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Cover illustration: Left coracoid bones of the Hawaiian Hawk, *Buteo solitarius*. Fossil bone from Kauai, presumably female (left) compared with modern male bone (right) [see page Olson & James, p. 65].

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Prehistoric Status and Distribution of the Hawaiian Hawk (*Buteo solitarius*), with the First Fossil Record from Kauai

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Introduction

Although listed as an endangered species, the Hawaiian Hawk or *'io* (*Buteo solitarius* Peale, 1848) is widely distributed on the island of Hawaii (Scott *et al.*, 1986), where it now feeds mainly on introduced rodents and thus may even have benefited from anthropogenic changes in the fauna and flora. That this relatively large, seemingly vagile predator has not been recorded with certainty in the historic period on any of the other Hawaiian islands has long been puzzling. The diverse deposits of fossil birds in the Hawaiian Islands (Olson & James, 1982, 1991; James & Olson, 1991) have hitherto yielded scant information on the Hawaiian Hawk, the only record away from the island of Hawaii being a single occurrence on Molokai (Olson & James, 1982).

First Kauai Occurrence

Here we report the first fossil record of Hawaiian Hawk for Kauai, from the same area in the Makawehi dunes near Poipu where almost all other fossil birds have been found so far on Kauai (Olson & James, 1982). Fossils from these dunes represent an interesting but far from complete avifauna, most of which was recovered in 1976 and 1977, with little new being added in subsequent years.

On 1 March 1996, Olson, with D.A. and L.P. Burney, located a new fossil site in the Makawehi Dunes, here designated K-4 (coordinates taken by Global Positioning System = 21°52'48"N, 159°26'03"W). This site faces south on a cliff overlooking the ocean where it is exposed to onshore winds. Near the top of the cliff, these winds are eroding unconsolidated, clean, yellowish sand that is overlain by an extremely indurated layer of light grayish sandstone about 25 cm thick. The wind creates hollows under this indurated layer, which is sometimes held up temporarily by pillars of more consolidated sand, until the indurated layer becomes too cantilevered to support the overlying strata and breaks off in large blocks that litter the slopes of the cliff.

Bones at this site are weathering out of the hollows beneath the indurated layer and occur both in place and scattered through the sand that has cascaded down the slope. They appear to be mineralized and are heavily encrusted with sand. Although the nature of dunes makes it notoriously difficult to derive meaningful stratigraphic inferences, we believe that it is likely that the bones from this site are older than Holocene. Because they occur at the windward edge of a sea-cliff, there now exists no source for the sand under which the bones were buried. Therefore, the deposition of the bones must have taken place during a lower sea-level stand when the dunes originally formed and before the dunes became perched above cliffs by the erosion of a rising sea.

Almost all of the bones collected at site K-4 are of Wedge-tailed Shearwaters (*Puffinus pacificus*), a seabird that still attempts to breed in the area. The only exception was a complete left coracoid of a hawk. This was originally heavily encrusted with sand, which was removed with dilute acetic acid. The specimen (Fig. 1) was found to be of a size compatible with females of *Buteo solitarius* (Table 1), with which it agrees in all other details of morphology, so we identify it with that species.

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Table 1. Measurements (mm) of comparative skeletons of *Buteo solitarius* and fossils.

	Coracoid		Humerus	
	Length	Width of sternal facet	Length	Distal width
Females	34.2–34.8	12.6–12.9	82.0–84.6	14.6–14.9
Males	30.3–32.3	10.9–12.6	71.6–77.9	12.9–13.8
Kauai fossil	34.3	12.6+		
Molokai fossil			83.7	14.6

Scarcity of the Hawaiian Hawk in the Fossil Record

Remains of the Hawaiian Hawk are encountered occasionally in lava tubes on the leeward slopes of the island of Hawaii (S. Olson & H.F. James, unpubl. data). In almost all instances, however, these are in an archeological context, among the refuse of human occupation, suggesting that Hawaiians caught these birds and presumably ate them or used their feathers. We have encountered only a single individual, a skeleton in a lava tube on Mt. Hualalai, that evidently was not preserved as a result of human agency.

On Maui, natural accumulations of bones of birds have been found in numerous lava tubes on the leeward slopes of Mt. Haleakala. Although a considerable variety of species is represented, not a single bone of a hawk has yet been found. This negative evidence is inconclusive for *Buteo*, especially considering that the endemic harrier *Circus dossenus*, which is known from Molokai and probably occurred on Maui as well, is likewise absent from the fossil record there.

In the extensive dune systems of Molokai, where large samples of fossil birds have been obtained at the Moomomi Dunes and at Ilio Point, we have encountered remains of *Buteo* only once. These were 3 bones (see "Material examined") which may well have come from a single individual, found in a large, steep, sheltered depression in the dunes known as Site 6 (Olson & James, 1982). Large concentrations of bones of Bonin Petrel (*Pterodroma hypoleuca*), along with remains of fish and shells of edible mollusks such as opihi and pipipi, indicate former human occupation of this site, so that most bird bones here may derive from midden deposits. It is possible, though unlikely, that a hawk could have been brought to Molokai from Hawaii. More probably it was a local bird that became incorporated into the dunes as a result of human activity. Because its possible human associations make the record somewhat equivocal, the fossil from Kauai, which must antedate the arrival of humans in the islands, becomes the more significant.

The island of Oahu has a particularly rich fossil record. Bones of birds occur primarily in Holocene sediments trapped in limestone sinkholes at Barbers Point, and in a Pleistocene lake bed at Ulupau Head that is more than 120,000 yr old (James, 1987). In the Pleistocene site, bones of *Buteo* are unusually common, the birds apparently having been attracted to the lakeshore environment. However, these bones are not identifiable as *Buteo solitarius* but are from a larger species of as yet undetermined affinities. Either the hawk represented at Ulupau evolved into the modern Hawaiian Hawk, or the species became extinct in the islands. In either case, not a single bone of *Buteo* has yet been found

Fig. 1. Left coracoids of Hawaiian Hawk (*Buteo solitarius*) in ventral view. The larger specimen on the left (USNM 490733) is a fossil from the Makawehi dunes on Kauai, presumably from a female, contrasted with that from a modern skeleton of a male, which is the smaller sex (BPBM 147954). The scale is in mm.

in the very extensive accumulations of Holocene bones from Barbers Point.

Several historical and ecological factors may explain the scarcity of *Buteo solitarius* in the fossil record of the Hawaiian Islands, apart from the fact that predators usually occur in lower numbers than prey. Two extinct lineages of raptors once occurred in the archipelago that had diverged greatly from their ancestral stock, the long-legged owls of the genus *Grallistrix*, and the harrier *Circus dossenus*. Both had evolved the proportions of bird-catching hawks of the genus *Accipiter* and were well adapted for preying on small forest birds (Olson & James, 1991). In addition, a sea-eagle (*Haliaeetus* sp.) once lived in the islands. No remains of these other predators have yet been found on the island of Hawaii.

Buteo solitarius may be a relatively recent arrival in the islands because it has not differentiated greatly from other species of *Buteo*. Like many species in that genus, it may have been restricted to more open environments and edge situations. The combination of the effects of active volcanism on vegetation and the possible absence of competitors may mean that the island of Hawaii was always the principle redoubt of *Buteo solitarius*.

The fossil record from Kauai shows that the Hawaiian Hawk is capable of dispersing naturally anywhere in the main Hawaiian archipelago, though whether it ever established viable populations anywhere besides Hawaii proper remains undetermined. The species should have benefited from Polynesian creation of more open habitats and the introduction of *Rattus exulans*, so its historical restriction to the island of Hawaii is a little difficult to understand unless it was hunted to extinction on the smaller islands. If the mention of "two large brown hawks or kites" from Kauai on Cook's voyage (Medway, 1981:107) refers to this species, then it disappeared from Kauai shortly after 1778.

Conservation implications

The restriction of the Hawaiian Hawk to the island of Hawaii in historical times and possibly before may have been the result of a combination of factors both natural and human-caused that are no longer in effect. The original forested environments of the islands and their native predatory birds are largely or entirely vanished. The introduction of rats (*Rattus*) by both Polynesian and European colonizers provided a food source for *Buteo* that may be as good or better than existed in prehistoric times, and there is more open habitat in the islands than existed at first human contact. Furthermore, human predation for food or shooting as "vermin" has been almost entirely eliminated. Because populations of Hawaiian Hawk could probably survive on Hawaiian islands other than Hawaii proper, introduction, or re-introduction as the case may be, to other localities may be worth considering as a possibility in further management of the species.

Material examined. KAUAI: Makawehi dunes, Site K-4: nearly complete left coracoid (USNM 490733). MOLOKAI: Moomomi dunes, Site 6: complete right humerus (USNM 386108), a left radius (USNM 386110, length 83.5 mm), and an ungual phalanx (USNM 386109, length 20.5 mm). The humerus falls well within the size range for females of *Buteo solitarius* (Table 1), and we assign all 3 bones to that species. HAWAII: various sites on the leeward side, mostly archeological midden, specimens in USNM and BPBM. Modern comparative material from the Bishop Museum comprised 11 complete skeletons (5 males and 6 females after unsexed and missexed individuals were assigned on size): BBM-X 147198 147954; BPBM 159018, 159514, 175751, 177085, 178144, 178298, 179417, 179418, 179419.

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New Record of Branchiostomidae from the Hawaiian Islands (Chordata: Cephalochordata)

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The subphylum Cephalochordata presently includes 20 described species in the Indo-Pacific Region. Two species are now known from Hawaiian waters. *Epigonichthys maldivensis* (Forster Cooper, 1903) was reported from Barber's Point, Oahu, at a depth of 32-40m in 1962 (Eldredge, 1967) and is a widespread species, ranging from East Africa to New Caledonia. Cephalochordate larvae, species unknown, have been collected in plankton samples between Oahu and Hancock Seamount at depths to 200m (Boehlert & Mundy, 1992).

Epigonichthys lucayanum (Andrews) **New state record**

Epigonichthys lucayanum is also known historically as *Asymmetron lucayanum* Andrews, 1893 and *Asymmetron caudatum* Willey, 1896 (see Richardson & McKenzie, 1994). This species is widespread with a discontinuous distribution on the east coast of the Americas and in the tropical parts of the central Indo-Pacific region from Madagascar to eastern Australia and the Solomon Islands. The present record reflects a significant

range extension for this species. The form and meristic characteristics of the Hawaiian specimens fall within the range previously observed elsewhere for this species (see Gibbs & Wickstead, 1996). The values obtained at different localities, not to mention the disjunct distribution of the species, make it possible that a species complex rather than a single species is involved (Richardson & McKenzie, 1994). This species is likely to be widespread in shallow water to 100m depth on coarse and sand bottoms. *Epigonichthys lucayanum* is frequently found in association with other chephalochordates, and *Branchiostoma belcheri*, *B. malayana*, and *E. cultellus* may well be collected in Hawaii.

Material examined: KAUAI: Hanalei Bay, July 1994, 50m from reef edge at 30m in medium-sized carbonate sand (BPBM Y263, 5 specimens), R. DeFelice. OAHU: Kaneohe Bay, March 1995, at 20m on Ahu o Laka sandbank (BPBM Y264, 6 specimens), D. Muir.

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