III.4 Direct and Indirect Effects of Insecticides on Native Bees

D. G. Alston and V. J. Tepedino

NOTE: Acephate is no longer approved by EPA for rangeland grasshopper control.

The successful reproduction of plants in both natural and agricultural ecosystems is highly dependent upon adequate populations of pollinators. The role of bees as pollinators in natural ecosystems, such as rangelands, is less obvious to the casual observer. The fact is that the majority of rangeland plants require insect-mediated pollination. Native, solitary bee species are the most important pollinators on western rangelands (Tepedino 1979).

Indiscriminate use of broad-spectrum insecticides is likely to cause changes throughout the rangeland community. In addition to controlling the targeted pest (grasshoppers), rangeland insecticides can have direct and indirect effects on nontarget insects and related animals (see also III.3). Potential negative effects of insecticides on pollinators are of special concern because a decrease in their numbers has been associated with decline in fruit and seed production of plants. And this decline may have dramatic repercussions throughout the rangeland food chain. Some of the possible negative effects to the ecosystem include changes in future vegetation patterns via plant competition, reduction in seed banks, and influences on the animals dependent upon plants for food.

Direct effects are those that are lethal in nature and cause direct mortality that can be attributed to use of insecticides. Indirect or sublethal effects are much more difficult to document. They generally act over a longer period of time and can result in negative effects on reproductive potential, lifespan, activity levels, body size, and behavior of current and future generations.

Important Characteristics of Native Bees

When choosing the timing of insecticide applications to rangelands, one should consider some important characteristics of native bees, of the insecticide applied, and of the growth cycle of native plants. The typical solitary bee overwinters in its nest and emerges as an adult the following spring to early summer (fig. III.4–1). Adult females are exclusively responsible for feeding the young and thus play the major role in plant pollination while foraging for nectar and pollen.

There is tremendous variation among bee species in the length of time that adults are active and foraging (fig. III.4–1). The seasonal activity period of solitary bees may extend from spring through early fall due to multiple generations per year and continual availability of blooming plants. Therefore, land managers cannot assume that simply avoiding the application of insecticides on rangeland during the major time of plant bloom will avoid endangering the native bee population.

Exposure of bees to insecticides is also influenced by foraging behavior and flight distance. For most native bees, our knowledge of foraging behavior is limited to information on flower associations, such as a particular species that has been seen collecting the pollen and/or nectar of certain plants. The leaf-cutting habit of the alfalfa leafcutter bee makes it particularly susceptible to residues of contact insecticides on plant foliage. Contaminated leaves, mud, water, or resins used for nest construction may result in detrimental effects to the young. Bees' flight range can greatly affect their exposure to insecticides. Extensive flight distances between nests and flowering plants increase their foraging time and make them more vulnerable to insecticides (see III.8).

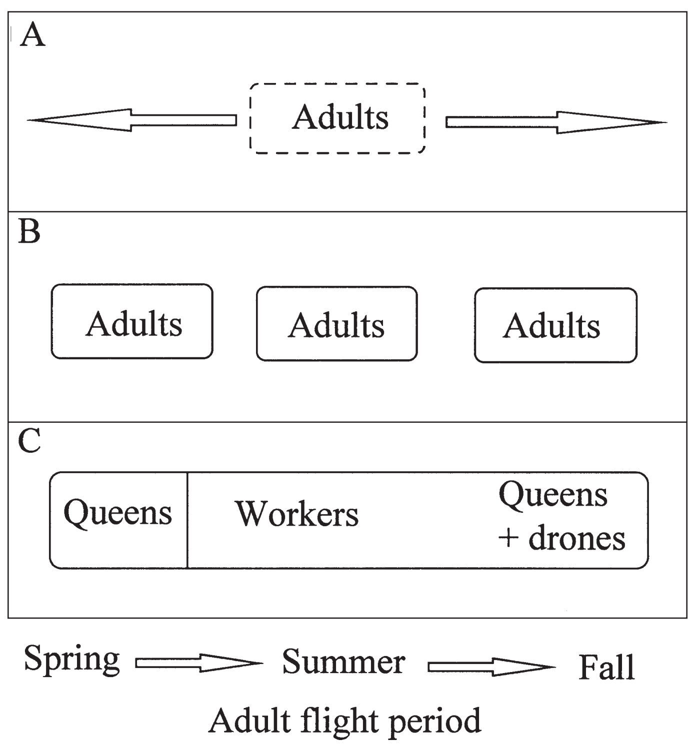

Figure III.4–1—Adult flight periods for three general life cycles of native bees: (A) Single generation per year, e.g., *Nomia* or *Osmia;* dotted lines indicate that flight period can shift in time depending on species. (B) Two or more generations per year, e.g., *Megachile* or *Ashmeadiella.* (C) Social, e.g., *Bombus.*

Body size of native bees also may affect susceptibility to insecticides in field situations. The greater surface-to-volume ratio of small bees increases their relative exposure to contact insecticides (Johansen 1972). Studies in a Montana forest (Flavell et al. 1975) found that, although the total bee population was not reduced following an application of the insecticide trichlorfon, the percentage of smaller bees (predominantly solitary species) present in the forest was significantly reduced. If this same effect is found in other ecosystems, then the greater susceptibility of smaller bees to insecticides is of particular concern for western rangelands.

Important Characteristics of Insecticides

Pesticide formulation strongly influences toxicity. Dusts and wettable powders tend to be more hazardous to bees than solutions or emulsifiable concentrates, while granular and bait formulations are generally low in hazard. Application technique is also important in determining toxicity; aerial spraying offers less opportunity for avoidance behavior and greatly increases drift (National Research Council of Canada 1981).

Currently, only broad-spectrum insecticides (acephate, carbaryl, and malathion) are registered for use on rangelands for grasshopper control. All three have received a high toxicity rating for their negative effects on bees (National Research Council of Canada 1981, Johansen and Mayer 1990, Johansen et al. 1983), and, therefore, are not registered for use on blooming crops or weeds if commercial bees are visiting the treatment area. Yet these insecticides are being sprayed on rangelands when native plants are in bloom and being visited by pollinators. Contact sprays can be very toxic to small, native bees because of direct contact with the insecticide or insecticide residue. Therefore, insecticides that are more selective in activity are highly desirable to reduce negative effects on bees.

One insecticide with promise for selectivity is carbaryl incorporated into bran flakes. Because such flakes act only upon ingestion, they are much more selective than contact formulations (Peach et al. 1994). Bees likely would encounter bran bait only when gathering pollen and nectar from open upright flowers into which particles of bait have fallen. Ingestion of the insecticide would have to occur in order for the bee to receive a toxic dose.

Lethal Effects

The direct, or lethal, effects of insecticides on bees have been the focus of much research. The majority of toxicological information has been obtained for three distantly related species: *Apis mellifera*, the honey bee; *Nomia melanderi*, the alkali bee; and *Megachile rotundata*, the alfalfa leafcutting bee. Toxicological data for the latter two species are of greater relevance to natural situations because of these bees' solitary nesting lifestyle and the primary role of adult females in foraging activities and provisioning the young. The greatest body of toxicity literature exists for the honey bee, but unfortunately these data have proved of limited use in prediction of toxicity to many species of native bees because of the major differences in lifestyle, behavior, physiology, and size.

On western rangelands where native plants are rare or their populations threatened, bait formulations of carbaryl have been suggested as a possible alternative to contact sprays. Liquid formulations of carbaryl can be quite toxic to all three bee species previously mentioned when bees directly contact insecticides or insecticide residues (Johansen and Mayer 1990). In contrast, under laboratory conditions, only extremely high doses of ingested carbaryl resulted in toxic effects to alfalfa leafcutting bee larvae when incorporated into the pollen provision either as liquid (Guirguis and Brindley 1974) or as bran bait (Peach et al. 1994). Such high rates of carbaryl are much greater than a bee would encounter in the field.

There were also no lethal effects of carbaryl bran bait on adult alfalfa leafcutting bees, even when they were fed a sustained diet of honey solution contaminated with carbaryl bait for up to 40 days (Peach et al. 1994). Other studies have found that young adult bees of this species (up to 4 days old) readily detoxify topically applied carbaryl, but this ability rapidly declines after day 4 (Lee and Brindley 1974).

Sublethal Effects

Other effects of insecticides to bees may not be as obvious. The long-term sublethal effects of insecticides to bees that would be most likely to lower visitation rates to flowers, and thereby reduce plant reproductive success, include negative changes in longevity of bees, adult activity levels, and number, size, and sex ratio of offspring produced. Such chronic effects could occur from the slow poisoning of the young through ingestion of contaminated pollen and exposure of foraging bees to insecticides through translocation in nectar. Although sublethal effects of insecticides can be subtle, in the long run they may have as great a weakening effect on bee populations as the mortality caused by direct toxicants.

Although few studies have addressed the subtle effects of insecticides on bees, some detrimental effects have been found. Female alfalfa leafcutting bees treated with contact applications of organophosphate insecticides showed reduced longevity and lower nesting rates and egg production than bees not treated (Torchio 1983, Tasei and Carre 1985, Tasei et al. 1988).

Approximately 40 percent of larvae of this bee fed provisions contaminated with deltamethrin could not successfully complete development (Tasei et al. 1988). However, studies with carbaryl bran bait found no sublethal effects on adults or larvae (Peach et al. 1994). There seems to be little reason for concern that any carbaryl eaten by foraging adult females from the nectar of open flowers will affect any aspect of reproduction. Again, it appears that the use of carbaryl bran bait on rangelands is a relatively safe option for pollinators (fig. III.4–2).

Figure III.4–2—Domestic bees often need protection during grasshopper conrol treatments using chemical sprays. Beekeepers can move the bees out of the application area, or control-program managers can leave a sufficient buffer zone to protect the bees. Applications of bran bait normally will be of little concern for beekeepers. (APHIS file photo.)

Implications for Management of Grasshoppers on Western Rangelands

Because of the multiple-use concept employed by managers of public lands, there is certain to be continual conflict among different users of the lands. The U.S. Department of Agriculture, Forest Service and the U.S. Department of the Interior, Bureau of Land Management have the unenviable task of making land-management decisions based on wide-ranging demands and input from recreational use and preservation of biodiversity to logging, mining, and grazing. Because of the current status of pest management technology, it is likely that use of insecticides for control of grasshoppers on western rangelands will continue for some time. Despite this current situation of conflict, there does appear to be some alternative in choice of insecticides that are more selective in their effects to nontarget plants and animals.

One such selective insecticide that appears well suited for use on rangelands is carbaryl bran bait. Demanding laboratory and greenhouse tests performed with the alfalfa leafcutting bee, a solitary nester, found no lethal or sublethal effects on adults and only minimal effects on larvae when doses much higher than would be encountered in the field were incorporated into their pollen provisions. However, there are more limitations to choosing carbaryl bran bait as a rangeland pest control tool. Because not all grasshopper species feed equally well on the bait (see II.12), proper identification of grasshopper species is especially important.

Although carbaryl bran bait may be a relatively safe option for a representative solitary bee, no one should feel comfortable with this assessment until there is further research on other pollinator species' susceptibility to various insecticides. Such research is critical for the preservation of insect biodiversity, as well as the biodiversity of the plants whose flowers cannot reproduce sexually without insect visits.

References Cited

Flavell, T. H.; Tunnock, S.; Barry, J. W.; Ekblad, R. B.; Ciesla, W. M. 1975. Western spruce budworm: a pilot control project with carbaryl and trichlorfon—environmental monitoring of aquatic organisms, birds, and insect pollinators. March 1978. Rep. 787-5. Missoula, MT: U.S. Department of Agriculture, Forest Service.

Guirguis, G. N.; Brindley, W. A. 1974. Insecticide susceptibility and response to selected pollens of larval alfalfa leafcutting bees, *Megachile pacifica* (Panzer)(Hymenoptera: Megachilidae). Environmental Entomology 3: 691–694.

Johansen, C. A. 1972. Toxicity of field-weathered insecticide residues to four kinds of bees. Environmental Entomology 1: 393–394.

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

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

Lee, R. M.; Brindley, W. A. 1974. Synergist ratios, EPN detoxification, lipid, and drug-induced changes in carbaryl toxicity in *Megachile pacifica.* Environmental Entomology 3: 899–907.

National Research Council of Canada. 1981. Pesticide–pollinator interactions. Ottawa, ON: National Research Council of Canada. 190 p.

Peach, M. P.; Alston, D. G.; 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.

Tasei, J. N.; Carre, S. 1985. Effets du traitement de luzerne en fleurs *(Medicago sativa* L.) avec de la deltamethrine et de la phosalone sur l'abeille solitaire: *Megachile rotundata* F. (Hym., Megachilidae). Acta Oecologica 6: 165–173.

Tasei, J. N.; Carre, S.; Moscatelli, B.; Grondeau, C. 1988. Recherche de la D.L. 50 de la deltamethrine (Decis) chez *Megachile rotundata* F. abeille pollinisatrice de la luzerne (*Medicago sativa* L.) et des effets de doses infralethales sur les adultes et les larves. Apidologie 19: 291–306.

Tepedino, V. J. 1979. The importance of bees and other insect pollinators in maintaining floral species composition. Great Basin Naturalist Memoirs 3: 139–150.

Torchio, P. F. 1983. The effects of field applications of naled and trichlorfon on the alfalfa leafcutting bee, *Megachile rotundata* (Fabricius). Journal of the Kansas Entomological Society 56: 62–68.