February 21, 2024

USDA Animal and Plant Health Inspection Service
Plant Protection and Quarantine
270 S. 17th Street
Las Cruces, NM 88005

Submitted via email to Waleska Ramirez, waleska.v.ramirez@usda.gov, and Shawn Carson, shawn.r.carson@usda.gov

Re: New Mexico Wild Comments on APHIS Draft Environmental Assessment for the Rangeland Grasshopper and Mormon Cricket Suppression Program in Rio Arriba County, New Mexico, Environmental Assessment #NM-24-01

Dear Responsible Project Official:

New Mexico Wilderness Alliance (New Mexico Wild) respectfully submits these comments to the USDA Animal and Plant Health Inspection Service (APHIS) on the Draft Environmental Assessment (EA) for the project identified as draft Environmental Assessment NM-24-01 for the Rio Arriba County, New Mexico Rangeland Grasshopper and Mormon Cricket Suppression Program (project). New Mexico Wild is a nonprofit 501(c)(3) grassroots organization dedicated to the protection, restoration, and continued enjoyment of New Mexico's wildlands and wilderness areas. Founded in 1997, we achieve our mission through administrative protection, federal wilderness designation, and ongoing stewardship. We represent thousands of individual members from all corners of New Mexico and across the nation, including members who live, work, and recreate on and around the federal public lands in Rio Arriba County that are included in this proposed project.

APHIS proposes to treat 25,500 acres in the Cebolla area of Rio Arriba County with pesticide to decrease competition by grasshoppers with livestock and other herbivores for rangeland forage.[1] APHIS proposes to use four different chemicals for the project: carbaryl, chlorantraniliprole,

[1] Animal and Plant Health Inspection Service (APHIS), Rangeland Grasshopper and Mormon Cricket Suppression Program, Draft Environmental Assessment, Rio Arriba County, NM, Cebolla Area, EA Number NM-24-01, at pp. 1, 9 (Jan. 2024) [hereinafter EA].

diflubenzuron, and malathion.[2] APHIS proposes to conduct aerial and ground applications of these pesticides.[3]

As described below, this project proposed by APHIS suffers from significant National Environmental Policy Act (NEPA)[4] and other statutory, regulatory, and policy deficiencies. NEPA dictates that APHIS take a "hard look" at the environmental consequences of a proposed action, and the requisite environmental analysis "must be appropriate to the action in question."[5] To take the "hard look" required by NEPA, APHIS must assess impacts and effects that include "ecological (such as the effects on natural resources and on the components, structures, and functioning of affected ecosystems), aesthetic, historic, cultural, economic, social, or health, whether direct, indirect, or cumulative."[6] NEPA regulations define "cumulative effects" as effects on the environment that result from the incremental effects of the action when added to the effects of other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal) or person undertakes such other actions. Cumulative effects can result from individually minor but collectively significant actions taking place over a period of time.[7]

NEPA also requires APHIS to evaluate a reasonable range of alternatives to proposed federal actions.[8] "Reasonable alternatives means a reasonable range of alternatives that are technically and economically feasible, and meet the purpose and need for the proposed action."[9]

APHIS has failed to analyze many of the significant adverse impacts that could result from this project, and much of the cursory analysis contained in the draft EA is flawed. As currently proposed and analyzed, the project will have undisclosed impacts on specially designated areas of federal public land; fish, wildlife, and pollinators; and water quality. Additionally, the project is likely to have undisclosed impacts on the recreating public and public safety, contemporary Tribal uses of the land, and cultural resources. The project also suffers from a lack of transparency, a failure to articulate any clear purpose and need for action, and a lack of reasonable alternatives.

A. PESTICIDE DRIFT

To address concerns around pesticide drift, the draft EA includes an Appendix that sets forth treatment guidelines for FY-2023, including buffers for water bodies and limitations on aerial spray during certain weather conditions.[10] But the EA lacks adequate information and analysis related to pesticide drift, as required for disclosure of the potential impacts of drift. This major deficiency in the EA renders APHIS's assumptions about buffers unsupported and likely invalid.

For example, the discussion of carbaryl reflects that "mitigations to limit spray drift" are needed to

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[2] *Id*. at 7.
[3] EA at Appendix A, p. ii.
[4] National Environmental Policy Act of 1969 (NEPA), 42 U.S.C. §§ 4321 et seq.
[5] *Robertson v. Methow Valley Citizens Council*, 490 U.S. 332, 348 (1989); *Utahns for Better Transp. v. U.S. Dep't of Transp.*, 305 F.3d 1152, 1162 (10th Cir. 2002).
[6] 40 C.F.R. § 1508.1(g)(4).
[7] 40 C.F.R. § 1508.1(g)(3).
[8] 40 C.F.R. § 1502.14; 43 C.F.R. § 46.415(b).
[9] 40 C.F.R. § 1508.1(z); 43 C.F.R. § 46.420(b).
[10] EA at Appendix A. It is unclear whether the reference to last year (FY-2023) instead of the current fiscal year (FY-2024) was intended or inadvertent.

protect human health.[11] Similarly, in its discussion of chlorantraniliprole, the EA acknowledges that "[d]rift may occur during applications," that pesticide will be "present in the atmosphere" during and after application due to drift, and that measures are needed to "minimize the potential for exposure and risk to the general public."[12] For malathion, the EA reflects that the pesticide must not be allowed to drift onto blooming plants because it is "highly toxic to bees."[13] Despite the risks that the pesticides pose to human health and non-target species, the draft EA provides little information about the risks and prevention of drift, other than a couple references to unspecified "drift mitigation measures,"[14] buffers for water bodies including perennial streams and rivers,[15] and a few weather-related limitations designed to minimize drift during aerial application of ultra-low volume (ULV) spray.[16] The draft EA further states that sensitive riparian areas identified by the BLM will be buffered by ¼ mile.[17]

In 2001, a study conducted in Australia in an agricultural context found that off-target droplet movement of the insecticide used in the study was detected 500 meters (0.31 miles) from the target application sites, averaged under a wide range of conditions.[18] Given that the Australian study occurred in an agricultural context with flat and consistent topography, pilots in the study were likely able to fly closer to ground level when applying the pesticide, as compared to a wildlands context with variable topography, like the Cebolla area in Rio Arriba County. Aerial pesticide applications conducted as part of this project are likely to drift beyond what has occurred in more controlled studies conducted on agricultural lands.

It is reasonable to expect, therefore, that even with up to ¼ mile buffers, pesticide drift will impact designated areas, fish and wildlife species, recreational users, waterways, and other resources, all of which are discussed below, despite assertions in the EA that these resources will be unaffected by the proposed action due to buffers. Analysis of drift does not even account for issues of pilot error, pesticide transport in waterways due to runoff, or other unknown factors, which together increase the likelihood of impacts on these resources well beyond what the EA discloses.

B. IMPACTS TO DESIGNATED AREAS

APHIS's program threatens significant adverse impacts to specially designated areas of federal public lands. Based on the information provided in the EA, the project is proposed to occur in the Cebolla area of Rio Arriba County on primarily Bureau of Land Management (BLM) managed lands, along with some private property and land managed by the State of New Mexico.[19] The EA is severely lacking in its analysis of impacts that the proposed treatment will have on specially designated federal public lands within and close to the project area. These areas include the Rio

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[11] I*d*. at p. 17.
[12] *Id*. at pp. 18-19.
[13] *Id*. at p. 24.
[14] *Id*. at pp. 17, 25.
[15] *Id*. at Appendix A, p. iii (providing 500' buffers for aerial spray near water bodies, defined as "reservoirs, lakes, ponds, pools left by seasonal streams, springs, wetlands, and perennial streams and rivers").
[16] *Id*. at Appendix A, p. iv (no ULV spray when winds exceed 10 miles per hour, during rainfall or dew conditions, or during air turbulence or temperature inversion events).
[17] *Id*. at Appendix E, p. xvii.
[18] **Exhibit A**, N Woods, IP Craig, G Dorr, and B Young. "Spray drift of pesticides arising from aerial application in cotton." *Journal of Environmental Quality*. May-June, 2001; 30(3): 697-701. doi: 10.2134/jeq2001.303697x.
[19] EA at pp. 9-10; Appendix B, p. v.

Chama Wilderness Study Area (WSA), the Chama Canyons Area of Critical Environmental Concern (ACEC), the Rio Chama Wild and Scenic River, the Rio Nutrias, which the BLM has identified as suitable and eligible for designation as a Wild and Scenic River, and the Chama River Canyon Wilderness. The project area is also in close proximity to an Important Bird Area (IBA) designated by Audubon.

First, the EA lacks critical analysis about impacts to the Rio Chama WSA, managed by the BLM. The EA states that environmental impacts to this area will be minimized by "operational exclusions for terrain and densely wooded areas and riparian buffers," combined with use of the "reduced agent area treatment" (RAAT) method. No further information or analysis is provided in the EA on the purposes for which the WSA was designated, what its values are, how these values will be impacted, or the legal, regulatory, policy, and other guidance that dictates how BLM manages the area.

Based on BLM policies, the BLM must "manage and protect WSAs to preserve wilderness characteristics so as not to impair the suitability of such areas for designation by Congress as wilderness,"[20] and the BLM must "review all proposals for uses and/or facilities within WSAs to ascertain whether the proposal would impair the suitability of the WSA for preservation as wilderness."[21] With regard to this non-impairment standard, BLM policies state, "Unless excepted ... all uses and/or facilities must meet the non-impairment standard (i.e. must be both **temporary** and...) ... The use or facility is **temporary**. The use or facility is needed for a defined time period to respond to a temporary need, and would be terminated and removed prior to or upon wilderness designation. **A chronic, repeated short-term use does not meet this definition of temporary."**[22] However, in discussing the RAAT strategy, the EA states "APHIS would **apply a single application of insecticide per year**..."[23]

The notion that APHIS intends to conduct repeated annual aerial pesticide applications in the Rio Chama WSA suggests that this activity would not be temporary as defined in BLM policy and would therefore violate the non-impairment standard. If this is the case, proposed project activities within the Rio Chama WSA would be prohibited by BLM policy. The notion that APHIS intends to propose and conduct repeated aerial pesticide applications in the WSA is further supported by the fact that APHIS proposed these activities in 2023, and has again proposed these activities in 2024, despite the APHIS New Mexico 2024 Grasshopper Hazard map projecting that the project area will remain below economic damage thresholds this year (the map appears to indicate that the project area is projected to have either 1-2 and/or 3-7 grasshopper density per square yard).[24]

Further, BLM policy states, "All uses or facilities proposed on public lands within WSAs are subject to the review requirements of the WSA Management Manual. When conducting NEPA for projects outside of WSAs, any impacts to WSAs should be included in the NEPA analysis."[25] BLM policy requires that the NEPA analysis for this project consider the values for which the Rio Chama WSA

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[20] U.S. Dep't of Interior, BLM, Manual 6330 - Management of Wilderness Study Areas (Public) (7/13/2012), p. 1-2, *available at* https://www.blm.gov/sites/default/files/uploads/mediacenter_blmpolicymanual6330.pdf [hereinafter "BLM Manual 6330"].
[21] *Id*. at p. 1-10.
[22] *Id*. at p. 1-10 (emphasis added).
[23] EA at p. 25 (emphasis added).
[24] EA at Appendix B, p. vii.
[25] BLM Manual 6330, p. 1-43.

was established and associated management requirements.

Because the EA does not provide any analysis on the effects of the project on the Rio Chama WSA beyond the unsupported statement that the project will minimize environmental impacts in the WSA, it is not possible to ascertain whether the project is consistent with BLM policies on the management of WSAs (other than clearly violating the policy direction related to considering these impacts in the NEPA process). This lack of analysis renders the project contrary to BLM policy on the management of WSAs. Furthermore, as discussed above, it appears that the proposed action violates BLM's non-impairment standard related to the management of WSAs, which is also contrary to BLM policy requirements on the management of WSAs.

Second, the EA fails to address the potential for adverse impacts to the Chama Canyons ACEC. The BLM designated the Chama Canyons ACEC under the Federal Land and Policy Management Act (FLPMA)[26] because the included lands contain regionally significant riparian, wildlife, water quality, and scenic resources.[27] The EA neither acknowledges the values for which the ACEC was established nor provides any analysis on the effects of the project on the ACEC, beyond an unsupported statement that impacts will be minimized. It is therefore impossible for the public to ascertain how the project would affect the values for which the ACEC was designated or whether the project is consistent with the associated management guidance for the ACEC in the 2012 Taos Resource Management Plan.

Third, the project area is located in close proximity to the Rio Chama Wild and Scenic River Corridor, which was designated by Congress under the Wild and Scenic Rivers Act[28] and is jointly managed by the BLM and the Santa Fe National Forest. Additionally, the project area is either in close proximity to or overlaps with the Rio Nutrias, which was found by the BLM to be eligible and suitable for designation as a Wild and Scenic River and subject to management "under guidelines for wild and scenic rivers."[29] Audubon, which has designated the Chama River Gorge and associated Golondrinas Mesa as an Important Bird Area (IBA), describes the area as follows:

> The Rio Chama is a major tributary of the Rio Grande. For 31 miles, it flows through a canyon (at times 1500 feet deep) and through designated wilderness. The river has towering cliffs, heavily wooded canyons, archeological sites, and dinosaur tracks. The Rio Chama was designated Wild and Scenic in 1988 and runs through six miles of the wilderness. Colorful sandstone bluffs and rock formations rise to high rims on both riverbanks. Water levels reflect releases from El Vado Lake Dam. With access limited, most people don't visit the grassland that dominates the upland portion of the area. Varying elevations in the canyon provide a wide range of trees, from low-lying piñon-juniper to ponderosa pine and fir. Mammals include mule deer, black bear, elk, coyote, and mountain lion. Most of the wilderness lies in Santa Fe National Forest, with a portion in Carson National Forest. There are a few private in-holdings

[26] Federal Land Policy and Management Act of 1976 (FLPMA), 43 U.S.C. §§ 1701-1785.

[27] U.S. Dep't of Interior, BLM Taos Field Office, Taos Resource Management Plan, at Appendix A, p. 100 (May 2012), *available at* https://eplanning.blm.gov/public_projects/lup/68121/86167/103325/Approved_Taos_RMP_-_5.16.12_(print_version).pdf [hereinafter "2012 Taos RMP"].

[28] Wild and Scenic Rivers Act of 1972, 16 U.S.C. §§ 558a–558d.

[29] 2012 Taos RMP at p. 101.

in the area.[30]

Due to a lack of adequate information in the EA, it is not clear where exactly the Rio Chama Wild and Scenic River Corridor and the eligible and suitable Rio Nutrias are located with respect to the proposed treatment area. The only "analysis" that the EA provides regarding effects to the Rio Chama Wild and Scenic River and the eligible and suitable Rio Nutrias are statements that these waterways will be buffered by ¼ mile, and therefore, the project will have no effect on either waterway.[31]

Based on BLM policies, the BLM "must ensure activities on Federal lands meet the protection and enhancement standard set forth in the [Wild and Scenic Rivers Act]. This may include actions outside the river corridor that have the potential to impact outstandingly remarkable values."[32] There is a very real possibility that the project would have unintended impacts on the Rio Chama Wild and Scenic River and/or the eligible and suitable Rio Nutrias, based on several possible factors. Because the EA does not provide any analysis on the effects of the project on the Rio Chama Wild and Scenic River, despite the fact that it is located in close proximity to the proposed spray area, nor the eligible and suitable Rio Nutrias, which is located within or in the vicinity of the proposed spray area, is it not possible to ascertain whether project is consistent with the Wild and Scenic Rivers Act and associated BLM policies on the management of wild and scenic rivers.

Fourth, portions of the southern boundary of the proposed treatment area are contiguous with the boundary of the Chama River Canyon Wilderness, which is managed by the Santa Fe National Forest (USDA Forest Service). Despite its proximity to the project area, the Chama River Canyon Wilderness is not even mentioned in the EA.

The Statement of Policy in the Wilderness Act provides, "…For this purpose there is hereby established a National Wilderness Preservation System to be composed of federally owned areas designated by Congress as 'wilderness areas,' and these shall be administered for the use and enjoyment of the American people in such manner as will leave them unimpaired for future use and enjoyment as wilderness, and so as to provide for the protection of these areas, the preservation of their wilderness character, and for the gathering and dissemination of information regarding their use and enjoyment as wilderness . . . ."[33]

Given that the Chama River Canyon Wilderness is managed by the Santa Fe National Forest, APHIS should consider Forest Service policy on the management of wilderness, which provides the following guidance:

- "Maintain wilderness in such a manner that ecosystems are unaffected by human manipulation and influences so that plants and animals develop and respond to natural forces."[34]

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[30] Audubon, Important Bird Areas, https://www.audubon.org/important-bird-areas.
[31] EA at Appendix B, at xvi.
[32] U.S. Dep't of Interior, BLM, Manual 6400 - Wild and Scenic Rivers – Policy and Program Direction for Identification, Evaluation, Planning, and Management (Public) (7/13/2021), p. 7-3, *available at* https://www.blm.gov/sites/blm.gov/files/uploads/mediacenter_blmpolicymanual6400.pdf.
[33] Wilderness Act of 1964, 16 U.S.C. §§ 1131 et seq.
[34] USDA Forest Service, FSM - 2300 - Recreation, Wilderness, and Related Resource Management, Chapter 2320 - Wilderness Management, p. 8, *available at*

- "Where there are alternatives among management decisions, wilderness values shall dominate over all other considerations except where limited by the Wilderness Act, subsequent legislation, or regulations."[35]
- "The Regional Forester is responsible for approving: 1. Transport and supply by aircraft, air drop, motor boat, or mechanical transport for situations that meet the conditions under items 2, 4, or 5, in FSM 2326.1 ... 5. To meet minimum needs for protection and administration of the area as wilderness, only as follows: a. A delivery or application problem necessary to meet wilderness objectives cannot be resolved within reason through the use of nonmotorized methods. b. An essential activity is impossible to accomplish by nonmotorized means because of such factors as time or season limitations, safety, or other material restrictions. c. A necessary and continuing program was established around the use of motorized equipment before the unit became a part of the National Wilderness Preservation System, and the continued use of motorized equipment is essential to continuation of the program. d. Removal of aircraft wreckage when nonmotorized methods are unsuitable."[36]

Additionally, regulations pertaining to the management of wilderness by the Forest Service state as follows:

- "The following are prohibited in a National Forest Wilderness: (c) Landing of aircraft, or dropping or picking up of any material, supplies, or person by means of aircraft, including a helicopter."[37]

Because the EA neither mentions the presence of the Chama River Canyon Wilderness as directly contiguous to the proposed spray area nor provides any analysis on the effects of the project on the wilderness, it is not possible to ascertain whether the project is consistent with the Wilderness Act and Forest Service policies and regulations on the management of wilderness.

The project poses a risk of significant adverse impacts to designated areas within the project area, yet fails to identify sensitive resources, relevant management guidance, or an analysis of effects. Additionally, given that the project proposes aerial pesticide applications, it is entirely plausible that the project will impact other designated areas that do not directly overlap with the proposed treatment area, due to pesticide drift, pilot error, transport of pesticide into waterways due to runoff, or other factors. As such, the broad-based statement by APHIS that the project will have no impact on these designated lands and waterways is arbitrary and capricious under NEPA.

C. IMPACTS TO FISH, WILDLIFE, AND POLLINATORS

The project poses a high risk of significant adverse impacts to non-target species, including species listed under the Endangered Species Act (ESA),[38] the New Mexico Wildlife Conservation

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https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev3_053277.pdf [hereinafter "Forest Service Manual 2320"].

[35] *Id*. at p. 9.

[36] *Id*. at pp. 63-64.

[37] 36 C.F.R. § 261.18 National Forest Wilderness, *available at* https://www.ecfr.gov/current/title-36/chapter-II/part-261.

[38] Endangered Species Act of 1973 (ESA), 16 U.S.C. §§ 1531-1544.

Act,[39] and the BLM Taos Field Office's list of special status species.[40] The project also poses a risk to migratory birds protected under the Migratory Bird Treaty Act[41] and to eagles protected by the Bald and Golden Eagle Protection Act.[42] As noted above, Audubon has designated lands in the vicinity of the project area as an IBA, which reflects the importance of the habitat in and around the project area to an array of birds and other species.[43]

Regarding the ESA, APHIS asserts that the agency initiated consultation with the U.S. Fish and Wildlife Service (USFWS) under Section 7 of the ESA nearly a decade ago, on March 9, 2015.[44] Nearly a decade later, USFWS has not yet concurred with APHIS's conclusion that the grasshopper suppression program will have insignificant impacts on federally listed species.[45] APHIS proposes to resolve this deficiency through annual consultations with USFWS field offices at the local level.

However, the draft EA reflects that APHIS's biological assessment and consultation with USFWS in 2024 has not been completed and remains "pending."[46] Moreover, APHIS's previous biological assessments and consultation efforts reflect serious shortcomings. On May 1, 2023, APHIS submitted a biological assessment related to the grasshopper suppression program in Rio Arriba County to the local USFWS field office in Albuquerque.[47] However, APHIS requested consultation only with regard to diflubenzuron,[48] which was one of four different insecticide options proposed for use in the 2023 Environmental Assessment.[49] And the biological assessment focused primarily on a newly listed endangered species, the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*), and its critical habitat, with minimal acknowledgement of the other federally listed species within the project area.[50] Although the consultation considered only diflubenzuron, when APHIS decided to move forward with an aerial spray in June 2023 and issued a request for quotes, APHIS sought to conduct aerial application of carbaryl,[51] which was not addressed in the biological assessment or consultation process.

APHIS's informal and cursory annual consultations do not fulfill APHIS's obligation under NEPA and the ESA to take a hard look at the environmental impacts that the project will have on endangered species. The pesticides proposed in the EA have demonstrated harmful impacts on

[39] N.M. Wildlife Conservation Act, NMSA 1978, §§ 17-2-37 to -46 (1974, as amended through 1995); see NMSA 1978, §§ 17-1-14 to -26 (granting rulemaking authority to the state game commission); see also 19.33.6 NMAC (List of Threatened and Endangered Species).
[40] 2012 Taos RMP, Appendix G, p. 197-201
[41] Migratory Bird Treaty Act of 1918 (MBTA), 16 U.S.C. §§ 703-712.
[42] Bald and Golden Eagle Protection Act of 1940, 16 U.S.C. § 668.
[43] Audubon, Important Bird Areas, https://www.audubon.org/important-bird-areas.
[44] EA at p. 30.
[45] *Id.*
[46] *Id.* at Appendix C, p. ix.
[47] **Exhibit B**, Letter from U.S. Dep't of Interior, Fish and Wildlife Service to USDS-APHIS, FWS Project Code 2023-0081664 (May 31, 2023).
[48] *Id.*
[49] USDA APHIS, Environmental Assessment Rangeland grasshopper and Mormon Cricket Suppression Program, Environmental Assessment for Rio Arriba County, NM, EA # NM-23-01 (Mar. 1, 2023), *available at* https://www.aphis.usda.gov/plant_health/ea/2023/nm-23-01.pdf.
[50] **Exhibit B.**
[51] **Exhibit C**, RFQ 03 Cebolla NM Block NM2301, Fixed wing Aerial Treatment of Carbaryl near Cebolla New Mexico (June 13, 2023) (Exhibit C was obtained from sam.gov and includes only the first two pages of the request for quotes).

insects and other wildlife. The impacts on plants and wildlife are compounded by the fact that many birds, mammals, and plants rely on insects for food and pollination. In the EA, APHIS relies on conclusory statements devoid of analysis. APHIS makes no meaningful attempt to consider cumulative impacts, i.e., how APHIS's program combines with actions taken by other actors—private, state, tribal, and federal—to affect native pollinators, other invertebrates, or animals and plants that depend on these invertebrates for food or pollination.

Instead, the EA makes erroneous assumptions and is deficient or entirely lacking in analysis on the impacts of the project on fish, wildlife, and pollinators within the project area. The EA states,

> Non-target species such as pollinators and other beneficial insects, which may be impacted by the suppression program are those present during application in the sprayed swathes by direct chemical contact, or by feeding upon the contacted surface of vegetation, litter or on affected grasshoppers. Some migratory and nesting birds in contact with the application may temporarily be affected, mainly by feeding on treated grasshoppers or other insects, but not adversely.[52]

The EA's summaries of effects of carbaryl, diflubenzuron, and malathion tell a different story. For example, with regard to the effects of carbaryl, the EA states that it "can have undesirable impacts to non-target organisms that are exposed," and that "the chemical is highly toxic to insects, including native bees, honey bees, and aquatic insects; slightly to highly toxic to fish; highly to very highly toxic to most aquatic crustaceans, moderately toxic to mammals, minimally toxic to birds; moderately to highly toxic to several terrestrial arthropod predators; and slightly to highly toxic to larval amphibians."[53] To dismiss the likely and substantial adverse impacts on non-target species, the EA states, "adherence to label requirements and additional program measures designed to prevent carbaryl from reaching sensitive habitats or mitigate exposure of nontarget organisms will reduce environmental effects of treatments."[54] The EA further provides that the half-life of carbaryl is up to 4.7 days in water, up to 253 days in aerobic soil, and up to 72 days in anaerobic soil.[55] Despite the fact that carbaryl is known to be "highly toxic to insects," the EA concludes that reduced application rates and buffers will reduce impacts to beneficial insects,[56] including pollinators, to the level that they only "may" be impacted.[57] This conclusion is unsupported by evidence or research and simply does not make sense. If aerial application of carbaryl is employed for the purpose of reducing grasshopper populations, the obvious conclusion is that this application will likewise have adverse impacts on the populations of non-target species, including imperiled bees and butterflies, at least at a localized level. APHIS's conclusion to the contrary is arbitrary and capricious.

Similarly, in its discussion of diflubenzuron, the EA states that while this pesticide is "desirable in controlling certain insects, it can have undesirable impacts to non-target organisms that are exposed," including pollinators and particularly terrestrial invertebrates in their immature stages.[58]

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[52] EA at p. 11.
[53] *Id*. at p. 14.
[54] *Id*. at p. 15.
[55] *Id*.
[56] *Id*. at p. 16.
[57] *Id*. at p. 11.
[58] *Id*. at pp. 20, 22.

Likewise, in its discussion of malathion, the EA states that this pesticide "can have undesirable effects to non-target organisms," is "moderately toxic to birds on a chronic basis, slightly toxic to mammals through dietary exposure, and acutely toxic to aquatic species," and is "highly toxic to bees if exposed to direct treatment on blooming crops or weeds."[59]

Despite the effects of the proposed pesticides on a wide range of vertebrates and invertebrates, the EA contains minimal acknowledgement and essentially no analysis of the impacts to imperiled species within the project area. The EA does state that the USFWS has identified 52 endangered and threatened species, plus two candidate species, in the state of New Mexico; and that the New Mexico Department of Game and Fish maintains a state list of 120 endangered and threatened species.[60] APHIS proceeds to conclude, without analysis, that the project "may affect, but is not likely to adversely affect," the following federally listed species and their critical habitat: New Mexico meadow jumping mouse (*Zapus hudsonius luteus*), Mexican gray wolf (*Canis lupus bayleyi*), Mexican spotted owl (*Strix occidentalis lucida*), yellow-billed cuckoo (*Coccyzus americanus*), and Southwestern willow flycatcher (*Empidonax traillii extimus*).[61] APHIS next proceeds to conclude, without discussion, that the project will have "no effect" on the following federally listed species and their critical habitat: Rio Grande cutthroat trout (*Oncorhynchus clarkii virginalis*), Monarch Butterfly (*Danaus plexippus*), Silverspot (*Speyeria nokomis Nokomis*), Knowlton Cactus (*Pediocactus knowltonii*), and Mesa Verde Cactus (*Sclerocactus mesae-verdae*).[62]

To the extent APHIS includes any discussion of the project's impacts on imperiled species, the EA contains contradictory statements and unsupported conclusions. For example, with respect to the monarch butterfly, the EA states only that the "proposed action is determined to have no effect" on the butterfly and/or associated critical habitat,[63] and that APHIS "will implement a 500-foot buffer around any populations of milkweed identified by the BLM. Therefore, the proposed action may affect but is not likely to affect this species."[64] These two statements about the effects on the monarch butterfly are contradictory: Will there be no effect on the monarch butterfly, or will the project possibly affect this species? More importantly, the EA provides no information about BLM's surveys for milkweed (*Asclepias spp*.), the monarch's larval foodplant, within the proposed spray area. Has the BLM completed a comprehensive milkweed survey within the project area? Or, has the BLM conducted any survey at all for milkweed within the proposed spray area? Further, while milkweed is an important host plant for the monarch butterfly, this species is well known to use a wide array of other flowering plants, including goldenrods and asters that serve as a crucial food source. These considerations are not merely academic: recent surveys of monarch butterfly populations in their wintering areas in Mexico demonstrate that the numbers have dropped by 59 percent this year, resulting in the second-lowest population levels since record keeping began.[65]

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[59] *Id.* at pp. 23-24.
[60] *Id.* at p. 11.
[61] *Id.* at pp. 30-31.
[62] *Id.* at 31.
[63] *Id.*
[64] *Id*. at Appendix E, pp. xiv-xv.
[65] *See, e.g.*, Xerces Society for Invertebrate Conservation, Eastern Monarch Butterfly Overwintering Area In Mexico Drops Precipitously (Feb. 7, 2024), *available at* https://xerces.org/press/eastern-monarch-butterfly-overwintering-area-in-mexico-drops-precipitously; Associated Press, Mark Stevenson, The number of monarch butterflies at their Mexico wintering sites has plummeted this year (Feb. 7, 2024), *available at* *https://apnews.com/article/mexico-monarch-butterflies-climate-change-9b8a69f58f3f576af0413fd045340c6e*.

Given the precarious position monarchs are in, APHIS must provide meaningful information in the EA about surveys, the real potential for adverse impacts, and the anticipated success of any proposed mitigation measures, based on the best available science.

The draft EA treats other imperiled in the same cursory manner, with little to no discussion or analysis. Moreover, the primary mitigation measure proposed in the draft EA, i.e., buffers around riparian areas and water bodies, does little to address adverse impacts. Some species, such as monarchs, could be located outside of these buffer areas when pesticide is applied and would be directly impacted by the spray. Additionally, as discussed in Section A of this comment letter, the EA fails to acknowledge, explain, or analyze the issue of pesticide drift. This issue calls the EA's analysis of the effects of the proposed action on fish, wildlife, and insect species, including endangered and special status species, into significant question. By failing to meet the requirements of NEPA and the ESA in the draft EA, APHIS places the survival of critically imperiled species at risk.

D. IMPACTS TO RECREATION AND PUBLIC SAFETY

As discussed in section B above, the draft EA fails to recognize that much of the project area consists of specially designated federal public lands. These areas are popular outdoor recreation destinations. As explained in the BLM's 2012 Taos RMP, "The Rio Chama is a destination for float boaters, primarily from New Mexico and Colorado, with others from Arizona, California, and Texas."[66] The BLM therefore manages this area "to provide exceptional high scenic quality opportunities for multi-day float boating trips and trout fishing in this primitive and back country setting."[67] Similarly, the BLM's New Mexico Wilderness Study Report writeup on the Rio Chama WSA acknowledges "outstanding" primitive recreation opportunities that include backpacking and hiking within the WSA.[68]

Despite the importance of this region for recreation, the EA barely mentions recreation, provides no actual analysis of the effects of the project on recreation or the recreating public, and lacks consideration of the safety of recreational users or other people in the proposed spray area. Instead, the EA states, "New Mexico has many historic and recreation sites . . . the majority of these visitor sites are not found on rangeland, except with low frequency."[69] And, APHIS "implements mitigation measures . . . such as a 500-foot treatment buffer zone from . . . recreational areas."[70]

APHIS's lack of acknowledgement of recreational use, including dispersed, primitive backcountry use, within the proposed spray area demonstrates a clear lack of understanding of the public use and value of the project area. As discussed above, the Rio Chama Wild and Scenic River, located adjacent to and an unknown distance from the project area (due to inadequate information in the EA), is among the most popular destinations in New Mexico for rafting, kayaking, and canoeing. Per

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[66] 2012 Taos RMP at p. 65.
[67] *Id*.
[68] U.S. Dep't of Interior, BLM, *New Mexico Wilderness Study Report: Volume 1 – WSA Recommendations* (September 1991), p. 12, *available at* https://ia800805.us.archive.org/7/items/newmexicowildern01unse/newmexicowildern01unse.pdf.
[69] *Id*. at p. 11.
[70] *Id*. at p. 28.

the BLM, "Because of the demand for trips in late spring and summer, the BLM uses a lottery system to reserve . . . launch dates."[71] Indeed, recreation is one of the Rio Chama's outstandingly remarkable values as identified by Congress under the Wild and Scenic River Act (i.e., river-related values that are rare, unique, or exemplary in a regional or national context).[72] Additionally, the Chama Canyons ACEC is part of the larger Chama Canyons Special Recreation Management Area (SRMA),[73] implying that recreation use exists and is of significance within and beyond the ACEC, and therefore within a large portion of the proposed spray area. Will APHIS buffer the entire Chama Canyons SMRA by 500 feet per its mitigation related to recreation areas?

Despite the BLM's identification of existing and outstanding recreation opportunities within the proposed spray area, the EA fails to acknowledge this well-documented public recreational use. Further, the EA provides no discussion or analysis of the health impacts to persons who may be recreating within the project area during implementation. Yet the EA acknowledges that buffers are required to protect human health, especially for children,[74] and provides that certain non-federal lands within the project area, such as ranch buildings and individual homesteads, will be buffered from pesticide application for reasons related to human health.[75] APHIS also proposes buffers of 1.25 miles for towns and parks to avoid adverse health impacts.[76]

Instead of evaluating and preventing the risks of toxic pesticide exposure to the recreating public, including families with young children who boat on New Mexico rivers and hike in the backcountry, the EA incredulously states that the project "should benefit human and environmental health by reducing the risk of insect annoyance . . . ."[77] The EA further justifies pesticide application by noting that "[o]ther market and non-market values such as . . . recreational use may also be impacted by grasshopper outbreaks in rangeland."[78] New Mexico Wild staff, members, and supporters would strongly disagree with the suggestion that the presence of native grasshoppers within the proposed spray area constitutes a hazard to human health or would lead to a decrease in recreational use or negative impact to the outdoor recreation economy. On the other hand, the possibility of being inadvertently sprayed with pesticide constitutes a clear threat to human health and safety and a factor that would impact the extent of future recreational use and enjoyment within the proposed spray area.

APHIS has demonstrated a radical lack of understanding of recreational use within the proposed spray area and a cavalier disregard of human health. APHIS's demonstrated lack of understanding of recreation use patterns within and adjacent to the proposed spray is particularly concerning in light of the pesticide drift issue discussed in Section A and the fact that the proposed action includes the potential aerial application of carbaryl. As summarized in the EA, carbaryl exposure can cause humans to experience "nausea, headaches, dizziness, anxiety, and mental confusion, as well as convulsions, coma, and respiratory depression," and is "likely to be carcinogenic."[79] The

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[71] U.S. Dep't of Interior, BLM, *Rio Chama Wild and Scenic River*, https://www.blm.gov/visit/rio-chama-wild-and-scenic-river.
[72] National Wild and Scenic Rivers System, *Rio Chama*, https://www.rivers.gov/river/rio-chama.
[73] 2021 Taos RMP at Appendix A, p. 100.
[74] EA at p. 12.
[75] *Id*. at pp. I0, 12.
[76] *Id*. at p. 10.
[77] *Id*.
[78] *Id*. at pp. 13-14.
[79] *Id*. at p. 16.

severity of potential impacts to public health and safety related to recreation in and adjacent to the proposed spray area merit much deeper analysis in the EA, which would lead a reasonable federal agency to conclude that aerial pesticide applications in this area is utterly inappropriate.

E. IMPACTS TO CULTURAL RESOURCES AND ISSUES WITH NATIONAL HISTORIC PRESERVATION ACT COMPLIANCE

With respect to the effects of the project on contemporary cultural uses of the land and on cultural resources, the EA states,

> Native American fiesta days and Colonial Hispanic ceremonies are not performed on rangeland, but in towns and pueblos. Old, abandoned community graveyards or "camposantos" and Indian burial grounds would be excluded as are heritage and historic, petroglyphs and pictographs sites that are protected and preserved in the National Park Service areas or in New Mexico State parks and monuments. These ancestral cultural areas are under the protection of the federal 1906 Antiquities Act and the 1965 National Heritage Act.[80]

The EA uses this radical misunderstanding of the cultural values associated with this landscape to erroneously assert that the project would have no effect on contemporary cultural uses of the land or on cultural resources.

It is widely understood that New Mexico's public lands are exceptionally rich in cultural resources, and that prehistoric sites such as burial grounds, petroglyphs, pictographs, cliff dwellings, pueblos, kivas, agricultural developments, and other features abound across New Mexico on federal public lands and nonfederal lands outside of National Park Service units. While the BLM's Taos Resource Management Plan does not address these values in detail, it does acknowledge the presence of cultural resources and contemporary cultural uses on the lands managed by the BLM Taos Field Office with the following guidance: "Identify, preserve, and protect significant cultural resources and ensure that they are available for appropriate uses by present and future generations."[81]

More pointedly, the recently revised Santa Fe National Forest Land Management Plan, which guides the management of National Forest System lands that are contiguous and directly adjacent to the proposed spray area on the project's west and south sides, provides abundant recognition of these values:

- "People have been living on and using this land for thousands of years and the forest has continually provided fuelwood, grazing for traditional and economic importance, hunting for subsistence and cultural purposes, and gathering of forest products for religious and ceremonial purposes."[82]
- "The Santa Fe [National Forest] manages the natural resources and landscapes that sustain northern New Mexico traditional communities, their cultures, and traditions. Local heritage, culture, traditions, and values have been handed down over generations and

[80] EA at pp. 11-12.
[81] 2012 Taos RMP at p. 5.
[82] USDA Forest Service, Santa Fe National Forest Land Management Plan, MB-R3-10-30, (July 2022), p. 101, *available at* https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd1046331.pdf.

predate control of this area by the United States. Long-standing use of the forest and its natural resources are fundamental to the interconnected economic, social, and cultural vitality of many northern New Mexico inhabitants, including federally recognized tribes."[83]

- "The Forest Service manages diverse landscapes and sites that are culturally important and held sacred by federally recognized tribes."[84]
- "No other place in the United States has a continuity of occupation equal to that surrounding the Santa Fe [National Forest]. Evidence of stable occupation can be found dating back at least 1,000 years."[85]
- "Human use and occupation began in the area over 10,000 years ago. Native Americans (American Indians) ancestral to the ethnic affiliations of the contemporary Pueblo and Athabaskan people have inhabited or utilized forest resources over much of this time."[86]
- "There are many cultural and historic resources on the Santa Fe [National Forest] that are significant to local communities, the State of New Mexico, the Southwestern region, and the United States. There are regions of archaeological importance associated with ancestral development of American Indian communities such as the Jemez Mesas, the Pajarito Plateau, **the Rio Chama**, and the Gallina region. In addition, many of these areas of archaeological significance have tribal importance to local American Indian Tribes."[87]

This guidance from the BLM and context from the adjacent Santa Fe National Forest debunk the notion in the EA that cultural resources (e.g. archaeological sites) and contemporary cultural uses by sovereign Tribal nations (and other traditional communities) do not exist in the project area. This lack of acknowledgement and the absence of associated analysis in the EA constitutes another significant flaw in the NEPA analysis for the project.

Furthermore, the fact that the EA clearly misunderstands the reality of cultural resources and contemporary cultural uses in the proposed spray area strongly suggests that neither APHIS nor the BLM have consulted on this project with affiliated Tribes or the New Mexico Historic Preservation Division (SHPO), as required under Section 106 of the National Historic Preservation Act.[88] This misunderstanding also strongly suggests that neither APHIS nor the BLM have consulted on this project with sovereign Tribal nations. If APHIS has failed to consult on this project with the SHPO and Tribes, this project is not compliant with the basic requirements in the National Historic Preservation Act and other guidance related to Tribal consultation.

F. IMPACTS TO WATER QUALITY

In the summary of operational procedures provided in the EA, APHIS states that the agency will avoid directly spraying and will buffer water bodies, which it defines as "reservoirs, lakes, ponds, pools left by seasonal streams, springs, wetlands, and perennial streams and rivers."[89] This approach is deeply flawed in that New Mexico is renowned for its intermittent and ephemeral streams, which flow seasonally due to snowmelt and/or following precipitation events. The failure

[83] *Id*. at p. 10.
[84] *Id*. at p. 103.
[85] *Id*. at p. 110.
[86] *Id*.
[87] *Id*. (emphasis added).
[88] National Historic Preservation Act (NHPA), 54 U.S.C. §§ 300101 et seq.
[89] EA at Appendix A, p. iii.

to exclude and buffer intermittent and ephemeral streams and waterways from pesticide application would likely result in pesticides migrating into what APHIS defines as "water bodies," including the Rio Chama Wild and Scenic River. If aerial pesticide application occurs in the spring runoff season or during the summer, and a subsequent monsoon event occurs, which is a common in northern New Mexico beginning in early-to-mid summer, the pesticides are likely to travel into water bodies. This very real possibility of pesticide transport in an intermittent or ephemeral water body would result in impacts to fish and wildlife species, water quality, and possibly public health and safety. The risks are amplified by length of time these chemicals persist in the environment, e.g., the half-life of carbaryl is up to 253 days, allowing it to persist in the soils of dry washes until a storm and spring runoff event. The EA does not consider the potential for these impacts, resulting in a deficiency in analysis and a reasonable likelihood that the effects determinations in the EA are incorrect. Additionally, as described above, the information provided by APHIS regarding pesticide drift is significantly lacking, and drift may also directly impact water bodies despite buffers.

G. OTHER NEPA COMPLIANCE AND TRANSPARENCY ISSUES

As a federal agency, APHIS must fully comply with NEPA prior to implementing this project. As discussed throughout this comment letter, there are significant omissions and inaccuracies in the analysis of the direct, indirect, and cumulative effects this project will have on a wide array of resource values that are only considered in the EA in a brief and cursory manner. Prior to finalizing the environmental review for the project, APHIS should complete the additional analysis and corrections needed to conform with NEPA requirements. The volume of needed changes far exceeds clerical corrections, and APHIS should conduct a second comment period, to give the public the opportunity it deserves to review and provide input.

The role of APHIS as the lead agency for this NEPA process and the development of this EA does not negate the legal requirements of other federal agencies. Specifically, given that most of the proposed spray area is located on lands managed by the BLM, this project must fully comply with BLM's regulations and policies under NEPA and other statutes. Further, as discussed above in Section B, the project design coupled with the likelihood of pesticide transport due to drift, pilot error, water-based transport, or other factors raises the potential for this project to affect the Chama River Canyon Wilderness, which is managed by the Santa Fe National Forest. As a result, the NEPA review for this project should consider impacts to directly adjacent National Forest System lands and should comply with Forest Service wilderness management regulations and policies. APHIS has entered Memorandums of Understanding (MOUs) with both the BLM and the Forest Service regarding grasshopper suppression projects.[90] All agencies have a responsibility to ensure that the provisions of these MOUs are followed, in addition to NEPA, the ESA, the 2012 Taos Resource Management Plan, the 2022 Santa Fe National Forest Land Management Plan, and the other federal laws and regulations that govern this project.

The proposed project also suffers from a significant lack of transparency. For one, the proposal by APHIS to conduct aerial spraying of carbaryl over the project area in 2023 generated such a public outcry that the BLM did not approve the project. Yet, it appears that APHIS failed to provide any opportunity for the public to engage in this project during its scoping period (if APHIS even conducted a scoping period). New Mexico Wild, for example, was involved in highlighting issues

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[90] *See* **Exhibit D**, MOU between APHIS and BLM, Doc. #22-8100-0870-MU (Jan 11, 2022); **Exhibit E**, MOU between APHIS and U.S. Forest Service, Doc. #19-8100-0573-MU (Nov. 6, 2019).

with the 2023 proposal and received notification of the opportunity to comment on the draft EA, but we did not receive notification related to any scoping period. Congress has instructed APHIS to take a holistic approach to grasshopper control, with pesticides as just one potential tool among many.[91] A publicly available scoping period would have provided the opportunity for the public to provide feedback on how APHIS might meet its management goals through a broader range of alternatives that better protect the resource values that we highlight throughout this comment letter.

A second transparency problem with this project relates to the grasshopper surveys that APHIS conducts and the lack of information that APHIS provides related to the results of these surveys. By statute, APHIS is allowed to treat grasshopper outbreaks only when they reach "levels of economic infestation."[92] Yet, the only information provided in the EA about these surveys is the statewide New Mexico 2023 Grasshopper Survey map.[93] This map includes information that at a statewide level in 2023, APHIS found one adult survey to include 15+ grasshoppers and seven adult surveys to include 7-14 grasshoppers, and eleven nymphal surveys to include 15+ nymphs and seven nymphal surveys to include 7-14 nymphs. Some unspecified number of these surveys occurred in Rio Arriba County, with others occurring in Colfax and Union Counties. With regard to the Rio Arriba County surveys, it is unclear based on the quality of the map and a lack of associated information elsewhere in the EA whether these findings occurred in the proposed spray area. Even if these surveys occurred in the project area, this map clearly depicts that many other survey findings in the immediate vicinity of these elevated surveys in Rio Arriba County showed lower levels of adult and nymph counts (0 and 1-8), though again, based on the quality of the map and lack of associated information it is not possible to tell how many surveys total occurred in the proposed spray area and what the results of those surveys were.

New Mexico Wild staff visited the proposed spray area in the summer of 2023 and observed reasonably healthy rangeland conditions on BLM-managed lands and few grasshoppers. Additionally, one of our partners that is engaged in ongoing scientific studies in partnership with the Bureau of Reclamation and New Mexico Wild conducted adult grasshopper surveys at ten sites within and adjacent to the proposed spray area in June 2023 using the Onsager and Henry method (including conducting 19 samples at each site).[94] The average number of adult grasshoppers observed was 1-3 at eight of these sites and 4-7 at two sites. This survey, coupled with New Mexico Wild staff observations in the proposed spray area, raises significant questions about the accuracy of any surveys that APHIS may have conducted in the proposed spray area and whether the APHIS surveys justify large-scale aerial pesticide applications in Rio Arriba County based on a finding of "economic infestation." The lack of transparency by APHIS regarding the location and results of its surveys coupled with New Mexico Wild and partner observations and survey findings in the area raise significant questions about the extent of possible grasshopper infestations and the resulting need for aerial pesticide applications in the project area.

Additionally, APHIS has failed to consider reasonable alternatives as required by NEPA. For example, APHIS should consider the use of a ground-based RAAT alternative to target localized

[91] *See* 7 U.S.C. § 7717; *see also* 7 U.S.C. § 136r–1.
[92] 7 U.S.C. § 7717(c)(1).
[93] EA at Appendix A, p. vi.
[94] Onsager, JA and JE Henry. "A method for estimating the density of rangeland grasshoppers (Orthoptera, Acrididae) in experimental plots." *Arcadia*. 1977; (6): 231-237.

grasshopper populations where levels of economic infestation have been confirmed with surveys based on the best available science. As compared to APHIS conducting indiscriminate and widespread aerial pesticide applications, a ground-based RAAT alternative would vastly reduce the impacts on the wide array of resource values discussed throughout this comment letter and would likely save substantial taxpayer dollars. Other options that should be considered include addressing any issues of rangeland health to prevent or minimize grasshopper outbreaks,[95] omitting federal public lands with special designations from any spray proposal, and obtaining supplemental forage to support ranchers if grasshopper population levels reach true economic infestation. Furthermore, the APHIS New Mexico 2024 Grasshopper Hazard map[96] does not appear to show any elevated risk of economic grasshopper infestation in Rio Arriba County, despite the fact that APHIS did not implement treatments in the proposed spray area in 2023. This raises significant additional questions about the need for aerial pesticide applications and the validity of a ground-based approach to respond to targeted issues, if they arise. If APHIS is unable to demonstrate a need for action under NEPA, the project should be canceled.

H. CONCLUSIONS

As explained above, the draft EA issued by APHIS fails to adequately demonstrate a need for this project, presents an inadequate range of alternatives, and contains an inadequate and flawed analysis of direct, indirect, and cumulative impacts to specially designated areas, wildlife including endangered and special status species, cultural resources, and public health. Additionally, APHIS has failed to conduct a public scoping process or provide adequate public transparency surrounding this project and previous proposals in New Mexico. As currently proposed and analyzed, this project risks violations of NEPA, FLPMA, the Wilderness Act, the Wild and Scenic Rivers Act, the National Historic Preservation Act, the Endangered Species Act, and other federal statutes, along with BLM and Forest Service regulations and policies.

Moreover, as a policy matter, the potential benefit of applying aerial pesticides over large swaths of federal public lands to control native grasshopper species for the benefit of permitted cattle is outweighed by the widespread impacts to other species, recreational users and human health, and water quality. The economic tradeoffs of this project likewise support a no-action alternative, due to the cost of conducting aerial pesticide operations.

Although New Mexico Wild would likely oppose any proposal to conduct aerial pesticide spraying on federal public lands, this project is especially problematic because it proposes the use of carbaryl, which poses significant and adverse effects to a wide array of species and on human health, and is proposed to occur in an area with multiple special designations and high recreational use. Put simply, APHIS should never propose aerial spraying of carbaryl on federal public lands.

Thank you for considering our comments. In addition to this letter, we have joined the comments submitted by The Xerces Society for Invertebrate Conservation and other conservation partners. We incorporate those comments by this reference. Please include our comments the official project record and ensure that New Mexico Wild is on the contact list for this project and future

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[95] *See* **Exhibit F**, Lightfoot, David C. “The effects of livestock grazing and climate variation on vegetation and grasshopper communities in the northern Chihuahuan Desert.” 35 Journal of Orthoptera Research 2018, 27(1) (describing the effects of livestock grazing on grasshopper populations in New Mexico).
[96] EA at Appendix A, p. vii.

APHIS Rangeland Grasshopper and Mormon Cricket Suppression programs anywhere in the State of New Mexico. We wish to receive all future updates on this project and related proposals in the state.

Sincerely,

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Cc: Melanie Barnes, BLM New Mexico State Director
Eric Valencia, Acting Field Manager, BLM Taos Field Office
Shaun Sanchez, Supervisor, Santa Fe National Forest

Encl: Exhibit A, Woods et al. (2001).
Exhibit B, Letter from USFWS to APHIS, FWS Project Code 2023-0081664 (2023).
Exhibit C, RFQ for Fixed wing Aerial Treatment of Carbaryl near Cebolla New Mexico (2023).
Exhibit D, MOU between APHIS and BLM, Doc. #22-8100-0870-MU (2022).
Exhibit E, MOU between APHIS and U.S. Forest Service, Doc. #19-8100-0573-MU (2019).
Exhibit F, Lightfoot (2018).

EXHIBIT A

Spray Drift of Pesticides Arising from Aerial Application in Cotton

Nicholas Woods,* Ian P. Craig, Gary Dorr, and Brian Young

ABSTRACT

This paper presents results from field studies carried out during the 1993–1998 Australian cotton (*Gossypium hirsutum* L.) seasons to monitor off-target droplet movement of endosulfan (6,7,8,9,10,10-hexachloro-1,5,5a,6,9,9a-hexahydro-6,9-methano-2,4,3-benzodioxathiepin 3-oxide) insecticide applied to a commercial cotton crop. Averaged over a wide range of conditions, off-target deposition 500 m downwind of the field boundary was approximately 2% of the field-applied rate with oil-based applications and 1% with water-based applications. Mean airborne drift values recorded 100 m downwind of a single flight line were a third as much with water-based application compared with oil-based application. Calculations using a Gaussian diffusion model and the U.S. Spray Drift Task Force AgDRIFT model produced downwind drift profiles that compared favorably with experimental data. Both models and data indicate that by adopting large droplet placement (LDP) application methods and incorporating crop buffer distances, spray drift can be effectively managed.

Agricultural aircraft are of great importance to the Australian cotton industry. Specialized aircraft are used to apply selected herbicides and fertilizers prior to planting, insecticides throughout the growing season, and defoliants prior to harvest. The use of agricultural aircraft has developed largely as a result of the greater speed, better timing, and efficiency of application offered by aerial distribution. Aircraft are able to apply agricultural products rapidly over large areas within narrow optimum application windows. When crop height and irrigated areas restrict the passage of wheeled vehicles, aircraft are able to place pesticides strategically on crops in response to economic thresholds, without contributing to soil compaction and breakdown.

There have been several previous studies that have addressed aircraft spray drift, for example Yates et al. (1978), Akesson and Yates (1974, p. 92–98), Riley and Wiesner (1989), Richardson et al. (1995), and the U.S. Spray Drift Task Force project (Spray Drift Task Force, 1997). Spray drift can pose a potential source of contamination to the environment, unless the application process is effectively managed. When pesticides are applied close to sensitive areas, management strategies are employed that can significantly reduce the off-target aerial movement of pesticides. This paper summarizes the work carried out from 1993 to 1998 to assess the aerial transport of pesticides on selected cotton properties and develop effective spray drift management strategies.

Two methods of endosulfan aerial application were studied: (i) ultra low volume (ULV) endosulfan (240 g/L oil-based application at 3.0 L/ha rates using Micronair AU5000 rotary cage nozzles [Micron Sprayers, Bromyard, UK]), and (ii) low volume (LV or emulsifiable concentrate [EC]) endosulfan (350 g/L water-based application with 2.1 L/ha in either 20 or 30 L/ha bulk rates using CP (CP Products, Tempe, AZ) or other hydraulic nozzles).

Nicholas Woods, Ian P. Craig, and Gary Dorr, Centre for Pesticide Application and Safety, Univ. of Queensland, Gatton, Queensland 4343, Australia. Brian Young, Food Science Australia, Werribee, Victoria. Received 9 Feb. 2000. *Corresponding author (nicholas.woods@mailbox.uq.edu.au).

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MATERIALS AND METHODS

Laser Droplet Sizing

Spray droplet size tests were conducted using a Malvern 2600 laser analyzer (Malvern Instruments, Malvern, UK) and a windtunnel. Tests were carried out with ULV and LV (EC) endosulfan formulations at windspeeds of 51 m/s (100 knots) and 67 m/s (130 knots) to simulate the airspeeds of slow piston–powered aircraft and fast turbine–powered aircraft, respectively. Details of the test procedure are described by Woods et al. (2000b).

Single-Flight-Line Drift Tests

Single-flight-line tests were carried out to determine the influence of nozzle type and droplet size on airborne drift profiles. To eliminate the effect of variable weather conditions with time, tests were carried out with two aircraft simultaneously. The aircraft were turbine powered (Air Tractor [Olney, TX] 502B) with similar airspeeds of approximately 60 m/s and flying heights of approximately 3 m. The first aircraft was equipped with Micronair AU5000 nozzles to apply endosulfan ULV as a standard and the second aircraft was equipped with a range of different hydraulic nozzles. Unbleached 1-mm-diameter cotton string was suspended vertically from 20-m-high trailer-mounted sampling masts. The masts were situated 100 m downwind from the single-flight-line path of each aircraft and were separated by approximately 1 km to avoid cross contamination. A fluorescent dye (Uvitex OB; Novartis Crop Protection, Basel, Switzerland) was added to the spray tank mix at a rate equivalent to approximately 15 g/ha. The string from the masts was cut into 2-m sections and the dye was extracted from 2-m sections of the string using 10 mL of isopropanol solvent. Dye concentration was measured using a Sequoia–Turner (Mountain View, CA) Model 450 fluorometer.

Full-Field Drift Tests

The off-target transport of droplets resulting from the commercial application of endosulfan was monitored during the 1993 to 1998 Australian cotton seasons (Woods et al., 1998a). In crop deposition characteristics were assessed by sampling leaves from top, mid, and low positions on the cotton plant. Ground deposition was assessed using 1-m-long chromatography paper–covered rulers placed perpendicular to and alternately half in and half out of the row. The leaf area index of the cotton canopy was assessed using the light squares method (Constable, 1986). Off-target transport of droplets was measured using an array of collection surfaces consisting of chromatography paper placed upon horizontal flat plates (usually at a 1-m height above ground), vertically orientated pipe cleaners, and cotton string suspended from 20-m-high towers

Abbreviations: EC, emulsifiable concentrate; GDM, Gaussian diffusion model; LDP, large droplet placement; LV, low volume; ULV, ultra low volume; VMD, volume median diameter.

Table 1. Summary of aerial transport characteristics of endosulfan application.

Parameter	ULV application†	LV application‡
Nozzle type	AU5000 @ 4000 rpm	hydraulic CP @ 30°
Formulation	endosulfan ULV	endosulfan EC
Application rate (L/ha)	3	2.1
Application	applied as oil	in 30 L/ha water
Malvern laser data (VMD§) (μm)	67	182
Airborne drift @ 100 m (%)	18	6
Leaf coverage (full field) (%)	60	50
Ground deposit (full field) (%)	25	50
Fraction leaving field (500-m field) (%)	14	7
Depositing within 500 m (500-m field) (%)	7	5
Deposition at 200 m (% of applied rate)	5	2
Deposition at 500 m (% of applied rate)	2	1

† ULV, ultra low volume.
‡ LV, low volume.
§ VMD, volume median diameter.

(Woods et al., 2000a). Applications of both endosulfan ULV (applied at a rate of 3 L/ha using Micronair AU5000 equipment) and endosulfan EC (generally applied at a rate of 2.1 L/ha in 30 L/ha using CP hydraulic nozzles) were assessed (Table 1). An Environdata (Warwick, QLD, Australia) meteorological station was used to record wind speed (at 2 and 5 m), wind direction, temperature (at 2.5 and 10 m), relative humidity, solar radiation, and rainfall during each trial. Endosulfan residue samples were quantified using an ELISA immunoassay technique developed by CSIRO and the University of Sydney (Lee et al., 1997; Kennedy et al., 1998). In addition, some collection devices were analyzed by the NSW Agriculture Chemical Residue Laboratory using high performance gas chromotography (GC).

Computer Modeling

The Gaussian diffusion model (Bache and Sayer, 1975; Spillman, 1982), which assumes a single line source, and the U.S. Spray Drift Task Force AgDRIFT (Teske et al., 1997) model, which uses Lagrangian equations to compute a complex source dependant upon aircraft parameters, were used to provide benchmark comparisons against experimentally obtained spray drift data. The Gaussian diffusion model is based upon the following equation:

$$d = khq/(ix^2)\exp[-(h - vx/u)^2/2(i^2x^2)]$$

where d = deposit (m^3/m^2), k = constant (0.4), h = release height (4 m), q = line source (m^3/m), i = turbulence intensity, x = downwind distance (m), v = sedimentation velocity (m/s), and u = mean windspeed (m/s). A more detailed explanation of this model has been provided by Craig et al. (1998). Both Gaussian diffusion and AgDRIFT models have been successfully compared with spray drift data sets, by several researchers including Dorr (unpublished data, 1996) and Bird et al. (1996).

Parameters were entered into the models (Table 2) that represented the most typical conditions experienced during the field trial program. Droplet size data was incorporated from the laser diffraction studies. Computer modeling and mass balance mean figures were derived by normalizing data to correspond with spray application over a theoretical 500-m field source width. Some data points were corrected to account for variation in wind direction.

RESULTS

Laser Droplet Sizing

The relationship between endosulfan droplet volume median diameter (VMD) and Micronair AU5000 cage rotational speed, at airspeeds of 51 m/s (100 knots) and 67 m/s (130 knots), is illustrated in Fig. 1. The curves illustrate that cage RPM and airspeed were the most important factors governing droplet VMD, with formulation type and flow rate having less important effects. The graph shows that with Malvern laser droplet sizing equipment, droplet VMDs much above 180 μm (VMD) were not recorded with the Micronair rotary cage atomizer within its normal range of rotational speed.

Malvern laser droplet size data for the CP hydraulic nozzle are illustrated in Fig. 2. The chart relates to endosulfan EC applied at 20 L/ha through a CP nozzle with deflector settings of 30° (*coarse*) and 90° (*fine*); nozzle orifice sizes of 0.062, 0.078, 0.125, and 0.175 inches; and airspeeds of 51 and 67 m/s. The bars represent VMD or D[v,0.5] (i.e., 50% of the volume of the spray composed of droplets less than this size). The lines through the bars represent the D[v,0.9] to D[v,0.1] interval (i.e., the 90% to 10% spectral width of the spray). From the graph it can be deduced that airspeed is an important factor determining droplet size. The ef-

Table 2. Constants assumed in computer modeling (curves of Fig. 4 and 5).

Parameter	GDM†	AgDRIFT ULV‡	AgDRIFT LV§
Wind speed (m/s)	3	3 (1.3–4.8)¶	3 (1.5–6.5)¶
Temperature (°C)	N/A	29 (21–29)¶	29 (21–29)¶
Relative humidity (%)	N/A	45 (29–89)¶	45 (29–69)¶
Height (m)	3	3.05	3.05
Aircraft type	N/A	Piper Brave PA 36	Air Tractor 502b
Flying speed (m/s)	N/A	51	67
Nozzle	N/A	AU5000	CP coarse 30° def
Number of nozzles	N/A	8	29
Nozzle layout	N/A	as measured	as measured
Initial droplet size	Malvern data	Malvern data	Malvern data
Material	nonvolatile	oil	water
Swath width (m)	20	20	20
Field width (m)	500	500	500
Surface roughness	N/A	0.0075	0.0075
Turbulence intensity	0.1	N/A	N/A

† GDM, Gaussian diffusion model.
‡ ULV, ultra low volume.
§ LV, low volume.
¶ Range of field meteorological condition shown in brackets.

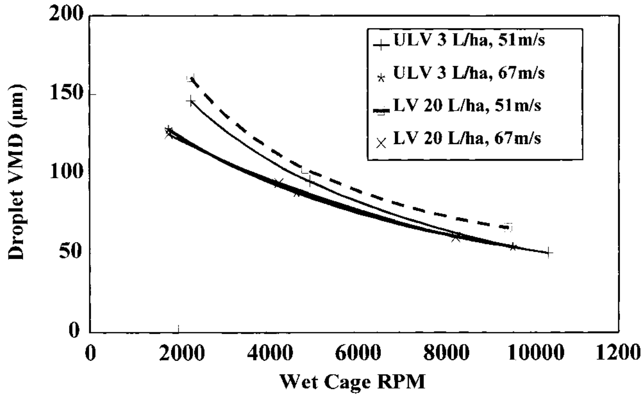

Fig. 1. Droplet size (volume median diameter [VMD]) generated by a Micronair AU5000 applying two formulations of endosulfan (ultra low volume [ULV] and low volume [LV]) at two airspeeds (51 and 67 m/s). Measured with a Malvern 2600 Laser Droplet Analyser in a windtunnel.

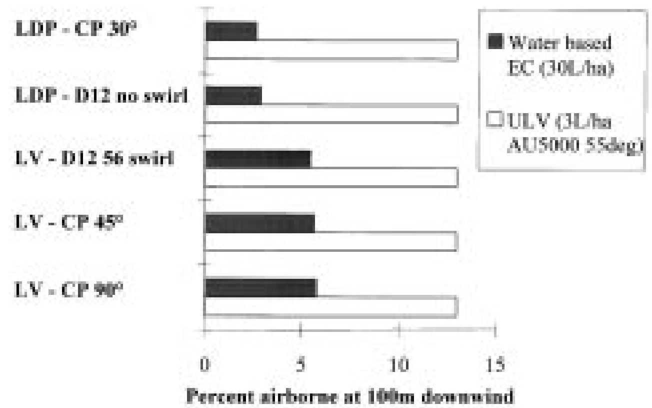

Fig. 3. Airborne drift values measured using towers placed 100 m downwind of endosulfan low volume (LV) and large droplet placement (LDP) single-flight-line applications, normalized against simultaneous ultra low volume (ULV) applications.

fect of increasing airstream velocity from 51 to 67 m/s was to decrease VMD from nearly 300 µm to less than 200 µm for the CP nozzle with a 30° deflector setting.

Single-Flight-Line Drift Tests

Simultaneous comparisons of the airborne drift from ULV and LV aircraft delivery systems are summarized in Fig. 3. The results were expressed as a percentage of the applied rate from the aircraft. This data demonstrates that the selection of large droplets using CP hydraulic nozzles with a 30° deflector plate (VMD values of about 250 µm) reduced the detected airborne fraction measured at 100 m downwind of release by a factor of two to three times compared with the AU5000 ULV application system.

Full-Field Drift Tests

Actual off-target deposition profiles obtained on paper-covered flat plates placed 1 m above the ground and downwind of the field during the monitoring of the commercial field trials are presented in Fig. 4 and 5. The data show the combined results from a number of different trials carried out during the period 1993–1998. The data show the decline in deposit with distance from the edge of the sprayed area when ULV and LV techniques were used. Some data points were corrected to account for variation in wind direction. A high degree of variation in off-target deposition values was observed between the trials, which is indicative of the range of meteorological and operating conditions observed. With a coarse average taken across all trials, mean off-target deposition values (in g/m^2) at a downwind distance of 500 m fell to approximately 2 and 1% of the field-applied rate for ULV and LV applications, respectively. These values compare reasonably with figures of approximately 1 and 0.3% predicted by the Gaussian diffusion and AgDRIFT models for a 500-m-wide field source width with neutral conditions (Fig. 4 and 5). Agreement between the two computer models was generally good for downwind distances greater than 100 m.

Mass Balance

Normalizing mean figures to a 500-m-wide field (Fig. 6), deposition upon cotton leaves was approximately 60 and 50% for ULV and LV application, respectively.

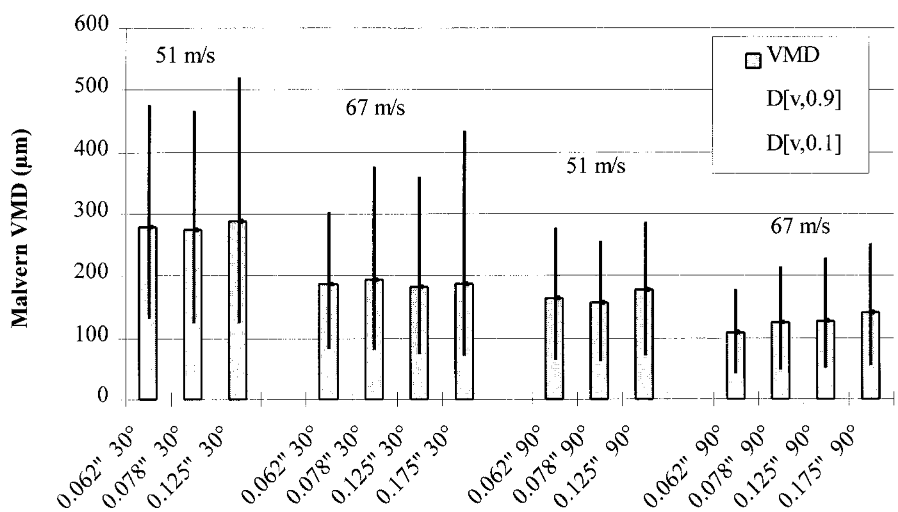

Fig. 2. Malvern laser volume median diameter (VMD) values for the CP nozzle spraying endosulfan emulsifiable concentrate (EC) at 20 L/ha, measured at two airspeeds and two deflector angles to the airstream. Lines represent D[v,0.9] to D[v,0.1] interval (i.e., the width of the spectrum).

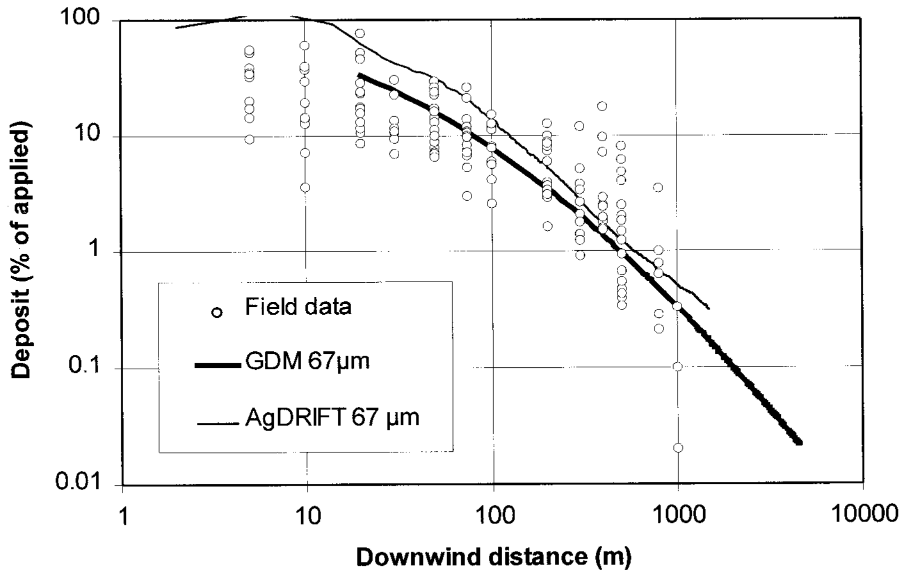

Fig. 4. Downwind deposition values obtained on horizontal flat plates for ultra low volume (ULV) application. Data compared against Gaussian diffusion (GDM) and AgDRIFT model outputs.

Ground deposition was notably higher at approximately 45% for the LV spray compared with 25% for the ULV spray. Of the total amount released per unit crosswind distance over a 500-m-wide field source width (in g/m), approximately 14% moved across the downwind edge of the field, with approximately half of this depositing within the first 500 m downwind. With LV application, this figure was approximately 7%, with most of this (5%) depositing within the first 500 m.

CONCLUSION

A comprehensive series of trials undertaken from 1993 to 1998 has helped to quantify the aerial transport of pesticides that occurs during normal commercial applications of endosulfan. Mean spray deposition upon cotton leaves crop surfaces was roughly equivalent for ULV and LV application, but losses to the air were higher with ULV applications, and losses to the ground were higher with LV applications. The high variation in data between trials was accounted for by the wide range of windspeed, temperature, humidity, atmospheric stability, and crop structure encountered.

Gaussian diffusion and AgDRIFT computer models (using droplet size data from laser difraction studies) have been successfully compared to the experimental data derived from this study. These models have proved useful in recommending spray drift buffer distances for implementation in spray drift management programs (Woods et al., 1998b; Dorr et al., 1998). The slight elevation of the AgDRIFT curve at mid-distance (Fig. 5) compared with the Gaussian diffusion model (GDM)

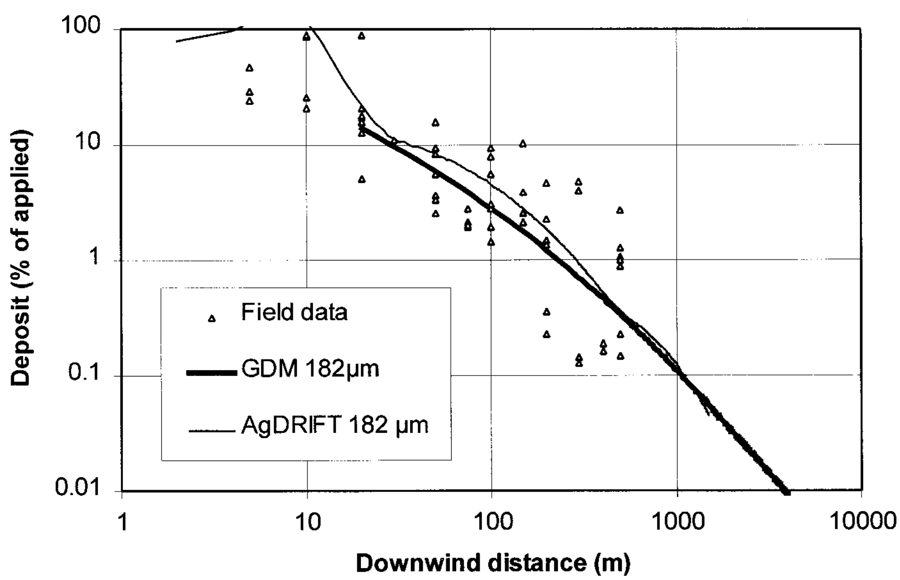

Fig. 5. Downwind deposition values obtained on horizontal flat plates for low volume (LV) application. Data compared against Gaussian diffusion (GDM) and AgDRIFT model outputs.

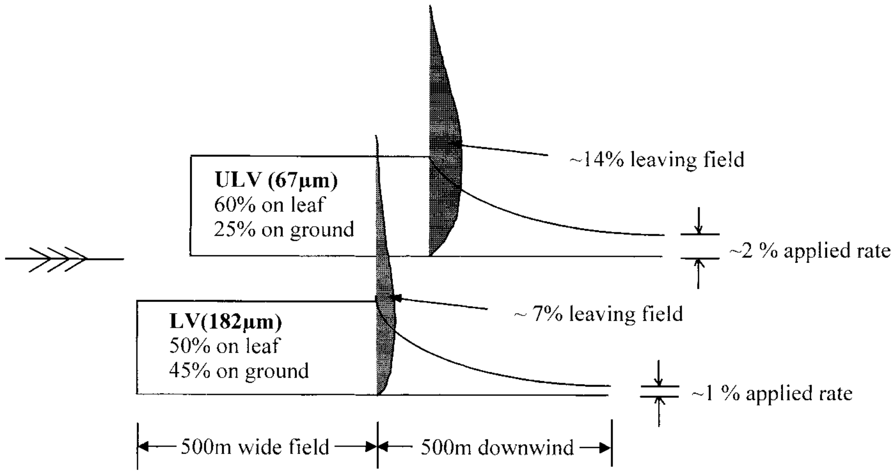

Fig. 6. Summary of transport characteristics for endosulfan insecticide, aerially applied in cotton.

curve for water-based spray drift may be due to the ability of the AgDRIFT model to predict the effect of droplet evaporation. There was, however, very good agreement between the models at distances greater than 500 m downwind. Some of the data was appreciably (up to 10 times) higher than levels predicted by the models. This may be because some of the trials were carried out in stable or dusk surface temperature inversion atmospheric conditions. Both the models assume a neutral atmosphere.

The selection of LDP water-based application techniques (i.e., VMD greater than 250 μm) reduced the detected airborne fraction by up to three times at 100 m downwind of a single flight line (Fig. 3). When larger droplets (VMD) are required, hydraulic nozzles should be used. However, higher volumes of carrier (up to 50 L/ha) may be required to ensure that droplet numbers per cm^2 on the leaf are sufficient for control of the insect pest. Compared with ULV application, efficacy may be reduced and losses to the ground may be increased. Future studies will be aimed at quantifying these effects.

ACKNOWLEDGMENTS

The work was funded by the Land & Water Resources Research & Development Corporation (LWRRDC) in conjunction with the Cotton Research and Development Corporation and Murray Darling Basin Commission. The cooperation during these trials of Auscott Warren/Narrabri, Nicholsons Air Services, Crop-Jet Aviation, Dr. Ivan Kennedy (the University of Sydney), and the NSW Agriculture Chemical Residue Laboratory is gratefully acknowledged.

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EXHIBIT B

United States Department of the Interior

FISH AND WILDLIFE SERVICE

New Mexico Ecological Services Field Office
2105 Osuna Road NE
Albuquerque, New Mexico 87113
Telephone 505-346-2525 Fax 505-346-2542
www.fws.gov/southwest/es/newmexico/

FWS Project code: 2023-0081664

May 31, 2023

Jacob K. Howell
USDA-APHIS
125 Valencia Dr. NE Suite B,
Albuquerque, NM 87108

Dear Mr. Howell:

This is in response to your email and draft biological assessment (BA) dated February 15, 2023, requesting consultation with the U.S. Fish and Wildlife Service (Service), pursuant to Section 7 of the Endangered Species Act of 1973, as amended (ESA). This consultation is for the United States Department of Agriculture-Animal and Plant Health Inspection Services (USDA- APHIS) regarding requests by land managers to conduct treatments to suppress grasshopper infestations as part of the Rangeland Grasshopper and Mormon Cricket Suppression Program (Program) in Rio Arriba County in New Mexico. The term "grasshopper" used herein refers to both grasshoppers and Mormon crickets, unless differentiation is necessary. A final BA was received in this Field Office on May 1, 2023.

Consultation is being requested due to the listing of an endangered species, the New Mexico meadow jumping mouse (*Zapus hudsonius luteus*) (jumping mouse) and its critical habitat since the last APHIS consultation on these control methods affecting the action area was completed in 1995. APHIS proposes to suppress economically damaging grasshopper populations on rangelands using only diflubenzuron, one of the authorized chemicals for such control, on private and state lands in Rio Arriba County, New Mexico. The BA cited the analysis provided in the 2019 Final Environmental Impact Statement (FEIS) for APHIS suppression activities in 17 western states that analyzed the effects of diflubenzuron and other pesticides on species. This BA addresses species which may not have been addressed in previous Biological Opinions (BO) or letters of concurrence (LOC). It also addresses the use of diflubenzuron as it relates to species previously consulted on in past BOs or LOCs. The conservation measures and any reasonable and prudent measures included in these prior BOs or LOCs or in any other agreement reached between APHIS and FWS will be in effect until a nationwide BO for the Rangeland Grasshopper Cooperative Management Program is issued. This nationwide BO is anticipated to be completed in 2023.

The BA describes an action area of 25,522 acres in Rio Arriba County of which treatment is proposed on approximately 12,761 acres. All treatment areas are located within rangelands and APHIS is not treating grasslands associated with riparian habitat, woodlands or forests. APHIS will employ buffer zones and other conservation measures from the 2007 "Recommended Protection Measures for Pesticide Applications in Region 2 of the U.S. Fish and Wildlife Service" guidelines for species and the pesticide (diflubenzuron) not covered in the aforementioned consultations, or whichever buffer is greater. The BA states that all aerial applications will be outside of a 0.25 mile buffer adjacent to any water source. This distance falls within the buffer guidelines in these 2007 Service pesticide application guidelines for aerial applications near aquatic habitats. This buffer distance will also assure that this action will be significantly outside of the 500 foot buffer for ground application described in the BA for other species. It also assures that this action will not impact any potential jumping mouse populations or habitat, since a 0.25 mile buffer around the action area will still be significantly far from any potential jumping mouse riparian habitat. The action will primarily use aerial application of diflubenzuron on targeted areas at the reduced agent area treatment (RAAT) rate of 1.0 fluid ounce per acre, with a coverage of 33-50 percent. For clarification and certainty, this 0.25 mile buffer for aerial application also will be outside of the 500 foot buffer for any ground application that may need to be done in this action area.

APHIS has determined that this grasshopper suppression project in Rio Arriba County will have **no effect** on the Canada lynx *(Lynx canadensis)*, Rio Grande silvery minnow *(Hybognathus amarus)*, Colorado pikeminnow *(Ptychocheilus Lucius)*, razorback sucker *(Xyrauchen texanus)*, Rio Grande cutthroat trout *(Oncorhynchus clarkii Virginalis)*, Jemez Mountain salamander *(Plethodon neomexicanus)*, monarch butterfly *(Danaus plexippus)*, silverspot *(Speyeria nokomis Nokomis)*, Knowlton cactus *(Pediocactus knowltonii)*, Mesa Verde cactus *(Sclerocactus mesae-verdae)*, and Mancos milk-vetch *(Astragalus humillimus)*. Although the ESA does not require Federal agencies to consult with the Service if the action agency determines their action will have "no effect" on threatened or endangered species or designated critical habitat (50 CFR 402.12), we appreciate your consideration for the conservation of these species and notification of your "no effect" determinations.

APHIS has also determined that the grasshopper suppression program **may affect but is not likely to adversely affect (NLAA)** the New Mexico meadow jumping mouse *(Zapus hudsonius luteus)*(jumping mouse), Mexican gray wolf *(Canis lupus bayleyi)*(wolf), Mexican spotted owl *(Strix occidentalis lucida)*(owl), yellow-billed cuckoo *(Coccyzus americanus)*(cuckoo), and the southwestern willow flycatcher *(Empidonax traillii extimus)*(flycatcher),and their designated critical habitats. The Service concurs with your determination that this action may affect, but is not likely to adversely affect the jumping mouse, wolf, owl, cuckoo and flycatcher, based on the following:

- APHIS evaluated the available data regarding exposure and response to diflubenzuron for the wolf, owl, cuckoo and flycatcher and their essential breeding, feeding, and sheltering habitats in their 2019 FEIS and prior consultations in 2010 and 2015 (2010-I-0047; 2015-I-0244), as they relate to use patterns defined for the program. The current BA indicates that this action will be sufficiently far from any potential jumping mouse riparian habitat and provide a sufficient 0.25 mile buffer from the effects of this aerial application to any riparian habitat that may be nearby, if any does occur. This would preclude any potential for adverse impacts to the jumping mouse or to its forage base of herbaceous riparian vegetation being negatively impacted by any possible contamination.

- Based on integration and synthesis of the exposure and response analyses to characterize risk to listed species and their habitat, APHIS established avoidance and minimization measures to ensure that diflubenzuron or the methods of application will not adversely affect individual listed species or the habitats upon which they depend.

- All program activities within the range of listed species and any designated critical habitat will incorporate all prescribed avoidance and minimization measures (RAATs, buffers, etc.) to ensure the use of diflubenzuron or its application will not result in any adverse effects to species or the habitat upon which they depend.

- The analyses APHIS used to develop these measures considered relevant exposure pathways to ensure that the integrity of the biological, chemical, and physical attributes of the previously listed species would be protected. These pathways were described in prior BAs submitted in 2010 and 2015 and also included in the most current 2019 FEIS. They are incorporated here by reference. The Service

Additionally, specific assessments for the NLAA determinations are summarized below:

SPECIES	**CRITICAL HABITAT**	**PROPOSED CONSERVATION MEASURE**
New Mexico meadow jumping mouse	No	No applications will occur within a 0.25 mile buffer from any riparian area
Mexican wolf	No	No established wolf packs in the action area. Ongoing communication with FWS wolf team on any wolf activity in the action area
Mexican spotted owl	No	No applications will occur over forested habitat or critical/recovery habitat. All applications will be over open rangeland
Yellow billed cuckoo	No	No applications will occur within a 0.25 mile buffer from any riparian area
Southwestern willow flycatcher	No	No applications will occur within a 0.25 mile buffer from any riparian area

The BA also provided the following information regarding pesticide application that further justifies our concurrence on your NLAA determinations:

Diflubenzuron ULV	There is a required 0.25 mile buffer for aerial and ground applications from all water sources. Only RAAT rates of application will be implemented

Application buffers are one of the primary mitigation measures for reducing the potential for drift and runoff to occur in areas where listed aquatic species may occur and for any designated critical habitat. The proposed 0.25 mile buffer will be applied to all aquatic habitats where listed species may be present or where critical habitat has been designated. In relation to designated critical habitat, APHIS proposed mitigation measures that are protective of biological and physical features required for the conservation of the listed species that occur in areas where program applications could occur.

In addition to the proposed application buffers, other mitigation measures are also necessary and proposed to further reduce the potential for exposure to listed species and their designated critical habitat. These measures include:

- Avoid applications when sustained winds speeds exceed 10 miles per hour (mph).
- Use RAATs where listed species are present and adjacent to designated critical habitat.
- Avoid applications under conditions where a temperature inversion is possible or when a storm event is imminent

The above reference to RAATs refers to the maximum RAAT rate and 100 percent coverage within the spray block and will be required for 500 feet making a ground application, or 1000 feet from an aerial application. Since the BA states that coverage may be less than 100 percent, we do not anticipate any exceedance of the criteria in the 2007 “Recommended Protection Measures for Pesticide Applications in Region 2 of the U.S. Fish and Wildlife Service” guidance document cited earlier.

We appreciate your efforts at coordinating your actions with the Service to ensure the conservation of threatened and endangered species. If you have questions or comments related to this project, please contact Mark Brennan at mark_brennan@fws.gov.

Sincerely,

SHAWN SARTORIUS Digitally signed by SHAWN SARTORIUS Date: 2023.05.31 09:45:10 -06'00'

Shawn Sartorius
Field Supervisor

EXHIBIT C

SOLICITATION/CONTRACT/ORDER FOR COMMERCIAL ITEMS

1. Requisition Number

2. Contract No.

3. Award/Effective Date

4. Order Number

5. Solicitation Number: RFQ 03 NM Block Cebolla

6. Solicitation Issue Date: 06/13/2023

7. For Solicitation Information Call: a. Name: Jason Wilking Jason.l.wilking@usda.gov

b. Telephone Number *(No collect calls)*

8. Offer Due Date/Local Time: **06/16/2023 1:30 pm cen**

9. Issued By — Code 82YY

USDA APHIS MRPBS AAMD
250 Marquette Ave
Minneapolis, MN 55401

10. This Acquisition is
- [ ] Unrestricted
- [X] Set-Aside 100% for
  - [X] Small Business
  - [ ] HubZone Small Business
  - [ ] 8(A)

NAICS: 115112

Size Standard: 7.5 million

11. Delivery for FOB Destination Unless Block is Marked.
- [ ] See Schedule

12. Discount Terms

13a. This contract is a rated order under DPAS (15 CFR 700) — N/A

13b. Rating N/A

14. Method of Solicitation: [X] RFQ [ ] IFB [ ] RFP

15. Deliver To — Code

South and West of Cebolla in Rio Arriba County NM

16. Administered By — Code

See Block 9

17a. Contractor/Offeror — Code — Facility Code

Telephone No. — TIN:

17b. Chck if Remittance is Different and Put Such Address in Offer. [ ]

18a. Payment Will Be Made By — Code 6395

www.IPP.gov

18b. Submit Invoices to:

19. ITEM NO.	20. SCHEDULE OF SUPPLIES/SERVICES	21. QUANTITY	22. UNIT	23. UNIT PRICE	24. AMOUNT
	See Continuation Pages				

25. Accounting and Appropriation Data

26. Total Award Amount *(For Govt. Use Only)*

[X] 27a. Solicitation incorporates by reference FAR 52.212-1, 52.212-4, FAR 52.212-3 and 52.212-5 are attached. Addenda [X] are [ ] are not included

[ ] 27b. Contract/Purchase Order incorporates by reference FAR 52.212-4, 52.212-5 is attached. Addenda [ ] are [ ] are not attached

[ ] 28. Contractor is required to sign this document and return ________ copies to Issuing Office. Contractor agrees to furnish and deliver all items set forth or otherwise identified above and on any additional sheets subject to the terms and conditions specified herein.

[ ] 29. Award of Contract: Reference. ________________ Offer Dated ________________. Your offer on Solicitation (Block 5), including any additions or changes which are set forth herein, is accepted as to items:

30a. Signature of Offeror/Contractor

31a. United States of America *(Signature of Contracting Officer)*

30b. Name and Title of Signer *(Type or Print)*

30c. Date Signed

31b. Name of Contracting Officer *(Type or Print)*

31c. Date Signed

32a. Quantity in Column 21 Has Been
[ ] Received [ ] Inspected [ ] Accepted, and Conforms to the Contract, Except as Noted: ________________

32b. Signature of Authorized Government Representative

32c. Date

32d. Printed Name and Title of Authorized Government Representative

32e. Mailing Address of Authorized Government Representative

32f. Telephone Number of Authorized Government Representative

32g. E-mail of Authorized Government Representative

33. Ship Number
[ ] Partial [ ] Final

34. Voucher Number

35. Amount Verified Correct For

36. Payment
[ ] Complete [ ] Partial [ ] Final

37. Check Number

38. S/R Account Number

39. S/R Voucher Number

40. Paid By

41a. I certify this account is correct and proper for payment

41b. Signature and Title of Certifying Officer

41c. Date

42a. Received By (Print)

42b. Received At (Location)

42c. Date Rec'd (YY/MM/DD)

42d. Total Containers

PART I – THE SCHEDULE
SECTION A –SERVICES AND PRICES / COSTS
Fixed wing Aerial Treatment
of Carbaryl near Cebolla New Mexico

PART I – THE SCHEDULE
SECTION A –SERVICES AND PRICES

A. ITEMS AND PRICES

Offeror shall submit a firm-fixed price quote for all costs necessary to perform services for the Aerial application of Carbaryl as stated in the attached Statement of Work for USDA, APHIS, PPQ. The contractor will be required to supply all chemicals, water, aircraft, supplies, materials, labor, supervision, equipment, personnel, services, tools, transportation, to complete the contract in the specified time. Price quotes should be of sufficient detail to determine their adequacy. The quote will include all cost associated per gallon of Carbaryl applied.

OFFERS SHALL BE SUBMITTED BASED ON A PRICE PER GALLON OF APPLIED CARBARYL (all costs included). THE CONTRACT AWARD WILL BE MADE TO THE LOWEST PRICE TECHNICALLY ACCEPTABLE OFFER.

BASE CONTRACT PERIOD: Date of award until the contract is completed or terminated.

Item No.	Description of Service	Unit	Est Gallons.	Unit Price	Total Amount
001	Aerial Treatment of Carbaryl near Cebolla NM	Per gallon of Carbaryl applied	782 gallons	$_______/gallon	$_________

*The estimated number of gallons of Carbaryl required to treat the block using alternate swathing is an estimated 782 gallons. The rate of application will be 16 total ounces per acre: 8 ounces of Carbaryl and 8 ounces of water.
Quotes need to be sent to the attention of Jason Wilking at: jason.l.wilking@usda.gov

EXHIBIT D

22-8100-0870-MU

MEMORANDUM OF UNDERSTANDING
BETWEEN THE
U.S. DEPARTMENT OF THE INTERIOR BUREAU OF LAND MANAGEMENT
AND THE
UNITED STATES DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE (APHIS)
PLANT PROTECTION AND QUARANTINE

ARTICLE 1 - PURPOSE

The purpose of this Memorandum of Understanding (MOU) is to cooperate regarding suppression of Grasshoppers and Mormon Crickets on lands administered by the Bureau of Land Management (BLM).

ARTICLE 2 - BACKGROUND

Cultivated crops and range plants in most Western States are periodically damaged by grasshoppers and Mormon crickets (GH&MC). Destructive GH&MC outbreaks occur on rangelands and croplands of all ownerships including public lands administered by the BLM. Some outbreaks are of local concern only, while others may serve as focal points from which pests spread to adjacent rangelands or croplands. The Plant Protection Act (PPA) of 2000 in Section 417 (7 U.S.C. 7717) authorizes the Secretary of Agriculture to carry out a program to control GH&MC on croplands and rangelands on Federal lands. Administration of the PPA is delegated to the U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS) at 7 CFR 2.80(a)(51).

The BLM is responsible for the protection and management of BLM-administered public lands. Unless otherwise specified by law, these lands are managed under the principles of multiple use and sustained yield to protect natural resources and provide opportunities for recreational use, livestock grazing, timber harvest, energy development, and other uses. Because high populations of GH&MC have the potential to negatively impact resources on public lands, the BLM supports cooperative and coordinated efforts for an integrated pest management approach for addressing GH&MC populations.

This MOU describes how the BLM and APHIS will cooperate with respect to the detection, evaluation, and suppression components of GH&MC management on BLM-managed lands.

ARTICLE 3 - AUTHORITIES

Under the PPA, as amended, (7 USC §§ 7701 et. seq.), the Secretary of Agriculture is authorized to issue regulations and orders to prevent, detect, control, eradicate, suppress, or retard the spread of plant pests or noxious weeds into or within the United States and to cooperate with other Federal agencies or entities, states or political subdivisions of states, national governments, local governments of other nations, domestic or international organizations, domestic or international associations, and other persons to carry out the purposes of the PPA.

The Plant Protection Act (PPA) of 2000 in Section 417 (7 U.S.C. 7717) authorizes the Secretary of Agriculture to carry out a program to control GH&MC on croplands and rangelands on Federal lands. Administration of the PPA is delegated to the U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS) at 7 CFR 2.80(a)(51).

The BLM is authorized to enter this MOU by Section 307 of the Federal Land Policy and Management Act (FLPMA), 43 U.S.C. 1737.

ARTICLE 4 - MUTUAL RESPONSIBILITIES

The BLM and APHIS mutually agree that:

a. All GH&MC suppression project(s) initiated under this MOU will conform to APHIS and BLM policies and will be approved by appropriate BLM and APHIS line officers.

b. Administrative and/or operational questions pertaining to the cooperative work of the BLM and APHIS arising in the field will initially be discussed by the local representatives of APHIS and the BLM, and that areas of disagreement will be referred to the BLM contact and to the appropriate APHIS State Plant Health Director for direction.

c. Either party may share needed equipment, which is otherwise unavailable, while retaining ownership of that equipment.

d. Although this MOU addresses the role of APHIS for GH&MC management on BLM-administered lands, there may be circumstances where it is more economical and efficient for county weed and pest districts or private contractors to conduct GH&MC control activities on BLM administered lands.

ARTICLE 5 - BLM RESPONSIBILITIES

The BLM agrees to:

a. Designate national and state program leaders to serve as the authorized representatives who shall be responsible for collaboratively administering the activities conducted under this MOU.

b. Transmit relevant information it receives from APHIS (including pertinent biological opinions, environmental assessments documents, survey maps, and GH&MC population data) to the appropriate BLM field contacts.

c. Provide the APHIS State Plant Health Director with the appropriate BLM field office contact information.

d. Assist in evaluating and selecting GH&MC suppression techniques that will meet the management needs of both the BLM and APHIS. APHIS has lead responsibility for compliance with environmental laws and statutes for the GH&MC program and for recommending the technology to be used in the program.

e. Coordinate in the preparation of the environmental analyses for projects that propose to control GH&MC populations, provide recommendations for BLM resource protective measures, and ensure compliance with field office land use plans.

f. Review the APHIS programmatic environmental assessment (EA) for Mormon Cricket and Grasshopper Suppression to determine whether it adequately evaluates the action and supports a Finding of No Significant Impact (FONSI). Policy directing the adoption of another agency's NEPA documents is outlined in BLM Handbook 1790-1 (NEPA Handbook) Section 5.4. In instances where the BLM determines that additional environmental analysis is necessary, it will prepare a NEPA document, incorporating the programmatic EA's analysis where appropriate, before issuing a decision to authorize treatment actions on BLM-managed lands.

g. Request, in writing, the inclusion of the appropriate lands in the APHIS GH&MC suppression project when treatment for GH&MC is necessary on BLM-managed lands. This request will be made in advance of any treatment to provide time for APHIS to plan and implement treatment. Requests should include information on the location and any resource protective measures within the treatment area.

h. Prepare a pesticide use proposal for GH&MC infestations on BLM-managed lands.

i. Assist APHIS with GH&MC suppression operations, when feasible, by providing personnel, available transportation, radios and temporary storage of equipment and supplies; approving use of airstrips; supplying land ownership maps; and providing information about the location of GH&MC populations and access routes.

j. Notify the APHIS State Plant Health Director when any new Mormon cricket or grasshopper infestation of concern is discovered and request follow-up evaluations with management options.

ARTICLE 6 - APHIS RESPONSIBILITIES

APHIS agrees to:

a. Designate the national policy manager for the GH&MC program its authorized representative who shall be responsible for collaboratively administering the activities conducted under this MOU. Should this individual be temporarily detailed to another position or on extended absence, a letter will be issued to the BLM by the APHIS signatory official to appoint a temporary ADODR.

b. Provide the BLM with statewide maps of potential GH&MC populations. The maps will be based on annual field surveys of GH&MC populations.

c. If fall surveys indicate high GH&MC numbers on BLM-managed lands, consult with the BLM on the best management approach. Should that approach involve pesticides, and in conjunction with available funding, APHIS will:

   1. Bear responsibility for cost and application of pesticide applications.

2. Identify sources for the purchase and storage of insecticides. Storage of insecticides on BLM-managed lands will be in accordance with applicable law and BLM policy. Any excess pesticides, pesticide containers, or mixed, but unused pesticide, will be disposed of by APHIS.

d. Prepare and issue to the public environmental documents that provide an appropriate level of analysis for the affected environment under consideration for suppression treatments. For most situations, this will include a programmatic EA and a FONSI. These documents will be prepared under the APHIS NEPA implementing regulations with coordination and input from the BLM.

e. Develop statements of work and identify available resources to apply a pesticide that will suppress GH&MC population outbreaks.

f. Provide an estimate of the acreage that may require treatment, cost estimates, a recommendation as to whether a suppression program is appropriate, and APHIS capabilities based on available funding and resources.

g. Prepare a work plan and implement a GH&MC suppression project on BLM-managed lands, upon receipt of a written request from the BLM for efficacious and cost-effective treatments. Such projects will adhere to applicable protective measures and operational procedures described by APHIS and BLM in the applicable NEPA and decision documents. Protective measures and other relevant decisions will also be implemented for Threatened and Endangered Species as required by the U.S. Fish and Wildlife Service, National Marine Fisheries Services, and land use plans.

h. Coordinate GH&MC Program activities and meet with stakeholders including representatives of the BLM, other agencies, state departments of agriculture, and private landowners who have an interest in GH&MC Program activities.

i. After completion of a GH&MC suppression project provide the BLM information that includes the acres treated, location, pesticide and amount used and provide treatment effectiveness, complications, follow-up actions, or any pertinent comments regarding project operations.

ARTICLE 7 – SECURITY REQUIREMENTS

a. If applicable, when connected to the USDA-APHIS network or hosting APHIS information and/or information systems, comply with the Federal, USDA, and APHIS security and privacy requirements to protect APHIS information and information systems against cyber threats and unauthorized intrusions as required by the Federal Information Security Management Acts (FISMA) of 2002 and 2014, the National Cybersecurity Protection Act of 2014, and the Privacy Act of 1974. Specific USDA/APHIS control guidelines are outlined in the most current version of the USDA/APHIS Information System Security Handbook. In accordance with USDA and APHIS regulations and policies on email, the BLM will not download any material (e.g., pictures, movies, or music files) bearing a copyright, nor access any material defined as inappropriate in these regulations and directives.

   In addition, the BLM agrees that all personnel that receive access to the APHIS network, any systems on the APHIS network, or any personnel using APHIS-owned or funded computer equipment will take all APHIS required security and privacy training. Furthermore, the BLM will not disseminate, post, or publish in any capacity official government information or data unless authorized to do so by this MOU.

   Current APHIS security and privacy requirements, policies, and guidelines can be obtained through the APHIS Information System Security Program Manager. APHIS follows USDA processes which are based on the most current National Institute of Standards and Technology (NIST) special publications such as NIST Special Publications (SP) 800-37 and SP 800-53 and -53A.

b. If applicable, work with the appropriate APHIS Program Unit's Information Systems Security Manager and the APHIS Information Systems Security Program Manager to ensure compliance with the FISMA assessment and authorization (A&A) requirements for APHIS information and information systems. The BLM must follow USDA/APHIS A&A guidelines and standards described in the USDA six step risk management framework process guide located at: Departmental Regulation: Security Assessment and Authorization. The regulation is based on applicable National Institute of Standards and Technology (NIST) publications such as, NIST SP 800 – 37, *Guide for Applying the Risk Management Framework to Federal Information Systems*; and, NIST SP 800 – 53, *Recommended Security Controls for Federal Information Systems*.

c. APHIS likewise agrees that when implementing the procedures in this MOU, it will comply with applicable Department of the Interior and BLM policies relating to security and privacy requirements. APHIS agrees that, when connected to the USDOI, BLM network, it will comply with the security guidelines as outlined in the Federal Information Systems Security Awareness Training including the DOI Rules of Behavior, Privacy Awareness, Records Management and Section 508 Compliance. The APHIS will not download any material (e.g., pictures, movies, or music files) bearing a copyright nor access any material defined as inappropriate in these regulations and directives. The APHIS agrees that any of its personnel that receives access to the BLM network, any systems on the BLM network, or any personnel using BLM owned computer equipment will take required BLM records, systems and IT security training.

ARTICLE 8 - DATA SHARING AND RESPONSIBILITIES

a. Data to be Shared: The parties agree to share plant protection and quarantine data. The data to be provided to each Party by the other Party includes, but is not limited to, Plant Protection and Quarantine surveys, diagnostic information, detection activities, inspection reports, and pest interception data. Each party is responsible for transmitting the provided data to its own authorized employees, cooperators, and contractors as applicable and necessary, in order to carry out responsibilities under their respective plant health authorities. Each party agrees that it will ensure, to the extent provided by applicable laws and regulations, that data provided by the other party is not released to anyone that is not authorized to receive it.

b. Data Utilization: The parties agree that the provided data will only be used in the administration and enforcement of each party's respective plant health laws and regulations. Data provided by the parties under this MOU may be used to ensure compliance with their respective plant health laws and regulations; to respond to domestic plant pest and disease emergencies, interceptions, and trace backs; to enhance delivery of pest exclusionary programs and activities; to support pest surveying activities; to develop quarantines and other appropriate measures for pest management and mitigation; to implement or improve international pre-clearance and/or pest eradication programs and activities, pest risk assessments, phytosanitary trade support, and the issuance of Plant Protection and Quarantine permits; and to develop, in cooperation with Federal research agencies, new and improved methods, techniques and procedures for use in cooperative Plant Protection and Quarantine programs and activities. Each party agrees that it will ensure that the provided data is used only for purposes specified in this MOU and only in a manner consistent with the provisions of the Plant Protection Act and the FLPMA.

c. Data Restrictions: The BLM agrees and acknowledges that the data provided by APHIS pursuant to this MOU is solely APHIS data and as such is or may be subject to the confidentiality provisions of 7 USC § 8791 of the Food, Conservation, and Energy Act of 2008, (formerly Section 1619 of the 2008 Farm Bill) and the Privacy Act of 1974. The BLM also agrees to safeguard such confidentiality and prohibit any unauthorized access to the data provided by APHIS as required by 7 USC § 8791. The APHIS agrees that data provided by the BLM pursuant to this MOU is solely BLM data. The BLM further agrees and acknowledges that if 7 USC § 8791 applies to some or all of the APHIS provided data, that pursuant to 7 USC § 8791, the BLM is bound to and will comply with 7 USC § 8791 (Appendix A) and related APHIS guidance. The BLM understands that it may not release any of the data provided by APHIS since it is Federal Government data and it agrees to refer any and all requests for the data provided by APHIS, not otherwise authorized to be released under this Agreement and applicable Federal laws and regulations, to the USDA, APHIS, Legislative and Public Affairs, Freedom of Information and Privacy Act Office, 4700 River Rd. Unit 50, Riverdale, MD 20737, Telephone: (301) 851-4102. Additionally, the BLM agrees that it will, if requested by APHIS, enter into a separate written agreement with APHIS to protect from release or disclosure any data provided by APHIS that is subject to 7 USC § 8791.

ARTICLE 9 - STATEMENT OF NO FINANCIAL OBLIGATION

Signing this MOU does not constitute a financial obligation on the part of APHIS. Each signatory party is to use and manage its own funds in carrying out the purpose of this MOU. Transfers of funds or items of value are not authorized under this MOU.

ARTICLE 10 - LIMITATIONS OF COMMITMENT

This MOU and any continuation thereof shall be contingent upon the availability of funds appropriated by the Congress of the United States. It is understood and agreed that any monies allocated for purposes covered by this MOU shall be expended in accordance with its terms and the manner prescribed by the fiscal regulations and/or administrative policies of the party making the funds available. If fiscal resources are to transfer, a separate agreement must be developed by the parties.

ARTICLE 11 - CONGRESSIONAL RESTRICTION

Under 41 USC 6306, no member of or delegate to Congress shall be admitted to any share or part of this MOU or to any benefit to arise therefrom.

ARTICLE 12 – NON-DISCRIMINATION CLAUSE

The United States Department of Agriculture and the Department of the Interior prohibit discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. Not all prohibited bases apply to all programs.

ARTICLE 13 – LIABILITIES

Nothing in this MOU is intended to or will be construed to limit or affect in any way the authority or legal responsibilities of APHIS or the BLM. Nothing in this MOU binds APHIS or the BLM to perform beyond their respective authorities. Nothing in this agreement may be construed to obligate APHIS or the BLM or the United States to any current or future expenditure of resources in advance of the availability of appropriations from Congress. Nor does this agreement obligate APHIS or the BLM or the United States to spend funds on any particular project or purpose, even if funds are available. The mission requirements, funding, personnel, and other priorities of APHIS and the BLM may affect their ability to fully implement all the provisions identified in this MOU. APHIS and the BLM assume no liability for any actions or activities conducted under this agreement except to the extent the recourse or remedies are provided by Congress under the Federal Tort Claims Act (28 U.S.C. 1346(b), 2401(b), 2671-2680).

ARTICLE 14 - AMENDMENTS

This MOU may be amended at any time by mutual agreement of the parties in writing.

ARTICLE 15 - TERMINATION

This MOU may be terminated at any time by mutual agreement of the parties with a sixty (60) days' notice in writing to the other party.

ARTICLE 16 - EFFECTIVE DATE AND DURATION

This MOU will become effective upon the date of the final signature and will continue in effect for five years from the date of the final signature, unless terminated.

ARTICLE 17 - SHARED INFORMATION

Any information furnished between the APHIS and the BLM under this MOU may be subject to the Freedom of Information Act, 5 U.S.C. § 552, *et seq.* (FOIA). APHIS and the BLM agree to consult one another prior to releasing potentially privileged or exempt documents.

DEPARTMENT OF THE INTERIOR
THE BUREAU OF LAND MANAGEMENT

NADA CULVER Digitally signed by NADA CULVER
Date: 2021.12.20 12:35:14 -07'00'

Nada Wolff Culver Date
Deputy Director, Policy and Programs
U.S. DOI, BLM

DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE

MARK DAVIDSON Digitally signed by MARK DAVIDSON
Date: 2022.01.11 17:22:07 -05'00'

Mark L Davidson, DVM, MS Date
Acting Deputy Administrator
USDA, APHIS, PPQ

EXHIBIT E

MEMORANDUM OF UNDERSTANDING (MOU)
BETWEEN
UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE (FS) - (RECIPIENT)
AND THE
UNITED STATES DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE (APHIS)
PLANT PROTECTION AND QUARANTINE (PPQ)

ARTICLE 1 - PURPOSE

The purpose of this Memorandum of Understanding (MOU) is for suppression of Grasshoppers and Mormon Crickets on National Forest System Lands.

ARTICLE 2 - BACKGROUND

Cultivated crops and rangeland in most Western States are periodically damaged by grasshoppers and Mormon crickets (GH&MC). Destructive GH&MC outbreaks occur on rangelands and croplands of all ownerships, including National Forest System (NFS) lands administered by the United States Department of Agriculture (USDA), Forest Service (FS). Some outbreaks are of local concern only, while others may serve as focal points from which pests spread to adjacent rangelands or croplands. The Plant Protection Act (PPA) of 2000 in Section 417 (7U.S.C. 7717) authorizes the Secretary of Agriculture to control GH&MC on croplands and rangelands across all ownerships. Administration of the entire PPA is delegated to the USDA, Animal and Plant Health Inspection Service (APHIS) under 7 CFR 2.80 (a) (51).

The FS is responsible for the protection and management of NFS lands. Forage, timber, wildlife, recreation, wilderness, minerals and water resources are produced from these lands under the multiple-use concept. GH&MC outbreaks may threaten FS resources. Any proposed response, including suppression action, must be evaluated to determine the expected impact on FS resources and those of adjacent landowners. The FS supports cooperative and coordinated efforts for an integrated pest management approach to deal with damaging GH&MC outbreaks. An APHIS role also exists in the detection, evaluation, and suppression components of GH&MC management on NFS lands and is the subject of this Memorandum of Understanding.

ARTICLE 3 - AUTHORITIES

Under the Plant Protection Act (PPA), as amended, (7 USC §§ 7701 et. seq.), the Secretary of Agriculture is authorized to issue regulations and orders to prevent, detect, control, eradicate, suppress, or retard the spread of plant pests or noxious weeds into or within the United States and to cooperate with other Federal agencies or entities, States or political subdivisions of States, national governments, local governments of other nations, domestic or international organizations, domestic or international associations, and other persons to carry out the purposes of the PPA.

ARTICLE 4 - MUTUAL RESPONSIBILITIES

FS and APHIS mutually agree and understand that:

a. GH&MC suppression project(s) initiated under this MOU will conform to APHIS and FS policies and will be approved by appropriate FS and APHIS line officers.

b. All questions pertaining to the cooperative work of the two Agencies arising in the field will be discussed by local representatives of APHIS and the FS, and that areas of disagreement will be referred to the Regional Forester and appropriate APHIS PPQ Associate Executive Director for Field Operations for resolution.

c. Either party may furnish needed equipment which is otherwise unavailable and will retain its ownership.

ARTICLE 5 - FS RESPONSIBILITIES

FS agrees to/that:

a. Designate, National Invasive Species Program Manager - National Forest System (Forest Management, Rangeland Management and Vegetation Ecology Staff Unit), Washington, D.C. as its authorized representative who shall be responsible for collaboratively administering the activities conducted under this MOU.

b. Regional Foresters will send survey maps and GH&MC population data received from APHIS to appropriate Forest Supervisors and provide APHIS State Plant Health Director with current FS personnel names for follow-up contacts.

c. Forest Supervisors or their representatives will assist in evaluating and selecting GH&MC suppression techniques that will meet the management needs of both Agencies. Although APHIS has lead responsibility to complete environmental documentation for a GH&MC program and for selecting the technology to be used in the program, the FS will serve as a cooperating agency and provide required resource information and participate in the review process of any environmental documents.

d. If required by APHIS, in a timely fashion and if the skills are available, the FS will provide expertise to APHIS interdisciplinary teams to complete the environmental analyses for projects that propose to control GH&MC infestations on NFS lands. The role of the FS will be as a cooperating agency in the conduct of environmental analyses. The FS will provide a pesticide use proposal for APHIS to treat GH&MC infestations under these circumstances. APHIS can implement treatments once APHIS approves the NEPA decision document and the FS provides the pesticide use proposal.

e. Forest Supervisors will forward both biological opinions received from APHIS and APHIS prepared site-specific environmental documents to all affected District Rangers.

f. Fully consider APHIS responsibilities and integrated pest management needs on intermingled and adjacent lands when receiving GH&MC management programs on NFS lands. All pesticide use activities conducted by APHIS will be coordinated with the respective Forest Supervisor, and pesticide use activity records will be provided to the Forest Supervisor for inclusion in the Forest Activity Tracking System (FACTS) database of record.

g. The responsible FS official will request, in writing, the inclusion of the appropriate lands in the APHIS GH&MC suppression project when treatment for GH&MC is necessary on NFS lands. This request will be made in advance of any treatment to provide time for APHIS to plan and implement treatment. Requests should include information in the location and nature of any sensitive areas within the treatment area and recommendation to APHIS concerning the requirements of the Endangered Species Act of 1973, as amended.

h. Assist APHIS with GH&MC suppression operations, when feasible, by providing personnel and available transportation and temporary storage of equipment and supplies; approving use of airstrips, supplying land ownership maps and providing information about location of outbreaks and access routes. Such use of FS personnel will be held at the minimum necessary to accomplish the GH&MC suppression project(s).

i. When connected to the USDA APHIS network, comply with the security guidelines as outlined in the USDA Departmental Manual 3140-001, "Management ADP Security Manual; APHIS Directive 3140.2, "APHIS Electronic Mail and Security and Privacy Policy"; APHIS Directive 3140.3, "APHIS Internet Use and Security Policy"; and APHIS Directive 3140.5, "APHIS Information Systems Roles and Responsibilities". The FS will not download any material bearing a copyright (i.e., pictures, movies, or music files) nor access any material defined as inappropriate in these regulations and directives.

j. If applicable, when connected to the USDA-APHIS network or hosting APHIS information and/or information systems, comply with the federal, USDA, and APHIS security and privacy requirements to protect APHIS information and information systems against cyber threats and unauthorized intrusions as required by the Federal Information Security Management Acts of 2002 and 2014 (FISMA), the National Cybersecurity Protection Act of 2014, and the Privacy Act of 1974. Specific USDA/APHIS control guidelines are outlined in the most current version of the USDA/APHIS Information System Security Handbook. In accordance with USDA and APHIS regulations and policies on email, the FS will not download any material (i.e., pictures, movies, or music files) bearing a copyright, nor access any material defined as inappropriate in these regulations and directives.

Additionally, the FS agrees that any of its personnel that are given access to the APHIS network, any systems on the APHIS network, or any personnel using APHIS-owned or funded computer equipment will take all APHIS required security and privacy training. Furthermore, the FS will not disseminate, post, or publish in any capacity official government information or data unless authorized to do so by this Agreement. Current APHIS security and privacy requirements, policies, and guidelines can be obtained through the APHIS Information System Security Program Manager. APHIS follows USDA's processes which are based on the most current National Institute of Standards and Technology (NIST) special publications such as NIST Special Publications (SP) 800-37 and SP 800-53 and -53A.

k. If applicable, work with the appropriate APHIS Program Unit's Information Systems Security Manager and the APHIS Information Systems Security Program Manager to ensure compliance with the FISMA assessment and authorization (A&A) requirements for APHIS information and information systems. The Recipient must follow USDA/APHIS A&A guidelines and standards described in the USDA six step risk management framework process guide located at: Departmental Regulation: Security Assessment and Authorization. The regulation is based on applicable National Institute of Standards and Technology (NIST) publications such as, NIST SP 800 – 37, *Guide for Applying the Risk Management Framework to Federal Information Systems*; and, NIST SP 800 – 53, *Recommended Security Controls for Federal Information Systems*.

ARTICLE 6 - APHIS RESPONSIBILITIES

APHIS agrees to/that:

a. Designate the National Policy Manager for the GH&MC program, 301-851-2229, as its Authorized Departmental Officer's Designated Representative (ADODR) who is responsible for collaboratively administering the activities conducted under this MOU. Should this individual be temporarily detailed to another position or on extended absence, a letter will be issued to the Recipient by the APHIS signatory official to appoint a temporary ADODR.

b. Provide FS Forest Supervisors with maps of potential GH&MC problems affecting respective geographic areas in the region. The maps will be based on annual spring and fall field surveys of GH&MC populations.

c. Prepare and issue to the public environmental documents that comply with the National Environmental Policy Act to suppress economically damaging GH&MC populations. For most situations this will include site-specific Environmental Assessment (EA) and a Finding of NO Significant Impact (FONSI). These documents will be prepared under the APHIS NEPA implementing regulations with cooperation and input from FS.

d. Develop statements of work and identify available commercial sources for full service contracts to provide, store, and serially apply pesticides for the suppression of economically damaging GH&MC populations.

e. When requested by the FS, to provide an estimate of the area (acreage that may require treatment), cost estimates, a recommendation as to whether a suppression program is advisable and APHIS capabilities based on available funding and resources

f. Prepare a work plan for and implement a GH&MC suppression project on FS lands, upon receipt of a written request from the FS for efficacious and cost effective treatments. Such projects will adhere to mitigation measures and operational procedures described by APHIS and FS in the EA and FONSI. Protective measures for Threatened and Endangered Species as required by the U.S. Fish and Wildlife Service and National Marine Fisheries Services, Land and Resource Management Plans, and other relevant decisions will also be implemented.

g. If circumstances warrant, to coordinate GH&MC program activities and meet with stakeholders including representatives of the FS, other agencies, State Departments of Agriculture, and private landowners who have an interest in GH&MC program activities.

h. To prepare a post-treatment report including acres treated, location, pesticide and amount used, treatment effectiveness, and pertinent comments regarding project operations, problems that arose, and the need for follow-up action. All pesticide use activities conducted by APHIS will be coordinated with the respective Forest Supervisor, and pesticide use activity records will be provided to the Forest Supervisor for inclusion in the Forest Activity Tracking System (FACTS) database of record.

ARTICLE 7 - DATA SHARING AND RESPONSIBILITIES

a. Data to be shared: The parties agree to provide plant protection and quarantine data to each other. The data to be provided to each Party by the other Party includes, but is not limited to, plant protection and quarantine surveys, diagnostic information, detection activities, inspection reports, and pest interception data. Each party is responsible for transmitting the provided data to its own authorized employees, cooperators, and contractors as applicable and necessary, in order to carry out responsibilities under their respective plant health authorities. Each party agrees that it will ensure, to the extent provided by applicable laws and regulations, that data provided by the other party is not released to anyone that is not authorized to receive it.

b. Data Utilization: The parties agree that the provided data will only be used in the administration and enforcement of each party's respective plant health laws and regulations. Data provided by the parties under this Agreement may be used to ensure compliance with their respective plant health laws and regulations; to respond to domestic plant pest and disease emergencies, interceptions, and trace backs; to enhance delivery of pest exclusionary programs and activities; to support pest surveying activities; to develop quarantines and other appropriate measures for pest management and mitigation; to implement or improve international pre-clearance and/or pest eradication programs and activities, pest risk assessments, phytosanitary trade support, and the issuance of plant protection and quarantine permits; and to develop, in cooperation with Federal research agencies, new and improved methods, techniques and procedures for use in cooperative plant protection and quarantine programs and activities. Each party agrees that it will ensure that the provided data is used only for purposes specified in this Agreement and only in a manner consistent with the provisions of the Plant Protection Act.

c. Data Restrictions: The Recipient agrees and acknowledges that the data provided by APHIS pursuant to this Agreement is solely APHIS data and as such is or may be subject to the confidentiality provisions of 7 USC §8791 of the Food, Conservation, and Energy Act of 2008, (formerly Section 1619 of the 2008 Farm Bill) and the Privacy Act of 1974 and also agrees to safeguard such confidentiality and prohibit any unauthorized access to the data provided by APHIS as required by 7 USC §8791. The Recipient further agrees and acknowledges that if 7 USC §8791 does apply to some or all of the APHIS provided data, that pursuant to 7 USC §8791, the Recipient is bound to and will comply with 7 USC §8791 (copy attached as Appendix A) and related APHIS guidance. The Recipient understands that it may not release any of the data provided by APHIS since it is Federal Government data and it agrees to refer any and all requests for the data provided by APHIS, not otherwise authorized to be released under this Agreement and applicable Federal laws and regulations, to:

USDA, APHIS
Legislative and Public Affairs
Freedom of Information and Privacy Act Office
4700 River Rd. Unit 50, Riverdale, MD 20737
Telephone: (301) 734-8296.

Additionally, the Recipient agrees that it will, if requested by APHIS, enter into a separate written agreement with APHIS to protect from release or disclosure any data provided by APHIS that is subject to 7 USC §8791.

ARTICLE 8 - STATEMENT OF NO FINANCIAL OBLIGATION

Signature of this MOU does not constitute a financial obligation on the part of APHIS. Each signatory party is to use and manage its own funds in carrying out the purpose of this MOU. Transfers of funds or items of value are not authorized under this MOU.

ARTICLE 9 - LIMITATIONS OF COMMITMENT

This MOU and any continuation thereof shall be contingent upon the availability of funds appropriated by the Congress of the United States. It is understood and agreed that any monies allocated for purposes covered by this MOU shall be expended in accordance with its terms and the manner prescribed by the fiscal regulations and/or administrative policies of the party making the funds available. If fiscal resources are to transfer, a separate agreement must be developed by the parties.

ARTICLE 10 - CONGRESSIONAL RESTRICTION

Under 41 U.S.C. 6306, no member of, or delegate to, Congress shall be admitted to any share or part of this Agreement or to any benefit to arise there from.

ARTICLE 11 – NON-DISCRIMINATION CLAUSE

The United States Department of Agriculture prohibits discrimination in all its programs and activities on the basis of race, color, national origin, age, disability, and where applicable, sex, marital status, familial status, parental status, religion, sexual orientation, genetic information, political beliefs, reprisal, or because all or a part of an individual's income is derived from any public assistance program. Not all prohibited bases apply to all programs.

ARTICLE 12 – LIABILITIES

APHIS assumes no liability for any actions or activities conducted under this agreement except to the extent the recourse or remedies are provided by Congress under the Federal Tort Claims Act (28 U.S.C. 1346(b), 2401(b), 2671-2680).

ARTICLE 13 - AMENDMENTS

This MOU may be amended at any time by mutual agreement of the parties in writing.

ARTICLE 14 - TERMINATION

This MOU may be terminated at any time by mutual agreement of the parties in writing, or by either party with sixty (60) days notice in writing to the other party.

ARTICLE 15 - EFFECTIVE DATE AND DURATION

This MOU will become effective upon date of final signature and will continue in effect for five years.

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

for Christopher B. French, Deputy Chief — 8/27/2019 Date
USDA Forest Service
National Forest System

UNITED STATES DEPARTMENT OF AGRICULTURE
ANIMAL AND PLANT HEALTH INSPECTION SERVICE
PLANT PROTECTION AND QUARANTINE

11/6/19

Osama El-Lissy — Date
Deputy Administrator
USDA, APHIS, PPQ

The authority and format of this agreement have been reviewed and approved for signature

TAWANA RANDOLPH Digitally signed by TAWANA RANDOLPH
Date: 2019.07.23 10:04:24 -04'00'

Tawana Randolph
U.S. Forest Service Grants & Agreements Specialist

EXHIBIT F

Research Article Journal of Orthoptera Research 2018, 27(1): 35-51

The effects of livestock grazing and climate variation on vegetation and grasshopper communities in the northern Chihuahuan Desert

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Abstract

Grasshoppers are important herbivores of North American semi-arid grasslands and shrublands, and vegetation and climate are key factors controlling their species compositions and population dynamics. Domestic livestock grazing is a historic and a current landscape-scale ecological perturbation that has caused reductions of perennial grasses and increases in woody shrubs and weedy annual herbs in desert grassland communities. Climate variation also affects vegetation and grasshopper production, and the combined effects of livestock grazing and climate variation on vegetation and grasshoppers have not been adequately studied in the American Southwest. I measured vegetation and grasshoppers for five years at a series of five semi-arid sites in the northern Chihuahuan Desert to evaluate the interactive effects of short-term livestock grazing and climate variation on plant and grasshopper community structure and species abundances. The study sites ranged from shrub dominated to grass dominated landscapes, with livestock fence lines separating land that was grazed at 30% annual forage utilization, and lands on the other sides of the fences excluded from grazing for at least 20 years. I assigned grasshopper species to life-form guilds based on their ecomorphologies and their microhabitat substrate uses that I observed. A wet spring/dry summer El Niño event occurred at the beginning of the study, and a dry spring/wet summer La Niña event occurred at the end of the study. Livestock grazing changed plant and grasshopper species compositions and abundances significantly during those wet years, further favoring annual forbs, annual grasses and non-graminicole grasshoppers on grazed lands during wet years, while favoring perennial grasses and graminicoles on non-grazed lands also during wet years. The biotic communities at all sites probably supported more perennial grasses and more graminicoles prior to European settlement and livestock grazing that began over a century before this study.

Key words

Acrididae, desertification, ecological disturbance, guilds, life-forms

Introduction

Grasshoppers are important primary consumers in semi-arid regions throughout the world (Uvarov 1977), and grasshopper species compositions are determined largely by geographic proximity to evolutionary source regions (Key 1959, Otte 1976) and by species adaptations to local soils and vegetation composition and structure (e.g. Anderson 1964, Mulkern 1967, 1982, Otte and Joern 1977, Joern 1979, 1982, Kang et al. 1989, Fielding and Brusven 1995a, Torrusio et al. 2002, Cigliano et al. 2010, Savitsky 2010). Population densities of many grasshopper species fluctuate widely over time, apparently largely due to bottom-up changes in food plant availability and quality, caused not only by variation in precipitation, but also by physiological responses to variation in temperature and moisture conditions (Rodell 1977, Capinera 1987, Fielding and Brusven 1990, Joern and Gaines 1990, Belovsky and Joern 1995). Density-dependent effects of other grasshoppers, predators, parasitoids, and disease also interact to affect grasshopper populations (Dempster 1963, Street and McGuire 1990). How grasshopper communities and populations respond to environmental disturbance such as domestic livestock grazing and climate change depends to what extent soil, vegetation and weather conditions change in magnitude, space and time, and to what extent different grasshopper species with variable environmental tolerances are affected by the changes. Some species are likely to respond in certain ways, while other species may show different responses (Fielding and Brusven 1996).

Convergence or divergence in grasshopper species ecologies and specializations are likely driven by the evolution of ecological traits (e.g. Van der Plas et al. 2012). Grasshoppers that occur in particular types of habitats and feed on particular types of plants have morphological, physiological and behavioral adaptations, or ecological traits that maximize evolutionary fitness for those species in their particular environments. Grasshopper species that share similar ecological traits for morphology, diet and behavior are ecological guilds; groups of species that exploit the same class of environmental resources in a similar way (Root 1967, Diamond 1975). How one choses to describe grasshopper community structure, including guilds, depends upon the purpose for such description (Lockwood 2011), and the guild concept is useful for understanding higher level ecological structure that may show patterns beyond taxonomically constrained species, tribes, subfamily and family ranks. The grasshopper community guild concept has been used to describe grasshopper community structure for specific assemblages and locations in North America (e.g. Joern and

Lawlor 1981), China (Hong-Shi 1991, Sun et al. 2013) and Africa (Prendini et al. 1996). Those studies assigned grasshopper species from local assemblages to guilds based on microhabitat and food resource use, which provided good descriptions of the ecological structures of those grasshopper communities.

Uvarov (1977) described grasshopper life-forms that occur globally, and that correspond to ecological/morphological traits of grasshoppers that live in particular types of microhabitats, such as open bare soil, grass, forbs and shrubs and trees. I previously applied Uvarov's life-form concept to describe grasshopper guild structure in North American desert grasshopper communities in the cool-temperate Great Basin Desert and in the warm subtropical Chihuahuan Desert, based on substrate use by individual grasshoppers (Lightfoot 1985). I found that life-forms reflected the ecological traits of grasshopper species: 1) terricoles live on bare soil or rock surfaces and feed on grasses and forbs, 2) herbicoles live and feed on forbs, 3) graminicoles live on and feed on grasses, and 4) arbusticoles live on and feed on woody shrubs (a subset of arboricoles). The life-form guild structure was similar in both deserts, while the species were not. Grasshopper species within life-form guilds should exhibit similar responses to changes in vegetation resources, relative to other responses of species in other guilds. Grasshopper life-form guilds have also proved useful for documenting the effects of burrowing rodents (*Cynomys* spp.) and livestock grazing on plant and grasshopper communities in the northern Chihuahuan Desert (Davidson and Lightfoot 2008, Davidson et al. 2010). Just as grasshopper species with different ecologies can serve as species indicators of environmental change in local geographic regions (Bazelet and Samways 2011), grasshopper life-form guilds transcend regional taxonomic constraints of species (Uvarov 1977), and have the potential to serve globally as grasshopper life-form guild indicators to environmental change.

Desertification is the anthropogenic environmental degradation of semi-arid grasslands from long-term excessive and unsustainable domestic livestock grazing, that has occurred extensively throughout the semi-arid regions of the world, including the semi-arid regions of North America (Nelson 1988). The most intense desertification in North America has taken place in the northern Chihuhuan Desert (Dregne 1986), largely the result of excessive domestic livestock grazing and droughts (York and Dick-Peddie 1969, Dick-Peddie 1993). Unlike more mesic grassland and savanna environments where vegetation and animals are adapted to grazing, domestic livestock are a substantial and unnatural perturbation to semi-arid desert grassland biotic communities that did not evolve with large ungulate grazers (Pieper 1994, Young 1994). Desertification in the Chihuahuan Desert has resulted in a dramatic reduction in the abundance of perennial grasses, and an increase in woody shrubs (Buffington and Herbel 1965, Archer 1994, Pieper 1994). Attempts to better understand and manage natural resources of desertified landscapes are evolving toward better applications of science and ecology to address the problem (Peters et al. 2015). Vegetation changes on North American rangelands associated with domestic livestock grazing and desertification continue to have disruptive impacts on the species composition, diversity, and stability of rangeland grasshopper assemblages and populations (Fleischner 1994, Laycock 1994, Jones 2006). Understanding both the short-term and long-term ecological implications of livestock impacts to grasshoppers (e.g. Fielding and Brusven 1996) will contribute to more sustainable natural resource management.

Livestock grazing typically causes changes to herbaceous vegetation composition and structure that in turn cause shifts in grasshopper species compositions and population densities in savanna, shrub-steppe and desert grassland environments (e.g. Capinera and Sechrist 1982, Jepsen-Innes and Bock 1989, Quinn and Walgenbach 1990, Fielding and Brusven 1993, 1995b, 1996, Prendini et al. 1996, Gebeyehu and Samways 2003, Debano 2006, Kang and Chen 2008, Branson and Sword 2010). Results of studies vary, especially between grasslands/savanna and desert grasslands, but grasshoppers that prefer more open microhabitats with sparser and lower stature vegetation tend to respond more favorably to livestock grazing than those that prefer taller and denser herbaceous vegetation (e.g. Prendini et al. 1996). Livestock grazing also can reduce grasshopper diversity, and favor fewer ecological generalist grasshopper species (e.g. Fielding and Brusven 1993) that can shift the temporal stabilities of such communities, making them more sensitive to changes in climate.

Fielding and Brusven (1996) provided a literature review of livestock grazing effects on semi-arid region grasshoppers of North America. They concluded that there is no one answer to the question of how livestock grazing effects grasshoppers; each situation is different, and each depends upon current and historic grazing regimes, local environments, grasshopper species ecologies, and ecological, temporal, spatial and functional characteristics of the system studied. Of particular importance is the differentiation of short-term (< 10 years) vs. long-term (decades to centuries) effects of grazing on soils, vegetation and grasshoppers. Long-term grazing can permanently change soils, vegetation and grasshoppers, while the impacts of short-term grazing may revert back to original conditions within a few years if grazing ceases (Fielding and Brusven 1996).

Variation in weather or long-term climate is known to be a key factor affecting grasshopper populations (Edwards 1960, Gage and Mukerji 1977, Begon 1983, Capinera and Horton 1989, Fielding and Brusven 1990, Jonas and Joern 2007, Nufio et al. 2010). Therefore, anthropogenic global climate change likely is and will have a significant influence on grasshopper communities, just as it is predicted to have on all biota globally (Parmesan 2006, Rosenzweig et al. 2008). Climate change will not only directly affect grasshopper physiological responses and phenologies (Nufio et al. 2010), but also will interact with other anthropogenic disturbances such as livestock grazing to cumulatively affect grasshoppers (Fielding and Brusven 1995b, 1996, Jonas and Joern 2007, Branson and Sword 2010). As global warming continues to accelerate, the climate of the American Southwest is becoming warmer, drier and the timing and intensity of precipitation more variable (Seager et al. 2008, Gutzler and Robbins 2011, Gutzler 2013), likely intensifying adverse impacts of livestock grazing to vegetation and grasshoppers.

Given that grasshoppers are key primary consumers in semi-arid ecosystems across the Southwest, and given that grasshoppers are known to be affected by variation in vegetation caused by livestock grazing and variation in climate, what effects do domestic livestock and climate have on vegetation and grasshoppers in the Southwest? I conducted this research project to address the following questions: 1) Does short-term livestock grazing alter the species compositions, plant life-form (i.e. grass, forb, shrub, tree) and grasshopper life-form guild structures, and abundances of rangeland plants and grasshoppers? 2) Does annual and seasonal variation in precipitation interact with livestock grazing to affect plant and grasshopper species assemblages and grasshopper guild structure? 3) Which grasshopper species and guilds are most sensitive to the impacts of short-term livestock grazing and climate variation?

This research was conducted as part of the U.S. Department of Interior (USDI), Bureau of Land Management (BLM), Global

Change Research Projects program, 1991–1996, which was intended to support long-term research on the ecological impacts of global climate change to natural resources. However, in 1996, the program was terminated due to politically motivated USDI administrative research program changes. This article presents the findings of the five-year vegetation and grasshopper grazing response research that was conducted from 1992–1996 as part of the Chihuahuan Desert Subproject. This research was intended to be a long-term (decades) study to document biotic community responses to climate change, but the entire Global Change Research Program was terminated, so the long-term goals were not accomplished.

Methods

Study sites and sampling design.—Study sites for this research were subjectively located where BLM lands within the Chihuahuan Desert in southern New Mexico were adjacent to lands under other ownership and/or management that excluded livestock grazing, and shared a common boundary with a standard 5 strand barbed-wire livestock fence. Livestock grazing was present on the BLM side of the fence, but not on the other side. From those potential locations, site selection then depended upon obtaining permission from the other landowner/agency to conduct the study, and then depended upon finding a 1 km long section of the boundary fence that had relatively homogeneous topography, soils, and vegetation, so that the presence of livestock grazing on the BLM side of the fence, but not on the other side, was the only primary factor that differed along the potential fence line. The grazed side of each fence line was BLM public land that was currently grazed by domestic cattle, and had been historically grazed for at least 20 years. The non-grazed side of the fences had been excluded from cattle for at least 20 years. Grazing intensity at all sites was year-round, approximately 30% utilization of available plant foliage by domestic livestock, the standard stocking rate for BLM public rangelands in the region. Each site consisted of semi-arid grassland or shrubland that was grazed by domestic cattle, and adjacent non-grazed land on the other side of the barbed-wire livestock fence line. All sites were further chosen to be situated at the same approximate elevation (~1,500 m above sea level), and all on similar topographic landscapes; lower piedmont slopes with silty to sandy loamy soils. All sites supported Chihuahuan Desert grassland or shrubland vegetation communities. Sites ranged from shrub-dominated to grass-dominated, but all sites had both grass and shrub elements.

The study sites were located in the northern Chihuahuan Desert (Chihuahuan Deserts Level III Ecoregion, Griffith et al. 2006), in south-central New Mexico, USA. The Sevilleta Site was located along the north boundary of the Sevilleta National Wildlife Refuge, Socorro County, and the vegetation was desert grassland dominated by black grama (*Bouteloua eriopoda*) and blue grama (*B. gracilis*); the Bosque Site was located along the east boundary fence of Bosque del Apache National Wildlife Refuge, Socorro County, and the vegetation was mixed desert grassland and shrubland dominated by sacaton grasses (*Sporobolus* spp.) and sand sage (*Artemisia filifolia*); the Jornada Site was located along the southwest boundary fence of the US Department of Agriculture, Jornada Experimental Range, Doña Ana County, and the vegetation was creosote bush (*Larrea tridentata*) shrubland; the Phillips Site was located along the east boundary fence of the US Army, White Sands Missile Range at the Phillips Hills, Lincoln County, and the vegetation was creosote bush shrubland; all four sites above were within the Chihuahuan Basins and Playas Level IV Ecoregion; and the Otero Site was located on the northwestern side of Otero Mesa along the boundary fence of a BLM grazing exclosure, Otero County, and the vegetation was desert grassland dominated by black grama and blue grama, and within the Chihuahuan Desert Grasslands Level IV ecoregion. See Dick-Peddie (1993) for detailed descriptions of the vegetation of those ecoregions in New Mexico. Table 1 provides location information for each site.

Sampling at each site was systematic, not random or subjective. Two 600 m, paired, grazed and non-grazed sampling transects were permanently installed at each of the five study sites. Each of the paired 600 m measurement transects were located parallel to, and each 20 m from the fence line between the two, to avoid roads and/or livestock trails along some of the fence lines. Each 600 m transect was partitioned into thirty, 20 m segments. All transects and segments were permanently marked and labeled with 0.5 m steel rods that were hammered into the soil.

Weather.—Weather data were obtained from the nearest long-term U.S. National Weather Service weather station to each of the five study sites. Monthly precipitation amounts and ambient temperatures were summed and averaged respectively over each year of this study. Table 2 presents the name and location of each of the weather stations.

Vegetation.—Vegetation was measured from a 1 m^2 quadrat located at the start (north or west end) of each of the thirty, 20 m segments per transect. The same permanent quadrats were repeatedly sampled over the five-year study period. A 1 m^2 vegetation measurement frame made of 0.5 inch PVC pipe with an internal string 10 by 10 grid of 100, 1 $decimeter^2$ subunits, was used to measure vegeta-

Table 1. Study site information based on center of each site.

Study site name	Location	Elevation	Level IV Ecoregion*
Bosque del Apache National Wildlife Refuge	N33°24', W106°45'	1,520 m	Chihuahuan Basins and Playas 24a
Jornada Experimental Range	N32°28', W106°	1,340 m	Chihuahuan Basins and Playas 24a
Otero Mesa	N32°29', W105°46'	1,540 m	Chihuahuan Desert Grasslands 24b
Phillips Hills, White Sands Missile Range	N32°27', W106°06'	1,490 m	Chihuahuan Basins and Playas 24a
Sevilleta National Wildlife Refuge	N34°24', W106°36'	1,610 m	Chihuahuan Desert Grasslands 24b

*Griffith et al. 2006

Table 2. U.S. National Weather Service weather stations that provided weather data for this study. Each of the five study sites was represented by one nearest weather station.

Study site name	Weather station name	Location	Elevation
Bosque del Apache National Wildlife Refuge	Bosque del Apache	N33°46', W106°54'	1,445 m
Jornada Experimental Range	Jornada Experimental Range	N32°37', W106°44'	1,440 m
Otero Mesa	Orogrande	N32°23', W106°06'	1,270 m
Phillips Hills, White Sands Missile Range	Carrizozo	N33°39', W105°53'	1,650 m
Sevilleta National Wildlife Refuge	Bernardo	N34°25', W106°50'	1,085 m

tion canopy cover by species. The PVC frame was attached to 1 m tall legs with height adjustments on each corner to keep it elevated immediately above the plant foliage canopies. The total foliage canopy cover of each plant species, and the maximum foliage height of each plant species per quadrat were recorded. Vegetation was sampled twice each year, at the end of the spring growing season in late May (especially for spring annual C3-photosynthetic pathway plants), and at the end of the summer growing season in late September for most other largely C4 plants. Vegetation was measured over a period of five years; 1992, 1993, 1994, 1995, and 1996. Plant species classification, common names and Latin names, life-histories and growth-forms follows USDA PLANTS Database (2017).

Grasshoppers.—Many different field sampling methods have been utilized to count grasshoppers (Onsager 1977). Most physical sampling methods are biased toward grasshopper species that are either less active than others, or more active than others, depending on the method and the environment. Physical sampling methods also capture and remove grasshoppers from study sites. I chose to use visual transect sampling instead, by slowly walking each of the thirty, 20 m by 1 m segments or strips of each transect. All grasshoppers observed in each 20 m strip transect along each segment were recorded. I walked slowly along each 20 m strip transect segment, tapping the ground and vegetation with a 1m long white 13 mm diameter PVC pipe to flush all grasshoppers ahead of me as I slowly walked forward. I recorded species, sex, age class, and substrate (physical surface that the individual flushed from) of each grasshopper observed on a voice-activated micro-audio recorder. I had ten years of prior experience visually identifying the regional grasshopper species in the field, and I was the only observer/recorder for this study. Resulting data were the absolute density of each grasshopper species per each 20 m by 1 m, or 20 m^2 transect segment, per sampling period.

The substrate was the physical surface that each grasshopper was first observed on, including soil surfaces, and different species of plants. I watched grasshoppers as they hopped and/or flew ahead of me and did not recount any individuals that I had already counted. Grasshoppers were sampled twice each year during the five-year study period, at the same time that vegetation was measured. Several species of grasshoppers in the region hatch from eggs in the late summer/fall, over-winter as juveniles and become adults in the late spring (e.g. *Psoloessa* spp., *Cibolacris parviceps, Arphia conspersa, Xanthippus* spp.). Also, one of the most common grasshoppers in the region, *Trimerotropis pallidipennis* has two distinct generations each summer in the region of this study, one early and one late (Richman et al. 1993). Most other grasshopper species hatch from eggs in the mid-summer, and become adults in the late summer/fall. Grasshopper sampling was conducted during the late morning to early afternoon hours when grasshoppers tend to be most active. Grasshopper sampling was conducted only when winds were less than 10 miles per hour, the sun was shining, and the soil surface and vegetation were dry. Grasshopper species classification, common names and scientific names follows Cigliano et al. (2017).

I assigned grasshopper species to ecological life-forms following the morphological descriptions of Uvarov (1977). I used multivariate cluster analysis (see McCune and Grace 2002) to evaluate groupings of grasshopper species in this study based on similarities in observed substrate use (see Results) to provide additional ecological information to evaluate grasshopper assemblage guild structure based on resource use (as indicated by substrate use) and morphology (as described by Uvarov 1977).

Data management and analysis.—Vegetation data were entered on field data forms and then transferred to a Microsoft Excel spreadsheet for management and error checking, then converted to a text file for analysis. Grasshopper data were entered from field audio-recordings to an Excel spreadsheet and converted to a text file for analysis. All data were quality checked and verified. The vegetation, grasshopper, and climate data resulting from this study were summarized and analyzed using SAS analytical software (Version 9.4, SAS Institute, Carey, North Carolina, USA). I used hierarchical group-average cluster analysis (SAS; PROC CLUSTER, PROC TREE) utilizing Euclidean distance for similarity measures of species composition or grasshopper substrate use to evaluate entire assemblages of species from different locations, each year and season. Vegetation data were mean canopy covers and heights of each species/quadrat over all 30 quadrats per site, by control and treatment sides of the fence (control vs. grazed; 30 quadrats each). I used paired t-tests (SAS; PROC TTEST) to test for significant differences in vegetation canopy cover and heights between grazed and non-grazed paired fence side locations within sites. I used Chi-square goodness of fit tests (SAS; PROC FREQ) to test for differences in grasshopper counts, summed by species, and categorized by life-forms, from each paired 600 m transect (non-grazed vs. grazed) at each site and year/season. I used a standard statistical test level of alpha (p) = 0.05. The relationships between grasshopper life-form counts from individual grasshopper species counts, and available plant life-form and bare soil cover values that were measured from the 1 m^2 quadrats, were evaluated with non-parametric Spearman-rank correlation analysis (SAS; PROC CORR).

Results

Weather.—Annual total precipitation summed over 12 months of each year from 1992–1996 across all five sites, ranged from 10 cm/year to 40 cm/year, with an overall decline trend over time, especially in 1995 (Fig. 1). El Niño / Southern Oscillation Events (ENSO) occurred in 1992 and in 1996. A moderate El Niño event occurred in 1991/1992, with above average rainfall during the winter and spring of that period, and weak El Niño events occurred in 1993 and in 1995, followed by a weak La Niña event in 1996, with above average late summer rains (NOAA 2016). The Phillips site had the most precipitation over the 5 year study, except in 1995, followed by the Otero site (both in the Tularosa Basin, adjacent to the Sacramento Mountains), while the Jornada, Bosque, and Sevilleta sites (all in the Rio Grande valley) tended to be drier over the 5 year study period. Annual average ambient temperatures, averaged over 12 months of each year from 1992–1996 across all 5 sites, ranged from 13.0°C to 17.5°C across the sites, with an overall increase of one degree centigrade over all 5 sites over the 5 year period, with particularly warm temperatures in 1994 (Fig. 2).

Vegetation.—A listing of all 151 plant species observed, their life-histories, and life-forms is presented in Suppl. material 2: Table S1. The majority of plant species sampled from all five study sites over the five-year period were herbaceous forbs, followed by grasses, shrubs, and cacti.

Plant species counts or richness ranged from about 15 to 30 species over the study sites and years, with most sites showing declines in 1994 and increases in 1995, and slightly more species were present during late summer/fall sampling than during the early summer/spring (Suppl. material 1: Fig. S1). Some sites like the Bosque and Jornada had slightly greater species richness

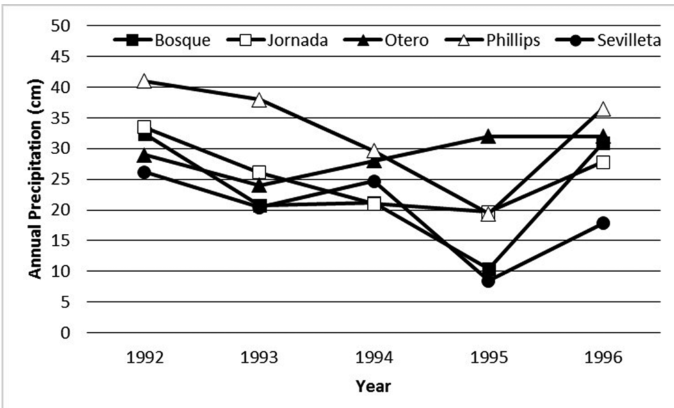

Fig. 1. Total annual precipitation (January-December) at each of the study sites over the five-year study period.

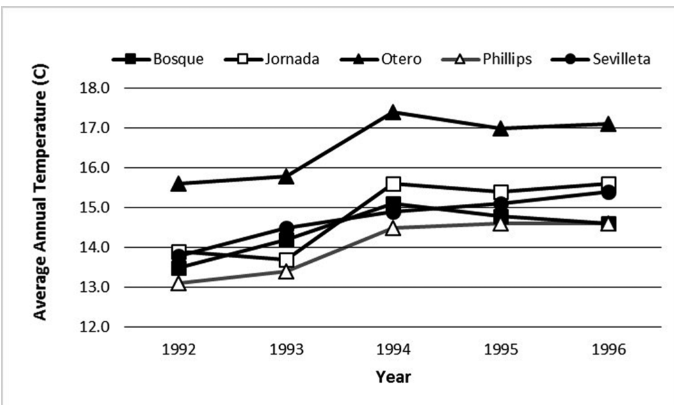

Fig. 2. Annual average (12 months/year) temperatures at each of the study sites over the five-year study period.

on grazed quadrats than on non-grazed quadrats, while the other sites showed greater richness on the non-grazed quadrats.

Cluster analysis of the five study sites and their control vs. grazed sides of the fences, and based on similarities of plant species compositions summed over the five-year period, revealed that each of the sites supported very distinct plant species compositions both in the spring and fall (Fig. 3). The branch or stem lengths of the dendrograms in Fig. 3 demonstrate much more similarity across grazed and non-grazed quadrats within each site, than between sites, and similarities between sites were greater during the spring seasons (Fig. 3A) than in the fall (Fig. 3B) based on cluster branch or stem lengths. Higher level groupings revealed that the Sevilleta, Bosque, and Phillips sites were more similar to each other than the Jornada or Otero sites in the spring, but that the Bosque, Sevilleta and Otero sites were more similar to each other than to the Jornada and Phillips sites in the fall over all five years. The Jornada and Phillips sites were creosote bush dominated shrublands on gravelly alluvial soils, while the Sevilleta, Bosque and Otero sites were black and blue grama grass, and burro (*Scleropogon brevifolius*) and sacaton grass dominated desert grasslands on finer alluvial and aeolian soils. The Sevilleta site was primarily grassland, the Bosque site also had considerable amounts of sand sage (*Artemisia filifolia*), and the Otero site had creosote bush but not as dominant as at the Jornada and Phillips sites.

Analysis of the major plant life-forms forbs, grasses, and shrubs, revealed that livestock grazing primarily affected grasses and forbs, but not shrubs (except for broom snakeweed). Across all five sites, forbs and grasses tended to have significantly more cover on the non-grazed sides of the fences than on the grazed sides, especially in association with the 1991/1992 El Niño event, and the 1996 La Niña event (Suppl. material 1: Fig. S2 and Suppl. material 2: Table S2). Spring and summer annual forbs at the Bosque and Otero sites increased significantly on the non-grazed side of the fences in 1995, only spring annual forbs increased in 1995 and on the non-grazed sides of the fences at the Jornada and Sevilleta sites, while annual forbs increased significantly on the grazed side of the fence at the Otero site in 1996 (Suppl. material 1: Fig. S2, Suppl. material 2: Table S2). Grass cover increased significantly in the fall of 1996 on the grazed areas at the Otero and Sevilleta sites, dominated by the annual grass sixweeks threeawn (*Aristida adscensionis*). Otherwise, grass cover at Otero and Sevilleta sites was dominated by the perennial grama grasses (*Bouteloua* spp.), and at the Jornada site where perennial bush muhly (*Muhlenbergia porteri*) was abundant, grass cover was generally significantly greater on the non-grazed areas over the five-year study (Suppl. material 1: Fig. S2). Plant height measurement data also revealed that perennial grasses were not significantly different, or were significantly taller on non-grazed vs. grazed areas at all sites across all years, except for Bosque and Sevilleta sites in 1996, where again, annual sixweeks threeawn created significantly taller grass on the grazed areas (Suppl. material 2: Table S2). Shrub canopy cover and heights tended to vary little over space and time (Suppl. material 1: Fig. S2, Suppl. material 2: Table S2). The only dynamic shrub species was broom snakeweed (*Gutierrezia sarothrae*) which increased significantly in the spring of 1992 and in the fall of 1996 on grazed areas at the Sevilleta site.

Overall, the canopy cover and abundance of annual forbs and annual grasses varied considerably in response to variation in rainfall over the five sites and five years, especially the late summer of 1996 when annual sixweeks threeawn grass had higher cover and height than perennial grasses at two of the five sites. Perennial grasses tended to be less variable in cover and height over time, but typically with consistently greater cover and height in non-grazed vs. grazed areas over the five years. Forb and grass canopy cover and height either did not significantly differ between grazed and non-grazed areas, or was significantly greater in non-grazed areas than grazed areas. Shrub cover tended to vary little over time, and generally was not significantly different between grazed and non-grazed locations, except for the small, short-lived shrub broom snakeweed that had greater cover in grazed areas following wet periods at the Sevilleta site. The only common exotic weed species, prickly Russian thistle (*Salsola tragus*), was typically more abundant on grazed than non-grazed lands.

Grasshoppers.—A total of 54 grasshopper species were observed across the sites and years; their names, life-form and life-history status are presented in Table 3. The majority of grasshopper species belonged to the family Acrididae (52), along with two species of Romaleidae. The subfamily Gomphocerinae was represented by 21 species, followed by 16 Oedipodinae, 14 Melanoplinae and one Cyrtacanthacridinae. The majority (45) of grasshopper species were late summer season species, 7 species were spring season, and two species had both spring and fall cohorts (Table 3). Summed numbers of individuals of each grasshopper species across all sites, treatments, years and seasons is presented in Suppl. material 3. Observed substrate use by all grasshopper species over all sites, treatments, years and seasons is presented in Suppl. material 4. Those same substrate use values also provide counts of each grasshopper species summed over the five-year study, and were used

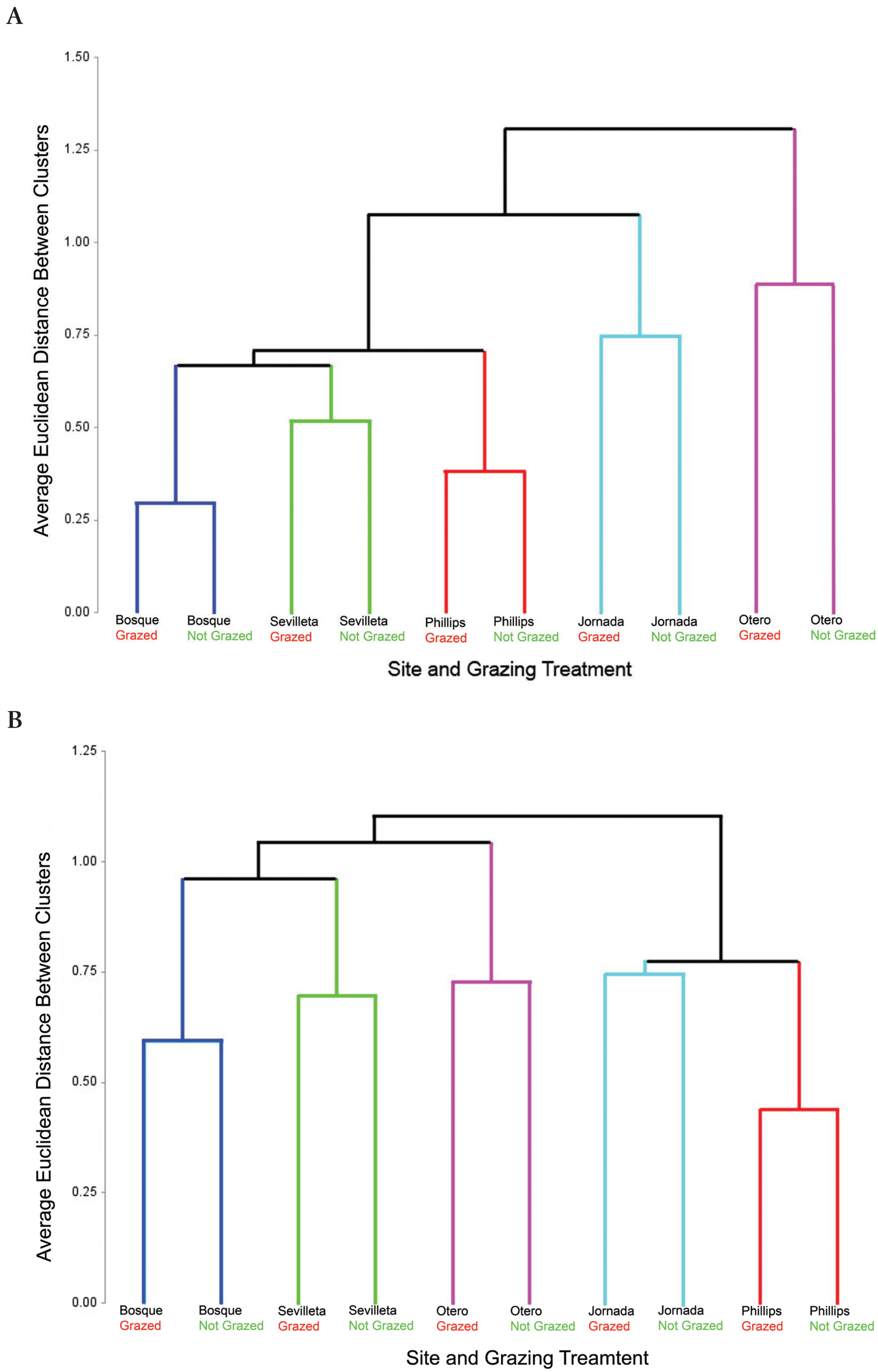

Fig. 3. Cluster analysis dendrogram showing the similarities of plant species compositions at sites and grazed and not grazed transects within sites, from annual canopy cover/m^2 averaged over all years and seasons; **A.** Spring; **B.** Fall.

Table 3. Grasshopper species observed across the 5 study sites. Taxonomic classification and names follow Cigliano et al. (2017). Table is sorted in alphabetical order.

Species	Family	Subfamily	Code	Life-form	Life history
Acantherus piperatus	Acrididae	Gomphocerinae	ACPI	G	SU
Acrolophitus maculipennis	Acrididae	Gomphocerinae	ACHI	T	SU
Ageneotettix deorum	Acrididae	Gomphocerinae	AGDE	TG	SU
Amphitornus coloradus	Acrididae	Gomphocerinae	AMCO	G	SU
Arphia conspersa	Acrididae	Oedipodinae	ARCO	T	SP
Arphia pseudonietana	Acrididae	Oedipodinae	ARPS	T	SU
Aulocara elliotti	Acrididae	Gomphocerinae	AUEL	TG	SU
Aulocara femoratum	Acrididae	Gomphocerinae	AUFE	TG	SU
Bootettix argentatus	Acrididae	Gomphocerinae	BOAR	A	SU
Brachystola magna	Romaleidae	Romaleinae	BRMA	H	SU
Campylacantha olivacea	Acrididae	Melanoplinae	CAOL	A	SU
Cibolacris parviceps	Acrididae	Gomphocerinae	CIPA	T	SP
Conozoa texana	Acrididae	Gomphocerinae	COTE	T	SU
Cordillacris crenulata	Acrididae	Gomphocerinae	COCR	TG	SU
Cordillacris occipitalis	Acrididae	Gomphocerinae	COOC	TG	SU
Dactylotum bicolor	Acrididae	Melanoplinae	DABI	H	SU
Eritettix simplex	Acrididae	Gomphocerinae	ERSI	G	SU
Hadrotettix trifasciatus	Acrididae	Oedipodinae	HATR	T	SU
Heliaula rufa	Acrididae	Gomphocerinae	HERU	T	SU
Hesperotettix viridis	Acrididae	Melanoplinae	HEVI	A	SU
Hippopedon capito	Acrididae	Oedipodinae	HICA	T	SU
Hypochlora alba	Acrididae	Melanoplinae	HYAL	A	SU
Lactista azteca	Acrididae	Oedipodinae	LAAZ	T	SU
Leprus wheelerii	Acrididae	Oedipodinae	LEWH	T	SU
Ligurotettix planum	Acrididae	Gomphocerinae	LIPL	A	SU
Melanoplus regalis	Acrididae	Melanoplinae	MERE	H	SU
Melanoplus aridus	Acrididae	Melanoplinae	MEAR	A	SU
Melanoplus arizonae	Acrididae	Melanoplinae	MEAR2	H	SU
Melanoplus bowditchi	Acrididae	Melanoplinae	MEBO	A	SU
Melanoplus flavidus	Acrididae	Melanoplinae	MEFL	H	SU
Melanoplus gladstoni	Acrididae	Melanoplinae	MEGL	H	SU
Melanoplus lakinus	Acrididae	Melanoplinae	MELA	H	SU
Melanoplus occidentalis	Acrididae	Melanoplinae	MEOC	H	SU
Melanoplus sanguinipes	Acrididae	Melanoplinae	MESA	H	SP, SU
Melanoplus thomasi	Acrididae	Melanoplinae	METH	H	SU
Mermiria texana	Acrididae	Gomphocerinae	METE	G	SU
Mestobregma terricolor	Acrididae	Oedipodinae	METE2	T	SU
Opeia obscura	Acrididae	Gomphocerinae	OPOB	G	SU
Paropomala pallida	Acrididae	Gomphocerinae	PAPA	G	SU
Phlibostroma quadrimaculatum	Acrididae	Gomphocerinae	PHQU	TG	SU
Phrynotettix robustus	Romaleidae	Romaleinae	PHRO	T	SP
Psoloessa delicatula	Acrididae	Gomphocerinae	PSDE	TG	SP
Psoloessa texana	Acrididae	Gomphocerinae	PSTE	TG	SP
Schistocerca nitens	Acrididae	Cyrtacanthacridinae	SCNI	A	SU
Syrbula montezuma	Acrididae	Gomphocerinae	SYMO	G	SU
Trachyrhachys aspera	Acrididae	Oedipodinae	TRAS	T	SU
Trachyrhachys kiowa	Acrididae	Oedipodinae	TRKI	T	SU
Trimerotropis californica	Acrididae	Oedipodinae	TRCA	T	SU
Trimerotropis pallidipennis	Acrididae	Oedipodinae	TRPA	T	SP, SU
Trimerotropis pistrinaria	Acrididae	Oedipodinae	TRPI	T	SU
Trimerotropis latifasciata	Acrididae	Oedipodinae	TRLA	T	SU
Tropidolophus formosus	Acrididae	Oedipodinae	TRFO	H	SU
Xanthippus corallipes	Acrididae	Oedipodinae	XACO	T	SP
Xanthippus montanus	Acrididae	Oedipodinae	XAMO	T	SP

*Life-form codes: A=arbusticole, G=graminicole, TG=terri-graminicole, H=herbicole, T=terricole.

**Life history codes: SP=spring/early summer, SU=late summer/fall.

Fig. 4. Examples of each grasshopper life-form type; **A.** Arbusticole; *Bootettix argentatus* on *Larrea tridentata*; **B.** Graminicole; *Paropomala pallida* on *Bouteloua eriopoda*; **C.** Terri-graminicole; *Phlibostroma quadrimaculatum*; **D.** Herbicole; *Tropidolophus formosus* on *Spharalcea hastulata*; **E.** Terricole; *Trimerotropis pallidipennis*.

for cluster analysis to evaluate similarities of substrate use across all grasshopper species. Based on morphology and substrate use, the resulting life-form guild terricoles, were the largest life-form group with 20 species, followed by 11 herbicoles, 8 arbusticoles, and 7 graminicoles (Table 3). Additionally, a group of species (*Ageneotettix deorum*, *Aulocara* spp., *Cordillacris* spp., *Phlibostroma quadrimaculatum*, *Psoloessa* spp.) used bare soil and low-growing grasses as their substrates, and had morphologies intermediate between graminicoles and terricoles. Uvarov (1977) called such intermediate life-forms terri-graminicoles, and I categorized those 8 species as terri-graminicoles: species that use both bare soil and low stature grasses as microhabitat substrates, and are known to feed largely on grasses. Examples of grasshopper life-forms represented by species observed in this study are presented in Fig. 4. Note that the determination of a species' substrate use in this study is relative to the number of observations made for each species; determinations for species with many observations are more likely to reflect the species actual substrate uses more accurately than for species with few observations (see Suppl. material 3 and Suppl. material 4).

Examination of the morphology of each species relative to Uvarov's (1977) life-form descriptions revealed high correspondence between substrate use groupings and life-form morphologies, except for some grasshopper species in the subfamily Melanopli-

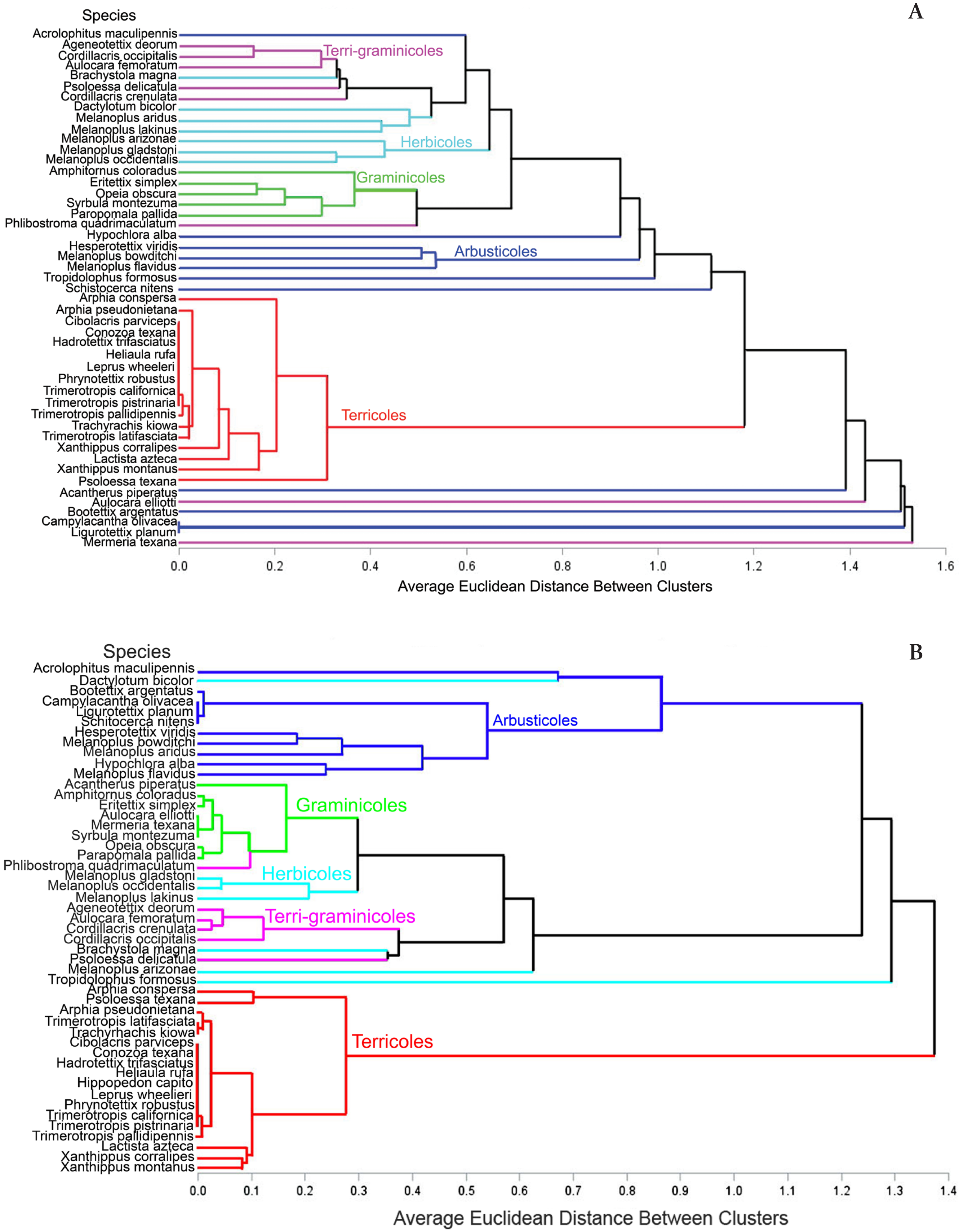

Fig. 5. Cluster analysis dendrograms of grasshopper species similarities based on substrate use among all grasshopper species over all sites, years and seasons; **A.** Based on specific substrate use to the plant species level and bare soil; **B.** Based on substrates categorized to forbs, grasses, shrubs and bare soil.

nae, which separated into both herbicoles and arbusticoles based on substrate use, while sharing similar ecomorphologies (Suppl. material 4). Some species that had herbicole life-form morphologies used shrubs (e.g. *Campylacantha olivacea, Hypochlora alba, Melanoplus aridus, M. bowditchi, and M. flavidus*), while others such as *Brachystola magna* and *M. arizonae* used forb, grass, and soil substrates. *Tropidolophus formosus* had the morphology of a herbicole but was distinct from other herbicoles based on primary substrate use of *Spharalcea* species forbs. *Acantherus piperatus* had the morphology of a graminicole, and occurred primarily on bush muhly grass, which grew inside of shrub canopies, and individuals often rested on shrub branches mixed with bush muhly. *Acrolophitus maculipennis* (Gomphocerinae) was associated primarily with the small shrub, hairy crinkle mat (*Tiquilia hispidissima*), and individuals were usually on their host plants, but also often on bare rocky gypsum soil in association with hairy crinkle mat plants. Overall substrate use did correspond well with grasshopper species life-form guild morphologies for most grasshopper species.

Cluster analysis of each grasshopper species based on observed specific substrate use by all individuals of each grasshopper species, over all five sites and all five years, revealed distinct groupings of species based on specific observed substrate use (Fig. 5A). Arbusticoles that were host plant specific, such as *Bootettix argentatus*, *Campylacantha olivacea*, *Ligurotettix planum*, *Hypochlora alba*, *Melanoplus bowditchi*, *Melanoplus flavidus*, *Schistocerca nitens* and *Hesperotettix viridis* were distinct from all other species. Terricoles such as *Arphia* spp., *Cibolacris parviceps*, *Conozoa texana*, *Hadrotettix trifasciatus*, *Heliaula rufa*, *Hippopedon capito*, *Leprus wheelerii*, *Phrynotettix robustus*, *Lactista azteca*, *Psoloessa texana*, *Trimerotropis* spp. *Trachyrhachys kiowa*, and *Xanthippus* spp., formed a large distinct group. Graminicoles such as *Amphitornus coloradus*, *Eritettix simplex*, *Syrbula montezuma*, *Opeia obscura* and *Paropomala pallida* grouped together. Terri-graminicoles such as *Ageneotettix deorum*, *Cordillacris* spp., *Aulocara femoratum*, and *Psoloessa delicatula*, grouped together, and all had mandible morphologies of grass-feeders. Herbicoles such as *Dactylotum bicolor* and all *Melanoplus* spp., except *M. bowditchi* and *M. flavidus*, grouped together.

I further examined the relationships between grasshopper life-forms, plant-life forms, and bare soil, by performing a second cluster analysis of observed grasshopper species substrate use, with plant species specific substrates pooled into the plant life-form categories instead of plant species; forbs, grasses or shrubs, along with bare soil. The resulting dendrogram (Fig. 5B) revealed similar but more pronounced substrate category use groupings to Fig. 5A. Arbusticole and herbicole grasshoppers formed more pronounced groups rather than separating as disparate species in Fig. 5A. All arbusticoles grouped together with the herbicole *Dactylotum bicolor*, which was observed on forbs, soil and shrubs. All graminicoles grouped together along with the terri-gramincole *Phlibostroma quadrimaculatum* and the herbicoles *Melanoplus gladstoni*, *M. occidentalis*, and *M. lakinus*, all of which were usually on forbs but also on grasses. The terri-graminicoles grouped together with the herbicole *Brachystola magna* which occurred on forbs, grasses and bare soil. Terricoles grouped together in a distinct cluster from all other clusters. One herbicole species, *Tropidolophus formosus*, did not group with any other herbicoles due to its primary association with forbs in the genus *Spharalcea*.

Spearman rank correlation analysis compared the total numbers of individual grasshoppers observed across all species, and assigned to grasshopper life-forms, with available plant life-form and bare soil cover measured from 1 m^2 quadrats and averaged over all sites, transects, years and seasons. Correlation analysis revealed significant relationships between grasshopper life-forms and substrate availability (Table 4). Arbusticoles were positively correlated with shrub canopy cover, while they were negatively correlated with bare soil and grass cover. Graminicoles were positively correlated with grass cover, and negatively correlated with bare soil and shrub cover. Terri-graminicoles were positively correlated with grass cover, and negatively correlated with shrub cover. Herbicoles were positively correlated with both forb and grass cover, and negatively correlated with shrub cover. However, terricoles were positively correlated with available grass cover, and negatively correlated with available bare soil.

Table 4. Spearman-rank correlation coefficients (r_S) and significance values (P) from testing relationships between grasshopper life-forms and the available cover of substrate categories measured on the grasshopper and vegetation transects at each study site, over all years and seasons. Correlation coefficients are listed first, above significance values within each life-form by substrate set of cells. Significant (P<0.05) correlations are in bold text, positive correlations are in regular font and negative correlations are in italic font. Sample size for all tests was 96.

	Substrate Categories			
Grasshopper life-forms	**Bare Soil**	**Grasses**	**Forbs**	**Shrubs**
Arbusticoles	***-0.24058***	***-0.24703***	0.14819	**0.61254**
	0.0182	***0.0153***	0.1496	**<.0001**
Graminicoles	***-0.31407***	**0.57682**	0.12125	***-0.26054***
	0.0018	**<.0001**	0.2393	***0.0104***
Terri-graminicoles	0.13191	**0.47328**	*-0.1248*	***-0.57136***
	0.2002	**<.0001**	*0.2257*	***<.0001***
Herbicoles	*-0.13658*	**0.23129**	**0.38279**	***-0.26019***
	0.1845	**0.0234**	**0.0001**	***0.0105***
Terricoles	***-0.28696***	**0.44601**	0.17449	*-0.18596*
	0.0046	**<.0001**	0.0891	*0.0697*

Cluster analysis of grazed vs. non-grazed sites in the spring and in the fall over all years revealed that, like vegetation, grasshopper species assemblages were unique to each site. Branch lengths in the dendrograms were not as long as for plant assemblages, demonstrating the site to site variation and differences in grazed vs. non-grazed in grasshopper assemblages was less than it was for plant assemblages (Fig. 3 vs. Fig. 6). Grasshopper species assemblages at the Bosque, Jornada and Phillips sites were more similar to each other than species assemblages at the Otero and Sevilleta sites (Fig. 6). The Otero site grazed area was unique from all other sites/treatments, in both spring and fall seasons. Grasshopper species richness ranged from about five species to about 20 species across the study sites, years and seasons. Overall grasshopper species richness generally ranged from five to 15 species at each site over the five-year period, averaging around 10 species at any given time, and more grasshopper species were typically present in the fall than in the spring of each year (Suppl. material 1: Fig. S3). The Jornada and Otero sites generally had the most grasshopper species, followed by the Bosque and Phillips sites. The grazed areas tended to support less grasshopper species than the non-grazed areas at all five sites over the five-year period, but that pattern was inconsistent (Suppl. material 1: Fig. S3). Overall, the non-grazed sides of the fences across all sites, years and seasons tended to support the highest grasshopper species richness.

Analysis of the grasshopper life-form guilds revealed that livestock grazing primarily affected graminicoles and terri-gramini-

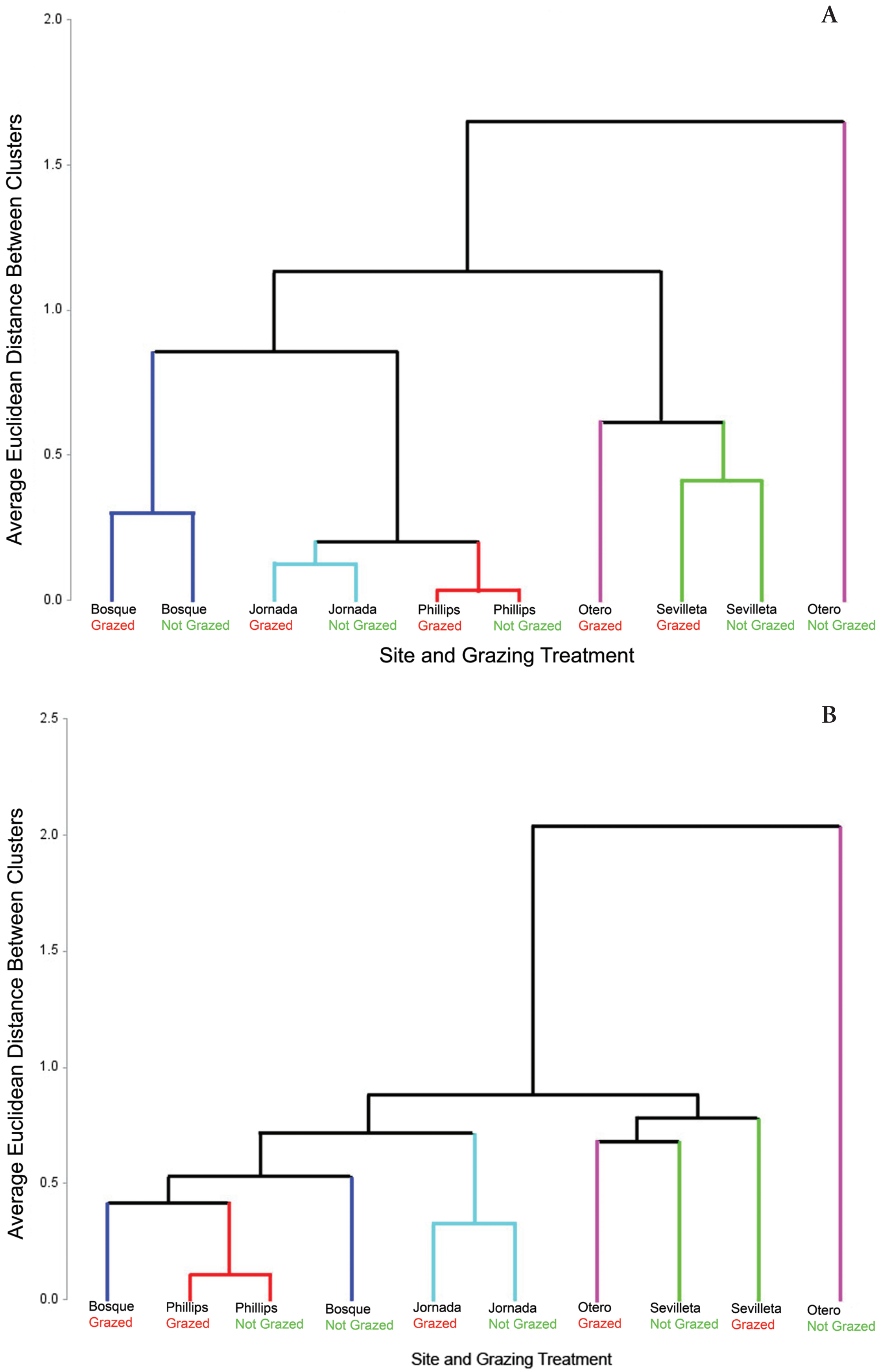

Fig. 6. Cluster analysis dendrograms showing site and grazing treatment similarities of grasshopper species compositions; **A.** Spring; **B.** Fall.

coles, which tended to be significantly more abundant on non-grazed than grazed areas, and especially at the Bosque, Otero, and Sevilleta sites, both in the spring and in the fall seasons (Suppl. material 1: Fig. S4, Suppl. material 2: Table S5). That pattern was especially pronounced in high precipitation years with high grasshopper abundance. Herbicoles followed a similar but less pronounced pattern of greater abundance on non-grazed sides of the fences across the same sites, especially in wet years. In contrast, terricoles tended to be significantly more abundant on grazed areas than non-grazed areas at the same sites and years as graminicoles and terri-graminicoles were more abundant on the non-grazed sides of the fences (Suppl. material 1: Fig. S4, Suppl. material 2: Table S5). Arbusticoles were generally less abundant than other grasshopper guilds, and were significantly more abundant on the non-grazed area at the Bosque site in fall 1993, but significantly more abundant on the grazed area at the Jornada site in fall of 1992 and 1993 (Suppl. material 2: Table S5, Suppl. material 1: Fig. S4).

Arbusticoles were mostly associated with one or a few species of perennial woody shrubs. *Bootettix argentatus* (Gomphocerinae) was associated only with creosote bush at the Jornada, Otero, and rarely at the Phillips sites. *Campylacantha olivacea* (Melanoplinae) and *Ligurotettix planum* (Gomphocerinae) were found only on tarbush (*Flourensia cernua*) at the Jornada and the Phillips sites, and *Hesperotettix viridis* (Melanoplinae) was only associated with broom snakeweed across the sites. *Hypochlora alba* (Melanoplinae) was associated primarily with sand sage (*Artemisia filifolia*), but also some forbs at the Bosque site (Suppl. material 3, Suppl. material 4). *Melanoplus aridus* and *M. bowditchi* (Melanoplinae) were associated primarily with shrubs in the family Asteraceae at the Jornada and Phillips sites, and *Schistocerca nitens* (Cyrtacanthacridinae) was associated with honey mesquite and tarbush shrubs at the Jornada site. Arbusticoles were consistently associated with woody shrubs, usually one or a few species of shrubs, but the grasshopper species belonged to different subfamilies.

The most abundant graminicoles were species in the subfamily Gomphocerinae; *Paropomala pallida* which was highly associated with black grama grass on the non-grazed side of the fences at the Bosque, Otero and Sevilleta sites, and less associated with bush muhly grass along with *Acantherus piperatus*, at the Jornada and Phillips sites, and *Eritettix simplex* and *Opeia obscura* that tended to be associated with galleta and tabosa grasses (*Pleuraphis* spp.) and burro grass (*Sceropogon brevifolius*) across all of the sites (Suppl. material 3, Suppl. material 4). Graminicoles all belonged to the same subfamily, and all were associated with grasses, but different species were associated with different grass species, and most species were most abundant on the non-grazed areas at the Bosque, Otero, and Sevilleta sites.

Abundant terri-graminicoles also were mostly in the subfamily Gomphocerinae; including *Aulocara femoratum*, *Cordillacris occipitalis*, *Ageneotettix deorum*, and *Phlibostroma quadrimaculatum* that were associated with blue grama and burrow grasses at the Otero and Sevilleta sites in the fall. *Psoloessa delicatula* was a terri-graminicole associated with fine soils and grasses at the Sevilleta, Bosque and Otero sites, while *P. texana* was a terricole associated with coarse gravelly soils at the Jornada and Phillips sites (Suppl. material 3, Suppl. material 4). Like graminicoles, terri-graminicoles were associated with grasses, but all were most associated with low-profile perennial grasses such as blue grama and burro grass.

The most abundant herbicoles were species in the family Melanoplinae; the fall species *Melanoplus arizonae*, *M. lakinus*, and *M. gladstoni* at the Otero and Sevilleta sites, *M. flavidus* at the Bosque site, and *M. aridus* at the Jornada and Phillips sites (Table S3, Table S4). Most herbicoles were melanoplines associated with a variety of plant species, but included *Brachystola magna* (Romaleidae) a generalist, and *Tropidolophus formosus* (Oedipodinae) a plant specialist which was associated with mallows (*Spharalcea* spp.: Malvaceae). As stated above, Melanoplinae had the ecomorphologies of herbicoles, but also were common on grasses, bare soils, and some on shrubs.

Terricoles were mostly in the subfamily Oedipodinae; the most abundant terricole was *Trimerotropis pallidipennis* across all sites and years, especially in the fall of 1995 and 1996 at the Sevilleta site, and *T. pallidipennis* was represented by two cohorts each year, one in the spring, and another in the fall; the spring cohort was affected positively by the El Niño event in 1992 and the fall cohort by the La Niña event in 1996 (Table S3). Other abundant terricoles included *Trachyrhachys kiowa*, *Trimerotropis californica*, and *Arphia pseudonietana* in the fall, and *Psoloessa texana*, *Xanthippus corallipes* and *Arphia conspersa* in the spring. The common terricole *Cibolacris parviceps* belonged to the subfamily Gomphocerinae, and the rare terricole *Phrynotettix robustus* to the family Romaleidae: Romaleinae. Most terricole species appeared to be more closely associated with specific soil surface types – clay, silt, sand, gravel – than to any particular plant species.

Discussion

The findings from this study demonstrate that short-term domestic cattle grazing and short-term climate variation did affect the species and life-form compositions and foliage canopy cover and height of vegetation, and the species and life-form guild compositions and abundances of grasshopper communities across a series of five study sites over five years. Grazing effects on vegetation and grasshoppers were significant during years with high rainfall, plant production and grasshopper abundance, but not years when rainfall, plant production and grasshopper abundance were all low. These results were similar to the findings of other research in North America (Jepsen-Innes and Bock 1989, Quinn and Walgenbach 1990, Fielding and Brusven 1993, 1995, Jones 2006), in Africa (Prendini et al. 1996, Gebeyehu and Samways 2003) and in China (Kang and Chen 2008). Grasshoppers in this study responded to grazing much as Fielding and Brusven (1996) reported for grasshopper communities from similar semi-arid desert grasslands and shrublands elsewhere in North America. Short-term livestock grazing reduced perennial grass cover and heights, increased annual grasses following periods of increased rainfall, and enhanced populations of terricole grasshopper species (reported as Oedipodinae by Fielding and Brusven 1996). This study demonstrates that short-term livestock grazing did alter the vegetation and grasshopper species and life-form compositions, annual variation in precipitation did interact with grazing to affect both plant and grasshopper species assemblages and grasshopper guild structure, and terricole, terri-graminicole, graminicole and herbicole grasshopper life-form guilds and their most abundant component species were most sensitive to livestock grazing and climate variation, while arbusticoles were not. The effects of livestock grazing on vegetation and grasshoppers were significant during an El Niño event in 1992 that produced high winter and spring rainfall, and during a La Niña event in 1996 that produced high summer rainfall, each affecting vegetation and grasshoppers differently during those different seasons.

The effects of livestock grazing on grasshoppers in this study were more pronounced in desert grassland environments than in desert shrubland environments. The Bosque, Otero and Sevilleta sites were desert grassland or shrub steppe and supported relatively high perennial grass cover on the non-grazed sides of the fences. The Jornada and Phillips sites were creosote bush shrublands, and most of the perennial grass at those sites was bush muhly which grew within the shrub canopies, while the soil surfaces between shrubs were primarily bare and gravelly. Livestock grazing at the desert grassland sites reduced the canopy cover and heights of perennial grasses on the grazed sides of the fences, while relatively higher perennial grass cover and canopy heights were present on the non-grazed sides of the fences. In spring 1992 and in fall 1996 grasshopper densities were high, and terricoles and terri-graminicoles were abundant along with annual grasses and forbs on the more open bare grazed fence sides, while graminicoles were more abundant on the denser perennial grasses on the non-grazed sides of the fences. Arbusticoles showed relatively little response to livestock grazing, because the perennial shrubs that they lived and fed on also did not change much over the five-year period.

Climate variation resulting primarily from opposing ENSO events over a five-year period further interacted with livestock grazing to amplify or reduce the effects of livestock grazing on vegetation and grasshoppers. Increased winter and spring precipitation from an El Niño event in 1992 positively affected both annual herbaceous vegetation and grasshoppers in the spring of 1992 and 1993, more so on grazed areas than non-grazed areas. The La Niña event of 1996 positively affected annual herbaceous vegetation and grasshoppers in the late summer of 1996, but not in the spring of that year, and that effect was more pronounced on grazed lands than non-grazed lands. Grasshopper responses to annual and season variation in precipitation were similar to the findings of Edwards (1960), Gage and Mukerji (1977), Begon (1983), Capinera and Horton (1989) and Fielding and Brusven (1990). While Jonas and Joern (2007) emphasized the importance of both the previous year's grasshopper population densities and winter precipitation on subsequent populations, the five-year temporal data from this study were not extensive enough nor partitioned into small enough periods to determine if time-lag effects were present, or how such lag effects may have resulted from previous grasshopper density and environmental conditions. Fielding and Brusven (1996) found that over a 27 year period, the previous November precipitation and mean April temperatures were the best predictors of variation in annual grasshopper densities, while cold winter temperatures reduced grasshopper densities. These findings all indicate that ongoing climate change will likely influence the interactive dynamics of grasshoppers, vegetation, livestock grazing and weather.

Grasshopper species and life-form guilds that were affected positively by livestock grazing and climate variation were those that preferred bare soil microhabitats, and also responded to increases in rainfall and annual forb and grass production on bare soils disturbed by livestock. Oedipodinae and Gomphocerinae species that tend to be terricole or terri-graminicole species also tend to be mixed grass and forb feeders with relatively broad diets (Mulkern 1967, Uvarov 1977, Joern 1985, Chapman 1990). Fielding and Brusven (1996) discussed how substrate matching camouflage is important for many grasshopper species, especially Oedipodinae that live on bare soils (i.e. terricoles), and that reduced vegetation cover from grazing favors such ground-dwelling terricole grasshopper species. Capinera and Sechrist (1982) also found that Oedipodinae (i.e. terricoles), were most abundant in heavily grazed areas compared to lightly grazed areas in short-grass prairie.

In this study, terricoles that preferred bare soil tended to show the greatest responses to increased production of annual herbaceous vegetation in disturbed grazed areas that also had bare soil substrates, especially *Trimerotropis pallidipennis*, *Trimerotropis californica*, and *Trachyrachis kiowa*. Although terricoles used bare soil surfaces almost exclusively as substrates, and are known to utilize bare ground as a microhabitat, correlation analysis revealed that they were negatively associated with available bare ground across locations, years and seasons, but were positively correlated with spatially and temporally variable annual grass cover. These results indicate that while terricoles require long-term availability of bare soil for a microhabitat substrate, over time and space, their densities vary positively over the short-term with the availability of annual grass and forb canopy cover as a food resource.

Terri-graminicoles also preferred microhabitats with sparse, low-growing grasses such as blue grama and burro grass, and spent much of their time on bare ground substrates (bare soil), and responded to increases in grasses as correlation analysis revealed. Those terri-graminicoles included the Gomphocerinae species *Aulocara femoratum*, *Ageneotettix deorum*, *Psoloessa delicatula*, *Psoloessa texana*, *Cordillacris occipitalis* and *Phlibostroma quadrimaculatum*, most of which were more abundant on the grazed sides of fencelines, but primarily at the Otero and Sevilleta sites that had short and patchy perennial grasses like blue grama and burrow grass. Quinn and Walgenbach (1990) also found that some of the same Gomphocerinae grasshopper species were more abundant in grazed areas with more bare soil and short sparse grasses, where those species were better camouflaged from predators. Also similar to these findings, Prendini et al. (1996) found grasshopper species in savanna environments that preferred sparse and low-profile vegetation were more abundant in heavily grazed areas, while those species that preferred tall and dense grass more abundant in non-grazed and lightly grazed areas.

Graminicoles were affected negatively by livestock grazing, apparently due to the reduced cover and heights of the perennial grasses that they lived and fed on, which were often significantly taller and had greater canopy cover on the non-grazed sides of fencelines at the grasslands Sevilleta and Otero sites. Graminicoles increased with increased rainfall and perennial grass production which occurred mostly in non-grazed areas where perennial grass cover was higher and not affected by current livestock grazing. Graminicoles primarily used grass plants as substrates, and were positively correlated only to available grass canopy cover over space and time. Common graminicoles such as *Paropomala pallida* and *Acantherus piperatus* were highly associated with black grama and bush muhly grasses respectively, which experienced reduced canopy cover when grazed, and increased canopy cover and height under high precipitation conditions. Other graminicoles appeared to be less associated with particular grass species, but *Eritettix simplex*, *Amphitornus coloradus, Syrbula montezuma* and *Opeia obscura* were associated with dense, tall perennial grasses that provided adequate structural microhabitats in ungrazed areas, compared to structurally less robust annual grasses (e.g. sixweeks threeawn) that dominated grazed areas. Unlike terri-graminicoles that also feed on and are associated with grasses, but are adapted to live on bare soil, graminicoles have morphological adaptations (elongate bodies and antennae and short legs with grasping tarsi and arolia and camouflage patterns and colors) for living on the stems and leaves of tall dense grasses as resting and feeding substrates (Uvarov 1977, Lightfoot 1985).

Herbicoles were composed largely of Melanoplinae, including several species of *Melanoplus*, and most appeared to be host-plant generalists except for the oedipodine *Tropidolophus formosus* that specialized on *Spharalcea* plants. Many of the common *Melanoplus* such as *M. arizonae*, *M. lakinus* and *M. sanguinipes* are known to have broad diets and have not evolved to specialize on any particular plants. Such generalization on leafy forbs may be attributed to low plant apparency in space and time, and the diversity of acutely toxic plant secondary chemical defenses such as flavonoids and glycosides that limit herbivores from specializing on those plants as food resources (Otte 1976, Otte and Joern 1977, Chapman 1990). Other research also has shown that melanoplines tend to have broad diets and are ecological generalists, especially agricultural pest species such as *M. sanguinipes*. Such generalist species also tend to have dynamic populations that vary considerably with weather and plant production (Fielding and Brusven 1990, Jonas and Joern 2007). In this study herbicoles did increase with increased rainfall and plant production, however the increases occurred both under grazed and non-grazed areas, apparently overriding grazing effects alone.

The arbusticoles also were strongly associated with plants, not soil; all were host-shrub specific species except for the shrub generalist *Schistocerca nitens.* Each arbusticole species was strictly associated with its host shrub species, and unlike the other grasshopper guilds that shared grasshopper species across sites, arbusticoles tended to be site-specific based on shrub species distributions. *Bootettix argentatus* only occurred at the Jornada, Otero and Phillips sites where creosote bush was present, and was not affected by grazing. *Campylacantha olivacea* and *Ligurotettix planum* were restricted to tarbush, which only occurred at those same three sites, while *Hypochlora alba* was restricted to sand sage at the Bosque site, the only site where sand sage occurred, along with the more generalist *Melanoplus flavidus*. Broom snakeweed occurred at all sites, and supported not only *Hesperotettix viridis* which is monophagous on broom snakeweed, but also *Melanoplus bowditchi* and *M. aridus* which occurred on a variety of shrubs in the plant family Asteraceae. While terricoles, terri-graminicoles and graminicoles were more closely associated with the microhabitat structure than particular plant species, arbusticoles also were associated with particular plant microhabitats, but those present on particular shrub species with particular morphologies and chemistries. For example *Bootettix argentatus* is a leaf and small stem mimic of cresosote bush foliage, and *Ligurotettix planum* is a stem mimic on tarbush. Each shrub species also has unique foliage chemistry, apparently driving the evolution of monophagy in arbusticoles as the result of plant apparency and the evolution of specialization on highly apparent host plants with different secondary plant chemistries and different substrates for camouflage from predators (Otte 1976, Otte and Joern 1977, Chapman 1990).

The application of life-form guilds as grasshopper indicators to environmental change has world-wide utility and allows for global comparisons of grasshopper life-form guild structure across continents in relation to landscape features and ecological patterns and processes. As with any attempt by humans to classify species into ecological categories, not all species fit well into grasshopper life-form guilds such as some mentioned above. However, most grasshopper species addressed in this study did correspond to particular life-form guilds, or some combination of more than one guild (e.g. terri-graminicoles). Based on these findings, the grasshopper life-form guild concept does have merit for understanding resource use and structure of semi-arid and arid environment grasshopper communities.

Livestock grazing is prevalent and often ecologically unsustainable across semi-arid regions around the world, as is desertification, the long-term result of unsustainable livestock grazing (Dregne 1986, Nelson 1988). Based on the findings of this study, one may assume that the desertified semi-arid landscapes of the world, and those studied here, now have different grasshopper community compositions than they did prior to desertification. Desertified landscapes that were formerly dominated by relatively stable desert grasslands, and likely corresponding graminicoles and terri-graminicoles, are likely now dominated by shrublands, and/or bare soil, and annual grasses and forbs that fluctuate with rainfall. Such desertified landscapes also are likely now dominated by terricoles, arbusticoles and herbicoles as in this study. As landscape vegetation changes, so too should the grasshopper species and life-form guild compositions and associated diets and resource uses. Shifts in grasshopper community life-form guild compositions also should have cascading effects on ecosystem processes such as energy flow and nutrient cycling. If desert grasslands shift from a dominance of perennial grass and grass-feeding graminicoles, to a dominance of annual grasses and forbs, woody shrubs, and mixed-diet terricoles, herbicoles and plant specific arbusticoles, the consumer roles of grasshoppers feeding on those different types of plants should also shift. Additionally, a number of independent research studies have demonstrated that soil and vegetation disturbance caused by heavy livestock grazing in semi-arid regions of North America leads to ecological instability and outbreaks of ecological generalist agricultural pest grasshopper species such as *Melanoplus sanguinipes* (Padft 1982, Quinn and Walgenbach 1990, Fielding and Brusven 1995b, 1996, Rambo and Faeth 1999, and Debano 2006). This same pattern may occur globally in other systems with other grasshopper pest species.

Given the global extent of semi-arid landscapes that have been and continue to be negatively impacted by livestock grazing (see Introduction), understanding the effects of grazing on vegetation and grasshoppers is key to understanding how to manage natural resources of such lands (Laycock 1994). Such knowledge of changes to grasshopper community composition and structure will contribute to guiding better management of the natural resources on desertified landscapes (e.g. Peters et al. 2015). Anthropogenic climate change is a serious environmental issue globally, and increasing global temperatures and increasing variation and reductions in precipitation across semi-arid regions is intensifying the negative effects of livestock grazing on soils, native plants and native animals. More research like this study is needed on a global-scale to better understand how livestock grazing and climate change are interacting in different world regions with different environments, plant and grasshopper species, human cultures and associated natural resource uses.

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