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Hāmākua Marsh State Wildlife Sanctuary

Waterbird Report, 2022

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I.   Overview

Hāmākua Marsh State Wildlife Sanctuary (heareafter 'Hāmākua Marsh') is a 91-acre wildlife sanctuary designated for the recovery of federally and state listed endangered waterbirds in Kailua, Hawai'i. Hāmākua Marsh is a seasonally brackish wetland on the windward side of the Ko'olau Range on the island of O'ahu.

Hāmākua Marsh has been identified by the U.S. Fish and Wildlife Service as a 'core' wetland for the recovery of three endemic and endangered waterbirds: the Hawaiian Coot (*Fulica alai*), Hawaiian Common Gallinule (*Gallinula galeata sandvicensis*), and Hawaiian Stilt (*Himantopus mexicanus knudseni*; U.S. Fish and Wildlife Service, 2011). The Department of Land and Natural Resources, Division of Forestry and Wildlife (DOFAW) manages Hāmākua Marsh with the goal of creating breeding, foraging and roosting habitat for three species of federally endangered waterbirds (hereafter 'waterbirds'): Hawaiian Coot, Hawaiian Gallinule, and Hawaiian Stilt.

Hawaiian waterbirds are considered 'conservation reliant' meaning that populations will require active management for the foreseeable future (Reed et al. 2012, Underwood et al. 2013). Wetland managers mitigate threats to Hawaiian waterbirds by controlling invasive plants and removing invasive predators. Monitoring the success of these strategies over time allows managers to adapt management actions to most efficiently protect waterbirds.

II.   Habitat Management

Habitat Manipulations.—The wetland portion of Hāmākua Marsh is approximately 23.3 acres and is comprised of four basins. Basins A, B, C, and D vary in area (A: 4.6; B: 9.5; C: 6; D: 3.2 acres) and each offer different proportions of open water to vegetation or mudflat. The wetland is fed from rainfall and runoff from the adjacent 68-acre Pu'u o 'Ehu hillside. Water from the adjoining Kawainui Canal will flood the interior of the wetland during the rainy season or when the sand berm at Kailua Beach Park is removed and the ocean tides result in a net increase in water level. The dominant vegetation within the wetland is pickleweed (*Batis maritima*) and saltmarsh bulrush (*Bolboschoenus maritimus*).

Habitat manipulations in 2022 included disking two times per year using a Marsh Master MM-2XL equipped with the disking attachment. Disking occurred in early October and early November. This was the first time the habitat was altered twice; the previous three consecutive years the habitat was altered three times (Table 1). Previously, the interior wetland area was manipulated once during the year, yet in 2019–2021 the habitat was selectively manipulated on three separate occasions while avoiding stilt nesting season (March–August); in 2022 the habitat was manipulated twice.

Mechanical manipulation was incorporated to minimize much of the pickleweed (*Batis maritima*) and to promote growth of the naturally occurring native seed bank, leaving islands of pickleweed habitat for nesting. Basin A was managed to provide 50:50 open water to vegetation in the wet season and a ratio of mudflat equal to water loss as it relates to the topography in the dry season. Basin B was managed to provide 70:30 open water to vegetation in the wet season

and a ratio of mudflat equal to water loss as it relates to the topography in the dry season. Basins C and D were manipulated to promote more *Bolboschoenus maritimus* to replace the pickleweed. Both Basins C and D were managed to provide 60:40 open water to vegetation in the wet season and a ratio of mudflat equal to water loss as it relates to the topography in the dry season. The frequency of habitat manipulations was needed to control vegetation regrowth in the mudflat areas.

Optimizing foraging and nesting habitat for waterbirds can be diametrically opposed, as improving foraging habitat may decrease nesting habitat. Gallinule nests (6) have been found in pickleweed (*B. maritima*) that had not been mechanically manipulated in 2019. Those six nests were found in pickleweed that was on average 45.5 cm above the water line. When planning habitat management for waterbirds in wetlands those manipulations for optimizing foraging may include disking and tilling, but for areas that nesting is encouraged pickleweed needs manipulation no more than once annually. Foraging for coots, gallinules, and stilts takes place in more open habitat especially for stilts and coots and to optimize foraging habitat vegetation manipulations are recommended. During habitat manipulations plant leaves are severed and decompose providing detritus for food and structure for microorganisms which provide food for macroinvertebrates, thus increasing invertebrate forage for waterbirds (Kaminski and Prince, 1981). In another study, it was posited that aquatic invertebrate mass and diversity was greatest in habitats that offered more detrital matter (Gray et al., 1999). Manipulations of vegetation may increase macroinvertebrate availability, but certainly increase accessibility to invertebrate prey when vegetation is thick (Gawlik, 2002; Chastant and Gawlik, 2018). The pickleweed in Hāmākua Marsh can grow densely when not mechanically manipulated potentially prohibiting waterbirds from accessing prey.

Water Level and Salinity.—In 2022, water levels ranged from 0–23.4, 10.8–25.2, 0–18.6, and 0–15.6 inches in Basins A, B, C, and D, respectively (Figure 1). Water level readings were taken during waterbird surveys ($n = 47$). Salinity measurements were taken four times and ranged from 10–81, 4–16, 11–46, and 9–45 ppt in Basins A, B, C, and D, respectively (Figure 1).

III. Waterbird Monitoring

a. Waterbird Surveys

1. Methods

Surveys.—The Wildlife Biologist conducted weekly to semi-weekly surveys. A census technique was used to count all waterbirds present using the direct count method. Waterbird surveys were conducted using consistent observation lines to maintain consistency amongst different observers. When conducting waterbird surveys observers walked along the stream edge paralleling Hāmākua Drive from Basin A toward Basin D (intersection of Hāmākua Drive and Kailua Road). Basin A is on the southeast corner of the wetland and Basin D is toward the northwest (Figure 5). Chicks and fledglings were recorded separately for each of the endangered wetland birds and all banding information observed was recorded

Observers also recorded ancillary environmental data: cloud cover, vegetation cover, rainfall, wind and gust speed, water level, and the degree of human influence. Cloud cover was estimated as a continuous percentage between 0 and 100 by tens. Vegetation cover was ranked in discrete categories from 0 to 3: 0 = open water, 1 = 26–50% cover, 2 = 51–75% cover, and 3 = ≥75% cover. Rainfall was recorded in discrete categories of 0 = no rain, 1 = mist or fog, 2 = drizzle, and 3 = light rain. Wind and gust speed were recorded as Beaufort categories: 0 = no wind, 1 = smoke drifts (4–7 mph), 2 = wind felt on face, and 3 = leaves, small twigs in constant motion (8–12 mph). Water level was recorded as a discrete category ranging from 0 to 3, where 0 = dry, 1 = lower than normal, 2 = normal, and 3 = higher than normal. Human impact was recorded as ranging from 0 to 2: 0 = indirect, 1 = moderate, and 2 = heavy.

Habitat Use.—Microhabitat was assessed for all the endangered birds encountered. Microhabitat was identified as: *stream*, *stream bank*, *open mudflat*, *vegetation*, *0–3" water*, *3–6" water* and *>6" water*. *Stream* is defined as stream water that is deeper than the tarsal-tibiotarsal joint (i.e., joint not visible) for stilts and water deep enough for the coot or gallinule to be swimming; *stream bank* is stream water not deeper than the tarsal-tibiotarsal joint (i.e., joint visible) in stilts, or coots and gallinules observed standing on vegetation inside the stream channel or in shallow enough water where swimming is not allowable; *open mudflat* is defined as exposed or bare soil with no emergent vegetation; *vegetation* is emergent vegetation with small pockets of mudflat or water present; *0–3" water* is water no deeper than the tarsal-tibiotarsal joint (i.e., joint visible) for stilts and walking in water for coots and gallinules; *3–6" water* is deeper than the tarsal-tibiotarsal joint (i.e., joint not visible) for stilts and swimming for coots and gallinules; and *>6" water* is such that no part of the leg is visible in the stilt, for the coot and gallinule depth of water was estimated by reading the nearest water gauge.

Fledging Success.—From 2005–2022, endangered waterbird fledging success was measured using the formula: (# of observed fledglings/# of observed chicks) x 100 = % fledging success. Fledglings and chicks were mapped each survey to aid in identifying each brood's chicks to fledging ratio. In addition to using the above formula for fledging success, fledging success was measured using the formula: (# of observed fledglings/# of broods) = ratio of fledglings per brood. The alternative formula for fledging success should aid in reducing the overestimating of fledging success because all chicks from a single brood are seldom all observed and the likelihood of observing one brood is greater than observing all chicks from a single brood. Furthermore, the USFWS was documented using this method in the Kahuku Wind Power Habitat Conservation Plan (SWCA, 2010), therefore fledging success data can more easily be used for comparison from other sites. The older method of calculating fledging success will be used as well, mostly to continue comparisons from previous years.

2.   Results

Surveys.—A total of 47 surveys were conducted at Hāmākua Marsh in 2022. Mean abundances (range) for coots were 24.5 individuals (14–45), gallinules were 34.3 individuals (24–65), and stilts were 32.9 (12–81) individuals per survey (Figure 2). The average abundances of coots, gallinules, and stilts were highest in Basins B, B, and B, respectively (Figure 3). The average density of coots, gallinules, and stilts per acre was highest in Basins C, C, and C, respectively. The average endangered waterbird per acre was 3.9 individuals.

Habitat Use.—Habitat utilization differed by species. The Hawaiian Coot was found most often in stream with 50.8% of the observations; the Hawaiian Gallinule was found most often in vegetation with 42.9% of the observations; and the Hawaiian Stilt was found in most often in 0–3" water with 53.8% of the observations (Figure 4). Coots utilized deeper water habitat, gallinules used vegetation, and stilts used shallow water and mudflat.

Fledging Success.—Fledging success in Hāmākua Marsh State Wildlife Sanctuary from 2005 to 2022 ranged from 0–91%, 13–96%, and 21–100% for coots, gallinules, and stilts, respectively. For 2022 coots, gallinules, and stilts had an overall fledging success rate of 0%, 36%, and 64%, respectively (Table 2). Fledging success rate in 2022 for coots and gallinules was below the pooled averages (60% and 73%, respectively); and average for stilts (64%). Coot fledging recruitment was 0 fledglings which was the lowest recorded recruitment for coots. The annual average recruitment for coots was 6.0 fledglings per year. Gallinule fledging recruitment was 4 fledglings which is below the annual average recruitment of 36.1 fledglings per year. Stilt fledging recruitment was 18 fledglings which is above the annual average recruitment of 12.0 fledglings per year.

3.   Recommendations

Further study is necessary to identify causes of chick mortality to determine if management strategies can mitigate for chick loss. Low fledging success rate for coots, gallinules, and stilts suggests potential for multiple causes of chick mortality. Further investigation of cause-specific chick mortality will continue in 2023 under the Competitive State Wildlife Grant project and will aid in understanding the ability management has on influencing chick mortality (i.e., predation, flooding, disease, starvation, toxicants, or exposure). Many potential causes of chick death may not benefit from management objectives, but we must determine the actions, if any, that will aid in chick survival.

Specific habitat mapping would help the Wildlife Biologist determine if the waterbirds are using microhabitat proportionate to availability and how the frequency of habitat manipulations affects microhabitat availability. The Wildlife Biologist provides the largest amount of influence by altering the habitat by controlling plant cover. In the long-term, understanding habitat proportions as it relates to waterbird abundances could aid in optimizing habitat for a particular waterbird species or group of species. In 2023, habitat preferences for nest locations will be compared with randomly available habitat to determine if nesting habitat is distinguishable from habitat characteristics of randomly selected habitat options. Determining nest habitat characteristics will inform the Wildlife Biologist on management techniques to increase or decrease nesting habitat for each waterbird species.

b.   Nest Surveys

1.   Methods

Nest Monitoring.—Nests were located during routine weekly or biweekly surveys using an area-search survey. During area-search surveys, a team of 3−7 observers walked meandering transects

with the goal of locating all nests in a given area. When conducting waterbird nest surveys observers walked the marsh beginning in Basin A and continued toward Basin D until the wetland was thoroughly searched (Figure 5). During non-stilt nesting season focus was made on searching coot and gallinule nest habitat.

Waterbird nests were monitored from January through December 2022. Nest success was monitored using SPYPOINT Solar Dark (GG Telecom, Quebec, Canada) passive infrared cameras (trigger speed: 0.07s) placed about 1 m from the nest, mounted on a 7.6-cm wide metal post 1.8-m long, fixed with a fully-adjustable camera mount that allows a camera angle of 0–90°. Cameras were programmed to take two images back-to-back immediately upon infrared motion activation. Cameras were programmed to take photos instantly for each activation (Instant setting recovery speed: 0.3s). Cameras were checked weekly for battery life and SD card data retrieval and were removed either immediately after a nest was confirmed failed or after a nest was confirmed successful (coot and gallinule nest cameras remained for 14 days post-hatch).

Reproductive Success.—Reproductive metrics were used to determine nest, fledging and overall reproductive success for coots, gallinules, and stilts. *Nest Success* was determined by using the formula: (# of broods observed/# of nests observed)*100 = % nests that hatched ≥1 chick; *Fledging Success* was determined by using the formula: (# of broods that produced ≥1 fledgling/# of broods observed)*100 = % of broods that produced ≥1 fledgling; and *Overall Reproductive Success* was determined using the formula: (# of broods that produced ≥1 fledgling/# of nests observed)*100 = % of nests that produced ≥1 fledgling.

2.   Results

Nest Monitoring.—Forty-four nest surveys were conducted from January through December 2022. Nests were found in April for Hawaiian Coot, January, April, October, and November for Hawaiian Gallinule, and May through June in Hawaiian Stilt. During the period of January through December 2022, 2 coot, 6 gallinule, and 15 stilt nests were observed (Figure 6). Out of 23 nests observed, Basin B contained the most nests (*n* = 14), then Basin A (*n* = 1), Basin C (*n* = 6), and Basin D (*n* = 2). Coot nests were found most often in Basin B (100%); gallinule nests were found most often in Basin B (83%); and stilt nests were most often found in Basin B (47%; Figure 6).

Nests observed peaked for coot and gallinule in April, and stilt nests observed peaked in May; and by July no nests were found for all species except two gallinule nests (October [1] and November [1]; Figure 6 [see Figure 7 for nest abundances by Basin]).

Overall Nest Outcomes
Out of 23 nests discovered, 52% (*n* = 12) produced at least one chick, 22% (n = 5) failed due to predation or partial predation, 0% (*n* = 0) failed due to flooding, 13% (*n* = 3) failed due to abandonment, 13% (*n* = 3) failed for unknown reasons, and 0% (*n* = 0) had unknown fates (Table 3).

Outcomes of Nests Monitored with Cameras

Out of 23 nests, 17 (74%) had a camera placed on them. Cameras were placed on 100%, 83%, and 67% of coot (*n* = 2), gallinule (*n* = 5), and stilt (*n* = 10) nests, respectively. Of the 17 nests with cameras, 71% (*n* = 12) produced at least one chick, 6% (n = 1) failed due to predation or partial predation, 17% (*n* = 3) failed due to abandonment, and 6% (*n* = 1) failed for unknown reasons (Table 3).

Reproductive Success.—We observed 1 coot, 3 gallinule, and 8 stilt broods; and 0 coot, 2 gallinule, and 7 stilt broods produced ≥1 fledgling (Table 4). The number of broods observed per nest were 0.5, 0.5, and 0.5 broods for coots, gallinules, and stilts, respectively. The number of fledglings per brood was 0.0, 1.3, and 2.3 fledglings for coots, gallinules, and stilts, respectively. The number of fledglings per nest was 0.0, 0.7, and 1.2 fledglings for coots, gallinules, and stilts, respectively.

3.   Discussion

Nest Monitoring.—Coot nesting success was reported to be high at 80% and the average clutch size was 5 eggs per nest (range: 1–10 eggs per nest; Pratt and Brisbin, 2002). Our study reported below average nesting success at 50% and an average clutch size of 4.0 eggs per nest.

Gallinule nesting success, as reported by van Rees et al. (2018), averaged 66% when combining data from five separate studies (range: 42–77%). The average clutch size was 5.1 eggs per nest (range: 4.2–6.3 eggs per nest; van Rees et al., 2018). Our study reported below average nesting success for gallinules at 50% and an average clutch size of 4.3 eggs per nest.

Stilt nesting success for Hāmākua Marsh, Kawainui Marsh, Honouliuli wetland unit, Waiawa wetland unit, and James Campbell National Wildlife Refuge in study years 2018 and 2019 was 63% for those nests that were monitored with a camera (Price, 2020). In 2022, Hāmākua Marsh had a stilt nesting success of 53%. The nesting success for Hāmākua Marsh is average when compared with other Oʻahu wetlands and across two separate nesting seasons. In 2018 and 2019, Hāmākua Marsh had a stilt nesting success of 47% and 68%, respectively (Price, 2020). Comparing stilt nesting success in 2022 to nesting seasons 2018 and 2019 (nesting success 58% combined), nesting success was average.

Outcomes of Nests Monitored with Cameras
Of nest failures, 7 of 11 (64%) nests failed due to predators or abandonment. Of the gallinule nests that failed due to abandonment or predation, one nest an adult gallinule was taken by an Owl sp. and one nest all the eggs were destroyed (2/6 [33%]). Of the stilt nests that failed due to predation or abandonment, two nests were destroyed by a bird, two nests were completely missing, and one nest was abandoned for unknown reasons (5/15 [33%]). In 2022, the cause for failure seems to be waterbirds destroying eggs (Table 3).

Reproductive Success.—As reported in the Kahuku Wind Power Habitat Conservation Plan, coots, gallinules, and stilts had 0.9, 1.3, and 0.9 chicks per observed brood per other studies (SWCA, 2010). In 2022, at Hāmākua Marsh coots had 0.0 fledglings per brood, gallinules had 1.3 fledglings per brood, and stilts had 2.3 fledglings per brood. Fledglings per brood observed is below average, average, and above average for coots, gallinules, and stilt, respectively, compared with other studies.

4. Recommendations

Nest Monitoring.—Weekly surveys are needed to observe all the nests throughout the nesting season and continuing with weekly surveys is recommended. In 2023, nest surveys will be conducted bi-weekly for the entire year and weekly for peak nesting season. All active nests will be checked twice per week.

Approximately, 74% of nests had a camera placed to monitor the nest fate, and 100% of all waterbird nests a fate could be determined due to frequent twice weekly nest checks. However, an additional 26% of nests the fate could only be determined as a failure with an unknown cause. The nests without a camera had incomplete clutches upon discovery and upon subsequent visit the eggs were missing or destroyed. We has such few nests in 2022 that all nests could have received a camera.

In the future, nests with camera data will be used to monitor nest success. Alternatively, nest success could be reported with the following formula: (# of observed broods/(# of observed nests - # of unknown nest fates)) x 100 = % nest success. This formula may report an underestimate of nest success if entire broods perish before observed, but could serve as a metric of nest success if camera availability or time is insufficient during the reporting year. Camera data remains the best option for reporting accurate nest success data.

c. Chick Surveys

1. Methods

Chick Monitoring.— One stilt or gallinule chick per brood was affixed with a radio transmitter (Holohil LB-2X), if the chick in the brood had perished another chick within the same brood was fitted with another transmitter if possible. Chicks were located daily to twice daily with a VHF telemetry receiver (Telonics TR-8 VHF Receiver; RA-23K VHF Antenna) until chick death or transmitter failure. Radio transmitters were re-glued weekly to ensure transmitter retention. Deceased stilt chicks with transmitters were necropsied to aid in determining the cause of death. Mortality was determined to be: predation, starvation, exposure, or unknown. All chicks of appropriate size, regardless of transmitter affixation, were banded with a USGS metal band and uniquely identifiable auxiliary band combination.

2. Results

Chick Monitoring.—In 2022, 11 gallinule chicks hatched from an available 26 eggs (42%). Of the 11 chicks that hatched only 8 (73%) chicks were marked with nail polish. Four chicks received a transmitter from three separate broods. A total of four chicks fledged from 2 separate broods (BY:OA [HG04-2022]; GB:AO, OA:WZ, & unmarked [HG06-2022]). Two tagged gallinule chicks were taken by unknown predator.

Twenty-eight stilt chicks hatched from an available 45 eggs (62%). Of the 28 chicks that hatched 19 (51%) chicks survived to transmitter or banding size (typically 7−10d of age). Nine chicks

received a transmitter from seven separate broods. Of the 19 chicks closely monitored with bands and transmitters, 18 (95%) chicks survived to the fledgling stage.

HAST Chick Survival (Transmitters Equipped; $n = 9$)
Of the nine stilt chicks marked with a transmitter seven (78%) chicks survived. Of the two stilt chick deaths, two (100%) could be attributed to possible predation (suspect 1 mongoose and 1 BCNH). In the mongoose suspected kill the transmitter, USGS band, and 3 auxiliary markers were found in the pickleweed; in the BCNH suspected death the banded chick was never seen again and no signal was received despite driving around Kailua looking for a signal.

HAST Chick Survival (Plastic Leg Bands Only; $n = 10$)
Of the 10 chicks monitored with bands only, 10 (100%) chicks survived.

HAST Chick Survival (No Bands; $n = 1$)
One chick from HS05-2022 survived to fledge and was not banded.

3.   Discussion

Chick Monitoring.—Gallinule chick mortality was high at 64% ($n = 11$) and similar when looking at the chicks outfitted with a transmitter ($n = 4$) at 75%. An average of 8.6d (1–27.5d) elapsed since hatch for gallinule chicks that failed.

Stilt chick mortality was low at 36% with all stilt chicks ($n = 28$) and similar when looking at the chicks outfitted with a transmitter ($n = 9$) at 22%. An average of 10.25d (4–22.5d) elapsed since hatch for stilt chicks that failed.

4.   Recommendations

Chick Monitoring.—We had no success in identifying predators responsible for predation of stilt chicks. All potential stilt chick predation events resulted in transmitters falling off and were not consumed. In 2023, we plan to deploy 24/7 video surveillance in the vicinities of stilt chicks equipped with transmitters. Often the stilt chicks are found in the same general location and home ranges seem to be small, so deploying a video surveillance system around stilt chicks could help managers identify the predators responsible for stilt chick deaths.

d.   Long-term Waterbird Population Analysis

1.   Results

Survey.—A total of 260 waterbird surveys were conducted during 2017–2022 ($n=25$, $n=44$, $n=45$, $n=49$, $n=50$, $n=47$, respectively). The average coot abundance for those years were 14, 18, 30, 40, 35, and 25 individuals; the average gallinule abundance was 69, 54, 72, 82, 57, and 34 individuals; and the average stilt abundance was 20, 26, 40, 46, 41, and 33 individuals, respectively (Figure 8).

2.   Discussion

The populations of coots, gallinules, and stilts at Hāmākua Marsh increased from 2018–2020 and decreased in 2021–2022; coot, gallinule, and stilt populations decreased on average 8%, 44%, and 4% in 2022, respectively. The cause in the decrease of coot, gallinule, and stilt populations was unknown, but could have been due to emigration of waterbirds to nearby wetlands. This may have been spurred on by meeting habitat carrying capacities at Hāmākua Marsh even given the new habitat manipulation regimen.

3.   Recommendations

Habitat management in 2023 will remain similar to 2019–2022, applying the disking technique three times per year focusing on leaving islands of pickleweed (*Batis maritima*) and saltmarsh bulrush (*Bolboschoenus maritimus*) for coot and gallinule nesting habitat and creating mudflat habitat for stilts. Creating ideal habitat for all three endangered waterbirds is accomplished by maintaining the pickleweed on the shallowest areas of all the basins during the wet season, which minimizes pickleweed re-growth and creates mudflat once the water recedes in the drier months. The deeper portions of all the basins were disked minimally to leave islands of pickleweed surrounded by deeper waters in the wet months and progressively shallower waters in the drier months. The pickleweed in the shallow water sections is completely disked, whereas, in deeper waters only pickleweed edges are completely disked to maintain the vegetation islands.

IV.   Predator Control

a.   Methods

DOC-200 kill traps ($n = 16$) were deployed for 6404.5 trap days in 2022; and one conibear cat-kill trap was distributed along the road in the interior that paralleled the marsh (Figure 10). The DOC-200 and conibear traps were mounted inside housings to protect the trap mechanism from the elements and to eliminate incidental take of non-target species. The DOC-200 kill traps and conibear trap were baited weekly to monthly with dry cat food mixed with either salmon oil, shellfish oil, or crayfish oil. All traps were checked weekly and left opened always.

b.   Results

DOFAW trapped 41 small Indian mongooses (*Herpestes javanicus*), 39 rats (*Rattus* spp.), and 5 cats (*Felis catus*; Table 5).

c.   Recommendations

Mongoose take in 2022 was well below the annual average mongoose take from 2007−2019 (127 mongooses). DOFAW changed trapping techniques from contracted live trapping efforts to in-house kill-trapping in June of 2020.

Despite the lower trapping success of mongooses from prior years utilizing live trapping techniques, DOC-200 kill-traps and Tomahawk live traps showed no statistical significant difference in trapping success; however, DOC-200 traps outperformed live traps in our study (Roerk et al., 2022). Predator control will include Goodnature A18 Mongoose Multi-kill traps for 2023.

At Hāmākua Marsh mongoose control seems less necessary than at Pouhala Marsh. In 2021, at Hāmākua Marsh, 0 of 58 nests monitored by a camera were depredated by a mongoose. On one occasion a mongoose was captured on camera pipping a gallinule egg and the egg was removed by the attending gallinule, but this nest was successful. In contrast, Pouhala Marsh had 3 of 5 (60%) stilt nests, monitored by cameras, predated by mongooses. Interspecific and intraspecific competition is more of an issue for nest success at Hāmākua Marsh as 9 of 58 (16%) nests, monitored by cameras, were predated or abandoned possibly due to the presence of coot, gallinule, or stilt.

V. Conclusions and Goals for 2023

Hāmākua Marsh provides adequate habitat for all endangered waterbirds present on Oʻahu. While Hāmākua boasts annual production of coots, gallinules, and stilts in the form of fledglings, the relatively small size of the wetland portion of Hāmākua Marsh limits the ability of the marsh to sustain the endangered waterbirds on the island of Oʻahu, and severely limits the marshes ability to sustain Hawaiʻi. Increasing the functionality of the marsh to provide increasing numbers of coots, gallinules, and stilts remains the greatest priority to managers of Hāmākua Marsh.

Waterbirds have many threats that impact survivorship of their nests. Current studies cannot allocate any one threat as a source of nest loss at Hāmākua. Future studies should consider the same potential threats to the chick stage of the waterbird life cycle. In 2023, we will continue the final year of the three-year Competitive State Wildlife Grant project for stilts. Radio telemetry will be used to further understand the chick stage of the Hawaiian Stilt. We will aim to improve identification of predators as we failed to determine predators responsible for 2 of 2 transmittered stilt chicks taken by a predator. Once sources of mortality are identified mitigation measures can be initiated.

In addition, we will continue a similar project studying cause specific mortality in Hawaiian Gallinule chicks with internal funds. This project is analogous to the stilt chick mortality study. Radio telemetry will be used to track chicks at their most vulnerable stage and aim to determine cause of death and provide a survivorship model for the Hawaiian Gallinule.

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VII.   Appendix
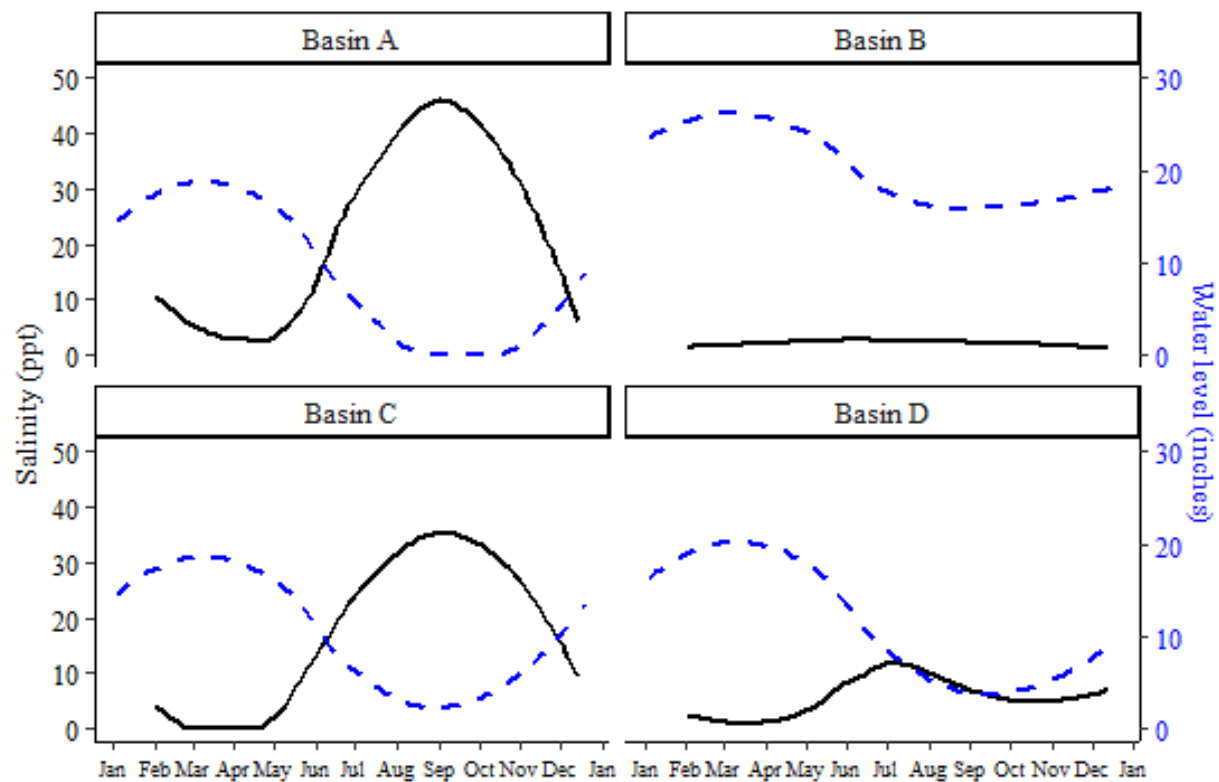
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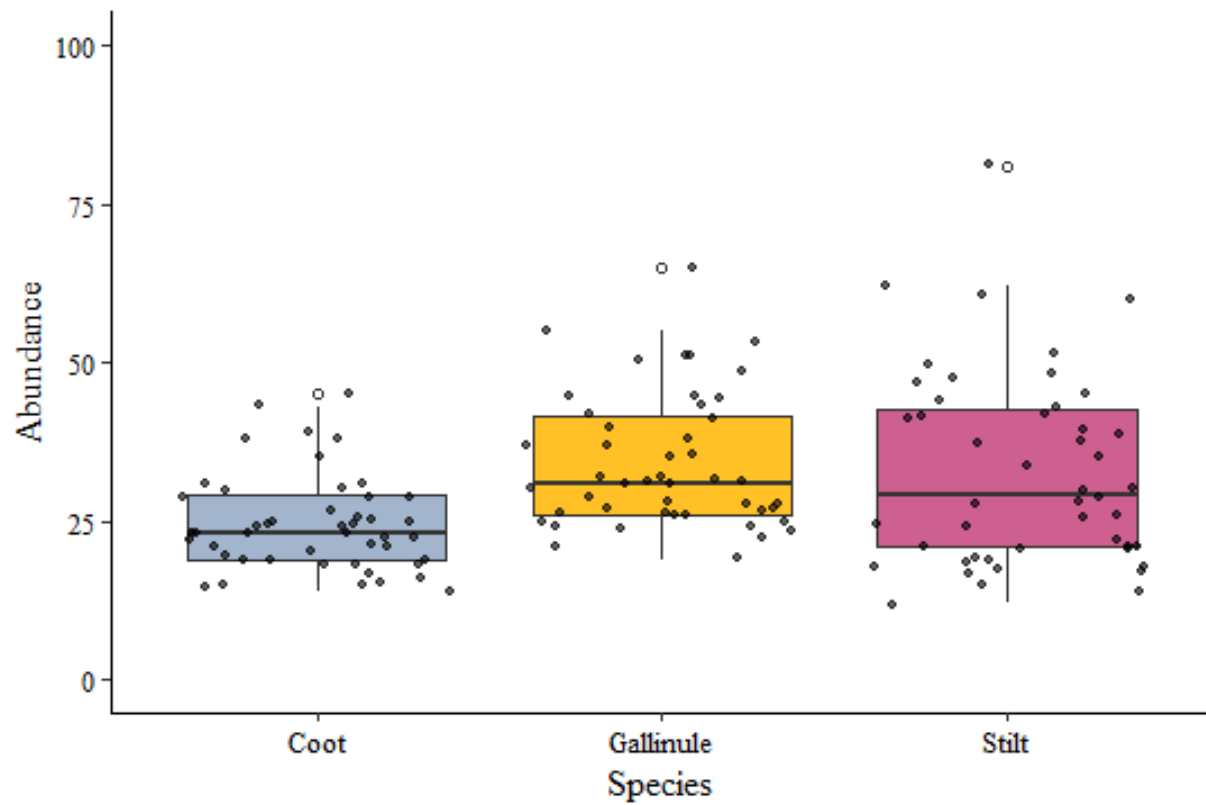
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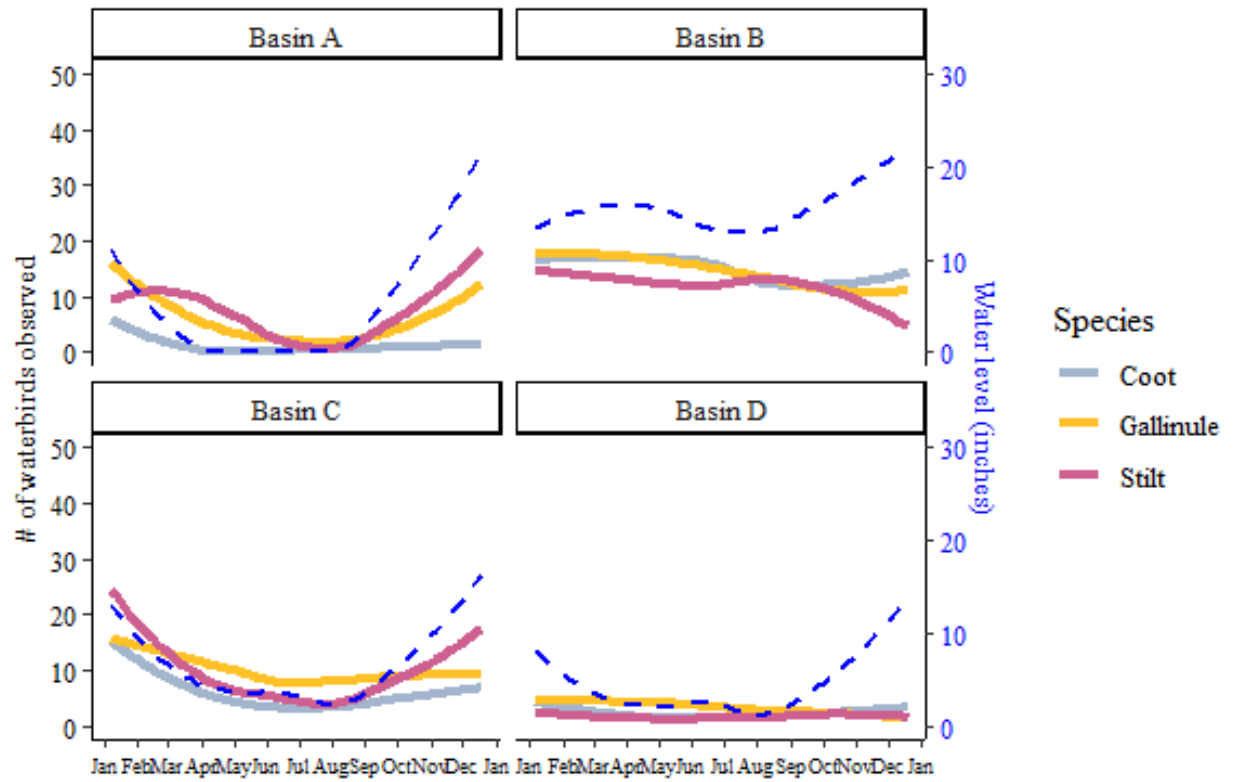
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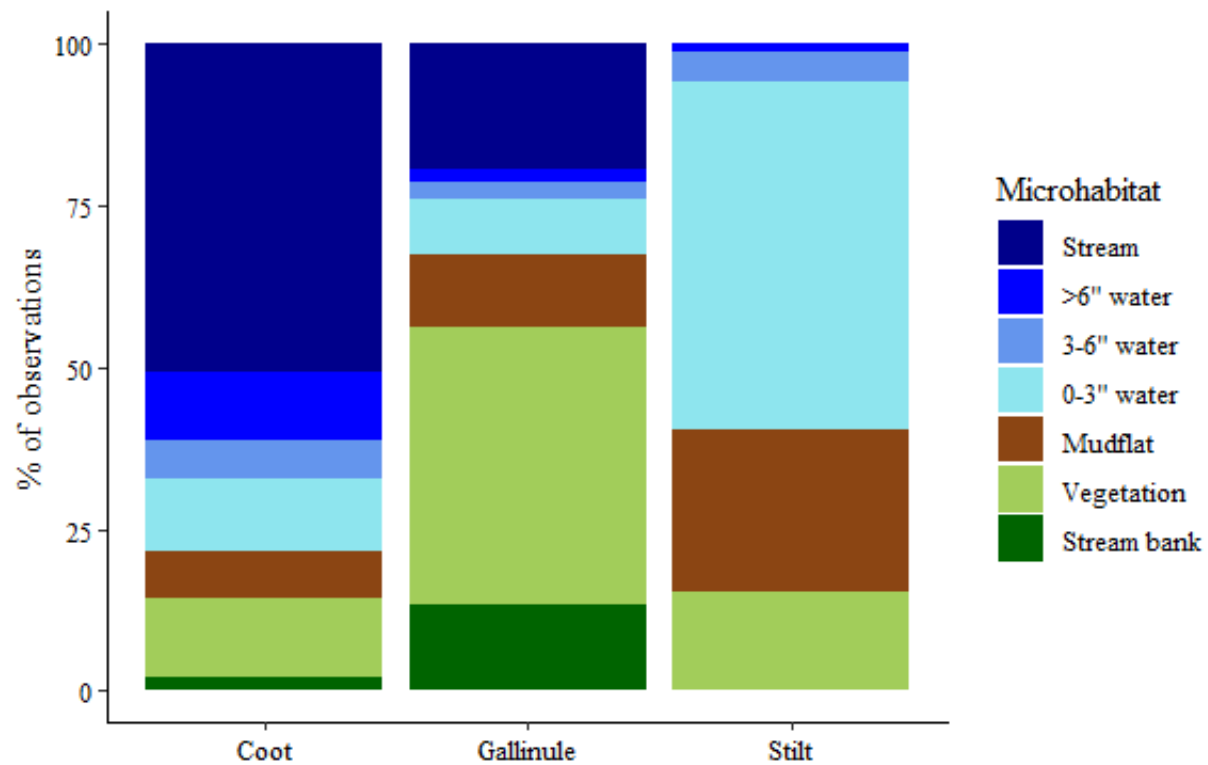
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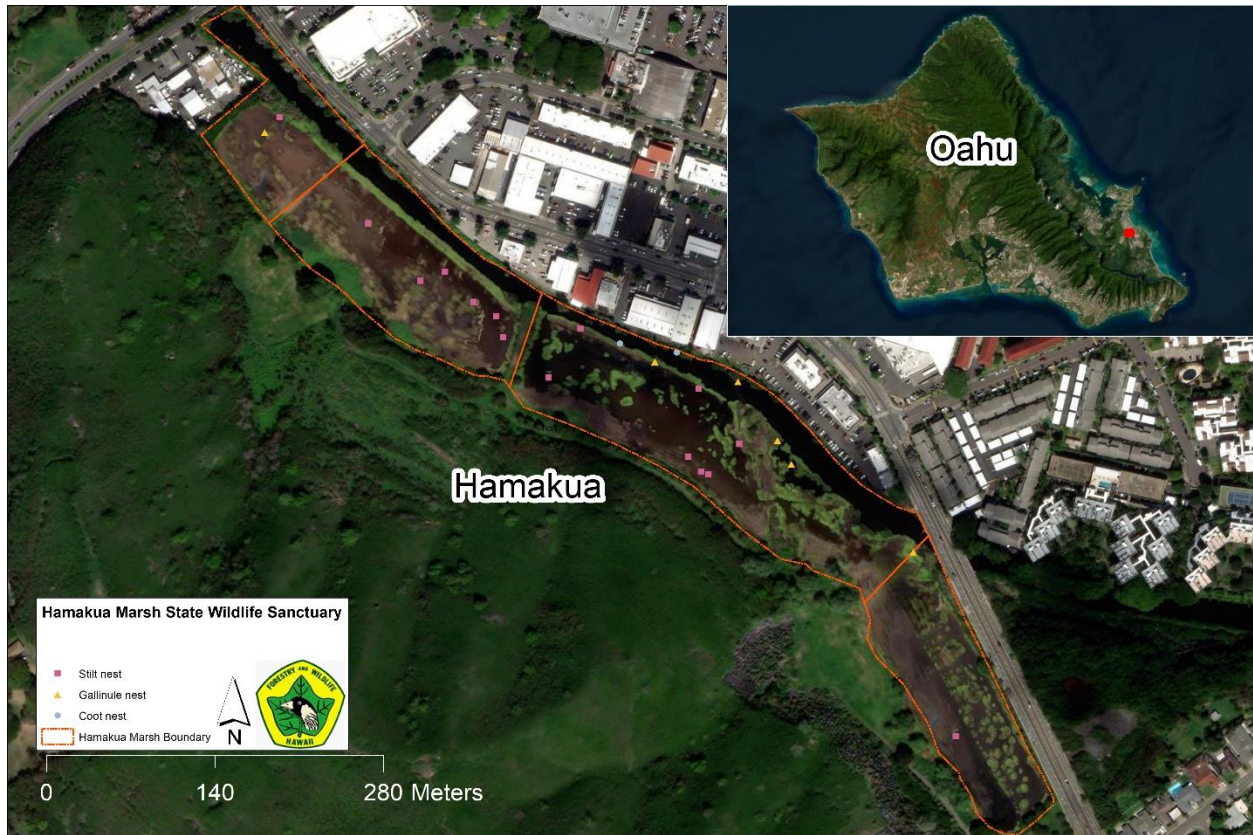
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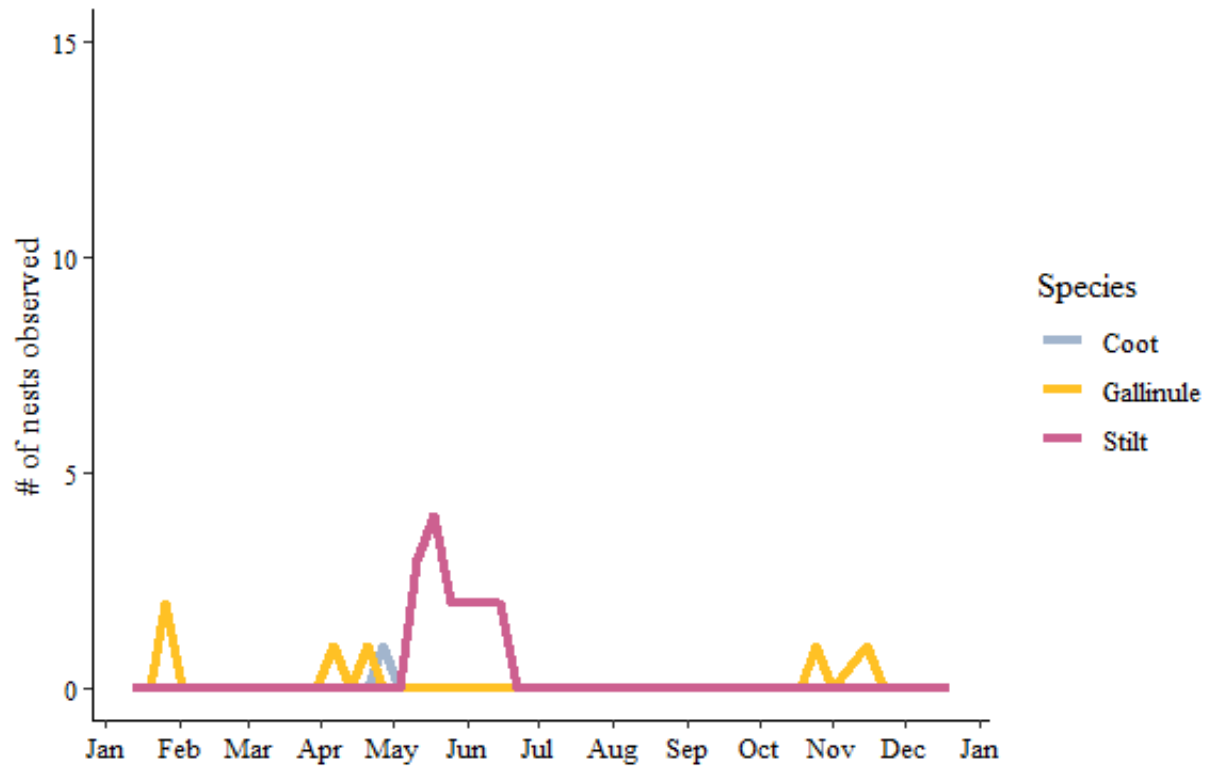
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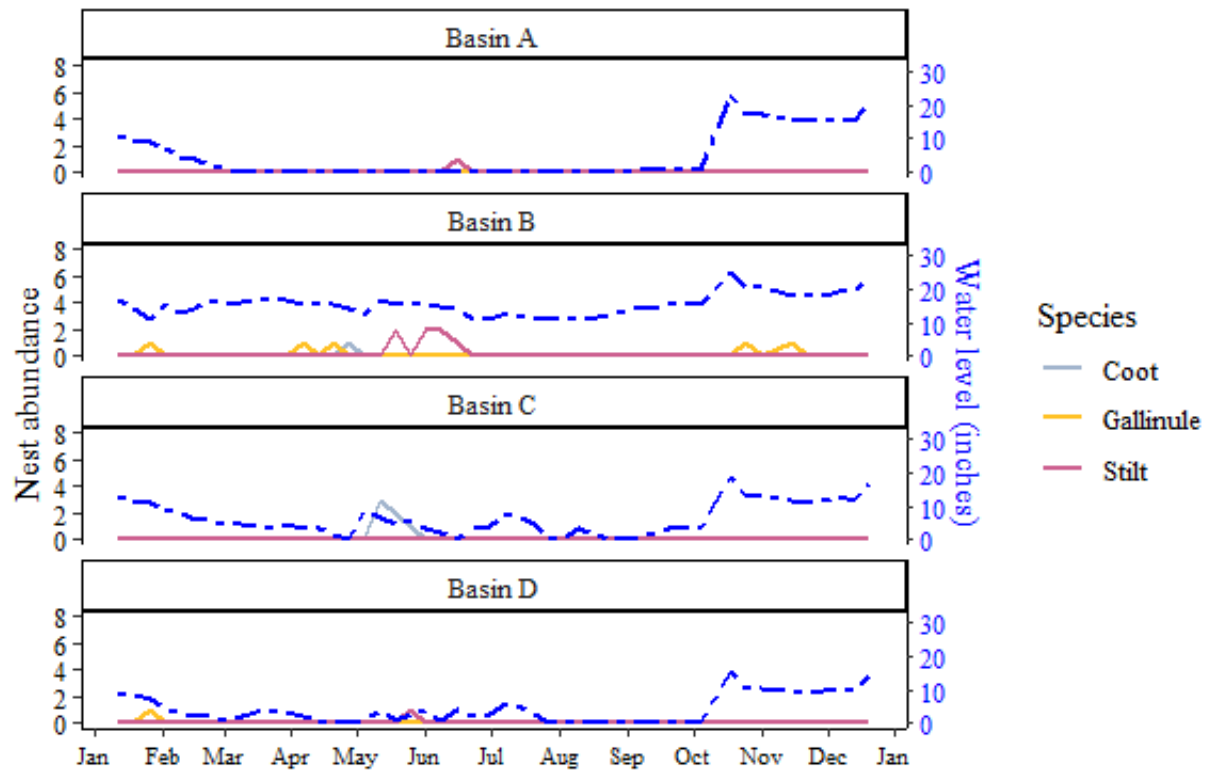
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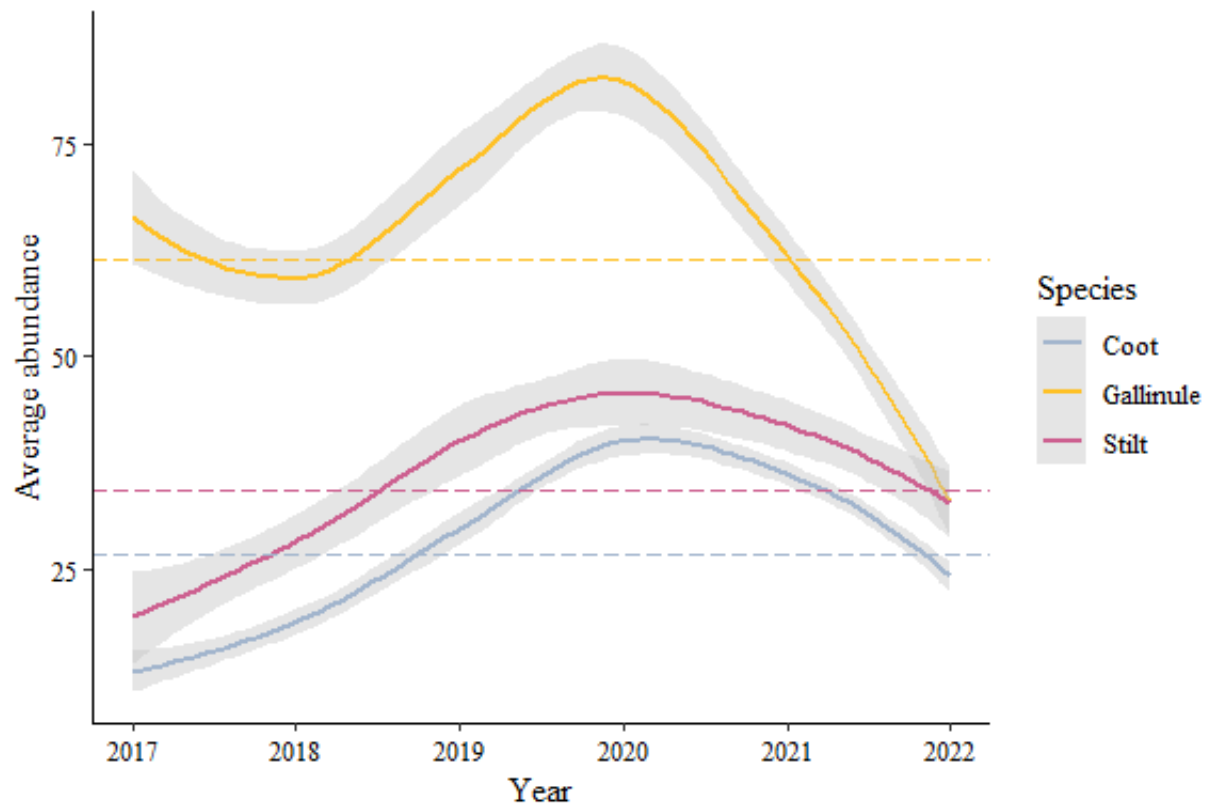
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Figure 9. Map of trap distribution for DOC-200 and conibear traps at Hāmākua Marsh, Oʻahu, Hawaiʻi.

Table 1. Habitat manipulation operations and techniques used within the wetlands at Hāmākua Marsh Wildlife Sanctuary, Kailua, Hawaiʻi, USA from 2003–2022.

| Year	Habitat manipulation
2003	Woody vegetation removed (i.e., mangrove)
2004	Woody vegetation removed (i.e., mangrove); tilling
2005	Limited tilling
2006	Tilling post-breeding 2005
2007	No tilling
2008	No tilling
2009	Increased vegetation removal; tilling post-breeding 2008
2010	Tilling post-breeding 2009
2011	No tilling
2012	Tilling post-breeding 2011
2013	No tilling
2014	Limited tilling
2015	Limited tilling
2016	No tilling
2017	Basin A was completely mowed and tilled; Basin B perimeters were tilled, interior left alone; Basin C interior was tilled leaving perimeters with buffer vegetation; Basin D was partially mowed and tilled in the interior.
2018	All Basins were mowed; Basin D tilled.
2019	Half of Basins A and B were disked in January; Half of Basin A and all of basins B, C, and D were disked in August; Half of Basin A and all of Basins B, C, and D were disked in October, but avoided disking center pickleweed islands in B and BolMar in Basin C.

2020   In early February, half of Basin A including the perimeter, the perimeter of Basin B, all of Basin C (minus the BolMar), and the perimeter of Basin D were disked to control mostly *B. maritima*. In late July, the untreated half of Basin A was cut and disked leaving patches and islands of taller *B. maritima*, the perimeter of Basin B was cut and disked leaving islands if *B. maritima* in the middle of the basin, all of Basin C was cut and disked leaving patches of BolMar, and Basin D was cut and disked leaving patches of BolMar. All cutting and disking in July focused on thinning the *B. maritima*. In late September, half of Basin A was tilled, a portion of Basin B between Basin A and the archeological site wall and portions of Basin C. The BolMar in Basin C was mowed using the cutter attachment then those areas were manipulated using the tilling attachment.

2021   In January, half of Basin A (drier side) and *B. maritima* patches in Basin B, C, and D were disked with the Marsh Master. In September, half of Basin A (drier side) and all of Basin C and D were disked with the Marsh Master. In October, half of Basin A (drier side), perimeter of Basin B, and half of Basin C (wetter side) and D (drier side) were disked with the Marsh Master. In December, half of Basin A (drier side), perimeter of Basin B, all of Basin C, and half of Basin D (drier side) were disked with the Marsh Master.

2022   In October, half of Basin A (drier side), perimeter of Basin B, and all of Basin C and D were disked with the Marsh Master. In November, half of Basin A (drier side), perimeter of Basin B, half of Basin C (drier side), and half of Basin D (drier side) were disked with the Marsh Master.

Table 2. The number of observed chicks, broods, fledglings, percent fledging success, and fledglings per brood for Hawaiian Coot, Hawaiian Gallinule, and Hawaiian Stilt from 2005−2022 at Hāmākua Marsh State Wildlife Sanctuary, Kailua, Hawai'i, USA.

	Coot				Gallinule				Stilt			
Year	# chicks (broods)	# fledglings	fledging success	fledglings per brood	# chicks (broods)	# fledglings	fledging success	fledglings per brood	# chicks (broods)	# fledglings	fledging success	fledglings per brood
2005	—	1	—	—	—	13	—	—	—	1	—	—
2006	—	0	—	—	—	50	—	—	19 (9)	17	89%	1.9
2007	2	1	50%	—	41	36	88%	—	16	13	81%	—
2008	—	5	—	—	35	33	94%	—	13	10	77%	—
2009	5	4	80%	—	52	50	96%	—	16	16	100%	—
2010	11	10	91%	—	56	44	79%	—	9	6	67%	—
2011	14	9	64%	—	33	30	91%	—	4	2	50%	—
2012	13	8	62%	—	31	20	65%	—	5	4	80%	—
2013	6	2	33%	—	43	25	58%	—	15	13	87%	—
2014	8	6	75%	—	95	77	81%	—	34	7	21%	—
2015	12	8	67%	—	62	42	68%	—	10	7	70%	—
2016	—	8	—	—	43	36	84%	—	42	32	76%	—
2017	11	6	55%	—	78	67	86%	—	12	9	75%	—
2018	13	7	54%	—	36	16	44%	—	16	7	44%	—
2019	13 (5)	3	23%	0.6	98 (27)	60	61%	2.2	27 (14)	20	74%	1.4
2020*	58 (26)	29	62%	1.1	61 (17)	30	49%	1.8	33 (18)	24	73%	1.3
2021*	15 (9)	2	13%	0.2	119 (26)	16	13%	0.6	37 (10)	10	27%	1.0
2022*	3 (1)	0	—	—	11 (3)	4	36%	1.3	28 (8)	18	64%	2.3
Total	**183 (41)**	**109**	**60%**	**0.8**	**894 (73)**	**649**	**73%**	**1.5**	**336 (59)**	**216**	**64%**	**1.5**

*Chick # determined through nest cameras.

Table 3. Summary of coot, gallinule, and stilt nest parameters (%HS = % hatching success) and nest failures. We collected data at Hāmākua Marsh, Kailua, Hawai'i, USA as determined by passive infrared cameras and manual nest surveys in 2022.

		Coot (*n*=2)	Gallinule (*n*=6)	Stilt (*n*=15)	Total (*n*=23)[a]
Camera		**1**	**5**	**10**	**17**
Nest parameters					
	Hatched (%HS)	1 (50)	3 (60)[b]	8 (80)	12
	Clutch size	4.0	4.8	4.0	
Nest failures					
Predator	Unknown			1[c]	1
Other failure	Abandoned		2[d]	1[e]	3
	Unknown				1
No camera		**1**	**1**	**5**	**6**
Nest parameters					
	Hatched (%HS)	0	0	0	0
	Clutch size	4.0	2.0	1.0	
Nest failures					
Predator	Unknown		1[f]	3[g]	4
Other failure	Abandoned				
	Unknown	1		2[h]	2

[a] Sum of independent hatching and nest failure events.
[b] Partial predation on one nest; two eggs hatched, one egg was seen outside the nest and looked predated on, last egg was removed from nest by attending gallinule (OO:AR).
[c] Nest destroyed by unknown predator; one egg observed broken open and contained a developing fetus.
[d] One nest incubated to full term, incubating adult (OA:GZ) removes all eggs serially from nest; one nest abandoned after parent was preyed upon by an owl (based on adult Hawaiian Gallinule [*Gallinula galeata sandvicensis*] carcass found 3 m from nest). Could not determine whether the owl was a non-native Barn Owl (*Tyto alba*) or native Hawaiian Short-eared Owl (Pueo; *Asio flammeus sandwichensis*) based on remains.
[e] Nest abandoned for unknown reason before expected hatch date.
[f] Nest depredated upon next visit; empty egg shell found outside of nest.
[g] Two nests with a single egg went missing after first discovery; one nest with a single egg destroyed by avian predator.
[h] Two nests each with a single egg, never taken nor destroyed; possible random eggs from a subadults.

Table 4. Reproductive metrics for coot (HACO; *n* = 2), gallinule (HAGA; *n* = 6), and stilt (HAST; *n* = 15) in Hāmākua Marsh, Kailua, Hawai'i, USA, 2022. Nest success is the proportion of nests that produced ≥1 chick, fledging success is the proportion of broods that produced ≥1 fledgling, and overall reproductive success is the proportion of nests that produced ≥1 fledgling.

	Nest Success			Fledging Success			Overall Reproductive Success		
Year	HACO	HAGA	HAST	HACO	HAGA	HAST	HACO	HAGA	HAST
2020	71%	65%	51%	73%	88%	72%	53%	58%	37%
2021[a]	60%	71%	50%	13%	48%	27%	7%	30%	15%
2022[a]	50%	50%	50%	0%	67%	88%	0%	33%	47%

[a] Based on intensive monitoring; not an estimation.

Table 5. Predators captured by month at Hāmākua Marsh, Kailua, Hawai'i, USA, 2022.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Mongoose	4	1	3	4	6	1	3	4	2	2	6	5	41
Cat	0	1	0	0	1	2	0	0	0	0	0	1	5
Rat	4	3	5	0	1	0	3	1	4	5	7	6	39