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THE HAWAI'I RARE BIRD SEARCH 1994–1996

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Abstract. We compiled the recent history of sightings and searched for 13 rare and missing Hawaiian forest birds to update status and distribution information. We made 23 expeditions between August 1994 and April 1996 on the islands of Hawai'i, Maui, Moloka'i, and Kaua'i totaling 1,685 search hours, 146 field days, and 553 person days. During our surveys we found four critically endangered birds: the Po'ouli (*Melamprosops phaeosoma,* five to six individuals), Maui Nukupu'u (*Hemignathus lucidus affinis,* one individual), 'I'iwi (*Vestiaria coccinea*) on Moloka'i (one individual), and the Puaiohi (*Myadestes palmeri,* 55–70 individuals). Detection rates for each species were 0.013, 0.002, 0.012, and 0.318 detections/hr, respectively. Although not visually confirmed during our surveys, auditory detections, unconfirmed sightings, and other reports suggest the possible existence of 'Ō'ū (*Psittirostra psittacea*) on Hawai'i, Kaua'i Nukupu'u (*Hemignathus lucidus hanapepe*), and Maui 'Ākepa (*Loxops coccineus ochraceus*) in perilously low numbers. Six undetected forest bird populations, Kāma'o (*Myadestes myadestinus*), Kaua'i 'Ō'ō (*Moho braccatus*), Bishop's 'Ō'ō (*Moho bishopi*), 'Ō'ū on Kaua'i, Greater 'Akialoa (*Hemignathus ellisianus*), and Kākāwahie (*Paroreomyza flammea*) have high probabilities of being extinct. Oloma'o (*Myadestes lanaiensis*) from Moloka'i are probably extirpated from the areas searched on that island but may persist on the unsurveyed Oloku'i Plateau.

Key Words: bird survey; critically endangered; extinct; Hawai'i; 'I'iwi; Nukupu'u; Po'ouli; Puaiohi.

Descending from a small number of original colonizers, Hawai'i's native plants and animals are an evolutionary panoply. Species underwent explosive adaptive radiation and specialization in the world's most isolated island chain (Carlquist 1974, Scott et al. 1986, Freed et al. 1987a, Howarth et al. 1988, James and Olson 1991, Olson and James 1991, Wagner and Funk 1995, Pratt and Pratt *this volume*). Striking examples of speciation occurred among the lobelioids, fruit flies, land snails, and Hawaiian honeycreepers (Fringillidae: Drepanidinae), with more than 50 known species having evolved from one cardueline finch colonizer (Johnson et al. 1989, Tarr and Fleischer 1995).

The isolation that allowed such unique adaptations also predisposed the ecosystem to vulnerability due to human caused and stochastic natural disturbances. Multiple pressures have resulted in catastrophic species extinctions; habitat destruction and nonnative species introductions, including ungulates, mammalian predators, pathogens, and disease vectors, have had the most extensive and detrimental effects on Hawai'i's island ecosystem (Atkinson 1977, Ralph and van Riper 1985, Scott et al. 1986, Loope et al. 1988, Atkinson et al. 1995). Recent fossil evidence indicates at least 50% of the original avifauna went extinct after the arrival of the Polynesians about 400 AD, and today 75% of the historically known native birds are either extinct or endangered (James and Olson 1991, Olson and James 1991, Ehrlich et al. 1992).

Coincident with increased human development and the spread of the *Culex* mosquito since the 1900s, Hawai'i's remaining native avifauna has experienced a steady decline with low-elevation and specialized species suffering particularly heavy losses (Baldwin 1953, Warner 1968, Scott and Kepler 1985, van Riper et al. 1986, Pratt 1994). Many species that were abundant or common into the early 1900s had low population densities during the extensive U.S. Fish and Wildlife Service (USFWS) Hawaiian Forest Bird Surveys (HFBS) of the 1970s and 1980s (e.g., 'Ō'ū [*Psittirostra psittacea*], Maui 'Ākepa [*Loxops coccineus ochraceus*], 'Ō'ō [*Moho* spp.], Hawaiian Crow [*Corvus hawaiiensis*] or 'Alalā, Moloka'i's Oloma'o [*Myadestes lanaiensis rutha*], and Kāma'o [*Myadestes myadestinus*]; Bryan and Seale 1901, Henshaw 1902a, Perkins 1903, Bryan 1908; Banko 1980a, 1980b, 1981a, 1984a, 1986; Scott et al. 1986). Today the existence of more than half Hawai'i's critically endangered (Mace and Lande 1991) birds is seriously in question (Pratt 1994, USFWS 1996a).

The Convention on International Trade in Endangered Species and the World Conservation Union (WCU 1982) have set 50 years of no sightings as the arbitrary limit to declare species extinction. This may be a useful definition in some cases, but it is hardly appropriate when periodic intensive search effort or surveys by qualified personnel make it possible to evaluate the likelihood of extinction objectively. While most of Hawai'i's endangered endemics are rare, often cryptic species that inhabit remote, rainy, and treacherous terrain where search effort is irregular (further complicated by difficulties in gaining access to rare bird habitat on both public and private lands), the periodic survey and intensive search methodology initiated in Hawai'i in the 1960s (Richardson and Bowles 1964, Sin-

cock et al. 1984) allows for a quicker, more objective assessment of a species' status than the WCU criterion. This regular monitoring approach is essential in island ecosystems, where ecological collapse and extinction can be swift (e.g., Guam's forest bird community crashed within 35 years of the introduction of the brown tree snake [*Boiga irregularis*]; Savidge 1987a).

Species accounts written over the last century provide a sobering historical review of their disappearance (Perkins 1903, Munro 1944; Banko 1980a, 1980b, 1981a, 1981b, 1984a, 1984b, 1986; Berger 1981, Scott et al. 1986; Pratt et al. 1987, 1997b; Fancy and Ralph 1998, Lepson and Freed 1997, Snetsinger et al. 1998), but fundamental questions remain unanswered: Which species persist? What is their distribution? How many remain? Are these populations viable? Through our surveys we sought to clarify the status of extremely rare Hawaiian endemics from four families: corvids (one species), turdids (three species), fringillids (eight populations, representing seven unique taxa), and melephagids (two species; Ellis et al. 1992a).

New conservation tools from New Zealand using alien predator removal and translocation of vulnerable species will improve our ability to preserve native biodiversity (Merton 1975, Butler and Merton 1992, Saunders 1994, Serna 1995). With more than 450,000 ha in Hawai'i now designated as reserve, the development of captive propagation and release tools for Hawai'i's passerines (Kuehler et al. 1994, 1995, 1996; Fancy et al. 1997), and improved understanding of the pathology of avian pox and malaria (Warner 1968, Ralph and van Riper 1985, Atkinson et al. 1995), conservation and management opportunities are expanding enormously. To apply these methods effectively and to make more defensible management decisions, basic knowledge about which species remain, their population and distribution, is essential.

STUDY SITES AND METHODS

Evaluation of Recent Reports

We reviewed published and unpublished reports of all critically endangered bird detections during the last 20 years in *'Elepaio*; *Hawaii's Forests and Wildlife*; the B. P. Bishop Museum *Sightings* database; and USFWS, Biological Resources Division of the U.S. Geological Survey (U.S. Geological Survey), and Hawaii Department of Land and Natural Resource (DLNR) files. For those species not reported, we reviewed Scott et al. (1986) and Banko (1980a, 1980b, 1981a, 1981b, 1984a, 1984b, 1986) for descriptions of the most recent sightings.

Study Area

We conducted 28 rare bird search expeditions from August 1994 to April 1996, selecting search areas with suitable habitat above 1,000 m or above the avian malaria belt (van Riper et al. 1986, Atkinson et al. 1995; Table 1). Native vegetation dominated survey sites, and we took care to reduce the accidental introduction of weeds into pristine areas by using new gear on each island, inspecting and cleaning clothing and equipment, and not cutting trails. Most search areas had historical sightings or had received little attention from ornithologists due to their remoteness and rough terrain. We reached remote sites by helicopter and hiked established trails to less isolated areas.

Rainfall averages up to 10 m/yr, and rainy periods often last for weeks (Scott et al. 1986, van Riper et al. 1986). The mountainous terrain is often precipitous, with flooding drainages, sheer cliffs, and gorges. Thick vegetation obscures treacherous volcanic earth cracks and lava tubes. Besides the hazardous and difficult field conditions, we found that access to many promising areas was restricted. Thus, we could not search several promising tracts.

We surveyed remote state and federal lands on the islands of Hawai'i: Ka'ū Forest Reserve (Ka'ū; 19°22′ N, 155°48′ W), Upper Waiākea Forest Reserve (Upper Waiākea; 19°40′49″ N, 155°16′64″ W), South Kona (19°11′ N, 156°30′ W), and Pu'u Maka'ala Natural Area Reserve (Pu'u Maka'ala; 19°12′30″ N, 155° W); Maui: Hanawī Natural Area Reserve (Hanawī; 20°45′ N, 156°06′ W), Kīpahulu Valley (20°44′30″ N, 156°' W), Kuiki (20°43′30″ N, 156°10′30″ W), and Waikamoi Preserve (Waikamoi; 20°43′ N, 156°10′30″ W); Moloka'i: Kamakou Preserve and Pelekunu Valley (Kamakou-Pelekunu; 21°08′15″ N, 156°54′30″ W); and Kaua'i: Alaka'i Swamp Wilderness Preserve: Koai'e (22°07′ N, 159°34′30″ W), Mōhihi-Waiakōali-Kōali (22°08′ N, 159°31′ W), Halehaha-Halepa'akai (22°06′ N, 159°31′ W), North Kawaikōī (22°09′30″ N, 159°34′ W).

Observer Training

Skilled field ornithologists knowledgeable in the identification of Hawaiian forest birds learned island-specific vocalizations and improved species identification skills through rigorous training: supplemental surveys in endangered forest bird habitat (25 field days not included in search effort; Table 1), practice with Hawaiian bird recordings (Cornell Laboratory of Ornithology 1995) on Bird Song Master 2.2 (Microwizard 1995) and *Voices of Hawaii's Birds* (Pratt 1996a), examination of museum skins, and study of field guides and historical references (Perkins 1903, Munro 1944, Berger 1981, Pratt et al. 1987).

Survey Methodology

For our surveys we used continuous observation during timed searches, a modified form of the "area search method," which uses 20–30 min timed searches (Ralph et al. 1993). Two-person survey teams conducted searches from base camps at helicopter drop sites or from satellite camps reached by backpacking. We used binoculars and listened for vocalizations to search for rare species. We incorporated the use of periodic playbacks (Johnson et al. 1981) for rare species with available recordings (Cornell Laboratory of Ornithology 1995): Kāma'o, 'Ō'ō 'ā'ā (*Moho braccatus*) or Kaua'i 'Ō'ō, 'Ō'ō, Po'ouli (*Melamprosops phaeo-*

TABLE 1. RARE BIRD SURVEY RESULTS AND SUMMARY OF SEARCH EFFORT AUGUST 1994–APRIL 1996

Island	Search area	Dates	Search effort (hr)[a]	Overall weather[b]	Number of critically endangered birds (unique individuals by expedition)	Observation time (hr:min:sec)[c]	Detection rate (detections/hr)
Maui	Waikamoi	20–21 Aug 1994	8.0	Poor	—	—	—
Maui	Hanawī	22 Aug–8 Sept 1994	154.0	Poor	Po'ouli (3)	0:05:20	0.02
Maui	Hanawī	19–27 Oct 1994	210.0	Fair	'Ākepa (1-auditory)	0:00:10	—
					Nukupu'u (1)	0:00:30	< 0.01
					Po'ouli (2)	0:00:55	0.01
Hawai'i	Upper Waiākea	7–8 Feb 1995	6.0	Fair	—	—	—
Maui	Hanawī	17–24 Feb 1995	94.0	Good	Po'ouli (2)	0:05:30	0.02
Maui	Hanawī	28 Feb–2 Mar 1995	64.0	Good	—	—	—
Moloka'i	Kamakou-Pelekunu	17–23 May 1995	85.0	Good	'I'iwi (1)	0:00:30	0.01
Hawai'i	South Kona	15, 22, 31 May–3 Jun 1995	88.0	Good	—	—	—
Maui	Hanawī	13–17 Sept 1995	60.0	Good	Nukupu'u (1)	0:01:15	0.02
Hawai'i	Ka'ū	26–27 Oct 1995	7.0	Good	—	—	—
Hawai'i	Hakalau (Training)	31 Oct–3 Nov 1995	105.0	Fair	—	—	—
Hawai'i	Hanawī (Training)	10–14 Nov 1995	21.8	Good	—	—	—
Hawai'i	Hanawī (Training)	28 Nov–1 Dec 1995	24.0	Fair	—	—	—
Maui	Kīpahulu Valley	27 Nov–1 Dec 1995	36.0	Poor	'Ākepa (1-auditory)	0:00:30	—
Maui	Kīpahulu Valley	27 Nov–3 Dec 1995	80.8	Poor	—	—	—
Maui	Kuiki	5–12 Dec 1995	126.0	Good	—	—	—
Hawai'i	Ka'ū	9–13 Jan 1996	59.5	Fair	—	—	—
Hawai'i	Kīlauea-Keauhou (Training)	16–19 Jan 1996	36.0	Good	—	—	—
Hawai'i	Upper Waiākea	22–26 Jan 1996	38.8	Poor	—	—	—
Hawai'i	Pu'u Maka'ala	12, 14 Feb 1996	6.3	Good	—	—	—
Kaua'i	Koai'e (Training)	8–13 Feb 1996	30.0	Fair	—	—	—
Kaua'i	Mōhihi	10–12 Feb 1996	17.3	Poor	Puaiohi (2)	0:21:00	0.23
Kaua'i	Southeast Interior-Upper Halepa'akai	20 Feb–1 Mar 1996	49.3	Poor	—	—	—
Kaua'i	North Kawaikōī	7–14 Mar 1996	77.4	Good	—	—	—
Kaua'i	Halehaha-Halepa'akai	14–21 Mar 1996	122.8	Good	Puaiohi (7)	0:28:08	0.06
Kaua'i	Mōhihi-Waiakōali	28 Mar–12 Apr 1996	132.8	Good	Puaiohi (27–34)	3:35:25	0.70
Kaua'i	Mōhihi-Kōali-Kawaikōī	17, 21–26 Apr 1996	95.4	Good	Puaiohi (28–31; 11 new)	2:10:00	0.60
Kaua'i	Halehaha-Halepa'akai	21–27 Apr 1996	66.8	Good	Puaiohi (12–14; 6 new)	0:27:39	0.30

[a] Search effort = cumulative party hours (e.g., two teams searching in different areas for 8 hr each = 16 hr of search effort).

[b] Weather: Good = ≥ 75% of search effort without precipitation (ppt) and wind < 11 kmph; Fair = ≥ 50% of search effort without ppt and wind < 20 kmph; Poor = > 50% of search effort with ppt and/or wind ≥ 20 kmph or with canceled surveys due to wind and rain (i.e., search effort = 0 hr).

[c] Total time observed = total time a critically endangered species was observed or heard.

TABLE 2. STATUS AND RECENT DETECTIONS OF HAWAI'I'S CRITICALLY ENDANGERED FOREST BIRD SPECIES

Species	Distribution	Status and sightings (*Unconfirmed)	References
'Alalā	South Kona, Hawai'i	1) 1 bird 1991 on Hualālai, plus S. Kona population	1) J. Giffin, DLNR, pers. comm.
		2) 4 birds 1999	2) D. Ball, USFWS, pers. comm.
Kāma'o	Alaka'i Swamp, Kaua'i	1) 2 birds 1985	1) in Pyle 1985b
		2) *2 birds 1989; *2 1993[a]	2) in Pyle 1989, 1993
		3) *1 bird 1995[b]	3) D. Holmes and C. Hayward, U.S. Geological Survey, pers. comm.
Oloma'o	Kamakou and Oloku'i Plateau, Moloka'i	1) 2–3 seen 1975	1) Scott et al. 1977
		2) 3 plus *3 sightings 1980	2) in Scott et al. 1986
		3) *1 bird 1988	3) DLNR unpubl. data
Puaiohi	Alaka'i Swamp, Kaua'i	1) 18 birds in 1994	1) DLNR/USFWS unpubl. data
		2) 145 ± 19 in 1996	2) Reynolds et al. 1997b
'Ō'ō'ā'ā	Alaka'i Swamp, Kaua'i	1) 1 pair 1981	1) Scott et al. 1986
		2) 1 bird 1985	2) in Pyle 1985b
		3) 1 heard 1987	3) in Pyle 1988
Bishop's 'Ō'ō	Northeast slope Haleakalā, Maui	1) *2 auditory 1973[c]	1) J. Jacobi *in* Sabo 1982, W. Banko and P. Banko *in* Banko 1981a
		2) *seen 1980[d]	2) Scott et al. 1986
		3) *seen 1981	3) Sabo 1982
		4) *seen 1983[3]	4) D. Boynton, pers. comm., field notes
'Ō'ū	Alaka'i Swamp, Kaua'i Windward districts, Hawai'i Island	1) 2 birds in 1989 on Kaua'i	1) in Pyle 1989
		2) 1 in 1987 from 'Ōla'a Forest, Volcano	2) USFWS, unpubl. data *in* Pyle 1989.
Greater 'Akialoa	Alaka'i Swamp, Kaua'i	1) 1 bird 1965	1) Huber 1966
		2) *1 bird 1969	2) P. Bruner *in* Ellis et al. 1992a
Kaua'i Nukupu'u	Alaka'i Swamp, Kaua'i	1) Several seen 1985	1) In Pyle 1985a, 1985b
		2) 1 bird 1987	2) by T. Telfer, USFWS/DLNR, unpubl. data
		3) *2 birds 1995	3) T. Casey and J. Jeffery, pers. comm.
Maui Nukupu'u	Northeast slope Haleakalā, Maui	1) 1 bird 1986	1) Engilis 1990
		2) 2 birds 1989	2) R. Fleischer, pers. comm.
		3) 1 bird 1994	3) J. Jeffery and M. Reynolds, pers. comm.
		4) resighted 1995, 1996	4) M. Reynolds, K. Berlin, pers. comm.
Kākāwahie	East slopes, Moloka'i	1) 2 seen 1961, 3 seen 1962, 3 seen 1963	1) Pekelo 1963
O'ahu 'Alauahio	Ko'olau Mountains, O'ahu	1) *41 reports 1941-1975 few with details	1) Shallenberger and Pratt 1978
		2) 3 seen 1977-1978	2) Shallenberger and Vaughn 1978
		3) 2 juveniles seen 1985[e]	3) A. Engilis et al. *in* B. P. Bishop Museum *Sightings* database
		4) *3 possible sightings 1984-1993[f]	4) B. Eilerts et al., D. Woodside and R. Saito, and E. VanderWerf *in Sightings* database

TABLE 2. CONTINUED.

Species	Distribution	Status and sightings (*Unconfirmed)	References
Maui ʻĀkepa	Northeast slope Haleakalā, Maui	1) 2 birds seen 1988 2) *1 audio 1994 3) *1 audio 1995	1) Engilis 1990 2) T. Snetsinger 3) T. Casey, pers. comm.
ʻIʻiwi on Molokaʻi	East slopes, Molokaʻi	1) 1 bird 1995	1) J. Jeffery, USFWS, and T. Casey, KSBE, pers. comm. (DLNR, unpubl. data)
Poʻouli	Northeast slope Haleakalā, Maui	1) 1 bird 1993 2) 5 birds sighted 1994-1995 3) 6 in 1996	1) B. Gange and T. Pratt, pers. comm. 2) Reynolds and Snetsinger 1994 3) T. Pratt, U.S. Geological Survey, pers. comm.

[a] Brief sightings reported as possible Kāmaʻo or Puaiohi.
[b] Field notes described a dull brown thrush quivering its wings. Observed for 1 min with binoculars in good light from 20 m away. Reported from Kukui Trail well below 1,000 m elevation in dry, scrubby forest, in an area unlikely to support Kāmaʻo.
[c] Auditory detections of Bishop's Ōʻō calls tracked down were mimicry by ʻĀkohekohe (*Palmeria dolei*), but observers appear to indicate that there was a detectable difference in mimic calls and actual *Moho* sp. calls.
[d] Described by observers as a large unidentified black bird, not ʻĀkohekohe.
[e] Poamoho Trail, 21 December 1985, detailed notes and sketch.
[f] June 1984 Waiʻalae Iki Ridge (identification termed "uncertain" by observers); 30 June 1989 N. Hālawa near HW-3 tunnels; 15 January 1993 Mānana Stream detailed notes (identification termed "uncertain" by EV).

soma), and Puaiohi (*Myadestes palmeri*). We recorded survey effort in hours (search hours) as the difference between start and end times for each two-person survey team. We recorded weather data (wind speed and precipitation) at the start of surveys and recorded any changes throughout the search period. We classified survey weather conditions as good (wind speed < 11 kmph and no precipitation), fair (wind speed > 11 kmph or light precipitation), or poor (wind and/or rain contributing to 20%–50% loss in visual or auditory detections; Ralph et al. 1995b). Survey effort during high wind (> 32 kmph), heavy rain, or other circumstances that severely hampered the ability of the observers to identify species, was excluded in the calculation of search hours.

We defined a "confirmed" sighting as one sighting of a bird by two observers or at least two separate sightings in the same vicinity by different experienced observers. We calculated the number of "confirmed" rare bird detections per search hour. These detection rates (detections/hr) served as an index of species rarity. When possible, we identified individual birds based on plumage, age, distance from previous detections, repeated sightings, and territorial behavior such as response to playback recording.

Subtle differences between species' call notes and some song types complicated by mimicry and an incomplete collection of Hawaiian forest bird vocalizations made auditory detection of critically endangered species as much art as science. Auditory records were not considered "confirmed" detections by the authors unless birds were sighted. We reported auditory records here only if two knowledgeable observers heard the vocalization and agreed on its identity. However, we did not consider these records as confirmation of the species' persistence and did not include auditory detections in the calculation of detection rates.

DATA ANALYSIS

We calculated detection probabilities for species undetected during our surveys to evaluate the likelihood of extinction. Scott et al. (1986) calculated the probability (p) of detecting one bird from a randomly distributed population of n individuals as:

$$p = 1 - \left(1 - \frac{a}{A}\right)^n \qquad (1)$$

We approximated a, the effective search area, on either side of the search transects using the effective detection distance (EDD) for each species. We used the EDD for each species calculated from HFBS data (Table 6 in Scott et al. 1986). We measured survey distances using a planimeter (Numonics model 1250) on topographic maps. A is the last known range of the species (Tables 10 and 11 in Scott et al. 1986). We note that many rare species have experienced range contraction since the HFBS, making our detection probabilities more conservative. We used Scott et al.'s (1986) detection probabilities, p, from the HFBS for Kona and Kaʻū because we used the same transects, but we recalculated new p for all other areas. We used 10 birds as the hypothetical population size, n.

Reed (1996) modified Guynn et al.'s (1985) statistical methods to infer species extinctions:

TABLE 3. DETECTION PROBABILITIES (DP) FOR ONE BIRD FROM A POPULATION OF 10 BIRDS RANDOMLY DISTRIBUTED ACROSS THE KNOWN RANGE

Island	Species	Range[a] (km²)	EDD[b] (m)	Independent visits[c] (N)	Effective search area[d] (km²)	DP during surveys	N_{min} = Visits[c] Needed (L = 3 km)[e] for DP = 95%, 99%	Probability of zero detection in N visits, (L = 3 km)[e]
Hawai'i	'Ō'ū	145	66	17	16.28	0.70	110, 169	0.628
	'Alalā	253	282	16	54.45	0.91	45, 69	0.342
Maui	Bishop's 'Ō 'ō	23[a]	75	67	10.04	>0.99	16, 24	<0.0001
	'Ākepa	23	34	67	4.55	0.89	34, 52	0.0026
Moloka'i	Oloma'o	16, 8[f]	23	9	1.75	0.69, 0.92[f]	35, 54	0.459
	Kākāwahie	16[a], 8[f]	28	9	2.13	0.76, 0.95[f]	29, 44	0.387
	Kāma'o	25	60	54 (+208)[g]	9.13	0.99	21, 32	0.0004
Kaua'i	'Ō'ō'ā'ā	25	150	54 (+208)[g]	16.07	>0.99	9, 13	<0.0001
	'Ō'ū	25	66	54 (+208)[g]	9.83	>0.99	19, 29	0.0002
	'Akialoa	25[a]	39	54 (+208)[g]	6.65	0.96	32, 49	0.0062
	Nukupu'u	25	39	54 (+208)[g]	6.65	0.96	32, 49	0.0062

[a] Range given by Scott et al. (1986). Range used for Bishop's 'Ō'ō was the same as Maui 'Ākepa, Kākāwahie was same as Oloma'o, Greater 'Akialoa was the same as other endangered Kaua'i forest birds.
[b] Effective detective distances (EDD) are given by Scott et al. (1986).
[c] Visits are defined as 10 hr search effort in good weather; 20 hr search effort in fair to poor weather.
[d] Effective Search Area = 2*EDD*Survey Length (L). Repeated searches of the same area were added into L only once.
[e] L = 3 km is a conservative value. This was the minimum survey length during our searches.
[f] Range excluding Oloku'i Plateau (i.e., assuming a population of 10 birds distributed in the Kamakou and Pelekunu Valley area).
[g] Additional fieldwork in the Koai'e-Mōhihi drainages by Puaiohi Recovery Project field crew not included in calculation of $p(0)$.

$$\text{Prob}(k) = \binom{N}{k} p^k (1 - p)^{N-k}$$

N is the number of independent visits made to search for the missing species, k is the number of sightings ($k = 0$ for an undetected species), and p is the probability of detection. We defined N conservatively and weighted it by weather conditions, assuming species will be more difficult to detect with decreasing visibility or deteriorating auditory conditions. We defined one "visit" as 10 hr of search effort in good survey weather or 20 hr under fair to poor weather conditions. We calculated the minimum number of visits,

$$N_{\text{min}} = \frac{\ln \alpha}{\ln(1 - p)}$$

N_{min}, needed for 95% ($\alpha = 0.05$) and 99% ($\alpha = 0.01$) probability of detection: We calculated p from Equation 1 with our minimum survey length = 3 km in 10 hr of good weather. Lastly, we calculated the probability of detecting zero birds during N visits using a conservative 3-km survey length.

DATA COMPARISON

Most forest bird censuses during the last 20 years have used the variable circular plot (VCP) method (Reynolds et al. 1980, Ramsey and Scott 1981) designed to determine multispecies bird densities in structurally complex habitat (Johnson 1995). Rare species require a much larger number of sampling points than common species, and the results of VCP censuses for rare species have yielded large confidence intervals. A sampling technique specific to the target species is most effective for censusing rare species. Differences in methodology preclude direct comparison of densities with results from previous surveys (Ralph et al. 1995b), but a review of the recent history of detections of each of these species is instructive in evaluating their status and distribution.

RESULTS

Since the comprehensive HFBS (Scott et al. 1986) and Avian History Reports (Banko 1979, 1980a, 1980b, 1981a, 1981b, 1984a, 1984b, 1986), little information on the distribution of Hawai'i's rare birds' has been published. Through our search of published and unpublished reports of critically endangered bird detections we found that many descriptions lack supporting documentation or fall into the status of unconfirmed detection according to our criteria. Table 2 summarizes status and recent detection information with sources for all of Hawai'i's critically endangered forest birds.

Search effort totaled 1,685.2 hr. We spent 146 field days and 553 person days in the field for surveys on the islands of Hawai'i (205.6 hr), Maui (832.8 hr), Moloka'i (85.0 hr), and Kaua'i (561.8 hr). Table 1 provides a summary of search effort, weather conditions, and species detections.

We failed to detect seven species during our surveys, but coverage was insufficient to infer extinction ($P \geq 0.95$) for one species, and our results for two species on Moloka'i were inconclusive (Table 3). Due to restricted access, we were unable to search the Oloku'i Plateau on Moloka'i, one of the last areas on that island to harbor that island's endemics. Unconfirmed detections of two species (Maui 'Ākepa and Kaua'i Nukupu'u [*Hemignathus lucidus hana-*

pepe]) by skilled observers provide some hope of their continued survival (Table 2). Below we summarize, by island, survey efforts during the last two decades. Within that context we provide species accounts that include results from our surveys, additional details on historical status, and recent records from published and unpublished sources.

Hawai'i

Survey effort

Variable circular plot surveys conducted after HFBS (1976–1978) on Hawai'i (Scott et al. 1986) include: Hakalau National Wildlife Refuge Surveys (USFWS, unpubl. data 1987–1997); Hāmākua and Ka'ū Forest Bird Survey (DLNR, unpubl. data 1993–1994); Geothermal East Rift Forest Bird Surveys (Jacobi et al. 1994); Kapāpala Forest Bird Surveys (U.S. Geological Survey, unpubl. data 1993–1994); Kīlauea-Keauhou Forest Bird Surveys (Kamehameha Schools Bishop Estate [KSBE], unpubl. data 1993–1996); Kūlani Prison Forest Bird Surveys (U.S. Geological Survey, unpubl. data 1990–1998); Hawai'i Volcanoes National Park Bird Surveys (U.S. Geological Survey, unpubl. data 1991–1994); Ka'ū-Kona 'Alalā Surveys (J. Klavitter et al., unpubl. rep.; Pacific Islands Ecoregion Office, USFWS, unpubl. data), and our rare bird search expeditions 1994–1996 (Table 2).

Species accounts

The Hawaiian Crow (*Corvus hawaiiensis*), hereafter called the 'Alalā, is a raven-sized, primarily frugivorous corvid. It is now found in a single tiny population in South Kona, Hawai'i (National Research Council 1992). Intensive surveys by the USFWS in 1995 using playback recordings in areas of recent reports and over broad areas of Ka'ū and Kona failed to confirm 'Alalā outside known territories in South Kona (USFWS, unpubl. data). We searched an additional 66.0 hr in Ka'ū without detections. While efforts to locate 'Alalā in Ka'ū and Kona were insufficient to be confident of their extirpation from these areas (for $P \geq 0.95$), other surveys have also failed to find this species and it is unlikely to be present (USFWS, DLNR, unpubl. data). As of 1999, in addition to the wild population of 4 'Alalā (Table 1), more than 21 are held in captive breeding facilities (C. Kuehler, The Peregrine Fund [TPF], pers. comm.).

'Alalā once ranged over much of Hawai'i Island but suffered rapid range contraction and population decline from the early 1900s through the 1940s (Banko 1980a). By the 1950s continued habitat degradation, avian diseases, predation, and persecution fragmented the population, resulting in more rapid population declines. The last confirmed sighting outside the current distribution was in 1991 (Table 2).

The 'Ō'ū is a heavy-set, frugivorous Hawaiian honeycreeper with a thick pink bill, and was once common and wide-ranging on all the main Hawaiian Islands (Snetsinger et al. 1998). We failed to find 'Ō'ū during surveys for rare birds on Hawai'i Island in 1994–1996. We are confident that 'Ō'ū are extirpated from South Kona ($P \geq 0.95$). However, search effort was insufficient in Ka'ū, Upper Waiākea, and Pu'u Maka'ala to be confident (for $P \geq 0.95$) of their absence (Table 3). While observers had auditory detections consistent with 'Ō'ū in Ka'ū some of these detections were mimicry by 'Apapane (*Himatione sanguinea*) in response to 'Ō'ū playbacks. During a 1994 survey J. Jeffrey (USFWS, pers. comm.) reported 'Ō'ū whistles without the use of playbacks, but the vocalizing bird could not be found.

The most recent population estimate on Hawai'i Island (1976–1978) was 400 ± 300 individuals (95% CI) with a high density pocket (101–200 birds/km^2) in Upper Waiākea (Scott et al. 1986). Lava flows from Mauna Loa destroyed much of this high density 'Ō'ū habitat in 1984, and no subsequent concentrations of 'Ō'ū have been found since. The last confirmed sighting on the island of Hawai'i was in 1987 (Table 2).

Insufficient visits to promising habitat and poor weather conditions during Upper Waiākea searches make additional effort necessary to determine the status of 'Ō'ū on Hawai'i. The historical concentrations of 'Ō'ū in Upper Waiākea, superior coverage of potential habitat in other areas, and periodic tantalizing reports of 'Ō'ū from this vicinity make it the most likely forest to harbor remnant individuals.

Maui

Survey effort

Specific searches to locate Maui's rarest forest birds were undertaken in 1967 and 1981 Kīpahulu Valley expeditions (Banko 1968, Conant 1981, Conant and Kjargaard 1984). In 1980 (Scott et al. 1986), 1992, and 1996, VCP censuses were conducted along HFBS transects (U.S. Geological Survey, USFWS, DLNR, unpubl. data). Additional surveys were conducted in 1981 (Conant 1981), 1983 (Conant and Kjargaard 1984), 1994–1995 (rare bird surveys; Table 2), and 1994–1996 (Maui Forest Bird Project surveys; U.S. Geological Survey, unpubl. data). After our findings, the Po'ouli Recovery Project 1995–1998 continued surveys in the area (U.S. Geological Survey, unpubl. data). Our 1995 rare

bird surveys in Kīpahulu Valley were limited to the upper shelf and plagued with poor weather. Maui 'Ākepa, Maui Nukupu'u (*Hemignathus lucidus affinis*), and Po'ouli distribution may occur in these undersampled areas.

Species accounts

Bishop's 'Ō'ō (*Moho bishopi*) is a honeyeater reportedly preferring lobelioid nectar (Perkins 1903, Sykes et al. in press). Despite excellent coverage of its presumed range, we did not detect this species during our searches, and it is probably extinct ($P > 0.95$). Search effort was sufficient to be confident of detecting Bishop's 'Ō'ō from combined search areas (Table 3).

Although Bishop's 'Ō'ō is historically known only from Moloka'i, Sabo (1982) described an 'Ō'ō thought to belong to this species seen on Maui in 1981. It is known from two sightings and several putative auditory detections (Table 2). Fossil remains identified as *Moho* sp. (Olson and James 1991) support the historic presence of an 'Ō'ō on Maui as do other reports summarized by Banko (1981a).

Maui Nukupu'u are honeycreepers with long decurved maxillas used for boring out invertebrate prey and nectivory (Amadon 1950). We confirmed the existence of Maui Nukupu'u (one individual; Table 1). Our detection rate was 0.002 detections/hr. Total observation time was 105 sec. All recent sightings (1994–1996) were of an adult male with bright yellow plumage from Hanawī at 1,890 m (Table 2).

The Maui Nukupu'u has been rare historically with infrequent sightings (Banko 1984b; Table 2). The HFBS in 1980 detected one Nukupu'u and they estimated the population size at 28 ± 56 individuals (95% CI). Last indication of breeding was a pair exhibiting courtship behavior in 1989 (R. Fleischer, Smithson. Inst., pers. comm.).

Maui 'Ākepa, a subspecies of the Hawai'i 'Ākepa (*Loxops coccineus*), were locally common in the 1890s (Perkins 1903) but have been rare since the early 1900s. Songs identified as 'Ākepa's were heard on 25 October 1994 in Hanawī at 1,882 m (T. Snetsinger, F. Warshauer, pers. comm.) and 28 November 1995 from Kīpahulu Valley at 1,872 m (T. Casey, S. Hess, pers. comm.), but were not confirmed visually (Table 2). Auditory detections of Maui 'Ākepa require visual confirmation because of possible confusion or mimicry with similar songs of Maui Parrotbill (*Pseudonestor xanthophrys*).

Observers of the HFBS of 1980 detected eight 'Ākepa in East Maui from Waikamoi, Hanawī, and Kīpahulu. Scott et al. (1986) described the population as relictual with a patchy distribution, estimated at 230 ± 290 individuals (95% CI). The last well-documented visual detections occurred in 1988 (Table 1).

The Po'ouli is a bark and an epiphyte forager discovered in 1973 (Casey and Jacobi 1974). We confirmed the continued existence and successful breeding of the Po'ouli (five to six individuals; Table 2) in 1994 after nearly two years without a sighting (Pratt et al. 1993). The detection rate for Po'ouli was 0.013 detections/hr. Total observation time was 11.75 min (Table 1). Sightings were from Kūhiwa drainage of Hanawī and included discovery of a family group (two adults and one fledgling) on 1 September 1994 at 1,890 m elevation (Table 2). We observed the fledgling Po'ouli begging and being fed. We found additional birds at 1,890 m and 1,500 m elevations and had an auditory detection at 1,902 m elevation east of the main Kūhiwa drainage (Table 2). Typical Po'ouli vocalizations are simple chips that readily blend with the call notes of several of Maui's other honeycreepers. During our searches we observed Maui 'Alauahio (*Paroreomyza montana*) and Maui Parrotbill respond to Po'ouli playbacks. Thus, auditory detections for this species should be confirmed visually.

Our results prompted the initiation of a project to collect more life history information, manage introduced mammalian predators, and evaluate other management strategies required to recover this very rare honeycreeper (Reynolds and Snetsinger 1994).

The Po'ouli's population has plummeted since it was first described (Banko 1984a, Kepler et al. 1996, Baker *this volume*). The 1980 HFBS recorded three birds, and Scott et al. (1986) estimated total population size as 140 ± 280 individuals (95% CI). Only a few observations have been documented since that time (Table 2).

MOLOKA'I

Survey effort

Moloka'i birds were surveyed in 1979, 1980 (Scott et al. 1986), 1988, and 1995 (DLNR, unpubl. data). An active presence of visitors and staff at The Nature Conservancy (TNC) Kamakou Preserve has not detected any rare species in the area, except an 'I'iwi (*Vestiaria coccinea*) in 1995 (Ed Misaki, TNC, pers. comm.). Ornithologists have not surveyed the Oloku'i Plateau, ungulate-free and one of the most pristine locations in the Hawaiian Islands, since 1988; Oloku'i may still harbor critically endangered birds.

Species accounts

Oloma'o, or Moloka'i Thrush, was abundant into the early 1900s (Perkins 1903) but was rare and declining before 1930 (Munro 1944). De-

tection probabilities suggest the Oloma'o has been extirpated from Kamakou-Pelekunu (assuming a population of 10 outside of the Oloku'i Plateau), but additional searches are required to improve confidence levels (Table 3). The extremely high density of the vociferous, dull gray-brown, Japanese Bush Warbler (*Cettia diphone*) throughout the native forest of Moloka'i further reduced the chance of detecting Oloma'o (DLNR, USFWS, unpubl. data). We did not search the remote Oloku'i Plateau, and it may still harbor the small population of Oloma'o present during the 1980 HFBS. The last well-documented sightings of Oloma'o were from 1963 (Pekelo 1963), 1975, (Scott et al. 1977) and 1980 (Scott et al. 1986), with additional unconfirmed detections since that time (Table 2).

Kākāwahie (*Paroreomyza flammea*), also called Moloka'i Creeper, was common in 1907 (Bryan 1908) but extremely rare by 1930 (Munro 1944). The likelihood of the Kākāwahie being extirpated from Kamakou-Pelekunu was also high based on detection probability ($P \geq 0.95$; Table 3). Searches have been unsuccessful in finding Kākāwahie since the last sighting in 1963, including surveys on the Oloku'i Plateau in 1980 and 1988 (Table 2). Considering our results and the failure of previous surveys to find this species since 1963, we believe the Kākāwahie to be extinct.

The 'I'iwi is a largely nectivorous honeycreeper, abundant in the high elevation forests of Hawai'i, Maui, and Kaua'i. It is rare on O'ahu, Moloka'i, and West Maui, but the state of Hawai'i lists it as endangered only on O'ahu. VanderWerf and Rohrer (1996) recently discovered a small resident population on O'ahu. Observers found one 'I'iwi on Moloka'i during the 1995 Moloka'i Forest Bird Survey and Rare Bird Search (Table 2; DLNR, unpubl. data) at 1,220 m above Kamalō Gulch on 23 May 1995 (Table 1). The detection rate was 0.012 detections/hr, and total observation time was 30 sec. The HFBS (Scott et al. 1986) found 12 'I'iwi from Kamakou Preserve and Oloku'i Plateau and estimated the population at 80 ± 65 individuals (95% CI).

The 'I'iwi is extremely susceptible to mortality from avian malaria (Atkinson et al. 1995). The remains of a juvenile 'I'iwi from forests of Lāna'i (T. Pratt, U.S. Geological Survey, and R. Pyle, B. P. Bishop Museum, pers. comm.) and the 'I'iwi's high-flying habits lead us to speculate that 'I'iwi found on Moloka'i may have been from a source population on Maui.

KAUA'I

Survey effort

Portions of the Alaka'i Swamp Wilderness Area, along HFBS transects, have received significant forest bird monitoring effort while other areas on Kaua'i remain unexplored by knowledgeable ornithologists. All of Kaua'i's historical avifauna was present into the 1960s (Richardson and Bowles 1964). Extensive surveys by John Sincock from 1968 to 1973 (Sincock et al. 1984), an eight-day expedition in 1975 by Conant et al. (1998), and the HFBS surveys in 1981 turned up all but the Greater 'Akialoa (*Hemignathus ellisianus*; Scott et al. 1986). In the last two decades, Hurricanes Iwa (1982) and Iniki (1992) raged through the forests, home to at least five of Kaua'i's most critically endangered birds. Engilis and Pratt (1989) and Pyle (1983) reported devastating effects of Hurricane Iwa on several species. USFWS and DLNR have conducted extensive VCP surveys (1985, 1989, 1993, 1994) along the 1981 survey transects. We conducted rare bird surveys from 1995 to 1996 (Table 1). The Puaiohi Recovery Project, based at a field camp along Koai'e and Kawaikōī streams (August 1995–1999), averages 600 person hr/mo of field effort. While most of Kaua'i's rain forest is remote and difficult to get to, easy access to intact native forest makes the Kōke'e area one of the most extensively bird-watched areas in the Hawaiian Islands.

Species accounts

The Kāma'o was sighted regularly until 1985 (T. Telfer, DLNR, pers. comm.). Our coverage of the search area was extensive, and we had a high probability of detecting Kāma'o present in the combined search areas (Tables 1 and 3). We detected none, and the Kāma'o is probably extinct ($P \geq 0.95$; Reynolds et al. 1997b). Periodic reports of this species since 1995 are unconfirmed (Table 1).

We found Puaiohi, or the Small Kaua'i Thrush, in greater numbers than expected (55–70 individuals). They were widely distributed across the Alaka'i Plateau from 1,060 to 1,280 m elevation, occupying five main drainages (South Kawaikōī-Kōali, Mōhihi, Waiakōali, Halehahā-Halepa'akai, and Koai'e streams). The detection rate was 0.318 detections/hr and the total observation time was 7.04 hr (Reynolds et al. 1997b). We observed a fledgling on 26 April 1996. One nest and six birds were discovered in the Koai'e study site in 1995 (T. Casey, KSBE, pers. comm.) and 50 nests and 75 birds were monitored in 1996 (U.S. Geological Survey, unpubl. data). Our data in combination with unpublished research on the Mōhihi-Koai'e population indicate the Puaiohi population may exceed 200 birds (Reynolds et al. 1997b; T. Snetsinger and C. Herrmann, unpubl. data). In 1996, 4 Puaiohi were hatched in captivity at Keauhou Bird Conservation Center from eggs collected at

the Koai'e study site, 10 were added to the flock in 1997, and 16 were hatched from eggs produced in captivity 1998 (C. Kuehler, TPF, pers. comm.).

The sedentary behavior and infrequent vocalizations of the Puaiohi make this species difficult to census. Some Puaiohi responded readily to playbacks of calls and songs. The most recent Puaiohi population estimate was 20–34 individuals (95% CI; Scott et al. 1986). Scott et al. (1986) noted the sampling design may have been biased against Puaiohi, which is associated with streams.

The 'Ō'ō'ā'ā, a black, large-bodied nectarivore, is vocally conspicuous and responds well to playbacks (Conant et al. 1998; T. Telfer, DLNR, pers. comm.). We did not detect the 'Ō'ō'ā'ā during our surveys. Detection probability was very high for 'Ō'ō'ā'ā in combined search areas, and our failure to find the species suggests it is extinct ($P \geq 0.95$; Table 3). The population estimate for 'Ō'ō'ā'ā from surveys 1968–1973 was 36 ± 29 individuals (95% CI; Sincock et al. 1984). Observers regularly sighted two or three 'Ō'ō'ā'ā from 1975 to 1981, but these birds had vanished by the 1989 DLNR survey (Table 2). We found that White-rumped Shama (*Copsychus malabaricus*) answered 'Ō'ō'ā'ā recordings and heard 'I'iwi mimic parts of 'Ō'ō'ā'ā song.

The last published 'Ō'ū sighting from Kaua'i was in 1989 in the southeastern Alaka'i (Engilis and Pratt 1989, Pyle 1989). From our detection probabilities, we believe the 'Ō'ū is extinct on Kaua'i ($P \geq 0.95$; Table 3). Auditory detections in 1995 to 1997 (U.S. Geological Survey, unpubl. data) along Koai'e Stream were unconfirmed. Estimated population size in 1968 to 1973 was 62 ± 82 individuals (95% CI; Sincock et al. 1984) and 3 ± 6 individuals (95% CI) in 1981 (Scott et al. 1986).

Greater 'Akialoa on Kaua'i, common in the 1890s (Perkins 1903), was last well documented in 1964 (Huber 1966). The likelihood of Greater 'Akialoa being extinct was high based on detection probability ($P \geq 0.95$; Table 3). An unconfirmed 1969 report may have been the last sighting (Table 2). Vocalizations of this species were never recorded. Greater 'Akialoa's extraordinary bill length of 6 cm (S. Johnson, unpubl. data) would make visual identification unquestionable.

Kaua'i Nukupu'u, historically an uncommon species, was extremely rare by 1960 (Perkins 1903, Richardson and Bowles 1964). We did not record Kaua'i Nukupu'u during our surveys nor did observers with the HFBS observe it (Scott et al. 1986). However, skilled observers reported three (unconfirmed) sightings of at least one male and one female) in 1995 near the Koai'e Gauging Station (Table 2; T. Casey and J. Jeffrey in Conant et al. 1998). Our lack of detections combined with our analysis of detection probability ($P \geq 0.95$) suggest the population is less than 10 birds.

Despite extensive fieldwork, J. Sincock observed Kaua'i Nukupu'u only twice from 1968 to 1973 (Sincock et al. 1984). Conant et al. (1998) report a 1975 sighting, and several observers provide convincing reports from the 1980s and 1990s (Table 2). Other Nukupu'u reports require additional confirmation due to the possible confusion with Kaua'i 'Amakihi (*Hemignathus kauaiensis*).

DISCUSSION

Six of the 13 missing Hawaiian birds are likely to be extinct (Kāma'o, 'Ō'ō'ā'ā, Bishop's 'Ō'ō, 'Ō'ū on Kaua'i, Greater 'Akialoa, and Kākāwahie), three of which disappeared in the last decade. Moloka'i's endemic Oloma'o could probably be added to this list, but to be confident of its extinction a thorough search of the restricted Oloku'i Plateau is warranted. Five of Hawai'i's rarest forest birds still exist ('Alalā, Puaiohi, Po'ouli, 'I'iwi on Moloka'i, and Maui Nukupu'u), and the results of our surveys and investigation were inconclusive for three additional populations (Kaua'i Nukupu'u, Maui 'Ākepa, 'Ō'ū on Hawai'i). Reports of Kaua'i Nukupu'u in the Alaka'i Swamp (1994, 1995), and 'Ō'ū from the Ka'ū (1993, 1995) and Pu'u Maka'ala (1991, 1992, 1996) reported to U.S. Geological Survey or the Bishop Museum (R. Pyle, pers. comm.) suggest that a few individuals of these species may still exist. Auditory detections of Maui 'Ākepa (1995, 1996) in combination with sightings within the last decade (Engilis 1990; T. Casey, pers. comm.) and insufficient coverage of the potential range make its status unknown.

Rare Hawaiian birds have been rediscovered after they were presumed extinct or have been found in larger populations than expected (Richards and Baldwin 1953, Richardson and Bowles 1964, Banko 1968, Shallenberger and Vaughn 1978, Sabo 1982, VanderWerf and Rohrer 1996, Reynolds et al. 1997b, VanderWerf et al. 1997). We hope this will also be the case for some of Hawai'i's rare species that we failed to find. While we searched habitat with historical records and/or high native-species diversity to increase our chances for rare bird detections, similar habitat with recent sightings of critically endangered species outside our search area exists.

Long-term declines in Hawaiian native bird populations signal the need for additional action against known threats such as feral ungulates,

alien weeds, introduced predators, and avian disease vectors (Richardson and Bowles 1964, Atkinson 1977, Sincock et al. 1984, Jacobi and Scott 1985, Vitousek et al. 1987, Atkinson et al. 1995). Active ecosystem management is the best way to conserve endangered species before they become rare and a species-by-species approach is impractical. Fortunately, endemic and endangered species occur in many areas held by federal and state agencies or private landowners with strong interests in conservation. Aggressive management and long-term population monitoring are essential to protect these areas and the endangered species they harbor.

We believe those birds not sighted in the last 20 years with high probabilities of being extinct should be taken off the Federal Endangered Species List to update the list, heighten awareness of Hawai'i's extinction crisis, and focus recovery on ecosystems and the species that we can assist. We encourage field observers to take detailed notes and report or publish their sightings so that monitoring the status of Hawai'i's rare birds will be easier.

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