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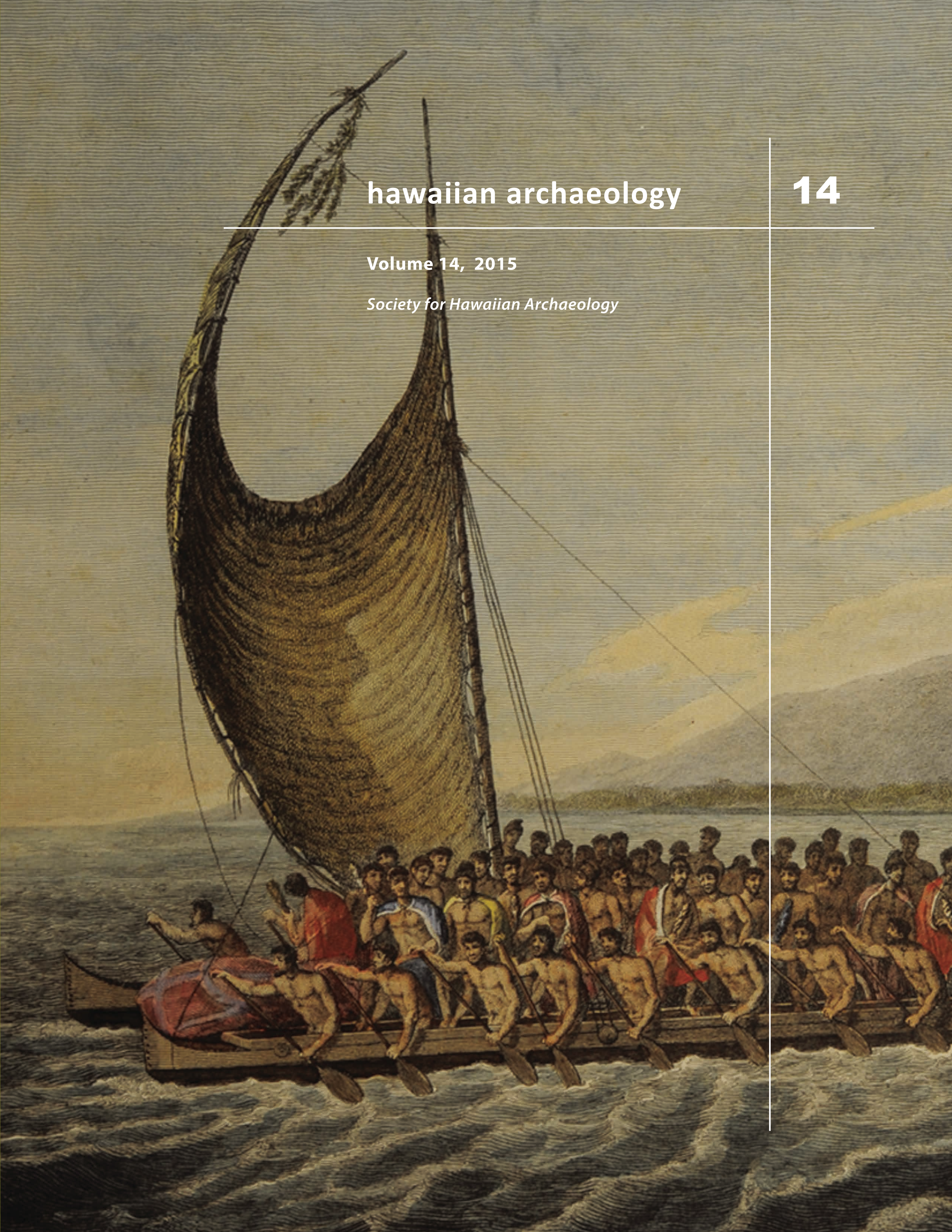

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# Extinct and Extirpated Birds and Other Vertebrates in the Faunal Assemblage of Hālawa Cave, a Rockshelter in North Hālawa Valley, O‘ahu, Hawai‘i

**Paul E. Langenwalter II**
Department of Anthropology, Biola University

**Helen F. James**
Department of Vertebrate Zoology, National Museum of Natural History, Smithsonian Institution

## Abstract

Hālawa Cave (50-Oa-B01-020) is a rockshelter located about 4.8 km inland of Pearl Harbor in the North Hālawa Valley, O‘ahu, Hawai‘i. Evidence of Native Hawaiian occupation is found in an approximately 50 cm deep midden, inside of the 6 x 8 m/sq shelter. The site appears to have been intermittently occupied as a base for local resource procurement beginning no later than the fifteenth century and continued to be used into the nineteenth century. Wood cutting was an important activity associated with the site. The vertebrate fauna is represented by a sample of 65 specimens including fish, bird and mammal bones. This assemblage provides evidence of limited vertebrate animal use, resource procurement areas, local paleoenvironment, and butchering. Fish species dominate the assemblage. Two of four avian species are endemic to the Hawaiian Islands and globally extinct, or extirpated from O‘ahu. Remains of the extinct O‘ahu *moa-nalo* (*Thambetochen xanion*) and the endangered Hawaiian Petrel (*Pterodroma sandwichensis*) occur in sediments from the occupation of the site, however only the Hawaiian Petrel is firmly associated with human occupation. Introduced species, including Red Junglefowl (*Gallus gallus*), dog (*Canis lupus familiaris*) and pig (*Sus scrofa*) were significant food sources consumed at the site. The vertebrate assemblage reflects a broad based procurement strategy with each vertebrate class being a significant contributor to the biomass represented in the assemblage.

## Introduction

The vertebrate animal remains recovered from the excavation of Hālawa Cave, ‘Ewa, O‘ahu (50-80-09-502) provide an example of prehistoric animal use at a small intermittent camp associated with wood cutting and other local activities. Hālawa Cave is a rockshelter located in the North Hālawa Valley approximately 4.8 km (2.98 miles) inland and northeast of Pearl Harbor. The cave contains a midden that extends onto a level area fronting the shelter. The midden is shallow, with a maximum depth of less than 0.5 m (20 in). Artifacts of stone, bone and plant materials were recovered, along with other ecofacts including *kukui* nut shells, shellfish, and vertebrate remains (Langenwalter and Meeker 2015). The vertebrate sample includes 65 bones and bone fragments representing 15 species of fishes, birds and mammals. Four bone tools made of dog and bird bone were recovered, as well. The fauna of Hālawa Cave is particularly important because two of the four avian species represented in the assemblage are extinct, or extirpated from the island of O‘ahu.

Avian remains in all Hawaiian archaeological sites are of particular interest since half or more of the endemic species of birds vanished from the islands in the late Holocene, apparently due to ecological changes related to colonization by humans, and are now only known from their bones (Olson and James 1991; James and Olson 1991; James 1995). This rampant extinction depleted a resource of potential importance to the pre-contact Hawaiians, and masked the true biotic richness of Hawaiian ecosystems.

The site was originally interpreted by its excavator William Wallace (personal communication, 1986) as a special-use site that may have been a camp used by wood cutters procuring resources from the forest on the adjacent slopes of the valley. A more recent study explores additional uses for the cave (Langenwalter and Meeker 2015), as does the present study. The artifactual remains at the site seem consistent with an entirely prehistoric occupation. However, butchering evidence and radiocarbon dating indicate that the occupation extended into the post-contact period.

The sample studied here was recovered from an exploratory excavation of Hālawa Cave by William J. Wallace as part of the 1966 University of Hawai‘i spring field school as a secondary project, in conjunction with their primary excavations at Kaloko Cave (Wallace, Wallace and Meeker 1966). Later, the site was considered for further sampling by other field schools, but passed over in favor of better sites (Meeker 2012). Hālawa Cave, also known as Hālawa Heights Rock Shelter, was originally designated O16 and later as Bishop Museum # 50-Oa-B0l-20. Wallace later attempted to complete the Hālawa Cave excavation report between 1986 and 1988. The present study began as part of the 1980s attempt (James 1987a; Langenwalter 1988a). A separate study of the archaeology of Hālawa Cave has been recently completed using the site records, photographs and related documentary resources recently located at the Braun Library in Los Angeles, California (Langenwalter and Meeker 2015). Aside from the vertebrate fauna and a sample of specimens located at the Bishop Museum, Honolulu, Hawai‘i, the whereabouts of much of the collection from the site is unknown.

The analysis of the vertebrate sample is focused on a reconstruction of animal use at the site, and the relationship of the extinct and extirpated avian species in the assemblage to the human occupation. Some information about site catchment and the relative importance of the species used for food during the occupation is reflected by the species represented. This includes procurement in the immediate vicinity of the site as well at a distance. The bone artifacts provide evidence of the selection of raw materials for manufacturing and some of the products used at the site. There is insufficient information to address other domains of inquiry.

## The Site

Hālawa Cave is a rockshelter with interior dimensions of approximately 7.6 x 10.6 m. The south facing entrance opens onto the steep slope of basalt outcropping on the north side of the North Hālawa Valley. The site is situated 30 m below the top of ‘Aiea Ridge which bounds the north side of the valley, and approximately 60 m above the valley floor. The shelter was formed from a lava tube or bubble which opened onto the slope. A rock retaining wall is located at the entrance, just inside of the dripline. Most of the wall and ceiling of the rockshelter is composed of basalt, although part of the ceiling consists of a breccia composed of angular, cobble-sized clasts imbedded in a silty groundmass. The ceiling attains a maximum of 2 m above the current floor of the shelter, arching to less than 30 cm at the back and around the sides. Four recesses, each several feet in breadth and depth, are located around the periphery (Langenwalter and Meeker 2015, fig. 1).

The cave fill and midden consist of roof fall overlain by stratified sediments that reach a maximum depth of approximately 50 cm (18-20 in) in the central part of the rockshelter (Langenwalter and Meeker 2015, fig. 2). The base of the midden and underlying paleosol sits on an irregular deposit of roof fall consisting of angular clasts (breccia) overlaying an unknown base, probably the floor of the original lava tube/bubble. Its composition varies, with some areas characterized by smaller pieces collected in a relatively flat-laying mass and other areas by large boulders that penetrate upward to depths as shallow as 15 cm (6 in). In areas outside the excavation trench, small boulders penetrate above the current shelter floor.

The sediments, which form the midden and paleosol, are thin and lensatic, pinching out around the periphery of the rockshelter, exposing the underlying breccia exposed in the alcoves and parts of the periphery of the rockshelter. The sediments are comprised of silt and sand which are likely a mixture of clasts derived from local and aeolian origins. Reddish clasts that are pebble-sized or larger appear to have been derived from the walls of the shelter. There is no visible evidence of clay in the deposit.

The central part of the midden contains sediments that can be broadly divided into three strata. The lower-most stratum, Stratum III, is a paleosol, which appears to predate the human occupation. This stratum contains vertebrate sub-fossils. Some of the artifacts and ecofacts recovered from the uppermost part of this stratum may have been reworked from elsewhere in the rockshelter. Strata I and II are complex anthroposols, reflecting multiple episodes of occupation during which there appears to have been occasional modification of materials from earlier periods. Both Strata I and II contain lenses and localized concentrations of ash, charcoal, shell and fish scales, as well as several features (Wallace 1987). The concentrations appear to represent the residuum of debris accumulated over short periods of time (Langenwalter and Meeker 2015).

Radiocarbon dating places the first occupation of Hālawa Cave beginning no later than the 15th century and its probable abandonment during the 19th century. These dates are based on 2 sigma calibrations using Beta Analytic calibration software (Beta Analytic 2013). A dog tooth from Stratum II, the deepest anthroposol in the rockshelter, yielded a date of cal AD 1430 to 1470 (cal BP 520 to 480; 440 ± 30 BP, BETA-354010) (Figure 1), establishing use of the rockshelter by the mid-fifteenth century. Stratum II contains evidence of multiple hearths from several episodes of occupation that accumulated a deposit up to 30 cm (12 in) thick over the semi-sterile paleosol, which forms Stratum III. The relationship of this date to the sequence of activity represented in Stratum II is unclear, as is the length of the period of deposition represented in Stratum II.

Occupation during the post-contact period commenced during the deposition of the lower-most part of Stratum I or the upper-most part of Stratum II. A butchered pig skull fragment was recovered from the 10-20 cm (4-8 in) level in Unit E-5 in proximity to the boundary between the two strata. The specimen, a temporal fragment from the root of the zygomatic arch, bears a cut mark from a cleaver or similarly bladed steel tool. This specimen yielded an AMS date (110 ± 30 BP, BETA-356008) with four intersects ranging from the late 17th century to the mid-20th century (cal AD 1680 to 1760 (cal BP 270 to 190) and cal AD 1770 to 1780 (cal BP 180 to 170) and cal AD 1800 to 1940 (cal BP 150 to 10) and cal AD Post 1950) (Fig. 1). Given the presence of the steel tool mark necessarily introduced in the post-contact period, the earliest intersect (cal AD 1680 to 1760) is not a valid date for the specimen; and, given the stratigraphic context of this specimen the latest intersect which includes the mid-20th century is unlikely.

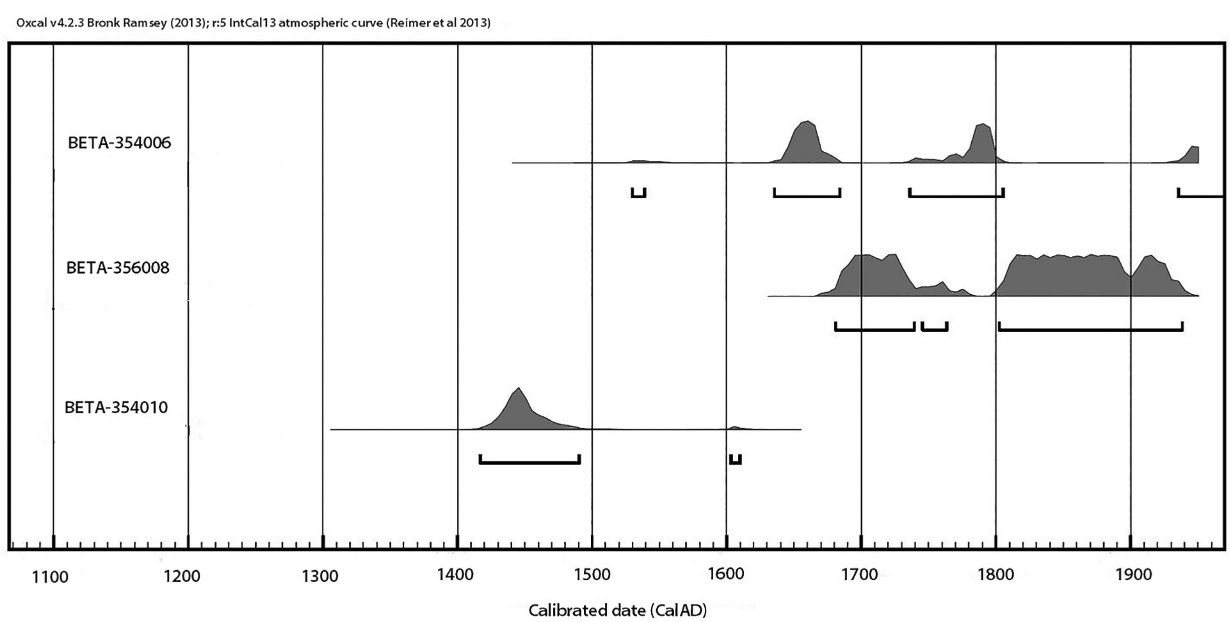


Figure 1. Oxcal plot of radiocarbon dates for Hālawa Cave occupation.

The terminal occupation of the site by Native Hawaiians is not easily placed. The assemblage belonging to the terminal occupation contained in Stratum I and on the surface of the cave floor includes artifacts from more recent non-native use. Some of the non-native artifacts mentioned in the site records can be clearly assigned an origin, including refuse from a Marine Corps exercise in the rockshelter. The cultural and temporal context of some specimens is equivocal, including the "bullet caps," mentioned in unit level records and taken to mean musket caps. While it is true that musket caps are known from other Native Hawaiian sites and not necessarily out of place with native occupation, these specimens could not be located for verification of their identification (Langenwalter and Meeker 2015).

The midden in Stratum I is composed of sands containing remnants of multiple hearths, ash and charcoal concentrations. A date obtained from a dog bone (230 ± 30 BP, BETA-354006) recovered from Stratum I provided a date with multiple intersects. These range from the late 17th century to the middle of the 20th century (cal AD 1640 1680 (cal BP 310 to 270) and cal AD 1760 to 1770 (cal BP 190 to 180) and cal AD 1780 to 1800 (cal BP 170 to 150) and cal AD 1940 to post 1950 (cal BP 10 to post 1950) (Fig. 1). The specimen may belong to any of the three earlier calibrations. However, the latest calibration (mid-20th century) is unlikely given the similarity in preservation of the specimen to others in the remaining collection.

## Methods

Vertebrate remains were collected from the surface of the site and from three of the four excavation units. Each unit was 5 x 5 ft (1.52 x 1.52 m), and excavated in 10 cm (4 in) increments from the existing ground surface to sterile. The site was excavated in feet and inches. Matrix was passed through 1/8 in (3.18 mm) mesh screen to recover cultural residuum, including ecofacts. The vertebrate data compiled in this study are recorded individually in a separate catalogue. Fishes were identified by Arnold Y. Suzumoto (Bishop Museum), birds by Helen James (Smithsonian Institution) and mammals by Paul E. Langenwalter (Biola University).

Taxonomic classification of specimens was based on external morphological attributes. Assignments were made taking into account similarities resulting from convergent evolution and common ancestry. Specimens from monotypic genera or represented by a single species in the region were assigned specific status although they may not possess species-specific attributes.

In addition to assignment of taxon, each specimen was identified as to element, portion of element, symmetry, age and sex wherever possible. Each

Table 1. List of species by total number of identifiable specimens (NISP), and minimum number of individuals (MNI).

| Common Name | Scientific Name | NISP | MNI |
|---|---|---|---|
| Chondrichthyes (Cartilaginous Fish) | | | |
| Carcharhinidae | | | |
| Requiem Sharks | Carcharhinidae | 2 | 1 |
| Actinopterygii (Ray-finned Fish) | | | |
| Balistidae | | | |
| Rough Triggerfish | cf. *Canthidermis maculata* | 1 | 1 |
| Monacanthidae | | | |
| Fantailed Filefish | *Pervagor spilosoma* | 2 | 2 |
| Labridae | | | |
| Wrasse | *Coris* sp. | 1 | 1 |
| Hogfish | *Bodianus* sp. | 1 | 1 |
| Wrasse | *Halichoeres* sp. | 1 | 1 |
| Scaridae | | | |
| Parrotfish | *Scarus* sp. | 2 | 1 |
| Parrotfish | *Calotomus* sp. | 1 | 1 |
| Bony Fish, taxon indet. | Actinopterygii | 1 | |
| Aves | | | |
| Procellariidae | | | |
| Hawaiian Petrel | *Pterodroma sandwichensis* | 19 | 3 |
| Wedge-tailed Shearwater | *Puffinus pacificus* | 1 | 1 |
| Anatidae | | | |
| Oahu moa-nalo | *Thambetochen xanion* | 7 | 1 |
| Phasianidae | | | |
| Red Junglefowl (domesticated) | *Gallus gallus* | 6 | 1 |
| Mammalia | | | |
| Muridae | | | |
| Rat | *Rattus* sp. | 1 | 1 |
| Canidae | | | |
| Dog | *Canis lupus familaris* | 13 | 2 |
| Suidae | | | |
| Pig | *Sus scrofa* | 4 | 1 |
| Mammal, taxon indet. | Mammalia | 1 | |
| Vertebrate, taxon indet. | Vertebrata | 1 | |
| Total | | 65 | |

specimen was also examined for evidence of cultural modification. This included burning, butchering and manufacturing marks, staining, painting, and unusual breakage.

Quantification of the sample is based on two calculations: the minimum number of individuals identifiable per taxon (MNI), and the total number of specimens identifiable per taxon (NISP) (Table 1). MNI was calculated using the most abundant skeletal element and portion of that element per taxon, with symmetry and age taken into account.

## The Sample

The Hālawa Cave vertebrate collection includes 65 NISP vertebrate specimens consisting of 12 fish bones, 33 bird bones, 19 mammal bones, and 1 unidentifiable vertebrate specimen (Table 1). The sample was recovered from the surface of the deposit and within the midden (Table 2). All three classes of vertebrates were distributed throughout the midden. The surface specimens may have come from anywhere within the rockshelter, including the surface areas bordering the walls where the roof fall, which underlies the midden, is exposed and may be of any age. Some may have been displaced by recent activity. The relatively large number of unprovenienced specimens reflects storage related data loss.

In addition to the unmodified vertebrate remains, several bone tools were found, including awls made from the ulna and tibia of a dog and a drilled dog canine ornament. Several "shellfish pickers" made of animal bone of indeterminate origin were recovered from the site. The bone tools indicate that the principal use of bone at the site was for tools (Langenwalter and Meeker 2015). Although the bone tools were used at the site, they may or may not have been manufactured there. Only the dog canine pendant represents an item of adornment.

Archival research associated with the preparation of the site report revealed that Wallace had discarded those vertebrate specimens which he considered

Table 2. Stratigraphic distribution of taxa by level throughout the trench and on the surface of the rockshelter.

| Common Name | Scientific Name | Surface | 0-4 | 4-8 | 8-12 | 12-16 | 16-20 | Unknown |
|---|---|---|---|---|---|---|---|---|
| Requiem Sharks | Carcharhinidae | 1 | | | 1 | | | |
| Rough Triggerfish | cf. *Canthidermus maculates* | | | 1 | | | | |
| Fantailed Filefish | *Pervagor spiolsoma* | | | 1 | | | | 1 |
| Wrasse | *Coris* sp. | | 1 | | | | | |
| Hogfish | *Bodianus* sp. | | | | | | | 1 |
| Wrasse | *Halichoeres* sp. | | | | | | | 1 |
| Parrotfish | *Scarus* sp. | | | 1 | | | 1 | |
| Parrotfish | *Calotomus* sp. | | | 1 | | | | |
| Indeterminate Bony Fish | Teleostei | | | | | 1 | | |
| Hawaiian Petrel | *Pterodroma sandwichensis* | 2 | 4 | 4 | 4 | 1 | | 4 |
| Wedge-tailed Shearwater | *Puffinus pacificus* | | | 1 | | | | |
| Oahu moa-nalo | *Thambetochen xanion* | 1 | | | 2 | | | 4 |
| Red Junglefowl (domesticated) | *Gallus gallus* | 2 | | 1 | 1 | | 1 | 1 |
| Rat | *Rattus* sp. | | | 1 | | | | |
| Dog | *Canis familaris* | 3 | 1 | 3 | 1 | | | 5 |
| Pig | *Sus* cf. *scrofa* | 1 | | 3 | | | | |
| Indeterminate Mammal | Mammalia | | | | 1 | | | |
| Indeterminate Vertebrate | Vertebrata | | | | | 1 | | |
| Total | | 10 | 6 | 17 | 10 | 3 | 2 | 17 |

unidentifiable. "Vertebrate remains judged to be unidentifiable were discarded either in the field or laboratory. Their numbers, by category, are listed in hand-written records labeled "Discarded Bones" (Braun Library) indicating that 34 "rodent bones," 13 bird bones and 13 mammal bones were discarded as unidentifiable. The rationale for discarding some bone was to reduce labor by eliminating so-called "unidentifiable specimens" (Langenwalter and Meeker 2015). This was a common practice among many archaeologists throughout the world prior to the 1980s. The impact of this practice upon the utility of the present collection for research is uncertain, but certainly limits the quantitative analysis of an already small sample. However, the sample continues to provide important data about animal use and subsistence at the site, as well as dating and paleobiological information.

## Fishes

Requiem Sharks (Carcharhinidae) are represented in the collection by two vertebrae. The specimens are not sufficiently diagnostic to determine which of the several species that are present in Hawaiian waters is represented in the collection. The vertebrae come from an intermediate-sized animal. These larger sharks, which include the tiger and blue sharks, occur throughout the region in waters outside of the surf zone. They can be speared, harpooned, or taken with hook and line, and were probably caught with the aid of a boat (Titcomb 1972).

Triggerfish (rough triggerfish; cf. *Canthidermis maculata*) are provisionally represented in the collection by one specimen (Table 1). This species occurs throughout island waters, but is not as common as several other related inshore species. Triggerfish, which were both eaten and used for fuel, can be caught by a variety of methods including the use of a baited basket in place of a net (Titcomb 1972).

The Hawaiian fantailed filefish or *ʻōʻili ʻūwi ʻūwi* (*Pervagor spilosoma*) is represented by the dorsal spines of two individuals (Table 1). This filefish is among the most common of the reef fishes in the Hawaiian Islands. It prefers shallow coastal reefs, but has been captured from depths of 60 m (Hutchins 1986:33). This small fish attains a length of only five inches (Gosline and Brock 1960:296). They were eaten or used as fuel (Titcomb 1972).

A wrasse of the genus *Coris* is represented by a maxilla (Table 1). Six species of this genus occur in the region. Species of the genus *Coris* attain lengths ranging from 30 to 60 cm. Another wrasse, the hogfish or *aʻawa* (*Bodianus* sp.) is represented at the site by an upper right maxilla (Table 1). Hogfish are among the largest wrasses in island waters, attaining sizes of about 51 cm (Randall 2010). They are normally caught in deeper water by hook and line. A third genus of wrasse recovered from the site is *Halichoeres* (ornamented wrasse; *H. ornatissimus*?), which is represented by a single skull part. All of these wrasses can be caught using nets or by hook and line, although the hogfish is more commonly captured in deeper waters using hook and line.

Two species of parrotfish, from the genera *Calotomus* and *Scarus,* are present in the collection (Table 1). The genus *Calotomus* is represented by a single mouth part (an edge of a beak made up of fused, individual teeth). Two species of *Calotomus* occur in the region (Gosline and Brock 1960:235-236). Both may have been captured using nets, traps, or spear. A second genus of parrotfish, *Scarus*, is represented by two specimens, part of the beak and a portion of the pharyngeal plate. This common genus of parrotfish is represented in Hawaiian waters by five species. All of them school inshore around coral reefs where they feed on algae growing on dead coral. They could have been taken using hook and line, traps, or other methods (Titcomb 1972).

One vertebra found at the site is identifiable only as being from a bony fish (Teleostei).

## Birds

Four species of birds were identified in the collection: the Hawaiian Petrel or *ʻuaʻu* (*Pterodroma sandwichensis*), the Wedge-tailed Shearwater or *ʻuaʻu kani* (*Puffinus pacificus*), the Oʻahu *moa-nalo* (*Thambetochen xanion*), and the Red Junglefowl or *moa* (*Gallus gallus* Table 1).

The Hawaiian Petrel is represented by 19 specimens and a minimum of three individuals, recovered from the midden and on the surface (Table 1; Figs. 2 and 3). Most of the petrel remains were recovered from Strata I and II. The Hawaiian Petrel (*Petrodroma sandwichensis*) is a Federally-designated endangered species that breeds only in the main chain of Hawaiian Islands (Welch *et al*. 2011). The species was never observed on Oʻahu historically, although its prehistoric presence was suspected (Munro 1966) and later confirmed by discovery of fossil and archaeological remains. Notably, the Hawaiian Petrel is by far the most common species of bird recovered from the extensive Holocene fossil deposits in sinkholes, caves, and pits of the karstic ‘Ewa Plain (Olson and James 1982b, Athens *et al* 2002), but is absent from the middle Pleistocene lake sediments at Ulupau Head, O‘ahu (James 1987b, Hearty *et al*. 2005). Based on radiocarbon dating of ‘Ewa Plain petrel bones, the species was extirpated from O‘ahu either during the prehistoric Hawaiian occupation, perhaps as long as 600 years ago (Wiley *et al*. 2013), or possibly in the early post-contact period (Athens *et al.* 2002).

At present, the species continues to breed on Maui, Lana‘i, Hawai‘i, Kaua‘i, and possibly Moloka‘i (Banko 1980; Judge 2011). Hawaiian Petrels nest colonially in natural crevices and cavities or in burrows that they excavate themselves. From the presence of immature birds among the paleontological bones found in ‘Ewa Plain paleontological sites (Hammatt and Falk 1981), it is evident that the birds once nested near sea level on O‘ahu (Olson and James 1982b). However, the colonies that persist on other islands are located in montane districts, a pattern that may result from the greater predatory pressure exerted by humans and introduced mammals at lower elevations.

Figure 2. Bones of adult Hawaiian Petrels (*Petrodroma sandwichensis*) from Hālawa Cave. Left to right, carpometacarpus, radius, and humerus. Scale bar = 2 cm.


Figure 3. Bones of immature birds from Hālawa Cave. **Panel A:** Three humerus fragments, a maxilla, and a tarsometatarsus representing first-year Hawaiian Petrels (*Petrodroma sandwichensis*) that were nearly full grown at the time of death. **Panel B:** A humerus and tibiotarsus representing much younger seabirds (most likely Hawaiian Petrels). Scale bar = 2 cm.

The breeding cycle of the Maui population of Hawaiian Petrels was studied in some detail by Simons (1985). It is long and highly synchronized, with most adults arriving to breed in late February, departing again in late March, then returning for egg laying between late April and mid-May. Eggs hatch in late June through mid-July, and the nestlings then remain in the burrows for about 110 days before fledging. The young fledge in October and leave the islands in November, by which time the adults have already gone (Berger 1981). Hawaiian Petrels are absent from the Hawaiian Islands in the non-breeding season, which they spend at sea apparently mainly to the south of the islands (Spear *et al*. 1995). Petrels that breed on Kaua'i, Lana'i and Hawai'i follow a similar, highly synchronized breeding cycle to the one on Maui, except that each stage of the breeding cycle apparently begins approximately one month later than in the Maui population, with the young fledging in mid- to late November (Judge 2011). Considering the genetic affinity between O'ahu fossil petrels and the modern Lana'i population (Welch *et al.* 2013), it is most likely that the timing of the O'ahu breeding cycle was similar to that of Lana'i, with chicks fledging in November.

Adult and nestling petrels can be captured in their nest burrows. Another possible method of capture involves attracting adults or fledglings to a light source at night. Since petrels fly over the islands only at night, when skies are dark and clouded, they are sometimes drawn in to lights and grounded or wounded (Simons 1985). It is difficult for them to navigate away from a solitary light source once within its glare. In the prehistoric period when petrels were numerous on O'ahu, harvesting grounded birds near campfires may have been commonplace.

The Wedge-tailed Shearwater is represented by one bone, a tibiotarsus shaft of what appears to have been an adult bird. The Wedge-tailed Shearwater is an indigenous seabird in the Hawaiian Islands, where it breeds in colonies near sea level, in burrows that are often excavated in sandy soils. Like the Hawaiian Petrel, this species has a protracted breeding season in the archipelago that extends from February to November (Whittow 1997). At present, the shearwater's Hawaiian population breeds primarily in the Northwestern Hawaiian Islands but also in smaller colonies in the main Hawaiian Islands, including at Ka'ena Point and several other localities on O'ahu and its offshore islets.

The O'ahu *moa-nalo* is represented by seven specimens (vertebrae and pedal phalanges; Fig. 4) recovered from the midden and the surface of the rockshelter (Table 1). Fossils remains from other sites indicate that the extinct species of *Thambetochen* and its allies, all heavy-bodied flightless waterfowl, were once widely distributed in the Hawaiian Islands (Olson and James 1982a-b; James *et al*. 1987; James 1995). Three genera and four species of these birds are known as fossils, *Chelychelynechen quassus* from Kaua'i, *Thambetochen xanion* from O'ahu, and *T. chauliodous* and *Ptaiochen pau* from Maui-nui, (Olson and Wetmore 1976; Olson and James 1991). *Thambetochen xanion* is particularly abundant in the Holocene fossil record of the 'Ewa Plain (Olson and James 1982b) and is also present in the middle Pleistocene lake beds at Ulupau Head on O'ahu (James 1987b).

*Thambetochen* was a terrestrial goose with a sturdy, pseudo-toothed beak that allowed the birds to forage on leafy foliage in the understory of Hawaiian

Figure 4. A vertebra and two pedal phalanges of the O'ahu *moa-nalo* (*Thambetochen xanion*) from Hālawa Cave. Scale bar = 1 cm.

forests (James and Olson 1983; James and Burney 1997). As is the case with the petrels, it is likely that the distribution of *Thambetochen* included the forested areas in and around North Hālawa Valley. On Maui, *Thambetochen* fossils occur in lava caves on the slopes of Haleakala, extending from near sea level to elevations much higher than that of Halawa Cave (Olson and James 1991).

The presence of *Thambetochen* in the Hālawa Cave sample does not resolve the relationship of pre-contact Hawaiians with this flightless waterfowl. Elsewhere on O'ahu, bones of *Thambetochen* were found in an archaeological context at Niu Rock Shelter and in a midden of Hawaiian Petrel bones at site 50-80-12-2763 (Olson and James 1982b, 1984). However, AMS dating of two specimens from the Hālawa Cave assemblage indicate that the species predates the human occupation of the cave (Figure 5). A cervical vertebra from the surface of the cave yielded a calibrated date of 1610 to1450 BC (cal BP 3560 to 3400, 3250 ± 30 BP, BETA-358782). A second specimen recovered from the 20-30 cm (8-12 in) level in Unit D5 yielded a date of 1369 to 1297 BC (cal BP 3275 to 3135; 3205 ± 70 BP, NSRL-154/AA-6098) (Fig. 5). The 20-30 cm level in Unit D5 yielded artifacts, but included sediments of both the Stratum II midden and the Stratum III paleosol. These dates indicate the presence of *Thambetochen* in North Hālawa Valley, or on 'Aiea Ridge, prior to the beginning of the Polynesian settlement of the Hawaiian Islands.

The Red Junglefowl, a pre-contact Polynesian introduction, is represented by six specimens distributed through the midden and on the surface (Table 1; Fig. 6). The specimens represent multiple individuals,


Figure 6. Bones of the Red Jungle-fowl (*Gallus gallus*) from Hālawa Cave. Left to right, a tibiotarsus, two tarsometatarsi, and a coracoid. Note the rodent gnaw marks on the tibiotarsus shaft. Scale bar = 2 cm.

indicating that the species was occasionally used as food at the site. The ends of the four limb bones have been broken away in the course of food preparation, and one tibiotarsus exhibits evidence of gnawing by rodents (Fig. 6). Red Junglefowl are the only non-native avian species in the sample, are have been occasionally recovered from other archaeological sites in North Hālawa Valley (Hartzell *et al*. 2003).

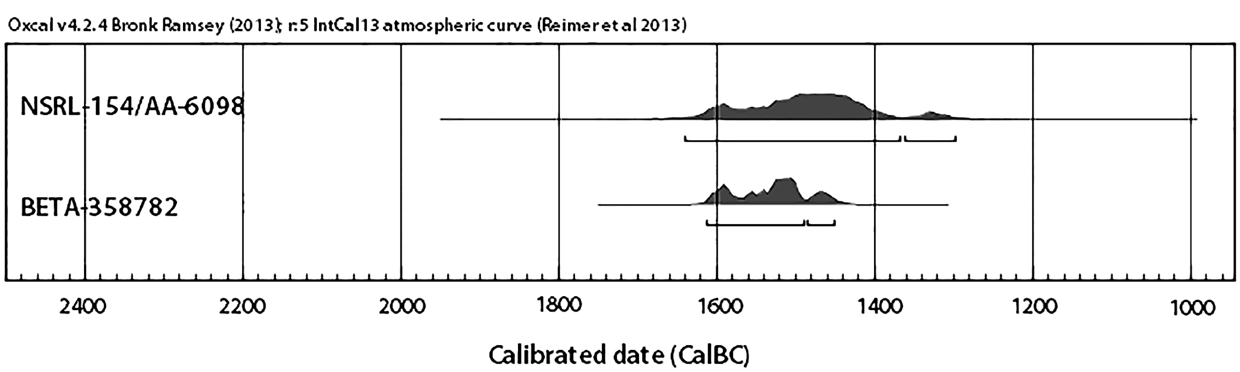


Figure 5. Oxcal plot of radiocarbon dates for *Thambetochen xanion*.

## Mammals

The mammalian fauna includes three introduced species brought to O'ahu during the early Polynesian occupation on the island (Table 1). Two of the three species, dogs and pigs, served as sources of food for the inhabitants of O'ahu. The third species, a rat, may represent the Pacific rat (*Rattus exulans*) which may have been introduced to the island by early Polynesian mariners, or a black rat (*Rattus rattus*) introduced after contact by visiting European ships. Rats lived in the cave, or visited it from nearby to feed on discarded food waste, as evidenced by gnawing on one of the junglefowl bones (Fig. 6). One unidentifiable mammal specimen was present in the collection (Table 1).

The most common of the mammals are dogs (*Canis lupus familiaris*) represented by thirteen specimens from a minimum of two individuals. These include a left frontal, right dentary with teeth (Fig. 7), an atlas, limb bone fragments and foot parts. One animal was an adult at death. This animal is distinguishable by an incomplete right $M^1$ with a crown length of 1.401 cm.

The second individual was a juvenile animal represented by a right $dI^1$ accompanied by a right $M^1$ from excavation unit D5. The $M^1$ is 17.72 mm long and 07.56 mm wide, and was fully developed at the time of death. The length of this specimen falls into the lower end of the range of lower carnassial lengths reported for smaller North American Indian dog populations, some of which are about 1 mm shorter (cf. Haag 1948). The juvenile animal was approximately 6-8 months old at death based on the presence of the $dI^1$ and development of the associated $M^1$ using eruption and exfoliation dates described by Kremenak (1967) and average time for development of the permanent root.

The atlas is nearly complete, while the frontal, limb bones and two metacarpals consist of fragmentary specimens. One metacarpal is burned. Their association with either of the individuals represented by the teeth is not determinable. The configuration of the skull frontal and limb bones imply a small-sized dog with gracile limbs. The frontal compares closely with the crania of two Hawaiian dogs described by Wood-Jones (1931). Size would have been in the range of animals belonging to the smaller morphotypes found among "pariah" and "athabascan" canid linages of Asia and North America (see Allan 1920; Haag 1948). Comparable information was not available for Hawaiian dogs.


**Figure 7.** Dog (*Canis lupus familiaris*) right dentary.

The remains of pigs (*Sus cf. scrofa*) are the next most abundant mammal in the assemblage with four identifiable specimens (Table 1). These include a zygomatic arch fragment from the left temporal, a proximal radius and two fibula shaft fragments. The zygomatic fragment and radius bear cut marks consistent with those made by narrow bladed steel tools, such as a cleaver of the type commonly used in the Asian community (cf. Langenwalter 1988b). The pig bone may reflect the transport of pig meat to the shelter, which was butchered elsewhere.

Rat (*Rattus* sp.) is represented in the assemblage by a right distal femur (Table 1) and tooth marks left on several specimens. It is probable that the rat is a natural introduction into the assemblage, not associated with the human occupation of the rockshelter except in the sense that rats apparently fed on kitchen waste in the shelter.

## Discussion

The vertebrate assemblage from Hālawa Cave (50-80-09-502) provides evidence for some aspects of the human activity at the site, but the amount of information available from the sample is modest, reflecting the small sample size. The environment in the immediate vicinity of the site, excepting the plant communities, is presumed to have been similar or the same as it is today. The radiocarbon date on an O'ahu *moa-nalo* bone from the site confirms that the species lived near the site in the Holocene. It is likely but not confirmed that the Hawaiian Petrel bred nearby. The aquatic species were transported to the site from marine habitats, while the dog and pig were brought to the site from other localities. The rats were presumably living in the vicinity of the rock shelter, or within it.

There is an important caveat regarding the *moa-nalo* bones in the site. Although remains of the O‘ahu *moa-nalo* occur in the midden, the radiocarbon determinations we obtained on the species in the site dated to long before Polynesian entry into the Hawaiian archipelago (Rieth *et al*. 2011; Athens *et al*. 2014). Given the shallow nature of the anthroposols in the cave, and the potential for mixing of sediments between the anthroposols and underlying paleosol through human activity or bioturbation, our study leaves room for doubt that *moa-nalo* remains entered the site through human agency. *Thambetochen* has not been reported from other sites in Hālawa Valley (cf. Hartzell *et al*. 2003) which may reflect that it was no longer present in the valley during the period of human occupation. The series of radiocarbon dates on bones of *Thambetochen* from the ‘Ewa Plain indicate that the species' extinction took place some time after AD 440-639 (Athens *et al*. 2002), yet the earliest confirmed human occupation of Hālawa Cave was not until the 15th century. Given this gap of over 700 years, we cannot exclude the possibility that the O‘ahu *moa-nalo* was already extinct when the site was first occupied. Additional support for this interpretation comes from the condition of the bird bones from Hālawa Cave: only the *Thambetochen* do not show evidence of breakage during food preparation or consumption. The *Thambetochen* remains are also set apart from those of the other avian species in the bone assemblage in that they do not include long bones from the meaty legs. Most published studies of archaeological bird bones from Hawai‘i have found that processing for food, or consumption, results in bone breakage, often at the ends of the long bones (i.e., Athens *et al*. 1991; Weisler and Gargett 1993; Moniz 1997). This caveat about the *Thambetochen* remains illustrates the care that is necessary to distinguish archaeological from paleontological material in mixed sites.

Several habitats were utilized to procure vertebrate resources. The marine waters 4.8 km away from the site provided the major portion of the vertebrate resources used at the site. Most of the fish represented at Hālawa Cave were probably captured in shallow inshore waters where they are present in open water beyond the surf. All of the species could have been taken in Pearl Harbor from rocks and sandy areas in the tidal zone, or by shallow water diving. There is sufficient habitat diversity along the shoreline within Pearl Harbor and adjacent waters of the Hālawa Ahupua‘a to account for the presence of these species (Kliegler 1995). There is no evidence that surf zone was a focus of procurement. Some of the fish were probably taken in open water, slightly further offshore. Members of the genus *Bodianus* are found mostly in deeper water, implying some procurement there. The second major area of resource use was the surrounding terrestrial habitats either close by or within several kilometers of the site. A number of fish ponds, including Queen Emma's Pond, existed in the Hālawa Ahupua‘a (Kliegler 1995), but there is no way to identify these as a source for any of the animals represented in Hālawa Cave.

The Wedge-tailed Shearwater would have been captured either at sea or, more likely, at a breeding colony near the coast or on a small offshore islet. The Hawaiian Petrel may have been procured within the vicinity of Hālawa Cave. The basalt outcrops that form the steep slopes of North Hālawa Valley in the vicinity of Halawa Cave contain occasional small horizontal crevices that could have been used for nesting by the petrels. ‘Aiea Ridge possesses sufficient soil cover to permit the birds to excavate their own burrows.

Archaeological sites on the lower slopes and valley floor where avifaunas have been recovered do not contain the remains the Hawaiian Petrel (cf. Hartzell *et al* 2003). Indeed, extensive radiocarbon dating and archaeological investigation indicate that the massive lowland petrel colony of the ‘Ewa Plain may have largely died out before the time period when Hālawa Cave was utilized by prehistoric people (cf. Athens *et al* 2002; Wiley *et al*. 2013). Breeding in montane regions is likely to have persisted longer, as it has done on other Hawaiian islands, and therefore the procurement of adult and juvenile petrels is one likely purpose for the Hālawa Cave occupation, where it may have served the occupants as an important locally derived food source.

The fishes, most birds, dog, and pig in the sample are attributed to the human occupation, and were presumably food sources. The vertebrate fauna indicate that the residents of the rockshelter utilized a wide array of foods, procured from a diversity of habitats occurring both locally and elsewhere in the *ahupua‘a*. While each of the vertebrate classes (fish, bird, and mammal) made significant contributions to the diet, the sample is too small to use as the basis for a quantified dietary analysis. The relatively greater abundance of the remains of pig and dog, both larger species, relative to the other taxa represented suggests that mammals may have been the most important food resource.

There is limited evidence of food processing in the sample. The ends of the junglefowl bones and all of the larger petrel bones (except one radius) are broken. Only the moa-nalo remains are unbroken. The breakage suggests that the prehistoric Native Hawaiians regularly butchered the birds they ate, either before cooking or before eating. The breakage may reflect the consumption of the joint cartilage rather than a desire to expose the marrow, since most of the broken bones would have contained air sacs, and consequently had little marrow inside them. Among the avian sample from Hālawa Cave, 56 percent of the bones are broken. This breakage is consistent with breakage of bird bones in other archaeological sites on Oʻahu and from the adze quarry sites on Mauna Kea (McCoy 1977). Such breakage is inferred to result from processes associated with cooking, serving, or consumption.

The only other evidence of processing occurs on two of the pig specimens. The pig temporal fragment bears a smooth cutting plane, 3.4 cm long, with an attendant compressed fracture at the root of the zygomatic arch. The mark compares to similar marks made using steel tools (cleaver, machete, etc.) directed with considerable force onto fresh bone (e.g., Langenwalter 1988b). Stone tools do not produce comparable marks. One tibia shaft section bears several parallel blade marks, which are sufficiently deep and narrow to imply that they were made by a metal tool with a knife type blade rather than with a stone flake tool (cf. Langenwalter 1988b).

Evidence for seasonal periodicity of the occupation of the site is meager. The Hawaiian Petrel (*Pterodroma sandwichensis*) provides a minimal period of the year when the site was used. The presence of late-stage nestlings or fledglings suggests activity at the cave between September and November, the period when nestlings reach full size and fledge, assuming that the breeding phenology of the Oʻahu population was like that of modern colonies on other islands (Judge 2011). The adult birds in the Hawaiian Petrel sample could have been taken at any time during the protracted breeding season, which extends from roughly February to November in the colonies on other islands (Judge 2011). It is not known if the cave was used during other parts of the year.

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