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Abstract: Bird–aircraft collisions (i.e., bird strikes) are a major problem at airports worldwide, often because birds are attracted to airfields to feed on seeds, insects, or rodents that abound in the grassy areas near runways and taxiways. We compared an alternative ground cover, wedelia (*Wedelia trilobata*), to existing vegetation (control plots) on the airfield at Lihue Airport, Kauai, Hawaii, to determine if bird populations on the airport could be reduced by eliminating their forage base. We studied wedalia because it is a low-growing plant that did not need mowing, was easily established in plots, and out-competed other plants, resulting in a significant decrease in plant diversity. Thus, wedelia indirectly results in a decreased seed base for granivorous birds. Total invertebrate biomass was 41% lower in wedelia plots than in other vegetation plots (control plots). Rodent populations were 67% lower in wedelia than in control plots. Zebra doves (*Geopelia striata*), spotted doves (*Streptopelia chinensis*), and mannikins (*Lonchura* spp.) used wedelia plots significantly less than control plots, whereas, the lesser Pacific golden-plover (*Pluvialis fulva*) was unaffected. By reducing seed production, insect densities, and rodant populations, wedalia should be a useful ground cover on tropical airports to reduce bird use and, ultimately, bird strikes on the airport.

Key words: bird–aircraft collisions, bird strikes, habitat modification, human–wildlife conflicts, long grass management, *Wedelia trilobata*, wildlife damage management, wildlife hazards

In recent years, the number of collisions between birds and aircraft (i.e., bird strikes) has increased (Blokpoel 1976, Burger 1983*a*, Dolbeer and Eschenfelder 2003, Dolbeer and Wright 2008). Bird strikes are a major concern because they threaten passenger safety and result in costly repairs and lost revenue for air carriers (Dale 2009, Klope et al. 2009). Although standards to make aircraft more bird-resistant have been implemented (MacKinnon et al. 2001), these efforts have not eliminated the problem. Bird and other wildlife strikes presently cost the U.S. civil aviation industry >$650 million per year (Dolbeer and Wright 2008, Dolbeer and Wright 2009). Efforts now focus more toward exclusion (DeVault et al. 2008, VerCauteren et al. 2005) and biologically-based management of wildlife populations in the airfield environment (Cleary and Dolbeer 2005, Schafer et al. 2007, Blackwell et al. 2008).

About 75% of all bird strikes experienced by civil aviation occur at or in the immediate vicinity of airports (Solman 1973, Burger 1983*b*, Machalek 1990, Dolbeer 2006, Blackwell et al. 2008). At Lihue Airport on the island of Kauai, Hawaii, only 4 out of 530 bird strikes from 1990 to 1995 occurred outside of the airport property (Linnell et al. 1996, 1999). This suggests that control measures for civil aircraft should concentrate within the airport environment.

Many techniques to reduce bird activity on airfields have been developed, but none completely exclude all birds. The underlying assumption behind most bird-control programs at airports is that a reduction in the localized avian population will result in fewer bird–aircraft collisions (Brough and Bridgman 1980; Burger 1983*b*, 1985; U.S. Department of Agriculture 1994, Schafer et al. 2007). A study at John F. Kennedy International Airport, New York, supported this assumption when direct control of the gull population on the airfield markedly reduced the number of bird strikes (Dolbeer et al. 1993, 2003).

Birds use airports for roosting, drinking, loafing, and foraging. However, it is the availability of food that attracts most birds (Wright 1968; Blokpoel 1976; Solman 1978; Brough and Bridgman 1980; Burger 1983*a, b;* Washburn et al. *2007*). Shooting and hazing birds with pyrotechnics, vehicular harassment, and propane exploders have not been effective deterrents for several species involved in bird–aircraft collisions at Lihue Airport both because of birds' behavioral characteristics and their protected legal status. Shooting may have been ineffective because the airfield served as a sink in which birds that were removed were quickly replaced (Van Tets 1969, Burger 1983*b*, Pulliam 1988), and control measures could not be implemented at the source of dispersal because of logistical constraints. It was apparent that only through elimination of the airfield attraction could a long-term solution be achieved (Van Tets 1969; Solman 1973; Burger 1983*b*, 1985).

Habitat manipulation through management of long grass has been implemented with varying degrees of success on several airfields (Mead and Carter 1973, Brough and Bridgman 1980, U.S. Department of Agriculture 1994, Barras et al. 2000, Seamans et al. 2007); and tests were conducted at 2 airfields in Hawaii during 1991–1992 (M. A. Linnell, unpublished data). However, in Hawaii, long-grass (30–35 cm in height) management was counter-productive both because an infrequently mowed habitat was attractive to many seed-eating birds and long-grass management caused lesser Pacific golden-plovers (*Pluvialis fulva*) to be displaced onto runways and taxiways where they posed an increased bird-strike hazard (M. A. Linnell, unpublished data).

Another form of habitat modification is the use of alternative ground cover (Conover 2002). This concept previously has been suggested as a solution for reducing bird and rodent populations on airfields (Austin-Smith and Lewis 1970, Blokpoel 1976, Brooks et al. 1976, Washburn et al. 2007) and parks (Conover 2002). However, there have been few reported attempts to test and implement alternative ground cover on airfields (Austin-Smith and Lewis 1970, Smith 1976), and published literature on the subject is generally lacking.

The ideal vegetative cover at an airfield should have minimal seed production, be drought resistant, attract few invertebrates, provide minimal harborage for rodents, exclude other plants, pose no fire hazard, withstand vehicular traffic, grow to a desired height, and require little maintenance (Austin-Smith and Lewis 1970, Blokpoel 1976). Although a reduction in the number of bird strikes is the ultimate measure of the effectiveness of an alternative ground cover, bird use, rodent density, invertebrate populations, seed production, and vegetative coverage also are important indicators. These indicators become increasingly valuable when the frequency of bird strikes is relatively low because the assessment of a ground cover based exclusively on a direct reduction in bird strikes would require many years (Brough and Bridgman 1980). Further, plantings may have to be very large to realize an appreciable impact on the bird-strike rates. Therefore, due to cost considerations, airport managers will require some assurances of its effectiveness before approving a large-scale implementation. These smaller resource-based indicators provide a means both to assess the potential of a ground cover to reduce bird strikes and enable managers to predict if other fauna may be attracted by the new vegetation.

Our objective was to identify and evaluate whether an alternative ground cover would render the habitat on the Lihue airfield unattractive to hazardous (in terms of bird strikes) bird species through elimination of their preferred food resources. Based on preliminary test plantings of 10 species of potential ground cover, we narrowed the options to a single species, wedelia (*Wedelia trilobata;* Figure 1). We assessed wedelia's ability to exclude birds, rodents, invertebrates, and other seed-producing plants on a subtropical airfield in Hawaii. We also assessed its ability to withstand the vehicular traffic that is common on airfields.

Wedelia is a mat-forming composite that propagates vegetatively and produces an infertile seed head that is unpalatable to granivorous birds. It is native to tropical regions

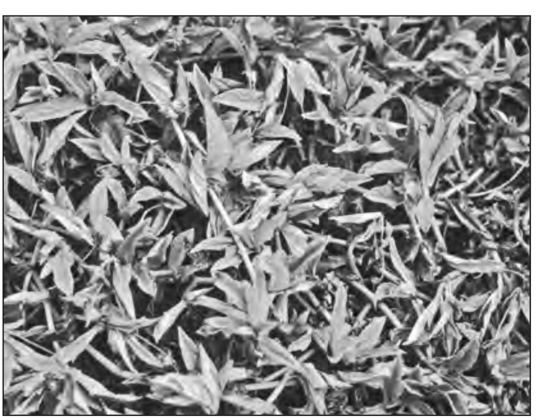

Figure 1. Close-up view of wedelia.

within the New World (Wagner et al. 1990) and is widely-used as a landscaping plant throughout the tropical Pacific. Wedelia typically grows to heights of 30 to 45 cm when irrigated as an ornamental. However, on the Lihue airfield, its growth was lateral rather than vertical, and it never exceeded 10 cm in height, presumably due to exposure and natural desiccation from the wind in an open, non-irrigated environment typical of airfields.

Methods

The Lihue Airport was a 284-ha facility located on the southeast coast of Kauai, Hawaii (latitude of 21° 59' 45" N, longitude 159° 20' 29" W), at an elevation of 45 m above sea level (Okamoto et al. 1989). The airport was surrounded by a haole koa (*Leucaena leucocephala*) forest-scrub community on its south and east borders, which provided roosting cover and nesting habitat for several avian species, such as zebra doves (*Geopelia striata;* Figure 2.). The airfield was bounded by sugar cane (*Saccharum officinarum*) on the north and by a golf course and resort on the west. The mean rainfall on the airfield was 112 cm per year, with approximately 84 cm falling in the wet season from October through April (U.S. Weather Service, unpublished report). The subtropical climate was characterized by moderate humidity, equable temperatures throughout the year (23°C to 27°C), and constant northeasterly trade winds (Wagner et al. 1990).

There were 31 species of birds that appeared on the Lihue airfield at some period during the year (M. A. Linnell, 1992–1995, unpublished data). Of these, zebra doves, chestnut mannikins (*Lonchura malacca*), nutmeg mannikins (*Lonchura punctulata*), spotted doves (*Streptopelia chinensis*), lesser Pacific golden-plovers, barn owls (*Tyto alba*), and short-eared owls (*Asioflammeus sandwichensis*) comprised >80% of the bird strikes from 1990 to 1995 (Linnell et al. 1996).

A diverse array of seed-producing plants grew within the Lihue Airport and provided forage to birds. Henry's crabgrass (*Digitaria adscendens*), wiregrass (*Eleusine indica*), false mallow (*Malavastrum coromandelianum*), prickly sida (*Sida spinosa*), graceful spurge (*Chamaesyce hypericifolia*), cowpea (*Macroptilium lathyroides*), ricegrass (*Paspalum orbiculare*), and smutgrass (*Sporobulus indicus*) were used most extensively by granivorous birds on the airfield (M. A. Linnell, unpublished data) and throughout the Hawaiian Islands (Schwartz and Schwartz 1951*a, b*). This plant community also provided food and cover for rodents and invertebrates that attract owls and insectivorous birds.

We established 15 wedelia plots with a mean size of 1,042 (SE = 146) m^2 per plot throughout the airfield in December 1992, which corresponds to the wet season on the island of Kauai. To establish the wedelia, treatment plots were sprayed on December 9, 1992, with a nonselective herbicide (Roundup® 2-4-D) to kill all existing vegetation. Nine days later, the plots were harrowed to a depth of about 15 cm and allowed to stand fallow for 3 weeks to facilitate germination of preexisting seed in the plots. The plots were again harrowed to kill any newly emerging vegetation, and the planting of wedelia began immediately thereafter. Wedelia cuttings approximately 25 to 45 cm in length were taken from sources near the airport. The newly-cut sprigs were uniformly spread upon the tilled plots at a density covering an estimated 20–30% of the surface, then they were tilled into the soil. The cuttings began to take root within 2 weeks, and new surface growth was observed within 3 weeks of the planting. We estimated the plots to be nearly fully established within 4 months of the initial planting, which roughly corresponded with the end of the wet season.

Each of these treatment plots was paired with a control plot of the same size and shape located 10–15 m from the corresponding wedelia plot. Control plots, however, contained existing vegetation and were void of wedelia.

Figure 2. Zebra doves, such as those pictured here, were attracted to forest scrub surrounding Lihue Airport, Hawaii. (*Photo courtesy USDA/Wildlife Services*)

The corners of all plots were delineated with surveyor's paint. Throughout the course of this study, vegetation at the airport, including all wedelia and control plots, was maintained at a height of 10–15 cm by mowing approximately once every 3–6 weeks.

In addition to the experimental plots, we established 4 smaller test plots of wedelia (9 m^2/plot) that were allowed to grow unmaintained to assess natural growth attributes in the airfield environment. We conducted no prey-base monitoring in these plots.

We sampled floral composition of wedelia and control plots to determine wedelia's capability to exclude other plant species. We used a 10-pin point frame method (Levy and Madden 1933, Bonham 1989) to assess vegetative cover within each plot. We took samples along randomly-selected transects and used a table of random numbers to determine the transect's point of origin and direction from the gridded perimeter of each plot. Density is difficult to monitor and accurately assess when the vegetation propagates with stolons or rhizomes (Pieper 1973, Bonham 1989). Therefore, we used percentage of cover (Higgins et al. 1994) and Simpson's weighted species diversity index (Begon et al. 1990) to monitor and evaluate wedelia's exclusionary effects against other plant species. We included sampling pins at a 45° angle, which tends to favor analysis of grass species (Pieper 1973), and this resulted in potentially conservative cover estimates of wedelia. We determined percentage of cover by dividing the number of hits on each species by the total hits on all vegetation (or bare ground) and multiplying by 100.

We tested the durability of wedelia to vehicular traffic by driving a 1,500-kg pickup truck along the same route over a wedelia patch 7 times per day for 32 consecutive days. We sampled vegetation within the traveled areas in the same manner as at other test and control plots to give an estimate of percentage of cover and species diversity.

Cattle egrets (*Bulbicus ibis*), lesser Pacific golden-plovers, common mynas (*Acridotheres tristis*), and barn owls (Tangalin and Jamieson 1992) consume primarily larger insects, such as cockroaches (Blattelidae), crickets (Gryllidae), and grasshoppers (Acrididae). Hence, we monitored these larger invertebrates associated with the ground litter in wedelia and control plots. We randomly established 1 pitfall collecting trap in each plot. We achieved randomization by partitioning each plot into a grid with a 1-m distribution between cells, and we used a table of random numbers to select in which cell the trap should be placed. We operated traps for a 6-day period, after which time we collected and reset them in a new, randomly-chosen location within the plot. We conducted 5 trapping periods, totaling 30 trap-days per plot. Traps consisted of 473-ml cups half-filled with a 3% formaldehyde solution buried at ground level (Kubista 1990). In addition to pitfall traps, we took 5 random sweep net samples per plot at the time the pitfall traps were reset to assess jumping or flying insects. Each 1-m sweep consisted of briskly moving a semicircular net (0.6 m in diameter and flattened on the bottom) through the vegetative canopy, keeping the net approximately 2 to 5 cm from the ground. We identified insect samples collected from each plot to the family level, then dried and weighed them to obtain an index of invertebrate abundance per plot. These sampling techniques did not permit a compositional assessment of the entire invertebrate population on the airfield, but we assumed that they did represent the major invertebrates birds preyed upon.

We sampled rodents in both wedelia and control plots by a combination of kill traps (snap traps) baited with dried coconut dipped in cheese and peanut butter and live trapping with repeating rodent traps (i.e., traps that could capture multiple rodents without re-bating or resetting). We killed all rodents taken from the airfield upon their removal from the live traps to avoid capturing the same animal more than once. We used 13 repeating rodent traps and 26 snap traps spaced at 5-m intervals in plot 11 (the largest treatment and control plot); in all other plots, we used 1 repeating rodent trap and 2 snap traps. In all cases, the number of trap nights was identical in each paired wedelia and control plot. We ran traps for 32 consecutive days beginning August 12, 1994, and checked and re-baited them daily. Every 5 days, we moved the traps to a new randomly-selected location within each plot. We applied the same randomization method described for the insect pitfall traps.

We monitored bird activity daily from August

Table 1. Mean coverage (%) of plants in treatment plots (n = 15) consisting of wedelia and control plots (n = 15) comprised of existing vegetation at the Lihue Airport, Kauai, Hawaii, during the period of August 11 to September 11, 1994.

	Wedelia		Control		Wilcoxon test	
Species	$\bar{x}$	SE	$\bar{x}$	SE	t	P
Bare ground	38.7	4.9	32.7	2.0	-0.43	0.670
Bermuda grass (*Cynodon dactylon*)	0.7	0.7	5.5	1.7	3.00	0.003
Crabgrass (*Digitaria adscendens*)	0.1	0.1	21.3	5.4	3.18	0.002
False mallow (*Malavastrum coromandelianum*)	0.1	0.0	5.7	1.7	2.93	0.003
Mimosa (*Mimosa pudica*)	4.1	1.1	5.8	0.9	1.66	0.096
Pitted beardgrass (*Andropogon pertuses*)	0.5	0.2	7.3	2.8	2.67	0.008
Prickly sida (*Sida spinosa*)	0.0	0.0	2.6	1.5	2.20	0.028
Smutgrass (*Sporobulus indicus*)	0.1	0.0	2.6	1.1	2.20	0.028
Swollen fingergrass (*Chloris inflata*)	0.0	0.0	2.8	1.0	2.67	0.008
Wedelia (*Wedelia trilobata*)	55.0	4.7	0.0	0.0	-3.41	0.998
Wiregrass (*Eleusine indica*)	0.2	0.1	3.2	1.6	2.11	0.035
Other[1]	0.5	0.3	10.5	2.5	3.23	0.001

[1] Comprised primarily of cowpea (*Macroptilium lathyroides*), ricegrass (*Paspalum orbiculare*), uhaloa (*Waltheria americana*), spiny amaranth (*Amaranthus spinosus*), and graceful spurge (*Chamaesyce hypericifolia*).

12, 1994, through September 14, 1994, using a fixed-strip count method (Franzreb 1981) established along a transect that ran through each plot; we counted as an observation each bird that we flushed. We counted birds in each plot a minimum of 7 times per day, and we staggered bird counts so that censuses were conducted at each plot equally at various times of the day. We recorded the number of birds by species for each plot.

Each plot served as a sampling unit. We analyzed the plant cover, rodent abundance, and bird data from each of the paired wedelia and control plots using a 1-tailed Wilcoxon signed ranks test (Zar 1984) to assess whether wedelia plots supported fewer plants and animals than control plots ($P < 0.05$). We used this nonparametric test in lieu of the paired t-test because of difficulties in meeting normality assumptions associated with the

Table 2. Mean number of invertebrates (categorized by family or order) and dry weight (mg) in wedelia (n = 15) and control plots (n = 15) at the Lihue Airport, Kauai, Hawaii, during the period of August 11 to September 11, 1994.

	Wedelia		Control		Paired t-test	
Family	$\bar{x}$	SE	$\bar{x}$	SE	t	P
Blattelidae						
Number	162.1	25.8	170.0	25.3	0.32	0.52
Biomass	5,930.8	1.00	5,830.7	1.00	-0.12	0.64
Acrididae						
Number	2.2	0.7	6.0	1.4	2.12	0.03
Biomass	56.3	0.01	272.0	0.07	3.07	0.004
Araneae						
Number	26.8	5.4	29.7	3.8	0.51	0.31
Biomass	684.6	0.13	761.9	0.09	0.49	0.32
Gryllidae						
Number	1.6	0.8	2.6	0.7	1.97	0.034
Biomass	243.2	0.11	604.6	0.15	3.38	0.002
Other[1]						
Biomass	7,682.3	1.03	13,163.3	2.03	2.66	0.01
Total						
Biomass	14,582.7	1.96	20,632.5	2.23	2.63	0.01

[1] Comprised of individuals in the family Carabidae and Tenebrinidae, and from the order Isopoda.

parametric equivalent. We compared plant diversity indices and invertebrate abundance using a 1-tailed paired t-test ($P < 0.05$). We used Bonferroni protected alpha levels to guard against making a Type I error. We conducted a post-hoc power analysis (NCSS-PASS 1991) to determine the probability of Type II error in the tests that were not significant (Day and Quinn 1989).

Results

Compared to plant cover in control plots, plant cover in the wedelia plots was lower for all species except for wedelia and mimosa (*Mimosa pudica*; Table 1). Species diversity also was lower in wedelia plots (t = 10.06, df = 14, $P < 0.001$) than in the corresponding control plots. The number of observations of some plant species that produce palatable seeds, such as cowpea, ricegrass, uhaloa (*Waltheria americana*), spiny amaranth (*Amaranthus spinosus*), and graceful spurge (Schwartz and Schwartz 1951*a, b*) was not sufficient to permit statistical analysis, so they were grouped in the “other” category (Table 1). The combined percentage of cover and frequency of occurrence of these rarer species was less in the wedelia plots (t = 3.23, df = 14, $P < 0.001$). Bare ground was equally common in wedelia and control plots.

Simpson’s index of species diversity within

Table 3. Mean number of birds in wedelia (n = 15) and control plots (n = 15) at the Lihue Airport, Kauai, Hawaii, during the period of August 12 to September 14, 1994.

	Wedelia		Control		Wilcoxon test	
Species	$\bar{x}$	SE	$\bar{x}$	SE	t	P
Zebra dove (*Geopelia striata*)	0.7	0.3	10.9	5.5	3.06	0.002
Mannikin (*Lonchura* spp.)	0.1	0.1	4.0	1.2	2.80	0.005
Spotted dove (*Streptopelia chinensis*)	0.0	0.0	1.4	0.5	2.67	0.01
Lesser Pacific golden-plover (*Pluvialis fulva*)	3.3	1.7	2.1	1.1	-1.19	0.234
Short-eared owl (*Asio flammeus*)	0.0	0.0	0.1	0.0	1.34	0.180
Common myna (*Acridotheres tristis)*	0.1	0.0	0.9	0.3	2.37	0.02
House finch (*Carpodacus mexicanus*)	0.1	0.1	1.5	0.8	1.57	0.12
Red-crested cardinal (*Paroaria coronata*)	0.1	0.1	0.5	0.3	1.83	0.07
House sparrow (*Passer domesticus*)	0.0	0.0	0.2	0.1	1.34	0.180
Western meadowlark (*Sturnella neglecta*)	0.2	0.1	1.8	1.2	1.78	0.075
Northern mockingbird (*Mimus polyglottus*)	0.0	0.0	0.3	0.2	1.34	0.180
All species combined	4.7	1.7	23.9	7.6	3.32	<0.01

wedalia plots was 2.42 in the undisturbed section and 2.04 within the portion exposed to frequent vehicular traffic. Percentage of bare ground within wedelia plots was 21% in undisturbed sections and 61% in sections exposed to heavy vehicular use, whereas the percentage of wedelia cover decreased from 57% in the undisturbed section to 34% in the travel zone. Because there was no replication, statistical analyses of the differences were not possible.

Total invertebrate biomass of all families combined was 29% less in wedelia plots than in the controls (Table 2). The number of individuals and dried biomass of the families *Acrididae* and *Gryllidae* also was significantly lower in the wedelia plots than in the controls. There were no differences, however, between the number or biomass of *Blattelidae* and *Araneae* in wedelia and control plots. The remaining invertebrates were lumped into the "other" category, which consisted primarily of individuals from the Isopoda, Coleoptera, and Dermaptera orders. The cumulative biomass of these invertebrates in the "other" category was significantly reduced in the wedelia plots compared to the controls.

We captured 46 house mice (*Mus musculus*), 22% of which occurred in wedelia plots and 78% in control plots. This difference was significant

(t = 2.86, df = 14, P = 0.004). We captured no other rodent species during the 32-day trapping period.

Overall avian use of wedelia plots was 80% less than of the control plots (Table 3). We observed only 2 barn owls during the study, both of which occurred in the control plots. In addition, we found 4 fresh owl pellets in the control plots and none in plots containing wedelia. We found lesser Pacific golden-plover with equal frequency in both wedelia and control plots. We observed 10 avian species during this study. All were more common in control plots than in wedelia plots, but observations of some of these species were too infrequent to yield statistically significant results (Table 3). When we combined all avian species, there was a significant reduction in overall bird use of wedelia plots relative to the controls.

Discussion

Our results suggest that wedelia can dominate sites, effectively excluding gramineous plant species and most forbs. The diversity and cover of the plants that produce seeds that regularly are consumed by granivorous birds on the airfield were lower in wedelia plots than in control plots, particularly crabgrass, wiregrass, false mallow, smutgrass, and prickly sida. Wedelia's dominance over crabgrass was particularly noteworthy because crabgrass, the most dominant naturally-occurring vegetation on the airfield, provided a strong attractant to zebra doves, spotted doves, and manikins, and comprised >70% of their diet from September 1992 through July 1994 (M. A. Linnell, unpublished data). Because of wedalia's unpalatability and vegetative dominance over seed-producing plants, we were not surprised to find that rodent numbers in wedelia plots were only 28% of their numbers in control plots.

Wedelia plots supported a lower population of the larger insects, such as Gryllidae and Acrididae, both of which occur in the diets of larger insectivorous birds, including cattle egrets and mynas that frequent the Lihue airfield (M. A. Linnell, unpublished data). Insects from the family *Blattelidae*, however, were equally abundant in both wedelia and control plots. Cattle egrets and mynah birds frequently consumed these insects, but these birds respond effectively to shooting and hazing techniques and comprise <3% of the bird strikes at Lihue (Linnell et al. 1996, 1999).

We hypothesized that most problematic birds were attracted to the Lihue airfield because of availability of foraging resources. If this is correct, then a decreased abundance of these food items should result in fewer birds. This hypothesis was supported by a reduction in the number of seed-eating birds observed in wedelia plots when compared to control plots on the airfield. We attribute these results to wedelia's exclusion of seed-producing plants that presumably resulted in decreased seed abundance.

Pacific golden-plovers, however, were not excluded from the wedelia plots, which possibly is the result of a strong site fidelity to their territories (Johnson et al. 1981) or because cover of bare ground in wedelia was similar to that within control. This open ground may help plovers locate food.

Because of the low abundance of owls on the airfield, we could not statistically compare their frequency both in wedelia and control plots. However, the few owls and owl pellets that we observed were all in control plots. We believe that decreased rodent and insect abundance were important indicators of wedelia's potential to reduce foraging by owls and perhaps other raptors in these areas.

Wedelia was only moderately resistant to vehicular traffic and may not be suited to areas of repeated exposure to traffic. Wedelia's percentage of cover decreased by 23%, and bare ground increased by 34% after we drove the same path 224 times in a 32-day period. This level of traffic exceeded what normally occurs on an airfield except on perimeter access roads. We conclude that wedelia's durability is sufficient to withstand relatively light levels of traffic, including mowing and periodic maintenance that are typical on most airfields.

We conclude that wedelia is a good ground cover for tropical airfields because of its vegetative dominance; ability to exclude most seed-producing plants, insects, rodents, and birds; ease of establishment and relatively low maintenance thereafter; low fire hazard; and moderate durability to traffic. Wedelia is an aggressive exotic species and should not be introduced into locations where it does not already exist. However, nearly all of the vegetation on the Lihue airfield consisted of introduced plants (as is the case on most tropical airfields), and volunteer stands of wedelia already existed in isolated patches on the airfield. Therefore, it posed no invasive threat to the native floral composition.

Our results demonstrate the value of using habitat management in the form of an alternative ground cover to exclude birds from airfields and suggest that a search for other locally-suitable ground covers may be worthwhile. Before selecting a ground cover specific to an airfield, the target wildlife must be identified, and potential secondary wildlife attractions must be carefully considered. Use of an unpalatable or dominant ground cover will be most effective against species that are attracted to airports for their foraging opportunities. Unpalatable ground cover, however, may be ineffective against birds that use airfields for roosting, loafing, nesting, or as a source of water, unless the vegetative structure is sufficiently thick to preclude access for such activities. Our data indicate that use of an alternative ground cover may reduce bird–aircraft collisions, but it would not eliminate them entirely. Hence, airport bird control, even with habitat modification, will require a dynamic, integrated approach to management.

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