). These concentrations are still below the soil concentration for a single application of malathion (table C–7). Carbaryl concentrations in runoff and percolating to groundwater are similar for one or two applications. A second malathion concentration does not increase either malathion concentrations in the soil, runoff water, or water percolating to the groundwater (table C–4).

Appendix D. References for Appendices A, B, and C

Adams, J.S., Knight, R.L., McEwen, L.C., and George, T.L., 1994. Survival and growth of nestling vesper sparrow exposed to experimental food reductions. The Condor 96:739–748.

Agency for Toxic Substances and Disease Registry, 1993. Case studies in environmental medicine #22: cholinesterase-inhibiting pesticide toxicity. U.S. Department of Health and Human Services, Public Health Service. September 1993.

Aldridge, W.N., Miles, J.W., Mount, D.L., and Verschoyle, R.D., 1979. The toxicological properties of impurities in malathion. Archives of Toxicololgy 42:95–106.

Ali, A., and Mulla, M.S., 1978a. Effects of chironomid larvicides and diflubenzuron on nontarget invertebrates in residential-recreational lakes. Environmental Entomology 7(1):21–27.

Ali, A., and Mulla, M.S., 1978b. Impact of the insect growth regulator diflubenzuron on invertebrates in a residential-recreational lake. Archives of Environmental Contamination and Toxicology 7:483–491.

Alston, D.G., and Tepedino, V.J., 1996. Direct and indirect effects of insecticides on native bees. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. III.4. Washington, DC.

Aly, O.M., and El-Dib, M.A., 1971. Studies on the persistence of some carbamate insecticides in the aquatic environment. I. hydrolysis of Sevin, Baygon, Pyrolan, and Dimetilan in waters. Water Res. 5:1191–1205.

Anderson, J.P., 1981. Factors influencing insecticide degradation by a soil fungus, *Mucor alterans*. Dissertation Abstracts Int. 32(6):3414B–3415B, 1971.

Antia, N.J., Harrison, P.J., Sullivan, D.S., and Bisalputra, T., 1985. Influence of the insecticide diflubenzuron (Dimilin) on the growth of marine diatoms and a harpacticoid copepod in culture. Can. J. Fish. Aquat. Sci. 42:1272–1277.

Apperson, C.S., Schaefer, C.H., Colwell, A.E., Werner, G.H., Anderson, N.L., Norman, L., Dupras, E.F., and Longanecker, D.R., 1978. Effects of diflubenzuron on *Chaoborus astictopus* and nontarget organisms and persistence of diflubenzuron in lentic habitats. Journal of Economic Entomology 71(3):521–527.

Archer, T.E., 1971. Malathion residues on Ladino clover seed screenings exposed to ultraviolet irradiation. Bulletin of Environmental Contamination and Toxicology 6:142–143.

Arnold, D.A., 1974. Mutagenic study with TH 6040 in albino mice. Industrial Bio-Test Laboratories, Northbrook, IL.

Atkins, E.L., Jr., Greywood, E.A., and McDonald, R.L., 1973. Toxicity of pesticides and other agricultural chemicals to honey bees. Publication M–16. University of California, Agricultural Extension Service, Berkeley, CA.

Atkins, E.L., Kellum, D., and Atkins, K.W., 1981. Reducing pesticide hazards to honey bees: mortality prediction techniques and integrated management strategies. Leaflet 2883. Division of Agricultural Sciences, University of California, Riverside, CA.

ATSDR—See Agency for Toxic Substances and Disease Registry.

Baker, K.N., 1985. Laboratory and field experiments on the responses by two species of woodland salamanders to malathion-treated substrates. Archives of Environmental Contamination and Toxicology 14(6):685–691.

Baron, R.L. 1991. Carbamate insecticides. *In* Hayes, W.J., and Laws, E.R. (eds.). Handbook of Pesticide Toxicology, Vol. 3, Classes of Pesticides, p. 1125–1190. Academic Press, San Diego, CA. (Cited in Abbott, 1996).

Barrett, G.W., 1968. The effects of an acute insecticide stress on a semienclosed grassland ecosystem. Ecolology 49(6):1019–1035.

Barretti, O.C.O., Halsman, M.W., Nonyama, K., Tamigaki, M., and Maspes, V., 1984. Congenital deficiency of erythrocyte NADH-dependent methemoglobin reductase (diaphorase). Sangre (Barc) 29(1):62–66.

Bartlett, B.R., 1968. Outbreaks of two-spotted spider mites and cotton aphids following pesticide treatments. I. Pest stimulation vs. natural enemy destruction as the cause of outbreaks. Journal of Economic Entomology 61(1):297–303.

Belovsky, G.E., 1996. Grasshopper population regulation. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. VII.14. Washington, DC.

Belovsky, G.E., 2000. Do grasshoppers diminish grassland productivity? A new perspective for control based on conservation. *In* Lockwood, J.A., Latchininshy, A.V., and Sergeev, M.G., (eds.), 1999. Grasshoppers and grassland health, managing grasshopper outbreaks without risking environmental disaster. Proceedings of the NATO Advanced Research Workshop on Acridogenic and Anthropogenic Hazards to the Grassland Biome, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Belovsky, G.E., Brusven, M.A., Fielding, D.J., and Manske, L., 1996a. Grasshopper habitat manipulation. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. VII.15. Washington, DC.

Belovsky, G.E., Lockwood, J.A., and Winks, K., 1996b. Recognizing and managing potential outbreak conditions. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. IV.8. Washington, DC.

Berry, J.S., Onsager, J.A., Kemp, W.P., McNary, T., Larsen, J., Legg, D., Lockwood, J., and Foster, R.N., 1996. Assessing rangeland grasshopper populations. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec VI.10. Washington, DC.

Beyers, D.W., Farmer, M.S., and Sikowski, P.J., 1995. Effects of rangeland aerial application of Sevin-4-Oil® on fish and aquatic invertebrate drift in the Little Missouri River, North Dakota. Archives of Environmental Contamination and Toxicology 28:27–34.

Beyers, D.W., and McEwen, L.C., 1996. Grasshopper treatment effects on aquatic communities. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. III.6. Washington, DC.

Bollen, W.B., 1961. Interactions between pesticides and soil microorganisms. Annual Review of Microbiololgy 15:69–92.

Booth, G., 1978. Dimilin and the environment. *In* Dimilin chitin inhibitor breakthrough in pest control. Agri-Fieldman and Consultant, Kansas City, KS.

Brown, M.A., Petreas, M.X., Okamoto, H.S., Mischke, T.M., and Stephens, R.D., 1991. Pilot study for the environmental monitoring of malathion, malathion impurities and their environmental transformation products on surfaces and in air during and after an aerial application in Garden Grove, California, in May of 1990. California Department of Health Services, Hazardous Materials Laboratory.

Brown, M.A., Petreas, M.X., Okamoto, H.S., Mischke, T.M., and Stephens, R.D., 1993. Monitoring of malathion and its impurities and environmental transformation products on surfaces and in air following an aerial application. Environmental Science and Technology 27(2):388–397.

Brusick, D.J., and Weir, R.J., 1977a. Evaluation of diflubenzuron. Litton Bionetics Project No. 2688. Litton Bionetics Inc., Arlington, VA.

Brusick, D.J., and Weir, R.J., 1977b. Mutagenicity evaluation of diflubenzuron technical, batch F144/60521. Litton Bionetics Project No. 2683. Litton Bionetics Inc., Arlington, VA.

Buckner, C.H., Kingsbury, P.D., McLeod, B.B., Mortensen, K.L., and Ray, D.G.H., 1973. The effects of pesticides on small forest vertebrates of the Spruce Woods Provincial Forest, Manitoba. The Manitoba Entomol. 7:37–45.

Burdick, G.E., Dean, H.F., and Harris, E.J., 1960. Effect of Sevin upon the aquatic environment. New York Fish and Game Journal 7(1):14–25.

California Department of Fish and Game, (1963). An investigation into the effect on fish of Sevin (carbaryl) used in rice culture. PR Project W-52-R, Wildlife Investigation Laboratory, Resource Agency, California Department of Fish and Game (unpublished).

California Department of Fish and Game, 1982. Impact on fish and wildlife from broadscale aerial malathion applications in South San Francisco Bay Region, 1981. Administrative Report 82–2, Environmental Services Branch, California Department of Fish and Game, Sacramento, CA.

California Department of Food and Agriculture, 1991. Environmental monitoring of malathion aerial applications used to eradicate Mediterranean fruit flies in southern California, 1990. California Department of Food and Agriculture, Sacramento, CA.

California Department of Health Services, 1991. Health risk assessment of aerial application of malathion-bait. California Department of Health Services, Pesticides and Environmental Toxicology Section, Berkeley, CA.

Caro, J.H., Freeman, H.P., and Turner, B.C., 1974. Persistence in soil and losses in runoff of soil-incorporated carbaryl in a small watershed. Journal of Agricultural Food and Chemistry 22(5):860–863.

Carpenter, C.P., Weil, C.S., Palm, P.D., Woodside, M.W., Nair, J.H., III, and Smyth, H.F., Jr., 1961. Mammalian toxicity of 1-naphthyl-N-methylcarbamate (Sevin insecticide). Journal of Agricultural Food and Chemistry 9:30.

Casale, G.P., Bavari, S., Gold, R.E., and Vitzthum, E.F., 1992. Inhibition of interleukin-2-stimulated enhancement of human natural killer (NK) cell activity by carbaryl, an anticholinesterase insecticide. Toxicology Letters 63:299–311.

Casale, G.P., Vennerstrom, J.L., Bavari, S., and Wang, T-I., 1993. Inhibition of interleukin 2 driven proliferation of mouse CTLL2 cells, by selected carbamate and organophosphate insecticides and congeners of carbaryl. Immunopharmacology and Immunotoxicology 15 (2&3):199–215.

Casida, J.E., and Lykken, L.L., 1969. Metabolism of organic pesticide chemicals in higher plants. Annual Review of Plant Physiology 20:607–636.

Catangui, M.A., Fuller, B.W., and Walz, A.W., 1996. Impact of Dimilin on nontarget arthropods and its efficiency against rangeland grasshoppers. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No.1809. Sec. VII.3. Washington, DC.

CDFA—See California Department of Food and Agriculture.

CDFG—See California Department of Fish and Game.

CDHS—See California Department of Health Services.

Cecil, H.C., Miller, R.W., and Corley, C., 1981. Feeding three insect growth regulators to white leghorn hens: Residues in eggs and tissues and effects on production and reproduction. Poultry Science 60:2017–2027.

Centa, A., Camera, G., Zucchinetti, P., and Di Pietro P., 1985. Methemoglobinemia in the newborn and nursing infant: genetic and acquired forms. Pathologica. 77(1052):659–665.

Chakraborti, S., Chatterjee, I., and Banerjee, S.K., 1983. Biochemical studies of some cell wall associated enzymes in malathion treated germinating seeds of *Vigna sinesis* (L.): effect of IAA and GA_3 supplementation. International Journal of Environmental Studies 21(3-4): 281–288.

Cohen, E., 1993. Chitin synthesis and degradation as targets for pesticide action. Archives of Insect Biochemistry and Physiology 22:245–261.

Cohen, S.D., and Ehrich, M., 1976. Cholinesterase and carboxylesterase inhibition by dichlorvos and interactions with malathion and triorthotolyl phosphate. Toxicology and Applied Pharmacology 37:39–48.

Cohen, S.D., and Murphy, S.D., 1970. Comparative potentiation of malathion by triorthotolyl phosphate in four classes of vertebrates. Toxicology and Applied Pharmacology 16:701–708.

Colwell, A.E., and Schaefer, C.H., 1980. Diets of *Ictalurus nebulosus* and *Poxoxis nigromaculatus* altered by diflubenzuron. Canadian Journal of Fisheries and Aquatic Sciences 37:632–639.

Cranmer, M.F., 1986. Carbaryl: a toxicological review and risk analysis. Neurotoxicology. 7(1):247–332.

Curbishley, T.B., and Skyler, P.J., 1989. User manual—Forest Service aerial spray computer model. U.S. Department of Agriculture, Forest Service, Davis, CA.

Cushing, W.J., Foster, R.N., Reuter, K.C., and Hirsch, D., 1996. Seasonal occurrence of common western North Dakota grasshoppers. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. VI.8. Washington, DC.

Davis, F.M., Leonard, R.A., and Knisel, W.G., 1990. GLEAMS user manual, Version 1.8.55. USDA-ARS Southeast Watershed Research Laboratory and the University of Georgia, College of Agriculture, Coastal Plain Experiment Station, Agricultural Engineering Department, Tifton, GA.

Desi, I., Varga, L., and Farkas, I., 1978. Studies on the immunosuppressive effect of organochlorine and organophosphoric pesticides in subacute experiments. Journal of Hygiene Epidemiology Microbiology Immunology 22(1):115–122.

DHHS, DOL, NIOSH, OSHA—See U.S. Department of Health and Human Services, Department of Labor, National Institute for Occupational Safety and Health, Occupational Safety and Health Administration.

Doane, C.C., and Schaefer, P.W., 1971. Aerial application of insecticides for control of the gypsy moth with studies of effects on nontarget insects and birds. Bulletin of the Connecticut Agricultural Experiment Station No. 724.

Dobroski, C.J., O'Neill, E.J., Donohue, J.M., and Curley, W.H., 1985. Carbaryl: a profile of its behavior in the environment. Roy F. Weston, Inc., West Chester, PA, and V.J. Ciccone and Associates, Inc., Woodbridge, VA.

Domanik, A.M., and Zar, J.H., 1978. The effect of malathion on the temperature selection response of the common shiner, *Notropis cornutus* (Mitchill). Archives of Environmental Contanination and Toxicology 7:193–206.

Dorough, H.W., 1970. Metabolism of insecticidal methylcarbamates in animals. Journal of Agricultural Food and Chemistry 18:1015–1022.

Duphar, B.V., 1985. Diflubenzuron 52 week oral toxicity study in dogs. Master Record Identifier No. 00146146; 353 pp., Duphar B.V., Weesp, the Netherlands.

Dysart, R.J., 1996. Relative importance of rangeland grasshoppers in Western North America: a numerical ranking from the literature. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. VI.6. Washington, DC.

Eisler, R., 1970. Latent effects of insecticide intoxication to marine molluscs. Hydrobiologia 36(3–4):345–352.

Eisler, R., 1992. Diflubenzuron hazards to fish, wildlife, and invertebrates: a synoptic review. Biological Report 4. Contaminant Hazard Reviews Report 25. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Eisler, R., 2000. Handbook of chemical risk assessment: health hazards to humans, plants, and animals. Lewis Publishers, New York.

El-Refai, A., and Hopkins, T.L., 1972. Malathion adsorption, translocation, and conversion to malaoxon in bean plants. Journal of the AOAC 55(3):526–531.

EPA—See U.S. Environmental Protection Agency.

EPA, ECAO—See U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office.

EPA, OERR—See U.S. Environmental Protection Agency, Office of Emergency and Remedial Response.

EPA, OHEA, ORD—See U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Office of Research and Development.

EPA, OPP—See U.S. Environmental Protection Agency, Office of Pesticide Programs.

EPA, OPPTS—See U.S. Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances.

EPA, OPTS—See U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances.

Epstein, S.S., Arnold, E., Andrea, J., Bass, W., and Bishop, Y., 1972. Detection of chemical mutagens by the dominant lethal assay in the mouse. Toxicology and Applied Pharmacology 23:288–325.

Fair, J.M., Kennedy, P.L., and McEwen, L.C., 1995a. Diet of nesting killdeer in North Dakota. Wilson Bulletin 107:174–178.

Fair, J.M., Kennedy, P.L., and McEwen, L.C., 1995b. Effects of carbaryl grasshopper control on nesting killdeer in North Dakota. Environmental Toxicology and Chemistry 14:881–890.

Feldman, R.J., and Maibach, H.I., 1974. Percutaneous penetration of some pesticides and herbicides in man. Toxicology and Applied Pharmacology 28:126–132.

Fielding, D.J., and Brusven, M.A., 1996a. Associations between grasshoppers and plant communities on the Snake River Plains of Idaho. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. II..5. Washington, DC.

Fielding, D.J., and Brusven, M.A., 1996b. Historical trends in grasshopper populations in

southern Idaho. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. V.2. Washington, DC.

Fischer, S.A., and Hall, L.W Jr., 1992. Environmental concentrations and aquatic toxicity data on diflubenzuron (Dimilin). Critical Reviews in Toxicology 22(1):45–79.

Fisher, J.W., Kemp, W.P., and Berry, J.S., 1996a. *Melanoplus sanguinipes* phenology North-South across the Western United States. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. IV.6. Washington, DC.

Fisher, J.W., Kemp, W.P., Pierson, F.B., and Wright, J.R., 1996b. Grasshopper egg development: the role of temperature in predicting egg hatch. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. IV.2. Washington, DC.

Foster, R.N., 1996. Introduction to chemical control. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. II..1. Washington, DC.

Foster, R.N., Reuter, K.C., Fridley, K., Kurtenback, D., Flakus, R., Bohls, R., Radsick, B., Helbig, J.B., Wagner A., and Jech, L., 2000. Field and economic evaluation of operational scale reduced agent and reduced area treatments (RAATs) for management of grasshoppers in South Dakota rangeland, 1997–1999. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Phoenix, AZ. Available online: http://www.sidney.ars.usda.gov/grasshopper.

Frawley, J.P., Fuyat, H.N., Hagan, E.C., Blake, J.R., and Fitzhugh, O.G., 1957. Marked potentiation in mammalian toxicity from simultaneous administration of two anticholinesterase compounds. Journal of Pharmacology and Experimental Therapeutics 121(1):96–106.

Fukuto, T.R., 1983. Toxicological properties of trialkyl phosphorothioate and dialkyl, alkyl- and arylphosphorothioate esters. Journal of Environmental Science Health B18(1), 89–117.

Gaines, T.B., 1969. Acute toxicity of pesticides. Toxicology and Applied Pharmacology 14:515–534.

Garretson, A.L., and San Clemente, C.L., 1968. Inhibition of nitrifying chemolithotropic bacteria by several insecticides. Journal of Economic Entomology 61(1):285–288.

Gibbs, K.E., Mingo, T.M., and Courtemanch, D.L., 1984. Persistence of carbaryl (Sevin 4-oil®) in woodland ponds and its effects on pond macroinvertebrates following forest spraying. Canadian Entomologist 116:203–213.

Gibson, R.L., and Scott, J.G., 1989. Comparative toxicity of fourteen insecticides to two species of carpenter ants (Hymenoptera: formicidae). Journal of Economic Entomology 82(4): 1121–1124.

Giles, R.H., Jr., 1970. The ecology of a small forested watershed treated with the insecticide malathion-S^{35}. Wildlife Monograph No. 24.

Gold, R.E., Leavitt, J.R., Holcslaw, T., and Tupy D., 1982. Exposure of urban applicators to carbaryl. Archives of Environmental Contamination and Toxicology 11(1):63–67.

Gramlich, F.J., 1979. Effects of Sevin on songbird cholinesterase. *In* Maine Department of Conservation, Bureau of Forestry, Augusta, ME. Environmental monitoring of Cooperative Spruce Budworm Control Projects.

Greenberg, J., and LaHam, Q.N., 1969. Malathion-induced teratisms in the developing chick. Canadian Journal of Zoology 47:539–542.

Griffin, D.E., and Hill, W.E., 1978. In vitro breakage of plasmid DNA by mutagens and pesticides. Mutatation Research 52:161–169.

Hansen, S.R., and Garton, R.R., 1992. Ability of standard toxicity tests to predict the effects of the insecticide diflubenzuron on laboratory stream communities. Canadian Journal of Fisheries and Aquatic Sciences 39:1273–1288.

Harrahy, E.A., Wimmer, M.J., Perry, S.A., Faber, D.C., Miracle, J.E., and Perry, W.B., 1993. Persistence of diflubenzuron on Appalachian forest leaves in stream water. Journal of Agricultural Food and Chemistry 41:2191–2196.

Hazardous Substances Database, 1987. On-line database. National Library of Medicine, Bethesda, MD.

Hazardous Substances Database, 1990. On-line database. National Library of Medicine, Bethesda, MD.

Hazardous Substances Database, 1991. On-line database. National Library of Medicine, Bethesda, MD.

Helbig, B., 2001. Personal communication via telephone with Pat Keatts, U.S. Department of the Interior, Bureau of Indian Affairs (BIA) Area Office, Aberdeen, SD, regarding total acreages of BIA-managed lands.

Hester, P.G., Floore, M.A., and Floore, T.G., 1986. Effects of diflubenzuron on three estuarine decapods *Callinectes* sp., *Palaemonetes pugio*, and *Uca pugilator*. Journal of the Florida Anti-Mosquito Association 57(1):8–14.

Heywood, D.L., 1975. Degradation of carbamate insecticides in soil. Environ. Qual. Safety 4:128–133.

Hoffman, D.J., and Eastin, W.C., Jr., 1981. Effects of malathion, diazinon, and parathion on mallard embryo development and cholinesterase activity. Environmental Research 26:472–485.

Hoffman, R.S., and Sauter D., 1989. Methemoglobinemia resulting from smoke inhalation. Veterinary and Human Toxicology 31(2):168–170.

Horvath, L., 1982. Persistence of organophosphorus pesticides in aquatic environments (coordinated programme on isotope-tracer-aided research and monitoring on agricultural residue-biological interactions in aquatic environment). Final report for the period 1 July 1976 to 31 July 1982. International Atomic Energy Agency, Vienna, Austria.

Howard, P.H., 1991. Carbaryl. *In* Handbook of environmental fate and exposure data for organic chemicals. Lewis Publishers, Chelsea, MI.

Howe, F.P., 1993. Effects of grasshopper insecticide application on diet, food delivery rates, growth, and survival of shrubsteppe passarine. Ph.D. dissertation, 108 p. Colorado State University, Fort Collins, CO.

HSDB—See Hazardous Substances Database.

Hudson, R.H., Tucker, R.K., and Haegele, M.A., 1984. Handbook of toxicity of pesticides to wildlife. Resource Publication 153. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Hurlbert, P.J., 1978. Effects of Sevin, a spruce budworm insecticide on fish and invertebrates in the Mattawamkeas River in 1976. *In* Maine Department of Conservation, Bureau of Forestry, Augusta, ME. Environmental monitoring of Cooperative Spruce Budworm Control Projects, Maine 1976 and 1977.

Ilnytzky, S., and Marshall, V.G., 1974. Phytotoxicity of four insecticides to germinants. Bimonthly Res. Notes Canad. 30(3):20–22.

Jenkins, D., Klein, S.A., Yang, M.S., Wagenet, R.J., and Biggar, J.W., 1978. The accumulation, translocation, and degradation of biocides at land disposal sites: the fate of malathion, carbaryl, diazinon, 2,4-D butoxyethyl ester. Water Research 12:713–723.

Joern, A., 1996a. Grasshopper communities and methodology. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. VII.13. Washington, DC.

Joern, A., 1996b. Grasshopper population regulation. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. VII..14. Washington, DC.

Joern, A., 1996c. Host plant quality and grasshopper populations. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. IV.4. Washington, DC.

Joern, A., 1996d. Nutritional needs and control of feeding. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. IV.7. Washington, DC.

Joern, A., 2000. What are the consequences of non-linear ecological interactions for grasshopper control strategies? *In* Lockwood, J.A., Latchininshy, A.V., and Sergeev, M.G. (eds.), 1999. Grasshoppers and grassland health, managing grasshopper outbreaks without risking environmental disaster. Proceedings of the NATO Advanced Research Workshop on Acridogenic and Anthropogenic Hazards to the Grassland Biome, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Joern, A., and Gaines, S.B., 1996. Population dynamics and regulation in grasshoppers. *In* Chapman, R.F., and Joern, A. (eds.). Biology of grasshoppers. New York City: Wiley and Sons.

Joern, A., Kemp, W.P., Belovsky, G.E., and O'Neill, K., 1996. Grasshoppers and vegetation communities. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. IV.3. Washington, DC.

Johansen, C.A., and Mayer, D.F., 1990. Pollinator protection: bee and pesticide handbook. Wicwas Press, Cheshire, CT. 212pp.

Johansen, C.A., Mayer, D.F., Eves, J.D., and Kious, C.W., 1983. Pesticides and bees. Environmental Entomology 12:1513–1518.

Johnson, W.W., and Finley, M.T., 1980. Handbook of acute toxicity of chemicals to fish and aquatic invertebrates. U.S. Fish and Wildlife Service, Resource Publication 137, Washington, DC.

Julin, A.M., and Sanders, H.O., 1978. Toxicity of the IGR, diflubenzuron, to freshwater invertebrates and fishes. Mosquito News 38(2):256–259.

Karinen, J.F., Lamberton, J.G., and Stewart, N.E., 1967. Persistence of carbaryl in the marine estuarine environment–chemical and biological stability in aquarium systems. Journal of Agricultural Food and Chemistry 15:148–156.

Keet, C., 1984a. Summary of the report "oncogenicity study in rats, diflubenzuron." Project Report No. 56645/48/84. Duphar B.V., Weesp, The Netherlands. June 1984.

Keet, C., 1984b. Summary of the report "the effect of diflubenzuron given by oral administration with the feed on toxicity and tumor development in male and female hc/cflp mice." Project Report No. 56645/49/84. Duphar B.V., Weesp, The Netherlands. June 1984.

Keet, C., Kemp, A., and Mass, W., 1982. Effects of diflubenzuron on methaemoglobin and sulfhaemoglobin levels and other red blood cell related parameters in mice, rats, cats, dogs, and sheep. Dupar Report No. 4770. Duphar B.V., Weesp, the Netherlands.

Kemp, W.P., McNeal, D., and Cigliano, M.M., 1996. Geographic information systems (GIS) and integrated pest management. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. VI.9. Washington, DC.

Kenaga, E.E., 1973. Factors to be considered in the evaluation of the toxicity of pesticides to birds in their environment. Environmental Quality and Safety 2:166–181.

Keplinger, M.L., and Deichmann, W.B., 1967. Acute toxicity of combinations of pesticides. Toxicolology and Applied Pharamacology 10:586–595.

Khakoo, G.A., Maconochie, I.K., and Jaffe P., 1993. An unusual blue baby. J. Royal Soc. Med. (London) 86(12):730–731.

Kingsbury, P., Sundarum, K.M.S., Holmes, S., Nott, R., and Kreutzweiser, D., 1987. Aquatic fate and impact studies of dimilin. Forest Pest Management Institute, Canadian Forest Service, Sault Ste. Marie, Ontario. File 78, 45 pp.

Klaassen, C.D., Amdur, M.O., and Doull, J., 1986. Casarett and Doull's Toxicology, the basic science of poisons. 3rd ed., Macmillan Publishing Co., New York.

Knaak, J.B., and O'Brien, R.D., 1960. Effect of EPN on in vivo metabolism of malathion by the rat and dog. Journal of Agricultural Food and Chemistry 8:198–203.

Knaak, J.B., Tallant, W.J., Bartley, W.J., and Sullivan, L.F., 1965. The metabolism of carbaryl in the rat, guinea pig and man. Journal of Agricultural Food and Chemistry 13:537.

Kubena, L.F., 1982. The influence of diflubenzuron on several reproductive characteristics in male and female layer-breed chickens. Poultry Science 61:268–271.

Kuhajda, B.R., Blanco, C.C., Green, M.M., Haynes, C.G., Hicks, M.B., Jones, D.B. III, Mayden, R.L., Miller, A.M., Nichols, G.A., and Smith-Somerville, H.E., 1996. Final Report Impact of malathion on fish and aquatic invertebrate communities and on acetylcholinesterase activity in fishes within Stewart Creek, Fayette County, Alabama. University of Alabama, Department of Biological Sciences, Tuscaloosa, AL. December 20, 1996.

Kuijpers, L.A.M., 1989. The side-effects of diflubenzuron (Dimilin) on bees: a review. Philips-Duphar B.V., The Netherlands, Crop Protection Division, Report No. 56635/07/89. February 1989.

LaFleur, K.S., 1979. Sorption of pesticides by model soils and agronomic soils: rates and equilibria. Soil Science 127(2):94–101.

Laney, R.F., and Hoffman, R.S., 1992. Methemoglobinemia secondary to automobile exhaust fumes. American Journal of Emergency Medicine 10(5):426–428.

Lechner, D.W., and Abdel-Rahman, M.S., 1986. Kinetics of carbaryl and malathion in combination in the rat. Journal of Toxicology and Environmental Health 18:241–256.

Lichtenstein, E.P., Schulz, K.R., Skretny, R.F., and Tsukano, Y., 1966. Toxicity and fate of insecticide residues in water. Archives of Environmental Health 12:199–212.

Lillie, R., 1973. Studies on the reproductive performance and progeny performance on caged white leghorns fed malathion and carbaryl. Poultry Science 52(1):266–272.

Lockwood, J.A., and DeBrey, L.D., 1990. A solution for the sudden and unexplained extinction of the Rocky Mountain grasshopper (Orthoptera: acrididae). Environmental Entomology 19(5):1194–1205.

Lockwood, D.R., and Lockwood, J.A., 1997. Evidence of self-organized criticality in insect populations. Complexity 2:49–58.

Lockwood, J.A., and Lockwood, D.R., 1991. Rangeland grasshopper population dynamics: insights from catastrophe theory. Environmental Entomology 20:970–980.

Lockwood, J.A., McNary, T.J., Larsen, J.C., and Cole, J., 1993. Distribution atlas for grasshoppers and the Mormon cricket in Wyoming 1988–1992. Misc. Rep. B–976. Laramie, WY: University of Wyoming and Wyoming Agricultural Experiment Station. 117 pp.

Lockwood, J.A., Schell, S.P., Foster, R.N., Reuter, C., and Rachadi, T., 2000. Reduced agent-area treatments (RAATs) for management of rangeland grasshoppers: efficacy and economics under operational conditions. International Journal of Pest Management 46(1):29–42.

Maas, W., van Hes, R., Grosscurt, A.C., and Deul, D.H., 1981. Benzoylphenylurea insecticides. *In* Chemie der Pflanzenschutz und Schadlingsbekampfunsmittel. Springer-Verlag, New York.

Macek, K.J., and McAllister, W.A., 1970. Insecticide susceptibility of some common fish family representatives. Trans. Amer. Fish. Soc. 99(1):20–27.

Majori, G., Romi, R., and Ali, A., 1984. Toxicity of the IGR diflubenzuron to neonate, adult, and gravid female *Daphnia magna* Straus (Cladocera: daphniidae) in the laboratory. Procedings and Papers on the Annual Conference on the California Mosquito and Vector Control Association (52nd) p. 68–70.

Mane, U.H., Akarte, S.R., and Muley, D.V., 1984. Effect of cythion-malathion on respiration in three freshwater bivalve molluscs from Godavari River near Paithan. J. Environ. Biol. 5(2):71–80.

Manske, L.L., 1996. Beneficial changes of rangeland through proper grazing. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. 1809. Sec V.7. Washington, DC.

Matsumara, F., 1985. Toxicology of insecticides. Plenum Press, New York, p. 77–89. p. 224–269.

Mayer, F.L., Jr, and Ellersieck, M.C., 1986. Manual of acute toxicity: interpretation and data base for 410 chemicals and 66 species of freshwater animals. Resource Publication 160. Department of the Interior, Fish and Wildlife Service, Washington, DC.

McEwen, L.C., MacDonald, J.E., and Peterson, J.E., 1962. The effects of Sevin on sharp-tailed grouse and waterfowl at the Lostwood Wildlife Refuge, North Dakota. Annual Progress Report, U.S. Department of the Interior, Denver Wildlife Research Center.

McEwen, L.C., Althouse, C.M., and Peterson, B.E., 1996. Direct and indirect effects of grasshopper integrated pest management (GHIPM) chemicals and biologicals on nontarget animal life. *In* U.S. Department of Agriculture, Animal and Plant Health

Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. 1809. Sec. III.2. Washington, DC.

McLean, R.G., Spillane, J.T., and Miles, J.W., 1975. A prospective study of the effects of ultralow volume (ULV) aerial application of malathion on epidemic *Plasmodium falciparum* malaria. American Journal of Tropical Medicine and Hygiene 24(2):193–198.

Miura, T., and Takahashi, R.M., 1974. Insect developmental inhibitors. Effects of candidate mosquito control agents on nontarget aquatic organisms. Environmental Entomology 3:631–636.

Miura, T, and Takahashi, R.M., 1975. Effects of the IGR, TH6040, on nontarget organisms when utilized as a mosquito control agent. Mosquito News 35:154–159.

Moeller, H.C., and Rider, J.A., 1962. Plasma and red blood cell cholinesterase activity as indications of the incipient toxicity of ethyl-p-nitrophenyl thionobenzenephosphonate (EPN) and malathion in human beings. Toxicology and Applied Pharmacology 4:123–130.

Moulding, J.D., (1972). The impact on forest bird and nontarget arthropod populations of the use of the insecticide Sevin for gypsy moth control. Rutgers University Ph.D. thesis (unpublished).

Mount, M.E., and Oehme, F.W., 1981. Carbaryl: a literature review. Res. Rev. 80:1–64.

Murray, F.J., Staples, R.E., and Schwetz, B.A., 1979. Teratogenic potential of carbaryl given to rabbit and mice by gavage or by dietary inclusion. Toxicology of Applied Pharmacology 5(1):81–89.

Murray, H.E., and Guthrie, R.K., 1980. Effects of carbaryl, diazinon, and malathion on native aquatic populations of microorganisms. Bulletin of Environmental Contamination Toxicology 24(4):535.

Murray, K.F., and Christie D.L., 1993. Dietary protein intolerance in infants with transient methemoglobinemia and diarrhea. Journal of Pediatrics 122(1):90–92.

Nash, R.G., 1974. Plant uptake of insecticides, fungicides and fumigants from soils. Chapter II. *In* Guengi, W.D., ed. Pesticides in soil and water. Soil Science Society of America, Madison, WI.

National Library of Medicine, 1988. Hazardous Substances Databank. National Institutes of Health, Bethesda, MD.

National Research Council, 1983. Risk Assessment in the Federal Government: Managing the Process. Committee on the Institutional Means for Assessment of Risks to Public Health. National Academy Press, Washington, DC.

National Research Council, 1994. Rangeland health: new methods to classify, inventory, and monitor rangelands. Committee on Rangeland Classification, Board on Agriculture, National Research Council, National Academy Press, Washington, DC.

Neary, D.G., 1985. Fate of pesticides in Florida's forests: an overview of potential impacts on water quality. Procedings Soil and Crop Science Society of Florida 44:18–24.

Neskovic, N.K., Terzic, M., and Vitorovic, S., 1978. Acute toxicity of carbaryl and propoxur in mice previously treated with phenobarbitol and SKF 525A. Arhivza Higijenu Rada I Toksikologiju 29:251–256.

Newberry, R.W., 1984. Hydrologic determinants of aquatic insect habitats. *In* Resh, V.H., and Rosenburg, D.M. (eds.). The Ecology of Freshwater Insects. Praeger, New York. 625 pp.

Nigg, H.N., Reinert, J.A., Stamper, J.H., and Fitzpatrick, G.E., 1981. Disappearance of acephate, methamidophos, and malathion from citrus foliage. Bulletin of Environmental Contamination and Toxicology 26:267–272.

Nigg, H.N., Cannizzaro, R.D., Stamper, J.H., 1986. Diflubenzuron surface residues in Florida citrus. Bulletin of Environmental Contamination and Toxicology 36(6):833–838l.

Nilsson, A., and Engberg, G., Henneberg, S., Danielson, K., and De Verdier, C.H., 1990. Inverse relationship between age-dependent erythrocyte activity of methaemoglobin reductase and prilocaine-induced methemoglobinemia during infancy. British Journal of Anaesthesia (London). 64(1):72–26.

NLM—See National Library of Medicine.

NRC—See National Research Council.

O'Brien, R.D., 1957. The effect of malathion and its isomer on carbohydrate metabolism of the mouse, cockroach and housefly. Journal of Economic Entomology 50(1):79–84.

Onsager, J.A., 1996. What modeling is and how it works. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Sec. IV.1. Washington, DC.

Onsager, J.A., 2000. Suppression of grasshoppers in the Great Plains through grazing management. Journal of Range Management 53(6):592–602.

Onsager, J.A., and Olfert, O., 2000. What tools have potential for grasshopper pest management? *In* Lockwood, J.A., Latchininshy, A.V., Sergeev, M.G. (eds.), 1999. Grasshopper and grassland health, managing grasshopper outbreaks without risking environmental disaster. Proceedings of the NATO Advanced Research Workshop on Acridogenic and Anthropogenic Hazards to the Grassland Biome, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Opdycke, J.C., Miller, R.W., and Menzer, R.E., 1982. Metabolism and fate of diflubenzuron in swine. Journal of Agricultural Food and Chemistry 30:1223–1227.

Panos Institute, 1993. Grasshoppers and locusts. Panos Institute, London, 114 pp.

Paris, D.F., and Lewis, D.L., 1973. Chemical and microbial degradation of ten selected pesticides in aquatic systems. Residue Rev. 45:95–124.

Parker, J.R., 1952. Grasshoppers. *In* Insects: The Yearbook of Agriculture, 1952. Washington, DC. U.S. Department of Agriculture. p. 595-604. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809, Sec. II.11. Washington, DC.

Parmenter, R.R., MacMahon, J.A., and Gilbert, C.A.B., 1991. Early successional patterns of arthropod recolonization on reclaimed Wyoming strip mines: the grasshoppers (Orthoptera: acrididae) and allied faunas (Orthoptera, gryllacrididae, tettigoniidae). Environmental Entomology 20(1):135–142.

Paschal, D.C., and Neville, M.E., 1976. Chemical and microbial degradation of malaoxon in an Illinois soil. J. Environ. Qual. 5(4):441–443.

Peach, M.P., Alston, D.G., and Tepedino, V.J., 1994. Bees and bran bait: is carbaryl bran bait lethal to alfalfa leafcutting bee (Hymenoptera: megachilidae) adults or larvae? Journal of Economic Entomology 87:311–317.

Perocco, P., Colacci, A., and Grilli, S., 1993. In vitro cytotoxic and cell transforming activities exerted by the pesticides cyanazine, dithianon, diflubenzuron, procymidone, and vinclozolin on BALB/c 3T3 cells. Environmental and Molecular Mutagenesis 21:81–86.

Perry, W., Christiansen, T., Perry, S., 1993. Effects of forest application of diflubenzuron on forest microarthropods. Abstract Society of Environmental Toxicology and Chemistry Meetings in 1993, Houston, TX. p. 260.

Pfadt, R.E., 1994. Field guide to common western grasshoppers. Second Edition, Wyoming Agricultural Experiment Station, Bulletin 912, University of Wyoming, Laramie, Wyoming, September 1994. *In* U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. Washington, DC.

Pillard, D.A., 1995. Comparative toxicity of formulated glycol deicers and pure ethylene and propylene glycol to *Ceriodaphnia dubia* and *Pimephales promelas*. Environmental Toxicology and Chemistry 14(2):311–315.

Potter, D.A., Buxton, M.C., Redmond, C.T., Patterson, C.G., and Powell, A.J., 1990. Toxicity of pesticides to earthworms (Oligochaeta: lumbricidae) and effect on thatch degradation in Kentucky bluegrass turf. Journal of Economic Entomology 83(6):2362–2369.

Pree, D.J., Archibald, D.E., and Morrison, R.K., 1989. Resistance to insecticides in the common green lacewing *Chrysoperla carnea* (Neuroptera: chrysopidae) in southern Ontario. Journal of Economic Entomology 2:29–34.

Quarles, J.M., Norman, J.O., and Kubena, L.F., 1980. Absence of transformation by diflubenzuron in a host-mediated transplacental carcinogen assay. Bulletin of Environmental Contamination and Toxicology 25:252–256.

Quinn, M.A., Foster, R.N., Cushing, W.J., Hirsch, D.C., Winks, K., and Reuter, K.C., 2000. The North Dakota grasshopper integrated pest management demonstration project, Tech. Bul. No. 1891. U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Plant Protection and Quarantine, Phoenix, AZ.

Rajendran, N., and Venugopalan, V.K., 1983. Effect of malathion on embryonic development of the frog *Microhyla ornata* (Dumeril and Bibron). Bulletin of Environmental Contamination and Toxicology 31:170–176.

Reckhow, K.H., and Chapra, S.S., 1983. Engineering approaches for lake management. Vol. 1—Data analysis and empirical modeling. Butterworth Publisher, Boston, MA.

Regan, J.D., Setlow, R.B., Francis, A.A., and Lijinsky, W., 1976. Nitrosocarbaryl: its effect on human DNA. Mutation Research 38:293–302.

Richmond, M.L., Henny, C.J., Floyd, R.L., Mannan, R.W., Finch, D.M., and DeWeese, L.R., 1979. Effects of Sevin 4-oil, Dimilin, and Orthene on forest birds in northeastern Oregon. United States Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, Research Paper PSW–148. Wseptember 1979.

Roberts, B.L., and Dorough, H.W., 1985. Hazards of chemicals to earthworms. Environmental Toxicology and Chemistry 4:307–323.

Robinson, W.S., and Johansen, C.A., 1978. Effects of control chemicals for Douglas-fir Tussock moth *Orgyia pseodotsugata* (McDonnough) on forest pollination (Lepidoptera: lymantriidae). Melanderia 30:10–56.

Rockwood, L.L., 1995. Presentation at the Association of Virginia Gypsy Moth Managers meeting, Luray, VA. January 11, 1995.

Rodgers, K., and Ellefson, D., 1992. Mechanism of the modulation of murine peritoneal cell function and mast cell degranulation by low doses of malathion. Agents and Action 35(1/2):57–63.

Ross, J., Thongsinthusak, T., Fong, H.R., Margetich, S., and Krieger, R., 1990. Measuring potential dermal transfer of surface pesticide residue generated from indoor fogger use: an interim report. Chemosphere 20(3/4):349–360.

Ryan, D.L., and Fukuto, T.R., 1985. The effect of impurities on the toxicokinetics of malathion in rats. Pesticide Biochemistry and Physiology 23:413–424.

Saha, L.C., and Singh, N.K., 1981. Effect of malathion on the primary production of phytoplankton in a fresh water pond. Comp. Physiol. Ecol. 6(1):17–18.

Schaefer, C.H., Colwell, A.E., and Dupras, E.F., Jr., 1980. The occurrence of p-chloroaniline and p-chlorophenylurea from the degradation of pesticide in water and fish. Proceedings of the 48th Annual Meeting of the Mosquito Vector Control Association, p. 84–89.

SERA—See Syracuse Environmental Research Associates, Inc.

Sheehan, P., Baril, A., Mineau, P., and Paustenbach, D., 1992. Predicting the effects of pesticides on aquatic systems and the waterfowl that use them: an ecological risk assessment. *In* Aquatic Toxicology. (Submitted as a case study.) February 13, 1992.

Shepard, M., and Sterling, W., 1972. Effects of early season applications of insecticides on beneficial insects and spiders in cotton. Texas Agricultural Experimental Station Bulletin MP–1045.

Siebert, D., and Eisenbrand, G., 1974. Induction of mitotic gene conversion in *Saccharomyces cerevisiae* by N-nitrosated pesticides. Mutation Research 22:121–126.

Singh, H., and Singh, T.P., 1980. Effect of two pesticides on ovarian ^{32}P uptake and gonadotrophin concentration during different phases of annual reproductive cycle in freshwater catfish, *Heteropneustes fossilis* (Bloch). Environmental Research 22:190–200.

Sinha, S.N., Lakhani, K.H., and Davis, N.K., 1990. Studies on the toxicity of insecticidal drift to the first instar larvae of the large white butterfly *Pieris brassicae* (Lepidoptera: pieridae). Annals of Applied Biology 116:27–41.

Sivaiah, S., and Ramana Rao, K.V., 1978. Effect of malathion on the excretory pattern of the snail, *Pila globosa* (Swainson). Current Science 47(23): 894–895.

Smalley, H.E., 1976. Comparative toxicology of some insect growth regulators. Clinical Toxicology 2:27.

Smalley, H.E., Curtis, J.M., and Earl, F.L., 1968. Teratogenic action of carbaryl in beagle dogs. Toxicology and Applied Pharmacology13(3):392–403.

Smith, G.J., 1987. Pesticide use and toxicology in relation to wildlife: organophosphate and carbamate compounds. Resource Publication 170. U.S. Department of the Interior, Fish and Wildlife Service, Washington, DC.

Sundaram, K.M.S., Holmes, S.B., Kreutzweiser, D.P., Sundaram, A., and Kingsbury, P.D., 1991. Environmental persistence and impact of diflubenzuron in a forest aquatic environment following aerial application. Archives of Environmental Contamination and Toxicology 20(3):313–324.

Syracuse Environmental Research Associates, Inc., 1993. Special issues related to the assessment of pesticide absorption. SERA TR 93-0021. Prepared by Syracuse Environmental Research Associates, Inc.

Syracuse Environmental Research Associates, Inc, 1996. Human Health Risk Assessment for the APHIS 1996 Rangeland Grasshopper Cooperative Management Program. Contract Number 53–3187–5–12. Syracuse Environmental Research Associates, Inc.

Tepedino, V.J., 1979. The importance of bees and other insect planetaries in maintaining floral species composition. Great Basin Naturalist Memoirs 3: 139–150.

Teske, M.E., and Curbishley, T.B., 1990. Forest Service Cramer Barry Grim FSCBG 4.0 user manual. Continuum Dynamics Report No. 90–06. Princeton, NJ.

Teske, M., Bentson, K., Sandquist, R.E., Barry, J.W., and Ekblad, R.B., 1991. Comparison of the FSCBG model predictions with heather seed orchard deposition data. Journal of Applied Meteorology 30(9):1366–1375.

Thomas, P.T., and House, R.V., 1989. Pesticide-induced modulation of the immune system. *In* Ragsdale, N.N., and Menzer, R.E. (eds.). Carcinogenicity and pesticides: principles, issues, and relationships. Symposium at the 196th meeting of the American Chemical Society, Los Angeles, CA. American Chemical Society, Washington, DC.

Thompson, S.G., and Swigert, J.P., 1993. Diflubenzuron: a 14-day toxicity test with duckweed (*Lemna gibba* G3). Final report. Wildlife International Ltd. Project No. 225A–103A, Solvay Duphar Int. Doc. No. 56835/22/93. 115 pp.

Tompkins, W.A., 1966. Sevin residues in marine and freshwater aquatic organisms. *In* Commonwealth of Massachusetts, Massachusetts Pesticide Board, report of the surveillance program conducted in connection with an application of carbaryl (Sevin) for the control of gypsy moth on Cape Cod, Massachusetts. Publication 547, p. 37–46.

Tsuda, T., Aoki, S., Kojima, M., and Harada, H., 1989. Bioconcentration and excretion of diazinon, IBP, malathion, and fenitrothion by willow shiner. Toxicology and Environmental Chemistry 24:185–190.

USDA, APHIS—See U.S. Department of Agriculture, Animal and Plant Health Inspection Service.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1987. Rangeland Grasshopper Cooperative Management Program, Final Environmental Impact Statement—1987. Washington, DC. U.S. Department of Agriculture, Animal and Plant Health Inspection Service. 221 pp.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1993. Medfly Cooperative Eradication Program, Final Environmental Impact Statement—1993.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996a. Grasshopper Integrated Pest Management User Handbook, Tech. Bul. No. 1809. U. S. Department of Agriculture, Animal and Plant Health Inspection Service, Washington, DC.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996b. Environmental Fate and Transport Modeling for Grasshopper Chemical Control Agents. Biotechnology, Biologics, and Environmental Protection, Environmental Analysis and Documentation, Riverdale, MD.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1996c. Hazard Analysis—Rangeland Grasshopper Cooperative Management Program.

U.S. Department of Agriculture, Animal and Plant Health Inspection Service, 1997. Environmental Monitoring Report: Cooperative Medfly Project, Florida, 1997. Riverdale, MD.

USDA, SCS—See U.S. Department of Agriculture, Soil Conservation Service.

U.S. Department of Agriculture, Soil Conservation Service, 1983. TR–20— Project formulation—hydrology technical release 20, computer user's guide.

U.S. Department of Health and Human Services/U.S. Department of Labor, National Institute for Occupational Safety and Health/ Occupational Safety and Health Administration, 1978.

Occupational health guideline for malathion. U.S. Department of Health and Human Services/U.S. Department of Labor, Washington, DC.

U.S. Department of the Interior, Fish and Wildlife Service, 1986. Letter and attachments to APHIS concerning effect of Mormon cricket control on endangered wildlife species in Utah and Colorado. Galen L. Buterbaugh, Regional Director, Denver, CO.

U.S. Environmental Protection Agency, 1975. Initial scientific and minieconomic review of malathion. Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency, 1993. Carcinogenicity peer review of carbaryl, 1-naphtyl N-methyl carbamate. MRID 421889–01, 02. Memorandum from Ray Landolt, Toxicological Branch II, October 7, 1993, 35 pp.

U.S. Environmental Protection Agency, Environmental Criteria and Assessment Office, 1984. Health and environmental effects profile for carbaryl. Environmental Protection Agency, Cincinnati, OH. January 1984.

U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, 1989. Risk assessment guidance for superfund: vol. 1: human health evaluation manual (part A). Interim final. EPA/504/1–89/002. Washington, DC. December 1989.

U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Office of Research and Development, 1988. Reference physiological parameters in pharmacokinetics modeling. EPA/600/8-88/004. Washington, DC. 1–1.

U.S. Environmental Protection Agency, Office of Pesticide Programs, 1984. Guidance for the registration of pesticide products containing carbaryl as the active ingredient. Washington, DC.

U.S. Environmental Protection Agency, Office of Pesticide Programs, 1989a. Inert ingredients in pesticide products: policy statement; revision and modification of lists. Federal Register 54(224): 48314–48317; November 22, 1989.

U.S. Environmental Protection Agency, Office of Pesticide Programs, 1989b. Toxchem no. 535–Malathion. Washington, DC. July 3, 1989.

U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances, 1980. Carbaryl decision document. Environmental Protection Agency, Washington, DC. p. 1–78. December 1980.

U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances, 1985. Pesticide Fact Sheet Number 21: carbaryl. Washington, DC. NTIS No. PB87–108973. Revised September 5, 1985.

U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances, 1987. Pesticide fact sheet no. 68.1: diflubenzuron. Washington, DC.

U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances, 1990. Environmental Protection Agency memorandum. Peer review of malathion. Washington, DC.

U.S. Environmental Protection Agency, Office of Prevention, Pesticides and Toxic Substances, 1994. RfD/Peer review of carbaryl. Memorandum from George Ghali to Hack Housenger, Copy dated March 10, 1994 courtesy of Dr. George Ghali.

Uvarov, B., 1966. Grasshoppers and locusts. A handbook of general acridology, Vol. 2. Centre for Overseas Pest Research, London, England.

Uvarov, B., 1977. Grasshoppers and locusts. A handbook of general acridology, Vol. 1. Cambridge University Press, Cambridge, England.

van der Leeden, F., Troise, F.L., and Todd, D.K., 1990. The water encyclopedia. Lewis Publishers, Inc., Chelsea, MI. 808 pp.

Walker, W.W., and Stojanovic, B.J., 1973. Microbial versus chemical degradation of malathion in soil. J. Environ. Qual. 2(2):229–232.

Wauchope, R.D., Buttler, T.M., Hornsby, A.G., Augustijn-Beckers, P.W.M., and Burt, J.P., 1992. The SCS/ARS/CES pesticide properties database for environmental decisionmaking. Reviews of Environmental Contamination and Toxicology 123:1–157.

Weil, C.S., Woodside, M.D., Bernard, J.B., Condra, N.I., King, J.M., and Carpenter, C.P., 1973. Comparative effect of carbaryl on rat reproduction and guinea pig teratology when fed either in the diet or by stomach intubation. Toxicology and Applied Pharmacology 26(4):621–638.

WHO—See World Health Organization.

WHO, IARC—See World Health Organization, International Agency for Research on Cancer.

Willcox, H., III, and Coffey, T., Jr., 1978. Environmental impacts of diflubenzuron (Dimilin) insecticide. Forest Insect and Disease Management, U.S. Department of Agriculture, Forest Service, Broomall, PA. 18 pp.

Wilson, J.E.H., and Costlow, J.D., 1986. Comparative toxicity of two Dimilin formulations to the grass shrimp, *Palaemonetes pugio*. Bulletin of Environmental Contamination and Toxicology 36:858–865.

Wimmer, M. 1994a. Professor, Department of Biochemistry, West Virginia University, Morgantown, WV. (Personal communication; comments from review of draft)

Wimmer, M. 1994b. (Unpublished data on file.) Environmental Analysis and Documentation, Animal and Plant Health Inspection Service, U.S. Department of Agriculture, Radnor, PA.

Wimmer, M.J., Smith, R.R., Wellings, D.L., Toney, S.R., Faber, D.C., Miracle, J.E., Carnes, J.T., and Rutherford, A.B., 1993. Persistence of diflubenzuron on Appalachian forest leaves after aerial application of Dimilin. Journal of Agricultural Food and Chemistry 41:2184–2190.

Wirth, S, and Vogel, K., 1988. Cow's milk protein intolerance in infants with methemoglobinemia and diarrhea. European Journal Of Pediatrics (Berlin) 148(2):172.

Woebkenberg, N.R., Mostardi, R.A., Ely, D.L., and Worstell, D., 1981. Carboxyhemoglobin and methemoglobin levels in residents living in industrial and nonindustrial communities. Environmental Research 26(2):347–352.

Wolfe, N.L., Zepp, R.G., Gordon, J.A., Baughman, G.L., and Cline, D.M., 1977. Kinetics of chemical degradation of malathion in water. Environmental Science and Technology 11(1):88–93.

Wolfe, N.L., Zepp, R.G., and Pacis, D.F., 1978. Carbaryl, propham, and chloropropham: a comparison of the rates of hydrolysis and photolysis with the rate of biolysis. Water Research 12:565–571.

World Health Organization of the United Nations, 1985. Pesticide residues in food—1985. Report of the joint meeting of the FAO panel of experts on pesticide residues in food and the environment and a WHO expert group on pesticide residues. Geneva, Switzerland.

World Health Organization of the United Nations, International Agency for Research on Cancer, 1983. International Agency for Research on Cancer monographs on the carcinogenic risk of chemicals to humans—miscellaneous pesticides (Vol. 30). International Agency for Research on Cancer, Geneva, Switzerland.

Zinkl, J.G., Henny, C.J., and DeWeese, L.R., 1977. Brain cholinesterase activities of birds from forests sprayed with trichlorfon (Dylox) and carbaryl (Sevin 4-oil). Bulletin of Environmental Contamination and Toxicology 17:379–386.

Appendix E.Federal Register Notices Associated With This Document

Rangeland Grasshopper and Mormon Cricket Control Activities

Environmental Impact Statements; Notice of Availabilty

Environmental Impact Statements; Notice of Availability; Amended Notice

Environmental Impact Statements; Notice of Availability; Amended Notice

Appendix F. Summary of Public Comments on the Draft Environmental Impact Statement

The Rangeland Grasshopper and Mormon Cricket Suppression Program, Draft Environmental Impact Statement (DEIS) was published on August 31, 2001. The U. S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS) originally provided a 45-day public comment period ending October 15, 2001. On October 15, 2001, APHIS received a request dated October 3, 2001, from Terence N. Martin, Office of Environmental Policy and Compliance, U.S. Department of the Interior, to extend the public comment period. In accordance with that request, APHIS extended the public comment period in 66 *Federal Register* (FR) 53219 until November 14, 2001. On November 13, 2001, APHIS received a phone call from Arthur Totten, Office of Federal Activities, U.S. Environmental Protection Agency (EPA), who requested another extension of the public comment period. In accordance with that request, APHIS extended the public comment period in 66 FR 58734 until November 28, 2001.

APHIS received 10 comment letters prior to the close of the comment period on November 28, 2001. Comments from the U.S. Fish and Wildlife Service were sent on March 6, 2002, and received by APHIS on March 29, 2002, after the close of the comment period, but have, nevertheless, been addressed in this document. Copies of the comment letters are included in this appendix.

Many of the comment letters provided technical corrections that have been incorporated into the final environmental impact statement (EIS). The comments also pointed out areas where the DEIS was unclear. All of the comments received were carefully considered, and the DEIS has been revised and finalized accordingly. While considering the comments, APHIS identified

25 primary issues that the commenters identified. Those issues are addressed in the following section and in no particular order. Each issue has been summarized and a response follows.

ISSUE 1: Some readers had difficulty with the organization of the document and locating the lists of references.

RESPONSE: Several changes have been made to assist readers. A preface has been added that describes the organization of the document. References cited in chapters 1 through 6 are listed in chapter 7. References cited in the appendices can now be found in a single place, appendix D.

ISSUE 2: The distinction between what land managers do for grasshopper management and what APHIS does for grasshopper suppression was unclear to some commenters.

RESPONSE: The Plant Protection Act (PPA) directs APHIS to generally carry out a program to control grasshoppers and Mormon crickets on all Federal lands to protect rangeland. The PPA also states that, "Subject to the availability of funds. . ." on request of the administering agency or the agriculture department of an affected State, the Secretary of Agriculture, to protect rangeland, shall immediately treat Federal, State, or private lands that are infested with grasshoppers or Mormon crickets at levels of economic infestation, unless the Secretary determines that delaying treatment will not cause greater economic damage to adjacent owners of rangeland."

Based on the above authority, APHIS directly intervenes and suppresses grasshopper and Mormon cricket populations only when requested, and only when those populations reach levels can cause economic damage to rangeland forage and/or adjacent cropland. In addition, APHIS conducts surveys and provides land managers technical assistance regarding grasshopper species composition, densities, and potential for economic damage to occur.

The role of land managers is to implement management efforts that hopefully prevent or reduce the severity of grasshopper outbreaks. While APHIS can provide technical assistance to land managers, implementing the actual practices such as grazing management that are intended to prevent grasshopper outbreaks are the responsibilities of the land managers rather than APHIS. Land managers may choose from among a variety of cultural and biological approaches to prevent or lessen the severity of grasshopper outbreaks. Some of these approaches are described in appendix A.

ISSUE 3: Several comments were received regarding how the FEIS will be used by other Federal agencies to fulfill responsibilities they may have under the National Environmental Policy Act (NEPA). How this EIS can be restricted to the action of a single Federal agency (APHIS) was also asked.

RESPONSE: Information has been added to the EIS that contains information on the ways in which other Federal agencies may use this programmatic document to fulfill their responsibilities under NEPA, including site-specific programs against grasshopper outbreaks. The information is also reiterated in chapter 1, Purpose of and Need for the Proposed Action and chapter 2, Background.

There are four methods from which Federal agencies may choose. One method is adoption

(§ 1506.3). NEPA regulations state "An agency may adopt a Federal draft or final environmental impact statement or portion thereof provided that the statement or portion thereof meets the standards for an adequate statement under these regulations." Another method is combining documents. Section 1506.4 states that "Any environmental document in compliance with NEPA may be combined with any other agency document to reduce duplication and paperwork." A third method is incorporation by reference (§1502.21) which says "Agencies shall incorporate material into an environmental impact statement by reference when the effect will be to cut down on bulk without impeding agency and public review of the action. The incorporated material shall be cited in the statement and its content briefly described. No material may be incorporated by reference unless it is reasonably available for inspection by potentially interested persons within the time allowed for comment. Material based on proprietary data which is itself not available for review and comment shall not be incorporated by reference."

A last method is tiering (§ 1502.20). "Agencies are encouraged to tier their environmental impact statements to eliminate repetitive discussions of the same issues and to focus on the actual issues ripe for decision at each level of environmental review (§ 1508.28). Whenever a broad environmental impact statement has been prepared (such as a programmatic or policy statement) and a subsequent statement or environmental assessment is then prepared on an action included within the entire program or policy (such as a site-specific action), the subsequent statement or environmental assessment need only summarize the issues discussed in the broader statement and incorporate discussions from the broader statement by reference and shall concentrate on the issues specific to the subsequent action. The subsequent document shall state where the earlier document is available. . . (§ 1508.28)."

Adoption, combining, incorporation by reference are the methods best suited when using the data provided by this EIS. State agencies also can use the information provided by this EIS.

This document is not restricted to the actions of a single agency; rather, it deals with a program, treating it by stage of technological development (40 Code of Federal Regulations (CFR)

§ 1502.4 (c)(3)), in which other Federal land management agencies and State agriculture departments may cooperate, as needed, in more localized operations.

ISSUE 4: To some readers the DEIS did not provide enough information on how site-specific environmental assessments (EAs) will be prepared.

RESPONSE: The appropriate environmental documentation for a site-specific program, usually an EA, will be prepared prior to implementing a specific grasshopper suppression program. If a Federal land management agency is proposing the program, that particular agency will prepare, or be involved in preparing, the EA. For State agriculture departments proposing a grasshopper program, the environmental documentation will be provided by APHIS. Should a grasshopper program be requested by private groups or individuals through their State agriculture department, APHIS would undertake the appropriate environmental process.

When site-specific grasshopper programs are proposed, the corresponding environmental documentation will include a thorough review of such subjects as alternatives; the affected environment; species of concern, including biological control insectary sites for noxious weeds; endangered and threatened species; cumulative impacts; compliance with the Executive Orders on minorities and low-income populations and children; and any required monitoring.

ISSUE 5: Commenters questioned whether there is a need for grasshopper treatments, if those treatments were economically justified, and whether the long-term benefits of grasshopper suppression outweigh the long-term costs. In particular, one commenter repeatedly suggested that grasshopper outbreaks were analogous to natural disasters such as fires and floods and that policies and management practices should recognize the benefits of allowing natural cycles to take place with a minimum of human interference.

RESPONSE: Congress directed USDA to protect rangeland from economic infestations of grasshoppers and Mormon crickets in the PPA. The need for a grasshopper suppression program in a particular rangeland location is evaluated on a case-by-case basis. For example, if the grasses in a rangeland area are abundant and the cattle have adequate forage—despite a high number of grasshoppers per square yard—a treatment may not be warranted. On the other hand, a lower grasshopper number per square yard under drought conditions may warrant a treatment.

Other scenarios in which a grasshopper treatment would not be warranted include the following: (1) in an area that has naturally high numbers of grasshoppers and ranchers have adjusted the number of livestock for the amount of forage available, and (2) in an area where grasshoppers are primarily species that pose little threat to rangeland forage.

The areas where a request for a grasshopper treatment would probably occur would be in areas where there are periodic outbreaks of grasshopper species that consume and destroy forage that livestock and range-consuming wildlife could use. In these areas it is difficult to adjust to the periodic swings in available forage that would be caused by grasshopper outbreaks.

In some regards, grasshopper suppression and forest fires are analogous. Just as not every forest fire is controlled by the Federal government, not every grasshopper outbreak is suppressed by APHIS. While it is likely that APHIS would be requested to intervene in widespread and severe grasshopper outbreaks, there may also be smaller outbreaks in areas of high value agricultural lands that would justify treatments. Additionally, assistance is available to the victims of disasters from groups and agencies such as nonprofit organizations, local relief agencies, and the Federal Emergency Management Agency. There are no such relief groups for grasshopper outbreaks.

ISSUE 6: Some commenters were unclear about when and where APHIS would conduct treatments and the criteria that will be used to determine if treatments are needed.

RESPONSE: The decision to conduct grasshopper treatments is based on many factors, some of which are difficult to quantify. Among the factors APHIS considers are: the number of grasshoppers present in the area, grasshopper and plant species composition, life-cycle stage of the grasshoppers, range condition, the economic significance of the infestation, and whether it would be feasible to conduct an effective treatment program. When State and private lands are involved, the land manager/land owner must cost-share from 33 to 67 percent of the total treatment costs, and they are not likely to request treatments, through their State agriculture departments, unless they are reasonably certain their investment is worthwhile.

There are many APHIS activities that precede any decision to conduct a grasshopper treatment. Every year APHIS conducts surveys and provides ongoing technical assistance to Federal, State, and private land managers. Federal land management agencies and State agriculture departments will frequently request that APHIS investigate complaints regarding damage that is being caused to rangeland by grasshoppers. In most every year, and in the majority of instances, the decision reached by APHIS is to not conduct a grasshopper treatment. For example, in Idaho in 2000,

26 requests for treatment resulted in only 4 treatments.

To assist in decisionmaking, APHIS developed a computerized decision support system named HOPPER in the mid-1990s. HOPPER evaluated the validity and cost-effectiveness of treating rangeland grasshopper outbreaks on Western rangeland. It would be necessary to update HOPPER and include technological advances, such as the use of diflubenzuron and the RAATs strategy, before HOPPER could again be implemented to its fullest extent in deciding whether grasshopper treatments are biologically and economically warranted.

APHIS conducts surveys for grasshopper populations on rangeland in the Western United States. In addition, APHIS provides technical assistance on grasshopper management to land owners/managers. In situations where direct intervention may be necessary to suppress grasshopper populations to below economically damaging levels, Federal land management agencies and State agriculture departments may request APHIS to assess the situation. The decision to conduct a grasshopper suppression program involves both APHIS and the land owner/manager.

APHIS would only treat grasshoppers that have reached a level of economic infestation. In some cases APHIS rangeland treatments protect not only the rangeland, but reduce the likelihood that the grasshoppers will move from the rangeland onto crops and other lands that border rangeland. There are also situations where APHIS has been requested to treat a rangeland area that has small amounts (typically less than 10 percent of the infested area) of infested croplands. In those situations the crop owner pays the entire treatment cost on the croplands.

ISSUE 7: A need for spring surveys and a better ability to predict grasshopper outbreaks before they occur were suggested.

RESPONSE: APHIS has historically conducted spring (nymphal) surveys in years when funds were available. While these surveys provided much valuable information regarding the status of grasshopper populations, the ability to accurately predict grasshopper outbreaks is based upon numerous factors. Among these are temperature, precipitation, vegetation, soil qualities, and natural enemies. There may also be other factors not yet known that help determine if grasshopper populations will become economically damaging. The Grasshopper Integrated Pest Management (GHIPM) Program concluded that as more information becomes known, the task of forecasting outbreaks becomes more complex.

Although economically damaging grasshopper outbreaks cannot yet be accurately predicted, APHIS does conduct nymphal surveys in the spring and adult surveys in the fall. Early in the season, the locations where the grasshopper species composition and densities indicate a high likelihood of becoming an economic problem are identified. Those “hot spots” could then be treated to prevent grasshopper populations from developing and spreading. Such an approach would require early and accurate surveys and was proven to be economical in North Dakota during the GHIPM Program.

In 2002 APHIS will conduct a comprehensive spring survey in the Western United States. This information will then be made available to land managers. APHIS will also provide technical support and expertise to cooperate in treatment of “hot spots” upon request of a Federal land management agency or State agriculture department and subject to the availability of funds.

ISSUE 8: Some commenters requested APHIS to publish the operational procedures that will be used when conducting grasshopper treatments.

RESPONSE: Operational procedures for conducting grasshopper treatments have not been included in this document because operational procedures are intended to be developed on a site-specific basis rather than in a programmatic document of this type. Operational procedures will be implemented to ensure that all treatments will be efficacious, cost-effective, conducted with restrictions according to the product label, and to protect sensitive areas identified in site-specific documents.

ISSUE 9: Some commenters wanted information on whether retreatments would occur and whether more than one insecticide would be used at a particular treatment site.

RESPONSE: When requested by a Federal land management agency or State agriculture department, APHIS' role in the suppression of grasshoppers may be the application of insecticides. APHIS typically applies either carbaryl, diflubenzuron, or malathion one time to a treatment site. Retreatments seldom occur for both scientific and economic reasons. The goal of a treatment is to reduce grasshopper populations to below those levels that cause economic damage. A single treatment according to either Alternative 2 or Alternative 3 is intended to sufficiently reduce grasshopper populations, and there should be no need for another treatment. In addition, while a single treatment must be cost-effective, there are very few situations where multiple treatments would be cost-effective. An exception could be migrating Mormon crickets that may sometimes require a second treatment.

There may, however, be situations where it is appropriate to use one insecticide or formulation in one part of a treatment area and a different insecticide or formulation in another part of that same treatment area with all applications conducted in accordance to the label directions. For example, ultra-low-volume (ULV) malathion may be used over the majority of a treatment area, but areas of special consideration may be treated with carbaryl bait. Should these situations occur, no area would be treated with more than one insecticide, and there would be no mixing or combination of insecticides.

State agencies, counties, and private groups or individuals may conduct their own grasshopper suppression programs. APHIS has no control over those activities, although technical assistance can be provided. Yet, it is highly unlikely that APHIS would be requested to treat areas that had already been treated by State, county, or private interests because of the cost involved, and there would be no need to further suppress the grasshopper populations.

Pesticides may also be applied on rangeland by States, local governments, and private groups or individuals to control weeds, pests, or insects other than grasshoppers. Again, APHIS has no control over those activities, and the multitude of treatments that could be made are too numerous to analyze in this document. Site-specific environmental documents will describe any synergistic and cumulative effects should APHIS be aware of other pesticide use in an area proposed for grasshopper treatments.

ISSUE 10: Many comments stated that the DEIS did not contain a reasonable range of alternatives. Mechanical control, biological control, and cultural control were among the alternatives suggested for analysis in this document, and many commenters proposed integrated pest management (IPM) as a preferred approach to grasshopper outbreaks. Others suggested which of the three alternatives contained in the DEIS they would prefer.

RESPONSE: In accordance with NEPA, alternatives relate to the underlying purpose and need to which the agency is responding (40 CFR § 1502.13). In the case of a programmatic EIS that is examining pest suppression issues by stage of technological development and not applying that technology to meet identified needs on the ground, the range of alternatives that have to be considered is somewhat limited. This EIS is intended to generally explore new information on insecticides and technological advances and their effects. No decision regarding the application of any technologies or alternatives that may be available to the affected land manager or owner will be made until such time as a “proposal” exists. It is when an agency becomes aware of a growing localized grasshopper problem that the purpose and need for action becomes clear. When an agency “has a goal and is actively preparing to make a decision on one or more alternative means of accomplishing that goal and the effects can be meaningfully evaluated

(40 CFR § 1508.23), a proposal exists.” APHIS does not contemplate an action, nor does it have an operational goal; therefore, a “proposal,” as such, does not exist.

APHIS' role in direct intervention of grasshopper infestations is to use an insecticide treatment to reduce grasshopper populations to a level below that which constitutes an economic infestation. APHIS' treatment alternatives analyzed in this EIS (see chapter 3, Alternatives) generally are carried out in conjunction with and complement Federal, State, and private efforts to prevent, control, or suppress grasshopper outbreaks. When a harmful grasshopper infestation reaches a level of economic infestation, direct intervention may be the most viable option.

ISSUE 11: Some commenters asked about the use of biological control agents, such as *Beauvaria*, to suppress grasshoppers.

RESPONSE: APHIS is aware that there are many natural enemies of grasshoppers in North America, and that using those natural enemies for the suppression and maintenance of grasshopper populations is a widely supported concept. Biological control was a major aspect of the APHIS GHIPM Program with specific emphasis on *Beauvaria.* GHIPM findings as well as research conducted in other countries has furthered the search for an effective biocontrol agent for grasshoppers. APHIS continues to have an interest in any grasshopper suppression strategy or method that reduces the reliance on insecticide use, but, thus far, biological control has not yet been proven to be consistently efficacious or cost-effective in reducing grasshopper outbreaks below economically damaging levels in the United States.

ISSUE 12: Technological advances in grasshopper suppression since the 1987 Rangeland Grasshopper Cooperative Management Program EIS were not evident to some readers.

RESPONSE: A discussion of the GHIPM Program is included in appendix A. This program conducted in the1990s addressed the main issues associated with grasshopper management. Among the technologies developed during the GHIPM Program and included in this EIS was the Reduced Agent Area Treatments (RAATs) strategy that can reduce insecticide loads by

75 percent or more. Another product of the GHIPM Program was research into the use of diflubenzuron, a chitin-inhibiting growth regulator, which is substantially less toxic to vertebrates than acetylcholinesterase-inhibiting chemicals. There have also been many other changes to the technical assistance APHIS provides as a result of the GHIPM Program.

ISSUE 13: The description of RAATs was confusing to some readers.

RESPONSE: The RAATs alternative is described in chapter 3 section C and the environmental consequences of that alternative are described in chapter 5, sections D and G. Figures have been added to chapter 3 of this document to visually depict this alternative.

In brief, the RAATs strategy is an approach to rangeland grasshopper suppression that reduces the insecticide application rate by 25 to 50 percent (or more) and swaths not directly treated (refuges) are alternated with treated swaths. By using the RAATs strategy, insecticide loads over the area being treated can be reduced by 75 percent compared to the rates that conventionally would be used in a blanket coverage of the treated area. The RAATs alternative works through both the action of the insecticide—meaning grasshoppers mortality occurs in the treated swaths—and conservation biological control—meaning the natural grasshopper predators and parasites remain in the untreated swaths.

A likely source of confusion in the EIS is that the risk assessment in appendix B was conducted using a set of reduced insecticide application rates, but the risk assessment assumes a blanket coverage of the reduced rates rather than reduction in the insecticide application area which would be an important part of the RAATs strategy. This was done to simplify the risk assessment because there is an almost unlimited number of combinations of reduced rates and reduced areas that could be considered. Therefore, the risk assessment for alternative 3 assumed the worst-case scenario in terms of insecticide load to an area, that being insecticide applied at a reduced rate, but over 100 percent of the entire treatment area with no untreated swaths. This does not mean that RAATs applications described in site-specific environmental documents will have 100 percent coverage; those site-specific RAATs will certainly cover less than 100 percent of the treatment area. However, this means that RAATs with less than 100 percent coverage will be expected to have environmental consequences that are no greater than the effects described in this EIS.

ISSUE 14: One commenter stated that the affected environment has been inadequately described in the DEIS.

RESPONSE: The description of the affected environment is adequate given the nature of the programmatic EIS. In the context of this document a fuller description of the affected environment would be tantamount to emphasizing background material, something the NEPA implementing regulations discourage (40 CFR § 1500.4(f)).

Once a suppression area has been identified, the site-specific environmental documentation prepared for that particular program will include the detailed information on the affected environment. As stated in chapter 4, Affected Environment, the characteristics of the program that may be analyzed include the potential effects of the program on human health, nontargets and socioeconomic issues. In addition, special considerations for minorities, low-income populations, and children will be examined, as well as cumulative effects and monitoring.

ISSUE 15: Additional information regarding carbaryl was requested in the comments. Questions were also raised regarding the use of carbaryl in both bait and ULV spray form.

RESPONSE: Additional information regarding carbaryl was submitted by the manufacturer and that information has been included in the document. Carbaryl can be applied as either a bait form, which is most often wheat bran that has been mixed with liquid carbaryl and is applied by either ground or aerial application, or in liquid form that is a ULV spray that is most commonly applied by airplane.

ISSUE 16: Some requested additional information on the environmental effects of diflubenzuron, and one commenter supplied additional information on diflubenzuron. The effects of diflubenzuron on aquatic invertebrates was of special concern.

RESPONSE: Additional information was supplied by the registrant for diflubenzuron. Much of this information served to update the analyses and has been included in the FEIS. There is considerable information about the effects of diflubenzuron (including on aquatic invertebrates) in the environmental risk assessment in appendix B of this document. Field studies involving diflubenzuron have also been summarized in chapter 5 sections B, C, and D.

As one commenter pointed out, EPA has estimated that diflubenzuron poses some risk to invertebrates when applied at the lowest rate for forestry applications. It should be noted that the lowest forestry application rate is 0.02 lb active ingredient per acre (a.i./acre) while the rangeland application rate for grasshopper suppression in Alternative 2 is 0.016 lb a.i./acre. In

Alternative 3 the rate is 0.012 lb a.i./acre but the total amount applied in a RAATs strategy will be reduced even further because diflubenzuron would only be applied directly to part of the treatment area.

ISSUE 17: A comment letter stated that the DEIS was unclear in its presentation of the effects of malathion on human health.

RESPONSE: The analysis of potential program effects of malathion on human health reveals comparable risks to those in EPAs recent risk assessments of malathion to comply with the Food Quality Protection Act. Readers are asked to refer to the Environmental Risk Assessment, appendix B, for details about human health effects that are summarized in chapter 5 of this final EIS.

ISSUE 18: More information contained on labels for carbaryl, diflubenzuron, and malathion was requested.

RESPONSE: Because insecticide product labels frequently change, labels have not been included in this FEIS. The most recent labels for these products can be found at: www.cdms.net/manuf/manuf.asp. However, many commenters were concerned about protecting water bodies. All labels for carbaryl, diflubenzuron, and malathion prohibit application directly to water, and it is highly unlikely that this requirement will change. APHIS will adhere to all label restrictions.

ISSUE 19: Some comments requested more information on how APHIS would protect the health, safety, and aesthetic concerns of workers as well as the public residing in areas where treatments could occur, including the need for a formal notification process to let allergic or hypersensitive individuals be informed before treatments.

RESPONSE: The effects of grasshopper treatments on humans and the measures APHIS will take to protect workers and the public are contained in several sections of the document such as chapter 5, section C. and appendix B.

An important aspect of protecting humans from the effects of insecticides used for grasshopper suppression is that APHIS will not conduct any suppression program unless requested to do so by the responsible land management agency. Those agencies would have their own procedures for protecting humans that APHIS will abide by. APHIS also conducts stakeholder meetings involving the wide range of land managers, land owners, and the public before any suppression programs are conducted and where health and safety issues can be addressed. In addition, APHIS complies with all product label requirements for human health and safety including the Worker Protection Standard (40 CFR § 170).

ISSUE 20: The effects of grasshopper suppression treatments on nontarget organisms, and ecosystems in general, were a concern to many. Specific concerns were raised regarding the toxicity of carbaryl, diflubenzuron, and malathion to birds, nontarget insects, including those used as biological control agents, and fish. In addition, a comment was made regarding the environmental effect of oils used during treatments.

RESPONSE: The effects of carbaryl, diflubenzuron, and malathion on nontarget organisms have been described in chapter 5 and appendix B. Except for those atypical instances when the effects of program insecticides were known for a particular species, the analyses in this document relied on representative nontarget species. Refer to appendix B, table B–3 for a list of the representative species. Both laboratory and field studies were used to describe the effects of grasshopper treatments on nontarget organisms. This document contains some information on nontarget organisms that was not available for the DEIS.

The available toxicity data from research on given pesticides is limited to a finite number of wildlife species. The determination of risk to a given species from potential program action is made by selection of toxicity data for that species or the most closely related surrogate species. The review of the quality of data from available research may influence the decision to select a given study or specific data for a given surrogate species over other available data. The decision to select specific data for a given surrogate for use in the grasshopper program risk assessments was made by a diverse team of scientists. The surrogate data were selected to best represent the species risk based upon the concensus of the team. This approach may not always portray the most sensitive outcome, but is designed to provide the decisionmaker with a realistic description of impacts of potential program alternatives. This information allows the risk manager to make an informed decision about differences in potential impacts among available alternatives to the program.

In Chapter 5, section E, Species of Concern, protected species, and threatened and endangered species were addressed. Each of those categories contain descriptions of the environmental consequences of grasshopper programs on an individual species. These species were intended to be examples and the findings will not necessarily apply to all species that could be of special concern. Site-specific documents will provide more detailed information on any species that may be of special concern for a given grasshopper suppression effort.

In response to the oil that would be used, the amount of oil used will be within the labeled rate which for diflubenzuron which currently allows for, but does not mandate, the use of emulsified vegetable or paraffinic crop oil. The maximum rate that oil would be applied for grasshopper suppression is 10 ounces of oil per acre. The risk of toxic effects from oil at this rate is extremely low.

ISSUE 21: Some comments asked about the effect of grasshopper treatments on bees.

RESPONSE: APHIS is well aware of the risks to bees in the vicinity of grasshopper suppression programs. The insecticides APHIS would use to suppress grasshoppers have varying degrees of toxicity to bees based on the insecticide’s mode of action. In general, bee mortality could be expected for bees exposed to carbaryl and malathion in spray form. However, bees are unlikely to be exposed to carbaryl in bait form. The insect growth regulator, diflubenzuron, is nontoxic to adult bees and immature bees would not likely be exposed to toxic levels of diflubenzuron residues returned by adults.

Grasshopper suppression carried out under Alternative 2 would have a greater effect on bees than would suppression programs that use a RAATs strategy, Alternative 3. Native and foraging bees in areas left untreated in a RAATs application would much less likely be directly exposed to any of the insecticides. Any beekeepers in the treatment area that could be affected will be notified. Site-specific environmental documents will describe what, if any, protective measures will be taken to protect bees from program insecticides.

ISSUE 22: Many comments pertained to federally listed threatened and endangered species, State listed species, and other special species of concern, and the process by which APHIS proposes to protect those species.

RESPONSE: Federally listed species are being addressed in the Endangered Species Act section 7 consultation, which will include listed and proposed species that occur within the 17 Western States where grasshopper treatments could occur. APHIS will implement all measures to minimize any adverse impacts on those species that are identified in the consultation. The potential effects of a particular grasshopper treatment may also be evaluated for State listed species and species of concern in the environmental document prepared for that site. In addition, APHIS will abide by all restrictions that land managers may impose.

ISSUE 23: Many commenters asked APHIS to describe what the effects of grasshopper treatments will be on threatened and endangered species.

RESPONSE: A biological assessment is a document prepared by the Federal agency to determine the potential impacts of its action on endangered and threatened species and their habitats. APHIS is preparing the biological assessment that will evaluate the potential effects of the use of the three insecticides on listed and proposed endangered and threatened species and their habitats that occur within the 17 Western States. Through the consultation process, protection measures will be developed that when implemented will ensure the grasshopper program will not adversely affect endangered or threatened species or their habitats.

ISSUE 24: The extent to which cumulative impacts were analyzed in the DEIS was questioned by some.

RESPONSE: The EIS could not analyze cumulative impacts because it is a programmatic EIS for 17 Western States. Cumulative impacts will be considered at the site-specific, operational level when the parameters of the program area can be identified. The application of an insecticide by APHIS will be added to the past, present, and reasonably foreseeable future actions that have or will occur in the treatment area. These will be the components evaluated under cumulative impacts.

ISSUE 25: Comments were received regarding the need for posttreatment monitoring to assess impacts on nontarget organisms.

RESPONSE: The GHIPM Program conducted studies on the effects of insecticide treatments on nontarget organisms. This information can be found in the IPM Manual available on line at www.sidney.ars.usda.gov/grasshopper/index.htm. Should environmental monitoring be conducted, a monitoring plan will describe the where, when, what, and how many samples should be collected. The types of samples collected might include flowing or stationary water, soil, sediment, fish, insects, and vegetation, as well as measuring airborne drift using dye cards.

Precision monitoring could be utilized to limit pesticide use to areas where pests actually exist or are reasonably expected and where economically and technically feasible. Samples will be analyzed for insecticide residues, and monitoring reports will be written should monitoring be conducted.

ALL COMMENT LETTERS SUBMITTED TO APHIS HAVE BEEN REPRODUCED HERE.

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Appendix I. Acronyms and Glossary

A

Acetylcholinesterase (AChE)—An enzyme produced at junctions in the nervous system that inactivates acetylcholine, thereby ending transmission of a nerve impulse once it has passed the junction.

Active Ingredient (a.i.)—The effective control agent of a pesticide formulation or the actual amount of the technical material present in the formulation.Acute Toxicity The potential of a substance to cause injury or illness when given in a single dose or in multiple doses over a period of 24 hours or less; in aquatic studies, exposure to a given concentration would be for 96 hours or less.

Amphipod—Any of a large group of small, aquatic crustaceans, commonly called scuds, with laterally compressed bodies.

Animal and Plant Health Inspection Service (APHIS) —An agency of the U.S. Department of Agriculture.

Arthropod—Members of the phylum Arthropoda include the insects, the crustaceans (crabs, lobsters, and shrimp), the arachnids (spiders, ticks, and scorpions), the millipedes, and centipedes. The arthropod is characterized by a rigid external body covering called a cuticle or exoskeleton, a segmented body, and paired, jointed appendages with at least one pair of functional jaws.

B

Bureau of Indian Affairs (BIA)—An agency of the U.S. Department of the Interior.

Bioaccumulation—The process of a plant or animal selectively taking in or storing a persistent substance over a period of time; a higher concentration of the substance is found in the organism than in the organism’s environment.

Biological Assessment (BA) —The document prepared to assess the potential impacts of a program on endangered and threatened species and their habitats.

Bureau of Land Management (BLM) —An agency of the U.S. Department of the Interior.

C

Carbaryl —A broad-spectrum carbamate insecticide that inhibits acetylcholinesterase.

Carcinogen —Substance that causes cancer.

Council on Environmental Quality (CEQ) —The agency that oversees implementation of the National Environmental Policy Act.

CFR—Code of Federal Regulations (U.S.).

Chemical Degradation—The breakdown of a chemical substance into simpler components through chemical reactions.

Chitin—A polysaccharide, hard substance that forms the outer cover of insects, crustaceans, and some other invertebrates.

Cholinesterase (ChE)—Any enzyme that catalyzes the hydrolysis of choline esters; for example, acetylcholinesterase catalyzes the breakdown of acetylcholine to acetic acid and choline.

Chronic Toxicity—Harmful effects of a chemical from prolonged exposure or repeated administration.

Cooperator —A landowner, Federal, State, or private individual, agency, or group that is involved in a grasshopper or Mormon cricket control program as a codecisionmaker or financially through an established cost-sharing formula.

Cropland —Any area planted with the intent to harvest. Crops planted and then grazed because of drought or insufficient growth will be considered cropland. Fallow land also will be considered cropland.

Cumulative Impacts—". . . the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." (40 CFR 1508.7)

D

DEIS—Draft environmental impact statement. See Environmental Impact Statement.

Diapause—A period of spontaneous dormancy independent of environmental conditions interrupting developmental activity in an embryo, larva, or pupa, or arresting reproductive activity in an adult insect and usually occurring during hibernation or estivation.

Diflubenzuron—An insect growth-regulating insecticide that inhibits the formation of chitin.

Diptera—Flies, mosquitoes, midges, and the like, that constitute a group of insects characterized by having only one pair of functional wings; a second nonfunctional pair is reduced to small knobbed structures called halteres.

Drift—That portion of a sprayed chemical that moves off a target site because of wind.

E

Economic Infestation—A measurement of the economic losses caused by a particular population level of grasshoppers or Mormon crickets to the designated rangeland.

Endangered Species —Any species of animal or plant that is in danger of extinction throughout all or a significant portion of its range.

Endangered Species Act (ESA) —A Federal law that regulates the conservation of endangered and threatened species and their habitats.

Environmental Assessment (EA) —An environmental document, prepared to comply with the National Environmental Policy Act of 1969, wherein the environmental impacts of a planned action (in this case grasshopper control programs) are objectively reviewed.

Environmental Impact Statement(EIS)—A document prepared by a Federal agency in which anticipated environmental effects of alternative planned courses of action are evaluated; a detailed written statement as required by section 102(2)(C) of the National Environmental Policy Act (NEPA).

Executive Order (E.O.)—A form of executive lawmaking implemented by the President.

Exoskeleton—The hard outer casing of an insect that is made of chitin.

Exposure Analysis—The estimation of the amount of chemicals that organisms receive during application of pesticides.

F

Family —A group of related plants or animals forming a category ranking above a genus and below an order, usually comprising several to many genera, but sometimes including a single genus of notably distinctive characters.

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)—A Federal law that provides the overall framework for the Federal pesticide program.

Fish and Wildlife Service (FWS) —An agency of the U.S. Department of the Interior.

Forage—All browse and nonwoody plants available to livestock or wildlife for grazing or harvesting for feed.

Forage Production—The weight of forage that is produced within a designated period of time on a given area. The weight may be expressed as either green, air-dry, or oven-dry. The term may also be modified as to time of production such as annual, current year's, or seasonal forage production.

Forb—A herbaceous plant other than a grass, especially one growing in a field or meadow.

Forest Service (FS)—An agency of the U.S. Department of Agriculture.

Federal Register (FR)—The official daily publication for Rules, Proposed Rules, and Notices of Federal agencies and organizations, as well as Executive Orders and other Presidential documents.

Formulation—The form in which a pesticide is packaged or prepared for use. A chemical mixture that includes a certain percentage of active ingredient (technical chemical) with an inert carrier.

G

Genus —A taxonomic category ranking below a family and above a species; used in taxonomic nomenclature, either alone or followed by a Latin adjective or epithet, to form the scientific name of a species.

Grasshopper Integrated Pest Management (GHIPM)—The Grasshopper Integrated Pest Management Program.

Granivorous—Feeding on grains and seeds.

H

Half-life —The time required for a substance (such as an insecticide) in or introduced into a living or nonliving system to be reduced to half of its original amount whether by excretion, metabolic decomposition, or other natural process.

Hazard Analysis —The determination of whether a particular chemical is or is not causally linked to particular harmful effects.

Herbivore —An animal that feeds exclusively on plants.

Hydrolysis —Decomposition or alteration of a chemical substance by water.

Hymenoptera —A large order of insects comprised of the ants, bees, sawflies, and wasps. The typical adult has four membranous wings and chewing-type mouth parts.

I

Integrated Pest Management (IPM)—The selection, integration, and implementation of pest control actions on the basis of predicted economic, ecological, and sociological consequences; the process of integrating and applying practical methods of prevention and control to keep pest situations from reaching damaging levels while minimizing potentially harmful effects of pest control measures on humans, nontarget species, and the environment.

Insectivorous— Insect-eating; in common usage, includes animals that eat insects and sometimes other selected invertebrates.

Instar —The term for an insect before each of the moults (shedding of its skin) it must go through in order to increase in size. Upon hatching from its egg, the insect is in instar I and is so called until it moults, when it begins instar II, and so forth.

Invertebrate Drift—Movement of aquatic insects and crustaceans downstream with the current in flowing water that results from exposure to substances that elicit repellant or toxic responses.

Isopod —Any of a large order (Isopoda) of small crustaceans with the body composed of seven free thoracic sections, each bearing a pair of similar legs. Commonly called sowbugs.

L

Leach —Usually refers to the movement of chemicals through soil by water; may also refer to the movement of herbicides out of leaves, stems, or roots into the air or soil.

Lepidoptera —A large order of insects, including the butterflies and moths, characterized by four scale-covered wings and coiled, sucking mouthparts.

M

Malathion—A broad-spectrum organophosphate insecticide that inhibits acetylcholinesterase.

Metabolite — A product of the chemical changes in living cells that provides energy and assimilates new material.

Methemoglobin—The compound in blood responsible for transport of oxygen.

Methemoglobinemia—The condition where the heme iron in blood is chemically oxidized and lacks the ability to properly transport oxygen.

Microbial Degradation—The breakdown of a chemical substance into simpler components by bacteria.

Microgram—One-millionth of a gram; abbreviated as µg.

Mixed Function Oxidase (MFO)—Enzyme responsible for the oxidation of organophosphorous insecticides, such as malathion, to compounds that are stronger inhibitors of acetylcholinesterase.

Molt—To shed or cast off hair, feathers, shell, horns, or an outer layer of skin in a process of growth or periodic renewal with the cast-off parts being replaced by new growth.

Moribund—At or near the point of death.

N

National Environmental Policy Act of 1969 (NEPA) —The act whereby Federal agencies evaluate the potential effects of a proposed action and its alternatives on the human environment.

National Marine Fisheries Service(NMFS) —An agency of the U.S. Department of Commerce.

Nontarget Organisms—Those organisms (species) that are not the focus of insecticide treatments.

Nymph—Any insect larva that differs chiefly in size and degree of differentiation from the adult.

O

Omnivorous—Eating both animal and plant substances.

Oncogenic—Capable of producing or inducing tumors, either benign (noncancerous) or malignant (cancerous), in animals.

Order—A category of taxonomic classification ranking above family and below class and often being made up of several families.

Orthoptera—An order of Insecta comprising insects with mouthparts fitted for chewing, two pairs of wings or none, and an incomplete metamorphosis.

Outbreak—An explosive increase in the abundance of a particular species that occurs over a relatively short period of time.

P

Pesticide—Any substance or mixture of substances used in controlling insects, rodents, fungi, weeds, or other forms of plant or animal life that are considered to be pests.

Phytotoxic—Poisonous or harmful to plants.

Piscivorous—Habitually feeding on fish.

Plecoptera—An order of Insecta, stoneflies, characterized by aquatic nymphs that are mostly phytophagous.

Plant Protection Act (PPA)—The Plant Protection Act.

Plant Protection and Quarantine (PPQ)—A unit within the Animal and Plant Health Inspection Service, U.S. Department of Agriculture.

R

Reduced Agent Area Treatments (RAATs)—A grasshopper suppression method in which the rate of insecticide is reduced from conventional levels, and treated swaths are alternated with swaths that are not directly treated.

Rangeland—An area on which the vegetation consists of native or introduced grasses, legumes, grasslike plants, forbs, or shrubs, and that is developed for range (grazing) use. Also counted as rangeland is native pastures or meadows that are occasionally cut or mechanically harvested and are grazed by livestock.

Riparian Area—Land areas that are directly influenced by water. They usually have visible vegetative or physical characteristics reflecting this water influence. Stream sides, lake borders, or marshes are typical riparian areas.

Riparian Habitat—Those terrestrial areas where the vegetation complex and microclimatic conditions are products of the combined presence and influence of perennial or intermittent water, associated high water tables, and soils that exhibit some wetness characteristics. Includes riparian zones plus one-half the transition zone (or ecotone) between riparian zones and upland habitat.

Runoff—That part of precipitation, as well as any other flow contributions, that appears in surface streams, either perennially or intermittently.

S

Shrubsteppe—A prairie ecosystem dominated by desert shrub vegetation.

Species—A fundamental taxonomic classification category, ranking after a genus and consisting of class or group with distinguishing characteristics and designated by a common name.

T

Threatened Species—Any species of animal or plant that is likely to become an endangered species throughout all or a significant portion of its range within the foreseeable future.

Toxicity—A characteristic of a substance that makes it poisonous.

Translocation—The transfer of substances from one location to another in the plant body.

U

Ultra-Low-Volume (ULV)—Sprays that are applied at 0.5 gallons or less per acre or sprays applied as the undiluted formulation.

Understory—Plants growing beneath the canopy of other plants. Usually refers to grasses, forbs, and low shrubs under a tree or brush canopy.

U.S.C.— United States Code.

U.S. Department of Agriculture (USDA) —The department in which the Animal and Plant Health Inspection Service and the Forest Service are located.

U.S. Department of the Interior (DOI) — The department in which the Bureau of Indian Affairs, the Bureau of Land Management, and the Fish and Wildlife Service are located.

U.S. Department of Commerce (DOC)—The department in which the National Marine Fisheries Service is located.

U.S. Environmental Protection Agency (EPA)—The Federal agency that creates and enforces environmental regulations such as FIFRA.