Habitat Use of Hawaiian Waterbirds in Kawainui Marsh

A Technical Report Written for the Department of Land and Natural Resources, Division of Forestry and Wildlife

Submitted by
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Executive Summary: In Kawainui Marsh, located on the windward side of Oʻahu, eleven man-made ponds were developed by the U.S. Army Corps of Engineers and the Hawaiʻi Department of Forestry and Wildlife (DOFAW) to supplement nesting and foraging habitat for endangered, native Hawaiian waterbirds (*ae'o* - Hawaiian stilt (*Himantopus mexicanus knudseni*), *ʻalae kea* Hawaiian coot (*Fulica alai*), and *'alae 'ula* - Hawaiian gallinule (*Gallinula galeata sandvicensis*). Management of hydrological conditions is thus a priority for DOFAW, as robust water circulation is critical to provide optimal wetland habitat for native waterbirds, as well as to prevent outbreaks of avian botulism caused by natural toxins produced in wetland soils. A better understanding of Hawaiian waterbird use of managed wetland habitat in relation to water quality is needed to implement effective management strategies. The objectives of this project are to: (1) compare water quality parameters among ponds within the Kawainui Marsh pond system; (2) determine the relationship between water depth and water quality; (3) evaluate habitat use of Hawaiian waterbirds in relation to water depth and water quality.

Weekly surveys were conducted in the wetland pond system from May 2018 through March 2019, between the hours of 8:00 AM and 11:00 AM, to measure water quality parameters (temperature, dissolved oxygen [DO], pH, salinity, turbidity, and oxidation-reduction potential [ORP]) using a YSI ProDSS sonde. A census of the number of Hawaiian waterbirds and their behaviors was recorded in the pond system concurrently during water quality surveys. Data was divided into wet and dry seasons, which correlated with precipitation. Two-way analysis of variance (ANOVA) tests were used to compare water quality parameters and presence of waterbirds between season and among ponds, as well as test for an interaction between season and pond. Regression models were used to determine the relationships between water depth and (1) water quality parameters, and (2) waterbird behaviors.

Hawaiian coots were observed most frequently during the wet season, when water depths were greatest, and primarily utilized the North Ponds, which had the greatest number of ponds with water throughout both wet and dry seasons. Hawaiian coots showed a preference for ponds with deeper water, particularly when foraging; however, no observations of nesting Hawaiian coots, and very few observations of resting Hawaiian coots, were recorded during this study period. Maintaining water depths above one foot may increase the number of foraging Hawaiian coots during the dry season. Hawaiian stilts were frequently observed in both the wet and dry seasons; however, Hawaiian stilts were observed nesting only during the dry season, which is likely because the dry season coincides with the Hawaiian stilt nesting season. Hawaiian stilts utilized the North and South Ponds for foraging, but primarily utilized the North Ponds for nesting, resting, and preening. The greatest number of nesting stilts were observed in pond 11, which may be due to the number of small islands that provided preferred nesting habitat. Hawaiian stilts do not seem to be limited by water depth, particularly when foraging; however, additional data on nest-site characteristics is needed to inform management decisions for Hawaiian stilt habitat. Hawaiian gallinules were not frequently observed during this study period, but when observed, gallinules primarily utilized the North Ponds for foraging in both wet and dry seasons. One Hawaiian gallinule was observed nesting in pond 4 during the dry season, which could be due to the availability of dense vegetation throughout that pond. Hawaiian gallinules may prefer ponds with deeper water, as they were most frequently found foraging in ponds with water depths of one to two feet. Overall, our results suggest maintaining water depths in Kawainui Marsh is most important for providing foraging habitat for Hawaiian coots and nesting habitat for Hawaiian stilts; however, more data collection is needed to determine specific water depths.

Introduction: Wetlands are some of the most productive ecosystems on Earth, supporting a large amount of the world's biological diversity. Waterbirds are among the many species that utilize wetlands for foraging and breeding. Management of wetland hydrological conditions is an important component of waterbird conservation, as water depth and water quality greatly impact waterbird productivity (Kushlan et al. 1975; Picman, Milks, & Leptich, 1993; Sanchez-Lafuente, Alcántra & Romero, 1998; Cain et al., 2003; Polak & Kasprzykowski, 2013). Kawainui Marsh, located on the windward side of O'ahu, provides primary nesting and foraging habitat for native Hawaiian waterbirds (*ae'o* - Hawaiian stilt (*Himantopus mexicanus knudseni*), *'alae kea* Hawaiian coot (*Fulica alai*), and *'alae 'ula* - Hawaiian gallinule (*Gallinula galeata sandvicensis*). Hawaiian waterbird populations face a number of threats, including habitat degradation, nonnative predators, and avian diseases, all of which may be influenced by wetland hydrological conditions (USFWS, 2011). A Recovery Plan for Hawaiian waterbirds has been introduced by the State Department of Land and Natural Resources and U.S. Fish and Wildlife Service that includes restoration of native wetland habitat; however, information on how Hawaiian waterbirds use wetland environments is limited, hindering management decisions regarding optimal restoration targets. Further, knowledge of Hawaiian waterbird habitat use in relation to surface water depth and water quality is needed, as management of wetland hydrological conditions is a priority for state managers of Kawainui Marsh (Mitchell, 2005).

In addition to providing suitable habitat, management of surface water levels is important for Hawaiian waterbird health. Water in Kawainui Marsh is primarily supplied by rainfall but is supplemented by nearby streams (USFWS, 2011). On the island of O'ahu rainfall intensity is highly variable on the windward side (Giambelluca et al., 2013). Fluctuating water levels may lead to variation in water quality parameters, such as temperature, pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), salinity, and turbidity, which are known to impact outbreaks of avian botulism (Work et al., 2010; Soos and Wobeser, 2006; Rocke and Samuel, 1999). Thresholds in water quality parameters that promote avian botulism outbreaks have been identified and include water temperatures between 25°C and 40°C, pH levels between 7.5 and 9.0, and salinity levels between 1.0 and 5.0 parts per thousand (Friend et al., 2012; Rocke and Samuel, 1999). Additionally, certain combinations of thresholds may increase the likelihood of an avian botulism outbreak. For example, low levels of DO coupled with low ORP can increase the amount of nutrients in surface water by converting sediment solids to aqueous forms. The resulting increase in turbidity may decrease light penetration, impacting primary production and invertebrate and microbe communities, which serve as food resources for Hawaiian waterbirds (USFWS, 2011). Fluctuating water levels may promote the decay of organic matter and organisms, which can serve as primary substrates for *Clostridium botulimum*, a bacterium that produces the toxin responsible for infecting avian species (Friend et al., 2012; Soos and Wobester, 2006). The toxin is transferred from decomposing organisms to invertebrates, such as zooplankton and maggots, which are consumed by waterfowl.

Sufficient water circulation is critical to provide optimal habitat for native waterbirds, as well as to prevent outbreaks of avian botulism caused by natural toxins produced in wetland soils. Additionally, with increasing variation in precipitation patterns due to climate change, it is important to determine possible impacts of variation in surface water levels on water quality and Hawaiian waterbird habitat use. The objectives of this project are to: (1) compare water quality parameters among ponds; (2) determine the relationship between water depth and water quality; (3) evaluate habitat use of Hawaiian waterbirds in relation to surface water depth and water quality.

Project Site: Kawainui Marsh is the largest wetland in the state of Hawai'i, at over 800 acres. Wetlands within the southern portion of Kawainui Marsh were rehabilitated through a joint project between the U.S. Army Corps of Engineers and the Hawai'i Department of Forestry and Wildlife (DOFAW), with the goal of creating nesting and foraging habitat for endangered Hawaiian waterbirds (DOFAW and Corps, 1998). The restoration site consists of two pond systems, North and South, that were excavated from upland pasture adjacent to Kawainui Marsh (Figure 1). Because preferred habitat requirements vary for each of the listed waterbird species, the depth of the ponds was designed to have a maximum range from 18 in. to 24 in. Each pond system is subdivided into five or six interior cells the arrangement of which follows the site topography, as to collectively drain water towards Kawainui Marsh and the ocean.

Cells within ponds connect through pipes to a single side-channel used to drain individual ponds as needed by way of flow control structures with adjustable weirs (Figure 1). This mechanism allows for adjustment of surface water levels within individual ponds so as to customize habitat conditions for particular waterbird species.

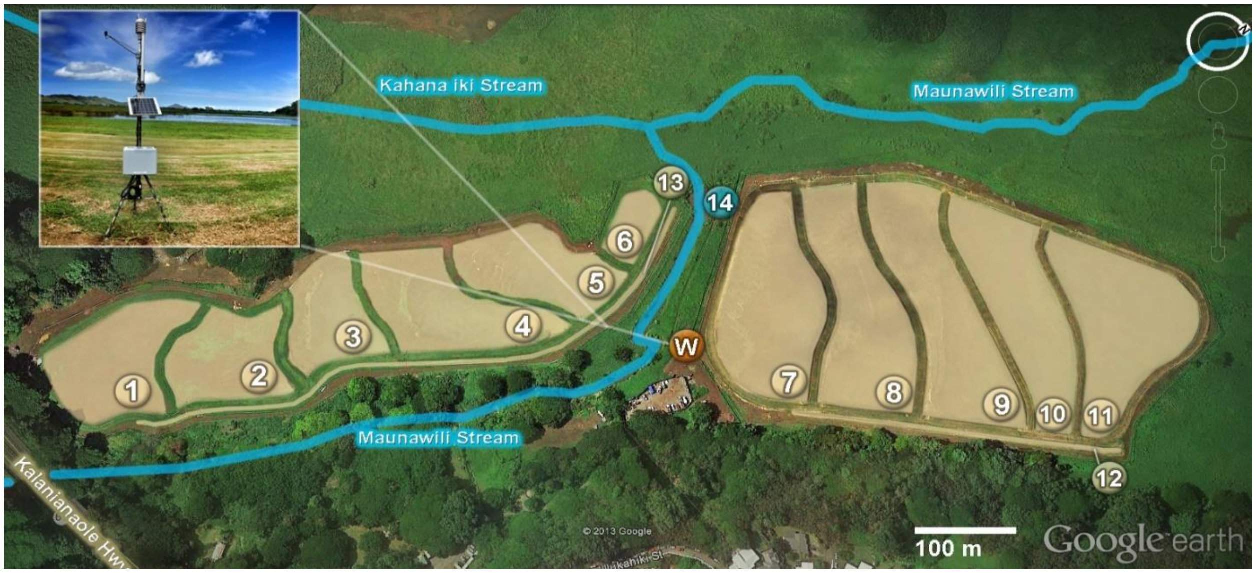


Figure 1: North and South ponds consisting of eleven man-made cells within Kawainui Marsh.

Research Questions

1. How does surface water depth and water quality differ between ponds?
2. How does surface water depth impact water quality parameters linked to outbreaks of avian botulism?
3. How do native Hawaiian waterbirds utilize the Kawainui pond system in relation to surface water depth and water quality?

Methods

Data Collection: Weekly surveys were conducted in the Kawainui Marsh pond system between the hours of 8:00 AM and 11:00 AM to measure water quality parameters (temperature, dissolved oxygen (DO), pH, salinity, turbidity, and oxidation-reduction potential (ORP)) using a YSI ProDSS sonde. Area surveys were conducted concurrently during water quality surveys to record the number of waterbirds, and their behaviors, in each pond. Waterbird surveys were conducted before water quality sampling, and consisted of driving around the perimeter of the ponds. Individuals were recorded as foraging, nesting, resting, or preening. If an individual was heard but not observed, and its call was identifiable, it was marked as present, but no corresponding behavior was recorded. Surveys started in the North Ponds (ponds 7-11) and ended in the South Ponds (ponds 1-6).

Data Analyses: Data was divided into wet and dry seasons, which correlated with precipitation. The wet season was from September 29th, 2018 to March 12th, 2019, and the dry season was from May 26th, 2018 to August 30th, 2018. Two-way analysis of variance (ANOVA) tests were used to compare water quality parameters and presence of waterbirds between season and among ponds, as well as test for an interaction between season and pond. Regression models were used to determine the relationships between water depth and (1) water quality parameters, and (2) waterbird behaviors.

Results

Water Quality Parameters Between Seasons and Among Ponds (Figure 2): Water depth was significantly different between seasons ($p<0.001$) and among ponds ($p<0.001$), and the relationship between water depth and pond was dependent on season ($p<0.001$). Turbidity was significantly different between seasons ($p<0.001$) but not significantly different among ponds ($p=0.34$), and the relationship between turbidity and pond was not dependent on season ($p=0.70$). Salinity was significantly different between seasons ($p<0.001$) but not significantly different among ponds ($p=0.27$), and the relationship between salinity and pond was not dependent on season ($p=0.21$). DO was significantly different between seasons ($p=0.05$) and was significantly different among ponds ($p<0.001$), but the relationship between DO and pond was not dependent on season ($p=0.90$). ORP was significantly different between seasons ($p=0.01$) and was significantly different among ponds ($p<0.001$), but the relationship between ORP and pond was not dependent on season ($p=0.24$). pH was not significantly different between seasons ($p=0.62$) but was significantly different among ponds ($p=0.01$), and the relationship between pH and pond was not significantly dependent on season ($p=0.20$). Temperature was significantly different between seasons ($p<0.001$) but not significantly different among ponds ($p=0.31$), and the relationship between temperature and pond was not significantly dependent on season ($p=0.75$).

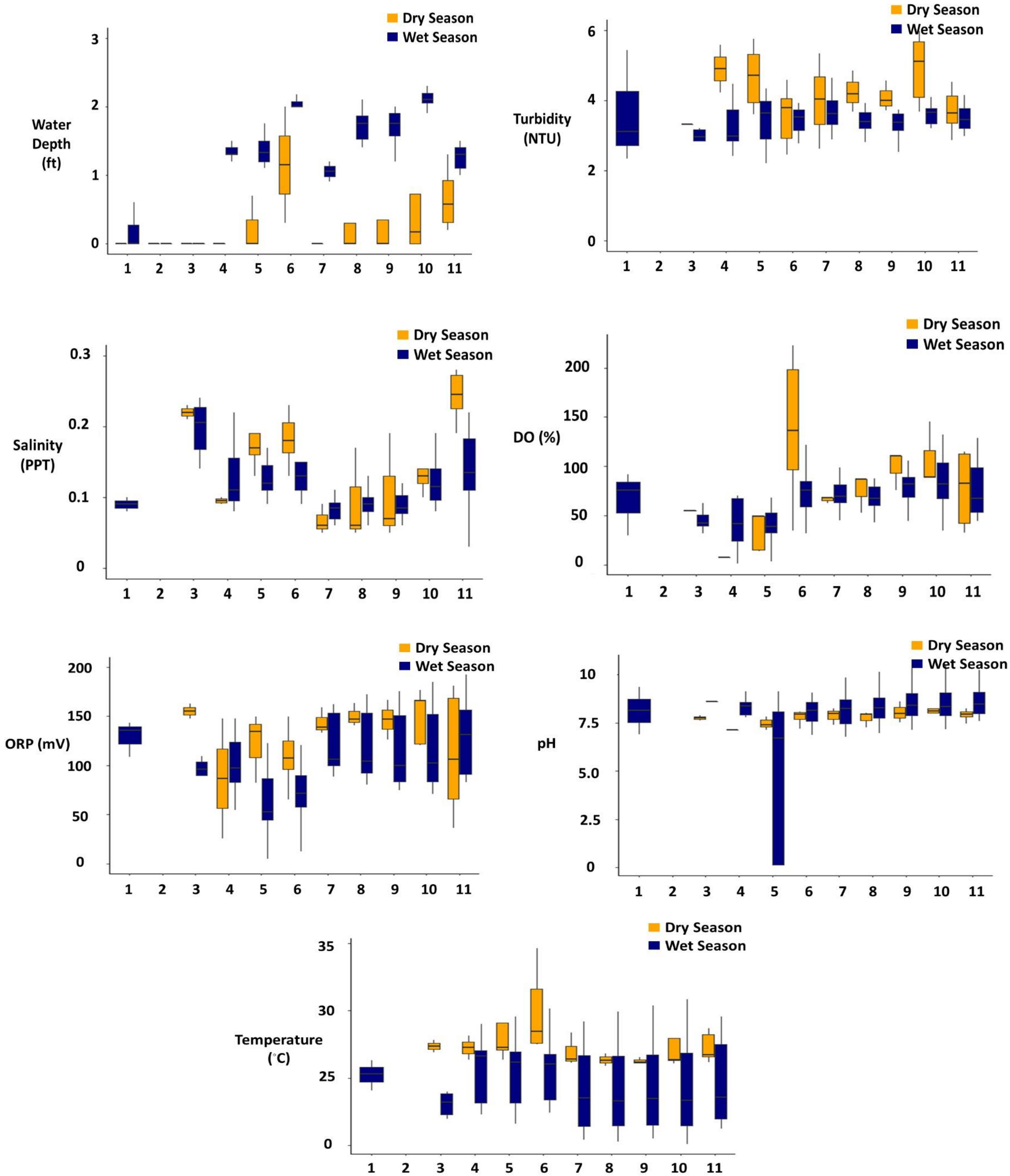
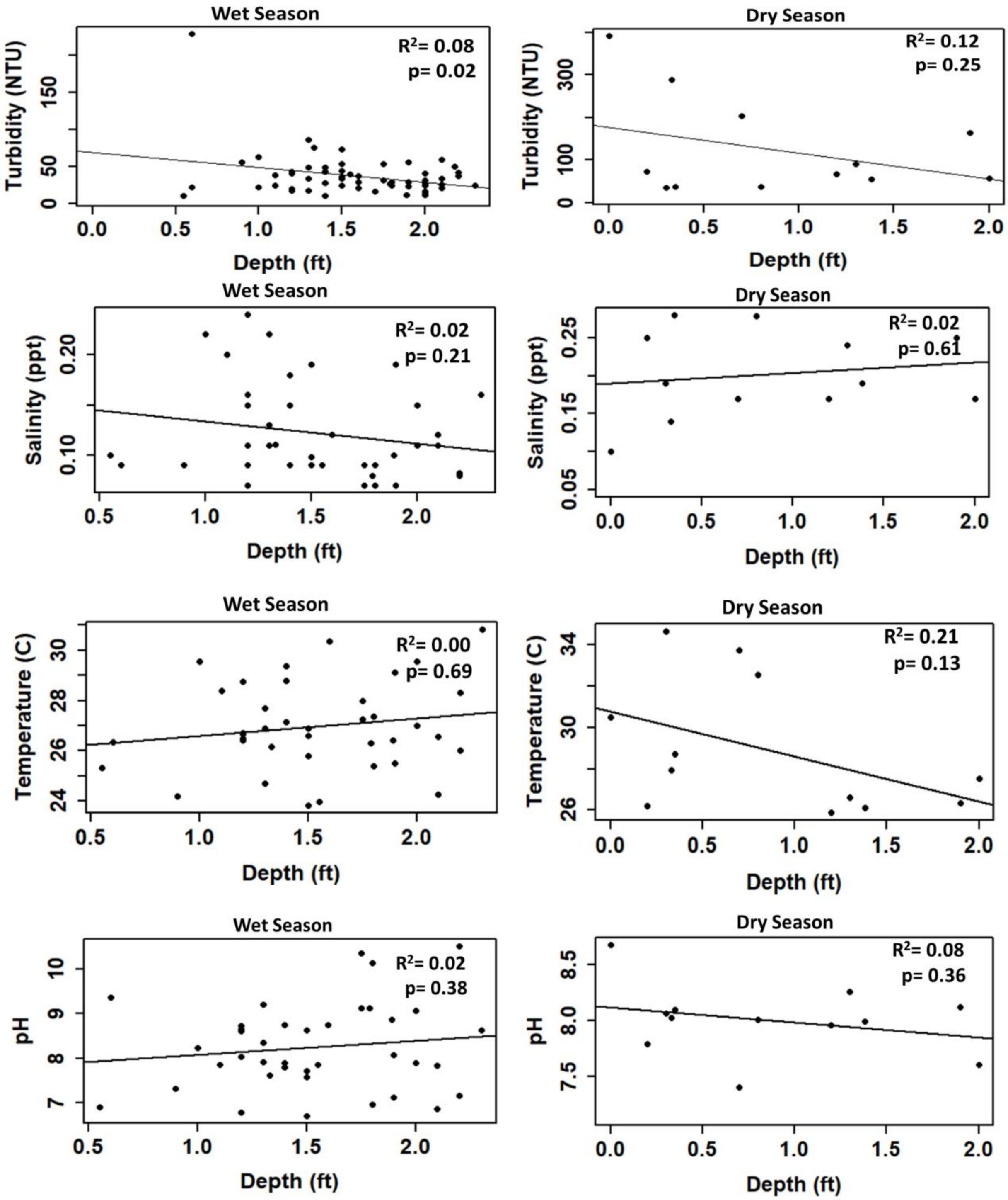


Figure 2: Comparison of water quality parameters between wet and dry seasons and among ponds.

Water Depth and Water Quality (Figure 3): During the wet season, turbidity was negatively correlated with water depth (p=0.02). No significant relationships were observed between depth and other water quality parameters during the wet season. No significant relationships were observed between depth and any water quality parameters during the dry season



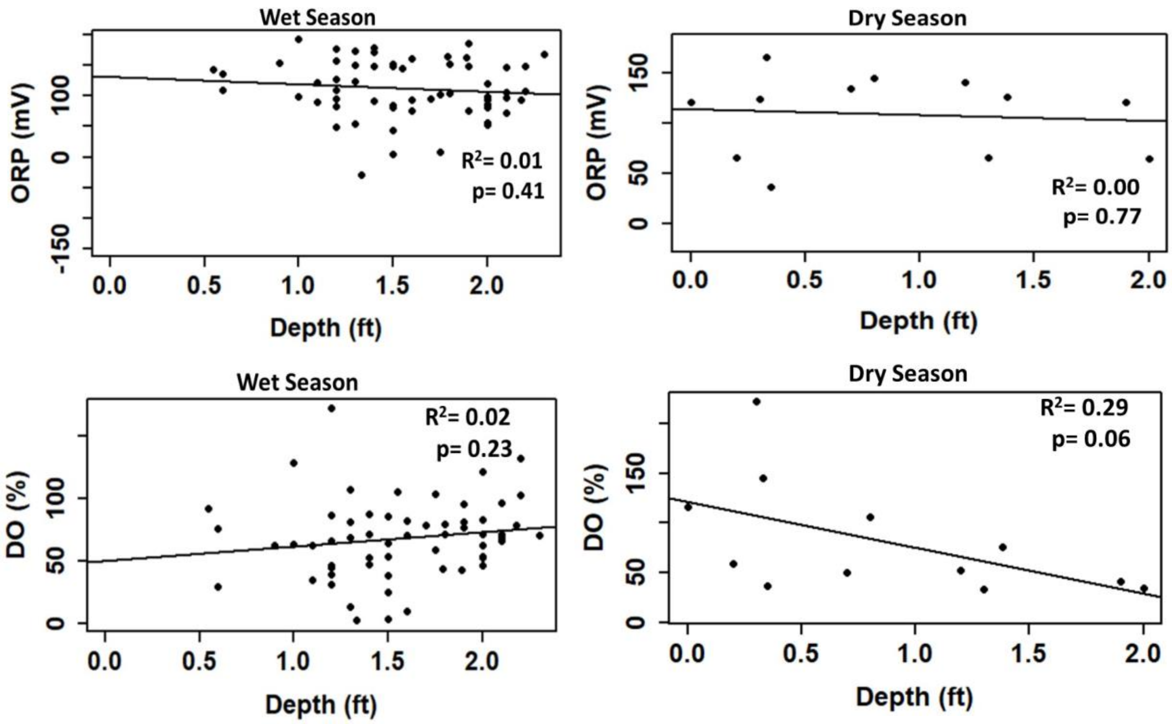


Figure 3: Linear regressions of the relationships between water depth and water quality parameters.

Hawaiian Coot Habitat Use Between Seasons and Among Ponds (Figure 4): The number of observations of foraging Hawaiian coots was significantly different between seasons (p=0.005) and among ponds (p<0.001), and the relationship between foraging Hawaiian coots and pond was significantly dependent on season. The number of observations of resting Hawaiian coots was not significantly different between seasons (p=0.33) and was not significantly different among ponds (p=0.08); further, the relationship between resting Hawaiian coots and pond was not significantly dependent on season (p=0.61). No Hawaiian coots were observed nesting during this study period.

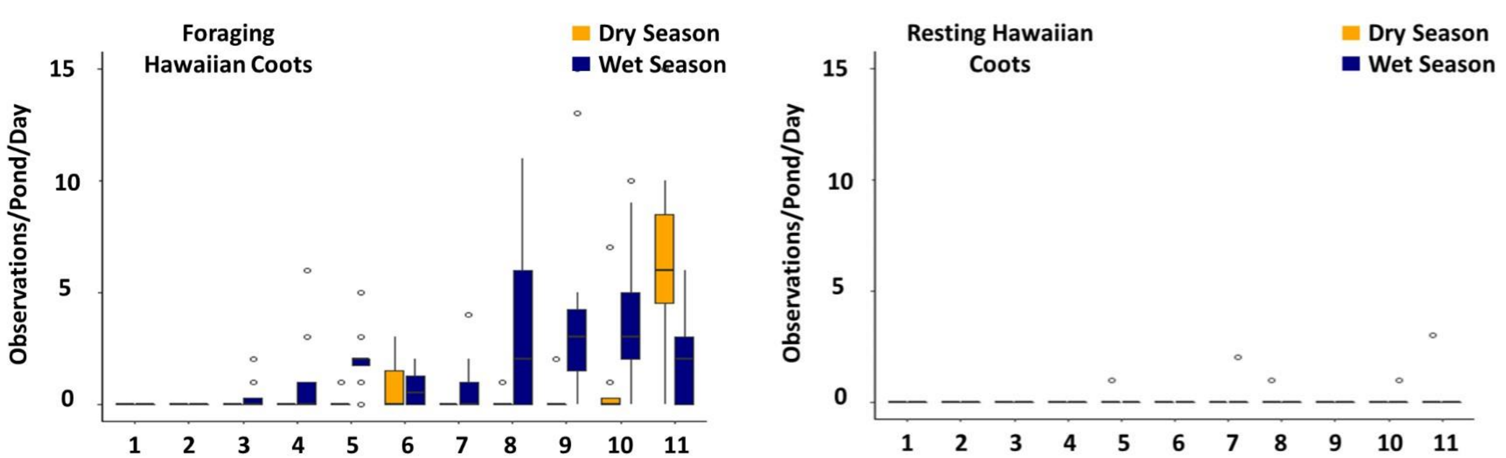


Figure 4: Comparison of observations of foraging and resting Hawaiian coots between seasons and among ponds.

Hawaiian Stilt Habitat Use Between Seasons and Among Ponds (Figure 5): The number of observations of foraging Hawaiian stilts was not significantly different between seasons (p=0.92) but was significantly different among ponds (p<0.001), and the relationship between foraging Hawaiian stilts and pond was significantly dependent on season (p=0.02). The number of observations of resting Hawaiian stilts was not significantly different between seasons (p=0.42) but was significantly different among ponds (p=0.02), and the relationship between resting Hawaiian stilts and pond was significantly dependent on season (p=0.002). The number of observations of nesting Hawaiian stilts was significantly different between seasons (p<0.001) and was significantly different among ponds (p<0.001), and the relationship between nesting Hawaiian stilts and pond was significantly dependent on season (p<0.001).

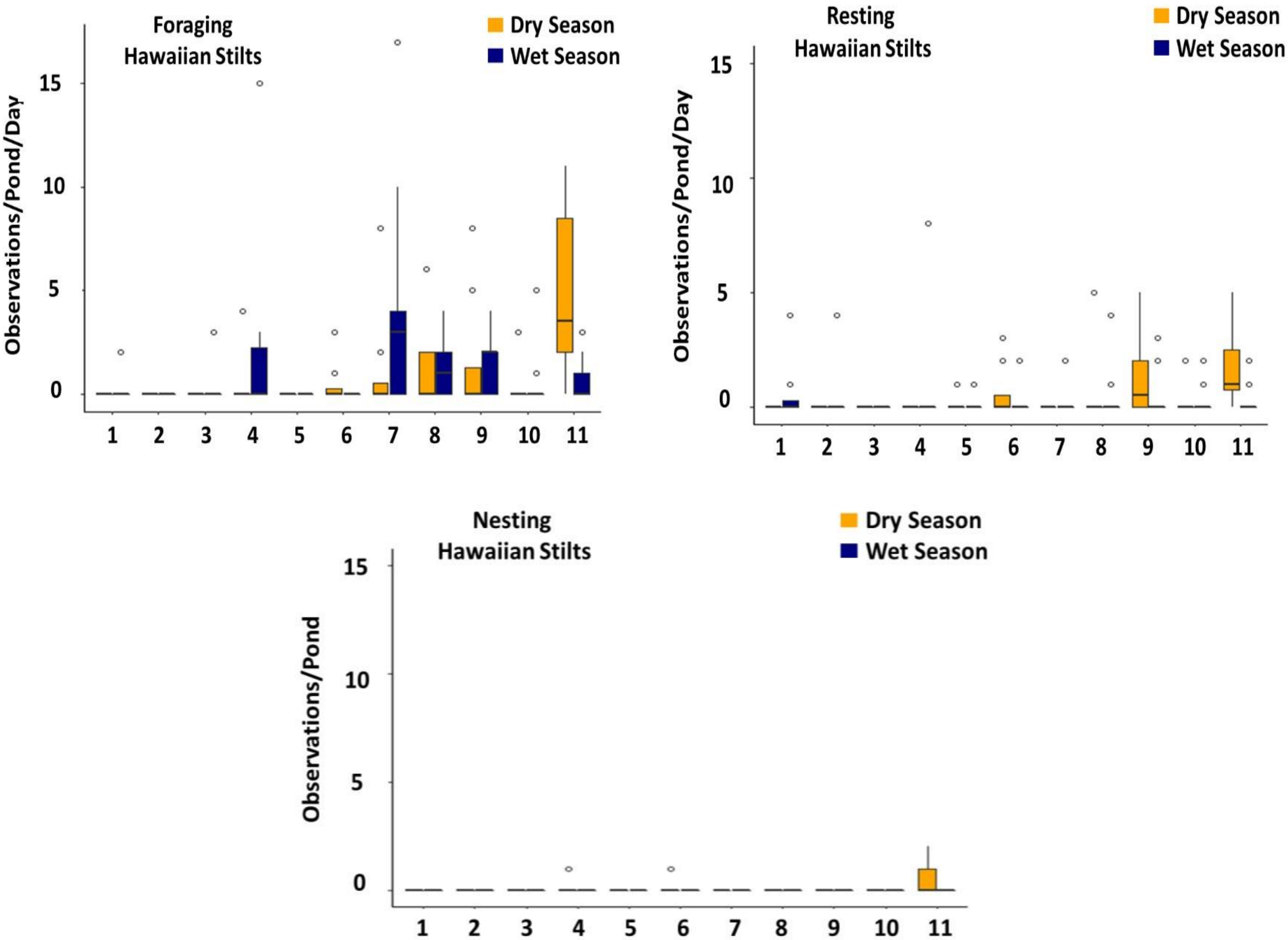


Figure 5: Comparison of observations of foraging, resting, and nesting Hawaiian stilts between seasons and among ponds.

Hawaiian Gallinule Habitat Use Between Seasons and Among Ponds (Figure 6): The number of observations of foraging Hawaiian gallinules was not significantly different between seasons (p=0.17) but was significantly different among ponds among ponds (p<0.001); the relationship between foraging Hawaiian gallinules and pond was not significantly dependent on season (p=0.46). There were not enough observations of resting Hawaiian gallinules to compare observations between seasons and among ponds. The number of observations of nesting Hawaiian gallinules was not significantly different between seasons (p=0.09) or among ponds (p=0.39), and the relationship between nesting Hawaiian gallinules and pond was not significantly dependent on season (p=0.28).

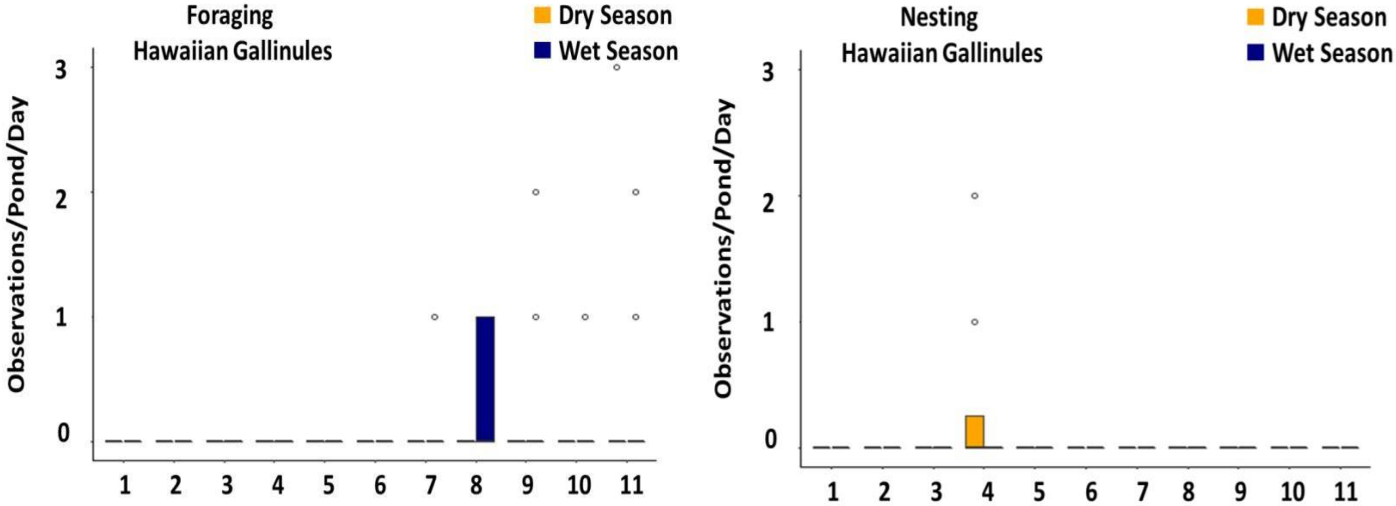


Figure 6: Comparison of observations of foraging and nesting Hawaiian gallinules between seasons and among ponds.

Hawaiian Coots and Water Depth (Figure 7): The number of observations of foraging coots was positively correlated with water depth in both the wet (p<0.001) and dry (p=0.001) seasons. There were not enough observations of nesting or resting Hawaiian gallinules to examine relationships with water depth.

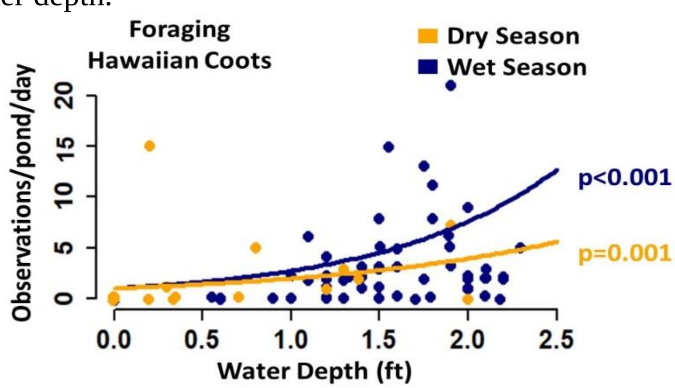


Figure 7: Generalized linear model showing relationship between water depth and observations of foraging coots for both wet and dry seasons.

Hawaiian Stilts and Water Depth (Figure 8): The number of observations of foraging Hawaiian stilts was not significantly correlated with water depth in the wet season (p=0.76) but was positively correlated with water depth in the dry season (p=0.05). The number of observations of resting and preening Hawaiian stilts was not significantly correlated with water depth in the wet season (p=0.83) but was positively correlated with water depth in the dry season (p=0.003). The number of observations of nesting Hawaiian stilts was not significantly correlated with water depth in the dry season (p=0.96). No Hawaiian stilts were observed nesting in the

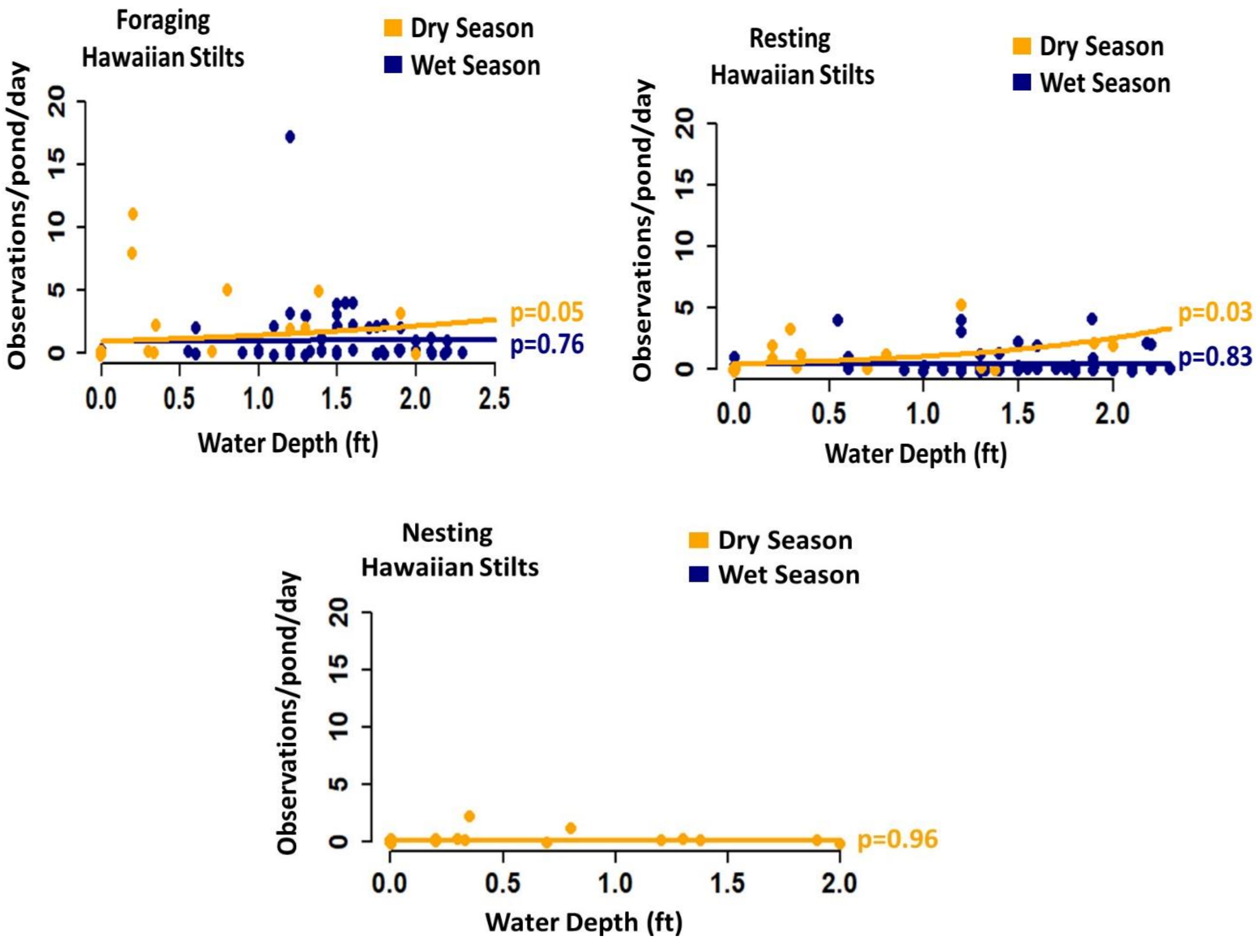


Figure 8: Generalized linear models showing relationships between water depth and observations of foraging, resting, and nesting Hawaiian stilts for both wet and dry seasons.

Hawaiian Gallinules and Water Depth (Figure 9): The number of foraging Hawaiian gallinules was positively correlated with water depth in the wet season (p=0.05) but was not significantly correlated with water depth in the dry season (p=0.06). There were not enough observations of nesting or resting Hawaiian gallinules to determine the relationships between counts and water depth.

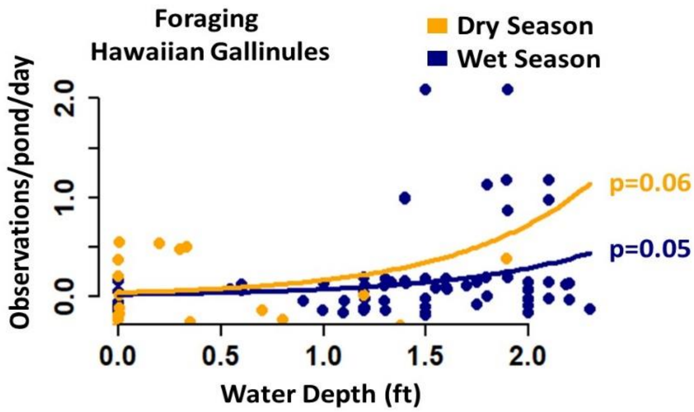


Figure 9: Generalized linear model showing relationship between water depth and observations of foraging Hawaiian gallinules for both wet and dry seasons.

Conclusions

Hawaiian Coot Habitat Use: Hawaiian coots were observed most frequently during the wet season, when water depths were greatest, and primarily utilized the North Ponds, which had the greatest number of ponds with water throughout both wet and dry seasons. Hawaiian coots showed a preference for ponds with deeper water, particularly when foraging; however, no observations of nesting Hawaiian coots, and very few observations of resting Hawaiian coots, were recorded during this study period, and more data should be collected to form conclusions about how Hawaiian coots are utilizing the pond system for resting, preening, and nesting. *Hawaiian Coot Management Recommendations*: Maintaining water depths above one foot may increase the number of foraging Hawaiian coots during the dry season.

Hawaiian Stilt Habitat Use: Hawaiian stilts were frequently observed in both the wet and dry seasons; however, Hawaiian stilts were observed nesting only during the dry season, which is likely because the dry season coincides with the Hawaiian stilt nesting season. Hawaiian stilts utilized the North and South Ponds for foraging, but primarily utilized the North Ponds for nesting, resting, and preening. The greatest number of nesting stilts were observed in pond 11, which may be due to the number of small islands that provide preferred nesting habitat. *Hawaiian Stilt Management Recommendations:* Hawaiian stilts do not seem to be limited by water depth, particularly when foraging. Additionally, Hawaiian stilts nested in ponds with varying water depths, from zero to two feet.

Hawaiian Gallinule Habitat Use: Hawaiian gallinules were not frequently observed during this study period, but when observed, gallinules primarily utilized the North Ponds for foraging in both wet and dry seasons. One Hawaiian gallinule was observed nesting in pond 4 during the dry

season, which could be due to the availability of dense vegetation throughout that pond.
Hawaiian Gallinules Management Recommendations: Hawaiian gallinules may prefer ponds with deeper water, as they were most frequently found foraging in ponds with water depths of one to two feet.

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