Ruyle adds that the data Halstead is collecting will be important not just for elk management but also for the whole multi-resource scheme. Besides elk, other ungulates that graze in the area include pronghorn, mule deer, and white-tailed deer.

Preliminary results, from data Halstead gathered during the spring and fall of 1997, indicate that the grazing system may be working differently than it was originally intended.

"We're finding that the elk are grazing where the cattle are not," Halstead notes. She thinks timing may make a difference. "This grazing system is designed to attract elk to the pasture after the cattle are there. In the winter, it does that. But in the spring they're on the opposite side of where the cattle are. They're where the cattle were last year. There are reasons for that--topography is one, the amount of tree cover is another. We have more tree cover, which the elk prefer, on the pastures not grazed this year by cattle."

The researchers found that levels of utilization in the pastures were light, Ruyle says. The study has another year to go, and it may help the USFS with its original goal of designing a grazing system where the cattle and elk both benefit.

"Hopefully the agencies will be able to use this data to adjust grazing management in the future," Halstead says. "You can't really herd elk around but you might be able to manage elk grazing by managing cattle, and that's a really important thing to know."

— Susan McGinley

The Study Area

The V Bar V Ranch and its associated Walker Basin allotment are located in the Beaver Creek and Long Valley Ranger Districts of the Coconino National Forest. The grazing allotment is divided into two main portions running west to east, with three seasonal grazing divisions, (i.e., winter, transitional and summer) in each portion. Each year, the cattle are moved up the elevational gradient through pastures on either the north or south half of the allotment during the growing season and then moved down the elevational gradient on the same half during the dormant season. The other half of the allotment is rested the entire year. Within the grazed half of the allotment, cattle are moved among pastures about every 10–14 days to promote uniform grazing on current growth and to prevent cattle grazing on regrowth.

L. Halstead

David Womack measures range grass.

— Lacey Halstead

Parasitic Wasps

Protecting greenhouse tomatoes

Parasitic wasps don't sting and they're hardly larger than the whiteflies they attack. Yet with careful monitoring both exotic and domestic species are becoming successful biological control agents on greenhouse tomatoes in the U.S. Southwest and in Europe.

Oscar Minkenberg, an entomologist in The University of Arizona College of Agriculture, and his staff raised nearly 30 million wasps last year for inundative release in commercial greenhouses and research facilities.

"We're currently producing three strains of wasps from Israel, the United Arab Emirates, and Pakistan," he says. "They were collected in the field over there by collaborators in the USDA/ARS. At the UA we developed a unique, mass-rearing technology that enables us to produce large numbers of the wasps for release here in Arizona, and in other states and countries."

Why use a mini-wasp? Most of the chemical sprays that kill whiteflies also kill the bumblebees that pollinate the tomatoes in greenhouses. Growers have been searching for ways to handle their insect problems without using pesticides.

Whiteflies damage plants by piercing leaf surfaces, sucking vital fluids and potentially transmitting viruses. They exude a sticky substance called honeydew that turns leaf surfaces black, cutting off the light the plant needs for photosynthesis. In Arizona the Bemisia species, or silverleaf (sweetpotato) whitefly has caused crop losses in cotton, melons and other vegetables, and has attacked greenhouse vegetables and flowers as well.

Parasitic wasps attack whiteflies by laying their eggs on or under the whitefly nymphs. As the wasp larvae feed, they destroy the whiteflies and emerge as adult wasps to begin the life cycle again. They do not injure the plant or other beneficial insects. The trick is to keep the balance between predator and prey steady enough to ensure the wasps a constant minimum supply of food while minimizing crop damage.

Arizona cotton growers, the Arizona Cotton Research and Protection Council and USDA/APHIS support biological control, according to Minkenberg, and they have funded mass rearings of parasitic wasps for release in Arizona.

"This is a unique collaboration between the UA and Arizona cotton growers and USDA/APHIS out of Phoenix," he says. Although Minkenberg has been releasing parasitic wasps in open field situations, he admits that the controlled environment in greenhouses has yielded more consistent results.

"Greenhouses are the mainstay," Minkenberg says. "It's where we see the successes right now." Species used in Arizona for biological control include *Eretmocerus californicus* (new name, *E. eremicus*), a native of the Southwest, and *Encarsia formosa*, the wasp commercially available.

K. Matesich

"In the Southwest, Eretmocerus does a lot better because it is suited to our high temperatures and lower relative humidity," Minkenberg says. He started raising and releasing Eretmocerus in 1992, then got involved with commercial biocontrol companies who have taken over mass rearings of the native species. Both Koppert in Ann Arbor, Mich., and Novartis (previously Ciba-Bunting North America) in Oxnard, Calif. have assumed the mass rearing of *Eretmocerus eremicus* once handled by the UA.

— Susan McGinley

Three commercial growers discuss their results

Commercial greenhouses in the Southwest have had varying degrees of success with the wasp, according to interviews with managers at three of them: Willcox Greenhouses and Bonita Nurseries in Cochise County, Ariz., and Colorado Greenhouses outside Denver, Colo.

"The best part about using biologicals is that you don't have to use chemicals," says Piet-hein van Baar, a manager at Willcox Greenhouses, where eight acres of beefsteak and cluster (cherry) tomatoes are cultivated in greenhouses. Van Baar has met with the UA's Minkenberg for advising purposes.

"The biggest problem with chemicals is that when you spray, the chemical doesn't work anymore after a while, because the insects build up resistance," van Baar says. "And the public doesn't want pesticides. So we started with the biologicals in August 1996. It's difficult: you have to get a balance between the beneficials and the pest. Sometimes you have to finish with a chemical."

The situation is complex because other insects besides whitefly can plague greenhouse tomatoes, and growers often juggle a mixture of insecticides and biological controls targeted to each pest.

"We use parasitic wasps such as Diglyphus to attack the leafminers, Trichogramma wasps for the pinworms, *Eretmocerus eremicus* and *Encarsia formosa* for the whitefly," van Baar notes. "This year wasn't a very good year for the wasps. We got some other pest bugs and had to use a chemical [which disrupted the biological control]. You always look at how many wasps there are, and you keep looking to see what you need and whether it's working or not working."

Based on this weekly monitoring, the grower knows how to schedule the wasp releases. Most of the parasitic wasps sold in the United States come from the Netherlands or England, where growers began using *Encarsia formosa* and other beneficial insects in greenhouses more than twenty-five years ago. Company consultants visit the U.S. periodically to check on the success of these wasp populations.

The wasp pupae arrive in small boxes which are placed on the plants so the wasps can emerge and colonize the greenhouse. A new batch of wasps is released weekly throughout the growing season.

Not only do the wasps control the whitefly, they also allow the plants to grow stronger in the absence of insect damage. When plants are not weakened by insects they can build their own natural defenses. Van Baar has found that this year's crop is so strong that it is providing resistance of its own right within the plant.

"What we see is that the crop is so strong now and the roots take up so much water that the pressure is high inside the plant. The stem is getting wet as the plant's own toxic substances ooze out of it; these toxins kill whiteflies as well," he says.

According to Jan de Kok, of Bonita Nurseries in Willcox, Ariz., both species of parasitic wasps are "working quite well." They just added Eretmocerus this year; their forty acres of beefsteak greenhouse tomatoes have been under biological control for the last two years.

"I am really surprised. We have not had to spray chemicals at all," de Kok says. "We started directly with biological control. In this location, we are separated from the other greenhouse businesses here. The balance was immediately there, and we didn't have a problem, even from the beginning."

Biological control can cost more than conventional pesticides when several different biocontrol agents are used for a variety of pests. The public doesn't always support the correspondingly higher priced product at the grocery store.

"Most growers want to go along with biological control because you get too much resistance with pesticides," de Kok says. "It's disappointing that the public sees the value in it but will not support it monetarily. People will not pay one cent more for pesticide-free tomatoes."

Colorado Greenhouses pest management advisor Frank Stonaker heard about Minkenberg's work a few years ago and contacted him regarding the wasps.

"Oscar provided us with our first Eretmocerus last year for a time," Stonaker says. "Now we use the European suppliers. We'd like to use locally developed products, but they're not available yet. We do have the greenhouse whitefly situation pretty well understood."

Stonaker uses both *Encarsia formosa* and Eretmocerus on 70 acres of beefsteak and cluster tomatoes. He has been using the Encarsia for about three and a half years, but began to rely more heavily on Eretmocerus beginning last year.

"We're still working out which is best," Stonaker admitts. "We're still learning, and from time to time we still use pesticides. Probably sixty to seventy percent of our efforts are real successful with parasites. The other forty percent we're still working out. We don't have good biocontrol agents for certain pests yet, such as the potato psyllid and the western flower thrips.

"There are not a lot of field proven situations," Stonaker adds. "We're writing the book and that's real frustrating sometimes. You assume you can plug into somebody else's research, but the intense light here in the Southwest, for example, throws off the introduction levels used in Europe."

Still, Stonaker is optimistic that biocontrol will work out for Colorado Greenhouses. "We use bumblebees to pollinate and we need pretty clean greenhouses as far as pesticides go," he says. "Biocontrol is about 25% cheaper than using pesticides. And the benefits are huge, because every time you spray a chemical you damage a plant. We are also concerned about environmental pollution. Our goal is to be under 100 percent biocontrol within two years."