Florida Field Naturalist

PUBLISHED BY THE FLORIDA ORNITHOLOGICAL SOCIETY

Vol. 48, No. 3 | September 2020 | Pages 77-139

Florida Field Naturalist 48(3):77-86, 2020.

IMPACT OF HYDRILLA ON USE OF THE LITTORAL ZONE BY THREE FORAGING WADING BIRDS IN CENTRAL FLORIDA

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Abstract.—Hydrilla (*Hydrilla verticillata*) is an invasive nonnative aquatic plant that can alter littoral plant communities by supplanting native species. Despite the negative effects of hydrilla, however, areas where it grows can have greater abundance and diversity of some invertebrate and fish species that are important forage for wading birds. We examined abundance and foraging of Great Egrets (*Ardea alba*), Little Blue Herons (*Egretta caerulea*), and Limpkins (*Aramus guarauna*) in relation to hydrilla presence in the littoral zone at four central Florida lakes during 2014–2015. Hydrilla was present at 49% of survey points, but we found no relationship to the number of birds observed or the presence of Great Egrets or Limpkins; we observed Little Blue Herons too infrequently to draw conclusions. We observed no significant differences in prey-capture efficiency between sites with hydrilla and those without hydrilla for Great Egrets or Little Bird Herons. We found significantly more captures by Limpkins in areas with hydrilla. Our study was somewhat constrained by small sample sizes, but our results suggest that hydrilla presence does not substantially affect the presence of Great Egrets or Limpkins or the foraging efficiency of Great Egrets and Little Blue Herons.

Key words: foraging, hydrilla, Kissimmee chain-of-lakes, limpkin, wading birds

Hydrilla (*Hydrilla verticillata*) is a macrophyte that was introduced into Florida from Sri Lanka in the early 1950s and has spread to lakes and rivers statewide (Sutton et al. 1980, Langeland 1996, Cuda et al. 2016). The Florida Exotic Pest Plant Council (FLEPPC) considers it a Category I plant or "an invasive that alters native plant communities by displacing native species or changing community structure and ecological functions" (FLEPPC 2015). Dense hydrilla infestations can negatively affect navigation and recreational activities, tourism, property values, water quality, flood control, and native plant communities (Langeland 1996, Haller 2009). Dense canopies of hydrilla also can block air exchange, which can reduce oxygen levels and result in fish kills (Madsen 2009). State and local government agencies actively manage hydrilla via chemical and mechanical treatments to keep it from dominating lakes and having negative impacts on fish, wildlife, boaters, and the overall health of Florida's freshwater lakes.

The negative effects of hydrilla on native ecosystems can be profound, but hydrilla also has been found to be neutral or even beneficial to some fish and wildlife species in managed or controlled sites. For example, overall richness, diversity, and abundance of aquatic birds has been shown to be similar at lakes with and without hydrilla (Hoyer et al. 2008), and juvenile and forage fish density were significantly higher in areas with hydrilla than in areas of other macrophytes species (*Panicum hemitomon* and *Potamogeton illinoensis*) in Lake Okeechobee (Chick and McIvor 1994). Increased hydrilla densities were associated with increased numbers and diversity of invertebrates and increased survival of young largemouth bass (*Micropterus salmoides*) in a study in two central Florida lakes (Moxley and Lanford 1982). Ducks, American Coots (*Fulica americana*), and Pied-billed Grebes (*Podilymbus podiceps*) may also be more abundant when hydrilla is present (Esler 1990), as has been seen in the littoral zone of Lake Okeechobee (Johnson and Montalbano 1984).

There is little quantitative information on hydrilla occurrence at specific littoral sites used by Florida's 16 species of wading birds. One study on Lake Okeechobee reported foraging Snowy Egrets (*Egretta thula*) and Tricolored Herons (*Egretta tricolor*) regularly used dense surface mats of hydrilla, in combination with the leaves of lotus (*Nelumbo lutea*) and water hyacinth (*Eichhornia crassipes*), to provide support while foraging in deep water. Great Egrets (*Ardea alba*) also were observed in areas with mixed macrophyte species potentially including hydrilla, *Vallisneria*, and *Potamogeton* (Smith 1997). A greater understanding of wading birds' use of hydrilla would be beneficial for sound management of Florida lakes. The objectives of this study were to 1) determine if hydrilla was present and at what density in the littoral zone of central Florida lakes at sites used by Great Egrets, Limpkins (*Aramus guarauna*), and Little Blue Herons (*Egretta caerulea*) and 2) opportunistically monitor foraging by those species and compare capture efficiency at sites with and without hydrilla. The three focal species differ in their prey preference and water depth where they forage. Moreover, the Little Blue Heron is state-listed as Threatened (FWC 2013a) and the Limpkin was only recently removed from being state-listed (FWC 2013b). Understanding what role if any hydrilla has with habitat used by and foraging of these three species would aid in their conservation.

Methods

We collected wading bird presence data on four lakes in central Florida where hydrilla has been documented: Lake Jackson, Lake Tohopekaliga, and Cypress Lake in Osceola County and Lake Kissimmee in Osceola and Polk counties (Fig. 1). We also collected foraging data at the four survey lakes, Lawne Lake in Orange County, and Lake Istokpoga in Highlands County (Fig. 1). The study lakes varied in size from 62.6 ha (Lawne Lake) to 12,915.5 ha (Lake Kissimmee), with a mean of 5,576.3 ha (SE = 2,297). All lakes were frequently used for fishing and other recreation, and all had some degree of shoreline development in the form of pastureland or housing.

We selected three wading bird species that occupy differing foraging niches in the littoral zone. Limpkins are primarily mollusks specialists, foraging on apple snails (*Pomacea* spp.) and freshwater mussels (Bryan 2002). Recent studies have linked Limpkin range expansion to nonnative apple snail and hydrilla expansion (Smith et al. 2019). Nonnative apple snails are described as voracious consumers of hydrilla (Baker et al. 2010) and Limpkin prey on the nonnative snails. Limpkins forage in shallow water (0.1–18.5 cm; T. A. Dellinger, *pers. obs*) and are known to walk and forage on mats of floating vegetation that can support their weight in deeper water (Bryan 2002, Hoyer 2009). Little Blue Herons forage at water depths similar to those used by Limpkins (5–15 cm), but instead of snails, they capture small fish, amphibians, and invertebrates (Rodgers and Smith 2012). Great Egrets are opportunistic hunters of fish, crustaceans, amphibians, reptiles, birds, and small mammals (McCrimmon et al. 2011), and their longer legs allow them to forage in depths of up to approximately 28 cm (Powell 1987).

We examined the number of wading birds as a function of hydrilla presence at four survey lakes during July–September 2014 and June 2015. We established fixed points at each lake (Fig. 1). Points were located one kilometer apart in the littoral zone and reached from an airboat. Water depth varied at the fixed points, so if the depth at a point was >50 cm, we steered the airboat toward the shore perpendicular to the point until we reached a depth of ≤50 cm. This shallow depth allowed us to still navigate the airboat yet see the complete 300-m view of the littoral zone and shoreline. Upon arrival at each point, we waited 5 min before beginning the survey to allow birds to return after we turned the airboat's engine off (Gawlik and Rocque 1998). At the start of the survey, we broadcast a recording of a Limpkin vocalization three times over a 20-s period, after which we conducted a 10-min survey, recording the presence of any individuals of the three focal species within 300 m of the point. We determined line-of-sight distances with a laser rangefinder (Bushnell Corporation, Overland, Kansas) and water depth with a stream gauge. We surveyed between an hour after sunrise and 1400 hours. After each survey we quantified hydrilla cover in a 100.3-m^2 circular plot. We established the circular plot to either side of the airboat and defined it with two 11.3-m floating ropes that crossed in the middle at right angles, positioned such that one rope was parallel to the shoreline, and secured the ropes to vertical rebar pushed into the lake bottom. We then assessed if hydrilla was present or absent at the plot center, and at four evenly spaced intervals along the ropes. Where present, we categorized the density of hydrilla as sparse (≤33%), moderate (34–67%), or dense (>67%). We averaged the nine values to characterize the water depth and hydrilla presence at the survey location. We attempted to repeat the wading bird survey at each point at least twice over the course of the study to increase the sample size and because hydrilla presence can vary from month to month.

To determine whether the density of hydrilla in the 100.3-m^2 circular plot represented hydrilla presence in the larger area around the survey point, we compared hydrilla amounts in the circular plot to foraging observation locations, see below. A post hoc comparison included circular plot measurements and foraging observation measurements that had been collected on the same day and were within 300 m of each other.

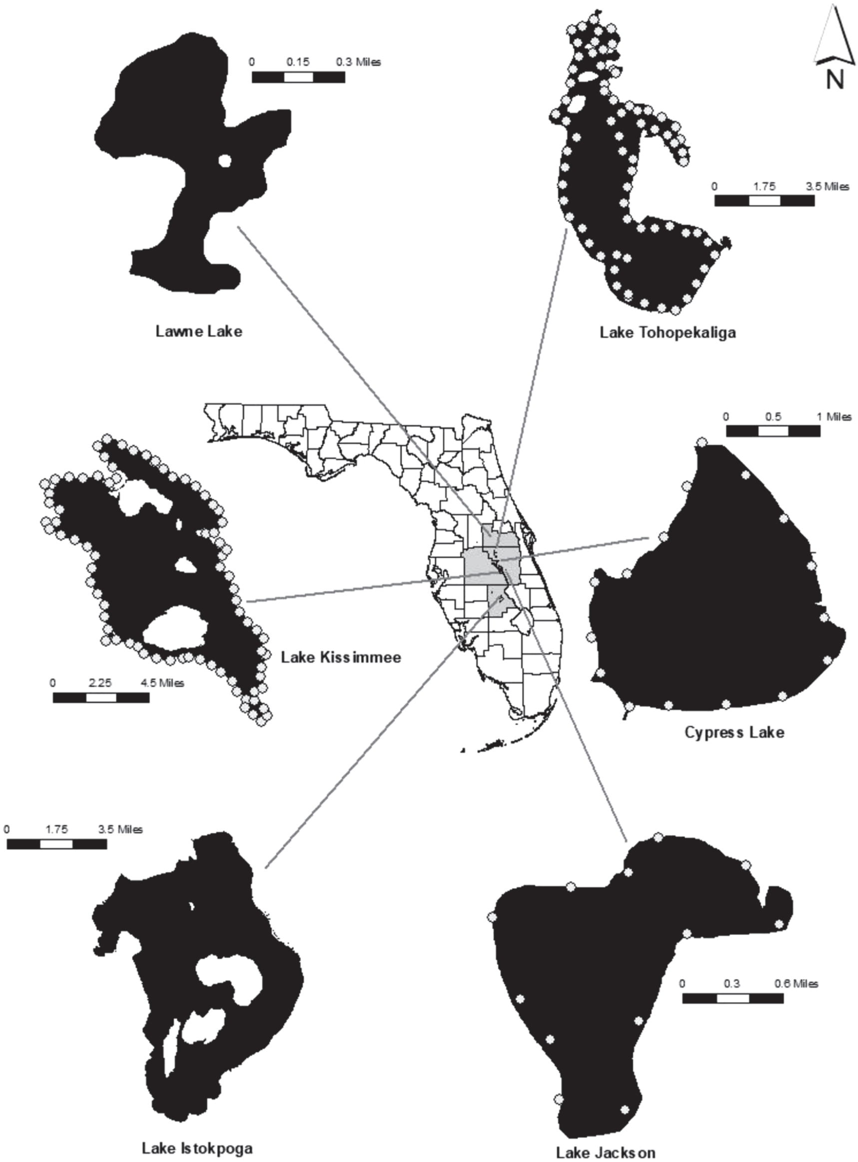

Figure 1. Locations of study lakes in Highlands, Orange, Osceola, and Polk counties used during foraging observations of Great Egrets, Limpkins, and Little Blue Herons in 2014–2015. We used the survey points depicted on Cypress Lake and lakes Jackson, Kissimmee, and Tohopekaliga for focal species surveys in 2014–2015.

We collected capture efficiency data opportunistically in the littoral zones at Cypress Lake, Lawne Lake, and lakes Istokpoga, Jackson, Kissimmee, and Tohopekaliga during March–December 2014 and January–June 2015. We observed birds for 5 min and noted any strikes and captures. From this, we calculated capture efficiency for Great Egrets and Little Blue Herons. Capture efficiency is the ratio of the number of captures of prey items to the number of strikes. Because Limpkins primarily hunt slow-moving mollusks, we assumed a high capture efficiency and recorded only the number of captures during the 5-min observation. We measured habitat characteristics at each foraging location following the observation period and after the bird had moved to a new location. We quantified hydrilla presence at the site by tossing a 1-×1-m square, made of 2.5-cm-diameter polyvinyl chloride (PVC) pipe, over our shoulder three times, each time assessing the hydrilla presence in the square. We averaged the three values for each foraging location to characterize hydrilla presence. We collected water depth at approximately half of the locations to help describe foraging sites.

We built generalized linear mixed models assuming a negative binomial distribution to assess the impact of hydrilla presence and density on the abundance of wading birds observed during the observation periods. We also built generalized linear mixed models, assuming a binary distribution, to assess the impact of hydrilla presence on the presence of Great Egrets and Limpkins. In each of these models, we included lake as a random effect to account for random variability between lakes. We also included the observation period within a lake as a random effect to account for multiple sampling sessions within each lake. We performed all analyses in SAS (SAS Institute 2003) using the GLIMMIX procedure. We used Student's t-tests to make the following comparisons: prey-capture efficiency of Great Egrets and Little Blue Herons between locations with and without hydrilla, and number of prey captured by Limpkins between locations with and without hydrilla.

RESULTS

Focal species surveys.—We surveyed 148.1 km of shoreline in the littoral zone of the four lakes during 2014 and 2015. We surveyed 81 points at Lake Kissimmee, 77 points at Lake Tohopekaliga, 16 points at Cypress Lake, and 12 points at Lake Jackson. Cypress Lake and Lake Jackson could be surveyed in a day, so we repeated the survey at each point three times. It took several days to survey lakes Kissimmee and Tohopekaliga, however, so we surveyed points up to two times. We omitted surveys at points (n = 32) where the shoreline was blocked by vegetation such as cattails. Our overall survey effort totaled 154 points, 88 (57%) of which were surveyed twice and 29 (19%) of which were surveyed 3 times. Time between repeated surveys ranged from 42–359 days. Points were located an average of 72.9 m (range = 1–384 m; SE = 4.71) from the nearest landscape structure such as shoreline, tree line, tussock, or floating mat. Sixty-four percent of the points were in emergent vegetation and 36% were in open water without emergent vegetation. The average water depth at points was 43.0 cm (SE = 1.1; range = 10.2–107.4 cm). Water depth was >50 cm at some points because of an irregular or sloping lakebed in the plot area. Hydrilla was present at 45% of the survey points; however, we characterized only 4% of those survey points as having dense amounts and 12% as having moderate hydrilla amounts. Given the majority of points with hydrilla were characterized as having only a sparse amount, we focused analyses on only presence and absence of hydrilla. We documented that hydrilla density increased or decreased over the course of the study at 75 (64%) of the 117 points with repeated surveys .

We observed focal species at 148 (95%) of the 154 survey points. Overall, we observed 158 Great Egrets, 80 Limpkins, and 17 Little Blue Herons at the survey points. We detected birds at distances of 12–300 m (mean = 123.06 m, SE = 5.13) from survey points. Our use of airboats affected foraging wading birds, which are typically quick to disperse in response to such disturbance. Nevertheless, birds often resettled and resumed foraging during the 5-min quiet period, and Limpkins were often immediately responsive to the playback. Hydrilla was absent from 77 (52%) of the 148 points at which we observed birds. There was no difference in the number of birds observed at points where hydrilla was present versus those where hydrilla was absent ($F_{1,289} = 0.00$, $P = 0.99$).

Overall, we observed 88 Great Egrets at survey points without hydrilla and 70 at points with hydrilla. We observed 49 Limpkins at points without hydrilla and 31 at points with hydrilla. We observed 11 Little Blue Herons from points without hydrilla and 6 from points with hydrilla. The presence of Great Egrets and Limpkins did not differ between points with hydrilla and those without it (Great Egret: $F_{1,289} = 0.34$, $P = 0.56$; Limpkin: $F_{1,289} = 0.92$, $P = 0.34$). The small sample of Little Blue Heron observations precluded statistical comparisons.

Because of logistical constraints, we rarely measured hydrilla densities at foraging locations and survey circular plots on the same day. However, seven wading bird foraging locations allowed comparison because they were within the 300-m survey area and the hydrilla density was measured on the same day as the survey circular plot. Six of 7 (86%) had the same hydrilla density, including the foraging location that was the farthest away (148 m) from the circular plot.

Prey-capture efficiency.—We observed 112 foraging bouts. We occasionally recorded water depths greater than the maximum known foraging depth for each species because of floating mats of vegetation supporting the birds or because the PVC square was randomly tossed over fish bedding holes. Hydrilla was present at 50% (n = 24) of the 48 locations at which we observed Great Egrets foraging. We observed Great Egrets wading and walking on floating mats while foraging, and the average water depth at their foraging locations was 45.6 cm (n = 18; range = 18–120 cm; SE = 0.08). Mean capture efficiency for Great Egrets was similar between sites with hydrilla (0.49; SE = 0.05) and sites without it (0.62; SE = 0.07; t = 1.53, P = 0.13).

Hydrilla was present at 35% (6 out of 17) of locations where we observed Little Blue Herons foraging, and mean capture efficiency was similar between sites with hydrilla (0.63; SE = 0.12) and without it

(0.60; SE = 0.09; t = −0.21, P = 0.84). We observed Little Blue Herons foraging while wading and walking on floating mats and emergent vegetation and the average water depth at foraging locations was 36.2 cm (n = 10; range = 7–70 cm; SE = 0.06).

Limpkins accounted for 45 of the foraging observations. Hydrilla was present at 42% (n = 19) of the locations at which we observed Limpkins foraging. Mean number of captures at sites with hydrilla was 2.47 (SE = 0.61; range: 0–12), versus a mean of 1.04 (SE = 0.18; range: 0–3) captures at sites without hydrilla (t = 1.44, P = 0.03). We observed Limpkins capturing prey during 18 of 19 (95%) foraging observations in areas with hydrilla, compared to 17 of 26 (65%) of observations in areas without hydrilla. We observed Limpkins foraging while wading or walking on floating mats, and the average water depth was 36.8 cm (n = 10; range = 3–136 cm; SE = 0.13); 60% of measured locations were in water <24 cm deep.

Discussion

Hydrilla in lakes or reservoirs can be beneficial to birds (Montalbano et al. 1978, Mulholland and Percival 1982, O'Meara et al. 1982, Johnson and Montalbano 1984, Esler 1990), be detrimental (Wilde et al. 2005), or have no discernable effects (Hoyer et al. 2008). Our study found that presence or absence of hydrilla had no discernible direct effect on the presence of Great Egrets or Limpkins. We were not able to assess the importance of hydrilla density on foraging birds because too few of our sites had moderate or dense hydrilla. As such, we cannot provide information on how dense hydrilla matting, which managers often target for removal, affects foraging birds. Further research that focuses specifically on high-density hydrilla patches is warranted. Wildlife management goals based on specific hydrilla densities would be much more practical than any based on presence/absence, especially because of the difficulty of eliminating the species in lakes where it is well established.

We found that foraging efficiency of Great Egrets and Little Blue Herons did not differ between sites with or without hydrilla. Wading birds prefer littoral zones with macrophytes over open water (Lantz et al. 2010), and whether the vegetation is native or nonnative may be less important than whether it provides the appropriate structure and resources for the birds' prey. Limpkin abundance also did not differ between sites with or without hydrilla; however, prey captures by Limpkins were significantly different. We observed Limpkins capturing prey at 95% of the foraging locations with hydrilla, compared to 65% of the foraging locations without hydrilla. Baker et al. (2010) documented heavy consumption of hydrilla by nonnative island apple snails, and

Monette et al. (2017) reported that hydrilla was the common factor among sites inhabited by nonnative, but not native, apple snails. Smith et al. (2019) suggested that expanding hydrilla provides food for an increasing nonnative apple snail population that has in turn allowed Limpkins to expand their range north in Georgia; thus, population growth of the three species may be intrinsically linked.

We recommend interpreting our results with caution because of the small number of observations of the focal species, especially Little Blue Herons; a greater number of observations may provide more insight into how the presence of hydrilla affects bird behavior. We also assumed that hydrilla at our survey points was representative of the habitat in which nearby birds were foraging. This was generally true at the small number of points at which we had data for a survey point and nearby foraging birds, and our approach to measuring hydrilla was consistent with that used by lake managers. Nevertheless, the point vegetation measurements may not always have been representative of hydrilla in the area because we did observe some patchiness in the presence of hydrilla within the 300-m count radius. Regardless, our study should have detected a relationship between hydrilla presence and the presence of wading birds if the effect size had been substantial. Future research that better assesses hydrilla density rather than presence, and a more refined characterization of the overall macrophyte community and its effect on foraging birds, will better inform lake managers how their activities affect Florida's wading bird community. Regardless, the lack of a negative effect of hydrilla on wading birds that we observed here should be contextualized within the pervasive negative impacts that hydrilla can have on native plant communities and the overall health of Florida's lakes.

Acknowledgments

We are grateful to Tim Coughlin for allowing us use of airboats. We thank Ryan Butryn, Jennifer Bock, and Ryan Druyor for a tremendous amount of GIS assistance. We also thank James Rodgers, Andrew Cox, and Martin Folk for guidance in developing this study. Bill Bibby, Linda Torres, Janine Morganstern, and Anna Jasent provided logistical support. Review of the manuscript by O. B. Crowder, Adrienne Doyle, Craig Faulhaber, Linda King, Rob Kipker, Matt Phillips, and Kelle Sullivan made significant improvements. Funding for this work was supported by Conserve Wildlife Tag grant program and the Florida Fish and Wildlife Conservation Commission.

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