Short Communications and Commentaries

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Study on Use of Alien Versus Native Plants by Nectarivorous Forest Birds on Maui, Hawaii

GEORGE H. WARING,[1] LLOYD L. LOOPE, AND A. C. MEDEIROS
Haleakala National Park, P.O. Box 369, Makawao, Maui, Hawaii 96768, USA

Elements of the flora and fauna of oceanic islands in general and the Hawaiian Islands in particular are highly susceptible to displacement by invasions of nonnative species, especially when human-mediated disturbance is involved (Loope and Mueller-Dombois 1989). Despite this, cooperative efforts by federal and state governments and private conservation groups have resulted in substantial progress being made in the past decade towards protecting representative samples of biological diversity of the Hawaiian Islands, especially at high elevations and in other extreme habitats (e.g. coastal strand zone and montane bogs).

The upper slopes of Haleakala Volcano on East Maui, within Haleakala National Park, The Nature Conservancy's Waikamoi Preserve, Hanawi (state) Natural Area Reserve, and adjacent State Forest Reserves, comprise one of the most viable areas for conservation in the Hawaiian Islands. Active management is underway to mitigate the threats of some of the most damaging alien invaders, such as the mongoose (*Herpestes*) and feral ungulates, as well as selected alien plants and insects (Stone and Loope 1987).

As an essential adjunct to management, research is being conducted to clarify relationships among native and alien species. It is not uncommon in the Hawaiian Islands to find alien species exploit the environment interactively (Loope and Mueller-Dombois 1989). For example, the extremely successful invading tree *Myrica faya* colonizes and thrives on nutrient-poor young volcanic substrates on the island of Hawai'i, aided by an introduced nitrogen-fixing symbiont (*Frankia*) and introduced birds (e.g. *Zosterops japonicus*) that disperse its seeds (Vitousek and Walker 1989). Concern over this pattern of mutual facilitation among alien species provided impetus for this investigation of interactions of the alien tree *Cytisus palmensis* (Christ) Hutch. (Fabaceae: Papilionoideae) with other plant and bird species.

Baldwin (1953) noted that while the native trees *Metrosideros* and *Sophora* are the major dietary nectar sources for the Hawaiian honeycreepers, there are other locally significant sources including "the introduced tree alfalfa *Cytisus proliferus* [*C. palmensis*] growing in certain upland pastures on Maui and to which *Vestiaria* and *Himatione* come in large numbers to feed." *Cytisus palmensis* is native to La Palma of the Canary Islands in the eastern Atlantic Ocean (Wagner et al. 1990). It was first noted ("a few large shrubs . . . in a pasture in Kula") and collected on Maui in 1927, probably introduced during 1910–1912 with packages of seeds of alien species in an attempt to improve forage for cattle (Degener 1936); its elevational range on Maui was given as 640 to 1,525 m by Wagner et al. (1990). It is sparse yet flourishing on East Maui and Hawai'i. Several trees occurring near the upper limit of rain forest in Waikamoi Preserve have attracted management attention because of visitation by native forest birds. This study was undertaken to assess the nectar-foraging pattern of native and alien forest birds on *Cytisus* and selected native plants in the Waikamoi Preserve.

Methods.—The study site was in Waikamoi Gulch (elevation 1,900 m) on the windward slope of Haleakala (Maui) in the western part of Waikamoi Preserve managed by The Nature Conservancy of Hawaii. The site is frequented by several species of birds, including the native Apapane (*Himatione sanguinea*), Maui Creeper (*Paroreomyza montana*), Iiwi (*Vestiaria coccinea*), and Common Amakihi (*Hemignathus virens*); the alien Japanese White-eye (*Zosterops japonicus*); and more rarely the endemic Crested Honeycreeper (*Palmeria dolei*) and Maui Parrotbill (*Pseudonestor xanthophrys*). At the study site, koa (*Acacia koa*) and 'ohi'a (*Metrosideros polymorpha*) were the primary trees. Mamane (*Sophora chrysophylla*), although not present at the study site, was within 0.5 km (adjacent to Hosmer Grove); nectarivorous birds (e.g. Apapane and Common Amakihi) wander from the forest to forage on mamane. From 15 January through 25 March 1989 (during much of the annual nesting cycle of drepanids), we studied the foraging behavior of birds on three prolonged-flowering plant species—the avian-pollinated native tree 'ohi'a, the tall native shrub 'ohelo (*Vaccinium calycinum*), and the tall alien legume *Cytisus palmensis*. 'Ohi'a trees display red, corymbose inflorescences accessible to nectar feeders along the upper surface of the tree; the 'ohelo shrubs have whitish, pendent inflorescences dispersed throughout the outer margins of the shrub; and *Cytisus* has whitish,

[1] Present address: Department of Zoology, Southern Illinois University, Carbondale, Illinois 62901, USA.

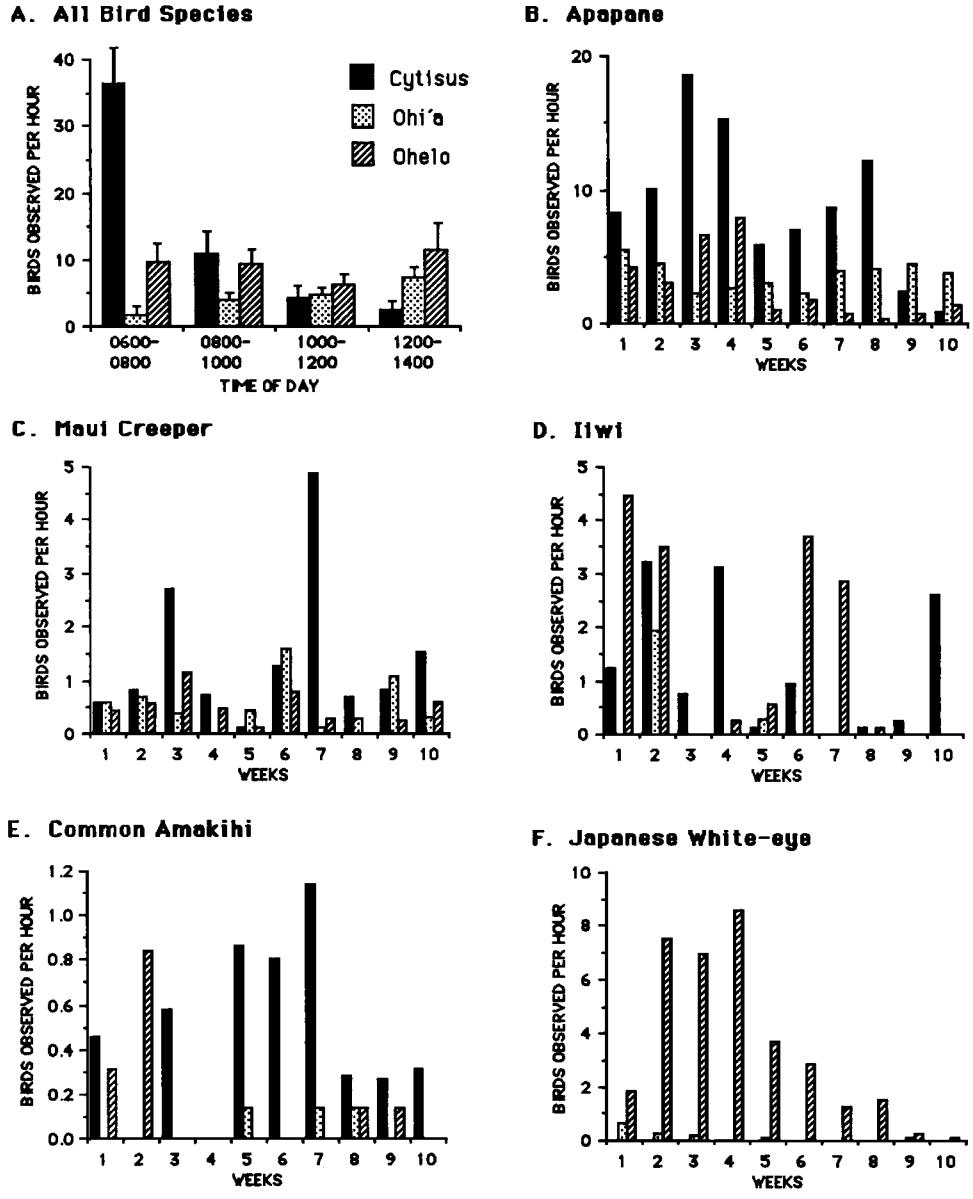

Fig. 1. Number ($\bar{x} \pm$ SE) of birds observed nectar foraging per hour of observation during 10-week study (January–March).

pea-like flowers dispersed throughout the shrub's outer surface.

At the study location, one target plant was selected to represent each of the three species; the three target plants were chosen for their abundant blossoms (>200), comparable surface area (estimated), and equal visibility from the observation site. The *Cytisus* was on the west slope of the gulch at a distance of approximately 50 m, the 'ohi'a rooted in the floor of the gulch was at a distance of 30 m, and the 'ohelo was 10 m from the observation site along the east slope of the gulch. Scan sampling (Altmann 1974) was employed at 2-min intervals to record the number and species of birds foraging on each of the three target plants. Weekly samples from the same observation position (exclusively by G.H.W.) began at first light and continued until 1400 Alaska-Hawaii Standard Time during each of 10 weeks. The technique provided an average of 370 data points per plant species per week. Binoculars (8 × 40) and a spotting scope

(20×) were used. The avian species studied were the Apapane, Maui Creeper, Iiwi, Common Amakihi, and the alien Japanese White-eye; they were chosen for their omnipresence in the study area. Based on the number of individuals present at any one moment, the Apapane was the most abundant species in the study area; no obvious difference was apparent in the local population size of the other four species (cf. Scott and Sincock 1977, Conant and Kjargaard 1984).

Observations were made when there was no or only light rainfall and only when visibility allowed a clear view of each target plant. Low clouds tended to increase through the day and often obscured visibility by 1400. Disturbance by humans or other intruders did not occur during sampling. During observations, minimum-maximum temperatures ranged from 2 to 13°C; wind ranged from 0 to 5 m/s.

Results and discussion.—Avian foraging peaked in the early hours of the day. Birds visited individual inflorescences for only a few seconds. The bill was inserted for 1 s or less into a blossom while the bird was perched (cf. Carothers 1982); then often the bird would probe a neighboring flower or two before shifting sites. The birds seemed to be continually in motion while foraging. Individuals rarely remained on the same plant more than a minute before flying to another location. Foraging appeared to be a solitary, and not a social activity; yet, occasionally, more than one individual and species would be on a given plant at the same time.

Each of the target plants received recurrent avian foraging during the 10 weeks of the study. The alien plant (*Cytisus*) was especially utilized as a food source early in the day by native birds (Fig. 1a). Foraging by Apapane, Maui Creeper, Iiwi, and Common Amakihi on *Cytisus* declined as the day progressed from dawn to early afternoon (Table 1), whereas foraging on the flowers of 'ohi'a increased ($P < 0.0001$, Kruskal-Wallis ANOVA). No difference was found between time blocks for 'Ohelo, which was visited more evenly through the day.

Although Apapane were the primary visitants to *Cytisus* (see Fig. 1), Maui Creeper, Iiwi, and Common Amakihi also foraged in this shrub. The Japanese White-eye was not seen foraging on *Cytisus*. Apapane, Maui Creeper, and Iiwi were the main visitors to 'ohi'a, while the Japanese White-eye, Apapane, Iiwi, and Maui Creeper were the more frequent visitors to 'ohelo.

The Apapane and Maui Creeper utilized each of the target plants throughout the study, showing some variation in intensity of use from week to week (Figs. 1b and 1c). The Iiwi and Common Amakihi, however, used different plant species from week to week (Figs. 1d and 1e). The Japanese White-eye visited 'ohelo, almost to the exclusion of the other two plant types (Fig. 1f).

We found that native birds heavily utilized the alien *Cytisus* plant as a food source during the January–March study period, especially in the early hours of the day; by midday few birds visited *Cytisus* blossoms. Although feeding territoriality and competition has been recognized among Hawaiian honeycreepers (e.g. Carpenter and MacMillen 1976a, b, Kamil and van Riper 1982, Pimm and Pimm 1982, Carothers 1986), resource defense was not obvious during this investigation, perhaps because of the abundance and wide distribution of food resources (cf. Carpenter and MacMillen 1976b). The daily shift away from *Cytisus* occurred at approximately 0800, just as direct sunlight reached the plant being monitored. Conversely, foraging at 'ohi'a flowers was infrequent early in the day and became more common toward the end of the sampling period (1200–1400). Further investigation would be needed to determine why these shifts occur, but they probably involve the production schedule of nectar in *Cytisus* and *Metrosideros*. Carpenter (1976) found that peak nectar flow for *Metrosideros* generally occurred between 1200 and 1600. That foraging patterns reflect the nectar content of flowers is further supported by the study of Kamil (1978), who found individual Common Amakihi were less likely to visit mamane flower clusters already visited earlier in the day.

TABLE 1. Number of birds observed nectar foraging ($\bar{x} \pm$ SE) per hour of observation on three plants during the January–March study, Waikamoi Preserve, Maui.

Time period	Cytisus	'Ohi'a	'Ohelo
	Apapane		
0600–0759	25.43 ± 4.92	1.66 ± 0.50	5.20 ± 1.92
0800–0959	8.55 ± 2.10	3.65 ± 0.45	3.65 ± 0.98
1000–1159	3.80 ± 1.34	3.55 ± 0.44	1.55 ± 0.77
1200–1359	2.00 ± 0.68	5.60 ± 0.76	3.02 ± 2.63
	Maui Creeper		
0600–0759	4.60 ± 1.67	0.00	1.27 ± 0.40
0800–0959	1.35 ± 0.70	0.50 ± 0.21	0.30 ± 0.15
1000–1159	0.25 ± 0.13	0.50 ± 0.20	0.25 ± 0.15
1200–1359	0.06 ± 0.06	1.12 ± 0.35	0.34 ± 0.15
	Iiwi		
0600–0759	5.26 ± 1.82	0.00	1.06 ± 0.78
0800–0959	0.40 ± 0.13	0.00	1.75 ± 0.74
1000–1159	0.20 ± 0.15	0.25 ± 0.25	1.30 ± 0.62
1200–1359	0.33 ± 0.24	0.62 ± 0.50	2.65 ± 1.22
	Common Amakihi		
0600–0759	1.26 ± 0.55	0.00	0.07 ± 0.07
0800–0959	0.60 ± 0.30	0.00	0.00
1000–1159	0.15 ± 0.08	0.10 ± 0.07	0.25 ± 0.13
1200–1359	0.11 ± 0.11	0.06 ± 0.06	0.22 ± 0.22
	Japanese White-eye		
0600–0759	0.00	0.00	1.99 ± 1.13
0800–0959	0.00	0.00	3.85 ± 1.01
1000–1159	0.00	0.40 ± 0.21	2.95 ± 0.87
1200–1359	0.00	0.06 ± 0.06	5.15 ± 2.78

The finding that Japanese White-eyes visited flowers of native 'ohelo and not the alien *Cytisus* flowers is somewhat unexpected. The Japanese White-eye, introduced to O'ahu in 1929, is the most widespread and abundant forest bird in the Hawaiian Islands, occurring from sea level to an elevation of 2,700 m (Scott et al. 1986). Analysis of interspecific competition (Mountainspring and Scott 1985) suggests that Japanese White-eyes have negative impacts on at least some native passerines (e.g. Iiwi). Scott et al. (1986) reported increasing and not yet stabilized numbers of Japanese White-eyes on Maui above 1,500 m elevation, based on dramatic changes between 1975 and 1980 surveys. They reported that these white-eyes tend to be more common along broad forest edges (such as in the study area) than within forest interiors. Although we found no facilitative interaction between *Cytisus* and the Japanese White-eye, mutual facilitation between some native birds and this alien plant is suggested. Further investigation is warranted.

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