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Successful nesting by 2 endangered Hawaiian waterbird species in a restored Indigenous wetland agroecosystem

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ABSTRACT—The Hawaiian Stilt (*Himantopus mexicanus knudseni*) and Hawaiian Gallinule (*Gallinula galeata sandvicensis*) are federally endangered waterbirds endemic to the Hawaiian Islands. Both species are conservation-reliant; their population persistence is dependent on invasive predator control and removal of invasive plants that degrade habitat. We present observations of successful nesting by one Hawaiian Stilt pair and one Hawaiian Gallinule pair at a site managed within an adaptive Indigenous agroecological framework on the island of O‘ahu, Hawai‘i. The Hawaiian Stilt nest, found in February 2019, contained 4 eggs and produced 3 hatchlings, 2 of which were banded and monitored after hatching. The Hawaiian Gallinule nest, found in February 2020, contained 6 eggs and produced 5 hatchlings. Although no individuals were banded from this nest, 2 adults and 2 hatchlings were continuously observed in the nesting area after the eggs hatched. *Lo‘i kalo* Hawaiian wetland agroecosystems centered around the cultivation of *kalo* (taro; *Colocasia esculenta*), have the potential to expand Hawaiian waterbird habitat beyond state and federal protected areas. We are aware of unpublished accounts of Hawaiian waterbirds nesting in commercially farmed *lo‘i kalo*, but until now, there have been no previously published accounts of native waterbirds breeding in *lo‘i kalo* managed as Indigenous agroecosystems. *Received 28 May 2020. Accepted 7 December 2021.*

Key words: conservation, *Gallinula galeata sandvicensis,* Hawai‘i, *Himantopus mexicanus knudseni*, lo‘i, wetland.

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Anidación exitosa de 2 especies de aves acuáticas hawaianas en peligro en un agroecosistema indígena restaurado

RESUMEN (Spanish)—La monjita *Himantopus mexicanius knudseni* y la gallareta *Gallinula galeata sandvicensis* son aves acuáticas federalmente en peligro endémicas a las islas hawaianas. Ambas especies dependen de acciones de conservación; la persistencia de sus poblaciones depende del control de depredadores invasores y de la remoción de plantas invasoras que degradan sus hábitats. Presentamos observaciones de anidación exitosa de una pareja de monjita y una de gallareta en un sitio manejado mediante prácticas indígenas agroecológicas en la isla de Oʻahu, Hawái. El nido de la monita, encontrado en febrero de 2019, contenía 4 huevos y produjo 3 polluelos, 2 de los cuales fueron anillados y monitoreados después de eclosionar. Aunque ningún individuo de este nido fue anillado, 2 adultos y 2 polluelos fueron continuamente observados en el área del nido después de que los huevos eclosionaron. Los agroecosistemas de humedales hawaianos (lʻoi) tienen el potencial de expandir el hábitat de las aves acuáticas hawaianas más allá de las áreas protegidas estatales y federales. Sabemos que hay reportes de aves acuáticas hawaianas sin publicar en lʻoi comercialmente cultivados, pero hasta ahora no había reportes previos publicados de aves acuáticas nativas en lʻoi bajo manejo como agroecosistemas indígenas.

Palabras clave: conservación, *Gallinula galeata sandvicensis*, Hawái, *Himantopus mexicanus knudseni*, humedal, lo‘i.

The Hawaiian Stilt (*Aeʻo*; *Himantopus mexicanus knudseni*) and Hawaiian Gallinule (*ʻAlae ʻula*; *Gallinula galeata sandvicensis*) are federally endangered waterbirds endemic to the Hawaiian Islands. Both species benefit from conservation actions, as their populations rely on control of invasive plants and predators to remain viable (Reed et al. 2012). Archeological evidence (Burney et al. 2001, Burney and Kikuchi 2006) suggests that *loʻi kalo* Hawaiian wetland agroecosystems, centered on the cultivation of *kalo* (taro; *Colocasia esculenta*), greatly expanded waterbird habitat in the pre-contact era (Winter et al. 2018b). However, in the 19th century, productive and biologically diverse wetland agroecosystems were transitioned into to low-biodiversity monocultures for plantation agriculture, which ultimately contributed to a regime shift in social-ecological systems in Hawaiʻi (Winter et al. 2018a, 2018b).

A decline in *loʻi kalo*, along with a decline in Hawaiian social-ecological systems, an increase in introduced species, and an increase in hunting of waterfowl associated with the introduction of guns to the islands, led to a collapse in native waterbird populations (Kameʻeleihiwa 1992). Today the Hawaiian Stilt and Hawaiian Gallinule are both habitat-limited species (Reed et al. 1998; van Rees and Reed 2018, 2020), and sea-level rise has the potential to further exacerbate the recovery of their populations (Kane et al. 2014, van Rees and Reed 2018, Harmon et al. 2021). However, restoration of *loʻi kalo* systems has the potential to preserve Hawaiian cultural practices and provide sustainable food production, while simultaneously increasing suitable habitat for Hawaiʻi's endangered waterbirds (Harmon et al. 2021).

Research conducted in commercial taro plantations on a U.S. Fish and Wildlife Service refuge (Greer 2005, Gee 2007) suggests that *loʻi kalo* provide foraging and nesting habitat for endangered Hawaiian waterbirds. However, *loʻi kalo* management practices used in single-objective high-intensity agribusiness models (Evans 2008) include substantial use of fertilizers and hydrological practices that facilitate avian botulism outbreaks in waterbirds. Such approaches to taro cultivation potentially create population sinks that attract waterbirds to breed and forage but result in increased mortality and decreased reproductive success (Battin 2004, Robertson and Hutto 2006, Buderman et al. 2020). In contrast, multi-objective, Indigenous wetland agroecosystems (Winter et al. 2018a) consist of a patchwork of fields in different phases of cultivation (Winter et al. 2018b), secondary crops along field borders (Kurashima and Kirch 2011), and *ʻauwai* (irrigation ditches and canals facilitating hydrological regimes that minimize the likelihood of botulism outbreaks), creating habitat mosaics that support a diversity of wetland organisms (Winter et al. 2020). As there are no previously published accounts of native waterbirds breeding in *loʻi kalo* managed as Indigenous agroecosystems rather than as agribusiness plantations, we present 2 observations of successful nesting by Hawaiian Stilts and Hawaiian Gallinules within 2 *loʻi kalo* basins at a site managed using Indigenous agroecology practices on the island of Oʻahu, Hawaiʻi.

The Heʻeia National Estuarine Research Reserve (NERR) on Oʻahu, Hawaiʻi (21.4339°N, 157.8112°W) contains an invasive-dominated wetland that is currently being restored for multiple Indigenous wetland agroecology systems including *loʻi kalo* and aquaculture production. Management of *loʻi kalo* at the site includes practices that aim to establish self-sustaining waterbird populations with limited human impact. In these restored

Figure 1. A Hawaiian Stilt nest with 4 eggs inside a wet, fallow *loʻi kalo* basin managed by Kākoʻo ʻŌiwi within the Heʻeia National Estuarine Research Reserve on Oʻahu. Three of 4 eggs hatched, and all 3 chicks survived at least 1 year, remaining with the adult pair in the immediate area.

Figure 2. A Hawaiian Gallinule nest with 6 eggs inside a flooded *loʻi kalo* basin managed by Kākoʻo ʻŌiwi within the Heʻeia National Estuarine Research Reserve on Oʻahu. Five of the 6 eggs hatched, and 2 chicks survived a minimum of 3 months, remaining in the immediate area.

loʻi kalo, one Hawaiian Stilt and one Hawaiian Gallinule nest were discovered in 2019 and 2020, respectively, during a waterbird survey. The Hawaiian Stilt nest with 4 eggs was found inside a wet, fallow *loʻi kalo* basin within the Heʻeia NERR on 22 May 2019. The nest had been constructed on a small mudflat within the basin, surrounded by sparse vegetation (Fig. 1). The nest was monitored with a Bushnell No-Glow Aggressor HD Trophy Camera, consistent with U.S. Fish and Wildlife Service Threatened and Endangered Species Permit #TE-25955C-1. The camera was programmed to take 2 images back-to-back immediately upon infrared motion activation with a 5 s delay between each successive activation. One control photo was taken every hour using field scan mode. The camera was checked weekly for battery life and data card retrieval and was removed immediately after the eggs hatched. The Hawaiian Gallinule nest with 6 eggs was found on 27 February 2020 inside a flooded *loʻi kalo* basin surrounded by *ʻohā* (*kalo* offshoots) also within the Heʻeia NERR (Fig. 2). The nest was monitored weekly during observational waterbird surveys.

Nest camera images of the Hawaiian Stilt nest confirmed that 3 of the 4 eggs hatched from 10 to 12 June 2019. Two of the chicks were captured and fitted with U.S. Geological Survey bands, as well as PVC color bands for individual identification, at ca. 4 weeks of age (pre-fledge). The 2 breeding adults and 3 offspring survived past the original nesting observation and continued to be observed foraging and resting within components of the agroecosystem, including basins at various *kalo* development stages, berms, and nearby wetlands and intertidal mud flats. On 13 March 2020 the Hawaiian Gallinule nest was found empty, and 5 gallinule chicks were observed near the nest site. Subsequent field surveys in March 2020 confirmed that the 2 adults and at least 2 chicks were still onsite and regularly utilizing *loʻi kalo* basins, nearby streams, and nearby wetlands. These individuals are not banded, but we believe our observations are of the same family, as gallinules are highly territorial (Chang 1990) and no other gallinule nests were observed during this time.

As sea-level rise is projected to negatively impact both the Hawaiian Stilts (Harmon et al. 2021) and Hawaiian Gallinules (van Rees and Reed 2018), the acquisition or creation of new waterbird habitat will be critical to achieve recovery goals for endangered endemic Hawaiian waterbird populations into the future. This study supports reported observations of waterbirds nesting and successfully fledging since 2010 within *loʻi kalo* basins at Heʻeia (JKK, pers. obs.; USFWS 2019), and further supports the notion that restoring Hawaiian wetland agroecosystems, under an Indigenous resource management framework, as suggested by Harmon et al (2021), does indeed have the potential to increase food production while expanding endangered waterbird habitat (Harmon et al. 2021). Moreover, contemporary Indigenous management of *loʻi kalo* often includes actions that are analogous with endangered species management in protected

areas, such as control of invasive plants and predators (Greer 2005), management of hydrological conditions to meet waterbird life history needs (USDA 2009), and management of human impacts, all of which are critical for Hawaiian waterbird conservation (VanderWerf 2012, Underwood et al. 2014). Thus, Indigenous management of Hawaiian agroecosystems, coupled with predator control, offers a sustainable landscape-level solution for expanding conservation of these species beyond state and federal managed protected areas.

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