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Japanese White-eye, an Introduced Passerine, Visits the Flowers of *Clermontia arborescens*, an Endemic Hawaiian Lobelioid[1]

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ABSTRACT: The Hawaiian Lobelioideae (Campanulaceae) are generally believed to have adapted to pollination by endemic passerine birds belonging to the Drepanidinae (Fringillidae) and Meliphagidae. The widespread extinction of many of these birds has raised concerns about the continued survival of the Hawaiian Lobelioideae. During July 1985, the Japanese White-eye (*Zosterops japonica* Temminck & Schlegel, Zosteropidae), was observed visiting the flowers of one of the endemic lobelioids, *Clermontia arborescens* (H. Mann) Hillebrand. These observations suggest that the Japanese White-eye may be a potential replacement pollinator for at least one of the Hawaiian lobelioids.

THE LOBELIOIDEAE (CAMPANULACEAE) are represented in the Hawaiian Islands by seven genera and 108 endemic species of woody plants found primarily in wet montane forests (Lammers, in press). The Hawaiian lobelioids are generally believed to have adapted to pollination by native nectarivorous passerine birds (Rock 1919; Porsch 1930; Spieth 1966; Carlquist 1974, 1980). The ornithological literature contains numerous reports [summarized by Cory (1984) and Lammers and Freeman (1986)] which describe visits to lobelioid flowers by endemic species of Meliphagidae and Fringillidae subfamily Drepanidinae (Table 1). Recent data from nectar-sugar compositions (Lammers and Freeman 1986) support this hypothesis of ornithophily.

Unfortunately, much of the native avifauna is extinct or in imminent danger of extinction (Greenway 1967, Berger 1981, Whitlock 1981). Approximately half of the historically known nectarivorous passerines are extinct or presumed so, and surviving taxa have suffered range reductions and population declines (Berger 1981, Scott et al. 1985). Because of these widespread extinctions, bird visitation of ornithophilous flowers may be much less frequent today than in the past. In a preliminary attempt to ascertain the current extent of bird visitation in Hawaiian lobelioid species, we observed a population of *Clermontia arborescens* (H. Mann) Hillebrand on Maui for visits by potential pollinators.

METHODS

Observations were made along the East Maui Irrigation Company's Waikamoi Flume in the Ko'olau Forest Reserve on the north slope of Haleakalā, East Maui. The flume runs along the contour of the mountain (elevation 1300 m) from Haipuaena Stream to Waikamoi Stream. The surrounding vegetation is wet native forest dominated by 'Ōhi'a-lehua (*Metrosideros polymorpha* Gaudich., Myrtaceae). Populations of several lobelioids occur here, including *Clermontia arborescens*, *Cyanea aculeatiflora* Rock, *C. bishopii* Rock, *C. hamatiflora* Rock, *C. macrostegia* Hillebrand, and *Trematolobelia macrostachys* (Hook. & Arn.) A. Zahlbr. The population of *Clermontia arborescens* numbered nearly a hundred individuals in the immediate vicinity of the flume. This was the only lobelioid species flowering at the time of our observations. Spieth

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TABLE 1[1]

ENDEMIC BIRDS THAT HAVE BEEN REPORTED TO FEED ON FLORAL NECTAR OF HAWAIIAN LOBELIOIDEAE (CAMPANULACEAE). In most cases, the plant is identified only as a "lobelioid." Nomenclature follows Greenway (1968) for Drepanididae, Salomonsen (1967) for Meliphagidae, and Rock (1919) for Lobelioideae. Information on range and status is taken from Berger (1981). H = Hawai'i, K = Kaua'i, L = Lana'i, M = Maui, Mo = Moloka'i, O = O'ahu; c = common, r = rare, px = presumed extinct, x = extinct

BIRD TAXON		RANGE	STATUS	PLANT TAXON	REFERENCE(S)
DREPANIDIDAE					
Drepanis funerea Newton	Mamo	Mo	x	Lobelioideae	Perkins (1895, 1903), Bryan (1908), Munro (1944), Amadon (1950)
D. pacifica (Gmelin)	Mamo	H	x	Lobelioideae	Perkins (1903), Amadon (1950)
				Clermontia sp.	Munro (1944)
Hemignathus o. obscurus (Gmelin)	'Akialoa	H	px	Lobelioideae	Perkins (1903)
				Clermontia sp.	Munro (1944)
H. o. lanaiensis Rothschild	'Akialoa	L	x	Lobelioideae	Perkins (1903)
H. o. procerus Cabanis	'Akialoa	K	px	Lobelioideae	Perkins (1903), Munro (1944)
Vestiaria coccinea (Forster)	'I'iwi	M	c	*Clermontia arborescens*	Spieth (1966), Berger (1981)
				Trematolobelia macrostachys	Berger (1981)
		O	r	Lobelioideae	Peale (1848)
		unspecified islands[2]		Lobelioideae	Wilson (1890), Perkins (1895, 1903)
Viridonia v. virens (Gmelin)	'Amakihi	H	c	Lobelioideae	Wilson (1890), Munro (1944)
V. v. chloris Cabanis	'Amakihi	O	r	Lobelioideae	Wilson (1890)
V. parva (Stejneger)	'Anianiau	K	c	Lobelioideae	Perkins (1903)
MELIPHAGIDAE					
Moho bishopi (Rothschild)	'Ō'ō	Mo	x	Lobelioideae	Perkins (1903), Munro (1944)
M. braccatus (Cassin)	'Ō'ō	K	r	Lobelioideae	Perkins (1903)
M. nobilis (Merrem)	'Ō'ō	H	x	Lobelioideae	Wilson (1890), Perkins (1903), Munro (1944)

[1] A condensed version of this table appeared in the *American Journal of Botany* (Lammers and Freeman 1986).
[2] In addition to M and O, also known from H (c), K (c), L (x), and Mo (r).

(1966) and Berger (1981) earlier observed 'I'iwi visiting flowers in this same population.

Two groups of flowering *Clermontia arborescens*, one with two trees (a total of ten flowers) and the other with six trees (a total of 23 flowers) were observed with binoculars. The two groups were located about 50 m apart. Each group was observed for one hour during the afternoon of 4 July 1985. During this period, the temperature was 15–17°C with constant light precipitation.

RESULTS AND DISCUSSION

We recorded nine visits by nectarivorous passerine birds to flowers of *Clermontia arborescens*. None involved the 'I'iwi, which had been reported earlier taking nectar to this population (Spieth 1966, Berger 1981). One visit involved the local race of the 'Amakihi, *Hemignathus virens wilsoni* (Rothschild). Although the Hawai'i and O'ahu races of 'Amakihi have previously been observed feeding at lobelioid flowers (Lammers and Freeman 1986), this is the first such report involving the race found on Lana'i, Maui, and Moloka'i. The 'Amakihi spent about two minutes in the first group of trees, foraging in several flowers and vocalizing loudly, and then flew to a nearby Ōlapa [*Cheirodendron trigynum* (Gaudich.) A. A. Heller, Araliaceae] where it vigorously wiped its bill on a branch. The remaining eight visits were made by single individuals or small groups of an introduced passerine, the Japanese White-eye (*Zosterops japonica* Temminck and Schlegel, Zosteropidae), which probed flowers for periods of up to three minutes per visit. It was not possible to determine whether the birds were contacting the staminal column and stigma or if they were bearing pollen on their heads. However, the structure of the flower makes it likely that such contact did occur. Floral nectar samples obtained from these trees were found to be rich in hexose sugars (Lammers and Freeman 1986). Such nectars are preferred by nectarivorous passerines (Baker and Baker 1983). The visits of the Japanese White-eyes were evenly divided between the two groups of trees. In all cases, no vocalizations were heard. This is the first report of a non-native bird visiting the flowers of any of the Hawaiian lobelioids.

The introduction and spread of the Japanese White-eye in the Hawaiian Islands began in 1929 with its release on O'ahu under the auspices of the Territorial Board of Agriculture and Forestry (Caum 1933). With subsequent releases and natural range expansion, it has become the most abundant land bird in the archipelago today, occurring on all major islands from sea level to tree-line in a wide range of habitats (Berger 1981). Japanese White-eyes subsist on insects and nectar and are known to feed occasionally on fruits (Berger 1981). Some evidence suggests a correlation between spread of the Japanese White-eye and decline of native passerines (Dunmire 1962, Mountainspring and Scott 1985). Cox (1983) has documented that the Japanese White-eye has become a substitute pollinator for 'Ie'ie (*Freycinetia arborea* Gaudich., Pandanaceae), a woody liana formerly pollinated (in Hawai'i at least) by the Hawaiian Crow (*Corvus tropicus* Kerr, Corvidae), the Kona Grosbeak (*Chloridops kona* Wilson, Drepanidinae] and the 'Ō'ū [*Psittirostra psittacea* (Gmelin), Drepanidinae].

Perkins (1903) was the first to discuss in detail the occurrence of ornithophily among the Hawaiian lobelioids. Because of the protandrous nature of the flowers, he believed that pollination could only be effected by drepanids and meliphagids. He speculated that once the last of these birds had disappeared, the lobelioids would follow. In contrast, subsequent studies have suggested or demonstrated the occurrence of autogamy in several Hawaiian lobelioids (Rock 1919, Skottsberg 1927, Cory 1984), and these species may persist despite extinction of the native avifauna. Recent studies by Cory (1984) demonstrated nearly 100% seed set in selfed flowers of *Clermontia kakeana* Meyen and *Cyanea angustifolia* (Cham.) Hillebrand on O'ahu. Japanese White-eyes were common in the vicinity of her study populations but no birds were ever observed visiting the flowers in 136 hr of observations. However, Young (1982) has shown a significant decrease in

germination rate, another aspect of fitness, in self-fertilized seed of two woody Afro-alpine species of *Lobelia*.

Any Hawaiian lobelioids that are not autogamous and formerly depended on native birds for pollination may benefit from the presence of the Japanese White-eye. More detailed studies are necessary to determine the degree of pollen transfer effected by Japanese White-eyes. Even if this introduced passerine is an effective pollinator, it may lead to differing levels of outcrossing compared to those resulting from visits by the native species of birds.

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LITERATURE CITED

BAKER, H. G., and I. BAKER. 1983. Floral nectar sugar constituents in relation to pollinator type. Pages 117–141, *in* C. E. Jones and R. J. Little (eds.), Handbook of experimental pollination biology. Scientific & Academic Editions, New York.

BERGER, A. J. 1981. Hawaiian birdlife, ed. 2. University of Hawaii Press, Honolulu.

CARLQUIST, S. 1974. Island biology. Columbia University Press, New York.

———. 1980. Hawaii: a natural history, ed. 2. Pacific Tropical Botanical Garden, Lawai.

CAUM, E. L. 1933. The exotic birds of Hawaii. Occas. Pap. Bernice Pauahi Bishop Mus. 10:1–55.

CORY, C. 1984. Pollination biology of two species of Hawaiian Lobeliaceae (*Clermontia kakeana* and *Cyanea angustifolia*) and their presumed coevolved relationship with native honeycreepers (Drepanididae). M.A. thesis, California State University, Fullerton.

COX, P. A. 1983. Extinction of the Hawaiian avifauna resulted in a change of pollinators for the ieie, *Freycinetia arborea*. Oikos 41: 195–199.

DUNMIRE, W. W. 1962. Bird populations in Hawaii Volcanoes National Park. 'Elepaio 22:65–70.

GREENWAY, J. C., Jr. 1967. Extinct and vanishing birds of the world, ed. 2. Dover, New York.

LAMMERS, T. G. In press. Campanulaceae. *In* W. L. Wagner, D. R. Herbst, and S. H. Sohmer, Manual of the flowering plants of the Hawaiian Islands. Bishop Museum Press, Honolulu.

———, and C. E. FREEMAN. 1986. Ornithophily among the Hawaiian Lobelioideae (Campanulaceae): Evidence from nectar sugar compositions. Amer. J. Bot. 73: 1613–1619.

MOUNTAINSPRING, S., and J. M. SCOTT. 1985. Interspecific competition among Hawaiian forest birds. Ecol. Monogr. 55:219–239.

PERKINS, R. C. L. 1903. Vertebrata. Pages 365–466 *in* D. Sharp (ed.), Fauna Hawaiiensis, vol. 1, part 4. University Press, Cambridge.

PORSCH, O. 1930. Kritische quellenstudien über blumenbesuch durch vögel. V. Biol. Gen. 6:133–246 + pl. 28–32.

ROCK, J. F. 1919. A monographic study of the Hawaiian species of the tribe Lobelioideae family Campanulaceae. Mem. Bernice Pauahi Bishop Mus. 7(2):i–xvi, 1–395.

SCOTT, J. M., C. B. KEPLER, and J. L. SINCOCK. 1985. Distribution and abundance of Hawai'i's endemic land birds: Conservation and management strategies. Pages 75–104, *in* C. P. Stone and J. M. Scott (eds.), Hawai'i's terrestrial ecosystems: Preservation and management. University of Hawai'i, Honolulu.

SKOTTSBERG, C. 1927. Iakttagelser över blomningen hos *Cyanea hirtella* (H. Mann) Rock. Acta Horti Gothob. 3:43–55.

SPIETH, H. T. 1966. Hawaiian honeycreeper, *Vestiaria coccinea* (Forster), feeding on lobeliad flowers, *Clermontia arborescens*

(Mann) Hillebr. Amer. Naturalist 100: 470–473.

WHITLOCK, R. 1981. Birds at risk. Moonraker Press, Wiltshire.

YOUNG, T. P. 1982. Bird visitation, seed set, and germination rates in two species of *Lobelia* on Mount Kenya. Ecology 63: 1983–1986.